Air Toxics Risk Assessment Reference Library

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Volume 3
Community-Scale Assessment

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Research Triangle Park, NC

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Volume 3
Community-Scale Assessment

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Acronym List

ADEQ	Arizona Department of Environmental Quality
AERMOD	American Meteorological Society/Environmental Protection Agency Regulatory Model
AFS	Air Facility System
AHERA	Asbestos Hazard Emergency Response Act
AIR2GIS	Software tool for preparing source-specific ISCST3 output files for import into Risk-MAP; part of RAIMI
AIRS	Aerometric Information Retrieval System
AMP	Air Modeling Preprocessor
AMS	Area and Mobile System
ASPEN	Assessment System for Population Exposure Nationwide
ASTDR	Agency for Toxics Substances and Disease Registry
ATRA	Air Toxics Risk Assessment
BAT	Best available technology
BEIS3	Biogenic Emissions Inventory System
BTU/SCF	British thermal units per standard cubic foot
CAA	Clean Air Act
CAC	Community Action Council
CAL3QHC	CALINE-based model with queuing and hot spot calculations
CALINE	Line source steady-state Gaussian dispersion model developed by California Department of Transportation
CalPUFF	Lagrangian puff dispersion model
CARE	Community Action for a Renewed Environment
CAS	Chemical Abstracts Service
CASRN	Chemical Abstracts Service Registry Number
CBEP	Community-Based Environmental Protection
CCACC	Cleveland Clean Air Century Campaign
CCAG	Chelsea Creek Action Group
CDC	Centers for Disease Control and Prevention
CEP	Community Environmental Partnership
CEP	Cumulative Exposure Project
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (Superfund)
CERCLIS	Comprehensive Environmental Response, Compensation, Liability Information System
CHIEF	Clearing House for Inventories and Emission Factors
CMAQ-AT	Community Multiscale Air Quality model (Air Toxics)
CMSD	Cleveland Municipal School District
CMV	Commercial marine vessel
COPC	Chemical of potential concern
CRA	Comparative risk analysis
CRARM	Congressional Commission on Risk Assessment and Risk Management
CWA	Clean Water Act
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane

DE	Diesel engine
DEOG	Diesel exhaust organic gases
DOQQ	Digital ortho quarter quad
DPM	Diesel particulate matter
DQO	Data quality objective
EC	Exposure concentration
ECHO	Enforcement and Compliance History Online
EGBE	Ethylene glycol butyl ether
EHP	Environmental Health Perspectives
EJ	Environmental justice
EJP2	Environmental Justice through Pollution Prevention
EMS-HAP	Emissions Modeling System for Hazardous Air Pollutants
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-To-Know Act
FERA	Fate, Exposure, and Risk Analysis
GACT	Generally available control technology
GIS	Geographic information system
HAP	Hazardous air pollutant
HAPEM	Hazardous Air Pollutant Exposure Model
HARP	Hotspots Analysis Reporting Program
HEM	Human Exposure Model
HEM-Screen	Human Exposure Model - Screen
HHRAP	Human Health Risk Assessment Protocol
HHW	Household hazardous waste
HI	Hazard index
HPV	High production volume
HQ	Hazard quotient
IAQ	Indoor air quality
IPM	Integrated Pest Management
IRIS	Integrated Risk Information System
ISC	Industrial Source Complex
ISC-Batch	Industrial Source Complex Batch
ISCST3	Industrial Source Complex Short-Term 3
IUR	Inhalation unit risk estimate
IUR	Inventory update rule
IWG	Federal Interagency Working Group on Environmental Justice
LCBO	Local community-based organization
LRTAP	Long-range transboundary air pollution
MACT	Maximum achievable control technology
MEI	Maximum exposed individual
MIR	Maximum individual risk
MSAT	Mobile source air toxics
MTBE	Methyl tertiary butyl ether
MWC	Municipal waste combustor
NAAQS	National Ambient Air Quality Standard
NAD27	North American Datum (1927)
NAD83	North American Datum (1983)
NADCON	North American Data Conversion

NARSTO	North American Research Strategy for Tropospheric Ozone
NAS	National Academy of Sciences
NATA	National Air Toxics Assessment
NATTS	National Air Toxics Trends Stations
NCEA	National Center for Environmental Assessment
NCEH	National Center for Environmental Health
NCOD	National Contaminant Occurrence Database
NCRP	National Council on Radiation Protection and Measurements
NEI	National Emissions Inventory
NEJAC	National Environmental Justice Advisory Council
NEPIS	National Environmental Publications Information System
NESHAP	National Emission Standards for Hazardous Air Pollutants
NGO	Non-governmental organization
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NLM	National Library of Medicine
NMIM	National Mobile Inventory Model
NOAA	National Oceanic Atmospheric Administration
NO_x	Oxides of nitrogen
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
NTI	National Toxics Inventory (former name of the air toxics portion of the current NEI)
NWISWeb	National Water Data gateway
NWS	National Weather Service
OAQPS	Office of Air Quality Planning and Standards
OPPT	Office of Pollution Prevention and Toxics
PACE EH	Protocol for Assessing Community Excellence in Environmental Health
PAH	Polycyclic aromatic hydrocarbons
PB-HAP	Persistent, bioaccumulative, hazardous air pollutants
PBT	Persistent, bioaccumulative, toxic chemical(s)
PCB	Polychlorinated biphenyls
PERC	Perchloroethylene
PHA	Public health assessment
PM	Particulate matter
$PM_{2.5}$	Particulate matter with an aerodynamic diameter less than or equal to 2.5 microns
PM_{10}	Particulate matter with an aerodynamic diameter less than or equal to 10 microns
POM	Polycyclic organic matter
POP	Persistent organic pollutant
PPA	Pollution Prevention Act
Project XL	Project eXcellence and Leadership
PSDB	Point-source database
QA	Quality assurance
QC	Quality control
RAGS	Risk Assessment Guidance for Superfund
RAIMI	Regional Air Impact Modeling Initiative
RBC	Risk-based concentration
RCRA	Research Conservation and Recovery Act

RfC	Reference concentration
Risk-MAP	Risk Management Analysis Platform
RSEI	Risk Screening Environmental Indicators
RTA	Regional Transit Authority
SCC	Source Classification Code
SCFM	Standard cubic feet per minute at 68° F
SCRAM	Support Center for Regulatory Air Models
SCREEN3	Screening-level single source Gaussian plume model
SDWA	Safe Drinking Water Act
SEP	Supplemental Environmental Projects
SLT	State, local, and tribal
SMOKE	Sparse Matrix Operator Kernel Emissions
SVOC	Semivolatile organic compounds
TCCR	Transparent, clear, consistent, and reasonable
TDM	Travel Demand Model
TIGER	Topologically Integrated Geographic Encoding and Referencing system
TNRCC	Texas Natural Resource Conservation Commission
TPY	Tons per year
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act
TSP	Total suspended particulate
TTN	Technology Transfer Network
TWSA	Toxicity Weighted Screening Approach
UAM	Urban Airshed Model
UAM-Tox	Urban Airshed Model for Toxics
URE	Unit risk estimate
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VMT	Vehicle miles traveled
VOC	Volatile organic compounds
WGS84	World Geodetic System ellipsoid of 1984
WME	Window to My Environment
WMPC	Waste Minimization Priority Chemicals

PART I

BACKGROUND

Chapter 1 Overview of Volume 3

Table of Contents

1.0 Preface

This resource document is the third in the Air Toxics Risk Assessment (ATRA) Library series. It presents an overview of the overall process and tools for evaluating cumulative risk from multiple air toxics emitted from sources at the community level and developing and implementing risk reduction activities to bring about meaningful environmental change. The first portion of the book is geared towards one type of toxics issue – understanding and mitigating the risks posed to human health by the simultaneous impact of multiple air toxics emissions sources on a specific geographic location. (Approaches for assessing the impact of multiple sources on ecological receptors are discussed in Part III of this book and in ATRA Volume 1, Part IV.[a]) The second part of this book expands on the issue of community toxics by focusing on the other types of environmental pollution issues that a community may face such as lead paint in homes, contaminated surface water, and pesticides use.

> **A Note on Terminology**
>
> The terms "**air toxics**" and "**toxic air pollutants**" are often used interchangeably with "**hazardous air pollutants**" (which is a Clean Air Act phrase specific to the 187 pollutants that are the focus of section 112 of the Act – see http://www.epa.gov/ttn/atw/188polls.html).* For the purposes of this reference library, however, the term "air toxics" is used in the more general sense to refer to any air pollutant (other than criteria pollutants) that has the potential to cause adverse impacts to human health or the environment.
>
> **"Criteria air pollutants"** are six common air pollutants determined to be hazardous to human health and for which EPA has established National Ambient Air Quality Standards (NAAQS). The six criteria air pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, sulfur dioxide, and particulate matter. A detailed discussion of criteria pollutants is available at http://www.epa.gov/air/urbanair/6poll.html.
>
> ---
>
> ***A Hazardous Air Pollutant (HAP)** is defined under the Clean Air Act as a pollutant that causes or may cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects. Currently, the Clean Air Act regulates 187 chemicals and chemical categories as HAPs.

There are many ways to conduct community toxics projects and the specific approach selected in a community will often reflect a balance between the complexity of the problem being evaluated, the uncertainties in the assessment that can be tolerated, and the resources available to do the work. As such, the tools and techniques described in this document should not be viewed as prescriptive; rather, they should be viewed as a guide to available approaches that could be used by practitioners in the field of risk analysis and risk mitigation. The chapters use non-mandatory language such as "may" and "should" to indicate that the information provided is recommended, but does not impose any legally binding requirements. (Interested parties are free to raise questions and objections about the substance of this guidance and the appropriateness of the application of this guidance to a particular situation. EPA and other decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from those described in this guidance where appropriate.)

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[a] The information provided here augments ATRA Volumes 1 and 2 by providing information tailored to multisource air toxics assessments. The reader may wish to refer back to the information provided in Volumes 1 and 2 for further explanations of some of the concepts found in this document.

1.1 Intended Audience

Community-scale multisource cumulative assessments and risk reduction efforts are often a joint partnership between regulatory agencies and various stakeholders in the communities where the study is taking place. With that in mind, Volume 3 was developed for the following two key audiences:

- Federal and state, local, and tribal (SLT) air agencies who either conduct, review, or otherwise participate in community-scale multisource air toxics assessments.

- Various community stakeholders who participate in the community-scale air toxics assessment process.

Should a community-scale toxics reduction effort expand beyond air toxics issues (for example, to water or solid waste concerns), the number and types of interested stakeholders will likely grow beyond those listed above.

Why Are Non-Air Toxics Issues Included in a Book about Multisource Air Toxics Risk Assessment?
Why Is a Range of Technical Approaches Provided?

Even though their overall intention is to focus on toxic air pollutants, many partnership teams performing a community-scale multisource assessment will sometimes be drawn into addressing other non-air environmental issues. To aid them in this work, Part IV of this document discusses some suggested approaches for identifying and implementing risk reduction projects for common non-air environmental toxics issues at the community level. (In some cases, a community may want to focus solely on these other non-air toxics issues, making their interest in this Volume limited to Part IV.)

Given that the interests and available resources, expertise, and time to perform an analysis (of any sort) may vary dramatically from community to community, this volume attempts to present a range of possible approaches for identifying and addressing community environmental toxics issues. In a multisource air toxics risk assessment, for example, an aggressive technical analysis may be possible that provides a high degree of certainty about community risk and the main contributors to that risk. In other cases, the community's interests or resources may lead to a more limited air toxics assessment effort. Likewise, the assessment of additional toxics issues may be more or less qualitative or quantitative depending on the interests and resources of the community. In many cases, the approach taken will be a combination of quantitative and qualitative. Ultimately, the needs of the partnership team and the resources they have to perform their work will drive the type of analysis they do and the environmental risk factors on which they focus. It is with such possibilities in mind that this volume discusses both complex technical approaches and more straightforward qualitative analyses.

1.2 Relationship to Volumes 1 and 2

This resource document is the third in the ATRA Library series. A brief description of the three-volume ATRA Library series is presented below and summarized in Exhibit 1-1.

Volume 1: Technical Resource Manual discusses the overall air toxics risk assessment process and the basic technical tools needed to perform these analyses. The manual addresses both human health and ecological assessment. It also provides a basic overview of the process of managing and communicating risk assessment results. Other types of evaluations (such as the public health assessment process) are described to give the community a more holistic understanding of the many issues that may come into play when evaluating the potential impact of air toxics on human health and the environment. *Readers new to the field of risk assessment or those needing more detailed information on the science of risk assessment are encouraged to consult ATRA Volume 1* at http://www.epa.gov/ttn/fera/risk_atra_vol1.html.

Volume 2: Facility-Specific Assessment builds on the technical tools described in ATRA Volume 1 by providing an example set of tools and procedures that can be used for source-specific or facility-specific risk assessments. Information is also provided on tiered approaches to source- or facility-specific risk analysis. Volume 2 can be found at http://www.epa.gov/ttn/fera/risk_atra_vol2.html.

Volume 3: Community-Scale Assessment (this volume) builds on the information presented in ATRA Volume 1 to describe approaches to evaluate and reduce air toxics risks posed by emissions from multiple sources at the local level. It includes information on screening level and more detailed analytical approaches, approaches to balance the need for assessment versus the need for action, approaches to identify and prioritize risk reduction options, and approaches to measure the success of risk reduction efforts. Since community environmental concerns and issues are often not limited to air toxics, this volume also presents information on additional environmental risk factors that may affect communities as well as strategies to reduce those risks. The document also provides additional information on stakeholder involvement, communicating information in a community-based setting, and developing the resources to fuel the effort.

Exhibit 1-1. Summary Diagram of Volumes 1, 2, and 3 of the Air Toxics Risk Assessment Reference Library

Volume 1:

TECHNICAL RESOURCE MANUAL

- What is an air toxics risk assessment?
- Why would stakeholders initiate an assessment?
- What is the process for conducting an air toxics risk assessment?
- What expertise, resources, and tools are required?
- What are the limitations of risk assessment?
- How can risk assessment results be used?

Volume 2:

FACILITY-SPECIFIC ASSESSMENT

- What is the procedure for conducting a source- and/or facility-specific air toxics risk assessment?
- What expertise, resources, and tools are required for conducting a source and/or facility-specific risk assessment?
- What is a tiered risk assessment and how is it implemented?
- What are the benefits and limitations of tiered, source- and/or facility-specific risk assessments?

Volume 3:

COMMUNITY-SCALE ASSESSMENT

Part I: Background

- What is community-scale air toxics assessment?
- Why is community-scale assessment important?

Part II: Multisource Human Health Assessment: Inhalation

- How is a cumulative multisource assessment conducted for inhalation exposures?
- How are the results of this type of assessment used to reduce risks?

Part III: Multisource Multipathway Risk Assessment

- When should a multisource multipathway risk assessment be conducted?
- What resources are available for this type of assessment?

Part IV: Other Environmental Risk Factors of Concern to Communities

- What other environmental risk factors should communities be aware of?
- How can communities get organized and involved?
- How can communities identify and prioritize environmental toxics issues?
- What are effective, sustainable methods for risk reduction?

Volume 3 and the *Community Air Screening How To Manual:* What's the Difference?

A companion document to Volume 3 is EPA's *Community Air Screening How To Manual* developed by EPA's Office of Pollution Prevention and Toxics (OPPT; see http://www.epa.gov/opptintr/cahp/catt.html). Volume 3 of the ATRA Reference Library builds on and is complementary to the *How To Manual*. Specifically, the *How To Manual* provides information for communities on how to organize and develop a risk-based *screening-level evaluation* of air toxics in their local area. In contrast, Volume 3 provides a more comprehensive discussion of approaches to cumulative, multi-source air toxics risk assessment and the tools for performing it, as well as a discussion of source apportionment of toxic air pollutant impacts on a local area. Additionally Volume 3 includes discussions of multipathway analyses and ranking air toxics and other community risk factors for risk management purposes.

Depending on the needs of the community partnership team, they may choose to perform only a screening-level analysis (e.g. using the *How To Manual* approach) or they may opt to begin with the risk assessment approach outlined in Volume 3. In many cases, the partnership team will begin with a screening-level analysis to identify the important chemicals and sources that will be a focus of the cumulative risk assessment.

Volume 3 also provides general background information on screening-level techniques that are commonly used as a prelude to a cumulative risk assessment. However, analysts are encouraged to become familiar with both the *How To Manual* and the contents of this document in order to better understand the available tools and techniques for screening analysis and the interplay between screening-level assessments and more detailed risk assessment approaches. The *How To Manual*, or parts of the *How To Manual*, written for a proad partnership audience, also can be used for education and training purposes in general. More information on the *How To Manual* is provided in Section 3.5.1.

1.3 Overview of the Document's Structure and Content

As noted above, Volume 3 builds on the information already provided in Volume 1 of the ATRA Library, and readers will generally find that Volume 3 focuses on information not already covered in ATRA Volume 1. For those subjects already covered in detail in ATRA Volume 1, pointers are provided back to the relevant sections of that document where more in-depth information is available.

Volume 3 is divided into four parts:

Part I (Background) presents an introduction to this document and the concept behind community-scale multisource cumulative assessments.

- **Chapter 1** (this chapter) describes the purpose of this document, its intended audience, its relationship to Volumes 1 and 2 of this series, and its structure and content.

- **Chapter 2** provides an introduction to community-scale air toxics assessment and other potential environmental community health concerns, the importance of localized assessment and risk reduction, and stakeholder involvement.

The Overall Framework of Volume 3

Part I of this document introduces readers to the types of **environmental toxics** issues that many communities face, include toxics in air, soils, water, and consumer products.

Part II of this document focuses on one type of environmental toxics problem – **inhalation** (i.e., breathing in) of toxic pollutants in the air. This part presents ways to assess the combined risk posed by the potentially multiple sources of pollution which may be simultaneously impacting a community along with ways to identify the main sources and chemicals responsible for any unacceptable risks found.

Part III of this document discusses the movement of air toxics out of the air and into soils, sediments, water, and living tissue where it can be contacted by living organisms (e.g., by ingesting contaminated food, drinking contaminated water, or touching contaminate soils) and potentially cause harm. This discussion of **multipathway risk** focuses on both the people in a community and the community's ecosystem.

Part IV provides insight into the variety of additional environmental toxics issues (other than air toxics) that a community may be concerned about, along with approaches to prioritizing the concerns as well as ways to reduce risk and sustain the effort over time.

All of these efforts will need strong support and participation by many types of people in the community and may require technical experts to be brought in from outside. Community participation and the need for technical expertise is discussed at various points throughout this document.

Part II (Human Health Assessment: Inhalation) provides an overview of available tools and approaches for conducting a community-scale multisource cumulative assessment.

- **Chapter 3** discusses the potential need for or usefulness of an assessment, the use of modeling and monitoring to estimate exposure, and examples of community-scale assessments and methodologies. This chapter also discusses how to balance the need for action with the need for analysis.

- **Chapter 4** describes the initial planning, scoping, and problem formulation steps of the risk assessment. Several key elements are highlighted, including identifying the concern(s) to be evaluated (usually by an analysis of existing data), determining the scope of the analysis, developing a conceptual model of the study area, developing a written plan for how the analysis will be carried out, and how to revise the approach as needed.

- **Chapter 5** describes the analysis phase of the multisource assessment, including emissions characterization, air dispersion modeling, quantifying inhalation exposure, and toxicity assessment.

- **Chapter 6** describes how to combine exposure information with toxicity data to quantify risk. This chapter also discusses how to apportion the risks among the sources and chemicals evaluated and how to assess the uncertainties associated with the overall assessment.

- **Chapter 7** describes risk communication, including methods for presenting risk results and understanding and presenting trends in risk over time.

- **Chapter 8** describes the process for identifying, prioritizing, and selecting risk reduction options for sources of air toxics emissions, including legal considerations, implementation issues, and how to monitor progress and sustain efforts over time.

Part III (Multisource Multipathway Risk Assessment) provides a brief discussion on assessing the impact of air toxics in other media on human health and the environment (e.g., mercury deposition with subsequent uptake in fish).

- **Chapter 9** describes key concepts and available tools and techniques.

Part IV (Other Environmental Risk Factors of Concern to Communities) describes how to put the results of the air toxics assessment in context with other community environmental risk factors and how to identify, prioritize, select, and implement risk reduction approaches for these additional concerns.

- **Chapter 10** describes the background of community risk reduction projects, how to form a partnership team to do the work, and how to involve and communicate with the larger community.

- **Chapter 11** describes how to identify and prioritize environmental concerns other than air toxics, including sources of available data and methods for prioritizing risk factors.

- **Chapter 12** describes how to identify, select, and implement risk reduction projects, including risk reduction approaches, legal considerations, implementation issues, assessing the success of the risk reduction efforts, and sustaining the process over time. This chapter also discusses how to fill important data gaps.

Several **Appendices** provide more detailed discussion of various topics.

- **Appendix A** provides several case studies. The first group of case studies illustrates the multisource cumulative assessment approach. The second set of case studies illustrates how to identify, assess, and address other environmental issues of concern to communities.

- **Appendix B** provides background information on air toxics screening level approaches.

- **Appendix C** presents the emissions inventory database structure for RAIMI (the Regional Air Impact Modeling Initiative).

- **Appendix D** provides a glossary of key terms used in this document.

Chapter 2 Introduction to Community-Scale Assessment

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2.0 Introduction

The mission of the United States Environmental Protection Agency (EPA) is to protect human health and to safeguard the natural environment – air, water, and land – upon which life depends.[1] Following this mission, the Agency has implemented a variety of laws and programs that require and encourage the safe use and management of toxic chemicals. Many of these programs focus on understanding the consequences of releasing chemicals to the air, land, and water and working to reduce those releases when they pose too great a risk. As described in the National Research Council's 1994 report, *Science and Judgment in Risk Assessment* (the "Blue Book"), risk assessment has frequently been adopted by Federal and state governments as a means for regulating hazardous substances.[2]

This chapter provides an introduction to the importance of assessment and mitigation of the variety of environmental risk factors that may affect communities. The discussion begins with toxic chemicals released to or created in the air (a ubiquitous problem across the United States) followed by a discussion of other common community environmental toxics concerns. The chapter concludes with a discussion of the importance of stakeholder involvement in community-scale assessment and risk mitigation efforts.

2.1 Air Pollution at the Local Level

The potential impacts of chemicals released to (or created in) the air depend on a number of factors, including the quantity of chemicals in the air, the location of the sources, how the chemicals move and transform in the environment, the length of time people or the environment is exposed, the toxic nature of the chemicals, susceptibility/sensitivity of the people exposed (e.g., due to an genetic susceptibility or a pre-existing medical condition), the ability of the exposed population to prepare for or recover from exposures, and other attributes of the exposed population. The human health effects of exposure to air pollutants can range from no response, responses that are relatively minor and reversible (such as mild eye irritation), responses that are more serious and debilitating (such as cancer) and, in some cases, fatal responses. Air pollution also can cause negative impacts on the environment, including distress and death in plants and animals, as well as damage to buildings and important cultural sites.

In the mid-20th century, Congress recognized the potential for air pollution to cause these kinds of problems and responded by enacting the Clean Air Act (CAA). Since that time, this Act, as amended, has provided the primary authority that EPA uses to develop programs for protecting people and the environment from the harmful effects of air pollution across the United States. For example, in the area of air toxics risk reduction:

- Strict control technology requirements on a number of categories of stationary sources (e.g., major industrial sources such as chemical plants, oil refineries, steel mills) have resulted in dramatic decreases in air toxics emissions over time. In addition, technological advances in motor vehicle and engine design, together with cleaner, higher-quality fuels, have reduced emissions so much that EPA expects the progress to continue, even as people drive more miles and use more power equipment every year.

Based on the data in the National Emissions Inventory (NEI),[a] estimates of nationwide air toxics emissions from these and other sources decreased by approximately 24 percent between baseline (1990-1993) and 1996. Thirty-three of these air toxics that pose the greatest threat to public health in urban areas have similarly decreased 31 percent. Although changes in how EPA compiled the national inventory over time may account for some differences, EPA and state regulations, as well as voluntary reductions by industry, have clearly achieved large reductions in overall toxic air pollutant emissions.

- Over the sixteen years from 1988 to 2003, total on- and off-site disposal or other releases of Toxics Release Inventory (TRI) chemicals decreased by 59 percent (by 1.87 billion pounds), including a 73 percent decrease in air emissions, looking at trends in the industries and chemicals that have been consistently reported since that time.

The 1990 Amendments to the CAA require that EPA significantly reduce emissions to the air of a particular set of chemicals that are known or suspected to cause serious health problems, such as cancer or birth defects. There are currently 187 **hazardous air pollutants (HAPs)**[b] that are regulated. This group of chemicals is also commonly referred to as the HAPs, **toxic air pollutants**, or simply **air toxics**. (The CAA also covers another important group of chemicals, known as **criteria air pollutants**; these various groups of air pollutants are discussed in more detail in Chapter 3.)

Many different types of sources can release air toxics. These sources include stationary facilities that individually release above threshold quantities of HAPs to the air (known as **major sources**); stationary facilities that individually release below threshold quantities of HAPs to the air (known as **area sources**); on-road and nonroad **mobile sources** (such as cars, trucks, and construction equipment) that release HAPs to the air; **indoor sources** of air toxics (such as paint, cleaning products, and second hand smoke); and **natural sources** of air toxics (such as fires, trees, soil, and volcanoes). Chapter 3 provides a detailed description of how EPA identifies and, in the case of anthropogenic (manmade) sources, regulates each of the various types of sources of air toxics.

Air toxics can also be released as a result of accidents, such as an explosion of a large storage vessel or the rupture of a tank car. Risk and hazard assessments of accidental releases are not discussed in this volume; in addition, the release and accumulation of gases under unusual circumstances such as an accidental release are not explicitly discussed. Resources on these other topics are available from EPA's Chemical Emergency Preparedness and Prevention Office (see http://yosemite.epa.gov/oswer/ceppoweb.nsf/content/index.htm).

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[a] The NEI is EPA's main inventory of air toxics emissions in the United States. It is updated every three years and contains information on stationary sources, mobile sources, and miscellaneous other sources such as certain forest fires. The NEI is discussed in detail in Chapter 4.

[b] Since the original Act (which listed 189 chemicals) two chemicals listed individually on the list of HAPs, caprolactam and methyl ethyl ketone, have been delisted, bringing the total number of listed air toxics to 187. One other chemical, ethylene glycol butyl ether (EGBE), was removed from the glycol ethers category (however, glycol ethers remains as a listed category). EPA has the authority to add and delete chemicals from the original list based on specified criteria [CAA Section 112(b)(3)].

2.1.1 Why Are There Special Concerns about Air Toxics at the "Community Scale?"

In a typical urban area (i.e., at the "community scale"), toxic air pollutants are of particular concern because people and sources of emissions are concentrated in the same geographic area. Since most people live in metropolitan areas,[c] this proximity leads to the potential for large numbers of people to be exposed to numerous air pollutants (some at potentially high concentrations). Within these communities, there may be additional exposure considerations of concern, including populations with special sensitivities (e.g., children and the elderly) or environmental justice communities (see Section 2.1.3).

Just How Big (or Small) is "Community Scale?"

There is no prescriptive answer to this question; however, community-scale analyses commonly range in size from a single neighborhood up to as large as a metropolitan area. The size of the "community" that is assessed will depend on the questions the partnership team wants to answer and the resources they have to perform the evaluation (e.g., a larger study area may lead to a higher cost). A discussion of how to define the scope of a multisource cumulative air toxics assessment is provided in Chapter 4.

As an example, consider a crowded city with its numerous busy streets and highways, autobody shops, dry cleaners, gas stations, and any number of other potential air toxics sources (e.g., large manufacturing plants), all located in and impacting a relatively small geographic area. It is easy to understand how this type of situation could lead to significant impacts that are, by their very nature, complex and variable (i.e., the number and types of sources can change from place to place).

While some of these urban chemical exposures tend to be fairly similar across the country (e.g., ambient air concentrations of benzene from petroleum use tend to be similar across the lower 48 states), studies also indicate that the concentrations of air toxics in many urban (and some nonurban) areas can vary significantly from one location to the next. In addition, many sources of urban emissions tend to be relatively small in size but large in number (e.g., gas stations or mobile sources), and they typically emit chemicals at ground level where people are more likely to be exposed to them.

Perception of Risk as a Driver for Action

Concerns about air toxics at the community level often begin with the *perception* among people in the area that they are sick because of local air quality. While such perceptions may lead to direct actions to reduce emissions from a particular source, more often the initial "action" that is taken is to examine whether the facts support the perception. For example, some level of risk assessment (such as the methodology described in this document) may be performed to evaluate current exposures and what they may indicate in terms of potential health threats. In some cases an epidemiological analysis may also be performed to evaluate actual cases of disease in the context of past exposures. Investigators will also look at what is already known (e.g., in the scientific literature) about the chemicals and types of sources in question and their potential to pose exposures of potential public health concern.

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[c] According to the 2000 census (www.census.gov), approximately 226 million out of 281 million Americans live in metropolitan areas.

The concern about multiple air toxics emissions at the community level is heightened by the fairly localized nature of many air toxics impacts. For example, it is common for a ground level toxic chemical emission to be undetectable (through monitoring) within a few miles from the point of release due to dilution and/or degradation. An exposure evaluation for such releases would need to focus on the people who spend time in the immediate vicinity of the point of release (i.e., at the community scale) and probably not the people more than a few miles away.[d]

Considering the large number of people potentially at risk from air toxics exposures, Congress directed in the 1990 CAA amendments that elevated outdoor (also called **ambient**) concentrations of air toxics in large urban areas be substantially reduced. In response to this mandate, EPA developed an **Integrated Urban Air Toxics Strategy**. This Urban Strategy, which was published in the *Federal Register* on July 19, 1999,[3] has since become EPA's **National Air Toxics Strategy** (the Strategy) and is part of the overall national effort to reduce air toxics. The Strategy presents an approach for reducing these risks by looking at the cumulative risks posed by multiple pollutants from multiple sources (mobile, area, major and indoor air) in urban areas. However, since air toxics exposures vary (in terms of toxic air pollutants and sources) among urban areas across the country, EPA's activities to reduce risk on a national scale may not address potential risks on the more local level. Consequently, the Strategy includes local and community-based initiatives which we envision will involve partnerships between EPA and the State, local, and Tribal governments.

In other words, the need to recognize the combined impact of all the various types of sources in a given area is an important factor when working to achieve meaningful risk reductions in ambient concentrations at the local level. Equally important is the recognition that air toxics exposures can and do vary from place to place, requiring approaches that are flexible enough to meet the needs of individual communities.

The Strategy attempts to address all the significant stationary, mobile, and indoor sources necessary to achieve protection of public health and the environment. The specific goals of the Strategy are to:

- Attain a 75 percent reduction in incidence of cancer attributable to exposure to HAPs emitted by stationary sources;

- Attain a substantial reduction in public health risks posed by HAP emissions from area sources; and

- Address disproportionate impacts of air toxics hazards across urban areas.

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[d] This is not to say that some chemicals are not long-lived (i.e., persistent) in the environment or do not travel long distances once released to the atmosphere (a number of the air toxics do have these properties). Some chemicals may even transform in the atmosphere to a more toxic chemical as they travel downwind from the point of release. Depending on the chemicals being emitted in (or upwind of) a given study area, a range of temporal and spatial exposure scenarios is possible. The partnership team designing the risk assessment must take these issues into account during the planning, scoping, and problem formulation phase of the analysis (see Chapter 4).

The Strategy identifies four main areas of action to help achieve these goals:

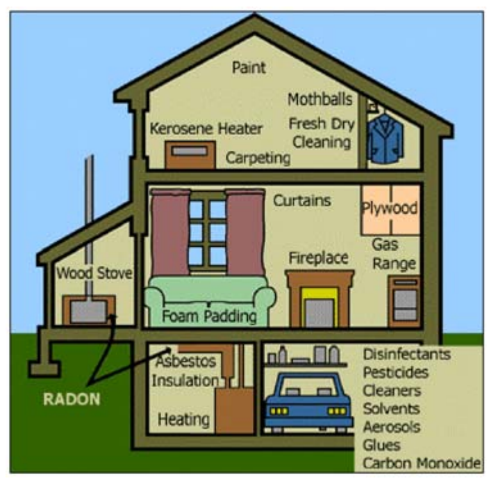
- **Develop regulations addressing sources of air toxics at the national and local levels**. Pursuant to this effort, the Agency will continue its work to develop rules that require reductions in air toxics emissions from stationary facilities (such as manufacturing plants, electric power plants, gas stations, and dry cleaners), as well as from cars, trucks, and other mobile sources and their fuels (Exhibit 2-1 provides an overview of progress in reducing air toxics emissions). EPA has historically developed and implemented many such standards over the years, and the Strategy indicates the need for additional standards to reduce risks in urban areas.

- **Initiate local and community-based projects to address specific multimedia pollutants (e.g., mercury) and *cumulative risks within urban areas***. The CAA requires EPA to "encourage and support area-wide strategies developed by the state or local air pollution control agencies" to address air toxics in urban areas. EPA is developing tools and is working with communities to assess and reduce risks at the community level. ATRA Volume 3 represents a key tool to help the Agency and its partners to help meet the specific Strategy goal of addressing cumulative risks within urban areas.

  The Strategy also recognizes the need to assess the risks from exposures to indoor air toxics and to develop non-regulatory, voluntary programs to address those risks. The Strategy also points out that air pollutants may move into other environmental media such as soil and water resulting in multimedia (i.e., more than just air) concerns. EPA is engaged in a number of activities that recognize the ability of several air toxics to deposit out of the air and bioaccumulate in biota consumed by humans and ecological receptors (e.g., deposition of mercury in watersheds, with subsequent uptake by fish – see Part III).

What About Sources of Indoor Air Toxics?

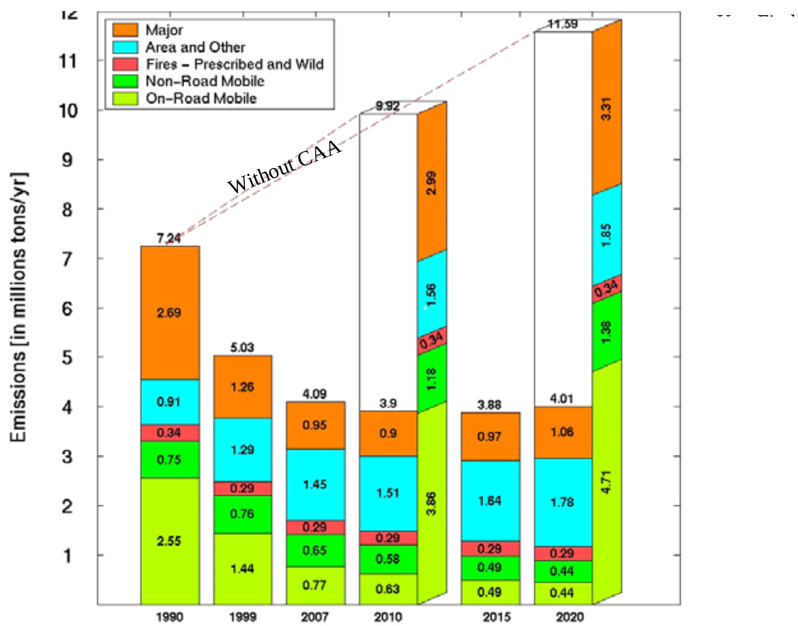
- Indoor air can become contaminated from numerous sources.
- Indoor air can have significantly higher concentrations of air toxics than outdoor air.
- EPA currently does not regulate indoor sources of air toxics.



(Although not shown in this figure, outdoor air is a source of indoor air toxics as well – via infiltration and ventilation. The importance of indoor air toxics sources on overall community exposure is discussed in Sections 3.2.4.1 and 4.3.)

Exhibit 2-1. Progress in Hazardous Air Pollutant Emissions

Total U.S. HAP Emissions* by Source Sector



This bar chart illustrates the decrease in HAP emissions to outdoor air from 1990 (baseline year) through 2020, assuming CAA controls (facing bars). The side bars indicate the estimated emissions that would occur in 2010 and 2020 without these controls.**

Note that indoor sources of air pollutants can be a significant contributor to an individual's overall air toxics exposure (information on ways to reduce exposure to indoor air pollutants is provided in Section 8.3.3). It should also be noted that, although reductions in emissions can result in decreased health risks, there is a distinction between emissions (i.e., the amount of chemical release to indoor or outdoor air) and the exposures that may result (i.e., the concentration of chemical in the air that people actually contact), with measures of exposure, rather than emissions, being preferred for assessing risk (see Exhibit 5-2).

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*Except mercury.
**After 2010, stationary source emissions are based only on economic growth. They do not account for reductions from ongoing toxics programs such as the urban air toxics program, residual risk standards, and area source program, which are expected to further reduce toxics. In addition, mobile source reductions are based on programs currently in place. Programs currently under development will result in even further reductions.

Source: Strum, M., Pope, A., Thurman, J., Ensley, D., Palma, T., Mason, R., Cook, R., Shedd, S. 2005. *Projection of Hazardous Air Pollutant Emissions to Future Years*, Presented at the International Emission Inventory Conference: Transforming Emission Inventories - Meeting Future Challenges Today, Las Vegas, NV, April 14, 2005 (http://www.epa.gov/ttn/chief/conference/ei14/session10/strum.pdf).

- **Conduct air toxics assessments to identify areas of concern, prioritize efforts to reduce risks, and track progress**. The Strategy identifies a variety of national-level assessment activities that will help EPA identify urban areas of particular concern, characterize the risks that air toxics pose, and track the progress toward meeting overall air toxics program goals. EPA is implementing the National Air Toxics Assessment (NATA) to address this goal. NATA includes:

  – Expanding air toxics monitoring (i.e., the establishment of National Air Toxics Trend Stations, or NATTS, implemented to characterize air toxics trends on a national basis);[e]
  – Improving and periodically updating emissions inventories;[f]
  – Assessing national- and local-scale air quality by using multimedia and exposure modeling;
  – Continuing to research the exposures to, and health effects of, toxic chemicals in ambient and indoor air; and
  – Using and improving exposure and assessment tools.

  These activities will help EPA and other stakeholders[g] better understand air toxics risks as well as risk reductions associated with emissions control standards and other initiatives aimed at reducing emissions. (For additional information on the National Air Toxics Strategy see http://www.epa.gov/ttn/atw/urban/urbanpg.html.)

  A particularly high-profile aspect of NATA has been the national-scale assessment of 1996 and 1999 emissions that produced predictions of county-level estimates of air toxics concentrations and calculated risks for a subset of HAPs. This analysis indicates that risks posed by air toxics are still relatively high and widespread across the United States (see Exhibit 2-2).

- **Perform education and outreach**. Given the scientific complexity inherent in air toxics issues, EPA recognizes that the success of the overall air toxics program depends on the public's understanding of the nature of air toxics risks and the activities that can help reduce those risks. To further this understanding, EPA will support education and outreach efforts at the national level and through its state, local, and tribal (SLT) partners. This resource document, for example, is an outgrowth of this educational/outreach effort.

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[e] Information on monitoring and the use of monitoring data for risk assessments can be found in ATRA Volume 1, Chapter 10.

[f] The Emissions Inventory Improvement Program (EIIP) was established to improve the quality of emissions information and to further the development of systems for collecting, calculating, and reporting emissions data (see http://www.epa.gov/ttn/chief/eiip/index.html). Additionally, the North American Research Strategy for Tropospheric Ozone (NARSTO) conducted an assessment on the status of North American emission inventories and suggested areas for improvement in future emissions inventories. More information about the NARSTO assessment is available at http://narsto.org/.

[g] This resource document uses the term "stakeholder" broadly to include all parties with a potential interest in a given air toxics risk assessment, including regulators, the regulated community, community partners, and individual members of the public. The "partnership team" is the group of people who come together as a group to perform the overall work of the assessment.

Exhibit 2-2. 1999 National Air Toxics Assessment Risk Characterization

In February 2006, EPA released the results of its national-scale assessment of 1999 air toxics emissions. The purpose of the national-scale assessment is to identify and prioritize air toxics, emission source types and locations which are of greatest potential concern in terms of contributing to population risk. The national-scale assessment includes 178 air pollutants [a subset of 177 air toxics on the Clean Air Act's list of 187 air toxics plus diesel particulate matter (diesel PM)]. The assessment includes four steps that focus on the year 1999:

- Compiling a national emissions inventory of air toxics emissions from outdoor sources;
- Estimating ambient concentrations of air toxics across the United States;
- Estimating population exposures across the United States; and
- Characterizing potential public health risk due to inhalation of air toxics including both cancer and noncancer effects.

This analysis found that more than 270 million people live in census tracts where the combined upper-bound lifetime cancer risk from these compounds exceeded 10 in one million risk and more than 190 million people live in census tracts where risk greater than 10 in one million resulted from known human carcinogens (Class A) alone. Some of the chemicals involved in these risks include benzene, arsenic, benzidine, 1,3-butadiene, chromium (VI), coke oven emissions, carbon tetrachloride, hydrazine, naphthalene, perchloroethylene, and polycyclic organic matter (POM).

Regarding noncancer hazard, EPA found that for two of the common health endpoints associated with air toxics (respiratory and neurological effects), the corresponding "hazard index" (i.e., the sum of the hazard quotients of the air toxics compounds that affect the respiratory or nervous system), are as follows: The respiratory hazard index, which was dominated by a single substance, acrolein, exceeded a value of 1.0 for nearly the entire U.S. population, and exceeded 10 for more than 48 million people. The neurological hazard index was similarly dominated by manganese compounds, with minor contributions by cyanide compounds, ethylene oxide, and mercury compounds. The neurological hazard index exceeded 1.0 for fewer than 800,000 people in the U.S.

The results provide answers to questions about emissions, ambient air concentrations, exposures and risks across broad geographic areas (such as counties, states and the nation) at a moment in time. As such, they help EPA identify specific air toxics compounds and specific source sectors such as stationary sources or mobile sources, which generally produce the highest exposures and risks in the country. However, they also are based on assumptions and methods that limit the range of questions that can be answered reliably. They cannot be used to identify exposures and risks for specific individuals and EPA recommends that the census tract data/maps be used to determine geographic patterns of risks within counties rather than to pinpoint specific risk values for each census tract. They also do not account for the reductions in emissions that have occurred since 1999 or those that will happen in the future due to regulations for stationary or mobile sources. These limitations, or caveats, must always be kept in mind when interpreting the results, and the results should be used only to address questions for which the assessment methods are suited. See additional limitations at http://www.epa.gov/ttn/atw/nata/natsalim2.html. For more information about NATA, see http://www.epa.gov/ttn/atw/natamain/.

As emphasized in the National Air Toxics Strategy, because the mix of sources and pollutants in specific community-scale geographic areas can be quite variable, one element of an effective approach for reducing any remaining unacceptable risks is to understand the cumulative impacts at the local level posed by the simultaneous impact of multiple pollutants released by multiple sources, target the problem sources and chemicals, and tailor risk reduction strategies to the local circumstances in those areas.

To encourage this type of air toxics risk reduction approach at the community level, EPA Headquarters and Regional Offices are working collaboratively with SLT and community partners to develop guidance, provide education/information exchanges, identify and assess pollution prevention and control options, and promote voluntary measures and innovative solutions to assess and address community air toxics problems.

In many cases these risks may be more appropriately and more effectively addressed at the SLT level, rather than at the federal level. Specifically, SLT air agencies may wish to address issues that are of concern on a state-wide, area-wide, community-wide, or individual neighborhood basis, and for areas in the immediate vicinities of specific air toxics sources. Some SLT governments are already addressing some of these issues; others are just beginning to develop their own programs.

2.1.2 Using a Risk-Based Approach for Addressing Community-Scale Air Toxics Issues

While there are several methodologies to assess potential health impacts of multiple sources of air toxics on populations at the local level, the risk-based approach is perhaps one of the most effective.

The general methodology described here, called **risk assessment**, is the process for evaluating:

- The sources of air toxics released to the environment;
- How the released chemicals move and change in the environment;
- Who may be exposed to the chemicals and at what levels;
- How exposures may occur;
- The toxic effects of the chemicals in question and how potent they are; and
- How likely it is that the potentially exposed people will experience harm because of the exposures.

In addition to impacts on humans, air toxics released to the atmosphere may also impact local ecosystems including adverse effects on animal and plant populations or on aspects of ecosystems on which they depend.

Strengths and Weaknesses of Risk Assessment

Before initiating a risk assessment as a way of addressing community-scale air toxics issues, analysts and stakeholders should be aware of some of the strengths and weaknesses of risk assessment. Some examples of each include:

Strengths

- Provides a systematic, tiered approach to problem solving
- Emphasizes data collection to address uncertainties
- Extensive guidance developed by EPA regarding risk assessment methodologies
- Provides a consistent basis for assessing the need for action and comparing impacts of a range of approaches/decisions

Weaknesses

- Traditionally incorporates conservative assumptions to fill data gaps, leading to potentially overstated estimates of risk
- Conclusions dependent on the quality of the underlying data

For more information on the pros and cons of using a risk-based approach to the assessment of air toxics, analysts may want to review *Science and Judgment in Risk Assessment* (see reference 2).

This kind of information can be extremely helpful to decision makers as they try to balance the competing concerns of protecting public health, fostering economic development, and evaluating issues of fairness and equity, among others. Specifically, risk assessment can provide:

- A predictive estimate of the potential health risks posed by air toxics, which may help determine the need for action;
- A basis for determining the levels of chemicals that can be released to the air without posing unacceptable risks to public health and the environment;
- A basis for comparing potential health impacts of various pollution reduction alternatives;
- A consistent process for evaluating and documenting threats to public health and the environment from toxic air pollution; and
- A basis for comparing risks from various exposure scenarios (e.g., the risk from breathing contaminated air compared to the risk from eating contaminated food).

Performing an air toxics risk assessment is often challenging. Risk assessments can be resource and time-intensive, depending on the specific questions being asked and the level of detail needed for informed decision making. Risk assessments usually require input from a number of scientists and engineers with a variety of skills (e.g., chemistry, toxicology, statistics, modeling, meteorology, monitoring). Decision makers may also need to acquire new skills in order to understand and use the risk assessment results. Finally, although they are based on science, risk assessments often rely on the best judgment of the analysts in the face of various uncertainties.

The general framework for performing and using the risk assessment approach to evaluate the simultaneous impact of multiple sources of air toxics on a local community is the focus of Parts II and III of this volume.

A multisource cumulative air toxics assessment at the community scale as a tool for reducing local risks will generally involve the following steps (and is discussed in detail in the next chapter):

- Evaluate the cumulative inhalation risk from air toxics sources in a defined geographic area;
- Evaluate whether the cumulative inhalation risk is acceptably low;
- If cumulative risk is not acceptably low, use the risk assessment results to identify the chemicals and sources that are causing the majority of the risk (i.e., the risk "drivers"); and
- Select risk reduction options (preferably for the sources and chemicals posing most of the risk – the risk drivers) that will bring the overall risk down to an acceptably low level.

The Framework for Cumulative Risk Assessment

In response to the increasing focus on the combined risk posed to people from multiple environmental risk factors across all media (air, land, water, and contaminated food), EPA has developed a *Framework for Cumulative Risk Assessment* as the first step in the long-term effort to develop cumulative risk assessment guidance.

The Framework defines cumulative risk assessment as *an analysis, characterization, and possible quantification of the combined risks to human health or the environment from multiple agents or stressors*. The community-scale approach to air toxics assessment and risk reduction, as described in this resource document, is an outgrowth of the *Framework*.

The Framework and associated materials can be accessed at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=54944.

Performing the analysis in this way can lead to more meaningful risk reduction in a community than simply focusing on one or a few sources because of a *perceived* threat. Note, however, that:

- Some communities may not have the desire or the resources to perform a comprehensive risk assessment approach and may opt for a simpler screening-level approach. [Section 3.5.1 discusses EPA's *Community Air Screening How To Manual* which provides information for communities that want to perform a screening-level assessment instead of (or as a prelude to) one of the other risk assessment approaches described in this resource document.]
- There are a variety of actions that any community can begin at any time that will provide meaningful risk reduction with little to no up-front analysis. For example, retrofitting older diesel school buses with newer pollution control devices, anti-idling options, and restrictions on secondhand smoke will all lead to significantly reduced risk for people in the community. Chapter 8 of this resource document discusses risk mitigation approaches for both outdoor and indoor air.

Air Toxics Community Assessment and Risk Reduction Projects Database

An important component of EPA's efforts to reduce unacceptable risks from air toxics is to work with SLT organizations to understand the risks at the local level, target the problem areas, and tailor reduction strategies to the circumstances in those areas. EPA has developed a database of completed and ongoing community level air toxics assessments across the country to aid in this effort. By sharing information about local efforts to measure, understand, and address air toxics emissions, this database will help ensure that communities designing and implementing their own assessments will be able to build upon past efforts and lessons learned. The following information on each assessment is provided in the database:

- Project Title
- Status of Project (complete or ongoing)
- Study Dates
- Study Summary
- General Information
- Assessment and Analysis Methods
- Risk Assessment Project Design
- Findings
- Outcomes
- Public Involvement
- Document Downloads

The database can be accessed at:
http://yosemite.epa.gov/oar/CommunityAssessment.nsf/Welcome?OpenForm.

- Even when there is a high degree of certainty about the chemicals and/or sources that drive a community's cumulative air toxics risk, there may be practical or legal reasons why the partnership team may choose to focus their risk reduction efforts elsewhere. For example, the technology may not currently exist to reduce the emissions from an emission source, and the community, acting as the risk manager, may be willing to live with a somewhat higher risk rather than close the facility and lose a crucial source of jobs or close a thoroughfare and lose the business along a transportation route. (In this instance, the citizens, acting as "risk managers," have balanced the need for jobs with the level of additional risk in deciding how to respond to the results of the risk analysis. A discussion of the principles of risk management is presented in ATRA Volume 1, Chapter 27, and Chapter 8 of this Volume.)

2.1.3 Community-Scale Air Toxics Assessment and Environmental Justice Issues

EPA defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no group of people should bear a disproportionate share of the negative environmental consequences resulting from industrial, governmental, or commercial operations or policies. Meaningful involvement means that: (1) people have an opportunity to participate in decisions about activities that may affect their environment and/or health; (2) the public's contribution can influence the regulatory agency's decision; (3) their concerns will be considered in the decision making process; and (4) the decision makers seek out and facilitate the involvement of those potentially affected."

A goal of environmental justice is to eliminate disproportionate risks or impacts across all groups, including low-income and/or minority populations. In 1999, the Institute of Medicine stated that "many communities contain potential sources of environmental risks (e.g., industrial facilities, waste treatment sites, or waste disposal sites). These can affect all racial, ethnic, and socioeconomic groups, but there is substantial evidence that minority and low-income groups face higher levels of exposure in terms of both frequency and magnitude."[(4)]

An overview of the role of environmental justice in environmental decision-making and the importance of multisource cumulative assessment and tools such as RAIMI in evaluating minority and/or low-income communities is provided here. More detailed information about environmental justice and it's role in EPA decision making can be found on EPA's Environmental Justice web page at http://www.epa.gov/compliance/environmentaljustice/index.html.

2.1.3.1 History of Environmental Justice at the Federal Level

The environmental justice movement was started by people, primarily people of color, who needed to address the inequity of environmental protection services in their communities. Grounded in the struggles of the 1960's civil rights movement, these citizens from every facet of life, emerged to elucidate the environmental inequities facing millions of people. These communities rose to articulate and sound the alarm about the public health threats which posed an immediate danger to the lives of their families, their communities and themselves.

In response to public concern, EPA established the Office of Environmental Justice in 1992. Within this office, a new organizational infrastructure was implemented to facilitate the incorporation of environmental justice into EPA's programs and policies. This included the creation of an Environmental Justice Executive Steering Committee, which provides leadership ensuring that environmental justice is incorporated into agency programs, as well as regional and program office environmental justice coordinators.

The National Environmental Justice Advisory Council (NEJAC) was created in 1993 to provide independent advice and recommendations to the Administrator of EPA on areas related to environmental justice. The NEJAC meets once a year to address the

> The National Environmental Justice Advisory Council (NEJAC) is a federal advisory committee established to provide independent advice, consultation, and recommendations to the EPA Administrator on matters related to environmental justice. Several NEJAC reports provide guidance on involving historically disenfranchised groups in community efforts including:
>
> - Environmental Justice in the Permitting Process
> - Environmental Justice and Community-Based Health Model Discussion
> - NEJAC Report on Integration of Environmental Justice in Federal Programs
> - Fish Consumption and Environmental Justice
> - Advancing Environmental Justice Through Pollution Prevention
> - Cumulative Risks/Impacts and Environmental Justice
>
> Information about NEJAC, its function, meetings, and products, is available at http://www.epa.gov/compliance/environmentaljustice/nejac/

concerns of community members, nonprofit and environmental organizations, tribes, academia, industry, and state and local government groups. The NEJAC Executive Council has 26 members drawn from important environmental justice constituencies and an additional seven subcommittees, including Air and Water, Enforcement, Health and Research, Indigenous Peoples, International, Puerto Rico, and Waste and Facility Siting.

Former President Clinton issued Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* on February 11, 1994. This Order directs attention to the environmental and human health disparities typical of minority and/or low-income communities. The Federal Interagency Working Group on Environmental Justice (IWG), established pursuant to this Order, consists of eleven federal agencies and several White House offices. Presently, the IWG has three task forces: Health Disparities, Native American, and Revitalization Demonstration Projects. These task forces address a variety issues related to some aspect of environmental justice, ranging from preservation of sacred tribal sites to community rehabilitation to assessment and examination of discrepancies in health.

Case Study

A Class I toxic waste dump was built in the late 1970s outside of Kettleman City, a small, predominately Latino agricultural community. When news of its proposed expansion reached the town, residents were shocked to learn that the dump just three miles from their homes had violated state environmental regulations on multiple occasions, yet was preparing to construct new facilities for incineration of additional waste. Residents and community leaders formed a citizen's group, El Pueblo para el Aire y Agua Limpio (Citizens for Clean Air and Water), that took legal action against the corporation operating the facility and was successful in preventing further expansion of the incinerator. Instrumental in strengthening the resolve of the community was Kettleman City residents' discovery of the Cerrell Report (1984). The report suggested that companies building waste incinerators would find the least resistance in small, rural, poor, uneducated, blue-collar communities. This was a suspiciously accurate description of Kettleman City, as well as the two other communities home to Class I toxic waste dumps in California.

Source: Cole, Luke W. and Sheila R. Foster. *From the Ground Up: Environmental Racism and the Rise of the Environmental Justice Movement*. NYU Press: New York, 2001.

2.1.3.2 Environmental Justice and Multisource Cumulative Assessment

One of the main goals of environmental justice is to ensure that no group, including racial and socioeconomic populations, is disproportionately burdened with negative environmental and health impacts associated with pollution. Multisource cumulative assessment attempts to characterize the multiple sources and chemicals, exposures, and pathways of pollution affecting human and environmental health within a defined geographical area. Ideally, these assessments should also attempt to incorporate the many risks or population-specific susceptibilities that are particular to a community, including those that are unique to or more prevalent in minority and/or low-income communities. For example, community health is affected by stresses (e.g., economic, societal, cultural) other than exposure to pollutants.

The tools and approaches available for multisource assessment that are described in this resource document, especially the Regional Air Impact Modeling Initiative (RAIMI) as well as the Human Exposure Model (HEM), provide an objective method for assessing risk both for the entire community and for specific segments of a community, including minority and/or low-income neighborhoods. Multisource cumulative assessments can be used to assess the relative exposure and risk faced by each neighborhood. **However, these tools and approaches do not provide a basis for determining whether or not any group, including minority and/or low-income populations, is experiencing a *disproportionate burden* of risk. The tools for determining disproportionate risk or impacts are being developed.** Moreover, that decision should include the input of each community, based on their own standards and values.

2.2 Environmental Concerns Other Than Air Toxics Emissions to Air

During its first 34 years, EPA, along with its state, local, and tribal government partners, has achieved substantial environmental progress using regulatory standards and voluntary programs to protect human health and the environment from a wide array of environmental threats (see Exhibit 2-3). However, even with the great strides in environmental management, a number of important issues remain. For example:

- Fish advisories that limit or restrict consumption are widespread across the United States, and many water bodies are under some form of fish consumption advisory (http://www.epa.gov/ost/fish/).

- Many homes built before 1978 contain lead-based paint, a potent childhood neurotoxin and some urban drinking water systems may have elevated lead concentrations (http://www.epa.gov/lead/).

- Many households purchase and use a variety of pesticides, including: cockroach sprays and baits; insect repellents for personal use; rat and other rodent poisons; flea and tick sprays, powders, and pet collars; kitchen, laundry, and bath disinfectants and sanitizers; products that kill mold and mildew; certain lawn and garden products, such as weed killers; and certain swimming pool chemicals. All of these products can be potentially harmful when improperly used or disposed (http://www.epa.gov/pesticides/).

While air toxics are often of central interest to community stakeholders, their concerns will often expand to include these additional types of issues. Some of these "non-air" concerns may be commonly occurring issues throughout many communities across the United States, while others may be particular to a given region or even unique to a specific community. For example, protection of public drinking water supplies may be a common interest in communities across the U.S., while concerns about an abandoned hazardous waste site will be of concern primarily to the neighboring community.

An understanding of the overall impact of all environmental toxicants on a community would require an evaluation of risk across this multitude of environmental risk factors (in addition to air toxics). The current level of scientific understanding as well as the tools to do such analyses are still in the development stage. There are, however, some assessment techniques and actions that can be performed (e.g., comparative risk analysis, or CRA) to help communities identify their more pressing environmental risk factors and select mitigation projects that can result in meaningful risk reduction. A discussion of the CRA process and various risk mitigation approaches is provided in Part IV.

Additional Environmental Justice Resources and References

Environmental Justice Alternative Dispute Resolution Training (http://www.epa.gov/compliance/resources/publications/ej/)

EPA Environmental Justice Program (http://www.epa.gov/compliance/environmentaljustice/)

National Environmental Justice Advisory Council (http://www.epa.gov/compliance/environmentaljustice/nejac/index.html)

Ensuring Risk Reduction in Communities with Multiple Stressors: Environmental Justice and Cumulative Risks/Impacts - Executive Summary (http://www.epa.gov/Compliance/resources/publications/ej/nejacmtg/nejac-cum-risk-reort-exec-summary.pdf)

Environmental Justice Training (http://www.epa.gov/compliance/training/index.html)

Environmental Law Institute Reports (http://www.elistore.org/reports.asp)

Communities and Environmental Laws Video (EPA, Office of Environmental Justice)

Advancing Environmental Justice through Pollution Prevention (http://www.epa.gov/compliance/resources/publications/ej/)

Office of Solid Waste, Environmental Justice web site (http://www.epa.gov/epaoswer/osw/ej/)

Social Aspects of Siting Hazardous Waste Facilities (http://www.epa.gov/epaoswer/hazwaste/tsds/site/k00005.pdf)

EPA Office of Air and Radiation TribalAIR website (http://www.epa.gov/air/tribal)

Science Policy, Environmental Justice Conference (Boston, MA 2004) "Science to Action: Community-based Participatory Research and Cumulative Risk Analysis as Tools to Advance Environmental Justice in Urban, Suburban, and Rural Communities." (http://epa.gov/osp/regions/envjust.htm)

The Environmental Justice Resource Center at Clark Atlanta University (http://www.ejrc.cau.edu)
Toward Environmental Justice: Research, Education, and Health Policy Needs (1999) (http://books.nap.edu/books/0309064074/html/index.html)

Lester, James P., David W. Allen, and Kelly M. Hill. *Environmental Injustice in the United States: Myths and Realities.* Boulder: Westview Press, 2001.

Exhibit 2-3. Example Advances in Environmental Quality

Water Quality. Over the past 30 years, EPA and its federal, state, and tribal partners have made significant progress in protecting and restoring the nation's waters. Today, more Americans have safe, reliable, and affordable drinking water, and people can fish, swim, and travel safely in rivers that were once polluted. For example, EPA has established and is working to implement health-based drinking water standards for more than 90 contaminants. To help drinking water systems implement the standards EPA, states, tribes, and key stakeholders work together to provide water systems with extensive technical assistance and training. Over the past decade, the Agency and its partners have made significant progress in providing the public with drinking water that meets health-based standards.

Land Preservation and Restoration. EPA's waste management and emergency response programs work with state, tribal, and local governments to implement and oversee 15 separate statutory authorities. Many stakeholders—including non-governmental organizations, industry associations, and Federal Advisory Committee Act groups—assist in these efforts. Four themes characterize this program: Revitalization (restoring contaminated land to economically viable use); the One Cleanup Program (a program to look across all cleanup programs to increase consistency and enhance effectiveness); Recycling, Waste Minimization, and Energy Recovery; and Homeland Security. As an example of success in this area, by the end of fiscal year 2004 the Superfund program completed construction at 926 sites and 458 construction projects were continuing at 345 sites (excluding federal facilities) with two-thirds of these projects (309) led by Potentially Responsible Parties. As a result of Superfund's cleanups, 490 NPL sites now have land ready for reuse, and 300 of these are in use.

Chemicals and Pesticides. EPA is committed to preventing risks from new chemicals and pesticides entering the environment, as well as to addressing legacy issues from old bad actors. The Agency reviews new chemicals and pesticides before they are put on the market, reassesses older chemicals and pesticides already in use, and takes appropriate action should they pose unacceptable risks. Working with industry, EPA has now screened over 22 percent of the more than 76,000 commercial and/or industrial chemicals in the U.S. inventory.

Compliance and Environmental Stewardship. EPA continues to improve national environmental performance by ensuring compliance with environmental law and promoting environmental stewardship to conserve resources, prevent pollution, and reduce waste. The Agency uses a wide spectrum of regulatory and nonregulatory strategies, including compliance assistance and incentives, monitoring and data analysis, pollution prevention, and civil and criminal enforcement. EPA also conducts research to identify innovative approaches to environmental protection and encourages states, tribes, and regulated entities to develop new approaches, ideas, and techniques. As an example of success in this area, fiscal year 2004 civil enforcement actions completed, reduced, properly treated, or eliminated an estimated 1 billion pounds of pollutants from release into the environment. An additional 25.3 million pounds of pollutants will be reduced as a result of FY 2004 criminal enforcement actions. Enforcement actions in that year will also require companies to invest $4.8 billion in pollution control and improve environmental management practices at facilities.

These are only a few of the many important environmental successes achieved in the U.S. over the past decades. A more comprehensive look at EPA's programs and progress can be found in the Agency's *Annual Performance Report* series located at: http://www.epa.gov/ocfo/finstatement/apr.htm.

In addition to pollution-associated risk factors that a community may face, there may be other factors affecting overall community health (see box at right). EPA usually has little or no authority to influence many of these factors, but these issues (and others) may nevertheless be identified as important considerations for a community that is seeking to *holistically* enhance its quality of life. Partnership teams working to understand and reduce pollution-associated risk factors will likely become engaged at some level with these other issues. At a minimum, participants in a community-scale environmental assessment project should be sensitive to these other issues and work to help the community identify persons or organizations who can assist them in addressing their other concerns.

Examples of Other Factors That May Affect Community Health

- Crime
- Education
- Diet
- Physical activity level
- Access to health care
- Poverty
- Sexually transmitted diseases
- Substance abuse
- Teen pregnancy
- Jobs

2.3 Localized Assessment and Risk Reduction – A General Goal

EPA is encouraging the use of collaborative community-based approaches to toxics risk reduction in any environmental media by working to develop the tools and support that communities will need to embark upon these projects. This ATRA Library, for example, was developed to fill an important gap in guidance on how to assess and reduce one specific toxics issue – air toxics impacts. Some of the other activities that EPA is pursuing to encourage local scale assessment and risk reduction include:

- Implementation of a National Air Toxics Strategy that, among other things, encourages the use of community-based assessments and risk reduction strategies (discussed above);

- Providing grants and other support to communities performing projects;

- Development of databases of projects to help communities learn from each other (what works well, what does not). For example, EPA recently developed an Air Toxics Community Assessment and Risk Reduction Projects Database to help communities performing air toxics assessments (see Section 2.1);

- Development and implementation of a new program called Community Action for a Renewed Environment, or CARE, an action-oriented effort to reduce the wide variety of toxics risks a community may face (see box on next page); and

- EPA's Community-Based Environmental Protection (CBEP) process, which integrates environmental management with human needs, considers

Who Are the Stakeholders in a Community-scale Project?

The **community** is often thought of as the people who live within the area of impact of pollution sources. In addition to residents, however, other individuals and organizations may also consider themselves "community" stakeholders.

For example, additional stakeholders can include people who own businesses in the area and their employees, local officials, health professionals, and the local media. It is often helpful when performing a community-scale project to keep in mind that many different people and organizations (not just the people who live there) may have an interest in the work being undertaken.

long-term ecosystem health and highlights the positive correlations between economic prosperity and environmental well-being (http://www.epa.gov/ecocommunity/).

Local-scale risk analysis and risk reduction efforts will typically be most successful when government entities and technical experts work effectively with the local community. This is especially true when successful risk reduction relies heavily on the participation of community members. The next section discusses this issue in more detail.

Community Action for a Renewed Environment (CARE)
and the CARE Resource Guide

Community Action for a Renewed Environment (CARE) is a new EPA initiative designed to establish a series of multimedia, community-based and community-driven projects to reduce local exposure to toxic pollution.

Through CARE, EPA is partnering with communities to help them create collaborative partnership teams that may include community organizations, other non-profits, state and local government agencies, other federal agencies, businesses, and academia. These partnership teams will use EPA Cooperative Agreements and other funding to select and implement local voluntary actions that reduce local exposure to toxics. This program will provide technical assistance by helping communities identify and access opportunities through a wide range of voluntary programs. CARE helps communities by responding to their needs, helping to reduce risk, and working with them on solving problems identified within their community. More information about CARE can be found at www.epa.gov/care.

The CARE Resource Guide

The CARE program has developed a Resource Guide to help participating communities, but it can be used by anyone interested in any aspect of working with communities to reduce toxics risks. In the CARE program, communities go through a multi-step process: getting organized, analyzing risks, reducing risks, and tracking progress. The Resource Guide enables partnership teams or anyone working with communities to find the on-line resources that can help their community through every step of the process as they move from getting organized to becoming stewards of their own environment. The first four parts of the Resource Guide track the CARE process and are roughly organized in order of the steps a community would go through as it moves through that process:

Part I	Getting Started and Building Partnerships
Part II	Understanding the Risks in Your Community
Part III	Methods to Reduce Your Exposure
Part IV	Tracking Progress and Moving Forward

Partnership teams are encouraged to use the Resource Guide to help them locate important guidance documents and other information they will need to draw on as they work to perform an analysis of risk factors in their community, select risk reduction projects, and evaluate their efforts over time.

The CARE Resource Guide can be accessed at:
http://cfpub.epa.gov/care/index.cfm?fuseaction=Guide.showIntro

2.4 Community-Scale Stakeholders and the Importance of Community Involvement

As noted previously, EPA and other regulatory programs have been very effective at reducing pollution and improving environmental quality across the United States. However, these programs have not always been able to fully address the varied and multiple impacts from toxic chemicals that people experience in a given place. Instead, community-scale solutions are needed that:

- Focus on a definable geographic area;
- Involve collaboration among a full range of stakeholders through partnerships;
- Assess, protect, and restore the quality of the environment in a place as a whole;
- Integrate public and private action using the most appropriate regulatory and non-regulatory activities to forge effective solutions for each unique community; and
- Monitor and redirect efforts through adaptive management.

Typical stakeholders in this process can include:

- EPA officials;
- State officials;
- Tribal leaders;
- Local officials such as environmental agencies, health department personnel, and city planners;
- Environmental groups;
- Non-governmental organizations (NGOs);
- Environmental justice stakeholders;
- Regulated and non-regulated businesses;
- Community groups;
- Academics; and
- Concerned citizens.

A large, diverse group of stakeholders such as this can provide a wide array of expertise and knowledge to help evaluate an area's interrelated problems. This also encourages the development of effective and appropriate problem-solving tools. For example, an approach that may improve water quality levels but exacerbates other pollution problems would be avoided under this type of community-scale approach because all the right stakeholders are talking to one another. Widespread stakeholder collaboration also improves environmental protection management by providing a means and forum for adaptive problem solving. If a risk reduction method is not working, the relationships established through collaborative work should facilitate discussion and implementation of alternative approaches.

In short, a key ingredient in the success of a toxics assessment and reduction project is effective community involvement since the members of the community are the people who have the greatest vested interest in improving community health. In addition, many laws recognize and accommodate the idea that individuals who are affected by a given decision have the right to participate in the making of that decision (a concept that can benefit non-regulatory activities as well). In the long run, integrating community stakeholders at the outset of the process and making them a trusted and valued partner at all points along the way will help to:

- Produce a comprehensive identification of local environmental toxics concerns;
- Set priorities and goals that reflect overall community values and concerns; and
- Forge comprehensive, short- and long-term solutions that are acceptable to the community and which the community is more likely to take ownership of and sustain over time.

ATRA Volume 1, Chapter 28, provides an overview of this topic. Additional discussions of how to engage the community are provided in Chapters 4 and 10.

Finally, it should be noted that the effort to build stakeholder partnerships and trust, collect and analyze data, write and communicate results, and develop and implement plans for making environmental improvements will likely require significant time and commitment to complete. Depending on the circumstances, it may take anywhere from less than a year to multiple years to develop and implement risk reduction actions. The stakeholder partners will need to adequately plan and make the necessary commitments to be able to complete the process, improve environmental quality, and sustain the effort over time.

Short-Term vs. Long-Term Actions and Results – Differences in Time Scales

The time required to achieve meaningful toxics risk reduction can vary widely depending on the type and scope of the effort that is initiated. Some actions may result in risk reductions in a relatively short time period while other efforts may require more time to bring about results. Two examples are presented here.

- Short-term: Until recently, smoking was allowed in restaurants and other public venues in a community study area. Based on available information on the health impacts of secondhand smoke, the partnership team was able to convince the local government and business community of the immediate need for a ban on smoking in public places. Once the ban went into effect, there was essentially an immediate and dramatic reduction in exposures to secondhand smoke (at least in public places).

- Long-term: In an industrialized urban area with a complex mix of emissions from factories, cars and trucks, and small businesses, a long-term program was established to reduce emissions from all of these types of sources over time. Elements of the plan include:

    - A program to educate residents regarding the benefits of reducing the number of single-passenger cars on the roads during commuting hours by carpooling and ride-sharing;
    - Working with local planning and transportation authorities to site new roadways in such a way as to reduce exposures to residents, increase the availability and attractiveness of mass transit options, institute anti-idling policies, and increase the use of electrified truck stops;
    - Engage industry (both large and small) to identify pollution prevention alternatives that might be instituted ahead of (or in addition to) regulatory requirements. This includes outreach, education, and establishing a local P2 resource center for small business owners.

  Although these actions did not immediately reduce overall air pollutant loadings, the program attempted to target all the important contributors to pollution in the local area, eventually resulting in a cumulative benefit for the community. The benefits of this program would probably take longer to realize than the previous example.

General Resources on Community Involvement

Community-Based Environmental Protection: A Resource Book for Protecting Ecosystems and Communities (http://www.epa.gov/ecocommunity/tools/resourcebook.htm)

The Model Plan for Public Participation (http://www.epa.gov/compliance/resources/publications/ej/)

The RCRA Public Participation Manual (http://www.epa.gov/epaoswer/hazwaste/permit/pubpart/manual.htm)

Enhancing Facility-Community Relations (http://www.epa.gov/epaoswer/hazwaste/tsds/site/f02037.pdf)

Notebook on Local Urban Air Toxics Assessment and Reduction Strategies (http://www.epa.gov/ttn/atw/wks/notebook.html)

References

1. U.S. Environmental Protection Agency. *Agency Mission Statement*. Updated June 11, 2002. Available at: http://www.epa.gov/history/org/origins/mission.htm. (Last accessed March 2004).

2. National Research Council (NRC). 1994. *Science and Judgment in Risk Assessment* (The "Blue Book"). National Academy Press, Washington, D.C.

3. U.S. Environmental Protection Agency. 1999. *National Air Toxics Program: The Integrated Urban Strategy*. *Notice*. *Federal Register* 64:38705. July 19, 1999. Available at: http://www.access.gpo.gov/su_docs/fedreg/a990719c.html (the PDF file is indexed at: http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=1999_register&docid=99-17774-filed.pdf).

4. Institute of Medicine. 1999. *Toward Environmental Justice: Research, Education and Health Policy Needs.* Washington, DC: National Academy Press.

PART II

MULTISOURCE CUMULATIVE HUMAN HEALTH ASSESSMENT: INHALATION

Chapter 3 Overview of a Human Health Multisource Cumulative Inhalation Assessment

Table of Contents

3.0 Background

The focus of this chapter is to:

- Provide an overview of the types of chemicals that may be present in a community's air and the sources of those chemicals;
- Provide an overview of multisource **inhalation** assessment [an assessment of additional non-inhalation pathways (e.g., ingestion and dermal exposures) – i.e., a **multimedia analysis –** is provided in Part III];
- Discuss some of the reasons a multisource analysis may be needed; and
- Identify and describe available approaches and tools for evaluating the cumulative inhalation impacts to human health, at the local level, from the multiple sources releasing air toxics in a study area.

A basic understanding of this information is necessary before beginning the planning and scoping process described in the next chapter. An illustration of how the release of air toxics can result in injury or disease is provided in Exhibit 3-1.

A Note on Terminology

The focus of Part II is on assessing the combined inhalation impact of air toxics sources and the chemicals they emit on a the human population in a specific study area. There are several terms one could use to describe this combined impact analysis such as "multisource inhalation risk assessment," "cumulative inhalation risk assessment," or the more cumbersome "multisource cumulative inhalation risk assessment." For the sake of brevity and clarity, Part II refers to this process simply as "**multisource cumulative assessment**." This phrase encompasses the idea of multiple sources simultaneously impacting a study area and that the calculated risks are summed across all evaluated chemicals and sources. Including the specific route of exposure (inhalation) is superfluous given that Part II is relegated to inhalation-only exposures.

The terms "**air toxics**" and "**toxic air pollutants**" are often used interchangeably with "**hazardous air pollutants**" (which is a Clean Air Act phrase specific to the 187 pollutants that are the focus of section 112 of the Act – see http://www.epa.gov/ttn/atw/188polls.html).* For the purposes of this reference library, however, the term "air toxics" is used in the more general sense to refer to any air pollutant (other than criteria pollutants) that has the potential to cause adverse impacts to human health or the environment.

"**Criteria air pollutants**" are six common air pollutants determined to be hazardous to human health and for which EPA has established National Ambient Air Quality Standards (NAAQS). The six criteria air pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, sulfur dioxide, and particulate matter. A detailed discussion of criteria pollutants is available at http://www.epa.gov/air/urbanair/6poll.html.

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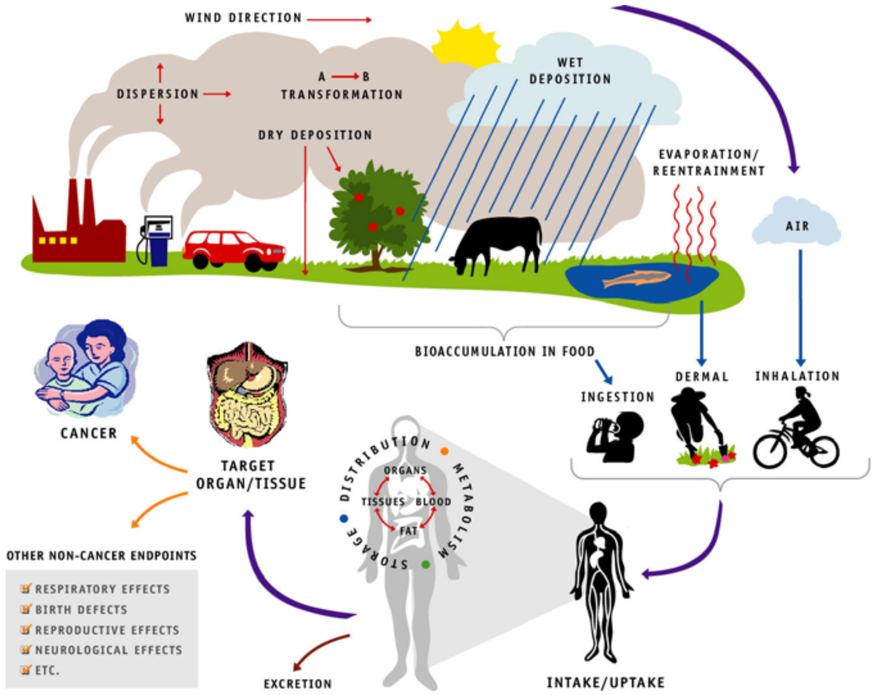
*__A Hazardous Air Pollutant (HAP)__ is defined under the Clean Air Act as a pollutant that causes or may cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects. Currently, the Clean Air Act regulates 187 chemicals and chemical categories as HAPs.

Exhibit 3-1. Generic Conceptual Model of How Air Toxics Releases May Result in Injury or Disease



Starting at the upper left hand side of this diagram, air toxics are released from one or more sources (e.g., factories, cars/trucks, small businesses, forest fires) to the air and begin to disperse by the wind away from the point of release. Once released, the chemical may remain airborne; convert into a different substance; and/or deposit out of the air onto soils, water, or plants. People may be exposed to air toxics by breathing contaminated air (inhalation, the focus of this part) or through ingestion of chemicals that can accumulate in soils, sediments, and foods (the latter process is called **bioaccumulation**; discussed in Part III). People also can be exposed to deposited chemicals via skin (dermal) contact; however, this tends to be a less important risk factor than ingestion or inhalation. Inhalation, ingestion, and dermal absorption are called the **routes of exposure**.

This description of what happens to an toxic air pollutant once it is released into the air is called **fate and transport** analysis. “Transport” evaluates how a toxic air pollutant physically moves (i.e., is transported) through the environment. “Fate” describes what ultimately happens to the chemical after it is released to the air (i.e., what is the “fate” of the chemical in the environment). The results of a fate and transport analysis is an estimate of the concentration of the toxic air pollutant in the air, soil, water, and/or food at the point where it is contacted by a person. The **exposure assessment** is the process of evaluating how human contact with the contaminated media occurs.

In the case of an air pathway analysis, the metric representing the inhalation exposure is called the **exposure concentration** (EC). For example, if benzene is released from indoor sources, mobile sources, gas stations, and a factory and all of this blows into a nearby neighborhood where people breathe it, the EC is the concentration of benzene in the air that they breathe.

Once an exposure occurs, toxic air pollutants can enter the body and exert an effect at the point of entry (the “portal of entry”) or move via the bloodstream to other target organs or tissues. The action of a pollutant on a target organ can result in no adverse effect or a variety of harmful effects, including cancer, respiratory effects, birth defects, and reproductive and neurological disorders. An overall risk assessment process evaluates what people are exposed to, how the exposure occurs, and, when combined with information about the toxic properties of the chemicals in question, estimates the likelihood that the exposure will result in injury or disease.

3.1 Introduction to Air Pollutants

Chapter 1 of this Volume introduced the terms "air toxics," "hazardous air pollutants" (HAPs), and "criteria air pollutants." This section will revisit each of these groups, as well as several other important chemical groupings, to provide more detailed information related to the chemicals on each of those lists. A thorough understanding of the different types of chemicals that may be of interest for a community-scale assessment, as well as the nuances of the various ways chemicals are written into those lists, will be important for the risk assessment team to comprehend before the assessment begins in earnest.

The term "air toxics" is a generic term that could conceivably encompass literally anything in the air that poses harm to people or the environment. For the purposes of this reference library, however, the term "air toxics" is used in the more general sense to refer to any air pollutant (other than criteria pollutants) that has the potential to cause adverse impacts to human health or the environment.

Risk Assessment for Air Toxics and Criteria Pollutants - What's the Difference?

This technical resource document is intended to provide a useful reference for assessing – at the community scale – cumulative risks associated with multiple air toxics emitted from multiple sources. Additional information regarding assessment of risks associated with the six commonly occurring ***criteria pollutants***, including current standards and plain language fact sheets, is available at the following web sites: http://www.epa.gov/ttn/naaqs/, http://www.epa.gov/ttn/fera, and http://www.epa.gov/ttn/fera/data/risk/naaqstbl_2003.pdf.

Several areas of potential crossover or overlap currently exist between the two pollutant groups. For example, ozone is formed by the interaction of volatile organic compounds (VOCs, many of which are air toxics), nitrogen oxides, and sunlight. As another example, particulate matter may be composed of a number of chemicals, such as nitrates and sulfates, organic and metallic compounds (many of which are air toxics), soil or dust particles, and allergens (such as fragments of pollen or mold spores). Lead is included in both the air toxics and criteria pollutant groups.

While the existence of separate programs for the criteria and hazardous air pollutants has generally led to the performance of risk assessments separately, even for the same locations, many of the same tools, methods, and programs may assist both the air toxics and criteria programs (e.g., emissions inventory development, monitoring programs for ozone precursors and particulate matter speciation, exposure model development, etc). However, differences in the nature of the information concerning the two sets of pollutants and in their associated policies and programs have contributed to differences in other assessment components, such as dose-response tools and risk metrics. Consequently, risk characterizations of situations involving some members of both sets of pollutants might be constructed as more of a "composite" than an integrated entity. Although a composite approach may be awkward, such composite risk characterizations would be more informative to the understanding of real-world exposures and risks than those that exclude one category or the other for reasons of analytical convenience. The Agency is, however, working toward a better understanding of cumulative health risks posed by all air pollutants collectively and the development of methods to facilitate more integrated assessments of air toxics and criteria air pollutants.

While the focus of most air toxics risk assessments will be on the 187 chemicals and chemical compounds listed as HAPs in the Clean Air Act (CAA) section 112(b), some assessment teams may wish to have a broader focus. The use of the term “air toxics” in this general sense is meant to provide for this flexibility. (In some cases, a community may want to go beyond the list of federal HAPs when assessing air toxics risks. It is for this reason that the partnership team must clearly understand why they are conducting an assessment and what chemicals and sources they want to include in that assessment.)

3.1.1 Introduction to Air Pollutant Lists

The various lists that are the focus of this technical resource library were all derived directly from the Clean Air Act, the Emergency Planning and Community Right to Know Act, or a specific EPA initiative (e.g., the PBT initiative list of chemicals – see Exhibit 3-3). It is important to keep in mind that there is not always consistency among these various lists in either the naming of chemicals or the meaning of the names. Specifically, the various lists of chemicals discussed below (e.g., HAPs, criteria air pollutants, TRI chemicals) do not always treat groups of chemicals (or chemical precursors/reaction products) in the same manner. Some examples of the ways in which these lists overlap or differ include the following.

- “Glycol ethers” are defined differently for the TRI and as HAPs (see box below).

- Ozone is formed by the interaction of NO_X, VOCs, and sunlight. Some of the HAPs are VOCs that may contribute to ozone formation.

- “Particulate matter” that is regulated as a criteria pollutant can be comprised of any number of individual chemicals and may contain various HAPs.

It is important to keep these overlaps and differences in mind since they can have important legal, policy, and other practical implications when studying air toxics impact or developing risk reduction alternatives for a particular location. The reader should also remember that the differences among chemical “lists” are based mostly on legal and regulatory considerations, not necessarily on toxicologic properties. It is also important to remember that some regulatory listings are comprised of multiple chemicals (e.g., polycyclic organic matter or POM), while toxicity data may exist only for the individual chemicals that make up the listing.

Glycol Ethers in the TRI and As HAPs

The Toxics Release Inventory (TRI) includes certain glycol ethers R–(OCH2CH2)–OR' where:
n = 1, 2, or 3
R = alkyl C7 or less; phenyl or alkyl substituted phenyl
R' = H, or alkyl C7 or less
OR' consisting of carboxylic acid ester, sulfate, phosphate, nitrate, or sulfonate.

The list of HAPs includes mono- and di- ethers of ethylene glycol, diethylene glycol, and triethylene glycol R–(OCH2CH2)n–OR' where:
n = 1, 2, or 3
R = alkyl or aryl groups
R' = R, H, or groups which, when removed, yield glycol ethers with the structure: R–(OCH2CH)–OH. Polymers (surfactant alcohol ethoxylates and their derivatives) are excluded from the glycol category.

Lists of toxic chemicals commonly provide the chemical identity by both a name and a unique identifying number, called a **Chemical Abstracts Service (CAS) Registry Number**.[a] However, most chemicals have multiple synonyms (sometime dozens). Fortunately, every unique chemical has only one CAS number and one can always refer to this unique number to identify the compound in question. For example, toluene and methylbenzene are synonyms for the same compound (which is normally referred to as toluene). However, there is only one CAS number for the compound: 108-88-3. No matter where one is in the world or what name is attached to a chemical, there is unanimity of identity through the CAS numbering system.

When there is any question about what a particular chemical name means, it is always advisable to try to pinpoint the identity through use of the CAS number. For example, a risk assessment team may ask for air sampling analysis for the HAP acetaldehyde (CAS number 75-07-0); however, when they receive the analytical lab report, acetaldehyde is not reported. A quick scan of the CAS numbers reported by the lab lists the CAS number 75-07-0 next to the name "ethanal." Ethanal is a synonym for acetaldehyde and, hence, has the same CAS number. EPA's *Handbook for Air Toxics Emission Inventory Development* includes a list of synonyms and CAS numbers for HAPs that is helpful in overcoming the nomenclature obstacle.[1] (Note, however, that there are nuances beyond this simplistic description. For example, some chemicals have one CAS number for their pure form and a different CAS number for a technical grade. A knowledgeable chemist can usually identify and clarify these issues.)

Some of the entries on chemical lists are for large groups of compounds and not just one single substance. For example, one of the HAPs is listed in the CAA as "polychlorinated biphenyls (aroclors)" and is most commonly referred to as PCBs. This listing is not for one single substance but, rather, for any one or a mixture of any of the 209 possible chemicals that are themselves PCBs. As another example, the pesticide "2,4-D" is written into the list of HAPs as "2,4-D (salts and esters)." This listing includes any possible salt of 2,4-D and any possible ester of 2,4-D. Likewise, the lead compound HAP listing includes any compound known to exist in or be emitted to the environment that contains a lead molecule as part of the compound's molecular structure (a potentially huge number of possibilities). Another important group of chemicals is called "POM" for polycyclic organic matter. This includes organic compounds with more than one benzene ring, and which have a boiling point greater than or equal to 100^{o}C [e.g., polycyclic aromatic hydrocarbons (PAHs) such as benzo(a)pyrene].

In reality, most risk assessments will deal with a relatively small number of chemicals because either the sources in a given place are releasing only a limited number of chemicals or the ability to model or monitor the numerous chemicals present is limited by the available inventories or monitoring/analytical methods, respectively.

In the initial stages of the assessment, risk assessors often sort the chemicals of interest into groups that generally have similar physical and/or chemical properties. This is a helpful thing to do as a way of making some educated guesses about how chemicals are likely to behave in the environment. The groupings also help an assessment team to plan for the types of sampling and

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[a] CAS (Chemical Abstracts Service) is a division of the American Chemical Society. A CAS Registry Number (CAS number or CASRN) is assigned in sequential order to unique, new substances identified by CAS scientists for inclusion in the CAS Registry database. Each CAS Registry Number is a unique numeric identifier; designates only one substance; and has no chemical significance. A CAS Registry Number is a numeric identifier that can contain up to nine digits, sometimes divided by hyphens into three parts. See http://www.cas.org/faq.html for more information.

analysis methods that will be needed, because the sampling and analytical methods tend to be broken out along these same lines. In general, all air toxics can be broadly categorized into three main groups, organic chemicals, inorganic chemicals, and organometallic compounds.

Organic Chemicals

Organic chemical compounds are composed of carbon in combination with other elements such as hydrogen, oxygen, nitrogen, phosphorous, chlorine, and sulfur. Organic compounds can generally be split into two different groups, based on their propensity to evaporate. The following such groupings are commonly employed by analytical chemistry laboratories for purposes of sample analysis.

- **Volatile organic compounds (VOCs)**. These are organic chemicals that have a high vapor pressure and tend to have low water solubility.[b] Simply put, VOCs have a high propensity to evaporate and remain airborne. Many VOCs are human-made chemicals that are used and produced in the manufacture of paints, pharmaceuticals, and refrigerants, as industrial solvents, such as trichloroethylene, or produced as by-products, such as chloroform produced by chlorination in water treatment. VOCs are often also components of petroleum fuels (e.g., benzene in gasoline), hydraulic fluids, paint thinners, dry cleaning agents, and many consumer products (e.g., glues and adhesives, floor polishes, hair care products, air fresheners).[c]

  A subgroup of VOCs is termed **carbonyl compounds** and includes chemicals such as formaldehyde and acetaldehyde. While such chemicals are themselves VOCs due to their high vapor pressure, they are often grouped as a separate class from the VOCs because of the special sampling and analytical methods necessary to measure them in air.

- **Semivolatile organic compounds (SVOCs)**. SVOCs are organic chemicals that have a lower vapor pressure than VOCs and, thus, have a lower propensity to evaporate from the liquid or solid form. Once airborne, they also tend to more readily condense out of the gas phase. Examples of SVOCs include most organic pesticides (e.g., chlordane), and certain components of petroleum, such as polycyclic aromatic hydrocarbons. Note that the demarcation between SVOCs and VOCs is not exact. For example, the two separate air sampling and analytical methods for VOCs and SVOCs will both usually detect naphthalene when present, indicating that this chemical is on the lower end of the VOC scale of volatility and on the higher end of the SVOC scale of volatility. In general, as chemicals increase in molecular weight and/or polarity, they become more SVOC-like.

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[b] The regulatory definition of VOC does not identify vapor pressure as a consideration. See 40 CFR 51.100(s).

[c] VOC refers to volatile organic compounds that contribute to ozone formation as defined by 40 CFR 50.100(s) as ozone precursors. VOC is a subset of VOCs. VOC emissions inventory information is sometimes used to derive estimates for specific chemicals; when this is done, the VOC number is said to have been speciated.

Inorganic Chemicals

This group includes all substances that do not contain carbon and includes a wide array of substances such as:

- Metals (e.g., mercury, lead, and cadmium) and their various salts (e.g., mercury chloride);
- Halogens (e.g, chlorine and bromine);
- Inorganic bases (e.g., ammonia); and
- Inorganic acids (e.g., hydrogen chloride, sulfuric acid).

Organometallic Compounds

This group is comprised of compounds that are both organic and metallic in nature. The alkyl lead compounds that were added to gasoline to enhance its properties can be used for illustration. "Alkyl" refers to the organic portion of a compound which is attached to the inorganic metal lead. The result is a so-called "organometallic" material, a hybrid of both metallic and organic. (Note that salts, such as sodium benzoate, are usually classified as an organic chemical, rather than an organometallic compound.)

An understanding of the general characteristics of organic chemicals, inorganic chemicals and organometallic compounds will aid in planning a risk assessment and developing an appropriate analysis strategy. For example, most VOCs tend to remain airborne and also do not tend to bioaccumulate to the same extent as some of the non-volatile chemicals. Thus, if an assessment were being planned to evaluate the impact of a source from which only VOCs were released, it becomes less likely that a multipathway risk analysis will be necessary (since VOCs do not tend to migrate into soil or water and do not tend to bioaccumulate as strongly in living tissue).

In addition, the sampling and analytical methods available to test for chemicals in environmental media are generally broken out along the same chemical groupings noted above. Thus, if one were interested in testing for airborne chlordane (an SVOC), a VOC monitoring method would not be used. Detailed information on available monitoring methods and the chemicals for which they have been validated is provided in ATRA Volume 1, Chapter 10.

In air toxics studies, both individual substances and mixtures of substances are of interest. Particulate matter (PM), for example, is almost never comprised of just one substance; instead, PM is usually made up of numerous individual substances (sometimes in the hundreds). Both the physical and chemical nature of a mixture will influence the fate and transport of the chemicals in the environment as well as the potential for the mixture to cause harm. For example, a toxic chemical adsorbed onto the surface of a relatively large particle (> 10 microns in diameter) will usually be trapped in the upper portion of the respiratory system and either coughed/sneezed out of the body or swallowed. The same chemical adsorbed onto a very small particle (< 2.5 microns in diameter) has a much higher likelihood of being inhaled into the deep lung.

3.1.1.1 Hazardous Air Pollutants (HAPs)

The HAPs are a group of 187 specific chemicals and chemical compounds and are identified in section 112(b) of the CAA. The Agency provides additional information on the HAPs online.[(2)] HAPs are pollutants known to cause or suspected of causing cancer or other serious human health effects or ecosystem damage. They include individual organic and inorganic compounds and pollutant groups closely related by chemical structure (e.g., arsenic compounds, cyanide compounds, glycol ethers, polycyclic organic matter) or emission sources (e.g., coke oven emissions). EPA may add or remove pollutants from the HAP list as new information becomes available, and since the original CAA was published, two chemicals (caprolactam and methyl ethyl ketone) have been delisted. In addition, one chemical (ethylene glycol butyl ether) was removed from the glycol ethers chemical category. A full list of the HAPs is provided in ATRA Volume 1, Appendix A.

When people talk about "air toxics risk assessment," they generally mean assessments of risks associated with one or more of the HAPs. This is largely because of the CAA listing of 187 HAPs and its requirement under section 112(f)(2) (Residual Risk) that EPA assess the risks associated with HAPs that remain after the application of the Maximum Achievable Control Technology (MACT) standards (section 112(d) of the Act).[(d)] However, given that this is a relatively short list of chemicals, many communities may want to go beyond this list when assessing risk. It is for this reason that assessors and other stakeholders in the partnership must clearly identify why they are conducting an "air toxics risk assessment" and what they want to include in that assessment.

In its National Air Toxics Strategy, EPA identified a subset of 33 HAPs as those posing the greatest risk in urban areas (see text box on following page). These 33 HAPs were selected based on a number of factors, including toxicity-weighted emissions, monitoring data, past air quality modeling analysis, and a review of existing risk assessment literature.

The national-scale assessment for 1996 (see Section 4.2.1.1) focused on 32 of these 33 Urban HAPs (dioxin was omitted) and also includes diesel particulate matter, which is used as a surrogate measure of diesel exhaust. The 1999 assessment expanded the evaluation to include 177 HAP plus diesel particulate matter.[(e)]

EPA maintains information about emissions of HAPs in its National Emissions Inventory (NEI). An overview of the NEI is provided in ATRA Volume 1, Section 4.4.1 and also discussed in Chapter 4.

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[d] See ATRA Volume 1, Chapter 2 and Section 3.2.1 below for a discussion of existing regulatory requirements for HAPs.

[e] In its health assessment document for diesel engine (DE) exhaust (http://cfpub.epa.gov/ncea/cfm/dieslexh.cfm), EPA examined information regarding the possible health hazards associated with this pollutant, which is a mixture of gases and particles. The assessment concludes that chronic inhalation exposure is likely to pose a lung cancer hazard to humans, as well as damage the lung in other ways depending on exposure. Acute exposures can cause irritation and inflammatory symptoms of a transient nature. Evidence for exacerbation of existing allergies and asthma symptoms is emerging. The assessment's health hazard conclusions are based on exposure to exhaust from diesel engines built prior to the mid-1990s. The health hazard conclusions, in general, are applicable to engines currently in use, which include many older engines. As new diesel engines with cleaner exhaust emissions replace existing engines, the applicability of the conclusions in the health assessment document will need to be reevaluated. Diesel exhaust is addressed in several regulatory actions and diesel particulate matter plus diesel organic gases are listed by EPA as a mobile source air toxic (see Section 3.2.3).

The Urban Air Toxics

In 1999, EPA identified a group of 33 HAPs (the *Urban Air Toxics*) as those most important to health risks in urban areas.

acetaldehyde	coke oven emissions	manganese compounds
acrolein	dioxin	mercury compounds
acrylonitrile	1, 2-dibromoethane	methylene chloride[b]
arsenic compounds	propylene dichloride	nickel compounds
benzene	1, 3-dichloropropene	polychlorinated biphenyls (PCBs)
beryllium compounds	ethylene dichloride[a]	polycyclic organic mater (POM)
1,3-butadiene	ethylene oxide	quinoline
cadmium compounds	formaldehyde	1, 1, 2, 2-tetrachlorethane
carbon tetrachloride	hexachlorobenzene	tetrachloroethylene[c]
chloroform	hydrazine	trichloroethylene
chromium compounds	lead compounds	vinyl chloride

[a] also represented as 1,2-dichloroethane
[b] also represented as dichloromethane
[c] also represented as perchloroethylene

3.1.1.2 Criteria Air Pollutants

The "criteria air pollutants" are six substances regulated pursuant to Title I of the CAA, for which "criteria documents" are developed by the Agency prior to national standard setting decisions. There are already national ambient air quality standards (NAAQS) in place for each of these pollutants as well as established regulatory programs and activities in place to meet those standards (see Exhibit 3-2). However, they are discussed here because there is some crossover between the realm of HAPs and criteria pollutants. The more important crossover issues are discussed below.

- **Particulate matter**. NAAQS have been established for particles with an aerodynamic diameter less than or equal to 10 microns (called PM_{10}) and particulate matter with an aerodynamic diameter less than or equal to 2.5 microns (called $PM_{2.5}$).[f] PM can be made up of as little as one or a few or as many as hundreds of individual chemicals. In many cases (and depending on the source of the PM), any number of specifically listed HAPs may be a part of the PM mix. It is for this reason that risk assessors may opt to evaluate the composition of PM and to include any identified toxic air pollutants in risk calculations.

[f] In December 2005, the EPA proposed revisions to the national air quality standards for fine particulate matter and also for some coarse particles. For additional information, see http://www.epa.gov/air/particlepollution/standards.html.

Exhibit 3-2. National Ambient Air Quality Standards (NAAQS)			
Pollutant	**Standard Value***		**Standard Type**
Carbon Monoxide (CO)			
8-hour Average	9 ppm	(10 mg/m^3)	Primary
1-hour Average	35 ppm	(40 mg/m^3)	Primary
Nitrogen Dioxide (NO_2)			
Annual Arithmetic Mean	0.053 ppm	(100 $\mu g/m^3$)	Primary & Secondary
Ozone (O_3)			
1-hour Average	0.12 ppm	(235 $\mu g/m^3$)	Primary & Secondary
8-hour Average	0.08 ppm	(157 $\mu g/m^3$)	Primary & Secondary
Lead (Pb)			
Quarterly Average	1.5 $\mu g/m^3$		Primary & Secondary
Particulate (PM_{10}) *Particles with diameters of 10 micrometers or less*			
Annual Arithmetic Mean	50 $\mu g/m^3$		Primary & Secondary
24-hour Average	150 $\mu g/m^3$		Primary & Secondary
Particulate ($PM_{2.5}$) *Particles with diameters of 2.5 micrometers or less*			
Annual Arithmetic Mean	15 $\mu g/m^3$		Primary & Secondary
24-hour Average	65 $\mu g/m^3$		Primary & Secondary
Sulfur Dioxide (SO_2)			
Annual Arithmetic Mean	0.030 ppm	(80 $\mu g/m^3$)	Primary
24-hour Average	0.140 ppm	(365 $\mu g/m^3$)	Primary
3-hour Average	0.500 ppm	(1300 $\mu g/m^3$)	Secondary
* Parenthetical value is an approximately equivalent concentration			

For example, it is possible to collect samples of PM_{10} for purposes of determining the types and amounts of individual substances contained in the particles. The risks posed by those individual chemicals may then be estimated for the inhalation route of exposure. Because particles with diameters greater than 10 microns are not generally inhalable, analysts usually select a PM_{10} monitor to capture samples for risk assessment purposes rather than a total suspended particulate (TSP) sampler, because TSP would capture larger particles that do not penetrate very far into the respiratory tract (thus leading to an overestimate in inhalation risk associated with the specific pollutants studied). Note that this would not be true for particle-bound chemicals that exert their toxic effects through interaction with the nasal passages (e.g., irritation, absorption).

- **Ozone and other criteria pollutants**. Certain other criteria pollutants are not specifically listed as HAPs, but HAPs may lead to their formation or they may lead to HAP formation. For example, ozone is produced by the interaction of certain VOCs, oxides of nitrogen (called NO_x), and sunlight. As noted previously, many of the HAPs are VOCs and may play a role in ozone formation. In contrast, sulfur dioxide is a criteria pollutant that can be transformed in the environment into sulfuric acid which, in turn, may become part of a listed HAP (e.g., cadmium sulfate). In general, the criteria pollutants ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide are not usually considered in air toxics risk assessments.

EPA maintains information about emissions of criteria pollutants and criteria pollutant precursors in its National Emissions Inventory (NEI). An overview of the NEI is provided in ATRA Volume 1, Section 4.4.1 and also discussed in Chapter 4 of this volume.

3.1.1.3 Toxics Release Inventory (TRI) Chemicals

Data on TRI chemicals are reported pursuant to section 313 of the Emergency Planning and Community Right-To-Know Act (EPCRA) of 1986 and section 6607 of the Pollution Prevention Act of 1990 (PPA). EPCRA and the PPA are intended to inform communities and citizens about chemical hazards in their areas. EPA and states are required to collect data annually on releases (to each environmental medium) and waste management methods (e.g., recycling) of certain toxic chemicals from industrial facilities, and to make the data available to the public in the TRI.(3) EPCRA section 313(d) permits EPA to list or delist chemicals based on certain criteria. In a 1994 rulemaking, EPA added 286 chemical categories to the TRI chemical list. The TRI chemicals are listed in 40 CFR Section 372.65, and information about the 666 currently-listed TRI chemicals is provided online.(4)

The current TRI chemical list contains 581 individually listed chemicals and 30 chemical categories (including three delimited categories containing 58 chemicals), for a total of 612 separate chemicals. If the members of the three delimited categories are counted as separate chemicals then the total number of chemicals and chemical categories is 666 (i.e., 581 + 27 + 58). The TRI list of toxic chemicals includes most of the HAPs. Similar to the HAPs, the TRI chemicals include VOCs, SVOCs, inorganic compounds, and organometallic compounds.

The utility of the TRI for air toxics risk assessment is two fold. First, it provides a broader perspective of industrial emissions than the HAP list because it includes information on air releases of many hundreds of additional chemicals. Second, accessing TRI information is extremely quick and easy. Using the TRI Explorer search engine (http://www.epa.gov/tri/tridata/index.htm), one may quickly identify the location of emissions sources and the identity and quantity of chemicals released to the air. The data is also updated annually (as opposed to the National Emissions Inventory (NEI), a nationwide inventory of emissions developed by EPA, which is only updated triennially). However, other characteristics of the TRI data may limit their use for risk assessments (see Section 4.2.1.2).

3.1.1.4 Toxic Chemicals That Persist and Which Also May Bioaccumulate

Some toxic compounds have the ability to persist in the environment for long periods of time and may also have the ability to build up in the food chain to levels that are harmful to human health and the environment. For example, releases of metals from a source may deposit out of the air onto the ground where they remain in surface soils for long periods of time. Children playing in the area may ingest this contaminated dirt through hand-to-mouth behaviors. The chemicals in the dirt may also be taken up into plants through the roots and accumulate in foraging animals which are then, in turn, consumed by people. A discussion on this topic is provided in Part III.

3.1.1.5 Other Chemicals

> **The HPV Challenge Program**
>
> EPA, in partnership with industry and environmental groups, recently created a voluntary chemical testing effort, the high production volume (HPV) Challenge Program. This program was developed to make publicly available a complete set of baseline health and environmental effects data on HPV chemicals (those manufactured in, or imported into, the United States in amounts equal to or exceeding 1 million pounds per year). Information on HPV chemicals is available at http://www.epa.gov/chemrtk/rtkfacts.htm.

The chemicals included in the various lists of air toxics described above – HAPs, TRI chemicals, and toxic chemicals that persist and which also may bioaccumulate – do *not* represent all of the chemicals potentially emitted to air in a given place. For example, EPA is required to maintain an inventory, known as the "Toxic Substances Control Act (TSCA) Inventory," of each chemical substance which may be legally manufactured, processed, or imported in the U.S. The TSCA inventory currently contains over 75,000 chemicals (see: "enforcement programs" at http://www.epa.gov/compliance/civil/index.html). As noted previously, this does not imply that risk assessments are always missing important information. To the contrary, the actual number of chemicals used in significant amounts and released to air are relatively small compared to the number of chemicals known. Nevertheless, it is important to keep in mind that the ability to evaluate air toxics releases is limited by current technology, the lack of toxicity information for all but a relatively small number of chemicals and, in some cases, costs (e.g., a single sample for certain analytes such as dioxin can cost upwards of $1,000 per sample, potentially making extensive sampling cost prohibitive).

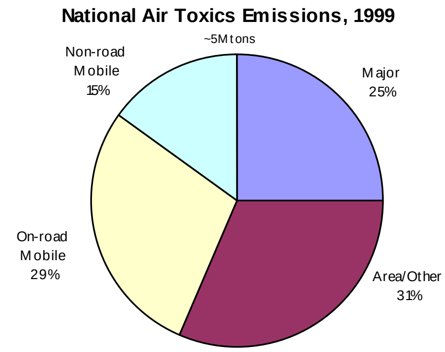
3.2 Sources of Air Toxics

Many anthropogenic and natural activities are sources of air pollutants. Examples of human activities that result in the release of air toxics include:

- Fuel combustion activities in power plants, factories, automobiles, and homes;
- Biomass burning and other agricultural activities;
- Use of consumer products, such as pesticides and cleaning agents;
- Commercial activities, such as dry cleaning; and
- Industrial activities, such as petroleum refining, chemical manufacture, and metal plating.

Sources of air toxics can be categorized in various ways – whether they occur indoors or out, whether they are stationary or mobile, by the amount of chemicals they release, or by other approaches. For the purposes of this discussion, air toxics have been placed into several major groupings that track EPA's programs and emissions inventories. [Note that some differences in terminology exist (see Exhibit 3-3).]

- Point sources;
- Nonpoint sources;
- On-road mobile sources;
- Nonroad mobile sources;
- Indoor sources;
- Natural sources; and
- Exempt sources.



In 1999, there were about 5 million tons of hazardous air pollutants reported to the NEI. Of that amount, almost half came from mobile sources, while only about a quarter came from large industry. Approximately one third came from smaller, diffuse stationary sources such as autobody shops, dry cleaners, gas stations, and electroplaters.

The first four categories are groupings of emission sources of HAPs and criteria air pollutants in the aforementioned NEI. The NEI is discussed in more detail as a source of quantitative emissions release data in Section 4.2.1.2.

Exhibit 3-3. Terminology Related to Groupings of Source Types

Source Type	How Defined in CAA	How Reported in NEI
Point source – Major	Point source – Major	Point source
Point source – Area	Point source – Area	Point source if location coordinates reported Area source if coordinates not reported
Nonpoint source	Nonpoint source	Area
Mobile source – On-road	Mobile source – On-road	Modeled
Mobile source – Nonroad	Mobile source – Nonroad	Modeled or estimated
Indoor	Not defined	Not reported
Natural	Not defined	Not reported
Exempt	Not defined	Not reported

3.2.1 Point Sources

Point sources of air toxics are stationary sources (i.e., sources that remain in one place) that can be located on a map. A large facility that houses an industrial process is an example of a point source – the facility and its emission release points (e.g., stacks, vents, fugitive emissions from valves) are stationary, and the emission rates of air toxics can be characterized, either through direct measurements, such as stack monitoring, or indirect methods, such as engineering estimates based on throughput, process information, and other data. The CAA divides point sources into two main categories primarily on the basis of annual emission rates:

- **Major sources** are defined in section 112(a)(1) as "any source or group of stationary sources located within a contiguous area and under common control that emits or has the potential to emit, considering controls, in the aggregate, 10 tons per year (tpy) or more of any hazardous air pollutant or 25 tpy or more of any combination of hazardous air pollutants."

- **Area sources** are defined in section 112(a)(2) as "any stationary source of hazardous air pollutants that is not a major source. For purposes of this section, the term 'area source' shall not include motor vehicles or nonroad vehicles subject to regulation under Title II." Examples of area sources include dry cleaners, gas stations, chrome electroplaters, and print shops. Though emissions from individual area sources may be relatively insignificant in human health terms, collectively their emissions can be quite significant, particularly where large numbers of sources are located in heavily populated areas. Note that sources that are classified as "area sources" pursuant to the CAA may be reported in the NEI as "point sources" if they can be located on a map.

Many sources of HAPs are subject to **National Emission Standards for Hazardous Air Pollutants (NESHAPs)** pursuant to section 112 of the CAA. This section of the CAA directs EPA to issue regulations listing categories and subcategories (commonly referred to collectively as **source categories**) of major sources and area sources of HAPs and to develop standards for each listed category and subcategory.(5) EPA periodically updates the list of source categories (see ATRA Volume 1, Appendix E).(6)

EPA regulates stationary sources in a two-phase process. First, EPA issues technology-based MACT standards that require sources to meet specific emissions limits. The emission limits are typically expressed as maximum emission rates, or minimum percent emission reductions, for specific pollutants from specific processes. In the second phase, EPA applies a risk-based approach to assess how well MACT emissions limits reduce health and environmental risks. Based on these **residual risk assessments**, EPA may implement additional standards to address any significant remaining, or residual, health or environmental risks (see ATRA Volume 1, Chapter 2 for a more detailed discussion of the MACT and residual risk programs).

Area sources may be subject to either MACT or **Generally Available Control Technology (GACT)** standards. GACT standards are generally less stringent than MACT standards. Area sources subject to MACT standards include Commercial Sterilizers using Ethylene Oxide, Chromium Electroplaters and Anodizers, Halogenated Solvents Users, and Asbestos Processors.

Physical Forms of Emissions

Air pollutants can be found in all three physical phases: solid, liquid, or gaseous. The distinct chemical and physical attributes of each phase contribute to the pollutant's transport and fate. Some of the common terms used to describe the form of a chemical in the atmosphere include:

Gas	A state of matter that is distinguished from solid and liquid states
Mist	Liquid particles measuring 40 to 500 micrometers that are formed by condensation of vapor
Particulate Matter	Fine liquid or solid particles

For example, as reported in the *Mercury Study Report to Congress*, gaseous elemental mercury vapor is not thought to be susceptible to any major process of direct deposition to the earth's surface due to its relatively high vapor pressure and low water solubility. Therefore, it is carried by the wind and subsequently dispersed throughout the atmosphere. However, divalent mercury, in either vapor or particulate phase, is thought to be subject to much faster atmospheric removal. For further details on fate and transport analysis, see ATRA Volume 1, Chapter 8.

3.2.2 Nonpoint Sources

The term nonpoint source refers to smaller and more diffuse sources within a relatively small geographic area. In the context of EPA's NEI, nonpoint sources of air toxics are stationary sources for which emissions estimates are provided as an aggregate amount of emissions for all similar sources within a specific local geographic area, such as counties or cities, rather than on a facility- or source-specific basis. Emission estimates for nonpoint sources are generated using "top-down" methods, when detailed information at the local level is lacking. Instead, the total emissions over a large geographic area (e.g., n tons in the northeastern states) are allocated to the local level (e.g., x percent is assigned to locality 1, y percent is assigned to locality 2, and so on). Note that for the purposes of this discussion, the nonpoint source category includes only stationary sources and does *not* include mobile sources.

Source-specific information may be available for *some* (but not all) of the specific facilities within a certain nonpoint source type. Area sources may be reported as either point or nonpoint sources in the NEI. If a state or local agency reports an area source emission as a point source, then the NEI retains the area source emission as a point source. The NEI does not aggregate point area sources as nonpoint sources, and **EPA has taken steps to avoid "double-counting" of emissions in the point and nonpoint source inventories**.

To compile nonpoint estimates for a category, the EPA first estimates county level emissions for nonpoint source categories. Then EPA replaces nonpoint EPA generated estimates with state, tribal, and local estimates. If a state, tribe, or local agency includes point source estimates for an EPA generated nonpoint source category, EPA removes the nonpoint estimate that it had generated and the point source inventory contains the S/L/T estimate. For example, in the Denver area, the State of Colorado inventories dry cleaners and service stations as point sources.

The NEI contains point sources estimates for these two categories in the six county area of Denver and the NEI does not contain nonpoint estimates for these two categories. Dry cleaners and service station emissions are contained in the NEI nonpoint inventory for the other fifty counties on Colorado.

A variety of sources are categorized as nonpoint sources in the NEI, including some small industrial/commercial processes (e.g., small dry cleaning facilities, hospital sterilization facilities, and dental offices). Additional nonpoint sources that contribute to air pollution are agricultural activities, residential trash and yard-waste burning, wood stoves and fireplaces, releases from spills and other accidents, and volatilization and resuspension of pollutants from contaminated sites. Examples of agricultural activities contributing to air pollution are biomass burning (e.g., for land clearing) and the application of fertilizers and pesticides. The open burning of forests are also categorized as nonpoint sources. Forest fires, including wildfires, are generally considered for the purposes of the NEI to be an anthropogenic source of air toxics because they are assumed to be directly or indirectly, for purposes of the NEI, caused by man.

Some nonpoint sources emit HAPs and are subject to NESHAPs pursuant to section 112 of the CAA (see ATRA, Volume 1, Section 4.3.1 for more information on NESHAPs). These nonpoint sources are area sources in that they emit less than 10 tpy of a single toxic air pollutant or less than 25 tpy of a mixture of air toxics. For example, facilities that perform perchloroethylene dry cleaning belong to a source category that is subject to NESHAPs.

3.2.3 On-Road and Nonroad Mobile Sources

Mobile sources pollute the air with fuel combustion products and evaporated fuel. These sources contribute greatly to air pollution nationwide and are the primary cause of air pollution in many urban areas. Section 202(l) of the CAA gives EPA the authority to regulate air toxics from motor vehicles. Based on 1996 National Toxics Inventory data (the NTI is the former name of the air toxics portion of the current NEI), mobile sources contributed 2.3 million tpy or about half of all air toxics emissions in the U.S. Mobile sources emit hundreds of air pollutants – for example, exhaust and evaporative emissions from mobile sources contain more than 700 compounds. EPA's Final Rule, *Control of Emissions of Hazardous Air Pollutants from Mobile Sources*, commonly known as the "Mobile Source Air Toxics" (MSAT) rule,[(7)] identified 21 compounds as HAPs emitted by mobile sources (see text box below). All of these compounds except diesel particulate matter and diesel exhaust organic gases (DPM + DEOG) are included on the CAA section 112 HAPs list. Although some mobile source air toxics are TRI chemicals, mobile sources are not generally subject to TRI reporting. Other mobile source regulations address emissions of criteria pollutants and their precursors, including carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter (PM), volatile organic compounds (VOCs), and sulfur dioxide (SO_2). These criteria air pollutant control programs for mobile sources have and will continue to result in substantial reduction of HAP releases.

Mobile Source Air Toxics Listed in 2001 Rule[3]

- acetaldehyde
- acrolein
- arsenic compounds[a]
- benzene
- 1,3-butadiene
- chromium compounds[a]
- diesel particulate matter and diesel exhaust organic gases (DPM + DEOG)
- dioxin/furans[b]
- ethylbenzene
- formaldehyde
- n-hexane
- lead compounds[a]
- manganese compounds[a]
- mercury compounds[a]
- methyl tertiary butyl ether (MTBE)
- naphthalene
- nickel compounds[a]
- polycyclic organic matter (POM)[c]
- styrene
- toluene
- xylene

[a] Although the different metal compounds may differ in their toxicity, the on-road mobile source inventory contains emissions estimates for total metal compounds (i.e., the sum of all forms).
[b] This entry refers to two large groups of chlorinated compounds. In assessing their cancer risks, their quantitative potencies are usually derived from that of the most toxic, 2,3,7,8-tetrachlorodibenzodioxin.
[c] Polycyclic organic matter includes organic compounds with more than one benzene ring, and which have a boiling point greater than or equal to 100 degrees Celsius. A group of seven polynuclear aromatic hydrocarbons, which have been identified by EPA as probable human carcinogens (benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, 7,12-dimethylbenz(a)anthracene, and indeno(1,2,3-cd)pyrene) are used here as surrogates for the larger group of POM compounds.

Mobile sources include a wide variety of vehicles, engines, and equipment that generate air pollution and that move, or can be moved, from place to place. In the NEI, EPA divides mobile sources into two broad categories. **On-road mobile sources** include motorized vehicles that are normally operated on public roadways for transportation of passengers or freight. This includes passenger cars, motorcycles, minivans, sport-utility vehicles, light-duty trucks, heavy-duty trucks, and buses. **Nonroad mobile sources**, (sometimes also called "off-road") include aircraft, commercial marine vessels (CMVs), locomotives, and other nonroad engines and equipment. The other nonroad engines and equipment included in NEI comprise a diverse list of portable equipment, such as lawn and garden equipment; construction equipment; engines used in recreational activities; and portable industrial, commercial, and agricultural engines.

Rulemakings and Voluntary Efforts to Reduce MSATs and Other Air Pollutants

- Tier 2 gasoline/sulfur rulemaking (http://www.epa.gov/otaq/tr2home.htm)
- Reducing nonroad diesel emissions (http://www.epa.gov/nonroad/)
- Voluntary diesel retrofit program (http://www.epa.gov/otaq/retrofit)
- Best Workplaces for Commuters (http://www.commuterchoice.gov)
- Clean School Bus USA (http://www.epa.gov/cleanschoolbus)
- It All Adds Up to Cleaner Air (http://www.italladdsup.gov)

EPA's National Air Pollutant Trends Report, 1900-1998[8] indicates that about 60 percent of mobile source air toxics emissions in the U.S. are from on-road sources, and 40 percent of mobile source air toxics emissions are from nonroad sources. The emissions distribution between on- and off-road sources emitting criteria pollutants depends on the chemical. CO comprises the majority of criteria pollutants emitted, with over 100 million tons per year emitted in the U.S. Releases of CO are *primarily* the result of mobile sources – like HAPs, these emissions are split approximately 60/40 between on-road and off-road sources. (The use of CO as a monitoring surrogate for mobile source emissions is discussed in ATRA Volume 1, Section 4.4.1.)

Within the two broader categories of mobile sources, EPA further distinguishes on-road and nonroad sources by size, weight, use, horsepower and/or fuel type. For example, categories of on-road vehicles include light-duty gasoline vehicles (i.e., passenger cars), light-duty gasoline trucks, heavy-duty gasoline vehicles, and diesel vehicles. Examples of nonroad sources include nonroad *gasoline* engines and vehicles, (e.g., recreational off-road vehicles, construction equipment, lawn and garden equipment, and recreational marine vessels that use gasoline), nonroad *diesel* engines and vehicles (including the vehicles and equipment listed above, *except* those that use diesel fuel), aircraft, non-recreational marine vessels, and locomotives. An additional category covers all nonroad sources that use liquified petroleum gas or compressed natural gas.

3.2.4 Sources Not Included in the NEI or TRI

In addition to the four primary categories used in compiling the NEI, five other sources of air toxics which are not captured by either the NEI or TRI are described below: Indoor sources, natural sources, secondary formation of air toxics, exempt sources, and international transport.

3.2.4.1 Indoor Sources

Indoor pollution sources that release gases or particles into the air are the primary cause of indoor air quality problems in homes (Exhibit 3-4). Inadequate ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the home.

There are many sources of indoor air pollution in any home. These include combustion sources such as oil, gas, kerosene, coal, wood, and tobacco products; building materials and furnishings as diverse as deteriorated, asbestos-containing insulation, wet or damp carpet, and cabinetry or furniture made of certain pressed wood products; products for household cleaning and maintenance, personal care, or hobbies; central heating and cooling systems and humidification devices; and outdoor sources such as radon, pesticides, and outdoor air pollution.

The relative importance of any single source depends on how much of a given pollutant it emits and how hazardous those emissions are. In some cases, factors such as how old the source is and whether it is properly maintained are significant. For example, an improperly adjusted gas stove can emit significantly more carbon monoxide than one that is properly adjusted.

Some sources, such as building materials, furnishings, and household products like air fresheners, release pollutants more or less continuously. Other sources, related to activities carried out in the home, release pollutants intermittently. These include smoking, the use of unvented or malfunctioning stoves, furnaces, or space heaters, the use of solvents in cleaning and hobby activities, the use of paint strippers in redecorating activities, and the use of cleaning products and pesticides in housekeeping. High pollutant concentrations can remain in the air for long periods after some of these activities.

Diesel Exhaust and Community Health

Diesel exhaust contains significant levels of small particles, known as fine particulate matter. Fine particles are so small that several thousand of them could fit on the period at the end of this sentence. Fine particles pose a significant health risk because they can pass through the nose and throat and lodge themselves in the lungs. These fine particles can cause lung damage and premature death. They can also aggravate conditions such as asthma and bronchitis. In addition, in its health assessment for diesel engine exhaust, EPA concluded that chronic inhalation exposure is likely to pose a lung cancer hazard to humans. The assessment's health hazard conclusions are based on exposure to exhaust from diesel engines built prior to the mid-1990s. The health hazard conclusions, in general, are applicable to engines currently in use, which include many older engines. As new diesel engines with cleaner exhaust emissions replace existing engines, the applicability of the conclusions in the health assessment document will need to be reevaluated (see http://cfpub.epa.gov/ncea/cfm/dieslexh.cfm for more information). Given the prevalence of diesel engines in communities, diesel exhaust will usually be an important factor in most community-scale multisource assessments and risk mitigation activities.

Who Is at Risk?

People with existing heart or lung disease, asthma or other respiratory problems are most sensitive to the health effects of fine particles. The elderly and children are also at risk.

Other Health and Environmental Effects

Diesel exhaust also contains pollutants that contribute to ozone formation (or smog), acid rain, and global climate change. Fine particles from diesel engines contribute to haze which restricts our ability to see long distances.

What's Being Done About It?

EPA is working aggressively to reduce pollution from new heavy-duty diesel trucks and buses, by requiring them to meet tougher and tougher emission standards in the future. In the meantime, there are a wide array of activities any community can adopt to help reduce exposure to diesel exhaust, including:

- Adopting anti-idling policies;
- Educating drivers and recognizing drivers that reduce idling time;
- Keeping diesel vehicles well maintained;
- Taking steps to retrofit existing vehicles with pollution controls;
- Replacing the oldest vehicles with new, clean vehicles; and
- Discouraging drivers from following directly behind other large vehicles, including school buses – especially if they see visible smoke being emitted.

For more information on diesel, its health effects and ways to reduce exposure, see http://www.epa.gov/diesel/index.htm.

Exhibit 3-4. Major Indoor Air Pollutants and their Sources	
Major Indoor Air Pollutants	**Sources**
Radon (Rn)	Earth and rock beneath home; well water; building materials
Environmental Tobacco Smoke (includes carbon monoxide, nitrogen dioxide, and respirable particles)	Cigarette, pipe, and cigar smoking
Biologicals (e.g., pollen, mold, animal dander, and fungi)	Wet or moist walls, ceilings, carpets, and furniture; poorly maintained humidifiers, dehumidifiers, and air conditioners; bedding; household pets
Carbon Monoxide	Unvented kerosene and gas space heaters; leaking chimneys and furnaces; back-drafting from furnaces, gas water heaters, woodstoves, and fireplaces; gas stoves. Automobile exhaust from attached garages
Nitrogen Dioxide (NO_2)	Kerosene heaters, unvented gas stoves and heaters. Environmental tobacco smoke
Volatile Organic Compounds (such as xylene)	Paints, paint strippers, and other solvents; wood preservatives; aerosol sprays; cleansers and disinfectants; moth repellents and air fresheners; stored fuels and automotive products; hobby supplies; dry-cleaned clothing
Inhalable Particles (such as particle-bound polycyclic aromatic hydrocarbons)	Fireplaces, wood stoves, and kerosene heaters. Environmental tobacco smoke
Formaldehyde	Pressed wood products (hardwood plywood wall paneling, particle board, fiberboard) and furniture made with these pressed wood products. Urea-formaldehyde foam insulation (UFFI). Combustion sources and environmental tobacco smoke. Durable press drapes, other textiles, and glues
Pesticides	Products used to kill household pests (insecticides, termiticides, and disinfectants). Also, products used on lawns and gardens that drift or are tracked inside the house
Asbestos	Deteriorating, damaged, or disturbed insulation, fireproofing, acoustical materials, and floor tiles
Lead	Lead-based paint, contaminated soil, dust, and drinking water
Source: U.S. Environmental Protection Agency and the United States Consumer Product Safety Commission. 1995. Office of Radiation and Indoor Air (6604J) EPA/402/K/93/007, April 1995. Available at: http://www.epa.gov/iaq/pubs/insidest.html.	

In addition to the same indoor air problems as single-family homes, apartments can have indoor air problems similar to those in offices, which are caused by sources such as contaminated ventilation systems, improperly placed outdoor air intakes, or maintenance activities.

How Does Outdoor Air Enter a House?

Outdoor air enters and leaves a house by: infiltration, natural ventilation, and mechanical ventilation. In a process known as infiltration, outdoor air flows into the house through openings, joints, and cracks in walls, floors, and ceilings, and around windows and doors. In natural ventilation, air moves through opened windows and doors. Air movement associated with infiltration and natural ventilation is caused by air temperature differences between indoors and outdoors and by wind. Finally, there are a number of mechanical ventilation devices, from outdoor-vented fans that intermittently remove air from a single room, such as bathrooms and kitchens, to air handling systems that use fans and duct work to continuously remove indoor air and distribute filtered and conditioned outdoor air to strategic points throughout the house. The rate at which outdoor air replaces indoor air is described as the air exchange rate. When there is little infiltration, natural ventilation, or mechanical ventilation, the air exchange rate is low, and pollutant levels can increase.

It should be noted that air toxics found in indoor air can originate from indoor sources, outdoor sources, or a combination of both indoor and outdoor sources. The concentrations that occur indoors and the actual exposures to people residing or working within a building will depend on a combination of factors, including infiltration and ventilation rates, characteristics of the indoor environment [such as indoor sources and personal activity patterns (e.g., time of day and length of time spent inside)], and other factors.

One particularly important indoor air toxics problem actually results from an outdoor natural source. In fact, radon gas, a HAP, is one of the leading causes of lung cancer in the U.S. The most common source of indoor radon is uranium in the soil or rock on which homes are built (thus, a natural source becomes an indoor air quality problem). As uranium naturally breaks down, it releases radon as a colorless, odorless, radioactive gas. Radon gas enters homes through dirt floors, cracks in concrete walls and floors, floor drains, and sumps. When radon becomes trapped in buildings and indoor concentrations build up, exposure to radon becomes a concern.

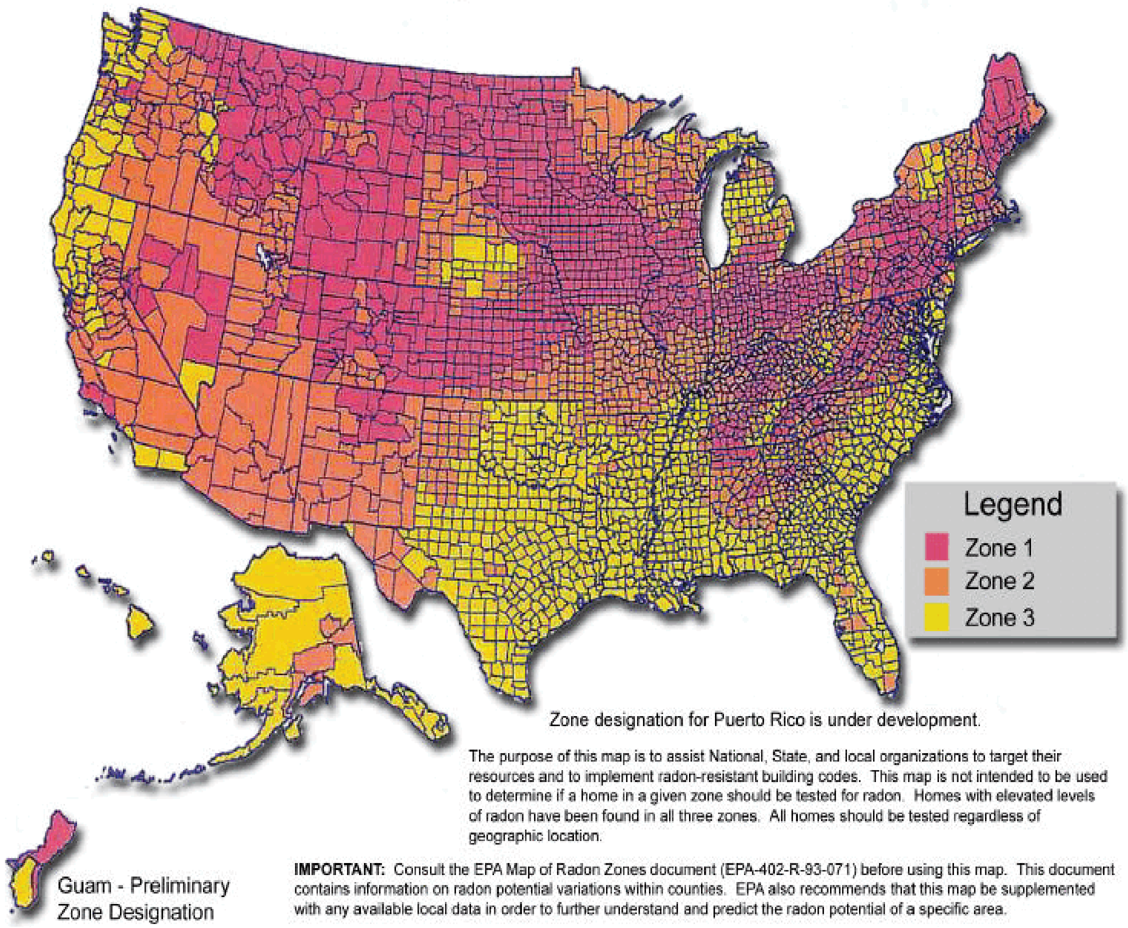
Sometimes radon enters the home through well water. In a small number of homes, the building materials can give off radon, too. However, building materials alone rarely cause radon levels of concern (see http://www.epa.gov/radon/risk_assessment.html for more information on radon risks). Exhibit 3-5 shows EPA's map of radon zones in the U.S.

3.2.4.2 Natural Sources

Natural processes are significant sources of some air pollutants, including VOCs, NO_x, O_3, PM and other pollutants (Exhibit 3-6). Examples of natural sources of air pollutants that are *not* covered by the four main categories described above include natural processes occurring in vegetation and soils (e.g., emissions from trees), in marine ecosystems, as a result of geological activity in the form of geysers or volcanoes, as a result of meteorological activity such as lightning, and from fauna, such as ruminants and termites. Sources associated with biological activity are called **biogenic sources**.

Natural pollutants contribute significantly to air pollution. For example, biogenic emission estimates for the United States were 28.2 million tons of VOC and 1.53 million tons of NO_x in 1997.[10]

Exhibit 3-5. EPA Map of Radon Zones



- **Zone 1** counties have a predicted average indoor radon screening level greater than 4 pCi/L (pico curies per liter)
- **Zone 2** counties have a predicted average indoor radon screening level between 2 and 4 pCi/L
- **Zone 3** counties have a predicted average indoor radon screening level less than 2 pCi/L

Exhibit 3-6. Categories of Natural Sources		
Category	**Examples of Emissions**	**Sources**
Geological	Sulphuric, hydrofluoric and hydrochloric acids	Volcanic gases
	Radon	Radioactive decay of rock
	Nitrogen oxides	Soils, lightning
Biogenic	Ammonia	Animal wastes
	Methane	Animal wastes, plant decay
	VOCs	Vegetation
Marine	Dimethyl sulfide, ammonia, chlorides, sulfates, alkyl halides, nitrous oxides	Sea spray released by breaking waves
Source: International Fertilizer Industry Association. 2001. Food and Agriculture Organization of the United Nations. *Global estimates of gaseous emissions of NH3, NO and N2O from agricultural land.* ISBN 92-5-104698-1. Available at: www.fao.org/DOCREP/004/Y2780E/y2780e01.htm.		

3.2.4.3 Formation of Secondary Pollutants

Some air pollutants, in addition to being directly emitted to the atmosphere by identifiable sources, are generated in the atmosphere by the chemical transformation of precursor compounds (a process called **secondary formation**). For example, under some meteorological conditions, up to 90 percent of ambient formaldehyde originates from secondary formation from a variety of precursor compounds in the presence of light (i.e., via a **photochemical reaction**). Some of the precursor compounds include isoprene (an organic compound released from trees), isobutene, and propene. The secondary formation of pollutants like formaldehyde and acetaldehyde is a complex process but can be estimated by some photochemical models (e.g., UAM-Tox, a special version of the Urban Airshed Model (UAM)). Other available models also address secondary formation but in a much more limited way (see ATRA volume 1, Chapter 9 for a more detailed discussion of air models).

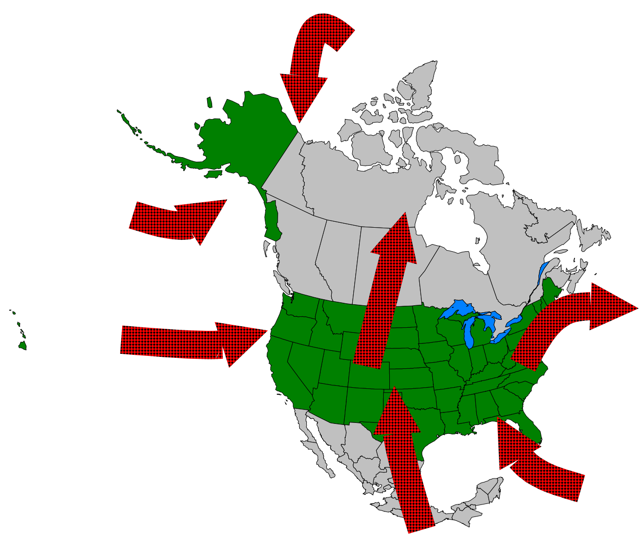
The NEI and other emission inventories generally do not include estimates of pollutants formed through secondary formation – only the initially emitted species are included. Because the formation of secondary pollutants depends on the meteorological conditions and the presence or absence of other compounds and/or light, a model that incorporates chemical transformation algorithms is required to estimate how much secondary product is formed from precursor compounds once they enter the atmosphere. EPA has in some instances developed estimates of secondarily formed chemicals to better inform the assessment of exposure of people to toxic air pollutants. For example, for the 1996 NATA, National-scale Air Toxics Assessment, risk characterization exercise, EPA developed a special inventory of precursor compounds to supplement the NEI, which was used in conjunction with the Assessment System for Population Exposure Nationwide (ASPEN) model to calculate ambient concentrations (see http://www.epa.gov/ttn/atw/natamain/). Formation of secondary pollutants is discussed in greater detail in Chapter 5.

3.2.4.4 Other Sources Not Included in NEI or TRI

Many air toxics sources, usually relatively small ones, may not be covered or are exempt from various emissions control, reporting, and other requirements, and in some cases the number or stringency of requirements is tiered according to source size or other criteria. For example, air pollution regulations for municipal waste combustors (MWCs) promulgated pursuant to section 129 of the CAA include separate rules for large MWCs (i.e., with capacities greater than 250 tons per day) and small MWCs (i.e., with capacities between 35 and 250 tons per day). However, there are no rules for MWCs with capacities less than 35 tons per day.

International Transport of Air Pollutants

There is the potential for toxic chemicals that persist and which also may bioaccumulate to be transported from long distances to contaminate distant regions of the globe. An investigation by EPA Region 5 has shown the possibility of long-range transport of certain of these chemicals (identified in an international treaty as "persistent organic pollutants," or POPs – see Exhibit 3-2) which were used in Central America prior to the 1980s to impact the Great Lakes. This is due to several phenomena. The semi-volatility of many POPs, allows them to be volatilized from warmer regions of the globe and redeposited in cooler regions in higher latitudes. Additionally, meteorological patterns during certain times of year can transport air masses and pollutants from the Central American region though the central U.S. into the northern states. Air masses from Central America have an unobstructed path to the Great Lakes (e.g. no physical barriers such as mountain ranges). Satellite photos show the transport of smoke from Central American fires in May of 1998 up through the Great Lakes Region.



This figure illustrates the mean wind flow at 1500 meters of altitude during the months of June, July and August from 1985 to 1996. Although these patterns can be disrupted by climatological events such as El Niño, it is clear that POPs released in the southern areas of this hemisphere can impact areas of the U.S. Studies have shown that long range transport from many regions of the globe is a significant source of POP chemicals to the Great Lakes and that mitigation efforts are going to be needed both in the U.S. and globally to address potential sources. The study of Central American sources has shown that this region is a potential contributor to POPs contamination in the Great Lakes, due to the fact that these chemicals degrade very slowly, and there still exist areas of high contamination and stockpiles of these chemicals that are no longer in use in Cental America.

For more information on International Issues & U.S. Air Quality, see EPA's Air Trends website at http://www.epa.gov/airtrends/international.html.

Other miscellaneous sources of air pollution (e.g., agricultural and residential burning) are controlled primarily by other S/L/T requirements. However, EPA conducts research, provides information, and pursues other non-regulatory means of addressing some of these pollution sources. For example, EPA, in conjunction with the Consumer Product Safety Commission and the American Lung Association, has published a guide for reducing pollution from residential wood combustion, including design information for less-polluting stoves and fireplaces.[9] Some local areas have ordinances that require new fireplace and wood stove installations to comply with the certification program, and others have ordinances that prohibit the use of a wood stove or fireplace on days that are conducive to the concentration of wood smoke emissions.

Ultimately, there is no single comprehensive source of information on all sources of air toxics in a given area. The NEI and TRI are good places to start an investigation of what is being released in a study area, but as noted above, in any given place, there are probably a number of air toxics sources that are not accounted for in these inventories. Nonregulated sources, natural sources, and material moving into a study area from distant sources all have an impact on overall air quality. Assessors need to clearly understand what these limitations are as they move into the planning and scoping stage of the risk assessment (see Chapter 4).

3.3 What Is Multisource Cumulative Assessment?

As described in this resource document, a human health multisource inhalation assessment is an evaluation of the ***estimated cumulative inhalation cancer risk and hazard to human health*** from multiple sources of multiple air toxics released to outdoor air to which the individuals in a study area may be exposed.[g] The human health multisource inhalation assessment follows the same general principles as the human health risk assessment process described in ATRA Volume 1 of this series. A multisource assessment will normally consider a larger number and variety of emission sources, may rely on a more complex set of analysis tools, and may cover a large geographic area such as an entire community, a series of neighborhoods, or whole industrial corridors.

Risk assessment uses science and judgment to evaluate the following questions:

- Who is exposed to air toxics?
- What air toxics are they exposed to?
- How does the exposure occur?
- What concentrations are people exposed to?
- What are the toxic properties of the chemicals?
- How likely is it that exposed people will suffer harm because of the exposures?
- How sure are we that the answers to the above questions are correct?

Since study areas can be quite large and impacted by a complex mixture of sources of toxic air pollutant emissions, another distinguishing characteristic of a multisource assessment is the need to generate results in a manner that allows "backtracking" to the sources and chemicals most responsible for the estimated risks (a process called source allocation). Without a way to understand how different sources in the area contribute to the local mix of pollutants, the development of a meaningful risk mitigation strategy might prove difficult.

The primary exposure assessment methodology described in this resource document for the multisource cumulative assessment is a *modeling approach*. This type of approach relies on air

[g] Refer to Section 4.3 for a discussion of exposure models and exposures to indoor air.

dispersion modeling to estimate concentrations of chemicals in air over space and time (a process called "fate and transport analysis"). The fate and transport results may be augmented by the application of an exposure model to develop refined estimates of exposure. The modeling approach is preferred for a community scale multisource assessment because it allows for: (1) a refined assessment of exposure gradients over a geographic study area; (2) a refined evaluation of exposures considering multiple time frames (acute vs. chronic exposures); (3) the evaluation of "what if" scenarios to determine the effects of changes in emissions; and (4) an identification of important sources (via source allocation).

A multisource cumulative assessment will commonly be supported by a limited amount of air quality monitoring in order to:

- Evaluate the air dispersion model results (e.g., by comparing to local NATTS or special monitoring study results);
- Identify gaps in the emissions inventory; and
- Help in the understanding of potential "hotspots."

That having been said, communities performing such analyses often express a strong preference for monitoring over modeling as the key analytical tool for exposure assessment. Good planning and scoping (described in Chapter 4) that includes all the necessary stakeholders at the outset of an assessment (including community members) can usually resolve this issue by helping everyone fully understand the questions to be evaluated and the strengths and limitations of the available analytical approaches (a discussion of the strengths and limitations of monitoring and modeling for exposure assessment is provided in ATRA Volume 1, Chapter 10 and is highlighted in Exhibit 3-7).

For example, in a community with an expectation that an analysis will provide a full accounting of the incremental impact of the complex set of sources and emissions, it is incumbent on the risk assessment technical team to clarify that a limited monitoring study can generally provide only a screening-level understanding of risks, and will usually be limited in its ability to distinguish among contributing sources (information that is necessary when deciding how to fix the problem). This is because monitoring results may or may not be representative of a large spatial area and may be difficult to use for source apportionment, particularly when local sources are numerous and emit a common set of chemicals.[h]

In short, air dispersion modeling will usually be the primary analytical tool for assessing air concentrations in a multisource cumulative assessment, while a limited amount of air monitoring will be used to provide important ancillary data. In some cases an exposure model will also be used to provide refined estimates of exposure. The correct balance of modeling and monitoring

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[h] The representativeness of an air toxics monitor's results for a specific geographic area will depend on a variety of factors, including the chemicals in question, the area's source characteristics, and the siting objectives of the monitor. For example, the concentration of Chemical X may be relatively homogeneous over a wide area, making the monitoring results from one central monitor representative of exposures over that area. A different chemical (Chemical Z) measured at the same central monitor may display a strong spatial gradient, making the Chemical Z monitoring results relevant for assessing exposures only to people located very close to the monitor.

Exhibit 3-7. Comparison of Modeling and Monitoring Approaches for Estimating Ambient Air Exposure Concentrations (ECs)	
Modeling	**Monitoring**
Modeling is relatively fast and inexpensive compared to monitoring. Many screening-level models can be run in spreadsheet formats and require relatively simple input parameters. Many dispersion models, along with technical reference manuals and other support documents, are available for free download from EPA's Support Center for Regulatory Air Models (SCRAM) website (http://www.epa.gov/ttn/scram/). Resources normally need to be expended to enhance the local air toxics emission inventories to make air toxics modeling more precise.	With monitoring, it takes time to build data, and there are methodological limits and logistical issues. How expensive monitoring is depends on what you are trying to do and how much you are willing to pay. Monitoring does not always require equipment purchase, and some states, tribal, and local areas already have equipment. Some less expensive monitoring techniques are now available (e.g., passive samplers).
Modeling results can estimate concentrations over a large spatial area (e.g., a 50-km radius from a source) and can provide a "big picture" view of the assessment area. Modeling also allows for analysis of EC at multiple points throughout the assessment area. The downside of modeling, however, is that these are predicted concentrations.	Monitoring results provide actual measured concentrations. Multiple locations may be required to characterize concentrations over an area, although Geographic Information Systems (GIS) methods facilitate interpolation between locations. The downside is that the monitoring may not be representative of a large geographic area.
Screening-level models can provide a predicted estimate of whether significant concentrations are likely. A simple screening analysis may be sufficient to make a risk management decision that no action is required.	Monitoring can be used to identify and measure exposures for specific individuals at a specific location of concern (e.g., a school). This data can provide a quick screen to determine whether more extensive monitoring is needed.
Models can be used to identify areas where maximum concentrations are likely to occur, and thus where to focus efforts for additional tiers of the assessment. Uncertainties in model parameters and the discrete division of the wind field used in models (often with only eight wind directions) can result in incorrect identification of the locations of maximum concentration.	Monitoring can identify areas and actual levels of exposure occurring at the monitoring sites. Monitoring can also be used to indicate the point of maximal exposure if the monitoring is designed for that purpose. The selection of the monitoring locations is critical; if placed in the wrong locations, monitors can provide incorrect and misleading information about maximal exposures.
Models can be used to identify the subset of chemicals of potential concern (COPCs) and exposure pathways/routes that have the greatest contribution to risk. This can be helpful in focusing efforts for additional tiers of the assessment as well as determining appropriate risk management actions.	Monitoring can be used to confirm significant exposure pathways and routes. (Measured concentrations can be compared to risk-based screening levels). It also can be used to identify compounds that may not have been suspected and, hence, were not included in models (i.e., monitoring allows identification of gaps in the emissions inventory).
Models allow "what if" scenarios to be evaluated (e.g., what if a permitted emission were doubled?).	Monitoring can only evaluate current conditions.
More complex modeling may allow explicit predictions and estimates of variability in exposure.	A large number of samples generally is needed to characterize variability; this may be prohibitively expensive. Monitoring, however, provides a direct and reliable means to characterize variability.
Models often use simplifying assumptions and data inputs that may or may not be representative of the specific assessment area. This introduces uncertainty into model predictions.	Monitoring can be used to confirm actual exposure levels, to investigate assumptions or calibrate models to site-specific conditions, and to close gaps in data, reducing uncertainties.

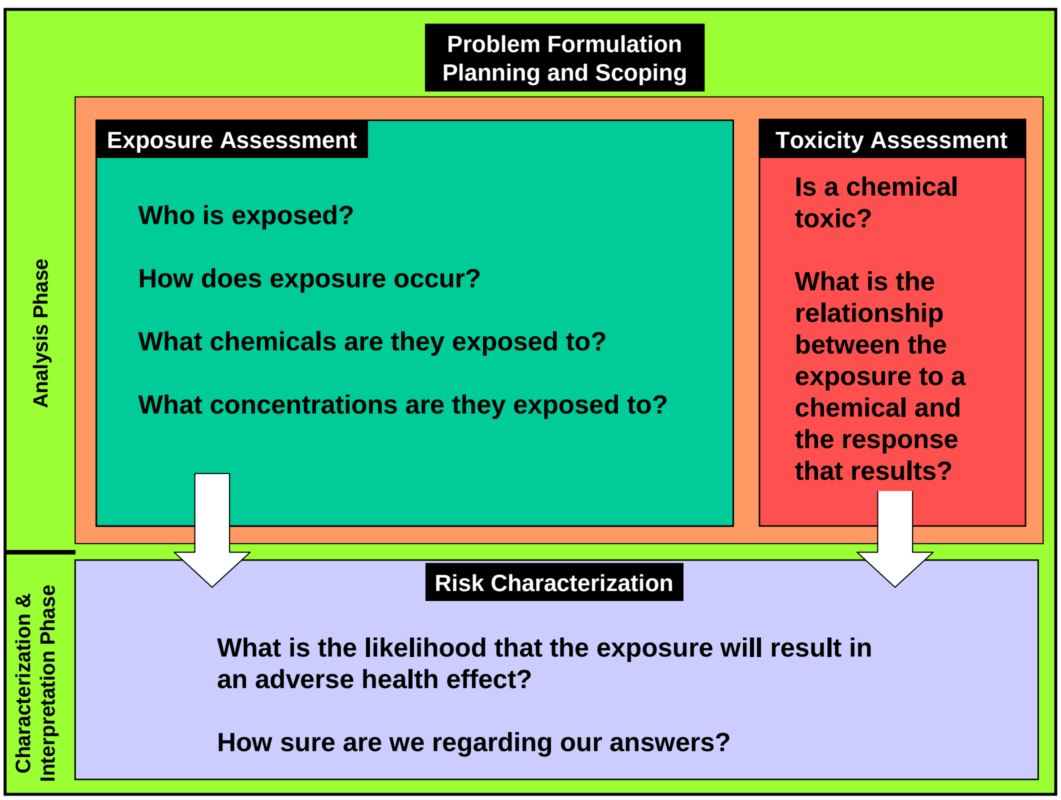
used in any given place will ultimately depend on the expectations and needs of the partnership team. A strong understanding of the strengths and weaknesses associated with the various modeling and monitoring approaches is crucial in order to correctly balance the modeling and monitoring efforts. A more thorough discussion of modeling and monitoring can be found in ATRA Volume 1, Chapters 9 and 10, respectively.

Note that the success of a modeling effort will be strongly dependent on the quality of the emissions inventory available for the study area. It is for this reason that a significant emphasis will be needed to identify the quantity and quality of emissions inventory data needed for the effort, to review the existing emissions inventory data to see if it meets the identified data quality objectives, and to augment the existing inventory, if necessary. An overview of available inventories is provided in Chapter 4. Information on augmenting an existing inventory is provided in Chapter 5.

3.3.1 Overall Framework of a Multisource Cumulative Assessment

As introduced in ATRA Volume 1 of this series, the human health risk assessment process that forms the overall framework for any kind of air toxics risk assessment (single source or multisource) is divided into three main phases (see Exhibit 3-8; for an overview of this topic, see ATRA Volume 1, Section 3.3.2 and Volume 1, Exhibit 3-5).

Exhibit 3-8. The General Air Toxics Risk Assessment Process



The general air toxics risk assessment process follows the risk assessment framework developed for EPA's *Framework for Cumulative Risk Assessment*[10] and is divided into three phases: (1) Planning, Scoping and Problem Formulation (of the entire assessment); (2) Analysis (consisting of exposure assessment and toxicity assessment); and (3) Risk Characterization. ATRA Volume 1 of this series discusses the overall air toxics risk assessment process and the basic technical tools needed to perform these analyses.

- **Planning, scoping, and problem formulation** is performed to identify the assessment questions, state the quantity and quality of data needed to answer those questions, establish the scope of this analysis, provide an in-depth discussion of how the analysis will be done, outline timing and resource considerations, identify product and documentation needs, and identify who will participate in the overall process from start to finish, along with their roles. Planning, scoping, and problem formulation is regarded as an iterative process that allows for adjustment as new information is obtained. During this process, an identification and evaluation of available data and ancillary information about the study area will be performed to help identify key chemicals, sources, and potential exposures, to determine what kind of analyses can be performed, and to establish the data gaps which need to be filled. This will usually include obtaining and evaluating basic environmental data (e.g., existing air modeling and monitoring data), demographic data, citizen complaints, heath studies and health outcome data (e.g., cancer statistics), and compliance/enforcement information (the types of data commonly evaluated at the outset of an assessment are described in Chapter 4).

- The **analysis phase** of the risk assessment is a process in which risk experts apply risk assessment approaches to evaluate the problem at hand (see ATRA Volume 1, Section 5.2.1 and Exhibit 5-1). Included in this phase are two important evaluations – exposure assessment and toxicity assessment. **Exposure assessment** is conducted to identify: (1) who is potentially exposed to air toxics; (2) what chemicals they may be exposed to; and (3) how they may be exposed to those chemicals, including the concentrations of chemicals in the air they breathe in. For a multisource cumulative assessment, these aspects of the exposure assessment are obtained through the analysis steps of emissions characterization, air dispersion modeling and application of an exposure model to the air modeling results. **Toxicity assessment** considers: (1) the types of adverse health effects associated with exposure to the chemicals in question; (2) the exposure circumstances associated with the effects (e.g., inhalation vs ingestion), and (3) the relationship between the amount of exposure and the resulting response (commonly referred to as the dose/response relationship).

- **Risk characterization** combines and summarizes the outputs of the exposure and toxicity assessments to characterize risk, both as quantitative (numerical) expressions and qualitative (descriptive) statements. Specifically, chemical-specific dose-response toxicity information is mathematically combined with modeled or monitored exposure estimates to give numbers that represent estimates of the potential for the exposure to cause an adverse health outcome. The risk characterization also provides a discussion of the variability in exposure and risk and uncertainties associated with the assessment. At this point, the assessors will also identify the key sources and chemicals that are responsible for most of the risk.

Like any air toxics risk assessment, multisource inhalation assessments follow the basic paradigm outlined in Exhibit 3-8. The defining feature of a multisource assessment, however, is the ***scope of the exposure assessment***. Specifically, a multisource inhalation air toxics assessment aims to include (if possible) all the significant sources that contribute pollutant loadings to the air in the geographic area of interest. This will, at a minimum, commonly require consideration of a wide variety of emission source types such as major and area stationary sources and mobile sources (both on- and off-road). Depending on study objectives, the assessment may also include other sources such as forest fires, long range transport of pollutants into the study area, and indoor sources.

The overall database of emissions (the **emissions inventory**) may potentially include hundreds or even thousands of individual sources and the time and resource constraints on a project may limit the scope of a particular analysis to only a few key sources and chemicals of interest. For example, in a community impacted by large and small stationary sources as well as car, truck, train, and marine traffic, the cost to fully evaluate all these sources together using a robust modeling effort may be beyond the financial resources and time considerations of those conducting the assessment. As noted previously, the analysts may decide to first apply several simple screening-level techniques to help limit the number of sources and chemicals to be evaluated in the full modeling effort. The result is that the scope of the assessment, while not encompassing "all" sources, is focused on the most likely contributors to significant risk. This approach provides a more streamlined analysis which, if performed appropriately, should have little impact on the risk conclusions. A discussion of several common screening level approaches to narrow the focus of a multisource assessment is provided in the *How To Manual* (see reference 15), and Chapter 5 and Appendix B of this Volume.

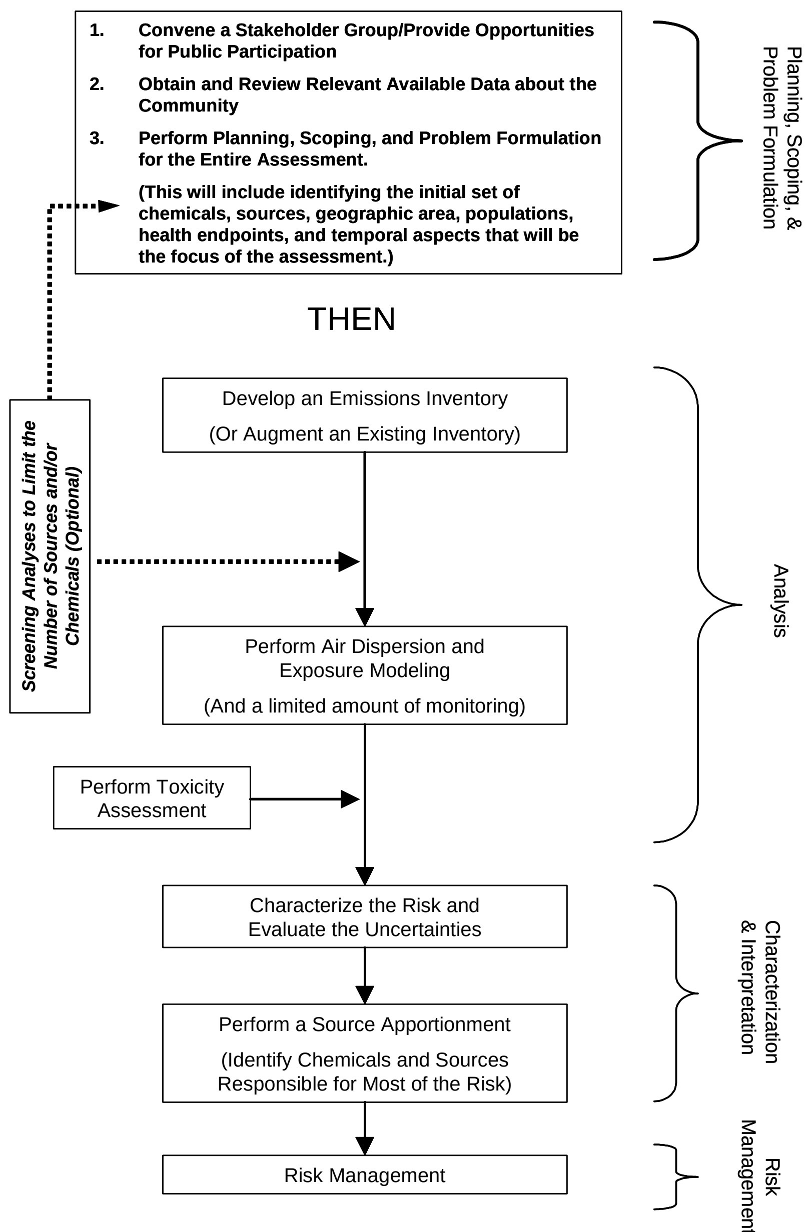
(Note that indoor sources can significantly contribute to a person's overall exposure to air toxics, but the tools to include them in a multisource assessment are not fully developed. A discussion of including indoor sources in a multisource assessment is provided in Chapter 4. Readers interested in indoor air toxics are referred to http://www.epa.gov/iaq/.)

For a multisource cumulative assessment, it is helpful to take the general framework described in Exhibit 3-8 and redraw it to highlight the key activities that analysts performing a multisource assess will usually need to accomplish (Exhibit 3-9).

Each of the steps in the process illustrated in Exhibit 3-9 are discussed in detail in the following chapters. Specifically, Chapter 4 discusses planning, scoping, and problem formulation, Chapter 5 the analysis phase, Chapter 6 discusses risk characterization and interpretation, and Chapter 8 discusses risk management. An additional chapter highlighting important risk communication information is provided in Chapter 7.

While the general risk assessment framework outlined above identifies the main phases of risk assessment, important related activities include risk communication and risk management. Specifically, good risk communication skills will help in the planning of the assessment and in conveying the results to the community. In addition, decision makers will have to decide how to respond to the information that comes out of the multisource analysis. Chapter 7 and 8 discuss the risk communication and risk management aspects of a multisource analysis in detail.

Exhibit 3-9. The General Multisource Cumulative Assessment Process for a Community Assessment



3.4 Evaluating the Need or Usefulness of a Multisource Cumulative Assessment

The reasons why the partnership team may consider a multisource analysis to be necessary is usually based on existing information that points to a potential problem. Some of the most obvious information that people commonly look to in this regard includes:

- Existing emissions inventory data (National Emissions Inventory or NEI,(11) the Toxics Release Inventory or TRI,(12) and SLT inventory and permit files);
- EPA's National Air Toxics Assessment (NATA) national-scale assessment risk characterization results for the study area;(13)
- Other screening-level air risk tool results (e.g., outputs from the TRI Risk Screening Environmental Indicators or RSEI tool);(14)
- Specific concerns voiced by citizens within the community;
- Existing community-specific monitoring and modeling data;
- Enforcement and compliance data on local business; and
- Existing epidemiological or other health outcome data.

A discussion of how to obtain and use these types of data to perform a preliminary evaluation of potential air toxics impacts at the local level is provided in Chapter 4.

When these data are considered together, they may paint a picture of a community with a potential air toxics problem that is the result of the combined impact of numerous sources emitting numerous chemicals. In such cases, it may make sense to pursue an assessment strategy that can both evaluate the combined risk and point to the sources most responsible for those risks.

In contrast, the partnership team may decide up-front that a simpler analysis will serve their purposes (e.g., a screening-level analysis using the approach described in EPA's *Community Air Screening How To Manual*, discussed in Section 3.5.1). The reasons for pursuing something other than a full-scale multisource analysis may include the following:

- Time considerations, financial and technical resources, or community support may make an expansive and as yet undefined multisource analysis untenable;
- The community may want to focus primarily on risks associated with only one type of source (e.g., risks posed by a specific local industry, risks posed by a concentration of mobile sources) and may have no interest in risks posed by combinations of source types;
- A desire by the community for a project that leads to "solutions" over the short term instead of a study that may be viewed as just "putting off the problem" (i.e., the community may have a strong "bias for action").

If the partnership team decides to perform an analysis of air toxics risks, there is no "one size fits all" approach for an assessment. Some partnership teams will opt to perform only a screening level approach, some will begin immediately with a comprehensive multisource assessment, and yet others will perform some level of screening to help them determine whether and how to proceed with a more comprehensive analysis. The local conditions and needs will usually drive the decisions on whether to simply take action, whether to take short-term action while proceeding with more formal analyses (either a screening level assessment or something more comprehensive), or whether to postpone action until analyses are complete.

The following section describes in more detail the logical progression analysts commonly take from an screening level approach to a more comprehensive multisource risk assessment. It should be emphasized that the choice of where to begin (and end) along this range of choices will depend on the needs and resources of the partnership team for whom the assessment is being performed.

3.4.1 Tiered Assessment Approaches

As discussed in ATRA Volume 1, Chapter 3, various EPA guidance documents and the Air Program's *Residual Risk Report to Congress* (available at http://www.epa.gov/ttn/oarpg/t3/reports/risk_rep.pdf) recommend a ***tiered approach*** to risk assessments. A tiered approach is a process for a systematic, informed progression from a relatively simple evaluation of readily available data about a study area to a more complex, formal assessment of risk to area populations. In the lower tiers of analysis, a limited amount of data specific to the study area are usually evaluated using a relatively simple analytical framework. The people performing the evaluation will commonly try to counterbalance the use of limited data and analytical simplicity with a conservative set of assumptions that (hopefully) lead to conservative estimates of risk.

Such a process may be able to demonstrate, with relatively little effort, that the sources and chemicals being evaluated pose insignificant risk. On the other hand, if the approach indicates that the risk appears to be relatively high for one or more sources or chemicals, the analysts may decide to pursue a higher tier of analysis to clarify whether the risk is a realistic concern or an artifact of the lower tier's conservative assumptions. The higher level of analysis reflects increasing complexity and, in many cases, will require more data, time, and resources. The upside to the approach is (usually) greater confidence about the estimated impacts of the exposures being evaluated. Higher tiers may also be able to better characterize variability and/or uncertainty in the risk estimate, which may be important for making risk management decisions.

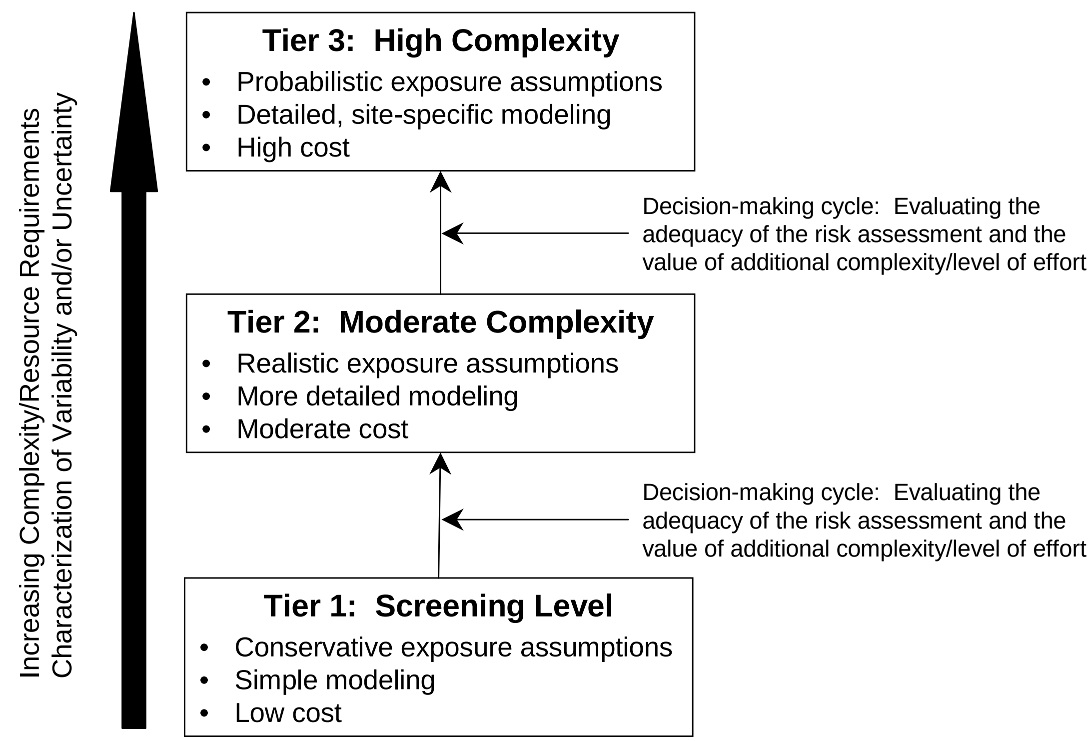
The deliberation cycle also provides an opportunity to evaluate the direction and goals of the assessment as new information becomes available. It may include evaluations of both scientific, policy, and other information.

In general, each of the Tiers represented in Exhibit 3-10 can be described as follows:

- **Tier 1** is represented as a relatively simple, screening-level analysis that relies on conservative exposure assumptions (e.g., receptors are located in the area with the highest estimated concentrations) and relatively simple modeling. The EPA's *Community Air Screening How To Manual* is an example of a Tier 1 type approach.

- **Tier 2** is represented as an intermediate-level analysis, generally using more realistic exposure assumptions and more detailed modeling (e.g., a model approach that evaluates the cumulative impact posed by multiple sources). The multisource approach outlined in Chapter 5 of this resource document (ATRA Volume 3) is an example of a Tier 2 type analysis.

Exhibit 3-10. The Generalized Tiered Approach to Air Toxics Risk Assessment



- **Tier 3** is represented as an advanced analysis using probabilistic techniques such as Monte Carlo analysis (see ATRA Volume 1, Chapter 31) or more detailed modeling (e.g., application of an exposure model).

Depending on the needs of the partnership team, they may begin with a relatively simple Tier 1 analysis and take actions based on the results. In contrast, they may decide to begin the process with a more formal multisource cumulative analysis. In some cases, they may develop Tier 1 results to help narrow the focus of the Tier 2 evaluation. If a fairly high level of understanding about emission impacts is required for the risk management decision, a Tier 3 analysis may be pursued for the most important chemicals and emission sources identified by the Tier 2 analysis.

Exhibit 3-10 illustrates a generalized representation of the tiered risk assessment approach. Central to the concept of the tiered approach is an iterative process of evaluation, deliberation, data collection, work planning, and communication aimed at deciding:

- Whether or not the assessment, in its current state, is sufficient to support the risk management decision(s); and

- If the assessment is determined to be insufficient, whether or not progression to a higher tier of complexity (or refinement of the current tier) would provide a sufficient benefit to warrant the additional effort.

Note that the tiered risk assessment approach provided in Exhibit 3-10 is not meant to imply that there is a clear distinction between Tiers 1, 2, and 3. For example, a series of refinements in a Tier 1 analysis might be indistinguishable from a Tier 2 analysis, or a Tier 2 analysis could incorporate probabilistic techniques. Instead, these three tiers are best thought of as points along a spectrum of increasing complexity and detail. The important focus is the specific ways in which a given assessment is refined in successive iterations, rather than whether or not it would be considered Tier 1, 2, or 3. (An additional discussion of screening approaches is provided in Appendix B.)

What Is "Screening" and When Would I Use It?

Screening is a process by which analysts apply some type of criteria to a group of issues to determine which of the issues is of sufficient concern to be considered for additional action. For example, in a community impacted by a large number and variety of air toxics emission sources and chemicals, analysts will commonly apply one or more techniques to try and "narrow the field" to those chemicals and sources that are probably the most important in terms of risk. This short list of sources and chemicals would then be the focus of more robust analysis or, potentially, immediate risk reduction efforts. The benefit of screening is that it can help reduce unnecessary work and help clarify what the important issues are for a community. The drawback is that, if not done properly, important information can be lost.

There are any number of "screening techniques" that could be used to limit the number of sources and chemicals in a community multisource analysis. The possibilities range from fairly arbitrary (and, thus, questionable) in nature to more scientifically objective. From a practical standpoint, the screening process usually takes shape in the form of an analysis that is performed in "tiers" (discussed above), with each tier having the flexibility to incorporate one or more screening techniques.

Analysts that are developing and/or using screening approaches should try to keep in mind that a good technique will usually need to meet three criteria:

(1) The screening technique will be a relatively simple approach;

(2) The inherent simplicity of the screening approach will be counterbalanced with reasonably conservative inputs and assumptions; and

(3) The decision criteria used to evaluate the screening results will also be reasonably conservative.

If the analyst is not reasonably confident that the technique will not lose or "screen out" important information, the technique may not justify removing sources or chemicals from further consideration. In all cases, a thorough explanation of the rationale for dropping a chemical or source should be provided.

It should be emphasized that, depending on the specific goals, needs, data quality objectives, and resources of a given community-scale assessment, the number, type, and timing of screening level techniques may vary significantly. More information on screening level techniques relevant to multisource cumulative assessment is provided in Chapter 5, Appendix B, and the *Community How To Screening Manual* (see Section 3.5.1).

3.5 Methodologies for Multisource Cumulative Assessment

This section presents an overview of several example community-scale assessment approaches that illustrate the range and variety of available methodologies.

3.5.1 The OPPTS *How To Manual* Approach and Its Use in Baltimore, Maryland

EPA's Office of Pollution Prevention and Toxics (OPPT) has established a Community Assistance Technical Team to focus on providing tools and training to help communities to improve local air quality and move toward healthy and sustainable communities. As introduced in Chapter 2, one of their products, the *Community Air Screening How To Manual*,[15] was developed as part of an effort to make air quality assessment tools more accessible to communities. Specifically, the Manual presents and explains a step-by-step ***risk-based screening*** process that a community may follow to:

- Form a partnership, including technical expertise;
- Identify and inventory all local sources of air pollutants;
- Perform a risk-based screening of these sources to identify those that may present a potential health risk to the community; and
- Set priorities and develop a plan for making improvements.

Resource Needs to Keep in Mind

Having example methodologies (such as the ones highlighted here) to consult when performing a multisource assessment is important; however, the partnership team will need to maintain a realistic perspective about the resources it will take to implement such a methodology. Typically, the time to identify a team of people to consistently work on and champion the project, plan and perform the analysis, interpret the results, implement selected risk reduction strategies, and measure results can take a number of years to complete.

Since many communities may not have access to the specialized technical skills that will be needed to perform various parts of the effort, they will need to recruit (and in some cases pay for) engineering, modeling, toxicological, and other experts. A long-term source of funding for all of the various elements of the project will be another important consideration.

These resource considerations should not discourage the team from pursuing the work. That having been said, a healthy appreciation of resource considerations and a willingness to communicate them openly will help to build and maintain trust with the larger community (especially if the team finds they have to reduce the scope of the effort based on limited resources).

The methods described in the *How To Manual* were first developed by the Air Committee of the *Southern Baltimore & Northern Anne Arundel County Community Environmental Partnership (CEP)* in Baltimore, MD. In 1996, the residents, businesses, and organizations of five Baltimore neighborhoods joined with local, state, and federal governments in a CEP to begin a new effort to find ways to improve the local environment and economy. The CEP conducted a comprehensive screening-level assessment of the combined concentrations of air toxics from all the industrial and city facilities in and around the neighborhoods and developed a first-for-Maryland survey of cancer incidence at the neighborhood level. Based on this work, the CEP began work with local facilities on pollution prevention opportunities for chemicals and sources identified as community priorities. The risk screening methodology and lessons learned were documented in the *How To Manual* for community use. A detailed description of the work and results of the Baltimore Case Study is presented in the *Baltimore Community Environmental Partnership Air Committee Technical Report*.[16]

The community-scale analysis presented in the *How To Manual* is an approach that allows a community, working with the necessary technical support, to survey the types of sources that may be impacting their area and to use various screening level techniques to identify those sources and chemicals that may pose exposures of potential public health concern. The *How To Manual* complements the multisource inhalation air toxics modeling approach described in this resource document by providing communities with an understanding of how to organize and identify the needed skills to perform a screening level assessment. It also provides a basic description of the methodology and tools that can be used to provide a screening-level evaluation of the impact of sources on a specific geographic area. Application of this process can also point the community to the need for a full-scale multisource air toxics inhalation assessment. It can also help identify the critical sources and chemicals to focus on in that assessment.

3.5.2 Hotspots Analysis Reporting Program (HARP)

The Hotspots Analysis Reporting Program (HARP)[17] is a software program designed specifically to assist with the California Air Resources Board's Air Toxics "Hotspots" Program. The HARP software package integrates the California emissions inventory, air modeling, risk analysis, and facility prioritization. HARP is a multisource, multipathway, publically available risk assessment software which utilizes conservative air and exposure modeling assumptions and inputs in accordance with the Hotspots Program. The HARP software can be used to assess the potential health impacts resulting from emissions from one or several sources that are close enough in proximity to each other that a single meteorological data set is appropriate. For the air modeling, it utilizes the EPA atmospheric modeling software ISCST3 and BPIP, and thus is capable of modeling point and area sources, but not mobile sources. It has been used to help California air pollution control and air quality districts, facility operators, and other stakeholders manage emissions inventory data and the health impacts associated with the data.

3.5.3 EPA Region 6 Regional Air Impact Modeling Initiative (RAIMI)

The Regional Air Impact Modeling Initiative (RAIMI) was established by EPA Region 6 as a means of assessing risk concerns on a community level as a result of aggregate exposure to multiple contaminants from multiple sources and pathways. RAIMI was designed to simultaneously calculate and track risks from hundreds or thousands of sources and contaminants based on various emissions scenarios (e.g., actual or estimated emissions data submitted by facilities to a state agency). As new or refined data become available, it can be directly incorporated into the assessment to obtain revised risk estimates on essentially a real time basis. Results from the RAIMI are generated in a fully transparent way such that estimated risk levels (using an assumption of continuous lifetime exposure to predicted air concentrations[i]) are completely traceable back to each source, each pathway and each contaminant. This allows for ranking of sources and contaminants based on the highest potential impact and helps risk managers to focus risk management opportunities on the most important

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[i] The current set of RAIMI tools does not include the application of an exposure model; however, an exposure model could be applied to the results of the air dispersion modeling prior to taking the results forward into the next steps of the RAIMI process (i.e., risk calculation and source apportionment).

sources and chemicals first. A detailed description of RAIMI is available at: http://www.epa.gov/earth1r6/6pd/rcra_c/raimi/raimi.htm.

As a test of the RAIMI methods and approach, a Pilot Study was designed and implemented in Port Neches, TX. The initial phase of this study was to test the methods and approach for initial ranking of sources based on estimated risks resulting from direct inhalation, while a second phase (currently underway) is to study indirect exposures resulting from air-related sources. The initial pilot study successfully demonstrated the:

- Identification and ranking of emission sources and contaminants (modeled emission sources and contaminants were ranked based on relative potential impact);

- Identification of data gaps with the most significant effect on the ability to accurately characterize potential risks; and

- Options and flexibility to incorporate new or refined data as they become available (consistent with the design of RAIMI, findings are anticipated to change as source and contaminant emission data sets become more complete).

Automating the Multisource Risk Assessment Process
The RAIMI Toolbox

Performing a full multisource cumulative assessment is conceptually straightforward but, depending on the number of sources and chemicals to be evaluated, can be computationally challenging.

The EPA Region 6 RAIMI program has developed a set of publicly available, user-friendly computer tools that seamlessly automate the multisource assessment process from mining and processing the emissions inventory data, to calculating and displaying risks, to source apportionment (see http://www.epa.gov/earth1r6/6pd/rcra_c/raimi/raimi.htm). These tools are the most cohesive set of computer applications to date for full-scale multisource analysis and are highlighted throughout Part II of this resource document.

Note that, depending on the specific requirements of a given assessment, one or more of the RAIMI tools may not be the most appropriate. Thus, while the discussion in this Part highlights the RAIMI process, it also presents other options for each of the analytical steps within the multisource framework illustrated in Exhibit 3-9. Analysts should carefully select the set of tools that will allow them to meet the overall goals and objectives of their particular assessment. In addition to the tools highlighted here, commercial vendors offer products that can be used for various aspects of the analysis.

3.6 Choosing the Correct Tools and Approach for a Multisource Cumulative Assessment

> **Data Quality Objectives (DQOs)**
>
> DQOs are qualitative and quantitative statements derived from the DQO process that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support the decisions.

While the conceptual framework for performing a multisource analysis is fairly straightforward (see Exhibit 3-9), performing an actual analysis can be complex. The specific tools and approach selected for each piece of the analysis will depend on both the established data quality objectives for the project and the time and resources available to do the work. For example, there are a variety of air dispersion models that can be used for a community-scale multisource analysis and analysts will need to choose the model that can evaluate their questions and meet their established data quality objectives (DQOs).

The following chapters provide a detailed discussion of each part of the conceptual framework illustrated in Exhibit 3-9 along with a selection of tools and approaches that are available for each the various parts of the process. Since the RAIMI approach for community-scale multisource cumulative assessment includes a comprehensive and cohesive set of computer tools that allows for a *seamless analysis and apportionment of multisource risks*, the RAIMI computer tools are highlighted within these chapters at relevant points.[(j)] *Note that, depending on the specific requirements of a given assessment, one or more of the RAIMI tools may not be the most appropriate. Thus, while the discussion in this Part highlights the RAIMI process, it also presents other options for each of the analytical steps within the multisource framework illustrated in Exhibit 3-9. Analysts should carefully select the set of tools that will allow them to meet the overall goals and objectives of their particular assessment.*

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[j] The RAIMI developers have gone to some lengths to make publicly available a seamless set of software, documentation, and real world examples that can readily be adapted to neighborhood or community-scale assessments. The remaining technical chapters of Part II relating to a full-scale multisource inhalation assessment closely follow the conceptual framework presented in the RAIMI methodology. Also note that RAIMI tools are currently focused only on the inhalation pathway. The RAIMI developers are working to expand their tools and concepts to multisource *multipathway* analysis as well. Analysts interested in this type of analysis are encouraged to check the RAIMI website for updates (http://www.epa.gov/Arkansas/6pd/rcra_c/raimi/raimi.htm).

References

1. U.S. Environmental Protection Agency. 1998. *Handbook for Air Toxics Emission Inventory Development, Volume 1: Stationary Sources* (Appendix C). Office of Air Quality Planning and Standards, Research Triangle Park, NC, November 1998. EPA/454/B98/002. Available at: http://www.epa.gov/ttn/chief/eidocs/airtoxic.pdf.

2. U.S. Environmental Protection Agency. 2003. Technology Transfer Network Air Toxics Website. *The Original List of Hazardous Air Pollutants*. Updated January 9, 2004. Available at: http://www.epa.gov/ttn/atw/188polls.html. (Last accessed March 2004.)

3. U.S. Environmental Protection Agency. 2001. *The Emergency Planning and Community Right-to-Know Act: Section 313 Release and Other Waste Management Reporting Requirements*. Washington, D.C. EPA/260/K01/001. Available at: http://www.epa.gov/tri/guide_docs/2001/brochure2000.pdf.

4. U.S. Environmental Protection Agency. 2001. *Emergency Planning and Community Right-to-Know Section 313; List of Toxic Chemicals*. Office of Environmental Information. Washington, DC, March 2001. EPA/ 260/B01/001. Available at: http://www.epa.gov/tri/chemical/chemlist2001.pdf.

5. U.S. Environmental Protection Agency. 1992. *Notice Initial Source Category List*. *Federal Register* 57:31576, July 16, 1992.

6. U.S. Environmental Protection Agency. 2002. *National Emission Standards for Hazardous Air Pollutants: Revision of Source Category List Under Section 112 of the Clean Air Act. Federal Register* 67:6521, February 12, 2002.

7. U.S. Environmental Protection Agency. 2001. *Control of Emissions of Hazardous Air Pollutants From Mobile Sources. Final Rule*. *Federal Register* 66:17230, March 29, 2001. Available at: http://www.epa.gov/fedrgstr/EPA-AIR/2001/March/Day-29/a37.htm.

8. U.S. Environmental Protection Agency. 2000. *National Air Pollutant Emission Trends: 1900-1998*. Office of Air Quality Planning and Standards, Research Triangle Park, NC. EPA/454/R00/002. Available at: http://www.epa.gov/ttn/chief/trends/trends98/index.html.

9. U.S. Environmental Protection Agency, Consumer Product Safety Commission (CPSC), and American Lung Association. 1998. *What You Should Know About Combustion Appliances and Indoor Air Pollution*. CPSC Document #452. Available at: http://www.cpsc.gov/cpscpub/pubs/452.html. (Last accessed March 2004.)

10. U.S. Environmental Protection Agency. 2003. *Framework for Cumulative Risk Assessment*. Risk Assessment Forum (EPA/630/P-02/001F), May 2003. Available at http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=54944.

11. The National Emissions Inventory website - Available at: http://www.epa.gov/ttn/chief/eiinformation.html.

12. The Toxics Release Inventory website - Available at: http://www.epa.gov/tri/.

13. The National Air Toxics Assessment website - Available at: http://www.epa.gov/ttn/atw/natamain/.

14. The Risk Screening Environmental Indicators website - Available at: http://www.epa.gov/opptintr/rsei/whats_rsei.html.

15. U.S. Environmental Protection Agency. 2004. *Community Air Screening How-To Manual, A Step-by-Step Guide to Using Risk-Based Screening to Identify Priorities for Improving Outdoor Air Quality*. EPA-744/B-04-001. Available at: http://www.epa.gov/ttn/fera/risk_atra_main.html.

16. U.S. Environmental Protection Agency. 2002. *Baltimore Community Environmental Partnership Air Committee Technical Report, Community Risk-Based Screening: A Case Study in Baltimore, MD*. Office of Pollution Prevention and Toxics (EPA 744-R-00-005), April 2000. Available at http://www.epa.gov/opptintr/cahp/case.html.

17. Hotspots Analysis Reporting Program (HARP) website - Available at: http://www.arb.ca.gov/toxics/harp/docs.htm?PF=Y.

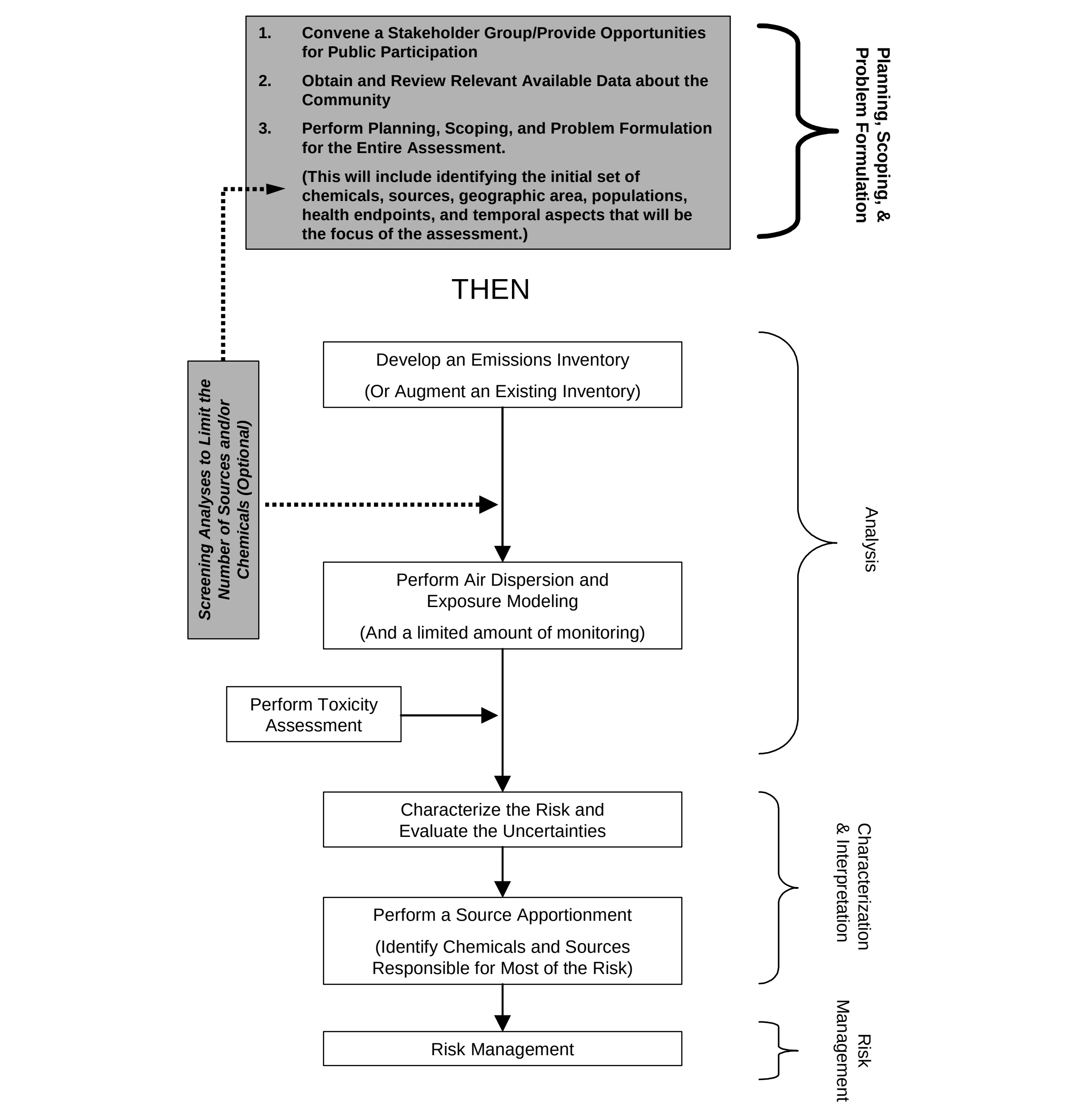
Chapter 4 Planning, Scoping, and Problem Formulation for a Multisource Cumulative Assessment

Table of Contents

4.0 Introduction

As introduced in Chapter 3, the three main phases of risk assessment are: (1) planning, scoping, and problem formulation; (2) analysis; and (3) risk characterization and interpretation. This chapter focuses on the first phase of the process – Planning, Scoping, and Problem Formulation (see highlighted portion of Exhibit 4-1).

Exhibit 4-1. The General Multisource Cumulative Air Toxics Risk Assessment Process for a Community Assessment - Focus on Planning, Scoping, and Problem Formulation



For a multisource community-scale air toxics assessment the process of planning, scoping, and problem formulation can move forward once the key stakeholders are engaged and the risk assessment technical team established. The discussion below is a summary of more detailed discussions in ATRA Volume 1 on these topics (Chapters 3, 5, and 6) as well as the *Community How To Manual* (Chapters 1 and 2),[1] and analysts are encouraged to review these chapters before proceeding. Additional discussions of planning, scoping, and problem formulation can be found in EPA's Risk Assessment Guidance for Superfund (RAGS): Volume I, Chapter 2.[2]

What You Should Know Before You Proceed

EPA's Science Policy Council has developed guidance that directs the Agency to take into account cumulative risk issues in scoping and planning major risk assessments and to consider a broader scope that integrates multiple sources, effects, pathways, stressors and populations for cumulative risk analyses in all cases for which relevant data are available.

Analysts performing a multisource cumulative assessment will find the following guidance documents helpful will performing planning, scoping, and problem formulation for a multisource inhalation air toxics risk assessment:

- *Framework for Cumulative Risk Assessment*
- *Guidance on Cumulative Risk Assessment. Part 1. Planning and Scoping*
- *Cumulative Risk Assessment Lessons Learned* Document

See: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=54944.

ATRA Volume 1, Chapters 5 and 6, also provide an overview of Planning, Scoping and Problem Formulation.

Good planning, scoping, and problem formulation at the beginning of the project is critical to the success of the overall effort because they clearly:

- Articulate the specific problem(s) that triggered the assessment and the questions it is intended to answer;
- Provide an evaluation of existing data to determine what is known about potentially important emission sources, chemicals, and exposures;
- State the quantity and quality of data needed to answer those questions to the satisfaction of the risk managers (the data quality objectives, or DQOs);
- Provide a detailed plan of how the assessment team will perform the analysis;

What Are Data Quality Objectives?

Qualitative and quantitative statements derived from the data quality objectives (DQO) process clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support the decisions. The DQO process is an example of "systematic planning" that assessors use to translate a decision maker's aversion to decision error into a quantitative statement of data quality needed to support that decision. This type of process is recommended when decision makers are using data to select between two opposing conditions such as determining compliance with a standard. To learn more about data quality in the air toxics risk assessment process, see ATRA Volume 1, Section 6.4. To learn more about EPA's quality program, including guidance documents on developing high quality data, see http://www.epa.gov/quality.

- Outline timing and resource considerations, as well as product and documentation requirements; and
- Identify who will participate in the overall process from start to finish and what their roles will be.

The planning, scoping, and problem formulation process also need to identify important gaps and uncertainties in existing data and the steps that will be needed to address these issues. Where the extent of data gaps and their potential impacts on the assessment are not fully understood, the planning, scoping, and problem formulation process may be iterative, with decision points specified during the analytical phase that are contingent on the results of data gathering efforts or sensitivity/uncertainty analyses.

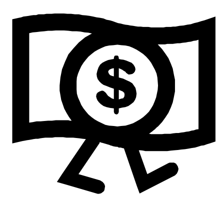
The importance of good planning, scoping, and problem formulation cannot be overstated. Poor planning, scoping, and problem formulation will almost certainly lead to a multisource assessment that does not answer the correct questions, does not provide a supportable basis for decision making or development of supportable risk reduction strategies, and wastes significant amounts of time, resources, and good will.

Planning, scoping, and problem formulation is composed of several functions, including:

- **Identifying "who needs to be involved" in the process.** Many different groups of people will probably be interested in the assessment, but not everyone will want to participate to the same degree. This step identifies the various interested stakeholders and ways to appropriately involve them in the process. The technical team that will actually perform the assessment is also identified as are the key customers of the assessment outputs (e.g., the key risk managers). A discussion of this topic is provided in Section 4.1. Additional information on community involvement can be found in Chapter 10.

Who's Going to Pay for All This Work?

All of the activities identified during the planning and scoping phase (and the concurrent activities to work with the community at large) will require resources. Money, in-kind services, and the partnership team's time will all be need to fuel the generation and analysis of data, work with community stakeholders (e.g., by holding meetings, hosting training opportunities, developing risk communication materials, etc.) and, in some cases, pay for implementing risk reduction activities. The amount of resources needed will, of course, vary from community to community and each stakeholder group will need to identify the best mix of public and private resources to fund their project. Section 10.2.2 of this resource document provides an overview of key resources the partnership team may which to consider to not only fund the analysis, but sustain the effort over time.



- **Identifying the concern(s).** This step brings together all necessary stakeholders and tries to understand their concerns. At the end of this step, the partnership team should have identified the specific perceived problem (or set of problems) that they want to evaluate using the risk assessment process. Depending on the identified problems, a full multisource cumulative assessment process may not be necessary (e.g., the partnership team may opt for a screening-level assessment as described in EPA's *How To Manual* - see Section 3.5.1). In order to help identify and clarify the initial set of concerns, it will be important at this point to gather together and perform a preliminary evaluation of existing data about the community (such as existing demographic and emissions inventory data). A discussion of this topic is provided in Section 4.2.[a]

- **Establishing the scope of the assessment.** In a multisource inhalation community-scale assessment, all sources impacting the study area could theoretically be evaluated; however, time, money, access to expertise and information, technological limitations, and other factors may limit the ability of the technical team to perform a complete analysis. Thus, the partnership team will use this step to set limits on the risk assessment study. Specifically, they will obtain and evaluate existing data to help identify the sources and chemicals to be evaluated, the geographic limits of the study area, timing considerations, and the health endpoints to be considered in the risk characterization. A discussion of this topic is provided in Section 4.3.

- **Further clarifying the perceived problem and describing how it will be studied.** During the progression of the planning and scoping phase, the technical team, in conjunction with other appropriate stakeholders, creates both a pictorial representation and written description of exactly how the sources of interest may be contributing to exposures of potential public health concern in the community (the **conceptual model**) along with a detailed written plan of how they are going to study each piece of that model (the **analysis plan**). A summary statement of the perceived problem (the **problem statement**) clarifies for all the stakeholders what question(s) is being studied and how. Statements of what will not be studied may also be included to help avoid expectations not being met at the end of the project. A discussion of this topic is provided in Section 4.4.

4.1 Identify Who Needs to Be Involved in the Process

On occasion, a community scale multisource assessment will be performed by only a small group of researchers with little or no input from other stakeholders in the community. More commonly, the process of organizing, performing, and responding to the results of a multisource assessment will require the ongoing participation and input from a larger group of community stakeholders. In such cases, getting a community-scale assessment started will require upfront work to build a broad partnership team within the community, clarify the assessment goals, prepare a plan for conducting the assessment, and prepare a plan for communicating with and involving the community. This effort can be time consuming but is necessary to help ensure that the technical analysis of local air quality and risk reduction measures are successful in the long run.

EPA's *How To Manual*[1] stresses the importance of building and maintaining a partnership within the community in order to successfully complete a community-scale assessment. This section draws on the information provided in the *How To Manual* to briefly describe the importance of such a partnership, the process for building the partnership, potential roles and

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[a] This activity illustrates that the risk assessment process is not completely linear. For example, the analysis of available data will commonly have already been done (to some degree) prior to convening a stakeholder workgroup (since it was probably existing data that led to the multisource assessment effort in the first place). However, at the point of formal planning, scoping, and problem formulation, the stakeholder group will want to revisit these data sources to more carefully evaluate what they indicate about important emission sources, chemicals, and exposures in the study area.

responsibilities of the partnership members, needed skills, and suggested teams for conducting the assessment. ATRA Volume 1, Chapter 28, provides further background on community involvement.

The effort needed to understand and improve local air quality is complex and will require a wide range of skills and resources (Exhibit 4-2). No single sector of the community or government will commonly have the ability or resources to do this work alone. A stakeholder partnership, on the other hand, will have the ability to bring together the required resources, information, and skills that will be needed to reach an agreement on the questions to be studied, the goals of the assessment, the approach to be taken, and an effective plan for action once the assessment is complete. The partnership will also provide the means for different parts of the community to share ideas and develop the trust that will be necessary for joint action.

Some of the important skills that will be needed over the course of the project include:

- **Leadership**. Successful completion of the assessment depends on leaders with a clear understanding of the partnership's goals and direction and the skills to lead the community toward those goals.

- **Dialogue**. The willingness and ability to exchange information and to learn from others is essential to maintaining a functioning partnership.

Exhibit 4-2. Potential Recruitment Pools for Membership in a Local Partnership

- Community residents
- Community civic, environmental, and economic development organizations and associations
- Local business representatives, including those representing potential air toxics sources
- Housing associations
- Religious organizations
- School staff
- Community students and student organizations or environmental clubs
- Youth organizations
- Local library staff
- Local and national business associations
- Unions representing local employees
- Colleges and universities, including college students and student organizations
- Local government, including elected officials and agency representatives from health, environmental, planning, permitting, development, public works, parks, police and fire departments
- State and tribal government agency representatives from transportation, environment, health and natural resources departments
- Federal government agency representatives from environment, housing, energy, and transportation
- National and state environmental organizations
- Environmental justice organizations
- Public health organizations
- Local foundations concerned with the environment or public health

- **Technical knowledge and skills**. Members with the technical skills needed to conduct the analysis are critical. Fundamental skills generally include:

  - Data collection;
  - Air dispersion modeling;
  - Engineering;
  - Database management;
  - Toxicology; and
  - Risk assessment.

  The partnership may have access to this expertise directly (e.g., from government agencies, universities, local organizations, or community members) or may need the aid of consultants to perform the technical analysis. Once the risks have been evaluated, identifying and implementing meaningful risk reductions measures may require specialized expertise such as transportation planning, environmental engineering, and pollution prevention.

- **Communication**. Because the work of the partnership depends on community support and participation, the ability to explain the work of the partnership to the community is essential. This will require both communication skills and knowledge of the community. The ability to communicate the science used in the assessment to non-scientists is especially important. Stakeholders should begin the communication process as early as possible and continue throughout the process. The partnership may want to make the development of a communication strategy and plan one of its first priorities. ATRA Volume 1, Chapter 29, discusses the fundamentals of risk communication. Chapter 7 of this volume provides additional examples of communicating assessment results.

- **Organizational skills**. Logistics such as chairing meetings, keeping records, organizing community events and actions, developing budgets, handling and raising funds, and other related administrative skills will be needed over the course of the assessment.

- **Facilitation skills**. The ability to foster a process that will build trust, improve communication, clarify goals, and develop participation in the partnership is essential.

- **Ability and willingness to develop and implement risk reduction strategies** (including a willingness to compromise, when necessary and appropriate). Developing and implementing risk reduction strategies will require the active participation of the business community, technical experts, and community leaders. Active participation of individual community members will often be critical to successfully implement risk reduction strategies.

The strategy for getting a partnership started will be different for each community and will depend on factors such as the types of established organizations, the availability of technical resources, and local interest in air quality issues. The partnership may be formed as a part of, or separate from, existing community organizations.

A successful partnership for a multisource analysis will usually require an organization to take the lead and act as a consistent champion of working together to improve air quality. A small steering committee (commonly, around 20 members) will commonly lead, organize, and oversee the work described in this resource document (referred to here as the “partnership team”).

The partnership team should include a balanced representation from as many different sectors of stakeholders in the community as possible. A broad representation will help ensure that all views are considered and that the partnership has access to the information and support needed for a successful outcome. A larger group of community members, or the entire community, would be expected to participate in activities organized by the steering committee by attending public meetings, providing input, and taking part in community activities to improve air quality.

Because the scope of partnership activities will depend on the specific assessment goals that are chosen, the tasks and membership in the steering committee may evolve as goals are clarified. At a minimum, the steering committee will need to do the following:

- Represent the views of the community residents, businesses, and other relevant organizations in partnership decisions;
- Exchange information so that all partnership members have the understanding necessary to participate fully in the work;
- Consider the views of all members of the partnership and work to develop a collaborative decision-making process;
- Participate, as appropriate, in the technical analysis of air quality;
- Help to communicate the work and results to the larger community;
- Help to develop and lead the implementation of an action plan to make improvements in air quality;
- Identify and obtain the resources to fuel the effort; and
- Help with group logistics such as organizing, chairing, and keeping meeting records.

The partnership team, augmented with other stakeholders, as appropriate, also acts as the Planning and Scoping Team. The Planning and Scoping Team should be comprised of all the people necessary to establish the assessment questions and goals, identify the data quality objectives for the project, and agree to the technical approach to be taken. At a minimum, this team must include both the risk assessors who will perform the work as well as the people who will be using the output of the risk assessment in the decision making process (the risk managers). Under this umbrella group, a number of topic-specific workgroups may be formed, including:

- **Risk Assessment Team** to direct the overall framework of the analysis and estimate exposures and risk;
- **Emission Inventory Team** to collect and organize emissions inventory data;
- **Modeling Team** to conduct air dispersion and/or exposure modeling;
- **Monitoring Team** to collect and analyze monitoring data;

- **Quality Assurance/Quality Control Team** to help establish data quality requirements, and audit technical analyses;

- **Recommendations Team** to decide whether the risks are acceptable or not and to develop risk reduction options (i.e., the risk managers);

- **Implementation Team** to implement selected risk reduction strategies and measure results; and

- **Communications Team** to be the primary interface with the community.

(Depending on the skills mix, these workgroups may combine functions, with the exact set of workgroups formed varying from study to study.)

What Level of Review Will the Risk Assessment Need?

In order to enhance the quality and credibility of risk management decisions, analysts should ensure that the scientific and technical work products underlying these decisions (the risk assessment, analysis plans, etc.) receive an appropriate level of technical review. Depending on the circumstances, an adequate review may be accomplished by people within the organization performing the analysis. In other instances, a formal peer review by independent scientific and technical experts might be necessary. The circumstances of each community-scale assessment will dictate the number, type, and timing of reviews a technical work product should receive. EPA's Peer Review Handbook provides policy and direction for risk assessments performed by the Agency and is a good source of basic information on when and how technical assessments should be performed (see http://www.epa.gov/OSA/spc/2peerrev.htm).

What is Peer Review? *Peer review is a documented critical review of a specific technical work product. The peer review is conducted by qualified individuals (or organizations) who are independent of those who performed the work, but who are collectively equivalent in technical expertise (i.e., peers) to those who performed the original work. The peer review is conducted to ensure that activities are technically adequate, competently performed, properly documented, and satisfy established quality requirements. The peer review is an in-depth assessment of the assumptions, calculations, extrapolations, alternate interpretations, methodology, acceptance criteria, and conclusions pertaining to the specific major scientific and/or technical work product and of the documentation that supports them. Peer review may provide an evaluation of a subject where quantitative methods of analysis or measures of success are unavailable or undefined; such as research and development. Peer review is usually characterized by a one-time interaction or a limited number of interactions by independent peer reviewers. Peer review can occur during the early stages of the project or methods selection, or as typically used, as part of the culmination of the work product, ensuring that the final product is technically sound.*

4.1.1 The Separation of Risk Assessment and Risk Management

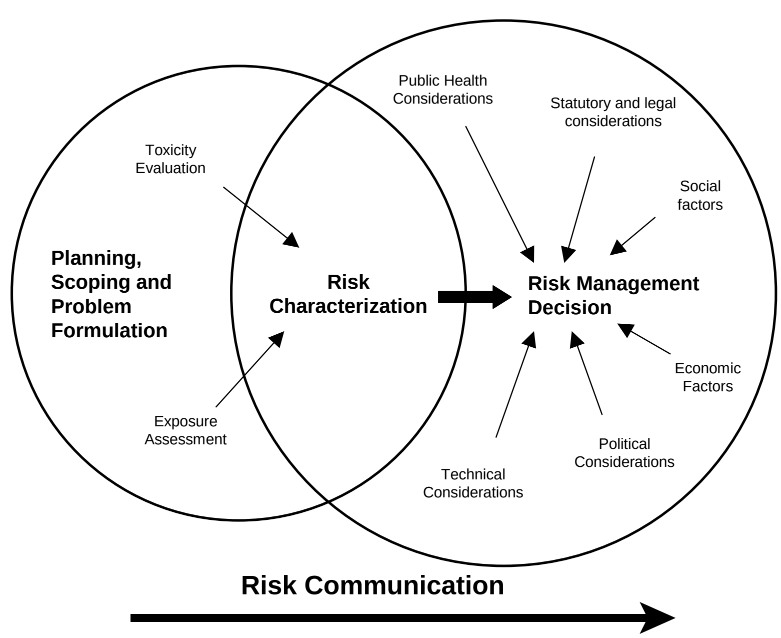
It is important to keep in mind that at the outset of the analysis, all key stakeholders must convene to establish the overall direction of the assessment. However, once the actual technical work begins, the activities of the technical workgroups should generally be separated from risk managers and other stakeholders with an interest in the assessment outcomes. It follows that the people performing the risk assessment and those who will be managing the risk results should not be the same people, if possible.

There has been a great deal of discussion and debate about how best to achieve an appropriate balance between those "doing the science" and those "managing the answers." For example, the National Research Council (NRC) of the National Academy of Sciences (NAS), in their 1983 study entitled *Risk Assessment in the Federal Government: Managing the Process* (the "Red Book"),[(3)] advocated a clear conceptual distinction between risk assessment and risk management, noting, for example, that maintaining the distinction between the two would help to prevent the tailoring of risk assessments to the political feasibility of regulating a chemical substance. However, the NRC also recognized that the choice of risk assessment techniques could not be isolated from society's risk management goals. (An example of the interplay between risk assessment and risk management is provided in Exhibit 4-3.) Ultimately, effective, yet appropriate, communication will be needed throughout the process between the risk assessors and risk managers and with external stakeholders (see Chapter 7).

Ultimately, the risk assessors should be aware of risk management goals; however, the fundamental science performed in the risk assessment should be impartial and based on the factual base of information, to the extent possible. The risk managers and the technical team should touch base at appropriate defined points along the way, particularly when some element of the project scope or analytical approach changes significantly. However, all parties must be careful not to let this interaction influence (or give the impression of influencing) the scientific process in such a way as to achieve a predetermined outcome.

In order to limit overt or unintentional skewing of the results of the analysis, it is prudent to establish an upfront scheme that will be followed in assessing the meaning of the risk results as well as the level of risk that the partnership team considers acceptable. With these decisions made prior to developing the actual risk estimates, the partnership and other relevant community

Exhibit 4-3. Illustration of the Integration Between Risk Assessment and Risk Management



stakeholders will have agreed on the "ground rules" early in the process, at a time when data and analytical results are not yet known. One way to do this is to develop a *risk management plan* that identifies both the agreed-upon risk management framework and a menu of generic risk management actions that might be pursued if risks are found to be unacceptably high.

More general information on the use of risk in decision making about air toxics and the interplay of risk assessment and risk management, see ATRA Volume 1, Chapter 27. Focused information on risk management for air toxics in a multisource context , including the development of a risk management plan, is provided in Chapter 8.

4.2 Identify the Multisource Concerns to Be Evaluated

The planning and scoping process is the appropriate step in the overall process for the needs and goals of the partnership team to be identified and then ***distilled down to a realistic set of assessment questions and goals*** that will be carried forward. Several important activities that need to happen during this process include:

- Identifying and evaluating existing data on potential air toxics emission sources, the chemicals they release, and the potential exposures to populations in the study area;
- Identify team members' concerns and interests;
- Preparing for different outcomes of the analysis;
- Setting realistic expectations;
- Identify and implement short- and long-term goals; and
- Integrate air quality goals with other community priorities.

Each of these topics is discussed in more detail below.

4.2.1 Identifying and Evaluating Existing Data on Sources, Chemicals, and Exposures

The partnership team will want to review existing information to help them understand what is already known about the potential impacts of air toxics on the local population. This will help them refine their concerns about the area, establish the questions they want the assessment to answer, and set the scope (the limits) of the study (discussed in Section 4.3 below). Information sources that are commonly considered include the NATA risk characterization, TRI data, census data, land use maps, local air monitoring and modeling data, citizen concerns and complaints, and health studies that have been performed in the area (e.g., studies of cancer rates). A discussion of how to obtain and use each of these data types is provided in the sections that follow.[b]

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[b] Depending on the situation, there may be little or no data to perform an initial characterization of the air toxics concerns in the study area and the stakeholder group may need to develop new information to support the multisource air toxics effort. New research or data collection (e.g, sample collection by air monitoring) should be carefully planned and executed to ensure that the resulting information is credible, accurate, and relevant to the concerns of the community. The process of developing an emissions inventory for multisource assessment is described in ATRA Volume 1, Chapter 7 and Chapter 5 of this Volume. Information on developing air toxics monitoring data is provided in ATRA Volume 1, Chapter 10.

EPA Internet Gateways to Community-level Information

EPA maintains a vast array of data and tools that can be used in planning and scoping a community-based multisource air toxics assessment. In an effort to help partnership teams access and use this information effectively and efficiently, the Agency has developed several internet-based gateways and other tools to help in the navigation of EPA resources. Several important internet-based tools include:

EnivroFacts (http://www.epa.gov/enviro/). This website provides access to several EPA databases that provide information about environmental activities that may affect air, water, and land anywhere in the United States. The partnership team can also use EnviroFacts to generate maps of environmental information.

EnviroMapper (http://www.epa.gov/enviro/html/em/). EnviroMapper is a powerful tool used to map various types of environmental information, including air releases, drinking water, hazardous wastes, water discharge permits, and Superfund sites. Users can select a geographic area within EnviroMapper and view the different facilities that are present within that area. EnviroMapper can be used to create maps at the national, state, and county levels, and link them to environmental text reports. Users can even insert dynamically created maps in their own webpages.

Window to My Environment (http://www.epa.gov/enviro/wme/). Window To My Environment (WME) is a powerful web-based tool that provides a wide range of federal, state, and local information about environmental conditions and features in a specific area. This internet tool is provided by EPA in partnership with federal, state and local government and other organizations.

The CARE Resource Guide (http://cfpub.epa.gov/care/index.cfm?fuseaction=Guide.showIntro). As noted in Chapter 2, the CARE program has developed this resource guide to help anyone interested in working with communities to evaluate and reduce environmental risk. The Resource Guide enables stakeholder groups to find on-line resources that can help their community through every step of the risk evaluation and risk reduction process.

Environmental Justice (EJ) Graphic Assessment Tool (http://www.epa.gov/enviro/ej/). EPA's EJ Graphic Assessment Tool can be used to map EPA environmental data in relation to available demographic data (e.g., population density, percent minority population).

4.2.1.1 National Air Toxics Assessment National-Scale Risk Characterization

As introduced in Chapter 2, EPA has developed a national-scale risk characterization for 177 toxic air pollutants and diesel particulate matter (Exhibit 4-4), based on 1999 emissions data. EPA used computer modeling of the 1999 NEI air toxics data as the basis for developing health risk estimates for each of these chemicals at the census tract level across the United States. The goal of the national-scale risk characterization is to identify those air toxics which may be of potential concern in terms of contribution to population risk. The results are being used to, among other things, set priorities for the collection of additional air toxics data (e.g., emissions data and ambient monitoring data). EPA plans to update the national scale assessment every three years.[c]

[c] EPA plans eventually to include all 187 HAPs in the NATA national-scale assessment.

Exhibit 4-4. Chemicals Evaluated in the 1999 NATA Risk Characterization

Acetaldehyde
Acetamide
Acetonitrile
Acetophenone
2-Acetylaminofluorene
Acrolein
Acrylamide
Acrylic acid
Acrylonitrile
Allyl chloride
4-Aminobiphenyl
Aniline
o-Anisidine
Antimony compounds
Arsenic compounds (inorganic, may include arsine)
Arsine
Asbestos
Benzene
Benzidine
Benzotrichloride
Benzyl chloride
Beryllium compounds
Biphenyl
Bis(2-ethylhexyl)phthalate
Bis(chloromethyl)ether
Bromoform
1,3-Butadiene
Cadmium compounds
Calcium cyanamide
Captan
Carbaryl
Carbon disulfide
Carbon tetrachloride
Carbonyl sulfide
Catechol
Chlordane
Chlorine
Chloroacetic acid
2-Chloroacetophenone
Chlorobenzene
Chlorobenzilate
Chloroform
Chloromethyl methyl ether
Chloroprene
Chromium III
Chromium VI
Cobalt compounds
Coke Oven Emissions
Cresols - Cresylic acid (isomers and mixture)
Cumene
Cyanide compounds
Diazomethane
Dibenzofurans
1,2-Dibromo-3-chloropropane
Dibutylphthalate
p-Dichlorobenzene
3,3-Dichlorobenzidene
Dichloroethyl ether
1,3-Dichloropropene
Dichlorvos
Diesel particulate matter
Diethanolamine
Diethyl sulfate
3,3-Dimethoxybenzidine
p-Dimethylaminoazobenzene
Dimethyl carbamoyl chloride
Dimethyl formamide
1,1-Dimethyl hydrazine
Dimethyl phthalate
Dimethyl sulfate
3,3-Dimethyl benzidine
4,6-Dinitro-o-cresol, and salts
2,4-Dinitrophenol
2,4-Dinitrotoluene
1,4-Dioxane
1,2-Diphenylhydrazine
Epichlorohydrin
1,2-Epoxybutane
Ethyl acrylate
Ethyl benzene
Ethyl carbamate
Ethyl chloride
Ethylene dibromide
Ethylene dichloride
Ethylene glycol
Ethylene imine (Aziridine)
Ethylene oxide
Ethylene thiourea
Ethylidene dichloride
Fine mineral fibers
Formaldehyde
Glycol ethers
Heptachlor
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Hexamethylene-1,6-diisocyanate
Hexamethylphosphoramide
Hexane
Hydrazine
Hydrochloric acid
Hydrofluoric acid
Hydroquinone
Isophorone
Lead compounds
Lindane (all isomers)
Maleic anhydride
Manganese compounds
Mercury compounds
Methanol
Methoxychlor
Methyl bromide
Methyl chloride
Methyl chloroform
Methyl ethyl ketone
Methyl hydrazine
Methyl iodide
Methyl isobutyl ketone
Methyl isocyanateMethyl methacrylate
Methyl tert butyl ether
Methylene chloride
4,4'-Methylene bis(2-chloroaniline)
4,4'-Methylenedianiline
Methylene diphenyl diisocyanate
N,N-Diethyl aniline
Naphthalene
Nickel compounds
Nitrobenzene
4-Nitrobiphenyl
4-Nitrophenol
2-Nitropropane
Nitrosodimethylamine
N-Nitrosomorpholine
N-Nitroso-N-methylurea
Parathion
Pentachloronitrobenzene
Pentachlorophenol
Perchloroethylene
Phenol
p-Phenylenediamine
Phosgene
Phosphine
Phthalic anhydride
Polychlorinated biphenyls (PCBs)
Polycyclic Organic Matter (POM)
1,3-Propane sultone
beta-Propiolactone
Propionaldehyde
Propoxur
Propylene dichloride
Propylene oxide
1,2-Propylenimine
Quinoline
Quinone
2,4-D, salts and esters
Selenium Compounds
Styrene
Styrene oxide
1,1,2,2-Tetrachloroethane
Titanium tetrachloride
Toluene
2,4-Toluene diamine
2,4-Toluene diisocyanate
o-Toluidine
Toxaphene
1,2,4-Trichlorobenzene
1,1,2-Trichloroethane
Trichloroethylene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
Triethylamine
Trifluralin
2,2,4-Trimethylpentane
Vinyl acetate
Vinyl bromide
Vinyl chloride
Vinylidene chloride
Xylenes (isomers and mixture)

The importance of NATA for local scale assessment is that it can provide important clues to the chemicals and sources that ***may be causing*** exposures of potential public health concern within a study area. For example, the NATA risk characterization results for an area can be used to identify the chemicals and sources (of those evaluated) that pose potentially significant exposures in a given place. At a minimum, these chemicals and sources would commonly be included the multisource analysis.

That having been said, analysts should use caution when interpreting NATA risk characterization results at the local level as the NATA was designed to help identify general patterns in air toxics exposure and risk across the country, not as a tool to characterize or compare risk at local levels (e.g., to compare risks from one part of a city to another). For more information about NATA activities, results, and caveats, see http://www.epa.gov/ttn/atw/natamain/. NATA is also discussed in ATRA Volume 1, Chapter 3.

4.2.1.2 Emissions Inventories

As discussed in ATRA Volume 1, Chapter 4, information on releases of air toxics is primarily compiled and maintained in **emissions inventories**. The primary emissions inventory for HAPs is EPA's NEI. EPA's TRI is a second inventory that has some utility for planning and scoping an air toxics risk assessment, but is of limited use for the actual modeling assessment because of the nature of the way the data are reported. In addition to the NEI and the TRI, SLT air agency permit files as well as localized inventories that have been developed, but not submitted to the NEI, can also provide information on the location and source characteristics of air toxics releases. An overview of emissions inventories is described in ATRA Volume 1, Chapter 4. An overview of the process for developing an emissions inventory is described in ATRA Volume 1, Chapter 7. Readers are encouraged to review these chapters for a more comprehensive on the structure and contents of readily available EPA emissions inventories as well as to provide insight into the kind of activities that may be required to augment an existing inventory or develop an inventory. A brief description of the two most common inventories used for community-scale multisource analysis is provided below. In addition, some of the key differences between these two inventories are highlighted in the text box that follows the descriptions.

Note that the success of a modeling effort will be strongly dependent on the quality of the emissions inventory available for the study area. It is for this reason that a significant emphasis will be needed to identify the quantity and quality of emissions inventory data needed for the effort, to review the existing emissions inventory data to see if it meets the identified data quality objectives, and to augment the existing inventory, if necessary. In addition to the information provided in ATRA Volume 1, Chapters 1, 4, and 7, information specific to augmenting an existing inventory for a multisource assessment is provided in Chapter 5 of this volume.

- **National Emissions Inventory (NEI).** EPA's Office of Air and Radiation compiles and maintains the NEI that includes quantitative data on emissions of HAPs as well as characteristics of the sources of these air toxics (e.g., stack heights, emission rates, etc.). It includes point, non-point, and mobile sources for all 50 states, Washington, D.C., and U.S. territories. HAP emissions data are available for 1993, 1996, 1999, and 2002. The NEI is available at http://www.epa.gov/ttn/chief/eiinformation.html. EPA plans to update the NEI every three years.

The NEI is developed by EPA's Emission Factors and Inventories Group with input from SLT agencies, industry, and a number of EPA offices. In some cases, if a SLT agency does not submit data, EPA may use data available from other sources (e.g., HAP collected by EPA as part of the development of emission standards, or data submitted by sources under the TRI program). Separate inventory documentation files have been prepared for each part of NEI (i.e., for point, nonpoint, and mobile sources).

An important fact to keep in mind about the NEI is that it includes data on HAPs from both small and large stationary sources and both on- and off-road mobile sources. Equally important, it is much more likely to include the data necessary for modeling (although many of the data fields needed for modeling are not "mandatory," and thus states and tribes are not required to provide this information to the NEI).[d] Information such as stack height, emission rate, and temperature are critical information for dispersion modeling and, thus, to developing reasonably accurate estimates of human exposure in the areas surrounding a source. It is for this reason that the NEI can be of more use than other emissions databases for developing exposure and risk estimates in a study area.

- **Toxics Release Inventory (TRI).** TRI is a publicly available EPA database that contains information about environmental releases and other waste management activities reported annually by certain covered industry groups as well as federal facilities for over 650 toxic chemicals (see http://www.epa.gov/tri/. This inventory was established under the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) and expanded by the Pollution Prevention Act of 1990. TRI reporting is required only for facilities that meet all of the following three criteria:

  - They have ten or more full-time employees or the equivalent (i.e., a total of 20,000 hours or greater; see 40 CFR 372.3);
  - They are included in specified industrial sectors; and
  - They exceed any one reporting threshold for manufacturing, processing, or otherwise using a TRI chemical.

  If a facility meets these criteria, then it must report releases to environmental media as well as waste management data. In 2003 (the latest year for which data are publicly available), on-site air emissions of toxic chemicals totaled 1.59 billion pounds (36% of all TRI chemicals disposed or otherwise released to the environment).[4]

  While the TRI data have utility for the scoping phase of an air toxics risk assessment project (they include release information on many more types of chemicals than the NEI); they have several significant limitations that assessors must understand. One important drawback is that the TRI only provides total facility annual air releases (segregated by stack releases and fugitive releases). While annual emissions are useful in evaluating chronic exposures, they may be of little use in assessing acute noncancer hazard associated with short term, peak

[d] Stack parameters and certain other release characteristics are provided in NEI for all releases. Where values for these fields were missing in the data submitted to EPA (e.g., state databases), EPA has included default values based on MACT category code, source classification code (SCC), or other data for the emission source. More information regarding EPA's inventory QA efforts and parameter default strategy for the most recent version of NEI can be found at http://www.epa.gov/ttn/chief/net/2002inventory.html.

emission levels.[e] Another drawback is that emission characteristics information is not reported to the TRI (e.g., exact location of release on the facility property, release rates, stack height, stack diameter, release temperature), making TRI of limited use as an input to dispersion modeling. Finally, it should be reiterated that TRI only covers an important, but limited, universe of emissions sources.

Summary of Key Differences Between NEI and TRI

	National Emissions Inventory	**Toxics Release Inventory**
EPA's purpose for creating database	Compile a national emissions data for use in air dispersion modeling, regional strategy development, regulation setting, air toxics risk assessment, and tracking trends in emissions over time	Inform citizens of chemical releases in their area from industrial sources
Chemicals included	HAPs and criteria pollutants, plus precursors (about 525 substances in all)	~650 TRI chemicals
Types of emissions	Point and nonpoint stationary and mobile source air emissions	Industrial facility emissions to air, water, and land (waste management information is also included)
Frequency	Updated every three years	Annually
Source of data	Submitted by state, local, and tribal agencies, industry, and EPA offices	Self-reported by industry
Quality Differences	Formal QA/QC methodology implemented by EPA: data from multiple sources blended/merged; defaults substituted for missing elements; data base reviewed internally and externally	Inventory data quality dependent on individual facility QA/QC procedures; facility reporting requirements enforced by EPA

Once appropriate emissions inventory data have been identified, they can be used during the scoping phase of the assessment to help hone in on the important sources and chemicals that will become the focus of the multisource air dispersion modeling exercise. For example, emissions can be "toxicity weighted" to provide a screening level assessment of hazard. Those chemicals that collectively pose most of the hazard (e.g., 99 percent) could be used to identify the specific emissions for the modeling exercise. Emissions can also be used as inputs to air dispersion models run in a "screening mode," the outputs of which could then be compared to screening-level "risk-based concentrations" or simply used to calculate screening-level estimates of risk and hazard. Appendix B provides an overview of some techniques to screen emissions inventory data. The *How To Manual* (see Section 3.5.1) also provides techniques for using emissions inventory data to perform a screening level assessment. (Note that caution should be used when using historic emission inventories as the emission profile for a study area may have changed significantly since the time the emissions data were collected.)

[e] Note that the NEI data for a community may also be limited regarding the variability of emissions from a given facility over the course of time. Analysts should carefully evaluate the level of detail provided in the NEI to determine whether the existing data will allow them to meet their modeling DQOs (see Chapter 5).

The Risk Screening Environmental Indicators (RSEI) Software

RSEI is a fast and effective screening tool that uses risk concepts to quickly and easily screen large amounts of TRI data, saving time and resources. RSEI users can perform, in a matter of minutes or hours, a variety of screening-level analyses to perform the complex and sophisticated analyses that are necessary to provide a risk-related perspective of TRI data. RSEI is particularly useful for examining trends to measure change, ranking and prioritizing chemicals and industry sectors for strategic planning, conducting risk-related targeting, supporting community-based projects, and investigating environmental justice issues.

How Does RSEI Work?

The model uses the reported quantities of TRI releases and transfers of chemicals to estimate the impacts associated with each type of air and water release or transfer from every TRI facility. For each exposure pathway from each chemical release, the model generates an *Indicator Element*. For instance, a release of the chemical benzene to air via a stack from the "ABC Facility" in 1999 is an indicator element. Each Indicator Element is associated with a set of results, including risk-related results, hazard-based results, and pounds-based results.

- Risk-related results — Surrogate Dose × Toxicity Weight × Population
- Hazard-based results — Pounds × Toxicity Weight
- Pounds-based results — TRI Pounds Released

Once results are calculated for each Indicator Element, they can be combined in many different ways. All of the results are additive, so a result for a specific set of variables is calculated by summing all the relevant individual Indicator Element results. This method is very flexible, allowing for countless variation in the creation of results. For example, results can be calculated for various subsets of variables (e.g., chemical, facility, exposure pathway) and compared to each other to assess the relative contribution of each subset to the total potential impact. Or, results for the same subset of variables for different years can be calculated, to assess the general trend in pounds-based, hazard-based, or risk-related impacts over time. For more information on RSEI, including limitations of the RSEI results, see: http://www.epa.gov/opptintr/rsei/.

4.2.1.3 Existing Monitoring or Modeling Data

In some communities, a certain amount of air dispersion modeling or air monitoring data may already be available. At a minimum, analysts should check with the relevant state, tribal, and local air agencies, local universities, and the following EPA websites:

- EPA AirData Website (http://www.epa.gov/air/data/); and
- Air Toxics Community Assessment and Risk Reduction Projects Database (http://yosemite.epa.gov/oar/CommunityAssessment.nsf/Welcome?OpenForm).

Usually, such data are limited (e.g., one monitor in one neighborhood collecting one class of chemical compound; one modeling study of one or a few chemicals from one facility). Such data, while useful in that they can provide a better understanding of potential exposures, will commonly be limited in their ability to fully represent exposures to the wider variety of chemicals and sources across the study area. Depending on the data, they may also be limited in their representation of spatial or temporal variation. It is for these reasons that analysts should use caution in interpreting existing monitoring and modeling data as a means of narrowing the scope of the larger assessment. Analysts should also evaluate whether conditions in the area have changed since the time the monitoring or modeling data were developed.

Procedures similar to those for screening emissions inventory data are applicable to evaluating existing monitoring or modeling data and are discussed in Appendix B.

4.2.1.4 Existing Health Studies and Health Outcome Data

In some communities, a public health agency or other researchers (e.g., university faculty) may have performed health evaluations that shed light on potential chemicals and sources of concern in the local area. For example, the Agency for Toxics Substances and Disease Registry (ATSDR) or their state health department partners routinely perform various types of ***public health assessments*** (PHAs) to evaluate relevant environmental data, health outcome data (e.g., cancer or asthma statistics), and community concerns associated with a study area where hazardous substances have been released. These studies typically attempt to identify populations living or working on or near areas for which more extensive public health actions or studies are indicated. These investigations can be conducted to confirm case reports, determine an unusual disease occurrence (e.g., a disease cluster), and explore potential risk factors such as exposures to air toxics. This type of data can be highly informative and useful to partnership teams working to identify chemicals and sources to include in the multisource assessment. Information about ATSDR's PHA process and the investigations that have been performed to date can be obtained on the ATSDR website (www.atsdr.cdc.gov). Analysts should also check with state, tribal, and local health departments, local health care providers (e.g., hospitals), and university researchers.

Biological Monitoring and Biomarkers

Public health studies can involve the use of *biological monitoring* in which samples (e.g., hair, tissue, blood) from individuals are analyzed for signs of toxic substances. The results of such tests are sometimes referred to as *biomarkers*. A biomarker is a biological index that is associated with or indicative of an endpoint of interest, such as an exposure level or effect. For example, mercury levels in blood or hair samples can be used as indicators of past exposure to mercury. Biological monitoring and biomarkers can be useful in some cases to help determine the extent and types of exposures and effects that may occur in a population.

[Note that readily available health outcome data may provide initial clues regarding an exposure of potential public health concern, but may ultimately prove to be of limited value unless a more in-depth follow-up epidemiological evaluation can be performed. For example, if an evaluation of summary-level state cancer registry statistics for a study area indicates an elevated rate of disease, a next step could be to evaluate the exposure histories of the patients involved (e.g., to see if they have lived in the exposure area for a period of time sufficient to reasonably suspect a potential causal relationship). Issues such as confidentiality concerns, access to medical records, and access to epidemiological and medical expertise could play a role in whether and how a stakeholder group would be able to perform such a follow-up evaluation. That having been said, analysts are encouraged carefully consider the type of conclusions that can legitimately be drawn from available health statistics. It is advisable, when evaluating such data, to engage appropriate experts who have a working knowledge of both the data and how to evaluate them (e.g., epidemiologists, public health scientists, and those in the medical profession).]

4.2.1.5 Information Provided by the Community

The people who live in the community are often one of the best sources of information about potential air toxics issues in the area and stakeholder groups may wish hold informational meetings or use other techniques to solicit concerns and information from citizens and other local stakeholders. For example, the planning and scoping team may wish to perform a survey of local citizens' concerns (see Section 12.3.1.3).

4.2.1.6 Demographic and Land Use Data

The U.S. Census Bureau (http://www.census.gov) is the main source of information on demographics in the United States. The Bureau also provides a range of economic information. For example, the Census Bureau can provide information on the numbers of people living within specified geographic areas (e.g., a census tract, a census block) along with information about their age, race, sex, and income levels (important information when evaluating exposure and impact at the local level).

In addition to demographics, the type of land use across the study area is another important consideration. For example, partnership teams may only be interested in exposures that occur within residential areas or they may be interested in exposures occurring over other types of land use as well. Land use cover data is available from a variety of sources including the U.S. Geological Service National Land Cover Database (http://landcover.usgs.gov/natllandcover.asp).

Other points of interest in the local study area can include locations where the young, the elderly, and people with special health concerns spend a large part of their day, such as schools, rest homes, and hospitals. Local government agencies are a good source of this information. EPA's Environmental Justice (EJ) Graphic Assessment Tool (http://www.epa.gov/enviro/ej/) can also be used to map EPA environmental data in relation to available demographic data (e.g., population density, percent minority population).

4.2.1.7 Compliance and Enforcement Data

Compliance and enforcement is an integral part of environmental protection. For example, EPA achieves cleaner air, purer water and better-protected land by working with companies to ensure compliance with environmental laws. Enforcement is also a vital part of encouraging governments, companies and others who are regulated to meet their environmental obligations.

EPA's Compliance and Enforcement Gateway

EPA's Office of Compliance and Enforcement Multimedia Data Systems and Tools website (http://www.epa.gov/compliance/data/systems/index.html) can be used as a gateway to access a wide array of national data systems related to compliance and enforcement, including systems related to air quality, hazardous waste, pesticides and toxics, and water quality.

As part of the stakeholder group's activities to gather and evaluate existing information about the community, members will commonly obtain and review information on the compliance status of local industry which have Clean Air Act (and other relevant statutory) requirements related to air toxics. One way to do this is by coordinating with the air permitting authority for the local area (usually a state, tribal, or local air agency). They are a good place to start for relevant information on allowable air releases as well as compliance and enforcement records. (For further information regarding the air permitting program, visit EPA's air permits page at http://www.epa.gov/oar/oaqps/permits/).

Another way to obtain compliance and enforcement information is through EPA's Air Facility System (AFS; http://www.epa.gov/oeca/data/systems/air/afssystem.html), which contains compliance and permit data for regulated stationary sources. States use AFS information to track the compliance status of point sources with various regulatory programs under the Clean Air Act. [AFS was once a part of Aerometric Information Retrieval System (AIRS), hence the historical utilization of that term may be incorporated within referenced documentation.]

AFS data is also visible in EPA's Enforcement and Compliance History Online (ECHO) Web site (http://www.epa.gov/echo/index.html). This tool provides the public with compliance, permit and demographic data from approximately 800,000 facilities regulated under the Clean Air Act stationary source program and other statutes. ECHO's integrated reports present inspections, violations, enforcement actions, penalties and locate facilities on demographic maps. EPA's Envirofacts Data Warehouse (http://www.epa.gov/enviro/) also contains the AFS data.

4.2.2 Identify Team Members' Concerns and Interests

Members of the stakeholder group will all share the goal of understanding and improving local air quality. Nevertheless, members will initially have different perceptions of this goal and how to achieve it. In addition, members may have personal objectives not directly related to air quality that they are hoping or assuming will be included in the scope of the assessment. Adequate time must be spent at the beginning of the process to discuss and understand the expectations of all the participants in order to discover and clarify the goals that can be accepted by all. Clarifying goals will help enable the partnership to develop an analysis plan that ensures that the results of the assessment will meet the established goals. Clarifying goals also will help set realistic expectations for the results of the assessment. For example, air quality is likely to be only one of the factors affecting community health and efforts to improve air quality, by themselves, may not meet a community member's goal of achieving measurable improvements in overall community health. (A fuller discussion of addressing non-air community environmental issues is provided in Part IV of this resource document.) Exhibit 4-5 identifies several potential goals of a community-scale air quality assessment.

Exhibit 4-5. Example Goals for A Community-scale Assessment
• **Estimate emissions (e.g., through development of an inventory)** of all significant sources of pollutants in community air with information about type and quantity of chemicals emitted to the air in the study area. • **Estimate concentrations** of chemicals in community air that result from all the sources in and around the community. • **Develop estimates of aggregate exposures** from all sources in the community. • **Calculate estimates of cumulative risk** by combining estimates of exposures with toxicological dose-response data that represents the carcinogenic and noncarcinogenic toxicological properties of the chemicals in question. • **Compare estimates of risk** to preestablished risk management goals. • **Establish clear priorities** for focusing community efforts on the chemicals and sources that present the greatest risk to the community. • **Develop a baseline** and the ability to measure progress in improving air quality. • **Increase community capacity** to understand and address air issues in the long-term that results from the knowledge, understanding, and trust gained in completing the process. • **Promote agreement** within the community on air issues based on the improved understanding provided by the assessment. • **Compare community air quality** to air quality in other reference communities where air concentrations have been measured or estimated (i.e., communities that are similar with regard to meteorology, land use, topography, and source mix).

4.2.3 Preparing for Different Outcomes of the Analysis

It will be important for the members of the stakeholder group to discuss all the possible outcomes of the assessment and what each outcome would mean to each of the members. What if small businesses, large businesses, households, or mobile sources were identified as the priority concerns? What would it mean if *my* business, *my* home, or *my* car were identified as a risk reduction priority? Some members of the partnership may also enter the process with a conviction about which sources will need to be targeted to improve air quality while other members may have different sources in mind. It is unlikely that the initial expectations of all the members can be met by any analysis. A discussion of all the different possible outcomes will allow participants to consider carefully what the project results might mean for them. In the end, discussions of this sort will help facilitate development of a consensus on at least some common goals and also introduce the concept that an unbiased assessment may reveal unexpected concerns.

4.2.4 Setting Realistic Expectations

It is important to discuss what the partnership will be able to do to improve air quality both during the analysis and when it is completed and priorities have been identified. Critical questions include:

- What resources will be available to make changes?
- What issues can be addressed by the community, and which are likely to require broader action (e.g., such as regulations that go beyond those currently required)?
- What issues are already being addressed by existing (or upcoming) regulations?

- What could be done early on if exploratory data analysis identifies an unambiguous concern from a specific large business, small business, mobile source, etc.?
- In what circumstances would enforcement authorities be used to improve air quality? What kind of information will be required to support this approach?
- In what circumstances would voluntary actions be used to improve air quality? What resources does the partnership have to implement these actions? What information will be required to support this approach?

This is also a good time to begin discussing any short-term actions that will be accomplished while the assessment is taking place. If there are obvious actions that do not depend on the outcome of the assessment, a discussion of those actions is also appropriate at this point (see next section).

4.2.5 Identify and Implement Short- and Long-Term Goals

Some members of the community will be more interested in action than in studying local air quality, and some problems may be so obvious that action can reasonably be taken without extensive study. The partnership should consider identifying areas where there is already sufficient agreement to begin immediate work to improve air quality. This will benefit everyone since the community will see real change in their environmental quality over the short-term while the long-term study proceeds. Examples of projects that might be started early on include working with the community to address indoor air problems by addressing known risk factors (e.g., second hand smoke); developing community plans for transportation sources (e.g., car-pooling bulletin boards, broader dissemination of mass transit information, diesel retrofits for school and/or city buses, anti-idling options); or working to provide pollution prevention assistance to local businesses. Specific examples and helpful web sites that provide information on a wide variety of indoor and outdoor air emissions and risk reduction actions are provided in Chapter 8 of this resource document.

The partnership may also wish to begin developing the long-term goals and capacity of the community to address air quality issues beyond the end of the assessment. Specific issues that might be addressed include:

- Mechanisms for retaining the knowledge and skills learned during the assessment;
- Mechanisms for responding to known risk factors currently in the community, but which will take a long-term effort to address (including funding for risk mitigation efforts);
- Mechanisms for responding to future new impacts on air quality;
- Maintaining long-term interest and momentum at the community level; and
- Mechanisms for working with other communities to build a larger resource pool for addressing air quality and community health concerns.

A discussion of sustaining efforts over time is provided in Section 12.5.

4.2.6 Integrate Air Quality Goals to Other Community Priorities

As noted previously, an understanding and improving air quality will not be the only community priority. Most communities will also be concerned about additional issues, such as education, jobs, crime, and access to quality healthcare. It will be important to identify these other community priorities to ensure that the air quality efforts can both support and complement these issues. For example, the assessment team could strive to organize work to avoid unnecessary conflicts, duplication of effort, and opposition by community members with other priorities. The ability to integrate work on air quality into the other community priorities may be essential to finding the resources that will be needed to address air quality issues. Part IV of this resource document provides information on other environmental factors that may be of concern to communities, along with basic information on how to assess and mitigate those risks.

4.3 What Will Be the Scope of the Multisource Assessment?

Once existing data for the study area have been gathered and evaluated and the concerns and needs of the partnership team considered, the team can set the initial scope of the assessment. The scope of the overall multisource assessment will follow directly from the concerns and goals identified by the partnership team and the resources available for the study. It may be narrow or broad, depending on the depth and breadth of specific goals. For example, an overall goal such as “reducing air toxics emissions from all the sources in the community” may require an extensive information gathering effort that examines many types of sources (e.g., stationary, mobile) and dozens or even hundreds of air toxics and following emissions changes over time. On the other hand, a goal such as “reducing the estimated cumulative cancer risk and hazard in the community” might entail development of an emissions inventory followed by air dispersion and exposure modeling to estimate exposure concentrations, identifying toxicity values, development of quantitative risk estimates, apportionment of risk to specific chemicals and emission sources, development and implementation of one or more risk reduction strategies, and periodic analysis to ascertain whether risks posed by these chemicals have actually been reduced over time.

The scoping process also helps to align the assessment design with the most important concerns and goals of the partnership team. For example, overly broad goals may require an assessment with a scope which is either difficult or impossible to achieve with available resources. Several iterations of goal setting may be required before the scope is fully aligned with the goals and the available resources; further iteration may be necessary once work begins and circumstances and information change.

As discussed in ATRA Volume 1, Chapter 5, critical aspects of establishing the assessment scope include:

- **Specific sources to be included**. A community-scale, multisource assessment may need to consider hundreds or even thousands of individual sources. The sources to be evaluated will usually include all of the major, area, and mobile source emissions in the study area. An evaluation of the existing inventory for the study area (i.e., the NEI or a more refined local inventory) is a critical first step in identifying the sources that will be carried forward to the air dispersion modeling step. If the existing inventory is found to be lacking, further steps in developing the community’s emissions inventory will be needed (see Chapter 5). [Note that some level of additional screening may have been performed to reduce the number of sources carried forward in the assessment (see the *How To Manual*, Chapter 5 of this Volume, and Appendix B).]

How Do I Evaluate Indoor Versus Outdoor Air Toxics Concentrations?

In a multisource cumulative assessment of the type described in this resource document, the focus of the evaluation is usually on the risk posed by exposures to chemicals *released to or created in outdoor air*. However, most people spend the majority of their time "indoors" (e.g., in office buildings, at home, in cars, in planes, etc.) where the concentrations of the chemicals in question may be different (either higher or lower). How do (or don't) some common exposure assessment approaches deal with this issue?

The Continuous Lifetime Exposure Approach to Outdoor Air Concentrations

In this approach, the analyst will make the (usually) conservative assumption that an exposed group of people spend all of their time (24 hours a day, seven days a week for a lifetime) standing in one outdoor location and breathing only outside air (i.e., they never go into an indoor environment of any type). This approach (which is referred to by some as the "porch potato" scenario) will usually (but not always) lead to estimates of exposure and risk to outdoor air pollution that are biased high. This approach is performed by simply using the results of the air dispersion modeling at given spatial locations (or, in some cases, ambient monitoring results) as a surrogate for chronic exposure (i.e., no exposure modeling has been performed – see below). The benefit of this approach is that it is relatively straightforward to perform and does not require the application of an exposure model. If the maximum concentration in an exposure area (the highest modeled or measured value) is used as a surrogate for exposure, the result could potentially be considered a high end (or bounding) estimate of risk for the entire exposed population. Because of its generally conservative nature, the continuous lifetime exposure approach is considered a "screening level" approach to exposure assessment.

> **Note:** A limited number of chemicals released to outdoor air may be more concentrated in an indoor space than is reflected by available outdoor air dispersion model or monitoring results. For example, benzene concentrations in the passenger compartments of vehicles traveling on highways will commonly exhibit higher concentrations than a nearby local air monitor might suggest (due to many cars emitting benzene in close proximity to one another).

The Microenvironment Approach

People do not really stand in one place for their entire lives breathing the same thing. Instead, most people move around quite a bit during the course of the day and spend a significant amount of time in different types of "microenvironments." For example, they will spend part of the day at home, part of the day at work or school, part of the day engaged in recreational activities or going shopping, etc. In addition, the concentration of a toxic air pollutant in outdoor air will usually decrease with distance from its emission source and may also be reduced as it moves into an indoor environment (an example of this is the physical filtering out of air toxics-bound particulate matter at the outdoor air intake on a building). The difference between outdoor air and indoor air concentrations of a toxic air pollutant (in the absence of indoor sources) is reflected by a penetration factor. [A penetration factor of one (1) indicates that concentrations inside and outside are equal; a value less than one (1) indicates lower concentrations in indoor spaces relative to outdoor air.]

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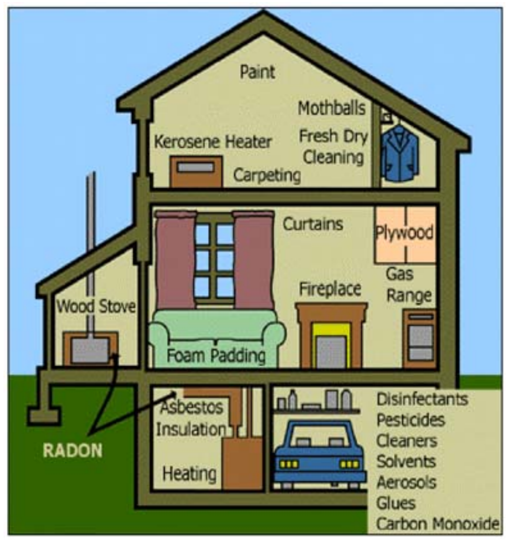
How do I Evaluate Indoor versus Outdoor Air Toxics Concentrations? (Continued)

Exposure models try to take these issues into account by both capturing the way in which different kinds of people move around within a geographic area, including how they move into and out of different microenvironments over the course of time, and by predicting (e.g., through the application of penetration factors) the concentrations of outdoor air pollutants within each of those microenvironments. This type of approach is used when a more complete estimate of potential exposures and risk is needed (e.g., when a screening level analysis points to need for a more robust assessment of risk). The microenvironment approach is also useful for deriving estimates of the distribution of risks across a population, based upon statistical distributions of activity patterns across a population and microenvironment partitioning factors across multiple microenvironmental types. The microenvironment approach to exposure assessment, along with a description of commonly used exposure models is discussed in ATRA Volume 1, Chapter 11.

What About Indoor Sources?

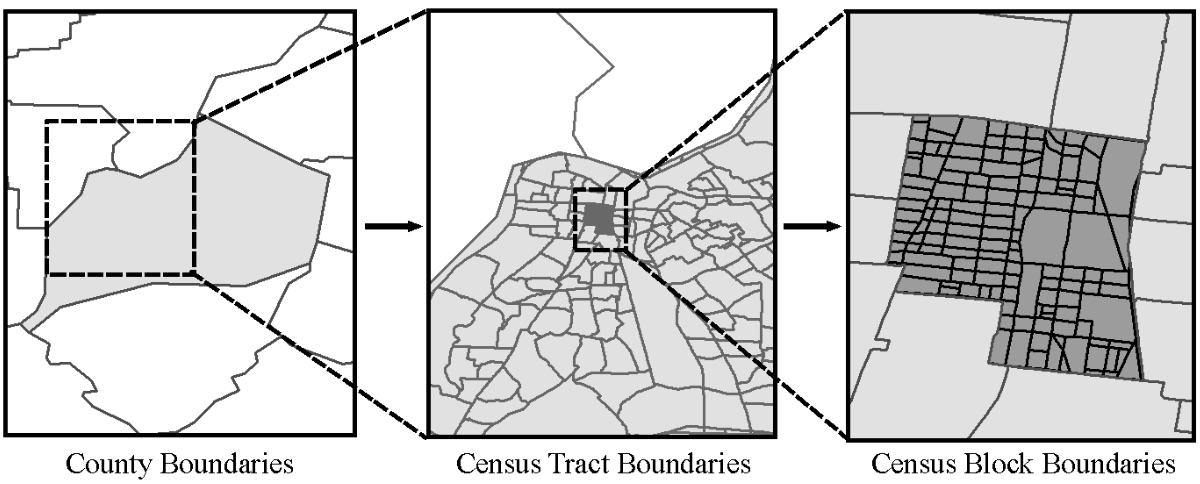
In addition to outdoor air moving into indoor spaces, there are many types of indoor sources of air toxics that can greatly contribute to the overall concentration of chemicals in indoor microenvironments. Unfortunately, there is currently no established methodology for routinely including these additional source contributions within the framework of a standard community-level multisource assessment. However, the most commonly used exposure models (e.g., HAPEM, TRIM.Expo/APEX) have the capability for simulating indoor sources of exposure, and analysts are encouraged to consider developing and evaluating inputs for inclusion of indoor sources, when appropriate to the assessment. If indoor source inputs are not included in the simulation, the potential impact of having omitted indoor sources should be included as a discussion in the uncertainty section of the risk characterization.



- **Specific air toxics to be included**. Once the sources of air releases have been identified, the specific chemicals they release are then determined. Of all the chemicals released by the study area sources, the only ones that are generally carried forward are those that (1) have sufficient emission characterization data to perform the air dispersion modeling, and (2) have toxicity data to perform the risk characterization. For some chemicals, all of these elements may not be available. If appropriate surrogate data for the missing elements are not available, these chemicals may be dropped from the quantitative portion of the analysis. The impact of not quantifying these chemicals would have to be discussed in the uncertainty write up for the evaluation. In some cases, a decision may be made to carry forward chemicals for which quantitative information is not readily available. For example, a planning team may be interested in evaluating a chemical for which a dispersion modeling analysis can be performed, but for which toxicity values are not available (for information on dealing with chemicals with no toxicity data, see ATRA Volume 1, Chapter 12). [Note that some level of additional screening may have been performed to reduce the number of chemicals carried forward in the assessment (see the *How To Manual*, and Chapter 5 and Appendix B of this Volume).]

- **Physical boundaries of the study area**. The physical boundary of the study area is commonly the land area that is made up of the human populations of interest and the sources potentially impacting them. For example, the partnership team may choose to set the physical boundaries at city limits or at a county boundary. In contrast, the partnership team may also choose to focus on just a specific neighborhood. Both the needs and desires of the partnership team as well as data and analytical limitations (e.g., available emissions data, limitations of analytical tools, data storage and file size challenges) will influence the decision. Exhibit 4-6 shows examples of several geographic boundary cutoffs for study areas at progressively higher levels of resolution.

Exhibit 4-6. Example Options for Establishing Physical Boundaries for the Assessment



Also related to establishing the physical boundaries of the study area is the consideration of how sources outside the boundary should be treated. For example, should the assessment include distant large point sources that are releasing chemicals subject to long-range transport? (In general, sources outside the study area that will likely impact the study area significantly should be included in the analysis.)

Finally, the partnership team must decide whether they will subdivide a large study area into subareas to facilitate the presentation and communication of results (e.g, will a county level assessment be presented at the neighborhood level, at the census tract level, etc.). When choosing subdivisions, the partnership team will need to consider the locations of exposed populations, the presence of special receptors such as high proportions of children or the elderly, and other groups of interest such as EJ areas. (Subdivisions of the study area are usually set at the census tract or census block level to allow the assessment to match available demographic data from the Census Bureau.) Examples of ways to represent exposures and risk are discussed in the following chapters and analysts should understand these different approaches in order to provide the most useful information to the risk assessment customers. Additional background information on displaying risk is provided in ATRA Volume 1, Chapter 13.

- **Temporal Issues**. Temporal considerations fall into several general categories, including the amount of time available to perform the assessment, the specific exposure timeframes to be evaluated (e.g., chronic and/or acute exposures), and timing considerations inherent in the emissions inventories.

  – ***Time to Perform the Assessment.*** Time and money are always limited; therefore, the planning and scoping process will almost certainly involve trade-offs between the amount and quality of information the partnership team desires and the time and resources available to obtain and analyze the information. The time to plan and perform a full multisource assessment can range from as little as a few months (when the assessment is performed by a small group of seasonal technical experts that have easy access to complete, high quality data) to as long as several years. The amount of time to perform the work will depend on the scope of the analysis, the available data, the expertise of the analysts, the access to resources, and the need to involve stakeholders. In particular, the need to refine (or develop) an emissions inventory of sufficient quality and/or perform ancillary monitoring efforts can substantially increase the amount of time needed to perform an assessment.

    Clear objectives, resource commitments, and estimated schedules from project management will drive the approach and level of detail that can be considered. Once timing and resource considerations have been identified, assessment teams should establish critical milestones and institute a clear, yet reasonably flexible, schedule to keep the assessment on track. (Resources may also determine whether the work is to be performed in-house by the assessment team or by a contractor or other external source, such as a local university).

    It should be noted that the need to coordinate with the schedules of other organizations may become an important factor in defining the scope of the project. Assessments that require short-term, low-budget efforts may not have the time or resources for extensive stakeholder involvement. When there is extensive stakeholder involvement, on the other hand, it is especially important that a budget and time schedule be developed and understood by all participants.

  – ***Exposure Timeframes.*** At a minimum, most assessments will evaluate chronic exposures. Since most emissions inventories provide (or allow the calculation of) annual emissions, analysts can usually perform this part of the analysis in a straightforward fashion. However, many assessments will also need to include an evaluation of acute exposures. Depending on the DQOs of the assessment, analysts may need to augment the existing emission inventory to provide additional details of the day to day variability in source emissions to allow a high quality acute assessment to be performed. In other words, if the emissions inventory only provides a single yearly amount of chemical released, an evaluation of shorter period high concentration spikes in releases is not possible. The team will have to either refine the emissions inventory to develop information on release variability or make simplifying assumptions using the existing data. (The NEI provides some emission data for non-annual time frames; in addition, the next version of NEI will have a new field indicating whether emissions are upset in nature.)

  – ***Emission Inventory Timing.*** Most emissions inventories are historical in nature. While the multisource assessment will commonly rely on the most recent emission inventory year available, it important to keep in mind that the inventory may not be completely reflective of current conditions. For example, in 2005, the most recent available NEI is for the year 2002. Thus, if contemporaneous emissions estimates are required for the assessment, data augmentation of the existing inventory will be needed. In some cases, state, tribal, and local agencies compile emission inventories on a more recent basis (e.g., annually), so a team may want to contact these agencies for data not reflected in the current version of NEI. At a minimum, the analysts should perform some level of exploratory analysis to determine if current emissions are expected to vary significantly from those represented in the available emissions inventory.

- **Potential exposure pathways**. The human health multisource assessments discussed in this chapter include only the inhalation exposure pathway. Furthermore, such assessments are usually limited to exposures to outdoor air sources (i.e., exposure to chemicals that have been emitted directly to outdoor air); however, if there is information on indoor sources, this can be factored in as well. In some cases it may be necessary to consider exposures via additional pathways (e.g., deposition of air emissions of dioxin which ultimately results in ingestion of dioxin-contaminated food). A detailed discussion of how to develop *multipathway analyses* for multiple sources at the community level is discussed in Part III of this Volume and in ATRA Volume 1, Part III. (Part III also discusses approaches to evaluating multisource assessments for ecological receptors.)

- **Potentially exposed populations**. The potentially exposed populations that will be the focus of the study are likely to parallel the way in which the physical boundaries of the study area are subdivided for analysis (e.g., at the census tract or census block level). If there are certain populations (e.g., children, elderly) of a particular concern, the analysis may also need to identify specific locations (e.g., schools, playgrounds, nursing homes) where these people spend large amounts of time.

- **Types of health risks to be evaluated**. The risk characterization for the assessment may include predictive estimates of cancer risk as well as chronic hazard and acute noncancer hazard for the study population(s). In the case of cancer risk, the estimates are most often provided in terms of an incremental excess probability of an individual developing cancer over a lifetime. The chronic and acute hazard estimates compare exposures to reference levels believed to have no adverse health effects over a chronic or acute exposure period, respectively. Acute hazard estimates are developed for effects other than cancer; this is usually also the case for chronic hazard estimates, but there may be instances in which a chronic hazard estimate includes cancer as a potential hazard.

Once all these issues have been evaluated, the scoping process will have produced a clear understanding of what the multisource assessment will include, what it will not include, and why. This process may require several iterations and some initial screening-level analyses to identify the final scope for the community-scale assessment. Once the analysis begins, more screening may be performed or new information brought to light that will result in a modification of the initial scope (see the *How To Manual*, and Chapter 5 and Appendix B of this volume for examples of screening level approaches).

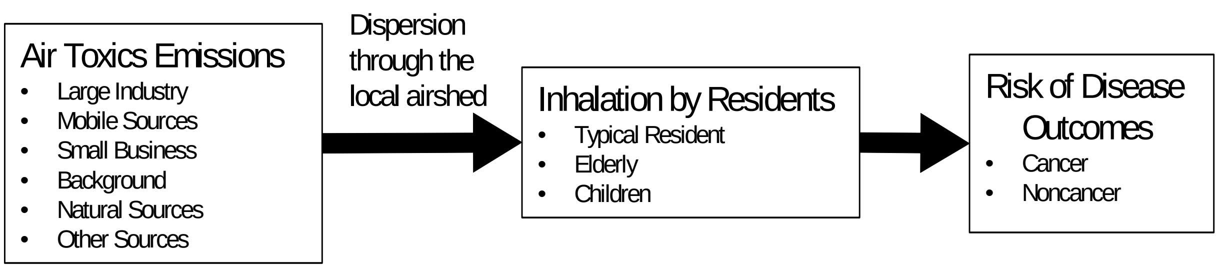
4.3.1 Problem Statement

A problem statement summarizes the end result of the planning and scoping process by describing the specific concerns that the risk assessment will address. The problem statement should be as specific as possible and may include explicit statements of how the analysis will be performed and what will not be assessed in the risk assessment. In short, this is a clear and unambiguous statement designed to communicate to all stakeholders what the perceived problem is that will be evaluated, how it will be evaluated, and what issues will not be evaluated. An example problem statement is provided below.

Example Problem Statement and Overall Study Plan

Problem Statement

The exposure to HAP air emissions from major sources, area sources, and mobile sources (both on- and off-road) in a county may be causing unacceptable long-term inhalation health risks to people in this county.



Study Plan - Key Components:

- A cumulative risk assessment based on air dispersion modeling, augmented with exposure modeling, will be performed to evaluate potential chronic and acute human health impacts of inhalation exposures to all HAPs emitted by all known sources in the county.
- Inhalation risks will be assessed for residential-type exposures and sensitive receptors (e.g., hospitals, schools, and nursing homes).
- Limited air dispersion monitoring will be performed to evaluate the modeling results, look for gaps in the emissions inventory, and help to evaluate potential hotspots.

What this Analysis Will Not Evaluate:

- Non-inhalation pathways will not be assessed.
- Risks to ecological receptors will not be assessed.
- Long-range transport from outside the county will not be considered.

4.4 Problem Formulation

During the planning and scoping steps described above, the partnership team will have provided answers to several key questions such as:

- What are the goals of the assessment?
- What are the specific questions the assessment will try to answer?
- What is the scope of the analysis?

They will have also written a summary statement of what they think the problem is and how (generally) they are going to study it. As they are performing these tasks, they will also need to further formulate the problem by building a formal **conceptual model** that explicitly identifies and describes all the sources, chemicals, receptors, exposure pathways, and potential health impacts that will be the focus of the assessment. (In the example problem statement provided in the previous text box, a simplified conceptual model was drawn to illustrate the general concept of the potential air toxics problem. The formal conceptual model expands on this generalized version by providing the details of each element contained within the model - see Section 4.4.1).

The last step in the process (after development of the formal conceptual model) is the development of an **analysis plan** that outlines the specific analytical approaches that will be used to actually perform the assessment. Another important part of problem formulation is developing study-specific DQOs to guide data collection and analysis. Each of these is discussed in a separate subsection below.

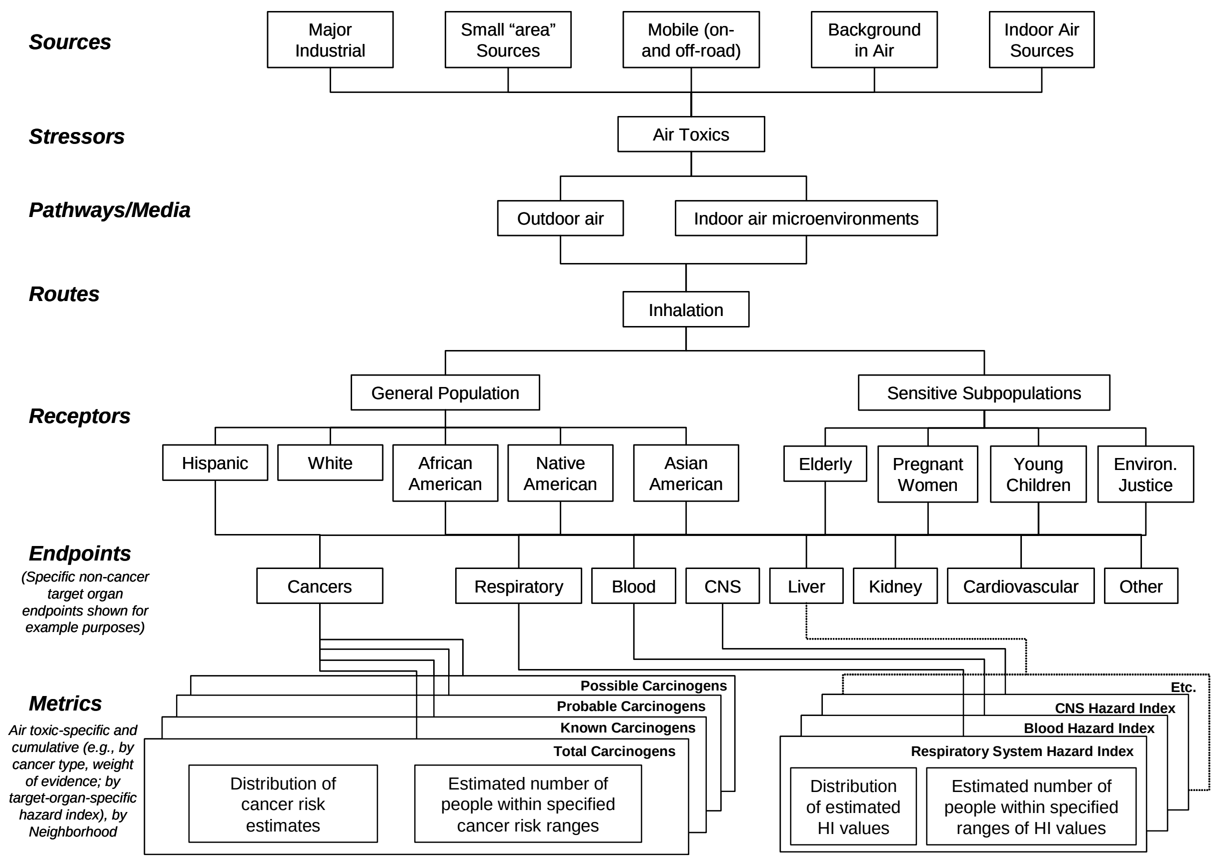
4.4.1 Developing a Multisource Conceptual Model

The study-specific conceptual model explicitly identifies the sources, chemicals, receptors, exposure pathways, and potential adverse human health effects of interest, their interrelationship, and specifies those aspects that the multisource community-scale assessment is going to evaluate. The conceptual model also describes the physical boundaries of the assessment area.

The conceptual model usually is illustrated using a picture (e.g., a flow diagram) of each model and is augmented with a written description of the actual names/locations of sources, the chemicals they release, the populations of concern and their location, the pathways by which the chemicals move from the point of release to the point of exposure (including the routes of exposures), and the specific potential health impacts of concern. The conceptual model is not static and the assessment team may revise or refine the conceptual model during the course of the risk assessment as they learn more about the study area. Exhibit 4-7 provides an example of a generalized conceptual model for multisource community-scale inhalation assessments.

The conceptual model may also include elements other than releases to air that may contribute to health impacts (e.g., waste sites, drinking water), even if these are not going to be quantitatively evaluated in the overall community-scale assessment. Including such other sources reminds all involved that air toxics likely represent only part of the overall health problem within the community (and may serve as a "placeholder" to guide future analyses).

Exhibit 4-7. Example Conceptual Model for a Multisource Community-based Inhalation Air Toxics Risk Assessment



This figure illustrates an example of a conceptual model for air toxics risk assessments. The conceptual model for a specific risk assessment will likely include only part of this model.

4.4.2 The Analysis Plan

After developing a formal conceptual model, the risk assessment team will then develop an analysis plan that details the link between each element of the conceptual model and the specific analytical approach that will be undertaken to evaluate the element (see ATRA Volume 1, Chapter 6). The analysis plan describes each of the analytical approaches (e.g., emissions characterization, risk calculations, etc.) in sufficient detail to assure that data of sufficient quantity and quality are developed to support the risk management decision. (The DQO process establishes what constitutes "data of sufficient quantity and quality." A general discussion of systematic planning, including the data quality objectives process, is discussed in ATRA Volume 1, Chapter 6, and in the chapters that follow).

The analysis plan is most helpful when it contains explicit statements of how the assessment team selected the various analytical approaches, what piece of the conceptual model they intended the approach to evaluate, how the approach integrates with other analytical elements, and specific milestones for completing the task. The analysis plan should include all methods, approaches, and assumptions that will be employed and, when possible, a discussion of known uncertainties associated with the analytical approach and methods for addressing these uncertainties.

The analysis plan may not result in just one document, but rather a combination of multiple work plans that, taken together, constitute "the analysis plan." For example, in a study where the assessment team will perform air dispersion modeling as part of the exposure assessment and air monitoring to assess the model results, the assessment team will develop separate work plans for the modeling and monitoring efforts. When multiple work plans are generated, it will be helpful to develop a master analysis plan that describes all the different analytical pieces and their relationship to one other. Exhibit 4-8 provides an example of the various pieces of a sample analysis plan for a community-level, multisource assessment.

Exhibit 4-8. Example Analysis Plan for a Multisource Community-scale Inhalation Air Toxics Assessment

A full scale multisource inhalation air toxics risk assessment will generally require a number of different analytical activities to happen (many of them simultaneously) by people with different expertise. Each of these major analytical steps will usually have its own workplan. However, a **master analysis plan** should be developed that describes the overall analytical framework and the relationship of all the analytical pieces to one another. This master plan should also show the linkages of the analysis plan to the conceptual model. Some of the most common workplans that will be developed as part of the overall analytical framework include the following:

- **Risk Assessment Workplan.** This workplan describes the overall process that will be used to perform the exposure assessment, toxicity assessment, and risk characterization. (If modeling and monitoring are performed as part of the exposure assessment, they will generally have their own workplans that interface with the risk assessment workplan – see below.) In particular, the risk assessment workplan will lay out any assumptions or surrogates that will be employed, the procedures that will be used to gather data about the study area population (e.g., demographic and location data), how any exposure modeling will be performed, how toxicity data will be identified, and the procedures that will be used (including equations) to calculate risk. The workplan will also discuss the DQO's for each step, the QA/QC procedures needed to ensure high quality work and products, how the efforts described by the workplan interface with other work efforts such as air dispersion modeling and monitoring studies, documentation requirements, schedules, and roles and responsibilities.

- **Air Dispersion Modeling Workplan.** This workplan describes the process by which the emissions inventory will be assessed and, if necessary, augmented for input into the air dispersion modeling. (A separate **Emissions Inventory Development Workplan** may also be developed and cited by the dispersion modeling workplan.) The model selection process will be described as well as the details of how the modeling will be performed. The workplan will also discuss the DQO's for the modeling effort, the QA/QC procedures needed to ensure high quality work and products, documentation requirements, schedules, roles and responsibilities, and how the efforts described by the workplan will interface with other work efforts such as monitoring studies.

- **Air Monitoring Workplan.** This workplan describes the process by which air monitoring data will be developed. The plan will usually discuss how the results will be used to assess the air dispersion modeling results, look for gaps in the emissions inventory, and evaluate hot spots. The workplan will also discuss the DQO's for the monitoring effort, the QA/QC procedures needed to ensure high quality work and products (including data validation), how the efforts described by the workplan will interface with other work efforts such as air dispersion modeling studies, and documentation requirements, schedules, and roles and responsibilities.

Additional References for Getting Started and Planning the Analysis

Community-Based Environmental Protection: A Resource Book for Protecting Ecosystems and Communities (http://www.epa.gov/ecocommunity/tools/resourcebook.htm)

Air Toxics Community Assessment and Risk Reduction Projects Database (http://yosemite.epa.gov/oar/CommunityAssessment.nsf/Welcome?OpenForm)

Risk Assessment Protocols for Hazardous Waste Combustion Facilities (http://www.epa.gov/epaoswer/hazwaste/combust.htm#risk)

Key Sources of Information on Pollution-related Risks Faced by Communities

General Information Gateways

- EPA's Envirofacts Information Gateway (http://www.epa.gov/enviro/)
- EPA's EnviroMapper Information Gateway (http://www.epa.gov/enviro/html/em/index.html)
- EPA's Toxic Release Inventory Information Gateway (http://www.epa.gov/tri/)

Outdoor Air Pollution

- EPA's Office of Air and Radiation Air Pollution Information Gateway (http://www.epa.gov/ebtpages/air.html)
- EPA's Criteria Pollutants Gateway (http://www.epa.gov/air/urbanair/6poll.html)
- EPA's Hazardous Air Pollutants Gateway (http://www.epa.gov/ebtpages/airairpohazardousairpollutantshaps.html)
- EPA's National Air Toxics Assessment (http://www.epa.gov/ttn/atw/natamain/)
- EPA's Trends in Air Pollution (http://www.epa.gov/airtrends/index.html)
- EPA's Technology Transfer Network Air Toxics Website (http://www.epa.gov/ttn/atw/)
- EPA's Pollutants and Sources (http://www.epa.gov/ttn/atw/pollsour.html)
- EPA's Notebook on Local Urban Air Toxics Assessment and Reduction Strategies (http://www.epa.gov/ttn/atw/wks/notebook.html)
- EPA's Clearing House for Inventories and Emission Factors (CHIEF) (http://www.epa.gov/ttn/chief/index.html)
- EPA's AirNow Website (http://cfpub.epa.gov/airnow/index.cfm?action=airnow.main)
- EPA's AirData Website (http://www.epa.gov/air/data/index.html)

Indoor Air Pollution

- EPA's Office of Air and Radiation Indoor Air Pollution Information Gateway (http://www.epa.gov/ebtpages/airindoorairpollution.html)

Mobile Source-related Air Pollution

- EPA's Mobile Source Pollutants Gateway (http://www.epa.gov/ebtpages/airmobilesources.html)

References

1. U.S. Environmental Protection Agency. 2004. *Community Air Screening How-To Manual, A Step-by-Step Guide to Using Risk-Based Screening to Identify Priorities for Improving Outdoor Air Quality*. EPA-744/B-04-001. Available at: http://www.epa.gov/ttn/fera/risk_atra_main.html

2. U.S. Environmental Protection Agency. 2001. *Risk Assessment Guidance for Superfund (RAGS): Volume I - Human Health Evaluation Manual (Part D, Standardized Planning, Reporting and Review of Superfund Risk Assessments) Final*. Office of Emergency and Remedial Response.
   Available at: http://www.epa.gov/oswer/riskassessment/ragsd/index.htm.

3. National Research Council (NRC). 1983. *Risk Assessment in the Federal Government: Managing the Process* (The "Red Book"). National Academy Press, Washington, D.C.

4. U.S. Environmental Protection Agency. 2005. *Toxics Release Inventory (TRI) Program.* Figures generated using TRI Explorer on TRI website, available at http://www.epa.gov/tri/; figures represent values for 2003 (latest year publicly available).

Chapter 5 Analysis for a Multisource Assessment

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5.0 Introduction

At the end of the planning and scoping process described in Chapter 4, the key stakeholders will have: (1) agreed to the scope of the assessment, (2) signed off on both the conceptual model for the study area and the analytical plan, and (3) created a problem statement that clearly articulates the perceived problem, how it will be studied, and what will not be studied. This chapter discusses the details of the next step in the overall process – the analysis phase (see Exhibit 5-1). Chapter 6 describes how to use the information developed during the analysis phase to create quantitative and qualitative expressions of risk.

As mentioned in Chapter 4, the methodology described in this resource document focuses on use of air dispersion modeling to estimate ambient concentrations, with monitoring data used primarily for secondary purposes such as evaluation of the modeling results (e.g., comparing to local NATTS or other special study monitors). The dispersion modeling results may be used as a generally conservative surrogate for exposure (a screening level approach, although in some cases ambient concentrations may underestimate actual exposures). In contrast, the risk analysts may decide to take the air dispersion modeling results and use them to develop refined estimates of exposure by the application of an exposure model such as HAPEM (see Exhibit 5-2). ATRA Volume 1, Chapter 11 discusses use of exposure modeling for refined air toxics risk assessments.

There are any number of paths that a given assessment may take to assessing multisource impacts in a given place; there is no “one size fits all” cookbook approach that will work in all cases. The approach ultimately taken depends on the needs of the risk managers (e.g., how thorough an understanding of the problem they need) and the resources available to the analysts. Some assessments, for example, will use a number of simplifying, yet conservative, assumptions to derive risk estimates (e.g., the exposure concentration for the entire study area population is represented by the concentration at the maximum impact location), while other assessments may rely on higher levels of analysis (e.g., probabilistic approaches) to derive a more thorough understanding of the problem. Nevertheless, there are certain elements of the multisource analysis process that will generally be common to most multisource assessments, and this chapter provides an overview of both these common elements and the general process flow that most assessments follow (see an example process flow in Exhibit 5-3).

It should also be noted that there are a variety of tools and models that can be used to accomplish the Exhibit 5-1 analysis tasks. These tools can range in complexity, refinement, and data requirements, and the planning process will have to identify the right tools for the job. In this chapter, the RAIMI methodology and certain other frequently used tools are presented as examples. For some assessments and situations, other less or more refined tools may be appropriate.

In addition to an overview of the general analytical framework described in this chapter, Appendix B provides the details of some of the common screening techniques that assessors may select to help narrow the focus of the assessment to the most important sources and chemicals.

Exhibit 5-1. The General Multisource Air Toxics Risk Assessment Process For a Community Assessment – Focus on Analysis

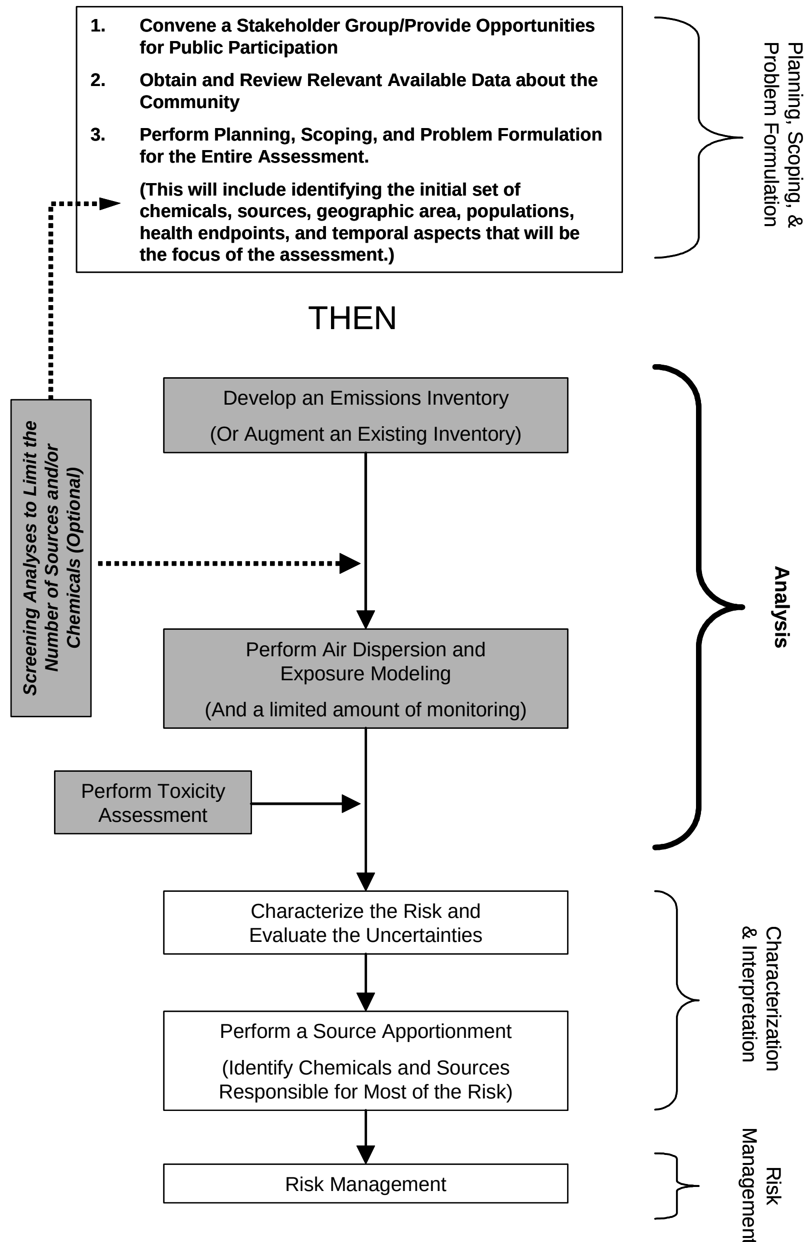


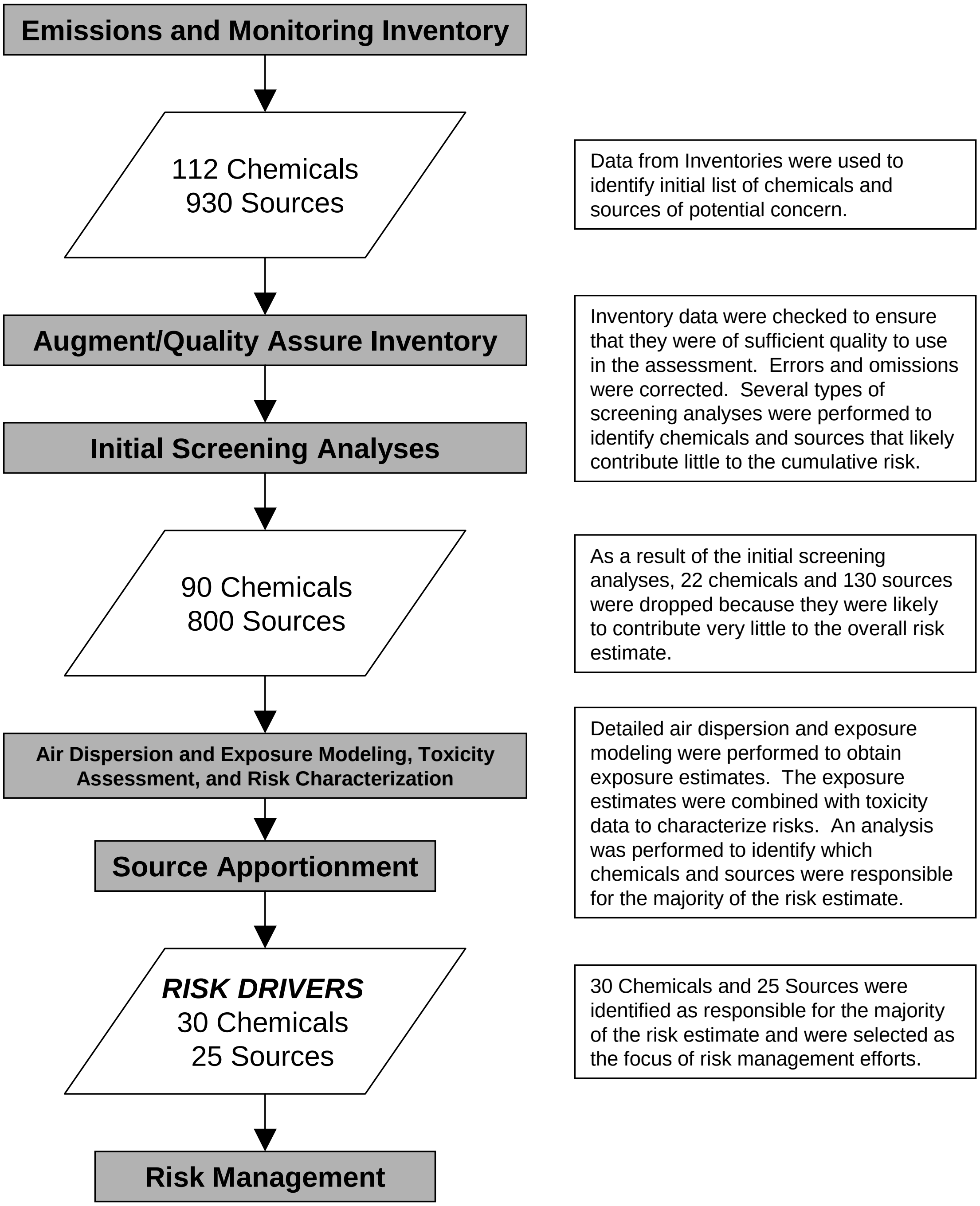
Exhibit 5-2. Approaches to Evaluating Exposure

For air toxics impact analysis, a variety of measures may be used to evaluate the potential exposures of a person to a chemical in the air. Some measures are fairly crude and some are more refined. The most common measures used to estimate exposure are listed below (generally, from most crude to most refined):

Pounds Released	A very crude indicator of potential exposure because there is no information on toxicity or fate and transport in the environment or on how people interact with the contaminated air.
Toxicity-weighted	Pounds released of each pollutant, adjusted for its relative carcinogenic potency or reference level for noncancer effects. This measure accounts for toxicity, but not fate and transport or exposure.
Ambient Concentration	A better indicator of potential exposure (fate and transport are included) but still lacks information on how people interact with the contaminated air. The quality of the concentration estimate depends on the method used to develop it (e.g., the various types of monitoring or modeling used, the quality of the emissions inventory, etc.).
Exposure Model Refined Ambient Concentration	An even better indicator of potential exposure because it does include information on how people interact with the contaminated air (e.g., do they remain in the immediate area constantly or do they move to areas with differing concentrations). The quality of the information depends on both the methods used to estimate ambient concentration and those used to evaluate demographics and behavior.
Personal Exposure	An even higher level of understanding of exposure, usually developed by personal exposure monitoring.

The term *exposure concentration* is used to describe the concentration of a chemical in its transport or carrier medium (i.e., an environmental medium or contaminated food) at the point of contact. This concentration can be either a monitored or modeled value and may or may not have been refined by the application of an exposure model.

Exhibit 5-3. Example Flow Diagram for a Cumulative Multisource Assessment



The overall framework for the multisource analysis phase has four key components:

- Emissions characterization (Section 5.1);
- Air dispersion modeling (Section 5.2);
- Estimating inhalation exposure (Section 5.3); and
- Toxicity assessment (Section 5.4).

The remainder of this chapter discusses each of these elements in detail. It should be noted that the information provided here augments the general information on these topics already provided in ATRA Volume 1 by emphasizing some of the key objectives and procedures that are used to perform a community-level multisource assessment.

5.1 Emissions Characterization

Emissions characterization (also commonly referred to as source characterization) is simply the development of information about the chemicals that are released to the air in the study area, including chemical identity, location of release, the pattern of release (e.g., continuous, intermittent, burst, etc.) and the physical characteristics of the release. The product of the emissions characterization step is a database of the collected information called the **emissions inventory** (see Section 4.2.1.2). [Since the local mix of sources, chemicals, and other factors (e.g., meteorology) will vary from place to place, the sources and chemicals ultimately found to be responsible for the majority of the risks can also vary from place to place. It is for this reason that the inventory developed for the location-specific multisource assessment initially include information on all important sources of air toxics impacting the study area. At a minimum, this will generally include both mobile sources and stationary sources.]

> **Emissions Characterization**
> **What Should I Know Before I Proceed?**
>
> To perform the emissions characterization step correctly, analysts should have a strong understanding of several key topics, including:
>
> - The types of chemicals that are considered "air toxics;"
> - The types of activities that result in emissions of air toxics, such as industrial and commercial activities, fuel combustion, mobile sources, and use of consumer products;
> - The available emission inventories of air toxics, such as the National Emission Inventory (NEI), the Toxic Release Inventory (TRI), and more locally developed inventories; and
> - The tools and steps used to develop an emission inventory (or to augment an existing inventory) for use with the selected air dispersion model.
>
> An overview of these subjects is provided in ATRA Volume 1, Chapters 4 and 7. The *How To Manual* (Section 3.5.1) also contains discussions on this topic.

The emissions inventory is one of the key inputs needed by the air dispersion model in order for the model to generate ambient air concentration estimates at the points selected by the analyst. Another key piece of information needed for the modeling effort is meteorological data.

Depending on the air dispersion model employed, different types of emissions inventory data (such as different types of emissions parameters) may be required. The discussion here provides examples of the parameters that are needed for a commonly used Gaussian plume model [the

Industrial Source Complex (ISC) model]. If an alternate dispersion model is used, the requirements of the emissions inventory may be different.

5.1.1 Development of Emissions Estimates - The Basics

For a multisource assessment, the analysts will commonly begin the process of (1) developing emissions estimates by obtaining the available emissions inventories for the study area – this will usually be the NEI and the TRI or, in some cases, a more refined state or local emissions inventory; and then (2) refining the inventory, as necessary, according to the data quality objectives (DQOs) that were established in the planning and scoping (planning and scoping) phase (see Chapter 4). In short, the analysts will look at what has already been developed and ask themselves the question, "Is the existing inventory good enough or do we need to refine the inventory to meet the DQOs established during planning and scoping?"

For example, if the planning and scoping process determined that all air toxics emissions reported to the NEI and the TRI would be the focus of the air dispersion modeling analysis, then using the NEI "as is" may not be sufficient. This is because HAP emissions from TRI sources are usually included in the NEI, but non-HAP emissions from TRI sources generally are not. The NEI would needed to be augmented to include the non-HAP air releases reported to the TRI in order to meet the DQOs for emissions estimates established during planning and scoping. More information on common DQOs for the emissions estimate step is provided below.

In some cases, further refinement of the inventory may need to be conducted for high risk pollutants after a screening-level risk assessment has been conducted. This step allows the analyst to focus resources and in-depth analysis efforts on those emission sources likely to have the highest impact on a community.

5.1.2 Emissions Characterization DQOs

Exhibit 5-4 presents some of the main emissions data that are needed when using ISC as the air dispersion model for sources in a community-scale multisource assessment. Some examples of the type and nature of DQOs for these data elements might be:

- **Accuracy**: Emission totals are accurate to within some acceptable range (e.g., ±25 percent when compared to sources such as emissions monitoring data, emissions from similar units at different facilities, emissions reported to multiple databases, historically reported emissions at the facility, estimated emissions generated using information in the literature such as industry-specific emissions profiles);

- **Completeness**: All sources emitting at least X tons/year of the compound within some specified distance of the study area boundary (e.g., 1 mile);

- **Completeness**: Emission totals for each source during an annual period;

- **Level of detail**: Emission sources stratified by Standard Classification Code (SCC) and AIRS area and mobile system (AMS) codes;

Exhibit 5-4. Example Input Data for Characterizing Emissions Sources for Use with the ISC Dispersion Model				
	Stack Sources	**Fugitive Sources**	**Flare Sources**[a]	**Mobile Sources**[b]
Emission Source Parameters	- Stack height [m] - Base elevation [m] - Stack diameter [m] - Stack gas exit velocity [m/s] - Stack gas exit temp. [K] - Horizontal discharge - Location [NAD-83]	- Source area [m^2] - Source volume [m^3] - Release height [m] - Base elevation [m] - Location [NAD-83]	- Gas flow rate [SCFM] - Average of lowest heats of combustion for flare feed stream constituents (BTU/SCF) - Molecular weight, average for flare constituents - Release height [m] - Base elevation [m] - Location [NAD-83]	- Source area [m^2] - Release height [m] - Base elevation [m] - Location [NAD-83]
Emissions Data	- Contaminant CAS number and name - Actual annual speciated emission rate [g/s] - Allowable (permitted) emission rate [g/s] - Historical speciated emission rates [g/s] and corresponding reporting year			
Emission Source Attributes	- State registration or account number for the facility - Company name, and name of the industrial facility - Nearest city and county - Date of most recent emissions data - Emissions point name and ID number - Name and ID of the process facility generating the emissions - Emissions permit number - Source classification code (SCC)			

Table notes:

[a] Flare sources, which are modeled as stacks in this example, can be reported as stacks or with other parameters which enable them to be modeled as stacks following conversion calculations.

[b] Mobile sources in this example have been modeled as an area source (e.g., to cover a segment of a major highway). Some of the emissions data and attributes listed here would not apply to mobile sources (e.g., facility name, permit number). Modeling of mobile sources, including a discussion of spatial allocation of such sources, are discussed in more detail in Section 5.1.3.5.

m:	meters	NAD-83:	North American Datum 1983
m^2:	square meters	BTU/SCF:	British thermal units per standard cubic foot
m/s:	meters/second	SCFM:	Standard cubic feet per minute at 68° F
g/s:	grams/second	CAS:	Chemical Abstract Service
K:	Kelvin		

Source: http://www.epa.gov/earth1r6/6pd/rcra_c/raimi/raimi.htm

Note: *This exhibit is not meant to be a comprehensive summary of all inputs required by ISC to complete a model run, and some data types listed here are not directly required by ISC (e.g., nearest city and county).*

- **Level of detail**: Spatial resolution of non-point source emissions to some acceptable geographic subdivisions (e.g., US Census tracts, 2-km grid squares); and

- **Level of detail:** Understanding of the temporal nature of emissions data (are they provided as an annual aggregate, as continuous emissions estimates, as intermittent emissions estimates, etc.). Will the emissions data allow an assessment of the exposure duration of interest? For example, data provided as an annual aggregate will provide limited information for acute exposure assessment, but are usually adequate for evaluating chronic exposures.

Other elements that might be considered in establishing an acceptable level of data quality might include:

- Verification and correction of source locations;
- Verification that all chemicals of interest (both HAP and non-HAP) have been included;
- Acceptable level of chemical speciation of the emissions being released; and
- Spatial allocation of non-point emissions to specific locations for dispersion modeling, if needed.

Approaches that can help meet these emissions characterization DQOs are discussed in the following sections.

5.1.3 Inventory Review and Augmentation

As mentioned above, there will usually be some emission information available for the study area from an existing inventory (e.g., the NEI or state/tribal/local inventory); however, review and refinement of the information will usually be required to create a study area-specific inventory that meets the study-specific DQOs. This section discusses some of the areas of refinement that are commonly needed in the development of the emissions inventory for the community-scale assessment.

5.1.3.1 Preparing Emissions Data for Assessment Purposes

Depending on what use the emissions data will be put to (e.g., as an input to a dispersion model), there may be different requirements for both the content of the emissions inventory as well as the format of the inventory (e.g., a particular database or file structure). The user's guides for the various air dispersion models should be consulted to insure that the emissions inventory development process will meet both the content and the file structure requirements for the selected model. For example, the emissions inventory database structure used in the RAIMI process (which can be developed with the assistance of the RAIMI "Data Miner Tool;" see text box below) is shown in Appendix C. Other models (e.g., HEM-Screen, CalPUFF, etc.) will have other emissions parameter and file formatting requirements.

In addition to creating the emissions file or database in the required format, some additional processing and management of calculated or revised source characterization data are often required to support the modeling analysis. Typical examples of further processing of source characterization data include the following:

- **Conversion of Reported Units**: Certain source characterization data may require conversion of reported units into alternate units to ensure accurate use in algorithms applied in source and risk characterization. Parameters for which conversions are typically required include release heights, source dimensions, stack gas exit parameters, etc. For example, the ISCST3 model requires that stack height be input in meters; therefore, heights reported as feet in an emission inventory would need to be converted (i.e., 1 foot = 0.3048 meters). Another parameter for which conversions are typically required include emission rates (such as actual and allowable emission rates being changed from tons per year to grams per second).

- **Calculation of Source Terms for Source Modeling of Emission Sources**: Certain source characterization data may be utilized in the calculation of additional emission source parameters for modeling fugitive and flare sources. For example, fugitive emissions from equipment leaks may be modeled as a representative volume source with the approximate dimensions of the entire area in which the pipes, flanges, valves, and other sources of equipment leaks are located, and operating conditions (hours of operation, flow rates, etc.) could be used to refine the emission rate and other required parameters. Calculated source

Automating the Process – Emissions Inventories

Modeling and cumulative-type risk assessment projects require inspection and analysis of large emissions inventory databases. Because there are numerous relational database possibilities, each having many fields, it can take significant time to track down particular details embedded in this mass of information. In addition to the complexity of the information, many applications are unable to handle the massive volumes of data. For example, common desktop software such as Microsoft Excel® cannot handle more than 65,600 rows of data.

The **RAIMI Data Miner** is one tool that helps the analyst overcome these limitations. This is a large database client-server processing system that facilitates the assembly of multi-source emissions inventories for air and risk characterization. With Data Miner, you can:

- Create and edit database table relationships and views for complete access to all emissions attributes maintained in the database;
- Link source-specific parameters necessary for air and risk characterization from multiple database tables through the Data Organizer component; and
- Extract the source-specific data sets by constructing and executing simple or complex data queries in the Query Builder component.

For more information on the RAIMI Data Miner, see: http://www.epa.gov/Arkansas/6pd/rcra_c/raimi/raimi.

Other tools are also available that may be more appropriate depending on the needs of the assessment. For example, EPA's Emissions Modeling System for Hazardous Air Pollutants (EMS-HAP) (http://www.epa.gov/scram001/dispersion_related.htm#ems-hap), which has been used to process emissions data and source parameters used in EPA national-scale assessments, is useful for particularly large applications. For smaller-scale assessments, desktop spreadsheet programs like Microsoft Excel® may be adequate. Commercial vendors also have products on the market to develop, track, and manage emissions inventory data.

parameter values, and any interim parameter values used in the calculations, may need to be tracked and managed in a way that allows one to quickly document new parameter values, and to ensure data integrity.

- **Summation of Multiple Emissions Records Reported for the Same Emission Source**: In some regulatory emissions databases, multiple sets of emissions from different processes are reported for the same source. This sometimes results in multiple emission rates of the same contaminant being reported from a single emission source (i.e., multiple emission records). For simplification in risk characterization, these multiple emission records (same contaminant at same source) are often summed before calculating the risk. If the total emissions from the facility result in high risk levels to a community, it may be necessary to revisit the original process-specific emissions when evaluating potential emissions reduction options.

5.1.3.2 Verification and Correction of Source Locations

Source location data in existing inventories is sometimes reported by the facility and sometimes developed by a regulatory agency using a variety of surrogate information sources to fill data gaps. This can result in inventories that are variable in accuracy and format. Since incorrectly identifying the source location can have potentially significant impacts on risk results, it is important to verify the accuracy of the reported locations for each emission source.

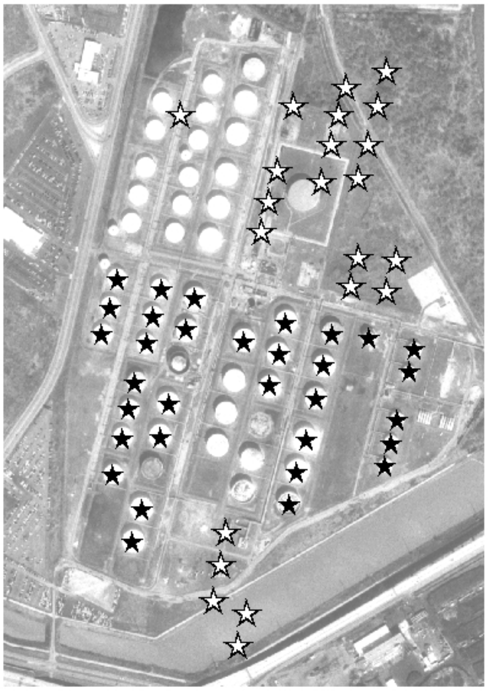
There are several tests that can be applied to source location information to verify its accuracy. One common approach (called a "geo-location process") is performed in two steps. First, source locations are adjusted to account for errors and inconsistencies in geographic position for each source that can result from using different geographic frames of reference, or "datums," when reporting locational coordinates. This can be accomplished by ensuring that all emission sources are reported in a common datum [e.g., 1983 North American Datum (NAD-83); see accompanying text box]. These positions are then graphically evaluated with respect to other known location information, such as facility boundaries, facility equipment and processing plants, land use zones, and other graphical data references.

An example of the geo-location method employed for multisource assessments is described below and shown graphically in Exhibit 5-5.

- **NAD 27 to NAD 83 Shift**: Each source location is reviewed to determine if the reported location was provided in NAD 83 or in NAD 27 format. For sources that are determined to have originally been reported in NAD 83, the reported source location is maintained in the project emissions inventory, and tracked as "not shifted" (this comment identifies the source location data as originally reported in NAD 83). For all other sources, the analyst assumes all locations are reported in NAD 27 and shifts the source locations reported in the emissions database to NAD 83 (e.g., the shift from NAD 27 to NAD 83 is approximately 200 feet north and 30 feet west for locations in south central United States). The shifted NAD 83 location becomes the source location for modeling, and is tracked as "shifted" without further comment. Both the reported and shifted source locations are then reviewed on a GIS platform and compared to referenced mapped data (see next bullet).

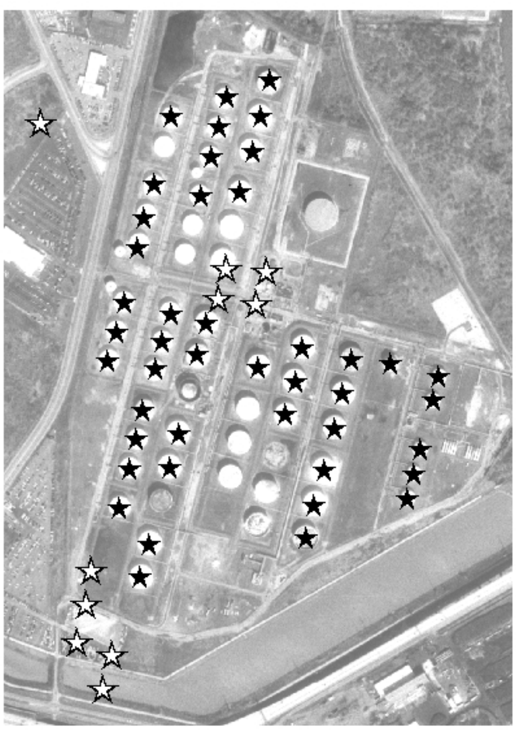
Exhibit 5-5. Example of How to Geo-locate Sources

Before



In this example, the analyst starts with an aerial photo of a facility of interest (a tank farm). The locations of the individual tanks are then plotted using the lat/long data from the existing inventory. In this example, some of the lat/long data (with locations represented by stars) are provided using the NAD83 datum and some are provided using the NAD27 datum. The unfilled stars are offset because they either are not the same datum as the photo, or the lat/long coordinates are incorrect for another reason.

After



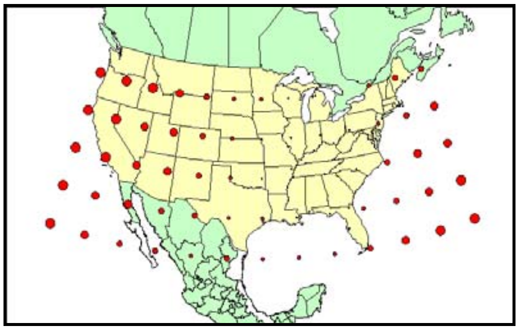
The lower picture shows the same site after the analyst converts the misplaced points from NAD27 to NAD83 and replots the locations of the tanks. It is clear that more of the tank locations now line up with the photograph. The analyst would need to further clarify the location of remaining questionable tank locations (indicated again with unfilled stars) based on additional data.

North American Datum

The earth is not a sphere but an ellipsoid distorted by rotation about its axis, with the globe bulging at the equator and flattened at the poles. There are multiple ellipsoid models that have been developed to approximate the shape of the earth; these different models are represented mathematically as datums.

For many years, the North American Datum of 1927 (NAD27) was the standard datum used in the United States. It is based on the Clarke ellipsoid of 1866, which was developed from a ground survey in Europe and North America in the 19th century. Use of this datum is gradually being replaced by the North American Datum of 1983 (NAD83) which is based on the World Geodetic System ellipsoid of 1984 (WGS84). Developed from satellite measurements of the earth surface in the 1970s and 1980s, NAD83 provides a more accurate representation of the earth's shape and a more accurate depiction of the location of objects on the earth.

Data sets should be presented in the same datum in order to be compared or used together. The coordinates generated for the same location using both NAD27 and NAD83 can differ by up to 200-300 feet in the western US to several tens of feet in the central and eastern US. The adjacent map indicates the difference between the two datums (the larger the dot, the more difference between coordinates).



There are several ways to convert between these two datums. Many desktop GIS software have conversion routines built in. The best conversion programs are based on the National Geodetic Survey's NADCON (North American Datum Conversion).

Source: USGS, *Datums and Projections: A Brief Guide*, March 1999. Available at: http://biology.usgs.gov/geotech/documents/datum.html.

Image used with permission from Tower Maps. Online at: http://www.towermaps.com/nad.htm.

- **GIS Review**: GIS review is then conducted by posting the reported and shifted source locations over background maps of high resolution aerial photographs [1-meter digital ortho quarter quad (DOQQ)], county boundary map, and digitized facility property boundaries. Analysts then look for remaining problems with source locations (e.g., an emission point in the middle of a lake). A GIS platform such as ESRI's ArcGIS software suite could be used for this review (http://www.esri.com/index.html). USGS DOQQ images as well as other geospatial data are available online for free or purchase from government and private sites, such as geodata.gov (http://www.geodata.gov/gos), the GIS Data Depot (http://data.geocomm.com), and other federal or state GIS web sites.[a]

[a] These software references and data sources are provided for information only; it is the analyst's responsibility to ensure the accuracy of data obtained from these or other sites.

In some cases, source location verification procedures may have been completed in the development of the emissions inventory (e.g., certain data augmentation and checking processes are completed for NEI data). However, a third step can also be completed to check those location coordinates for which default values have been assigned in the inventory used as a data source. For example, some sources in the NEI have been assigned default coordinates where actual source locations were not available. The default flags for such coordinates should be reviewed, and actual locations may need to be obtained as a part of the assessment.

5.1.3.3 Chemical Speciation of Emissions

It is often the case that emissions are reported as pollutant mixtures, such as "gasoline," "volatile organic compounds," "hydrocarbons," or "particulate matter." This presents a problem for the assessment team, since the identity and amount of the various components in the mixture are needed because toxicity values are usually not created for such complex mixtures. To estimate identities and amounts of the mixture components, one would need to apply a ***speciation profile*** to the mixture. In general, speciation profiles are industry-specific or source category-specific conversion factors that are used to estimate pollutant-specific emission rates from emission rates of pollutant mixtures. For example, the toxic speciation profile for a particular type of gasoline might be one percent benzene, 10 percent toluene, and 5 percent xylene.

Screening Chemical Mixtures

If a speciation profile is not readily available for the source of interest, one screening-level technique that can be used to evaluate the importance of the mixture in the overall analysis of risk is to assume that the mixture is made up entirely of the most toxic constituent. For example, in a mixture containing compounds X, Y, and Z (but of unknown proportion), the analyst might assume (as a screening level exercise) that the entire mixture is made up of the most toxic chemical in the mixture (chemical X). If the risk posed by the mixture under this assumption is small compared to other sources and chemicals, the analyst may be able to drop it from further consideration (thus, averting the need for an accurate speciation profile for the mixture).

The most accurate way to determine the speciation profile is with analysis of the actual emissions source, but this is a very resource-intensive approach. Alternatively, if the emissions inventory contains speciated emissions for similar sources, the profile for those sources might be assumed to apply to the unspeciated sources. Similarly, speciation profiles for various source types are sometimes published in peer-reviewed journals. Industry-specific speciation profiles may be quite limited, but there is some information in EPA's AP-42 documentation for selected categories of sources (see http://www.epa.gov/ttn/chief/ap42/index.html). More information is available about speciation profiles of gasoline and onroad mobile source emissions in the MOBILE6.2 User's Guide (http://www.epa.gov/otaq/m6.htm).

5.1.3.4 Spatial Allocation of Stationary Non-Point Source Emissions

In community-scale assessments, it is often necessary to obtain information about the exact location of all sources, when possible, rather than rely on "spatial surrogates" for diffuse, smaller nonpoint (see Section 3.2.2) sources that are reported in the aggregate in an existing emissions inventory. For example, the NATA risk characterization generally evaluates smaller sources that are widely dispersed throughout urban areas (e.g., gas stations, dry cleaners, autobody shops, etc.) and reported in the aggregate by distributing the total amount of emissions from each such source category across a geographic area using a spatial surrogate (e.g., allocating dry cleaning emissions according to population) without consideration of the actual source locations. While this is appropriate in the NATA evaluation (given its intended purpose of providing a characterization of risk at the national scale), in a local-scale assessment, this detail may not provide the level of accuracy needed for local risk management.

> **A Tip for Engaging the Community**
>
> Refining the emissions inventory can take time and resources and people are sometimes tempted to take "short cuts" to avoid some of this work. However, keep in mind that a complete and accurate emissions inventory is the key to a successful multisource analysis.
>
> One way to get the community involved in the process is to have them help refine the emissions inventory. With one short class in how to use a GPS, community members can be sent out to find and document the many small area sources in the study area. This easy process will help community members feel engaged, will teach them about the process, and will provide valuable information (basically for free) that can dramatically enhance the overall quality of the resulting emissions estimates.

For example, consider an emissions inventory that provides only one sum total tonnage of benzene emissions at the county level for gas stations. One way to allocate the emissions is by population (e.g., using census block data). While this puts the emissions where the people are (in a general sense), it is still only a guess about where the gas station emissions are actually occurring. To evaluate where the gas stations truly are in relation to the potentially exposed populations will require someone to physically locate the gas stations. This could be done by either a computerized search, a review of the phone book, or a "windshield survey" in which someone drives through the study area with a global positioning system (GPS) unit and physically records the exact location of each gas station.

Some tools exist to assist the analyst in allocation of non-point sources to specific locations. For example, EPA's Emissions Modeling System for Hazardous Air Pollutants (EMS-HAP) contains a processor that allows the analyst to model airport-related emissions (e.g., emissions from aircraft and aircraft refueling activities) as discrete sources located at airports instead of spatially-allocated mobile sources.

Sometimes it is neither necessary nor practical to gather this level of detail. Sometimes the contribution from a source type is so small that the effort to locate the individual emissions locations is not justified (see Appendix B for information on screening techniques for small, diffuse sources). In other cases, the resources may not be available to verify the locations and a more generic emissions allocation approach will be selected. Ultimately, the DQO's and resources available for the project will drive the efforts to identify the location of all the sources in a specific area. An example of one method for allocating diffuse source emissions across a geographic area is presented in Exhibit 5-6; more detailed information is described in the *How To Manual*,[1] the NATA risk characterization documentation (http://www.epa.gov/ttn/atw/nata/), and the NEI documentation (http://www.epa.gov/ttn/chief/net).

5.1.3.5 Mobile Sources

For the purposes of inventory development, the choice of conducting a top-down versus a bottom-up inventory for mobile source emissions is based on the purpose and scale of the inventory application as well as available data. For a community-scale assessment, it is preferable to use data specific to the area of study, as this will provide more accurate data regarding the sources and distribution of risk in the population.

Top-down inventories are developed for use in national- or regional-scale assessments (where highly refined data is impractical), such as the NEI. To estimate mobile source emissions the NEI uses various surrogates such as population and vehicle activity data and equipment activity data to allocate emissions to individual counties. County-level emissions are then allocated to smaller geographic areas (grid cells or census tracts) using spatial allocation factors such as land use or roadway miles.

County-level emissions for on-road sources are estimated as the product of emission factors (grams per mile) and vehicle miles traveled (VMT), by vehicle class, roadway type, and month or season. County-level VMT in the NEI is allocated from state or urban area totals obtained from the Federal Highway Administration's Highway Statistics series using county level population data. County level emissions are then computed using a highway vehicle emissions factors calculated using EPA's MOBILE6.2 model. For national and regional scale analysis, default or average values are often used for many input parameters such as driving speed and vehicle age distribution. These emissions are then spatially allocated to the subcounty level for air quality modeling using an emissions preprocessor such as EMS-HAP.[b] EMS-HAP allocates on-road emissions using road miles for different road types. Emissions are also allocated temporally, by hour of the day, using this preprocessor and time-activity profiles.

County-level emission inventories for nonroad sources are estimated using the NONROAD model (see http://www.epa.gov/otaq/nonrdmdl.htm). Allocation factors used to calculate emission inventories for nonroad equipment can be found in the EPA Technical Report No. EPA420-P-04-014 and allocation factors for aircraft, commercial marine vessels and locomotives can be found at http://www.epa.gov/ttn/chief/net.

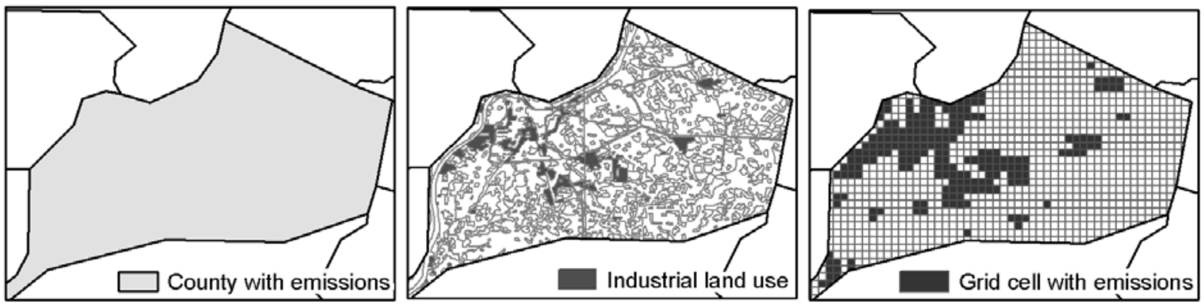
National Mobile Inventory Model (NMIM) is a free, desktop computer application developed by EPA to calculate estimates of current and future emission inventories for on-road motor vehicles and nonroad equipment (see http://www.epa.gov/otaq/nmim.htm). NMIM uses MOBILE6.2 and NONROAD to calculate emission inventories, based on multiple input scenarios that the user enters into the system. NMIM can be used to calculate national, individual state, or county inventories.

Inventory estimates derived using the top-down approach are very useful as screening tools and for identifying priorities for further analysis. However, surrogates may not adequately represent local mobile source activity and default inputs used in emission models may not reflect local-scale conditions. Since studies have demonstrated that there can be strong spatial gradients of some pollutants associated with roads, more accurate emissions data at the local scale is important in developing strategies to assess and reduce risk at the local level.

[b] For more information on EMS-HAP see www.epa.gov/scram001/tt22.htm.

A bottom-up method to develop mobile source emissions inventories uses local-scale input data specific to the community being studied. To develop a local-scale inventory for on-road mobile sources, emissions are assigned to individual roads and a Travel Demand Model (TDM) provides data specific to the roadways (see Exhibit 5-6). Models employing individual roadway data are termed ‘link level’ models. Information provided by a TDM includes roadway traffic volume,

Exhibit 5-6. Examples of Spatial Allocation of Emissions

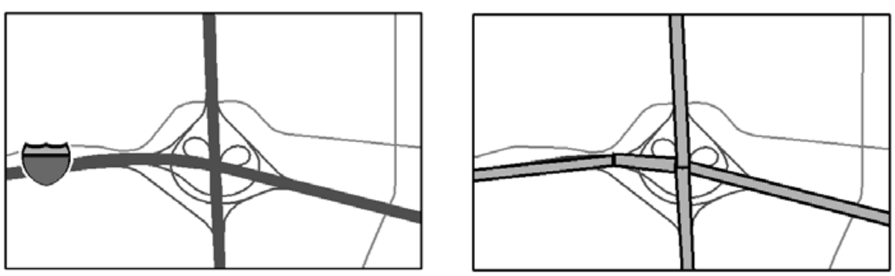


1. Gather data on area source emissions from a database such as NEI for a location (e.g., a county).

2. Use a spatial surrogate (e.g., industrial land use) to identify locations where area source emissions would occur.

3. Spatially allocate the area source emissions to small grid cells that overlap areas classified with the surrogate land use. Divide the county's emissions among the selected cells.

Spatial allocation of diffuse stationary point sources: In this example, county-level emissions data for a given type of emission source are assigned to smaller cells using land-use data and GIS techniques. Although this procedure is not as accurate as determining actual source locations, it offers a refinement to the county-level emission estimate that may be appropriate in some cases (e.g., considering the resources and desired level of detail of the assessment). The assignment of source locations to grid cells would be particularly useful when using a grid-based model.



1. Gather data for on-road mobile sources based on road type and usage in the area of interest.

2. Apply the emissions to road segments based on length and other properties of each road. Create area or volume sources to represent the on-road emissions in a model.

Spatial allocation of mobile sources: In this example, emissions from vehicles on a well-traveled road are estimated based on available information and then assigned to area or volume sources for inclusion in dispersion modeling.

capacity, number of lanes, and sometimes speeds. These data can be used with the MOBILE6.2 emissions model to create detailed emissions concentrations and spatial distributions.[c] For nonroad emissions, use of local equipment population and activity data can greatly improve the quality of inventories for local scale assessments. Applying a bottom-up inventory in a dispersion model for local-scale assessments has several advantages over top-down approaches, including the ability to identify communities with potentially higher risks, better characterization of pollutant gradients and improved temporal resolution.

To estimate ambient concentrations for community-scale mobile source assessments, air dispersion models are used, as discussed in the following section. For mobile source applications, dispersion models such as ISC or AERMOD can be used, and are especially useful in cases where a freight terminal, port or similar facility is being modeled. Models designed more specifically to estimate ambient concentrations of mobile source emissions include Gaussian plume models for line sources such as CALINE3 (to model episodic events) and CALINE4 (to model annual averages). CAL3QHC is the EPA-approved model for assessing intersections that is includes traffic queues, idling and stop/go cycles. More information regarding mobile source emission models can be found at www.epa.gov/otaq/models.htm. Information on air quality models can be found on the SCRAM website (www.epa.gov/scram001).

5.2 Air Dispersion Modeling

Air dispersion modeling is used in the multisource analysis to simulate the transport of chemicals released from a source through the air to a point where a person can inhale them. The process is performed using a computer with the resulting concentrations being represented at various points (referred to as modeling locations or nodes, also known as receptor locations or nodes), usually an evenly spaced grid located around the source out to a predetermined distance. ATRA Volume 1, Chapter 9, provides an overview of air dispersion modeling used in air toxics risk assessments, including examples of air dispersion models and air dispersion model applications. Documentation, software, and user's guides for commonly-used air dispersion models are available on EPA's SCRAM website (http://www.epa.gov/ttn/scram/). Several EPA guidance documents related to modeling air toxics are also listed in the text box below.

[c] See http://www.planning.dot.gov/Documents/BriefingBook/BBook.htm#2BB for additional information on the Metropolitan Transportation Planning Process.

Selected EPA Guidance on Air Quality Modeling of Air Toxics

EPA's Air Quality Modeling Group has developed numerous guidance documents on modeling air toxics pollutants that may be useful for reference. Below is a list of some of these documents.

- *User's Guide to TSCREEN, A Model For Screening Toxic Pollutant Concentrations.* 1990.
- *Guidance for Application Of Refined Dispersion Models For Air Toxics Releases.* 1991. EPA-450/4-91-007.
- *Evaluation of Dense Gas Simulation Models.* 1991. EPA-450/4-90-018.
- *Workbook of Screening Techniques for Assessing Impacts of Toxic Air Pollutants (Revised).* 1992. EPA-454/R-92-024.
- *Guidance on the Application of Refined Dispersion Models for Hazardous/Toxic Air Releases.* 1993. EPA-454/R-93-002.
- *Contingency Analysis Modeling for Superfund Sites and Other Sources.* 1993. EPA-454/R93-001.
- *User's Guide to TSCREEN- A Model for Screening Toxic Air Pollutant Concentrations (Revised).* 1994. http://www.epa.gov/scram001/userg/screen/tscreend.pdf.
- *Development and Testing of a Dry Deposition Algorithm (Revised).* 1994. EPA-454/R-94-015.
- *Air/Superfund National Technical Guidance Study Series, Volume V-Procedures for Air Dispersion Modeling at Superfund Sites.* 1995. EPA-454/R-95-003. http://www.epa.gov/scram001/guidance_other.htm
- *Dispersion Modeling of Toxic Pollutants in Urban Areas: Guidance, Methodology and Applications.* 1999. EPA-454/R-99-021. Office of Air Quality Planning and Standards, Research Triangle Park, NC. http://www.epa.gov/scram001/guidance_other.htm
- *A Simplified Approach for Estimating Secondary Production of Hazardous Air Pollutants (HAPs) Using the OZIPR Model.* 1999. http://www.epa.gov/scram001/guidance/reports/oziprpt/oziprhps.pdf.
- *User's Guide for the Assessment System for Population Exposure Nationwide (ASPEN, Version 1.1) Model.* 2000. http://www.epa.gov/scram001/userg/other/aspenug.pdf.
- *Example Application of Modeling Toxic Air Pollutants in Urban Areas.* 2002. http://www.epa.gov/otaq/toxics.htm.
- *User's Guide for the Emissions Modeling System for Hazardous Air Pollutants (EMS-HAP) Version 3.0.* 2004. http://www.epa.gov/scram001/userg/other/emshapv3ug.pdf.
- *Guidance on Hazardous/Toxic Air Releases* (5 documents). http://www.epa.gov/scram001/guidance_other.htm.
- *National Speciality Workshop on Technical Tools for Air Toxics Assessment Final Report.* 1997 http://www.epa.gov/scram001/guidance_other.htm.

This section focuses on information for selecting and applying an air dispersion model in a multisource community-scale assessment. A detailed example of the application of the ISCST3 model for multisource community-level air toxics analysis is provided in an abbreviated version in Appendix A. As emphasized throughout this chapter, other air modeling techniques (e.g., using more refined models that take into account chemical transformation) may also be appropriate, depending on the desired level of detail and the resources available to the analyst. For example, the use of a unit emission rate in air dispersion modeling is described in this chapter. This step may incur a small "cost" in accuracy that may be acceptable given the approach's efficiency and flexibility when compared against the time and resources it could take to perform an alternate analysis (see Section 5.2.3.2 and the text box in that section for more details).

5.2.1 Air Dispersion Modeling DQOs

Prior to selecting or running an air dispersion model, the partnership team must agree to study-specific modeling input parameter DQOs (example DQOs are provided below).

- **Accuracy**: Point source emission locations accurate to within some acceptable distance (e.g., 100 meters);
- **Completeness**: All sources emitting at least X tons/year of the compound within some acceptable distance of the study area boundary (e.g., 1 mile);
- **Completeness:** Stack parameters provided for all point sources;
- **Level of detail:** Emission sources stratified by Standard Classification Code (SCC) and AIRS area and mobile system (AMS) codes;
- **Level of detail:** Spatial resolution of model nodes to some acceptable geographic subdivisions (e.g., 90 meter spacing);
- **Level of detail**: Spatial resolution of non-point source emission to some acceptable geographic subdivisions (e.g., US Census tracts, 2-km grid squares).

Note that many of the dispersion model DQOs link directly to the quality of the emissions inventory and the accuracy of the model inputs. Understanding how the selected air model works, the questions to be answered, and the various resolutions of air model input parameters are key to understanding the accuracy of the dispersion results.

5.2.2 Air Dispersion Model Selection

Criteria for selection of an air dispersion model for a cumulative multisource assessment include (1) the ability to meet the modeling DQOs, and (2) the availability of required data inputs. Timing considerations are also important because some modeling approaches are dramatically more time intensive than others (which can lead to higher costs).

5.2.2.1 Available Models

Available air dispersion models range from those that are relatively easy to use with existing inventory data to complex models with additional input requirements. In addition, the physical characteristics of the study area may influence the model selection since some models are better at estimating concentrations in complex terrain (e.g., in river valleys, coastal environments). ATRA Volume 1, Chapter 9, provides an overview of the various types of models, their capabilities, and their utility in different types of settings. Typical applications are summarized in Exhibit 5-7 (this information is updated from that originally presented in Exhibit 9-5 in ATRA Volume 1, Chapter 9). For multisource assessments, the last two columns of Exhibit 5-7 (i.e., multiple sources) are most relevant.

Exhibit 5-7. Typical Applications for Common Dispersion Models

	Averaging Period	Terrain Type	Single Source		Multiple Sources	
			Rural	**Urban**	**Rural**	**Urban**
Screening Models	Short Term (1-24 hour average)	Simple	SCREEN3	SCREEN3	ISCST3, AERMOD	ISCST3, AERMOD
		Complex	SCREEN3, ISCST3	SCREEN3, ISCST3	ISCST3	ISCST3
	Long Term (Monthly-Annual)	Simple	ISCLT3	ISCLT3	ISCLT3, ASPEN	ISCLT3, ASPEN
		Complex	ISCST3	ISCST3	ISCST3	ISCST3
Refined Models	Short Term (1-24 hour average)	Simple	ISCST3, AERMOD	ISCST3, AERMOD	ISCST3, AERMOD	ISCST3, AERMOD, CMAQ-AT
		Complex	AERMOD, CALPUFF	AERMOD, CALPUFF	AERMOD, CALPUFF	AERMOD, CMAQ-AT, CALPUFF
	Long Term (Monthly-Annual)	Simple	ISCST3, AERMOD	ISCST3, AERMOD	ISCST3, AERMOD	ISCST3, CMAQ-AT, AERMOD
		Complex	CALPUFF, AERMOD	CALPUFF, AERMOD	CALPUFF, AERMOD	CALPUFF, CMAQ-AT, AERMOD

5.2.2.2 Ability to Meet DQOs

ATRA Volume 1, Chapter 9, also provides discussion of some of the strengths and weaknesses of each model. Review of this information will be helpful in determining which of the commonly used air dispersion models have the ability to meet the DQOs for a specific multisource assessment, such as the capability to treat complex terrain, perform dry and wet deposition, assess chemical transformation, and evaluate building downwash.

For example, ISCST3 is one of the regulatory air dispersion models that has been used most commonly by regional, state, and local agencies. Because the ISCST3 model accomplishes all of the same modeling objectives with more universal application to various sources types than ISCLT3, and because ISCST3 provides short-term (e.g., 1-hour) concentration estimates, ISCST3 is the air dispersion model that has been used for many community-scale assessments (particularly those that focused on both long- and short-term impact assessment).[(d)]

It is important to note that AERMOD has replaced ISC as the preferred regulatory model for EPA air dispersion modeling applications. The rule establishing AERMOD as the preferred model became effective December 9, 2005, and analysts are encouraged to use AERMOD rather than ISC3 for dispersion modeling applications due to the superior ability of AERMOD to estimate ambient air concentrations resulting from air emissions, especially in modeling downwash and dispersion across complex terrain. EPA has stated that the use of ISC3 for regulatory modeling analyses will be allowed during the one-year period following December 2005 at the discretion of the regulatory authority for which the analyses are being conducted. Technical documentation, user guidance, and other materials related to AERMOD (including detailed comparisons of AERMOD to ISCST3 and other dispersion models) are available from EPA's Support Center for Regulatory Atmospheric Modeling at http://www.epa.gov/scram001/dispersion_prefrec.htm#aermod.

A Note on the Use of AERMOD for Community-Scale Assessment

Because many community-scale assessments conducted to date have used ISC3, and because ISC3 (specifically, ISCST3) is the current modeling platform used in the RAIMI methodology, ISC is referenced in some of the examples presented in this chapter. However, the analyst should be aware that a new dispersion model called AERMOD (American Meteorological Society/EPA Regulatory Model) recently replaced ISC3 as the EPA's preferred model for certain regulatory applications (see http://www.epa.gov/scram001/dispersion_prefrec.htm#aermod) and analysts should consider using this model, when appropriate. (Note that the RAIMI methodology may be updated in the future to provide the same automated features using AERMOD as it currently does with ISCST3. Analysts should check the RAIMI website for updates to the RAIMI software – see http://www.epa.gov/Arkansas/6pd/rcra_c/raimi/raimi.htm.)

[d] It should be noted that while achieving certain community-level modeling DQOs with respect to the temporal resolution may be limited if ISCLT3 is selected (e.g., because it can provide only annual average concentration predictions), some commonly used air toxics modeling applications (e.g., HEM-Screen) use ISCLT3 as part of their architecture. Analysts are again reminded to pick the analytical tool that will match the DQOs for the study at hand.

Automating the Process - Preparing Input Data

Air modeling for cumulative multisource assessment must consider a variety of issues, including the local variability in land use, terrain, and meteorological conditions to address site-specific fate and transport of airborne contaminants. Processing large data files of emissions data, meteorological data, land use, and terrain information is time- and computer-intensive, particularly when assessing releases from hundreds or thousands of sources and several computer tools have been developed to help bring efficiency to the process. Additionally, automation of methods helps ensure more consistency and fewer errors in the air modeling analyses. Some of the available air modeling data preprocessors include:

The RAIMI Air Modeling Preprocessor. The RAIMI Air Modeling Preprocessor (AMP) provides automated data pre-processing to prepare source-specific meteorological and air model source input files while accounting for localized variations in site characteristics, including variations in land use and terrain (see http://www.epa.gov/Arkansas/6pd/rcra_c/raimi/raimi.htm).

Emissions Modeling System for Hazardous Air Pollutants (EMS-HAP). This SAS-based processor can prepare annual emission inventory data from a source like NEI for subsequent air quality modeling using, for example, the ASPEN or ISCST3 model (see http://www.epa.gov/ttn/chief/emch/projection/emshap30.html).

Sparse Matrix Operator Kernel Emissions (SMOKE). This processor speciates and temporally and spatially allocates mass emissions inventory data and prepares data in formats for input to emission estimation tools such as MOBILE6 and BEIS3 (see http://cf.unc.edu/cep/empd/products/smoke/index.cfm#Summary).

Other factors or circumstances may also be important in selecting an appropriate model that can meet the DQOs of an assessment. Two examples of such factors are presented here; other considerations may also be important.

- **Treatment of meteorological data.** In localized areas with complex wind patterns, consideration of a model's treatment of meteorological data is important. The most accurate results for these localized wind patterns will be obtained with a model like CALPUFF that uses 3-dimensional wind fields. However, the development of such wind fields requires the application of a meteorological model and assimilation of multiple raw measured data sets which can become quite resource-intensive (see http://www.epa.gov/scram001/tt22.htm#calpuff).

- **Spatial resolution and formation of secondary pollutants.** Achievement of modeling DQOs with respect to the spatial resolution of model predictions may be limited if a numerical grid model (e.g., CMAQ-AT) is selected, since the resolution is constrained to the size of the three-dimensional grid cells throughout which pollutant concentrations are assumed to be uniform. However, the upside is that these types of models can be used to address the formation of secondary pollutants. In cases where secondary pollutants are of interest, the ability to model the formation of such pollutants using a grid model may be more important than the higher spatial resolution afforded by a Gaussian plume model.

5.2.2.3 Availability of Required Model Inputs

Depending on the air quality model, a variety of inputs will be required. As the model becomes more complex, the data needs also tend to increase. In addition, some models will allow the user to select preset defaults for various inputs or provide user-specified data. Which course the user selects, of course, links back to the DQOs for the modeling exercise, and to the needs and purpose for the assessment as developed during the planning process.

For the purpose of cumulative multisource assessment, the air dispersion model will generally require, at a minimum, the following inputs:

- ***The Emissions Inventory***. It is worth restating that problems with the emissions inventory must be addressed prior to dispersion modeling to obtain useful results, no matter which model is selected. For example, many air toxics emissions can display a strong concentration gradient once released to the atmosphere. Thus, a mislocated source in the emissions inventory can also pose a critical accuracy issue in the resulting air modeling results.

  Note that with the exception of emissions resulting from operational upsets or maintenance activities, emissions are usually reported as annual totals. Some additional data augmentation may be required to ensure that source-specific temporal profiles correspond to the type of exposure being assessed (i.e., chronic or acute).

- ***Speciation Profiles***. As discussed above, emissions are sometimes reported as groups of compounds in some state inventories (e.g., gasoline, volatile organic compounds, or particulate matter). To develop chemical-specific estimates of ambient concentration in the dispersion modeling exercise, speciation profiles specifying the fractional composition of the emission (e.g., 5% benzene, 10% toluene, 5% xylene) will be needed.

- ***Meteorological Data***. Selection of appropriate meteorological data is critical for any air modeling project. In many situations, data collected at the nearest Nation Weather Service (NWS) station is adequately representative. However, in some situations (e.g., severely complex terrain such as a source located in a deep river valley) meteorological data from the nearest NWS station may not be representative of the actual conditions. For these more complex situations, it is recommended that the analyst consult with the appropriate EPA regional or state Agency modeling contact for assistance in selecting the most appropriate data. A list of EPA regional and state Agency modeling contacts is provided on EPA's SCRAM website (http://www.epa.gov/scram001/tt28.htm). Additional guidance for preparation of meteorological data for use with Gaussian models is also available on EPA's SCRAM website (http://www.epa.gov/scram001/tt24.htm). The development of 3-dimensional wind fields for more advanced models like CALPUFF and UAM-Tox require the use of a meteorological model, a resource-intensive process. However, the models used for geographic areas that are out of compliance with the tropospheric (ground-level) ozone NAAQS also use 3-dimensional wind fields, so that for such areas at least some of the requisite meteorological data may already be available.

- ***Secondary Pollutants***. When the analysis needs to evaluate the production of secondary pollutants, the input to the model will need to include emissions of precursor compounds. The precursors for many of the secondary air toxics are generally contained in emission inventories developed for modeling tropospheric ozone, which is also a secondary pollutant. For such areas a precursor inventory that can be used to model secondary air toxics of interest may be available. Examples of secondary pollutants and the emitted pollutants from which they are formed are provided in the accompanying text box. A technical discussion of the formation of secondary pollutants is provided in ATRA Volume 1, Chapter 8.

5.2.3 Special Considerations

When performing a multisource assessment, there are several special considerations that should be noted. Some of these flow from the need to meet study-specific DQOs; others relate to the computational requirements of evaluating and tracking a large array of chemicals and release points. Several special considerations that commonly occur are emissions partitioning, the use of unit emissions rates, working with a "universal grid," bounding analyses for non-point sources, and dealing with background concentrations; other considerations may also need to be addressed depending on the model and technical approach implemented.

5.2.3.1 Emissions Partitioning

To account for the partitioning of emitted contaminants among various physical phases in the ambient air after release in both Gaussian and puff models, it is important to consider the need to conduct separate air modeling runs to represent partitioning to the vapor phase, particle phase, and particle-bound phase. Partitioning of emitted contaminants is of particular concern when a contaminant is released as a particle, or has a portion of its mass adhered onto particles because the fate of emitted pollutant mass can be sensitive to the deposition and removal processes.

The tendency of a contaminant to be present in a particular phase (i.e., as a vapor, as a particle, or adsorbed onto existing particles) can be expressed as the fraction of the air concentration of the contaminant in the vapor phase, F_v, as follows:

- All contaminant in the vapor phase: $F_v = 1.0$
- Some contaminant in the particle-bound phase: $0 < F_v < 1.0$
- All contaminant in the particle phase: $F_v = 0$

The vapor phase is used to evaluate volatile organic compounds (VOCs) that are assumed to occur in the vapor phase (i.e., contaminants with $F_v = 1.0$).

The particle-bound phase is modeled to evaluate the fraction of organic contaminants that upon release to the atmosphere have condensed onto the surface of associated particles (i.e., contaminants with F_v between 0 and 1.0). The portion of contaminants in the particle-bound phase is dependent on the particle surface area available for chemical adsorption.

The particle phase is modeled when evaluating metals and organic contaminants with low volatility that are assumed to occur in the particle phase (i.e., contaminants with $F_v = 0$). Particle size is the main determinant of the dispersion and deposition of particles in the emission, whether wet or dry deposition.

Processes that Alter Atmospheric Concentrations of Chemicals

A variety of physical and chemical processes can affect the fate and transport of toxic pollutants in the atmosphere. For example, dry and wet deposition reduce atmospheric pollutant concentrations in the absence or presence of precipitation, respectively. Another mechanism for pollutant removal is by chemical reactions in which a toxic air pollutant is destroyed through the action of sunlight, through reactions with atmospheric chemical pollutants, or through a combination of these pathways. Yet another possibility is for potentially harmful pollutants to be formed as a result of atmospheric chemical reactions (a process that is called secondary production or secondary formation - see examples below). Analysts are encouraged to understand the capabilities of the various fate and transport models to account for chemical removal and formation and to carefully articulate the uncertainties in the resulting concentration estimates based on the tools selected for a given assessment. (A more thorough discussion of fate of air toxics in the atmosphere is provided in ATRA Volume 1, Section 8.3.)

Examples of Secondary Pollutants

Secondary Pollutant	Formed From
acetaldehyde	propene, 2-butene
acrolein	1,3-butadiene
carbonyl sulfide	carbon disulfide
o-cresol	toluene
formaldehyde	ethene, propene
hydrogen chloride	nitric acid, chlorinated organics
methylethyl ketone	butane, branched alkenes
N–nitroso-N–methylurea	N–methylurea
N–nitrosodiethylamine	dimethylamine
N–nitrosomorpholine	morpholine
phosgene	chlorinated solvents
propionaldehyde	1-butene

Source: Rosenbaum, A.S., Ligocki, M.P., and Wei, Y.H. 1998. Modeling Cumulative Outdoor Concentrations of Hazardous Air Pollutants, Volume 1: Text. SYSAPP-99-96/33r2. Prepared for U.S. EPA, Office of Policy, Planning and Evaluation, by Systems Applications International, Inc., San Rafael, CA. 1998.

A detailed example of the treatment of emissions partitioning in air dispersion modeling is presented in EPA's *Regional Air Impact Modeling Initiative (RAIMI): Standard Screen Analysis Methods, Technical Support Document*, (see http://www.epa.gov/earth1r6/6pd/rcra_c/raimi/raimi.htm). For more information on this and other related subjects, consult the *Guideline on Air Quality Models* (GAQM)[2] on EPA's Support Center for Regulatory Air Models (SCRAM) website (http://www.epa.gov/scram001/index.htm). Guidance materials for the specific models discussed here (e.g., ISCST3, AERMOD, CALPUFF) can also be found on this site.

5.2.3.2 Unit Emission Rates

In standard Gaussian plume models (e.g., ISCST3, AERMOD) and puff models (e.g., CALPUFF), concentration predictions resulting from a release are proportional to the emission rate. That is, for a given set of stack parameters and meteorological conditions, the concentration predicted for an emission rate of 2 g/s would be twice as high as the concentration predicted for an emission rate of 1 g/s.

> **Use of Simplifying Assumptions – A Balancing Act**
>
> Simplifying assumptions – such as the use of a unit emission rate – are sometimes employed to allow for a more efficient assessment. However, the analyst must be aware of the impact of assumptions on the end results (i.e., are they likely to over or underestimate exposures and risks). Overall, it is the planning and scoping team's responsibility to balance the needs of the assessment (embodied by the modeling DQOs) and the desired level of detail with the resources available to complete the assessment. Since some of the people on the planning and scoping team will have little experience in this area, technicians familiar with these issues will need to carefully describe the various options so that the overall planning effort will result in a plan that meets the needs of all team members.

This relationship can be used to minimize computer resources when modeling an emission source that releases more than one pollutant, or if multiple emission rate scenarios need to be evaluated (e.g., reported actual emissions, permitted allowable emissions, revised quantities of emissions due to operational changes, or inclusion of new contaminants in the emissions profile). Instead of estimating receptor concentrations several times, once for each pollutant or scenario, the modeler can estimate concentrations at each grid node receptor for an emission rate of 1 unit, and then scale the receptor concentration prediction by the pollutant emission rate with a post-processor to determine the corresponding prediction for each pollutant. Ultimately, the user need only provide the actual emission rates for each source. Then, as a post-processing step, emission rate scalars are applied to each receptor/source combination, and the concentration contribution from each source is summed for each grid node receptor/pollutant combination.

For example, suppose that a particular stack A emits benzene at a rate of 3 g/s and toluene at a rate of 5 g/s. Furthermore, suppose that the Gaussian model predicts a grid node receptor concentration of 0.4 $\mu g/m^3$ for an emission rate of 1g/s from stack A. With a post-processor, the modeler can scale the predicted receptor concentration to obtain a benzene concentration of 1.2 $\mu g/m^3$ and a toluene concentration of 2.0 $\mu g/m^3$. (This type of relationship is applied in the RAIMI methods using the ISCST3 model.)

In addition to eliminating the extensive effort that would be required to model each pollutant separately, the benefit of this approach is that it provides the flexibility of being able to conduct "what if" scenarios using any combination of new or revised emissions scenarios without having to conduct additional air dispersion modeling of the source. Thus, the same modeling for a source can be used to evaluate that source's potential resulting risks for any combination of emissions scenarios specific to current or anticipated future releases. (Being able to perform such "what if" scenarios would be important for a community that is evaluating both risk mitigation options for current emissions as well as looking at the potential impact of growth in the future.)

Note that proceeding in this manner is not without its limitations. For example, such simplifying assumptions have the tendency to treat all chemicals in a group as equal (e.g., all VOCs behave the same) and does not take into account the different fate and transport characteristics of chemicals once released to the environment. If a more robust analysis of individual constituents is needed, analysts may need to take a different (and likely more computationally challenging) approach. A list of pros and cons of using the unit emission rate approach is provided in the accompanying text box.

5.2.3.3 Using a Universal Grid

Because of the need to integrate several types of geographic information (e.g., location of sources, population data, digital elevation data, land use) for a multisource modeling analysis, defining a "universal grid" system for the entire project provides increased efficiency. The "universal grid" system selected should be a standardized geographic coordinate system consistent to all geographic-based data. A convenient choice is the NAD 83 latitude/longitude curvilinear (datums such as NAD83 are discussed in Section 5.1.3.2), which provides this consistency and efficiency since it is the system that is used by the U.S. Geological Survey (USGS) for land use/land cover, digital terrain, aerial photographs and feature maps (http://biology.usgs.gov/geotech/documents.html). Because the latitude/longitude system is not limited in spatial extent, it also allows for seamlessly tracking source locations and integrating air model and risk characterization results over distances greater than ten kilometers, typical of community scale analyses. However, distances and areas cannot be measured accurately in a latitude/longitude system. An alternative choice would be the Universal Transverse Mercator (UTM) system (http://erg.usgs.gov/isb/pubs/factsheets/fs07701.html) used by most air dispersion models [the UTM system is rectilinear (as opposed to the curvilinear system), which therefore limits the size of the modeling region to some extent, but provides accurate area and distance measurements within the modeling region]. For the air modeling portion of community scale risk assessments, some air models require temporary conversion of latitude/longitude coordinates into a rectilinear system to satisfy the mathematical assumption in the air model. For example, RAIMI utilizes the UTM system to satisfy this computational requirement of the ISCST3 air model before converting the air model results at grid nodes back into the Universal Grid system. This integrated universal grid approach, as implemented in the RAIMI methodology, further supports special spatial processing capabilities, such as risk averaging across and between grid nodes (i.e., RAIMI approach for determining average exposure concentration or risk values for census blocks).

Once a coordinate system is selected, it can be used to define a reference set of locations that span the modeling region in the form of a grid. Required geographic-based data, such as terrain elevations and land use/land cover, are specified for each grid node. These grids nodes may also be used to define the modeling receptors, or the grid cell centroids for a numerical grid model to avoid the necessity for data interpolation.

Automating the Process: The RAIMI ISCBatch and Air2GIS

ISCBatch allows the user to execute several ISCST3 air modeling runs in a single "batch run." For each run that is completed as a part of this "batch," the air model generates results for each grid node (approximately 7,500-8,000 nodes) including a discrete value for the one-hour average air concentration for use in acute risk assessment, and annual average values for air concentration, dry deposition, and wet deposition for use in chronic risk assessment.

AIR2GIS is a software tool that assembles the ISCST3 modeling output files for each modeled source and creates a single file for import into the Risk Management Analysis Platform (Risk-MAP; discussed in Chapter 6). This allows the user to track results for each source and grid node location using Risk-MAP.

For more information on the RAIMI ISCBatch and Air2GIS, see: http://www.epa.gov/earth1r6/6pd/rcra_c/raimi/raimi.htm.

5.2.4 Dealing with Background Concentrations

An important consideration for both the understanding of study area cumulative risk and for the evaluation of model performance is the ***background concentration*** of toxic chemicals in study area air. The term background concentration is used here to mean the ambient pollutant concentration that would occur in the study area in the absence of the emission sources being explicitly evaluated in the air dispersion modeling effort. Example components of background concentrations may include (1) local emission sources not included in the model inputs, (2) emissions transported from sources outside of the modeling domain, including those immediately upwind of the study area and those more distant, and (3) historical releases of persistent compounds.

The Importance of Background Concentrations

Depending on the circumstances, the background concentration of a chemical in an area may be trivial compared to the influence of local emissions sources or it may dwarf the local sources (potentially making the estimated risk using only the local inventory of source substantially different from the cumulative risk from air toxics actually present). Likewise, the air dispersion model predictions of ambient concentration based on only local emission sources may be difficult to compare with measured concentrations since measured concentrations capture all sources influencing the monitor, including background sources. The planning and scoping team should keep this in mind as they develop their analysis plan in order to allow for the development of an appropriate level of understanding of potential background concentrations.

The first component can be addressed by creating as comprehensive a local emission inventory as possible. There are several approaches for addressing the second component, (i.e., medium- and long-range transport). One way is to estimate the value of this component from upwind measurements, if available. However, this approach can be difficult to interpret if there are several dominant wind directions for the modeling region. An alternative approach is to estimate the value on the basis of model predictions. Still another approach is to expand the modeling domain to include all significant medium- to long-range emission sources, if possible. Regarding the third component, upwind measurements or estimates of regional background concentration may be available from the

Using a Unit Emission Rate: Pros and Cons

Use of a unit emission rate in air dispersion models offers advantages in terms of flexibility and efficiency, but also potential drawbacks with respect to accuracy and data management. A few of the key pros and cons are summarized here.

Pros:

- Emissions tracking is maintained in a separate database by emissions specialists, which helps minimize the need to repeat air modeling. For example, if a stack location is incorrectly reported in an emissions inventory for one source, only that source will need to be modeled again, rather than re-modeling all sources.

- Automated generation of air model input files is simplified by not tracking and integrating emissions databases.

- Air modeling can proceed with source parameters while emissions data inventories are assembled and verified in parallel, rather than sequentially. Thus, the project performance schedule and expertise are managed in parallel, accelerating project schedules and allowing functional performance to be completed by specialists in their disciplines.

- For sources run at unit emission rates, separate air model runs can be performed to account for the different reaction rates in the atmosphere of various chemicals emitted. For example, if the source emits both high and low reactivity chemicals, two separate air model runs with appropriate reaction rates for that source will account for the chemical transformation. The emission rate for the highly reactive chemical is multiplied by the air parameter results from the highly reactive run, and the emission rate for the low reactivity chemicals is multiplied by the results from the low reactivity run.

Cons:

- Air modeling of individual sources requires data management during execution as well as results tracking for integration with emissions data as a post-processing step.

- File management is more complex compared to traditional air modeling, where all sources are compiled at specified emission rates into large single runs.

- When air modeling at 1 g/s for all sources, if a source has very low impacts (i.e., tall stacks impacting grid nodes long distances from release) the source impacts will not be correctly indicated when multiplying impacts at or near the computational limit of the model by the actual emissions. For long distances (greater than about 10 km) or tall stacks, all unit emission rates could be increased to 10, 100 or 1000 g/s for all sources.

- If sources are run in a single pass assuming no chemical transformation takes place (e.g., degradation or secondary formation), the air parameters from the air model will be slightly over-predicted or under-predicted, depending on the reactivity rate of the specific chemical and travel times in the atmosphere after release.

literature. As such, it may be most appropriate to communicate this information by developing a side-by-side comparison of the estimates of background concentration and risk to estimates of study area risk developed through the modeling exercise. An example approach for communicating information about background risk is provided in Section 6.2.2.

5.3 Estimating Inhalation Exposure

At the end of the dispersion modeling portion of the analysis, the risk assessment team will have estimates of chemical concentration at specified points throughout the study area. This section discusses how to take the results of the air dispersion modeling to the next step of the analysis - estimating exposure. The background for this discussion is found in ATRA Volume 1, Chapter 11, and analysts are encouraged to become familiar with that chapter before proceeding. Another key resource is EPA's *Guidelines for Exposure Assessment* (http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=15263).

Information on Background Concentrations

Several important information sources on general background concentrations are provided below. Additional information on background concentrations may be available in the scientific literature. Background information for a specific community can also be developed de novo, typically by monitoring.

NATA National-Scale Risk Characterization

The 1999 national-scale assessment provides background concentrations for 13 air toxics based on available monitored data. For the remainder of the air toxics in the assessment, EPA used values reported in technical literature as identified in the Cumulative Exposure Project (CEP; 15 air toxics), or the background concentration was assumed to be zero (105 air toxics) if no values were reported in the CEP. The values taken from the CEP were based on technical literature and are not representative of any particular year. For all 28 air toxics with estimated background concentrations, each census tract in a county is assigned the same county-specific background concentrations. The total estimated concentration for each pollutant in each census tract is the sum of the background and the modeled concentrations (from modeled emission sources). For a list of pollutants and background concentration distributions, see http://www.epa.gov/ttn/atw/nata1999/background.html.

ATSDR Toxicological Profiles

Estimates of ambient background concentrations for 275 substances are provided in the ATSDR Toxicological Profile series: http://www.atsdr.cdc.gov/toxpro2.html.

5.3.1 Inhalation Exposure Assessment DQOs

For the estimated ambient concentrations to be of use in evaluating exposures, they will have to meet certain minimum DQOs.[e] And like the other DQOs discussed in this chapter, a quick review will show the linkages back to the DQOs for emissions characterization and air dispersion modeling.

- **Time scale used to estimate exposure concentrations**. The ambient concentration estimates derived from air dispersion modeling must be pertinent to the time frames of the exposure periods of interest. Commonly, the air dispersion modeling should provide, at a minimum, an annual average concentration for an evaluation of chronic exposures.

  The model may also need to provide shorter term concentrations for an analysis of acute exposures. It is important that the planning and scoping phase of the assessment perform an analysis of the available acute toxicity data for the chemicals to be evaluated to identify the most pertinent averaging times to be produced by the dispersion modeling. Ideally, the averaging times of the acute toxicity values and those produced by the model should match. For example, an acute toxicity reference concentration with a one-hour averaging time should be compared to an estimate of ambient concentration that also has a one-hour averaging time.

- **Spatial scale**. The air dispersion modeling should provide estimates of ambient concentration at predetermined points throughout the modeling domain where the assessment of exposure is desired. This will commonly include all the points on the modeling grid, but may also include additional points such as census tract internal points, census block internal points, and special locations such as schools, hospitals, day care centers, and retirement centers.

- **Population activity data**. If an exposure model is subsequently applied to the air dispersion modeling results (see ATRA Volume 1, Chapter 11), it is important to assess whether the resolution of the emissions inventory, meteorological data, and activity patterns are temporally matched. For example, most emissions data are reported as a single aggregate amount released per year (e.g., tons per year). The exposure model, on the other hand provides activity patterns that may be reflective of hourly, daily, or seasonal time scales. emissions data, may result in misleading answers. Analysts need to carefully assess whether the application of an exposure model will provide any additional useful information (i.e., whether their DQOs for this exercise are achievable).

- **Analytical framework**. The DQOs developed for a study will depend on whether the analytical framework is deterministic (i.e., inputs and outputs are discrete, or "point" values) or stochastic (i.e., inputs and outputs are characterized by distributions representing variability and/or uncertainty). For example, when probability density functions (PDFs) are

[e] Model outputs are not truly "data" (although they are often referred to as such) because they are estimates of a value based on modeling rather than a measurement; therefore, it is not technically accurate to refer to data quality objectives for modeled exposure estimates. In this section, however, the phrase "DQO" is applied to exposure assessment for simplicity and consistency.

used to represent a particular activity pattern for individuals in a population, the DQO may stipulate the certainty associated with that PDF.

5.3.2 Developing the Exposure Concentration Estimates

The term *exposure concentration* (EC) is used to describe the concentration of a chemical in its transport or carrier medium (i.e., an environmental medium such as air or contaminated food) at the point of contact. This concentration can be either a monitored or modeled value and may or may not have been refined by the application of an exposure model. Some of the more common ways of developing an EC are provided in Exhibit 5-2 above. A background discussion on ECs is provided in ATRA Volume 1, Section 11.2.

Utilizing the unit emission rate approach discussed previously, the determination of the ambient concentration for each toxic air pollutant is typically a two-step process. First, the air dispersion modeling analysis computes the unit ambient concentration for each chemical for each point in the study area that was modeled. Each source (or group of sources) is modeled individually using this approach. This results in a unit ambient concentration from each source at each of the assessment point(s) of interest for each toxic air pollutant. For example, in a study area with 30 different sources, this step would require 30 separate air model runs.[f]

Second, the total ambient concentration for a specific toxic air pollutant at each assessment point may now be determined. For each source (or group of sources), the unit ambient concentration from the air modeling at each assessment point is multiplied by the emission rate of the specific toxic air pollutant. The resulting product is the ambient concentration for that specific toxic air pollutant at each assessment point from that source. The sum of the ambient concentrations for all sources of the specific toxic air pollutant at each assessment point is the predicted ambient concentration for that specific toxic air pollutant. This procedure is repeated for all air toxics of interest by multiplying the source-specific emission rate for each toxic air pollutant for each source by the unit ambient concentration from the air modeling for each source, and summing the products.

The resulting ambient air concentrations are then used to determine the EC in one of two ways (see Exhibit 5-8):[g]

- **Use the Unmodified Ambient Air Concentrations as a Surrogate for Exposure**. Concentrations of air toxics estimated by air dispersion models and/or measured at specific locations are often used as surrogates for the inhalation EC for the populations in the study locations. When used in a chronic lifetime exposure assessment, the underlying assumption, which should be made clear among the risk assessment team and explicitly stated in the risk characterization, is that the population of concern is breathing outdoor air continuously at the

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[f] As noted previously, each combination of source and chemical emitted can be modeled without the use of unit emission rates. This approach allows for more refined modeling techniques (e.g., accounting for chemical-specific degradation characteristics) but also results in a greater number of model runs.

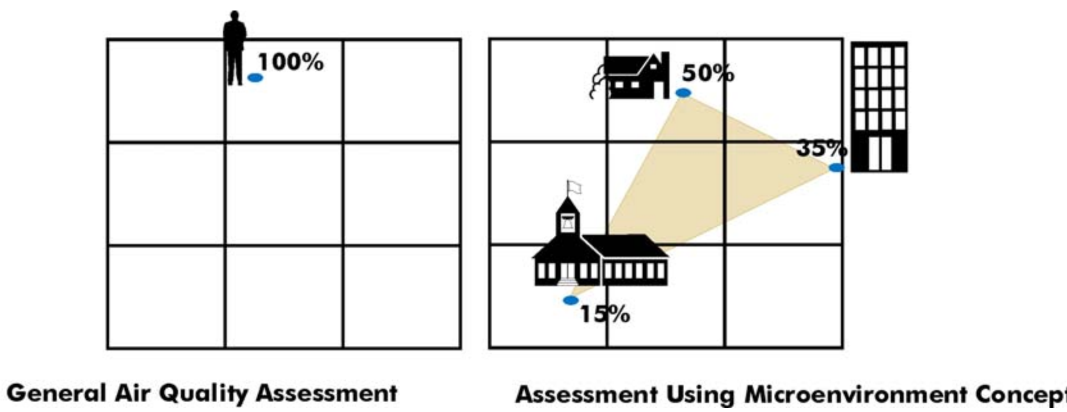
[g] This process can be done manually (with off-the shelf computer tools such as a spreadsheet) or it can be done automatically by some existing air toxics modeling tools (such as those in the RAIMI toolbox). When there are many sources and chemicals in an area, it is recommended that analysts consider using tools that have been specifically designed for this task.

specified location in question for a lifetime. As such, risk estimates developed using this approach are necessarily "screening-level" estimates of risk.

- **Refine the Ambient Air Concentration through Application of an Exposure Model** (e.g.,TRIMExpo, HAPEM5; see http://www.epa.gov/ttn/fera/). Concentrations of air toxics estimated by air dispersion models at specific locations are combined with demographic information about people in the study area, their activity patterns, and microenvironment concentrations. The assessment objective is to develop a refined estimate of EC by taking into account the different concentrations in the different locations (or microenvironments) in which people in the study area interact with the contaminated air being evaluated (see Exhibit 5-8). A more complete discussion of exposure modeling is provided in ATRA Volume 1, Chapter 11.

A **microenvironment** is a small 3-dimensional space (e.g., an office, a room in a home, a garden, a car) in which people spend their time during their daily routine that is treated as homogeneous (or well characterized) with regard to the exposure concentration for one or more air pollutants.

Exhibit 5-8. Two General Ways to Estimate Inhalation Exposure Concentration



The left-hand side illustrates the use of ambient air concentrations as a surrogate for the EC. In this example, the analysis assumes that individuals spend 100 percent of their time at a given location, so the estimate of ambient concentration = EC. The right-hand side illustrates the use of exposure modeling. In this example, the analysis assumes that an individual spends 50 percent of his/her time at home; 15 percent at a school; and 35 percent at an office. The exposure model also takes into consideration that the indoor air concentrations at each location (indoor microenvironment) are different than the corresponding outdoor ambient air concentrations. The EC is the weighted sum of the product of the ambient concentrations at each location and the amount of time spent there. Both outdoor and indoor concentrations of air are usually considered at each location (see ATRA Volume 1, Chapter 11).

5.3.3 Representing Exposures in the Study Area

At the end of the air dispersion modeling study (and possibly after the further application of an exposure model), the analysts will be in a position to describe exposures across the study area. There are many ways to do this, such as evaluating exposure at specific locations (e.g., the areas with the highest or lowest predicted ECs). Descriptions of exposures may be limited to all residentially zoned areas or may focus specifically on locations where people are known to currently reside. In contrast, some assessments may decide to also display exposures at businesses in the area or at more generalized points (e.g., a census tract centroid). Other options for displaying exposure include isopleths of EC and population exposures (i.e., the numbers of people at a given exposure level). The ways to represent exposure are analogous to risk representations. An introduction to this topic is provided in ATRA Volume 1, Chapter 13 and illustrated further in the next chapter.

5.4 Toxicity Assessment

The purpose of the toxicity assessment is to weigh available evidence regarding the potential for toxicity in exposed individuals (**hazard identification**) and to quantify the toxicity by deriving an appropriate dose-response value (**dose-response assessment**). Much of the work of identifying the potential health effects of common urban pollutants and developing toxicity factors for them has already been accomplished. EPA has identified the resulting peer-reviewed toxicity information and dose-response values for these chemicals at http://www.epa.gov/ttn/atw/toxsource/summary.html. Where multiple sources of this information are available for a particular chemical, a hierarchy has been applied for the purposes of screening level assessments. (Note that these and other toxicity values are subject to change as new information and analyses become available, and the analyst is encouraged to check for the most recent data when carrying out an assessment.) For more complex, refined risk assessments (i.e., those developed to support regulatory decisions for particular sources or substances), analysts may evaluate dose-response in detail for each "risk driver" to incorporate appropriate new toxicological data.

In most air toxics risk assessments, the development or evaluation of new toxicological data will not generally be required. However, it is important for analysts to understand how the available toxicity data were developed in order to both select and use toxicity values appropriately and to be able to describe their associated uncertainties (see ATRA Volume 1, Chapter 13). A basic understanding of toxicity assessment will also aid in identifying and filling significant data gaps, interpreting the results of the risk analysis, and communicating the results to stakeholders. To that end, ATRA Volume 1, Chapter 12, is repeated here to provide an overview of this topic. (Stakeholders are cautioned that the evaluation and interpretation of toxicity data for risk assessment purposes generally requires specialized toxicological expertise; as such, a toxicologist with the appropriate background should be part of the partnership team.)

5.4.1 Hazard Identification and Dose-Response Information

As part of the hazard identification step, evidence is gathered from a variety of sources regarding the potential for an toxic air pollutant to cause adverse health effects in humans. These sources may include human data, experimental animal studies, and supporting information such as *in* *vitro* laboratory tests. The source of data affects the overall uncertainties in the resulting human dose-response values, as discussed below.

- **Human data**. Human toxicity data associated with exposures to air toxics may be located in epidemiological studies, controlled exposure studies, or studies of accidental exposures. Well-conducted epidemiological studies that show a positive association between exposure to a chemical and adverse health effects often provide evidence about human health effects associated with chronic exposures. Such data, however, are available only for a limited number of air toxics. Epidemiological data also are very difficult to interpret, because the number of exposed individuals may be small, the incidence of effects may be low, doses are usually not well-characterized, and there may be complicating factors such as simultaneous exposure to multiple chemicals and heterogeneity among the exposed group in terms of age, sex, diet, and other factors. Controlled exposure studies provide stronger evidence, since both the exposure duration and exposure concentrations are more accurately known. However, such studies with humans are generally limited to acute exposure durations. Studies reporting health effects associated with accidental exposures may be helpful, although exposure concentrations to air toxics may be high, and effects may be acute rather than chronic. Also note that small sample size is often a significant limitation to interpreting controlled and accidental exposure studies.

> **Epidemiology** is the study of the distribution and determinants of disease or health status in a population.

- **Animal data**. The toxicity database for most air toxics is drawn from experiments conducted on non-human mammals such as rats, mice, rabbits, guinea pigs, hamsters, dogs, or monkeys. The underlying assumption is that the susceptibility of humans and these animals to the effects of the chemicals is broadly similar because we share many common biological attributes (e.g., similar organs, similar and, in some cases, identical metabolic processes). However, some observations in animals may be of uncertain relevance to humans (e.g., if tumors are observed in an animal experiment, but the organ in which the tumor is formed does not exist in humans). Also, it is necessary to adjust the results from animal studies to humans due to differences in body mass, anatomy, metabolic rate, and other species-specific factors (see, for example, ATRA Volume 1, Section 5.6.3). This is why derivation of dose-response values from animal studies requires considerable expertise.

- **Supporting data**. Metabolic, pharmacokinetic, and genotoxicity studies are sometimes used to infer the likelihood of adverse effects in humans. Metabolic studies on absorption, distribution, metabolism, and elimination can provide information about the mechanisms of toxicity associated with a particular chemical in humans. In physiologically based pharmacokinetic (PBPK) models,[h] the body is subdivided into a series of anatomical or physiological "compartments" that represent specific organs or lumped tissue and organ groups, and the behavior of the chemical is modeled in each compartment. Data on a chemical's pharmacokinetics, genotoxicity, and possible mode of action can be used to refine a toxicity assessment. In some cases, computer models using structure-activity relationships (i.e., predictions of toxicological activity based on analysis of chemical structure) also may

[h] A PBPK model estimates the dose to a target tissue or organ by taking into account the rate of absorption into the body, distribution among target organs and tissues, metabolism, and excretion.

be used as supporting evidence. EPA considers these types of data to be supportive, not definitive, evidence of a chemical's toxicity.

Information from these sources is considered in the hazard and dose-response assessment steps in characterizing a chemical with regard to the type(s) of effect a chemical produces (the hazard) and the circumstances in which this occurs, as well as the level of exposure required to produce that effect. The output of the dose-response assessment is the relationship between **dose** (the level of exposure) and the resulting **response** (the increased incidence and/or severity of adverse effects). A dose-response assessment is the process of quantitatively evaluating toxicity information, characterizing the relationship between the dose of the contaminant received (or the inhalation exposure concentration, for inhalation assessments) and the incidence of adverse health effects in the exposed subjects (which may be animal or human) and then, as appropriate, extrapolating these results to human populations. Depending on the type of effect and the chemical, there are two types of dose-response values that traditionally may be derived: predictive cancer risk estimates, such as the **inhalation unit risk estimate (IUR)**, and predictive non-cancer estimates, such as the **reference concentration (RfC)**.[i] Both types of dose-response values may be developed for the same chemical, as appropriate.

Inhalation Dose-Response Values[a]

Inhalation Unit Risk (IUR): The upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent via inhalation per µg/m^3 over a lifetime. The interpretation of the IUR would be as follows: if IUR = 2×10^{-6} µg/m^3, not more than 2 excess tumors are expected to develop per 1,000,000 people if exposed continuously for a lifetime to 1 µg of the chemical per cubic meter of inhaled air. The number of expected tumors is likely to be less; it may even be none.

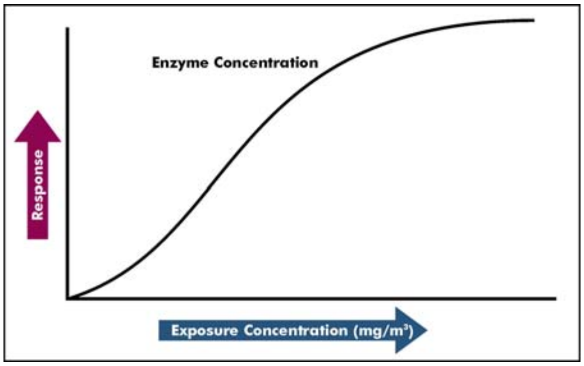
Reference Concentration (RfC): An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive sub-populations) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Generally used in EPA's noncancer health assessments.

[a]The phrase "dose-response" is used generally here and elsewhere in the document. EPA's values for inhalation, however, are derived for exposure concentration, although with consideration of dose. Consideration of the relationship between exposure concentration, dose, and dosimetry (how the body handles a chemical once it is inhaled) is inherent in the derivation of these exposure concentration-response values.

The relationship of dose to response can be illustrated as a graph called a **dose-response curve**. There are two general types of response data that may be considered and graphed. One is termed "continuous" and refers to responses such as the severity in changes to a physiological parameter in a given individual as dose increases (see Exhibit 5-9, A) . The second describes the incidence of a particular response in a population (see Exhibit 5-9, B). By convention, dose or exposure is represented on the x-axis; response on the y-axis (Exhibit 5-9).

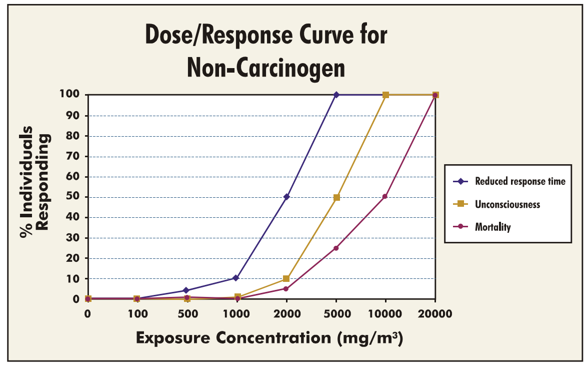
[i] While the majority of RfCs are derived for effects other than cancer, RfCs may be derived for all effects, including cancer, when a non-linear mode of action has been demonstrated for carcinogenicity.

Exhibit 5-9. Examples of Dose-Response Curves



A. Continuous Response Data

Simple example of a dose-response curve for graded responses of a specific physiological parameter to increasing exposure.



B. Different Responses in a Population

Simple example of the incidence of three different effects in an exposed population in response to different exposure concentrations (over the same duration).

While the primary focus of this chapter is on description of dose-response values relevant to chronic (long-term) exposures, the information reviewed for developing those values may include effects associated with acute (short-term) exposures. Additionally, information on acute exposures is essential to the development of acute exposure reference values (see Section 5.9).

- **Acute exposures** are usually relatively short in duration, but relatively high in concentration and may result in immediate respiratory and sensory irritation, chemical burns, narcosis, eye damage, and various other effects. Acute exposures also may result in longer-term health effects.

- **Chronic exposures** are usually relatively long in duration, but relatively low in concentration and may result in health effects that do not show up immediately and that persist over the long term, such as cardiovascular disease, respiratory disease, liver and kidney disease, reproductive effects, neurological damage, and cancer.

Generally, chronic reference values are derived for exposure periods between seven years and a lifetime. Acute reference values (see Section 5.9) are generally developed for very short exposures (e.g., hours to days; Exhibit 5-10). For intermediate exposures, subchronic reference values are available from some sources (e.g., ATSDR). Most air toxics risk assessments will focus on chronic and acute evaluations; however, under more limited circumstances, subchronic evaluations may be performed.

Exhibit 5-10. Reference Values of Different Durations
In the Agency's *Review of the Reference Dose and Reference Concentration Processes*,[3] it was recommended that in addition to the traditional chronic reference value (i.e., RfC or RfD) included in the IRIS database, values of several shorter durations also be developed, where possible. As a first step in this direction, the *Review* proposed the following definitions. EPA currently is considering these and other recommendations made in the *Review*. These definitions are based on exposure durations for humans, and were not intended to be rigid specifications, but simply general descriptions of the relevant exposure time period. • **Acute**: Exposure by the oral, dermal, or inhalation route for 24 hours or less. • **Short-term**: Repeated exposure[a] by the oral, dermal, or inhalation route for more than 24 hours, up to 30 days. • **Longer-term**: Repeated exposure by the oral, dermal, or inhalation route for more than 30 days, up to approximately 10 percent of the life span in humans[b] (more than 30 days up to 90 days in typically used laboratory animal species[©]). • **Chronic**: Repeated exposure by the oral, dermal, or inhalation route for more than approximately 10 percent of the life span in humans (more than approximately 90 days to 2 years in typically used laboratory animal species).
[a]A repeated exposure may be either continuous, periodic, or intermittent. A continuous exposure is a daily exposure for the total duration of interest. A periodic exposure is one occurring at regular intervals (e.g., inhalation exposure 6 hours/day, 5 days/week; or oral exposure 5 days/week). An intermittent exposure is one in which there is no effect of one exposure on the effect of the next; this definition implies sufficient time for the chemical and its metabolites to clear the biological system before the subsequent (i.e., noncumulative pharmacokinetics). A periodic exposure may or may not be intermittent. [b]An average of 70 years is typical default used for chronic exposures. [c]Examples of typically used laboratory species include rats, mice, and rabbits.

5.4.2 Dose-Response Assessment Methods

Depending on whether a substance causes cancer and whether its dose-response curve is thought to have a threshold, EPA may use either of two approaches in a dose-response assessment. One approach produces a predictive estimate (e.g., inhalation cancer risk estimate), and the other produces a reference value (e.g., RfC). Historically, the use of a predictive estimate has been limited to cancer assessment. That is, dose-response assessments for cancer have been expressed as predictive cancer risk estimates based on an assumption that any amount of exposure poses some risk. Assessments of effects other than cancer usually have been expressed as reference values at or below which no harm is expected. Many substances have been assessed both ways: the first for cancer and the second for adverse effects other than cancer. While this use of predictive estimates for cancer and reference values for other effects is still the practice for the vast majority of chemicals, EPA now recognizes that there are chemicals for which the data support an alternate approach.

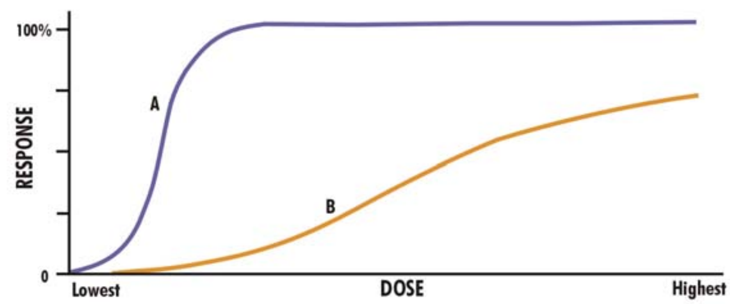
An important aspect of dose-response relationships is whether the available evidence suggests the existence of a threshold. For many types of toxic responses, there is a **threshold dose** or dose rate below which there are thought to be no adverse effects from exposure to the chemical. The human body has defenses against many toxic agents. Cells in human organs, especially in the liver and kidneys, break down many chemicals into less toxic substances that can be eliminated from the body in urine and feces. In this way, the human body can withstand some chemical exposure (at doses below the threshold) and still remain healthy. For example, many air toxics are naturally occurring substances to which people routinely receive trace exposures at non-toxic levels.

Identification of a threshold dose depends on the type of response and the way in which the toxic chemical produces it. EPA has developed guidelines[4] for assessing the dose-response for various types of adverse effects, which provide more information about evaluating evidence to determine if a threshold exists.

All substances are poisons: there is none which is not a poison. The right dose differentiates a poison and a remedy.
– Paracelsus

Both the point at which the dose-response curve begins to ascend (its threshold, which may be zero) and the slope of the curve (its steepness) provide information about the toxicity of a chemical (Exhibit 5-11). The potency of a chemical is a measure of its strength as a toxicant compared with other chemicals. Therefore, the lower the threshold dose, the more potent (or toxic) the chemical. The slope of the curve is a measure of the range of doses from the threshold dose (at which the adverse effect is first measured) to the dose at which the effect is complete (i.e., higher doses produce no additional incidence of that effect, although other adverse effects may begin to appear). The steeper the dose-response curve, the smaller the range between the first appearance of an effect and a substantial response.

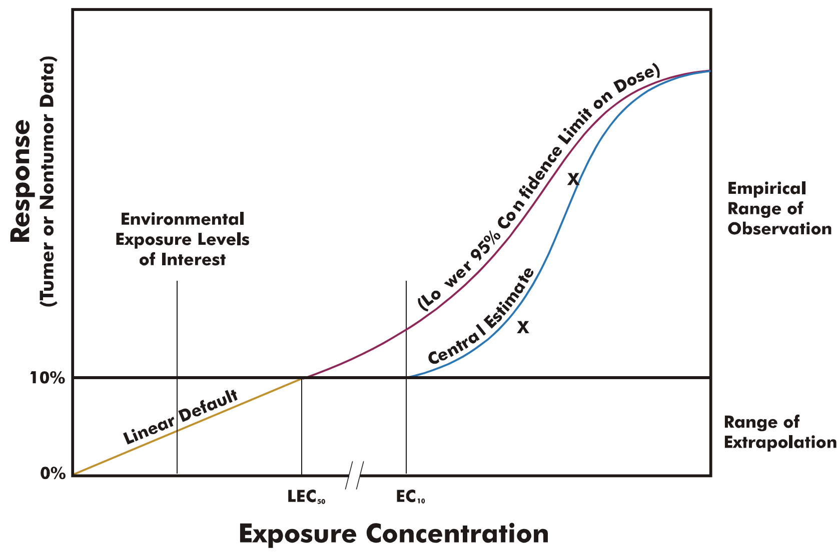
Different Responses Exhibit Different Dose-Response Curves



Line A – A sharp increase in response with increasing dose
Line B – A more gradual increase in response with increasing dose

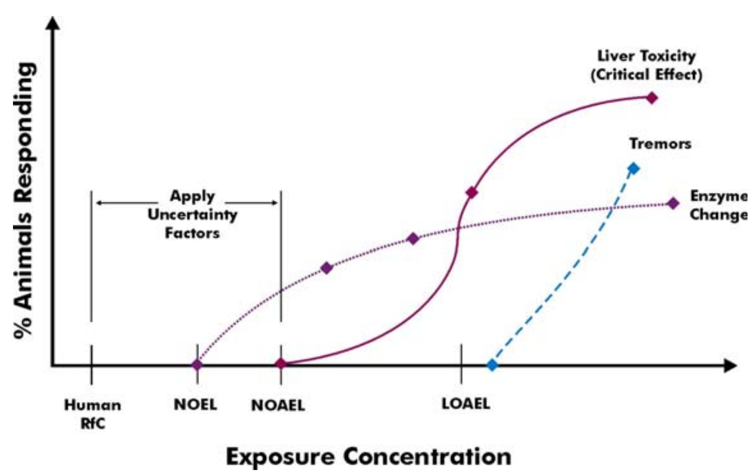
Exhibit 5-11. Dose-Response Relationships for Carcinogens and Noncarcinogens

A. Example Linear Carcinogen



In the absence of clear evidence to the contrary, EPA assumes as a matter of science policy that even a very low exposure to a cancer-causing pollutant can increase the risk of cancer (albeit a small amount). Experimental data are used to construct a dose-response relationship and identify the point of departure – the dose that can be considered to be near or in the range of observed responses and, thus, no significant extrapolation is needed. To estimate the dose-response relationship at doses below the point of departure, the dose-response relationship between the point of departure and zero is assumed to be linear. Thus, at doses below the point of departure, with each unit of increase in exposure (dose), there is an increase in cancer response. Where evidence supports the acceptance of a non-linear mode of action, a reference concentration approach may be employed, as shown in "B" below. LEC_{50}= lethal effective concentration for 50 percent of the population; EC_{10}= effective concentration that causes an observable adverse effect in 10 percent of the population.

B. Example Non-linear Approach



A dose may exist below the minimum health effect level for which no adverse effects occur. EPA typically assumes that at low doses the body's natural protective mechanisms prevent or repair any damage caused by the pollutant, so there is no ill effect at low doses. Even long-term (chronic) exposures below the threshold are not expected to have adverse effects. The dose-response relationship (the response occurring with increasing dose) varies with pollutant, individual sensitivity, and type of health effect. NOEL = no-observed-effect-level; NOAEL = no-observed-adverse-effect-level; LOAEL = lowest-observed-adverse-effect-level.

Epidemiologic and toxicologic data on air toxics typically result from exposure levels that are high relative to environmental levels. Therefore, **low-dose extrapolation** (prediction) is necessary to derive an appropriate dose-response value. For a few air toxics (e.g., the criteria air pollutants ozone and carbon monoxide), data are sufficient to characterize dose-response relationships at environmental levels. In such cases, there is no need for extrapolation of toxicity data to lower doses. Such is not the case for most air toxics. Low-dose extrapolation requires either information or assumptions about the type of dose-response curve likely under low dose situations. EPA risk assessment guidelines provide more detailed information on how EPA performs low-dose extrapolation for chemicals with various toxic effects, such as developmental effects or neurotoxic effects.[(4)]

5.4.3 Hazard Identification

The hazard identification, which is usually part of an existing dose-response assessment for each chemical, provides a summary of the available toxicity information for the air toxics being studied, and includes the weight of evidence determination and identification of critical effects. This step should answer the following questions:

Items to Include in the Hazard Identification of an Air Toxics Risk Assessment

- List of chemicals detected
- Summaries of toxic effects and quality of the toxicological evidence
- Discussion that focuses the risk assessment on chemicals most likely to cause adverse effects

- Can exposure to a chemical be linked causally to particular health effects?

- Could these effects occur at environmentally relevant concentrations?

- What is the nature and strength of the evidence of causation?

By definition, all HAPs and many other air toxics have the potential to cause adverse effects in the exposed population. Exhibit 5-12 provides examples of cancer and non-cancer effects. Appendix C of ATRA Volume 1 identifies which HAPs have been associated with carcinogenic (cancer) effects or non-cancer effects, along with the strength and ratings of the toxicity evidence that has been evaluated by EPA or other international environmental agencies.

Exhibit 5-12. Examples of Adverse Health Effects
• Birth defects • Tremors • Infertility • Skin rash • Melanoma

An air toxics risk assessment should include in its hazard identification a summary of the quality of the toxicological evidence (i.e., the nature and strength of the evidence of causation) for the chemicals of concern. Study factors such as the route of exposure used, the type and quality of health effects, the biological plausibility of findings, and the consistency of findings across studies all contribute to the strength of the hazard identification statement.

5.4.3.1 Weight of Evidence – Human Carcinogenicity

A major determination made during the hazard identification step concerns the potential of a chemical to cause cancer in humans. This determination, which involves considering (or weighing) all the available evidence, is called the weight of evidence determination. This determination is complicated by possible inadequacies of the published studies, as well as differences in body processes between people and laboratory animals. EPA's *Guidelines for Carcinogen Risk Assessment* guide scientists in interpreting available studies to assess the potential human carcinogenicity of environmental pollutants. (EPA's carcinogen risk assessment guidelines were first published in 1986. Revisions were proposed in 1996 and 2001 and the July 1999 draft of the revisions was adopted as interim guidance. A subsequent 2003 draft of the Guidelines has been released for public and scientific review prior to adoption as final. The guidelines are available on the web.)[5] When compared with EPA's original 1986 guidelines, the 1999 interim Guidelines recommend a more comprehensive evaluation of the evidence with regard to a chemical's potential mode of action, and a more complete description of the context of a chemical's carcinogenic potential (e.g., "likely carcinogenic by inhalation and not likely carcinogenic by oral exposure"). The weight of evidence determination now includes one of five descriptors, and is accompanied by additional text that more completely summarizes EPA's interpretation of the evidence. The narrative statements consider the quality and adequacy of data and the consistency of responses induced by the agent in question (see Exhibit 5-13).

Exhibit 5-13. Information Regularly Included in a Narrative Statement Describing the Characterization of Weight of Evidence for Carcinogenicity (1999 Interim Guidelines)

- Name of agent and Chemical Abstracts Services number, if available
- Conclusions (by route of exposure) about human carcinogenicity, using one of five standard descriptors: "Carcinogenic to Humans" "Likely to be Carcinogenic to Humans" "Suggestive Evidence of Carcinogenicity, but Not Sufficient to Assess Human Carcinogenic Potential" "Data are Inadequate for An Assessment of Human Carcinogenic Potential" "Non Likely to be Carcinogenic to Humans".
- Summary of human and animal tumor data on the agent or its structural analogues, their relevance, and biological plausibility
- Other key data (e.g., structure-activity data, toxicokinetics and metabolism, short-term studies, other relevant toxicity or clinical data)
- Discussion of possible mode(s) of action and appropriate dose-response approach(es)
- Conditions of expression of carcinogenicity, including route, duration, and magnitude of exposure

Source: EPA (1999) *Guidelines for Carcinogen Risk Assessment. Review Draft*[5]

The *2005 Guidelines* place particular importance on the consideration of a chemical's mode of action (MOA) and emphasize an analysis of the available data with regard to the key events inherent in how exposure to a chemical results in cancer. In addition to being critical to selection of the dose-response approach (see Section 5.6.3), performance of such an analysis as part of the cancer hazard characterization is critical to the *2005 Supplemental Guidance,* which provides specific guidance on potency adjustment for carcinogens acting through a mutagenic

MOA.[j] [See Farland 2005 memo at http://www.epa.gov/osa/spc/pdfs/canguid1.pdf for information on applying the *Guidelines* MOA framework in determining whether a chemical has a mutagenic MOA).] For example, when assessing cancer risk for exposures early in life for such chemicals, the *Supplemental Guidance* recommends use of default adjustment factors if no chemical-specific data on early life exposure-response were available for use in the development of the dose-response assessment (see Chapter 6 of the *Supplemental Guidance* for more information).[k] Where such data are available, the *Supplemental Guidance* recommends that they be used (regardless of the chemical's MOA) in developing the dose response assessment for that chemical, with attention to any lifestage-specific differences in potency.[l] Information on how the Agency is implementing the *2005 Cancer Guidelines* and *Supplemental Guidance* is available on the Agency's web site (see www.epa.gov/cancerguidelines and http://www.epa.gov/osa/spc/cancer.htm).

Many existing carcinogen assessments were developed pursuant to EPA's 1986 *Guidelines for Carcinogen Risk Assessment,* which used a simpler but less informative weight of evidence system (see Exhibit 5-14).

Information bearing on the qualitative assessment of carcinogenic potential may be gained from human epidemiological data, animal studies, comparative pharmacokinetic and metabolism studies, genetic toxicity studies, structure-activity relationship (SAR) analysis, and other studies of an agent's properties. Information from these studies helps to elucidate potential modes of action and biological fate and disposition.

Upon such consideration, both EPA systems assign a consensus interpretation to the weight of evidence, evaluating the likelihood that the agent is a human carcinogen. Toxicological evidence is characterized separately for human studies and animal studies as: sufficient, limited, inadequate, no data, or evidence of no effect. The characterizations of these two types of data are combined, and based on the extent to which the agent has been shown to be a carcinogen in experimental animals or humans, or both, the chemical is given a weight of evidence classification.

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[j] As explained in the *2005 Guidelines* (p. 1-10), a carcinogenic "mode of action" is a sequence of key events and processes, starting with interaction of an agent with a cell, proceeding through operational and anatomical changes, and resulting in the formation of cancer. Simply stated, the MOA explains processes that may result in disease following chemical interruption of normal cellular activity. Cancer refers to a group of diseases involving abnormal, malignant tissue growth. The development of cancer involves a complex series of steps, and carcinogens may operate in a number of different ways. Ultimately, cancer results from a series of defects in genes controlling cell growth, division, and differentiation. Thus, all cancers caused by chemicals will have mutations. At issue is how the mutations originated, i.e., the MOA. The Agency intends to issue a document describing considerations in assessing the potential for a chemical to have a mutagenic MOA.

[k] For example, when the IRIS assessment for a chemical states that a weight of evidence evaluation supports a determination that a chemical is carcinogenic by a mutagenic mode of action, and chemical specific potency estimates reflecting lifestage susceptibility have not been derived, the risk assessor would utilize that determination and the appropriate application of recommended age dependent adjustment factors with age-specific estimates of exposure and the chemical's IRIS inhalation cancer slope factor (see Chapter 6 of the *Supplemental Guidance*).

[l] In the absence of chemical-specific data indicating differential early-life susceptibility or when the MOA is not mutagenicity, it is the Agency's long-standing science policy position that use of the linear low-dose extrapolation approach (without further adjustment) in the dose-response assessment provides adequate public health conservatism.

Exhibit 5-14. EPA's Weight of Evidence Classification for Carcinogens (1986 Guidelines)	
Group A:	Human Carcinogen (sufficient evidence of carcinogenicity in humans)
Group B:	Probable Human Carcinogen (B1 - limited evidence of carcinogenicity in humans; B2 - sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans)
Group C:	Possible Human Carcinogen (limited evidence of carcinogenicity in animals with inadequate or lack of human data)
Group D:	Not Classifiable as to Human Carcinogenicity (inadequate or no evidence)
Group E:	Evidence of Noncarcinogenicity for Humans (no evidence of carcinogenicity in adequate studies)
Source: EPA (1986). *Guidelines for Carcinogen Risk Assessment*[5]	

Generally, no single factor is determinative. For example, strength of association is one of the criteria for causality. A strong association between exposure and cancer in animals is more likely to indicate causality than a weak association. However, finding of a large cancer incidence in a single study must be balanced against the lack of consistency as reflected by null results from other equally well-designed and well-conducted studies. In this situation, the positive association of a single study may either suggest the presence of chance, bias, confounding factors, or different exposure conditions. On the other hand, evidence of weak but consistent associations across several studies suggests either causality or that the same confounder may be operating in all of these studies.

If information is available to consider the mode of action for carcinogenicity, the carcinogenicity assessment will evaluate that information and draw conclusions that influence the dose-response method for the substance. If the evidence is sufficient to support a conclusion of nonlinear dose-response, then the information on carcinogenicity may be considered in combination with the information on other effects in deriving a reference value such as an RfC (see Section 5.7). Otherwise, a linear dose-response approach leading to a predictive risk estimate, such as an IUR, will usually be pursued. If the information supports it, the guidelines also accommodate the development of a non-linear predictive risk estimate.

Biological Effects of Carcinogens

Carcinogens are chemicals that induce cancers. Examples include:

- *4-Aminobyphenol*, which targets the bladder;
- *Benzene*, which targets the tissue that make white blood cells;
- *Asbestos*, which targets the lung's tissue;
- *Benzidene*, which targets the bladder;
- *Beryllium*, which targets the lungs;
- *Chromium*, which targets the respiratory tract;
- *Radionucleotides*, which targets bone marrow and the lungs; and
- *Vinyl chloride*, which targets the liver.

There are various types of carcinogens, including:

- **Primary Carcinogens**: A primary carcinogen is a substance that is carcinogenic as it occurs in the environment.
- **Procarcinogen**: A procarcinogen is a substance that becomes carcinogenic only after conversion from some benign form. Most environmental carcinogens are of this type.
- **Cocarcinogen**: A cocarcinogen is a substance that is not carcinogenic by itself, but potentiates the carcinogenic effect of other chemicals.

Chemicals also can serve as **mutagens**, causing changes in genetic material that can disrupt cell function and lead to cancer or other health problems.

5.4.3.2 Identification of Critical Effect(s) – Non-Cancer Endpoints

As part of the characterization of the available information on non-cancer health effects (or including cancer, if a threshold mode of action has been established), the targets of chemical toxicity within the body are identified, along with what have been termed "critical effects" associated with the toxicity. A **critical effect** is described as "either the adverse effect that first appears in the dose scale as dose is increased, or as a known precursor to the first adverse effect." Underlying this designation is the assumption that if the critical effects are prevented, then all other adverse effects observed at higher exposure concentrations or doses are also prevented.[m] Note that not all observed effects in toxicity studies are considered adverse effects. The identification of the critical effect(s) depends on a comprehensive review of the available data with careful consideration of the exposure conditions associated with each observed effect, so that comparisons of effect levels or potential reference values are made on a common basis (see Section 5.7). A more comprehensive discussion of hazard identification and the evaluation of the underlying database for non-cancer effects is included in the EPA documents *Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry* (1994) and *A Review of the Reference Dose and Reference Concentration Process* (2002).[6]

[m] A similar, more recent term, "key event," is defined as "an empirically observed precursor" to an adverse effect (e.g., liver cancer or other liver toxicity) consistent with a particular mode of action. The phrase "mode of action" refers to the way a given chemical may act in the body to initiate one or more adverse effects.

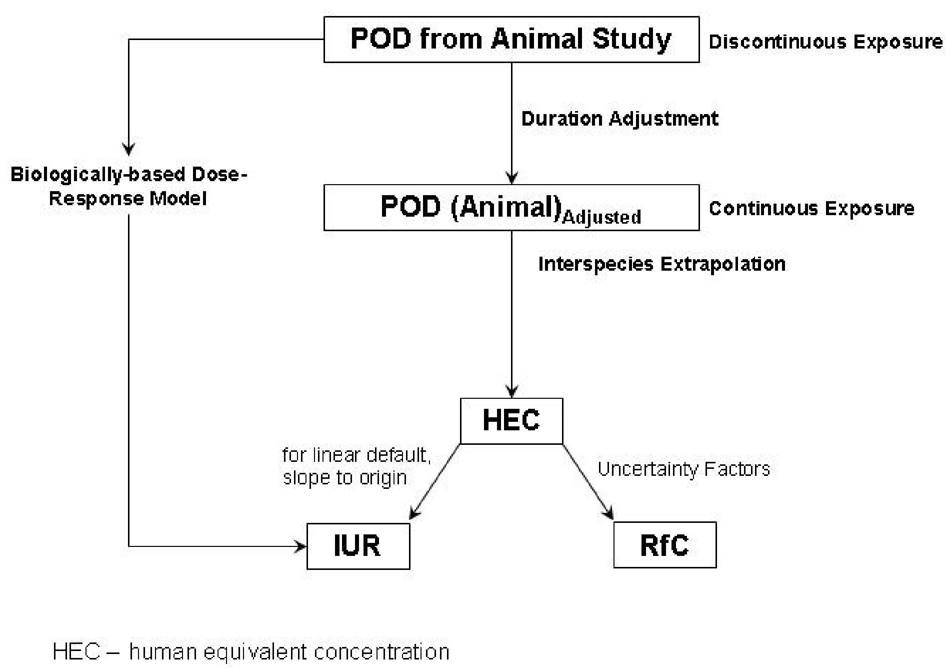
5.4.4 Dose-Response Assessment for Cancer Effects

The process for deriving a quantitative dose-response estimate for cancer (e.g., a cancer slope factor) involves the following three steps:

1. Determination of the concentration associated with the point of departure or POD (Section 5.6.1);
2. Derivation of the human equivalent concentration corresponding to the POD (Section 5.6.2); and
3. Extrapolation from the POD (expressed as human equivalent concentration) to derive carcinogenic potency estimates (Section 5.6.3).

The first two steps are also performed in the derivation of reference values such as the RfC (Exhibit 5-15); in that case, these steps are followed by the application of uncertainty factors (see Section 5.7).

Exhibit 5-15. Steps involved in deriving an RfC or IUR From an Animal Study



5.4.4.1 Determination of the Point of Departure (POD)

Dose-response assessment for cancer and other effects begins with identification of the point of departure (an exposure concentration or intake) from the experimental data. This point (in terms of its human equivalent), while within the range of observation, is the point from which extrapolation begins, either for the purposes of deriving a cancer risk estimate (the IUR) or a RfC for non-cancer health effects.

Example POD for Benzene

EPA's characterization of the carcinogenic effects of benzene was updated in 1998. The IUR for benzene is based on epidemiologic studies showing clear evidence of a causal association between exposure to benzene and leukemia. The specific mechanisms by which benzene and its metabolites lead to cancer remain uncertain.

EPA selected the Rinsky et al. 1981 epidemiologic study of 1,165 Pliofilm rubber male workers at three facilities in Ohio as the data set for the dose-response relationship for determining the IUR. The workers had been employed between 1940 and 1965 and were followed through 1981. Rinsky et. al. expanded the study to include additional workers and published it in 1987. The Rinsky data suffers - as many epidemiologic studies do - from uncertainties about exposure levels in the early years. There are no measurements of benzene in the facilities' air prior to 1946, so exposures for these years must be estimated.

Using one set of exposure estimates with the Rinsky et al. study, EPA concluded that exposure to benzene increases the risk of leukemia at a level of 40 ppm-years of occupational exposure (8 hours/day, 5 days/week, 50 weeks/year). Below this number, the shape of the dose-response curve cannot be determined. Converting the occupational exposure of 40 ppm-years to an equivalent lifetime of environmental exposure yields 120 ppb, as a POD, below which the shape of the dose-response curve is uncertain.

EPA decided there is not sufficient evidence to demonstrate that the dose-response relationship below the POD is non-linear. As a science policy default, EPA assumed low-dose linearity for extrapolation from the POD to zero. Given a range of plausible exposure estimates for the Rinsky et al. study, the Agency determined that the benzene inhalation unit risk at 1 $\mu g/m^3$ ranges from 7.1×10^{-3} to 2.5×10^{-2} depending on the exposure estimates and modeling approach used to derive the POD.

Source: U.S. EPA. 1998. *Carcinogenic Effects of Benzene: An Update*. Office of Research and Development, National Center for Environmental Assessment, Washington, D.C. EPA/600/P-97/001F.; Rinsky, R.A., Young, R.J., and Smith, A.B. 1981. Leukemia in benzene workers. *American Journal of Industrial Medicine*. 2(3) 217:245.

The POD may be the traditional no observed adverse effect level (NOAEL), lowest observed adverse effect level (LOAEL), or **benchmark concentration (BMC)**.[n] EPA has recommended the use of the BMC approach, where possible, because the traditional use of the LOAEL or NOAEL in determining the POD has long been recognized as having several limitations (and generally is not used in dose-response for cancer effects. In particular, the LOAEL-NOAEL approach:

[n] Note that the corresponding value for ingestion exposures is the benchmark dose (BMD). This often is used as the general term for the BMC/BMD process.

- Is limited to one of the doses in the study and thus is dependent on study design;
- Does not account for variability and uncertainty in the estimate of the dose-response relationship;
- Does not account for the slope of the dose-response curve; and
- Cannot be applied, where there is no NOAEL, except through the application of an uncertainty factor.

If the dose-response data are of high quality, a mathematical dose-response model may be fitted to the data to determine a more precise POD than the NOAEL or LOAEL. When a model is used, the POD is calculated as the statistical lower confidence limit of the dose at which there is a low toxic response (usually 5 or 10 percent incidence in populations with an effect or a change in a physiological measurement indicating adversity).(7) The selection of the response percentage is intended to coincide with the sensitivity limit of the experimental design or professional judgment. This calculated POD is called the BMC.

The BMC approach is an alternate way of determining the point of departure for low-dose extrapolation. It can be used in cancer and noncancer risk assessment as the starting point for linear low-dose extrapolation, calculation of a margin of exposure, or application of uncertainty factors for calculating RfCs or other dose-response values. BMC methods involve fitting various mathematical models for dose-response to reported data and using the different results to select a BMC that is associated with a predetermined benchmark response, such as a 10 percent increase in the incidence of a particular lesion or a 10 percent decrease in body weight gain (Exhibit 5-16). EPA has developed the Benchmark Dose Software (BMDS) to facilitate these operations. BMDS currently offers 16 different mathematical models that can be fit to the laboratory data. EPA plans to continually improve and expand the BMDS system.(7)

It is likely that there will continue to be situations that are not amenable to BMC modeling and for which a NOAEL or LOAEL approach should be used. In some cases, there may be a combination of benchmark doses and NOAELs to be considered in the assessment of a particular agent.

5.4.4.2 Derivation of the Human Equivalent Concentration

Because inhalation toxicity studies typically involve discontinuous exposures (e.g., animal studies routinely involve inhalation exposures of 6 hours per day, 5 days per week), the POD will usually need to be extrapolated to a continuous exposure scenario (as appropriate for the RfC and IUR). This duration adjustment step is essential in interpreting inhalation studies, but is not routinely necessary for the interpretation of oral exposures. Operationally, this is accomplished by applying a concentration-duration product, or **C × t product**(o) for both the

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o "C × t" is a component of Haber's Law that refers to the default assumption (in lieu of information to the contrary) that effects observed are related to the cumulative exposure or "area under the curve" (quantified by concentration, C, multiplied by duration, t). It is noted that when going from a discontinuous inhalation exposure regiment to a continuous exposure, the result will always be a lower value for concentration, thus providing an automatic margin of protectiveness for chemicals for which C alone (vs. C × t) may be appropriate, while providing the appropriate conversion for substances for which cumulative exposure is the appropriate measure.(4)

Exhibit 5-16. Example Derivation of Benchmark Dose Level

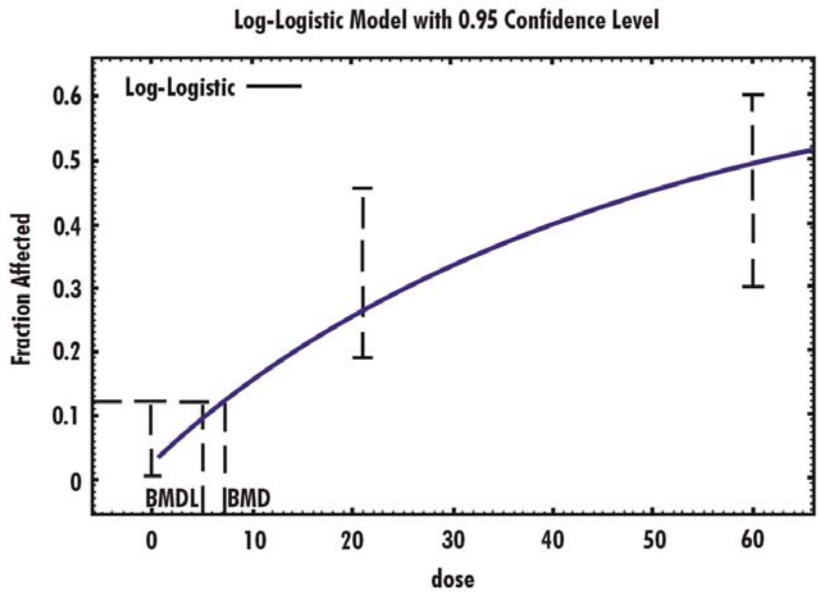


Illustration of the computation of a benchmark dose (BMD) and BMDL (a lower one-sided confidence limit on the BMD) for an extra risk of 0.10 (as suggested by the BMDS guidance document), using a one-sided 95 percent confidence interval. A number of models were fit to the data, and the log-logistic model illustrated provides the best fit to the example data. The predicted curve comes well within the confidence limits for each data point. Other data and models are illustrated in examples provided in the BMDS guidance document.[7]

number of hours in a daily exposure period and the number of days per week that the exposures are performed. For example, for a POD of 100 mg/m^3 derived from an animal study in which animals are exposed by inhalation for 6 hours per day, 5 days per week, the adjustment to a continuous exposure concentration would consider both hours per day and days per week:

$$100\, mg/m^3 \times \frac{6}{24} \times \frac{5}{7} = 18\, mg/m^3 \qquad \text{(Equation 5-1)}$$

Thus, 18 mg/m^3 is the POD concentration adjusted for continuous exposure versus 100 mg/m^3 unadjusted. This approach assumes there is no dose-rate effect (i.e., that the same total inhaled material produces the same effect regardless of the time over which this material was inhaled).

Exposures documented from human occupational epidemiological studies are most often reported as 8-hr time-weighted averages (TWAs) and therefore, also are discontinuous. Adjustment of these exposures is usually done as part of the dosimetric adjustment to derive a human equivalent concentration (HEC), rather than as a discrete step, and is explained below in Section 5.6.3. The duration adjustment step also is explicitly incorporated into physiologically based pharmacokinetic (PBPK) models used to extrapolate an animal or occupational study-derived POD into an HEC.

After duration adjustment, the POD is converted into a **human equivalent concentration (HEC)** from the experimental animal dose. This conversion may be done using default methods specific to the particular chemical class of concern or more refined methods such as PBPK modeling.

The Agency's inhalation dosimetry methodology[6] provides a recommended hierarchy, as well as default generalized procedures for deriving **dosimetric adjustment factors** (**DAFs**) for this extrapolation. Application of DAFs to an animal exposure value yields an estimate of the corresponding concentration relevant to humans (i.e., the HEC) given differences in physiology and in the form of the pollutant that influence how the chemical exerts its effect. The DAF depends on the chemical category (i.e., gas or particle) and whether the adverse effect occurs in the respiratory tract or outside of the respiratory tract. HECs are derived using DAFs for both RfC development (noncancer effects) and IUR development (cancer).

When data are adequate to support it, the preferred EPA approach for calculating a HEC is to use a chemical-specific PBPK model parameterized for the animal species and regions (e.g., of the respiratory tract) involved in the toxicity (Exhibit 5-17).

In PBPK models, the body is subdivided into a series of anatomical or physiological "compartments" that represent specific organs or tissue and organ groups. The transfer of chemicals between compartments is described by a set of differential equations. The parameters of the model are of three types: physiological parameters (such as tissue perfusions or tissue volumes), physicochemical parameters (such as partition coefficients that describe the degree of partitioning of a given chemical to a given tissue), and biochemical parameters describing metabolic processes. The structure of a PBPK model is determined by the intended use of the model, the biochemical properties of the chemical studied, and the effect site of concern.

Choice of a Default DAF for Extrapolation from Animal Data
Depends on the Physical and Chemical Properties of the Pollutant

Gases

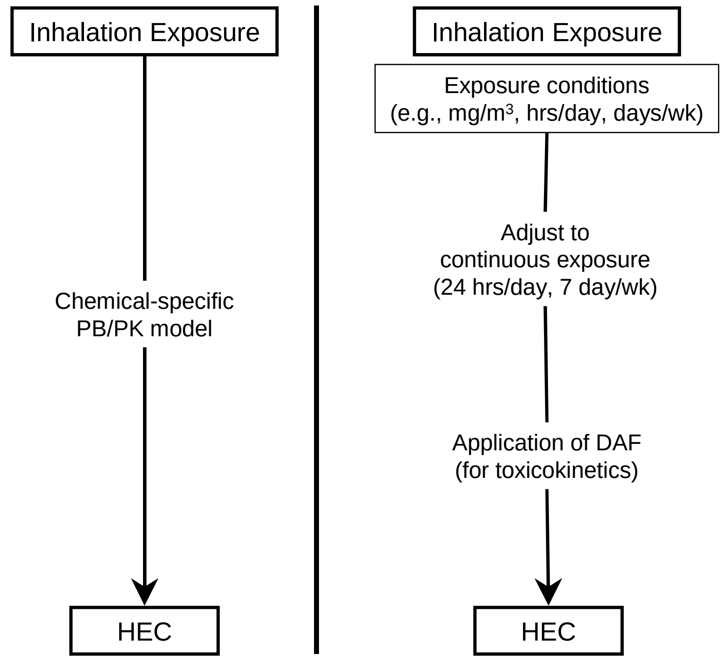
- Category 1 (effect in respiratory system) – default DAF based on inhalation rate, and surface area of target portion of respiratory tract
- Category 2 (some characteristics intermediate or common to category 1&3) – default DAF is the more restrictive of the defaults for category 1 & 3
- Category 3 (systemic effect[s]) – default DAF based on blood:air partition coefficient

Particles

- Respiratory toxicant – default DAF based on fractional deposition, inhalation rate, and surface area of target portion of respiratory tract
- Systemic toxicant – default DAF based on inhalation rate, body weight, and fractional deposition

Source: U.S. EPA. 1994. *Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry*.[6]

Exhibit 5-17. Extrapolation of Inhalation Exposure to Calculate the HEC



EPA employs a hierarchy of approaches for deriving the human equivalent concentration. Preference is given to the use of a physiologically-based pharmacokinetic model, followed by intermediate, less detailed approaches, which are followed by the default approach, which utilizes a DAF specific to the type of chemical and how it exerts its effect.

With sufficient data, a PBPK model is capable of calculating internal doses to a target organ in an animal from any exposure scenario and then estimating what human exposure would result in this same internal dose (i.e., the HEC). A formal DAF is not calculated in this process; rather, the model itself serves as a DAF in estimating HECs. However, constructing a PBPK model is an information-intensive process, requiring much chemical-specific data. Consequently, these models are usually available for only a subset of chemicals. For example, EPA's IRIS toxicity assessment for vinyl chloride relies on a PBPK model.

5.4.4.3 Extrapolation from POD to Derive Carcinogenic Potency Estimates

Observable cancer rates in laboratory or human occupational epidemiologic studies tend to be several orders of magnitude higher than cancer risk levels that society is willing to tolerate from involuntary chemical exposures. To obtain observable results, laboratory studies need to be conducted at exposures usually well above environmentally relevant concentrations. Thus, extrapolation from the POD-HEC to lower doses is usually necessary. This extrapolation is performed consistent with the mode of action, if adequately supported. Where the mode of action supports a biologically-based model and the data set is not rich enough to support a biologically based model, a non-linear reference concentration approach is employed (see Section 5.7.2). When the data are insufficient to support a mode of action decision, or where the data support a linear mode of action, a linear extrapolation is employed.

For linear extrapolation, a straight line is drawn from the point of departure expressed as a human equivalent dose to the origin (i.e., zero incremental dose, zero incremental response) to give an incremental probability dose unit. That is, the slope of the line expresses extra risk per dose unit (e.g., the IUR, expressed as extra risk per $\mu g/m^3$ of lifetime exposure). EPA's 1999 proposed guidelines[5] for carcinogen risk assessment recommend the use of the lowest effective dose using a 10 percent response level (LED_{10}) (as estimated by the lower one-sided confidence limit on the benchmark concentration [or $BMCL_{10}$]) as the POD for linear extrapolation. This approach is to draw a straight line between the estimated point of departure, generally, as a default, the LED_{10}. The LED_{10} is the lower 95 percent limit on a dose that is estimated to cause a 10 percent response. The linear extrapolation approach to assessing risk is considered generally conservative of public health, including sensitive subpopulations, in the absence of specific information about the extent of human variability in sensitivity to effects.

The inhalation cancer dose-response value derived by linear extrapolation is the IUR. It is presented as an upper-bound estimate of the excess cancer risk resulting from a lifetime (assumed 70-year) of continuous exposure to an agent at a concentration of 1 $\mu g/m^3$ in air. As illustrated previously in Exhibit 5-11A, risk is the product of the slope and the estimated exposure. The IUR is a plausible upper-bound estimate of the risk (i.e., the risk is not likely to be higher but may be lower and may be zero). When adequate human epidemiology data are available, maximum likelihood estimates may be used instead of upper bounds to generate the IUR. When only animal data are available and linear extrapolation is used, the IUR is derived from the largest linear slope that is consistent with the data (within the upper 95 percent confidence limit). In other words, the true risk to humans, while not identifiable, is not likely to exceed the upper-bound estimate (the IUR), and is likely to be lower. This means that any estimate of risk for air toxics using an IUR is likely to be protective of all potentially exposed populations. In addition, this means that air toxics risk estimates are likely to be conservative, that is, protective of public health.

Risk = EC × IUR, where

EC	=	lifetime estimate of continuous inhalation exposure to an individual air toxic
IUR	=	the corresponding inhalation unit risk estimate for that air toxic

The evidence for the carcinogenic mode of action may lead to a conclusion that the dose-response relationship is nonlinear, with response falling much more quickly than linearly with dose, or may be most influenced by individual differences in sensitivity. In some cases this may be due to the mode of carcinogenic action being a secondary effect of toxicity or of an induced physiological change that is itself a threshold phenomenon. EPA does not generally try to distinguish between modes of action that might imply a "true threshold" from those with a nonlinear dose-response relationship. Except in unusual cases where extensive information is available, it is not possible to distinguish between these empirically. Therefore, as a matter of science policy, nonlinear probability functions are only fitted to the response data to extrapolate quantitative low-dose risk estimates when the carcinogenic mechanism of the toxicant is very well-understood. When the evidence indicates a non-linear dose response function containing a significant change in slope, and alternate nonlinear approach may be considered. For example, when carcinogenesis can be shown to be a secondary effect of threshold toxicity, the EPA *2005 Cancer Guidelines* recommend derivation of a reference concentration.

5.4.5 Dose-Response Assessment for Derivation of a Reference Concentration

The reference concentration is defined as an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive sub-populations) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfC is expressed as a chronic exposure level to the chemical in ambient air (in units of milligrams of the substance per cubic meter of air, or mg/m^3). This value is usually derived for use with effects other than cancer. But when a chemical's carcinogenicity has been shown to be associated with a nonlinear mode of action (see Agency's Cancer Guidelines),[(5)] a reference concentration may be derived for use with all effects, including cancer.

Inherent in the derivation of a reference concentration is the recognition of an exposure level likely to be without an appreciable risk of adverse effects (e.g., a sub-threshold level for adverse effects). The objective of this type of dose-response assessment, then, is to estimate that exposure level for humans. The RfC is derived after a thorough review of the health effects database for an individual chemical and identification of the most sensitive and relevant endpoint (the "critical effect") along with the principal study(ies) demonstrating that endpoint. In addition to an analysis of the study data available for the chemical, risk assessors also use uncertainty factors to account for differences in sensitivity between humans and laboratory animals, the possibility of heightened sensitivity of some population groups (e.g., people with respiratory disease, very young children, the aged), and any limitations of the database. The methodology for derivation of an inhalation reference concentration is described in detail in EPA's *Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry*.[(6)]

The first part of this type of assessment, which involves a careful qualitative and quantitative analysis of the study data, parallels that performed for linear cancer dose-response assessment (i.e., derivation of the point of departure in terms of a human equivalent concentration [POD_{HEC}]). The qualitative analysis is described in Section 5.5.2, while the quantitative analysis is described in Sections 5.6.1 and 5.6.2. The latter part of this type of assessment involves the application of uncertainty factors to address limitations of the data used (e.g., the factors raised above).

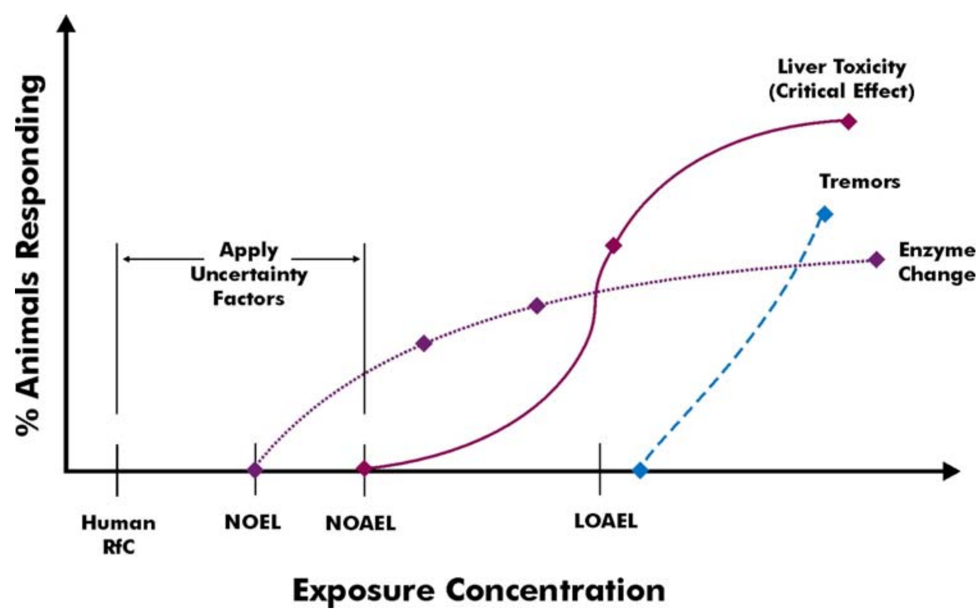
In IRIS, EPA includes with each RfC a statement of high, medium, or low confidence based on the completeness of the database for that substance. High confidence RfCs are considered less likely to change substantially with the collection of additional information, while low confidence RfCs may be especially vulnerable to change.[(6)]

5.4.5.1 Determination of the Point of Departure and Human Equivalent Concentration

In earlier sections (Section 5.5.2, 5.6.1 and 5.6.2) the analysis of the database and identification of the critical effect, as well as the derivation of the POD in terms of human equivalent concentrations are discussed.

In developing a dose-response assessment, toxicologists evaluate the available data for a substance. Studies of high quality are selected, and the assessment is focused on the most appropriate studies. As the RfC is a chronic value, preference is given to long-term studies over short-term ones, to studies using animals that exhibit effects similar to those experienced by humans, to studies using an appropriate exposure route (e.g., inhalation exposure for developing an RfC), and to studies showing a clear pattern of increasing frequency or severity of response with increasing dose. Toxicologists use the information to identify the **critical effect** (i.e., the adverse effect that appears at the lowest dose). Afterwards, appropriate human data are chosen as the basis for the RfC or, if human data are not adequate, data from the most appropriate species are identified. If this is not known, the data from the most sensitive species is usually chosen. This analysis is described in Section 5.5.2. The objective in identifying the critical effect or effects is to identify the effect(s) - among all those associated with exposure to the chemical of interest - that occur at the lowest exposure and would lead to derivation of the lowest RfC (Exhibit 5-18).

Exhibit 5-18. Overview to Develop a Reference Concentration



The LOAEL (HEC) and NOAEL (HEC) are illustrated with low-dose extrapolation with the application of uncertainty or modifying factors to derive the human health-protective RfC. Note that this figure represents data from appropriate animal species.

Using the dose-response relationship for the critical effect, toxicologists identify the POD from the experimental data. This exposure concentration (in terms of its human equivalent) which marks the boundary between the range of observation and that of extrapolation, is the point from which extrapolation begins for derivation of a RfC. The POD may be derived from benchmark modeling (see Section 5.6.1 regarding the derivation of a BMCL). If the data do not meet requirements for benchmark modeling, the POD is derived by the use of a statistical analysis to identify the **no-observed-adverse-effect-level**, or **NOAEL**, defined as the highest dose level administered to laboratory animals that did not cause statistically or biologically significant observable adverse effects after chronic (usually lifetime) exposure in the studied population. In some cases, a LOAEL is used in the absence of a NOAEL. In either case, the POD is transformed into a continuous inhalation exposure (e.g., from an intermittent animal exposure, 6 hours/day, 5 days/week) and then into a human equivalent concentration (as described in Section 5.6.2). In order for the appropriate critical effect to be identified, a comparison of PODs across different endpoints is done in terms of human equivalent concentrations (or potential RfC values, which incorporate the application of UFs, need to be compared).[6]

Derivation of RfC Using BMC Methodology – 1,3-Dichloropropene

A review of the available animal studies indicated changes to the surface cells of the nasal portion of the respiratory tract as the critical effect for 1,3-dichloropropene. Benchmark modeling was performed on the data demonstrating this effect. The seven statistical models for dichotomous data from the Agency's benchmark dose modeling software (BMDS Version.1b) were applied to the incidence data for the adjusted administered doses. The best model fit was determined by eliminating all models that did not have a statistically significant goodness-of-fit ($p<0.05$). The remaining models were then ranked by best visual fit of the data, especially for the lower doses, as observed in the graphical output of the Benchmark Dose Software. The model with statistically significant goodness-of-fit and best visual and statistical fit was used to estimate the BMC at 10 percent risk and the 95 percent lower confidence limit of the BMC (the BMCL). The gamma, logistic, multistage, Weibull, and quantal-quadratic models provided statistically significant fits. The gamma model was the best fit overall because it provided the best visual fit. This model yielded a BMC_{10} of 5.9 mg/m^3 and a $BMCL_{10}$ of 3.7 mg/m^3.

The $BMCL_{10}$ was identified as the POD and was adjusted from experimental conditions to a continuous inhalation exposure value (POD_{adj}). Because the critical target was the nasal mucosa, algorithms for extrathoracic effects for Category 1 gases were used to adjust continuous animal exposure concentration to HEC. The POD_{HEC} for a Category 1 gas was derived by multiplying the animal $BMCL_{10}$ by an interspecies dosimetric adjustment for gas:respiratory effects in the extrathoracic area of the respiratory tract. Using default values, the adjustment factor was equal to 0.2. For example, for 1,3-dichloropropene:

$$POD_{HEC} = BMCL_{10}(HEC) = BMCL_{10}\,(adj) \times 0.2 = 3.7 \times 0.2 = 0.7\ mg/m^3$$

The POD_{HEC} was divided by uncertainty factors for interspecies extrapolation (UF of 3) and intraspecies variation (UF of 10) and rounded to one significant figure to yield the RfC for 1,3-dichloropropene:

$$RfC = POD_{HEC} / 30 = 0.02\ mg/m^3$$

5.4.5.2 Application of Uncertainty Factors

The RfC is an estimate derived from the POD_{HEC} for the critical effect (based on either a $BMCL_{HEC}$, $NOAEL_{HEC}$ or $LOAEL_{HEC}$) by consistent application of UFs. The UFs are applied to account for recognized uncertainties in the use of the available data to estimate an exposure concentration appropriate to the assumed human scenario. The general formula for deriving an RfC from a POD_{HEC} is:

$$RfC\,(mg/m^3) = \frac{POD_{HEC}(mg/m^3)}{UF} \qquad \text{(Equation 5-2)}$$

A UF of 10, 3, or 1 is applied for each of the following extrapolations used to derive the RfC (see Exhibit 5-19):

- Animal to human;
- Human to sensitive human populations;
- Subchronic to chronic;
- LOAEL to NOAEL; and
- Incomplete to complete database.

The UFs are generally an order of magnitude (10), although incorporation of dosimetry adjustments or other information may result in the use of reduced UFs for RfCs (3 or 1). The composite UF applied to an RfC will vary in magnitude depending on the number of uncertainties involved; however, an RfC will not be derived when use of the data involves more than four areas of extrapolation. The composite UF when four factors are used generally is reduced from 10,000 to 3,000 in recognition of the lack of independence and the conservatism of these factors.

The 2002 Agency review of the reference dose (RfD)/reference concentration process(3) encouraged the development of guidance in the area of chemical-specific adjustment factors (CSAFs). These factors utilize specific data to replace the default UFs for interspecies or inter-individual variation. The review panel noted, however, that the CSAF approach for any single substance is determined principally by the availability of relevant data. For many substances there are relatively few data available to serve as an adequate basis to replace defaults for interspecies differences and human variability with more informative CSAFs.

Exhibit 5-19. Uncertainty Factors Used in the Derivation of an Inhalation RfC	
Standard Uncertainty Factors	**Processes Considered in UF Purview**
A = Animal to human Extrapolation from valid results of long-term studies on laboratory animals when results of studies of human exposure are not available or are inadequate. Intended to account for the uncertainty in extrapolating laboratory animal data to the case of average healthy humans.	• Pharmacokinetics/Pharmacodynamics • Relevance of laboratory animal model • Species sensitivity
H = Human to sensitive human Extrapolation of valid experimental results for studies using prolonged exposure to average healthy humans. Intended to account for the variation in sensitivity among the members of the human population.	• Pharmacokinetics/Pharmacodynamics • Sensitivity • Differences in mass (children, obese) • Concomitant exposures • Activity Pattern • Does not account for idiosyncrasies
S = Subchronic to chronic Extrapolation from less than chronic exposure results on laboratory animals or humans when there are no useful long-term human data. Intended to account for the uncertainty in extrapolating from less than chronic NOAELs to chronic NOAELs.	• Accumulation/Cumulative damage • Pharmacokinetics/Pharmacodynamics • Severity of effect • Recovery • Duration of study • Consistency of effect with duration
L = LOAEL to NOAEL Derivation from a LOAEL instead of a NOAEL. Intended to account for the uncertainty in extrapolating from LOAELs to NOAELs.	• Severity • Pharmacokinetics/Pharmacodynamics • Slope of dose-response curve • Trend, consistency of effect • Relationship of endpoints • Functional vs histopathological evidence • Exposure uncertainties
D = Incomplete to complete data Extrapolation from valid results in laboratory animals when the data are "incomplete". Intended to account for the inability of any single laboratory animal study to adequately address all possible adverse outcomes in humans.	• Quality of critical study • Data gaps • Power of critical study/supporting studies • Exposure uncertainties
Source: U.S. EPA. 1994. *Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry*.[6]	

Because of this procedure to address the lack of information on the translation from experimental data to a human scenario, the resulting RfC for many HAPs is on the order of 100 to 300 times lower than the NOAEL actually observed in the animal testing (see Exhibit 5-20). This reflects the lowering of the RfC to address the uncertainties in the extrapolations mentioned above. For those HAPs that have had their effects well documented in human studies, the RfC may be much closer to the highest concentration at which an adverse effect was not observed (e.g., within a factor of 3 to 10).

Exhibit 5-20. Examples of the Use of Uncertainty Factors in Deriving RfCs	
RfC from NOAEL **Example: Diesel Engine Emissions**	**RfC from LOAEL** **Example: Toluene**
Toxicity data: 144 µg chemical/m^3 air ($NOAEL_{HEC}$ from chronic rodent study) *Uncertainty factors*: 3 x 10 = 30 3 = animal-to-human extrapolation 10 = human to sensitive human subpopulations RfC = 144/30 = 4.8 µg/m^3 = 0.005 mg/m^3	*Toxicity data:* 119 mg chemical/m^3 air ($LOAEL_{HEC}$ from chronic occupational study) *Uncertainty factors*: 10 x 10 x 3 = 300 10 = human to sensitive human subpopulations 10 = LOAEL-to-NOAEL extrapolation 3 = database deficiencies RfC = 119/300 mg/m^3 = 0.4 mg/m^3
$NOAEL_{HEC}$ = No-Observed-Adverse-Effect Level (Human Equivalent Concentration) $LOAEL_{HEC}$ = Lowest-Observed-Adverse-Effect Level (Human Equivalent Concentration) *Source*: EPA's IRIS database http://www.epa.gov/IRIS/.	

In some of the older IRIS assessments a "modifying factor" may have been applied in addition to the traditional uncertainty factors. It had been used with professional judgement when it was determined that another uncertainty factor was needed; its magnitude depended upon the professional assessment of scientific uncertainties of the study and database not explicitly treated via the other uncertainty factors.(6) The 2002 Agency review of the RfD/RfC process, however, recommended against continued use of the modifying factor. It was felt that the traditional factors could account for any remaining uncertainties.(3)

5.4.6 Sources of Chronic Dose-Response Values

Appendix C of ATRA, Volume 1 provides a current listing of appropriate chronic dose-response values (i.e., RfCs or comparable values and IURs) for HAPs.(p) References for acute exposure levels are provided below in Exhibit 5-21. Hazard identification and dose-response assessment information for chronic exposure (presented in ATRA Volume 1, Appendix C), was obtained from various sources and prioritized according to (1) conceptual consistency with EPA risk assessment guidelines, and (2) level of review received. The prioritization process was aimed at incorporating into our assessments the best available science with respect to dose-response information. The sources listed below were used, and provide this information for chemicals beyond the 187 Clean Air Act hazardous air pollutants listed in Appendix C of ATRA Volume 1.

- **U.S. Environmental Protection Agency (EPA)**. EPA has developed dose-response assessments for chronic exposure to many pollutants. These assessments typically specify an RfC (to protect against effects other than cancer) and/or IUR (to estimate the probability of contracting cancer). Background documents, particularly for the more recent files, also contain information on physical and chemical properties, toxicokinetics, and hazard

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(p) As noted earlier, see http://www.epa.gov/ttn/atw/toxsource/summary.html for a current listing of this information.

characterization. EPA disseminates dose-response assessment information in several forms, based on the level of review. Dose-response assessments that have achieved full intra-agency consensus are incorporated in the **Integrated Risk Information System (IRIS)**, which is regularly updated and available on-line (www.epa.gov/iris). All IRIS assessments since 1996 also have undergone independent external peer review. In the past, dose-response assessments for some substances were prepared by the EPA Office of Research and Development, but were never submitted for EPA consensus. EPA has assembled the results of many such assessments in the **Health Effects Assessment Summary Tables (HEAST)**. Although the values in HEAST have undergone some review and have the concurrence of individual Agency program offices, they have not had enough review to be recognized as Agency-wide consensus information. In addition, since HEAST has not been updated since 1997, other sources described here are, for many chemicals, more reliable.

- **Agency for Toxic Substances and Disease Registry (ATSDR)**. ATSDR, which is part of the US Department of Health and Human Services, develops and publishes Minimum Risk Levels (MRLs) for many toxic substances. The MRL is defined as an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (other than cancer) over a specified duration of exposure. MRLs are derived for acute (1-14 days), intermediate (>14-364 days), and chronic (365 days and longer) exposures by inhalation and oral routes. ATSDR describes MRLs as substance-specific estimates to be used by health assessors to select environmental contaminants for further evaluation. MRLs are presented with only one significant figure and are considered to be levels below which contaminants are unlikely to pose a health threat. Exposures above an MRL do not necessarily represent a threat, and MRLs are therefore not intended for use as predictors of adverse health effects or for setting cleanup levels. The MRL data undergo a rigorous review process, including internal ATSDR review, peer reviews, and public comment periods. ATRA Volume 1, Appendix C shows the ATSDR chronic MRL where no IRIS value is available, because the MRL's concept, definition, and derivation are philosophically consistent (though not identical) with EPA's guidelines for assessing noncancer effects. ATSDR publishes MRLs as part of pollutant-specific toxicological profile documents, and also in regularly-updated on-line tables.[8]

- **California Environmental Protection Agency (CalEPA)**. The CalEPA Office of Environmental Health Hazard Assessment (OEHHA) has developed dose-response assessments for many substances, based both on carcinogenicity and health effects other than cancer. The process for developing these assessments is similar to that used by EPA to develop IRIS values and includes significant external scientific peer review. The non-cancer information includes inhalation health risk guidance values expressed as chronic inhalation reference exposure levels (RELs). CalEPA defines the REL as a concentration level at (or below) which no health effects are anticipated, a concept that is substantially similar to EPA’s approach to non-cancer dose-response assessment. ATRA Volume 1, Appendix C shows the chronic REL (including both final and proposed values) where no IRIS RfC/RfD or ATSDR MRL exists. CalEPA’s quantitative dose-response information on carcinogenicity by inhalation exposure is expressed in terms of the IUR, defined similarly to EPA’s IUR. ATRA Volume 1, Appendix C shows specific CalEPA UREs where no IRIS values exist. CalEPA’s dose response assessments for carcinogens and noncarcinogens are available on-line.[9]

- **International Agency for Research on Cancer** (**IARC**). The IARC, a branch of the World Health Organization, coordinates and conducts research on the causes of human cancer and develops scientific strategies for cancer control. The IARC sponsors both epidemiological and laboratory research, and disseminates scientific information through meetings, publications, courses and fellowships. As part of its mission, the IARC assembles evidence that substances cause cancer in humans and issues judgments on the strength of evidence. IARC's categories are Group 1 (carcinogenic in humans), Group 2A (probably carcinogenic), Group 2B (possibly carcinogenic), Group 3 (not classifiable), and Group 4 (probably not carcinogenic). The categorization scheme may be applied to either single chemicals or mixtures; however, IARC does not develop quantitative dose-response metrics such as UREs,. IARC's categories for substances are included in ATRA Volume 1, Appendix C to support or augment EPA's weight-of evidence (WOE) determinations, which do not cover all substances and in some cases may be out-of-date. The list of IARC evaluations to date is available on-line (http://193.51.164.11/monoeval/grlist.html).

Additionally, the EPA has compiled fact sheets for the 187 CAA hazardous air pollutants and makes them available on the Air Toxics website (http://www.epa.gov/ttn/atw/hapindex.html). This collection is called the **Health Effects Notebook for Hazardous Air Pollutants**, and provides for each HAP a summary of available information in the following categories: hazard summary, physical properties, uses, sources and potential exposure, and health hazard information. These fact sheets are useful for describing hazards associated with the 187 HAPs.

5.4.7 Acute Exposure Reference Values

Many air pollutants can cause adverse health effects after acute or short-term exposures lasting from a few minutes to several days. For some pollutants, acute exposures may be of greater concern than chronic exposures. The severity of effects from acute exposures may vary widely. Agency-wide guidance on how to assess toxic effects from short-term exposures is currently being developed. This guidance for Acute Reference Exposure (ARE) levels is intended to assist acute risk assessment activities. A variety of other short-term, acute exposure limits are also described in Exhibit 5-21.[10] ATRA Volume 1, Appendix C provides a current listing of acute dose-response values for HAPs.

Methods for dose-response assessment of acute exposures are usually similar to the approach for chronic exposure, with their derivation involving the identification of a "critical effect," determination of a NOAEL or comparable value for that effect, and application of uncertainty factors (e.g., animal to human population). However, the process by which most acute inhalation dose-response assessment values are derived differs from the chronic RfC methodology in two important ways. First, "acute" may connote exposure times varying from a few minutes to two weeks. The time frame for the value is critical, because the safe dose (or the dose that produces some defined effect) may vary substantially with the length of exposure. Second, some acute dose-response assessments include more than one level of severity. A typical assessment may have values for level 1 (at which only mild, transient effects may occur), level 2 (above which irreversible or other serious effects may occur), and level 3 (above which life-threatening effects may occur). Therefore, many acute assessments present dose-response assessment values as a matrix, with one dimension being length of exposure and the other a severity-of-effect category.

Exhibit 5-21. Examples of Available Short-Term, Acute Exposure Levels				
Acronym	**Full Name**	**Group or Agency**	**Purpose/Definition**	**Source/Website**
AEGL	Acute Exposure Guideline Level	National Research Council (NRC) National Advisory Committee (NAC)	The AEGLs represent short-term threshold or ceiling exposure values intended for the protection of the general public, including susceptible or sensitive individuals, but not hypersusceptible or hypersensitive individuals. The AEGLs represent biological reference values for this defined human population and consist of three biological endpoints for four different single emergency (accidental) exposure periods (30 minutes, l hour, 4 hours, and 8 hours). In some instances, AEGLs also are developed for 5 or 10 minutes. The biological endpoints are defined as follows: • AEGL-1 is the airborne concentration (expressed as parts per millions [ppm] or milligrams [mg]/meters [m]^3) of a substance at or above which it is predicted that the general population, including "susceptible" but excluding "hypersusceptible" individuals, could experience notable discomfort. Airborne concentrations below AEGL-1 represent exposure levels that could produce mild odor, taste, or other sensory irritations. • AEGL-2 is the airborne concentration (expressed as ppm or mg/m^3) of a substance at or above which it is predicted that the general population, including "susceptible" but excluding "hypersusceptible" individuals, could experience irreversible or other serious, long-lasting effects or impaired ability to escape. Airborne concentrations below the AEGL-2 but at or above AEGL-1 represent exposure levels that may cause notable discomfort. • AEGL-3 is the airborne concentration (expressed as ppm or mg/m^3) of a substance at or above which it is predicted that the general population, including "susceptible" but excluding "hypersusceptible" individuals, could experience life-threatening effects or death. Airborne concentrations below AEGL-3 but at or above AEGL-2 represent exposure levels that may cause irreversible or other serious, long-lasting effects or impaired ability to escape.	http://search.nap.edu/books/0309072948/html/
ARE	Acute Reference Exposure	U.S. Environmental Protection Agency	The ARE is an informed estimate of the highest inhalation exposure (concentration and duration) that is not likely to cause adverse effects in a human population, including sensitive subgroups, exposed to that scenario, even on an intermittent basis.[(11)] For these purposes, acute exposures are single continuous exposures lasting 24 hours or less; AREs may be derived for any duration of interest within that period. "Intermittent" implies sufficient time between exposures such that one exposure has no effect on the health outcome produced by the next exposure. EPA is in the process of finalizing the methodology for development of AREs.	

Exhibit 5-21. Examples of Available Short-Term, Acute Exposure Levels				
Acronym	**Full Name**	**Group or Agency**	**Purpose/Definition**	**Source/Website**
BEI	Biological Exposure Indices	American Conference of Governmental Industrial Hygenists	BEIs® are health-based values for use by industrial hygienists in making decisions regarding safe levels of exposure to various chemical and physical agents found in the workplace.	http://www.acgih.org/TLV/
CEEL	Community Emergency Exposure Level	National Research Council (NRC) National Advisory Committee (NAC)	CEELs are ceiling exposure values for the public applicable to emergency exposures of foreseeable magnitude and duration, usually not exceeding 1 hour. Three CEELs were established: • CEEL-1: Concentration above which discomfort, for example eye and nose irritation or headaches, becomes increasingly common; • CEEL-2: Concentration above which disability, for example, severe eye or respiratory irritation, becomes increasingly common; • CEEL-3: Concentration above which death or life-threatening effects, for example, pulmonary edema, cardiac failure, or cancer, become increasingly common.	Guidelines for Developing Community Emergency Exposure Levels for Hazardous Substances (NRC, 1993)
EEGL	Emergency Exposure Guidance Level	NAS Committee on Toxicology	Exposure levels judged to be acceptable for military personnel performing tasks during emergency situations. Not considered safe exposure level for routine or normal operations.	
ERPG	Emergency Response Planning Guideline	American Industrial Hygiene Association's (AIHA) Emergency Response Planning Committee	These guidelines are intended for application by persons trained in emergency response planning. ERG-1: The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor. ERG-2: The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action. ERG-3: The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.	http://www.bnl.gov/scapa/erpgpref.htm http://www.bnl.gov/scapa/scapawl.htm
IDLH	Immediately Dangerous to Life or Health Concentration	National Institute for Occupational Safety and Health (NIOSH)	An immediately dangerous to life or health condition is one "that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment. The purpose of establishing an IDLH is to ensure that the worker can escape from a given contaminated environment in the event of failure of the respiratory protection equipment.	NIOSH Respirator Decision Logic [NIOSH 1987], http://www.cdc.gov/niosh/idlh/intridl4.html

Exhibit 5-21. Examples of Available Short-Term, Acute Exposure Levels				
Acronym	**Full Name**	**Group or Agency**	**Purpose/Definition**	**Source/Website**
LOC	Level of Concern	U.S. Environmental Protection Agency, Federal Emergency Management Agency, U.S. Department of Transportation	Defined by the Technical Guidance for Hazards Analysis (a guide developed to assist in planning for accidental chemical releases). As the concentration of an extremely hazardous substances in air above which there may be serious irreversible health effects or death as a result of a single exposure for a relatively short period of time. In the 1987 Technical Guidance for Hazards Analysis document, an LOC was estimated by using one-tenth of the IDLH level published by the National Institute for Occupational Safety and Health. For the purposes of offsite consequence analysis performed as part of accidental release requirements under Section 112®) of the CAA, this value is superceded by ERPG-2 values as available, and the Agency intends to supercede those values with AEGL-2 values as they are developed and adopted.	Technical Guidance for Hazards Analysis. Emergency Planning for Extremely Hazardous Substances. (USEPA, FEMA, USDOT, 1987). 61 FR 31672; June 20, 1996
MRL	Acute Minimum Risk Levels	U.S. Agency for Toxic Substances and Disease Registry (ATSDR)	The MRL is an estimate of human exposure to a substance that is likely to be without an appreciable risk of adverse effects (other than cancer) over a specified duration of exposure, and can be derived for acute exposures by the inhalation and oral routes. Unlike the one-hour focus of most of the other values listed here, acute MRLs are derived for exposures of 1 to 14 days duration.	http://www.atsdr.cdc.gov/mrls.html
REL	Reference Exposure Level	California EPA Office of Environmental Health Hazard Assessment (OEHHA)	The acute REL is an exposure that is not likely to cause adverse effects in a human population, including sensitive sub-populations, exposed to that concentration for one hour on an intermittent basis. RELs are based on the most sensitive, relevant, adverse health effect reported in the medical and toxicological literature. RELs are designed to protect the most sensitive individuals in the population by the inclusion of margins of safety. Since margins of safety are incorporated to address data gaps and uncertainties, exceeding the REL does not automatically indicate an adverse health impact OEHHA has defined the lowest available acute severity level as the REL.	http://www.oehha.ca.gov/air/pdf/acuterel.pdf
SPEGL	Short-term Public Emergency Exposure Guidance Level	National Academy of Sciences (NAS) Committee on Toxicology	The NAS develops short-term public emergency exposure guidance levels (SPEGLs) to apply to the exposures of the general public to contaminants during airborne chemical releases; SPEGLs are generally set at a level of 0.1 to 0.5 times the EEGL and are measured as 60 minute or 8 hour exposure time frames.	*Criteria and Methods for Preparing Emergency Exposure Guidance Level (EEGL), Short-Term Public Emergency Guidance Level (SPEGL), and Continuous Exposure Guidance Level (CEGL) Documents.* 1986. National Academy Press, National Academy of Sciences ,Washington, D.C.

Exhibit 5-21. Examples of Available Short-Term, Acute Exposure Levels				
Acronym	**Full Name**	**Group or Agency**	**Purpose/Definition**	**Source/Website**
STEL	Short-Term Exposure Limit	American Conference of Governmental Industrial Hygenists (ACGIH)	STELs are time weighted average (TWA) guidelines for the control of short term exposure in the workplace. These are important supplements to the eight-hour TWA exposure standards which are more concerned with the total intake over long periods of time. Generally, STELs are established to minimize the risk of the occurrence in nearly all workers of: intolerable irritation; chronic or irreversible tissue change; and narcosis to an extent that could precipitate industrial accidents, provided the eight hour TWA exposure standards are not exceeded. STELs are recommended for those substances only when there is evidence either from human or animal studies that adverse health effects can be caused by high short term exposure. STELs are expressed as airborne concentrations of substances, averaged over a period of 15 minutes.	

5.4.8 Evaluating Chemicals Lacking Health Reference Values

5.4.8.1 Use of Available Data Sources

If EPA-derived IRIS assessments are available for the chemicals being examined, these values should generally be used in the risk assessment. Use of IRIS or other EPA-derived dose-response values prevents duplication of effort in toxicity assessment and ensures consistency in the dose-response values among risk assessments. If EPA-derived dose-response values are not available, the other sources described in Section 5.9 should be given next priority. Use of these sources in a hierarchical manner has been implemented in tables developed for the 187 hazardous air pollutants (see ATRA Volume 1, Appendix C and http://www.epa.gov/ttn/atw/toxsource/table1.pdf). The Toxicology Excellence for Risk Assessment (TERA) maintains a database of international dose-response values (see www.TERA.org/iter).

If those sources also lack inhalation dose-response values, then route-to-route extrapolation (discussed below) may be considered. This approach, however, may be quite detailed, and requires assistance from a professional toxicologist. If all sources and approaches have been researched, and no dose-response value is available, the assessor should describe the effects of the chemical qualitatively and discuss the implications of the absence of the chemical from the risk estimate in the uncertainty section of the risk assessment.

5.4.8.2 Route-to-Route Extrapolation

For cases in which appropriate dose-response values are not available for the route of exposure being considered, but are available for another route, it may be possible to use route-to-route extrapolation. Route-to-route extrapolation is recommended only from oral to inhaled exposure and only for carcinogens. The ability to perform quantitative route-to-route extrapolation is critically dependent on the amount and type of data available. Regardless of the toxic endpoint being considered, a minimum of information is required to construct plausible dosimetry for the routes of interest. This information includes both the nature of the toxic effect and a description of the relationship between exposure and the toxic effect.

Route to route extrapolations should only be done by qualified toxicologists.

Data from other routes of exposure may be useful to derive an RfC (for carcinogens only; discussed below) only when respiratory tract effects and/or "first pass" effects can be ruled out. First pass effects are cases where metabolism takes place in the portal-of-entry tissues, prior to entry into the systemic circulation. The respiratory tract can exhibit a first-pass effect after inhalation. Unless the first-pass effect and dosimetry are adequately understood, there can be substantial error introduced in route-to-route extrapolation that does not account for these considerations.

Oral toxicity data should *not* be used for route-to-route extrapolation in the following cases (unless these effects can be accounted for in a PBPK model):

- When groups of chemicals have different toxicity by the two different routes (e.g., metals, irritants, and sensitizers);

- When a first-pass effect by the respiratory tract is expected;
- When a first-pass effect by the liver is expected;
- When a respiratory tract effect is established, but dosimetry comparison cannot be clearly established between the two routes;
- When the respiratory tract is not adequately studied in the oral studies; and
- When short-term inhalation studies, dermal irritation, in vitro studies, or characteristics of the chemical indicate potential for portal-of-entry effects at the respiratory tract, but studies themselves are not adequate for an RfC development.

The actual impact of exposure by different routes can only be estimated by taking account of factors that influence absorption at the portal of entry, such as (1) physicochemical characteristics of the chemical; (2) exposure factors; and (3) physiologic parameters. The preferred method for performing route-to-route extrapolation involves the development of a PBPK model that describes the disposition of the chemical for the routes of interest. As previously discussed, PBPK models account for fundamental physiologic and biochemical parameters and processes such as blood flow, ventilatory parameters, metabolic capacities, and renal clearance, tailored by the physicochemical and biochemical properties.

If appropriate toxicity information is not available, a qualitative rather than quantitative evaluation of the chemical is recommended. The implications of the absence of the chemical from the risk estimate should be discussed in the uncertainty section.

5.4.9 Dose-Response Assessment for Mixtures

The recommended approach for assessing risks from exposure to a mixture of pollutants (e.g., coke oven emissions, diesel exhaust, etc.) is to utilize a dose-response assessment developed for that mixture or a mixture judged similar.(12) (13) Where such an assessment is not available, a component-by-component approach may be employed. There are several commonly used approaches. Selection among the approaches involves consideration of the similarity of the mixture components with regard to their toxicological activity. There are a few groups of toxicologically similar chemicals for which the Agency recommends the use of relative potency factors (RPFs) or toxicity equivalence factors (TEFs). These factors have been developed by EPA and other organizations for two classes of compounds: PAHs and dioxins/furans. The World Health Organization (WHO) has developed TEFs for polychlorinated biphenyls (PCBs) as an extension of the factors for dioxins/furans (see Exhibit 5-22).

- **Polycyclic Aromatic Hydrocarbons (PAHs)**. EPA has not developed IURs or CSFs for carcinogenic PAHs other than benzo(a)pyrene. EPA recommends use of a RPF based on the potency of each compound relative to that of benzo(a)pyrene.(14) Although several references may be found in the literature with proposed RPFs for PAHs, EPA recommends the following RPF values for seven PAHs, which are classified as B2, probable human carcinogens:[q]

PAH	RPF
Benzo(a)pyrene	1.0
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.01
Chrysene	0.001
Dibenz(a,h)anthracene	1.0
Indeno(1,2,3-c,d)pyrene	0.1

Thus, for these seven PAHs, the IUR for benzo(a)pyrene is multiplied by the applicable RPF to derive the IUR.

- **Dioxins, Furans, and PCBs**. For carcinogenic dioxins and furans, the TEF approach has an underlying assumption of additivity across mixture components. EPA currently recommends TEFs for specific congeners, rather than isomeric groups (see Exhibit 5-21). TEFs were determined by inspection of the available congener-specific data and an assignment of an "order of magnitude" estimate of relative toxicity when compared to 2,3,7,8-TCDD. The cancer potency of certain dioxin and furan congeners is estimated relative to 2,3,7,8-TCDD based on other toxicity information that is available for the congeners. Scientific judgment and expert opinion formed the basis for these TEF values. External review of the toxicity and pharmacokinetic data utilized in setting these TEF values supported the basic approach as a "reasonable estimate" of the relative toxicity of polychlorinated dibenzo-dioxins (PCDDs) and polychlorinated dibenzo-furans (PCDFs).[15] TEF values developed by scientific groups over the past 15 years are provided in Exhibit 5-21. The most recent consensus of the scientific community (including representation by EPA scientists) is represented by the WHO 1997 values.

  TEFs based on the relative cancer potencies are used to adjust the exposure concentrations of mixture components, which are subsequently summed into a single exposure concentration for the mixture. That exposure concentration based on TEFs is then used, along with the 2,3,7,8-TCDD IUR or noncancer reference value, to estimate cancer risks or other health hazards for the mixture.

[q] CalEPA has developed IURs based on RPFs for several additional PAHs that have been classified as probably or possibly human carcinogens (e.g., IARC).

Exhibit 5-22. Toxicity Equivalence Factors for Dioxins, Furans and PCBs				
Congener	**EPA (1987)**[16]	**NATO (1989)**[17]	**WHO (1994)**[18]	**WHO (1997)**[19]
TCDDs				
2,3,7,8-TCDD	1	1		1
1,2,3,7,8-PeCDD	0.5	0.5		1
1,2,3,4,5,8-HxCDD	0.04	0.1		0.1
1,2,3,7,8,9-HxCDD	0.04	0.1		0.1
1,2,3,6,7,8-HxCDD	0.04	0.1		0.1
1,2,3,4,6,7,8-HpCDD	0.001	0.1		0.01
1,2,3,4,6,7,8,9-OCDD	0	0.001		0.0001
TCDFs				
2,3,7,8-TCDF	0.1	0.1		0.1
1,2,3,7,8-PeCDF	0.1	0.05		0.05
2,3,4,7,8-HxCDF	0.1	0.5		0.5
1,2,3,4,7,8-HxCDF	0.01	0.1		0.1
1,2,3,7,8,9-HxCDF	0.01	0.1		0.1
1,2,3,6,7,8-HxCDF	0.01	0.1		0.1
2,3,4,6,7,8-HxCDF	0.01	0.1		0.1
1,2,3,4,6,7,8-HpCDF	0.001	0.01		0.01
1,2,3,4,7,8,9-HpCDF	0.001	0.01		0.01
1,2,3,4,6,7,8,9-OCDF	0	0.001		0.0001
PCBs **IUPAC # Structure**				
77 3,3',4,4'-TCB			0.0005	0.0001
81 3,4,4',5-TCB			–	0.0001
105 2,3,3',4,4'-PeCB			0.0001	0.0001
114 2,3,4,4',5-PeCB			0.0005	0.0005
118 2,3',4,4',5-PeCB			0.0001	0.0001
123 2',3,4,4',5-PeCB			0.0001	0.0001
126 3,3',4,4',5-PeCB			0.1	0.1
156 2,3,3'4,4',5-HxCB			0.0005	0.0005
157 2,3,3',4,4',5'-HxCB			0.0005	0.0005
167 2,3',4,4',5,5'-HxCB			0.00001	0.00001
169 3,3'4,4'5,5'-HxCB			0.01	0.01
170 2,2',3,3',4,4',5-HpCB			0.0001	–
180 2,2',3,4,4',5,5'-HpCB			0.00001	–
189 2,3,3',4,4',5,5'-HpCB			0.0001	0.0001
Source: EPA's dioxin reassessment activities[20]				

References

1. U.S. Environmental Protection Agency. 2004. *Community Air Screening How-To Manual, A Step-by-Step Guide to Using Risk-Based Screening to Identify Priorities for Improving Outdoor Air Quality*. EPA-744/B-04-001. Available at: http://www.epa.gov/ttn/fera/risk_atra_main.html

2. U.S. Environmental Protection Agency. 2005. *Guideline on Air Quality Models*, Appendix W (November 2005) of 40 CFR Part 51. See http://www.epa.gov/scram001/guidance/guide/appw_05.pdf.

3. U.S. Environmental Protection Agency. 2002. *A Review of the Reference Dose and Reference Concentration Process*. Risk Assessment Forum, Washington, D.C., 2002. EPA/630/P-02/002F. Available at: http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=55365

4. U.S. Environmental Protection Agency. 2002. Office of Research and Development, National Center for Environmental Assessment. *Risk Assessment Guidelines*. Updated June 30, 2002. Available at: http://cfpub.epa.gov/ncea/raf/rafguid.htm. (Last accessed March 2004).

5. U.S. Environmental Protection Agency. 1999. *Guidelines for Carcinogen Risk Assessment. Review Draft*. Risk Assessment Forum, Washington, D.C., July 1999. NCEA-F-0644. Available at: http://cfpub.epa.gov/ncea/raf/rafguid.htm

   U.S. Environmental Protection Agency. 1986. *Guidelines for Carcinogen Risk Assessment*. *Federal Register* 51(185):33992-43003, September 24, 1986. Available at: http://cfpub.epa.gov/ncea/raf/rafguid.htm

   U.S. Environmental Protection Agency. 2003. *Draft Final Guidelines for Carcinogen Risk Assessment (External Review Draft)*, Risk Assessment Forum, Washington, D.C. NCEA-F-0644A. Available at http://cfpub.epa.gov/ncea/raf/rafguid.htm

6. U.S. Environmental Protection Agency. 1994. *Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry*. Washington, D.C.

   U.S. Environmental Protection Agency. 2002. *A Review of the Reference Dose and Reference Concentration Process.* Risk Assessment Forum, Washington, D.C. December 2002. EPA/630/P-02/002F. Available at: http://www.epa.gov/iris/RFD_FINAL%5B1%5D.pdf (Last accessed April 2004).

7. U.S. Environmental Protection Agency. 2002. Benchmark Dose Software (BMDS). Office of Research and Development. Updated June 30, 2002. Available at http://cfpub.epa.gov/ncea/cfm/bmds.cfm. (Last accessed March 2004).

   U.S. Environmental Protection Agency. 1996. *Benchmark Dose Technical Guidance Document*. Risk Assessment Forum, Washington, D.C., August 1996. EPA/600/P-96/002A. Available at: http://www.epa.gov/cgi-bin/claritgw?op-Display&document=clserv:ORD:0603;&rank=4&te

mplate=epa.

8. Agency for Toxic Substances and Disease Registry (ATSDR). 2004. Toxicological Profile Information Sheet. Updated March 19, 2004. Available at: http://www.atsdr.cdc.gov/toxpro2.html. (Last accessed March 2004).

   Agency for Toxic Substances and Disease Registry (ATSDR). 2004. Minimal Risk Levels (MRLs) for Hazardous Substances. Updated March 22, 2004. Available at: http://www.atsdr.cdc.gov/mrls.html. (Last accessed March 2004).

9. State of California Office of Environmental Health Hazard Assessment. 2003. Air - Hot Spots Guidelines. Available at: http://www.oehha.ca.gov/air/hot_spots/index.html. (Last accessed March 2004).

10. Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration. 2002. Occupational Exposure Limits. Updated March 26, 2002. Available at: http://response.restoration.noaa.gov/cameo/locs/worklims.html. (Last accessed March 2004).

11. The ARE is described in http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=60983.

    U.S. Environmental Protection Agency. 1998. *An SAB Report: Development of the Acute Reference Exposure*. Science Advisory Board, Washington, D.C., EPA-SAB-EHC-99-005. November 1998. Available at: http://www.epa.gov/sab/pdf/ehc9905.pdf.

12. U.S. Environmental Protection Agency. 1986. *Guidelines for the Health Risk Assessment of Chemical Mixtures*. Risk Assessment Forum, Washington, D.C. EPA/630/R-98/002. Federal Register 51(185):34014-34025, September 24, 1986.

13. U.S. Environmental Protection Agency. 2000. *Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures*. Risk Assessment Forum, Washington, DC, EPA/630/R-00/002. Available at: http://www.epa.gov/ncea/raf/pdfs/chem_mix/chem_mix_08_2001.pdf.

14. U.S. Environmental Protection Agency. 1993. *Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons*. EPA/600/R-93/089.

15. Olson, J.R., Bellin, J.S., Barnes, D.G., et al. 1989. Reexamination of data used for establishing toxicity equivalency factors (TEFs) for chlorinated dibenzo-p-dioxins and dibenzofurans (CDDs 45 and CDFs). *Chemosphere* 18(1-6):371-381.

16. U.S. Environmental Protection Agency. 1987. *Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Chlorinated dibenzo-p-dioxins and -dibenzofurans (CDDs and CDFs)*. EPA/625/3-87/012.

17. NATO/CCMS. 1989. *Scientific Basis for the Development of International Toxicity Equivalent Factor (I-TEF) Method of Risk Assessment for Complex Mixtures of Dioxins and Related Compounds*. Report No. 178, December, 1998.

18. Ahlborg, U., Becking, G.C., Birnbaum, L.S., et al. 1994. Toxicity equivalence factors for dioxin-like PCBs: Report on a WHO-ECEH and IPCS consultation, December 1993. *Chemosphere* 28(6):1049-1067.

19. van Leeuwen, F.X.R. 1997. Derivation of toxic equivalency factors (TEFs) for dioxin-like compounds in humans and wildlife. *Organohalogen Compounds* 34:237.

20. For more information on EPA's dioxin reassessment activities, see: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=55264&CFID=12120688&CFTOKEN=95507561.

Chapter 6 Risk Characterization

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6.0 Introduction

In the risk characterization step, information from the preceding steps of the assessment (exposure and toxicity data) is integrated to develop risk conclusions that are complete, informative, and useful for decision making (see Exhibit 6-1). Quantitative and qualitative statements of risk are presented in the context of uncertainties and limitations in the underlying data and methodology. The basics of risk characterization and uncertainty analysis are provided in ATRA Volume 1, Chapter 13, and analysts are encouraged to review this information. This chapter introduces some of the ways in which the results of the multisource assessment can be graphically and tabularly presented. Chapter 7 elaborates on this topic by discussing additional risk communication techniques.

The risk characterization will commonly describe the risk results in terms of both individual risk and population risk (e.g., estimates of the number of people at different risk levels). The risk assessment team will usually also identify the percentage of the cumulative risk attributable to each of the sources evaluated. The cumulative multi-source risk estimates and results of the source apportionment are commonly displayed in both tabular format as well as graphically (e.g., using GIS formats).

EPA has developed several key documents about how to characterize and present risk assessment information, including EPA's Policy for Risk Characterization.(1) The purpose of the policy is to help ensure that risk management decisions are well-supported and well-understood, both inside the EPA and outside the Agency, and that the confidence in the data, science policy judgments, and the uncertainties are clearly communicated. The *Handbook for Risk Characterization*(2) provides additional background and approaches to presenting the risk characterization results. The assessment team should become familiar with the information provided in both the policy and handbook before beginning a risk assessment. Section 3.5 of the *Residual Risk Report to Congress*(3) provides additional discussion on risk characterization for air toxics.

6.1 Quantification of Multisource Risk and Hazard

As noted above, the process for calculating hazard and cancer risk was discussed in detail in ATRA Volume 1, Chapter 13, and readers are referred to that chapter for an in-depth discussion of the inhalation risk and hazard calculation equations. The only difference between the process described in ATRA Volume 1 and a multisource analysis is that in a multisource inhalation analysis, risk and hazards are combined not only across chemicals, but across sources as well. For example, at a particular receptor of interest, carcinogenic risks from Source A will be combined with carcinogenic risks from Source B and Source C, etc. The result is a cumulative

The Basic Equations for Calculating Chemical-Specific Risk and Hazard

Chemical-specific cancer risk = EC × IUR

Chemical-specific noncancer hazard = EC/RfC

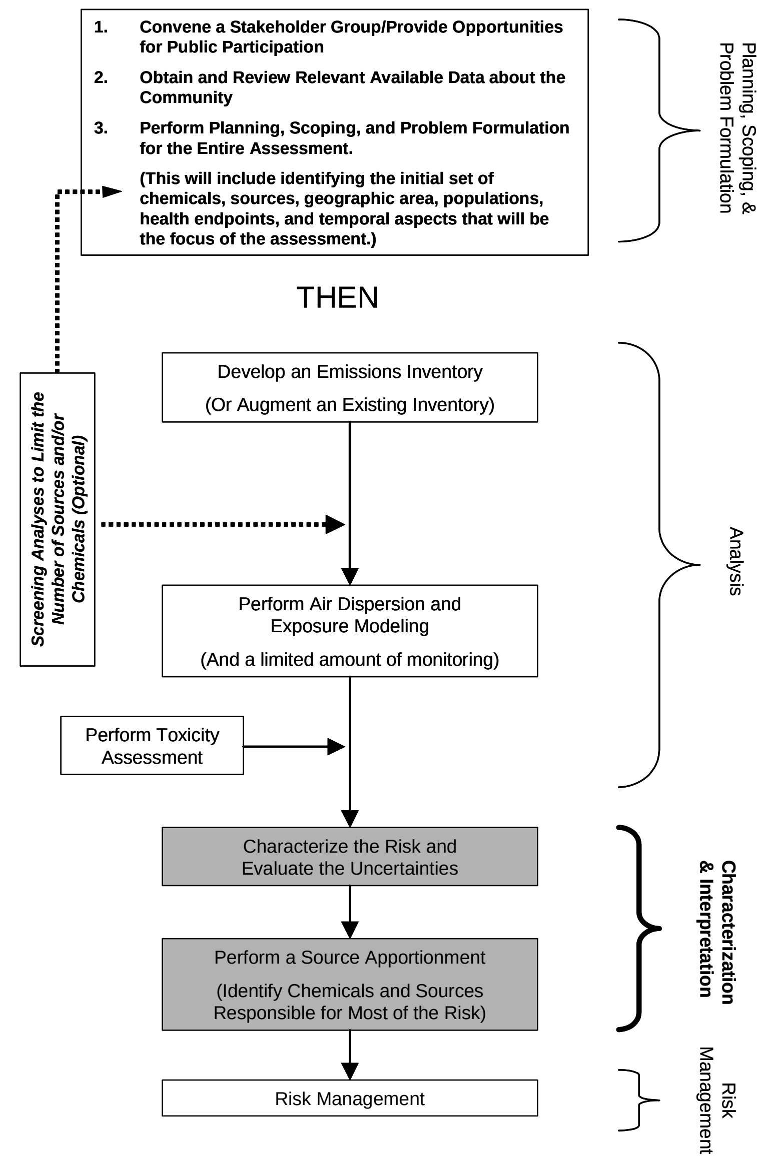
where:

EC	=	lifetime estimate of continuous inhalation exposure to an individual air toxic (ug/m^3)
IUR	=	the corresponding inhalation unit risk estimate for that air toxic (ug/m^3)
RfC	=	the corresponding reference concentration for that air toxic (ug/m^3)

incremental carcinogenic risk associated with breathing air impacted by emissions from all those sources. A similar approach is used for hazard.

In addition to the information provided in ATRA Volume 1, Chapter 13, further detail on multi-chemical assessment is provided in the *Agency's Guidelines for the Health Risk Assessment of Chemical Mixtures* (4) and the *Supplemental Guidance for Conducting Health Risk Assessment of Chemical Mixtures*.(5) It is noted that the Agency guidance recommends that the "combining" or component-by-component approach to multipollutant exposures be performed for mixtures with "approximately a dozen or fewer chemical constituents" (see reference 5). Larger groups of chemicals may be considered in an initial screening step which allows the identification of the more important subset of chemicals that likely pose most of the risk and that should be included in the actual risk assessment.

Exhibit 6-1. The General Multisource Cumulative Assessment Process for a Community Assessment - Focus on Risk Characterization and Interpretation



Steps in an Inhalation Risk Characterization

1. Organize outputs of inhalation exposure assessment and toxicity assessment.
2. Derive inhalation cancer risk estimates and hazard quotients for each pollutant for each exposure scenario receptor being studied (e.g., modeling grid receptors, special receptor sites such as hospitals and schools, etc).
3. Derive cumulative inhalation cancer risk estimates and hazards estimates for each receptor for all chemicals.
4. Display the risks both in written form (usually as a narrative and in tabular form) and graphically.
5. Apportion the risks among the sources that contribute to the risk.
6. Identify key features, limitations and assumptions of exposure and toxicity assessments.
7. Assess and characterize key uncertainties and variabilities associated with the assessment.
8. Consider additional relevant information.

Risk characterization should be transparent, clear, consistent, and reasonable (TCCR). A discussion of the TCCR principles is provided in Section 6.4.

6.2 Approaches for Characterizing and Presenting Multisource Risk and Hazard

ATRA Volume 1, Section 13.3, provides an overview of presenting inhalation risks and hazards. The concept for multisource analysis is the same. As such, the following discussion emphasizes the elements that are particular to multisource analysis.[a]

6.2.1 Common Risk Descriptors

Similar to all other aspects of the risk assessment, the way in which risk characterization is performed will depend on the scope, goals and purpose of the overall analysis. For example, the purpose may include identifying the sources and chemicals posing the greatest risk in the study area to assist the community in prioritizing risk reduction actions. Another goal could be to identify the locations associated with the highest risks for the siting of air monitoring stations. The risk characterization will have to be crafted to meet these needs in a way that is acceptable to the decision makers, particularly from the standpoint of their need to avoid errors in their decision making process. Part III of the EPA's Risk Characterization Guidance, available at http://www.epa.gov/osa/spc/pdfs/rcguide.pdf, provides additional information on the subject of risk descriptors.

[a] Standard rules for rounding apply which will commonly lead to an answer of one significant figure in both risk and hazard estimates. For presentation purposes, hazard quotients (and hazard indices) and cancer risk estimates are usually reported as one significant figure.

Automating the Process: The RAIMI Risk-MAP

EPA developed Risk-MAP (Risk Management and Analysis Platform) to support the data-intensive and analytically complex nature of multisource cumulative assessments. The design and functionality of Risk-MAP has been driven by the need to go a step beyond analysis and serve as a direct and seamless platform to support solution selection, implementation, and tracking. As such, Risk-MAP represents a unique shift in risk tool design. Risk-MAP has the ability to:

- Calculate exposure pathway-specific values in a spatially layered data environment (e.g., source and receptor locations, concentrations at grid locations, etc.);
- Support the needed capacity (number of sources and contaminants) typically required of cumulative-type studies conducted at a high level of resolution;
- Provide custom visual displaying of interim and final results in traditional (tabular, etc.) and mapped (isopleths, spatial attributes, etc.) formats; and
- Link results directly to source attributes to support solution consideration, implementation, and tracking.

For more information on the RAIMI Risk-MAP, see: http://www.epa.gov/Arkansas/6pd/rcra_c/raimi/raimi.htm.

Another Tool in the Toolbox: EPA's Human Exposure Model

EPA's Human Exposure Model (HEM) is another tool that can be used to generate risk results for multisource cumulative assessments. The HEM is available in two versions, HEM-Screen and HEM-3. Both versions model dispersion using EPA's ISC model and built-in meteorological data, calculate exposure concentrations for U.S. Census block internal points via interpolation, and generate risk and population outputs for the modeling region. HEM-Screen has lower input data requirements, a short run time, and incorporates a relatively simple dispersion algorithm that estimates only long-term average concentrations. By contrast, HEM-3 uses more advanced dispersion algorithms and more refined meteorological data that allow for more accurate dispersion modeling and both short- and long-term exposure outputs, but the input data requirements are greater, run time is longer, and there are limitations on the geographic scale that can be modeled. Although neither of the HEM versions can provide the level of refinement (including visual displays, source information, and other automated capabilities) that the RAIMI Risk-MAP provides, the HEM is a relatively non-resource-intensive option that analysts may want to consider, as long as they are aware of the limitations of HEM. *As with all aspects of risk assessment, it is important that the analyst use the appropriate tool for the questions that the assessment is addressing.* For more information on HEM, see: http://www.epa.gov/ttn/fera/human_hem.html.

One of the important data quality objectives for risk characterization is the need to present multiple descriptors of risk, given the likely *distribution* of exposure for the study area population. Except where these descriptors clearly do not apply, all Agency risk assessments are expected to address or provide descriptions of:

- **Individual Risk (central tendency** and **high-end** estimates of individual risk and hazard). Such measures are intended to give a sense of the risks posed to a typical individual in the community as well as more highly exposed individuals. Specifically, the **central tendency estimate** might describe the exposure and risk experienced by people in the community with average exposures to air toxics. One way to do this is to rank order all the risk values calculated across all modeling nodes in the study area and use the 50th percentile value as the measure of central tendency. Another method is to identify the arithmetic average of all calculated risks. There is no prescribed way of representing the "average person" and risk managers will often find it helpful to see several different ways of representing central tendency.

> **MIR and MEI -**
> **What Do These Terms Mean?**
>
> **Maximum Individual Risk (MIR) -** An MIR represents the highest estimated risk to an exposed individual in areas that people are believed to occupy.
>
> **Maximum Exposed Individual (MEI) -** The MEI represents the highest estimated risk to an exposed individual, regardless of whether people are expected to occupy that area.
>
> These concepts are discussed more fully in EPA's *Residual Risk Report to Congress* (http://www.epa.gov/ttn/oarpg/t3/reports/risk_rep.pdf).

The **high-end** estimates of individual risk and hazard are intended to give a sense of the risk that is expected to occur for individuals in the upper range of risk values across the study area (e.g., risk at the 90th or 95th percentile of risk across the study area). The intent is to "convey an estimate of risk in the upper range of the distribution, but to avoid estimates which are beyond the true distribution."(6) Similar, but slightly different, concepts are the MIR and MEI (see text box). If air quality modeling is performed only at census tract (or block) internal points, the internal point with the highest concentration may be used to describe the exposure scenario with the highest risk. (Note that these various risk metrics can be presented in a variety of ways, such as individual values, individual values with uncertainty bounds, or probabilistic distributions. The method chosen to describe the results depends on the information needs of the end user and the ability of the analyst to develop the data to describe the variability and uncertainty associated with the exposures. This topic is discussed in Section 6.4.)

- **Population Risk (e.g., the number of people at different risk and hazard levels).** These measures are particularly important for risk managers because they answer the broad question "are many people at high risk, or only a few?" For example, the analyst might decide to select risk bins (e.g., Bin 1 includes all people with a risk below 1E-06, Bin 2 includes all people with a risk of 1E-06 to 1E-05, etc.) and determine the numbers of people in each bin. The populated bins could then be displayed as a bar graph (see Exhibit 6-2).

- **Sensitive Subpopulations.** In its risk assessments and risk characterizations, the EPA attempts to identify the universe of people that may be affected, including potentially sensitive populations (e.g., children, ethnic groups, or people of a given age, gender, nutritional status, or genetic predisposition).[b] Accordingly, in the planning and scoping phase of the risk assessment process, the potential for higher exposures or for other increased susceptibility to adverse effects among some populations should be noted. Any potentially

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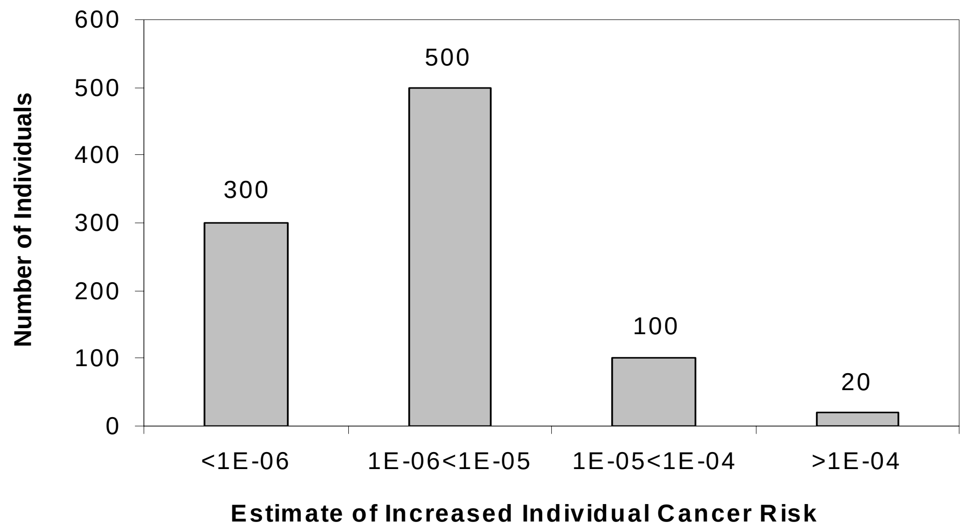
[b] Two terms that are related to sensitive populations are susceptibility and susceptible subgroups. The term susceptibility is used to mean an increased likelihood of an adverse effect over that of the general population, and susceptible subgroups are those population subgroups with the susceptibility. The subgroups may be described by demographic features which contribute to the susceptibility, such as age, gender, race, socioeconomic status, and including pre-existing medical conditions, genetic characteristics, etc. Diet can also be an important feature of susceptibility, particularly with respect to tribes.

Exhibit 6-2. Example Description of Population Risk Estimates



sensitive populations that are identified should be evaluated in the risk assessment, and the assessment should contain an appropriate characterization.[c] It may not be necessary or possible to do a quantitative risk assessment on each one. For instance, where there are many sensitive population groups for a given pollutant, it may be sufficient to estimate risks for the most sensitive group, with the idea that as long as they are protected by the associated risk management action, other groups may be protected adequately.

While all potentially sensitive populations need to be considered, Executive Order 13045 entitled "Protection of Children from Environmental Health Risks and Safety Risks" (http://www.epa.gov/fedrgstr/eo/eo13045.pdf) and the Administrator's "Policy on Evaluating Health Risks to Children" (http://bronze.nescaum.org/committees/aqph/memohlth.pdf) specifically require that EPA risk assessments, risk characterizations, and environmental and public health standards characterize health risks to infants and children, as appropriate. In addition, the Agency has issued specific guidance for rule writers about how to address children's risk pursuant to Executive Order 13045. This is found in the "EPA Rule Writer's Guide to Executive Order 13045" issued as interim final guidance in April 1998 (http://yosemite.epa.gov/ochp/ochpweb.nsf/content/rrguide.htm/$File/rrguide.pdf).

[c] Note that the EPA's traditional dose-response tools for air toxics (e.g., inhalation reference concentration and inhalation unit risk for cancer) are derived with consideration of potentially susceptible subgroups. For example, the derivation of a reference concentration typically incorporates specific factors to account for sensitive subgroups. Accordingly, proper use of these tools will usually provide risk metrics that account for any subpopulations with increased susceptibility. The exposure assessment (and subsequent risk characterization), however, will need to include consideration of any subpopulations that have different exposures than the general population. (For inhalation exposures, evaluating different types of people within a population is usually done by applying an exposure model – see ATRA, Volume 1, Section 11.3.) An important document that can provide guidance in this area is EPA's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (2005), which can be found at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=146583.

6.2.2 Presenting Risk Results

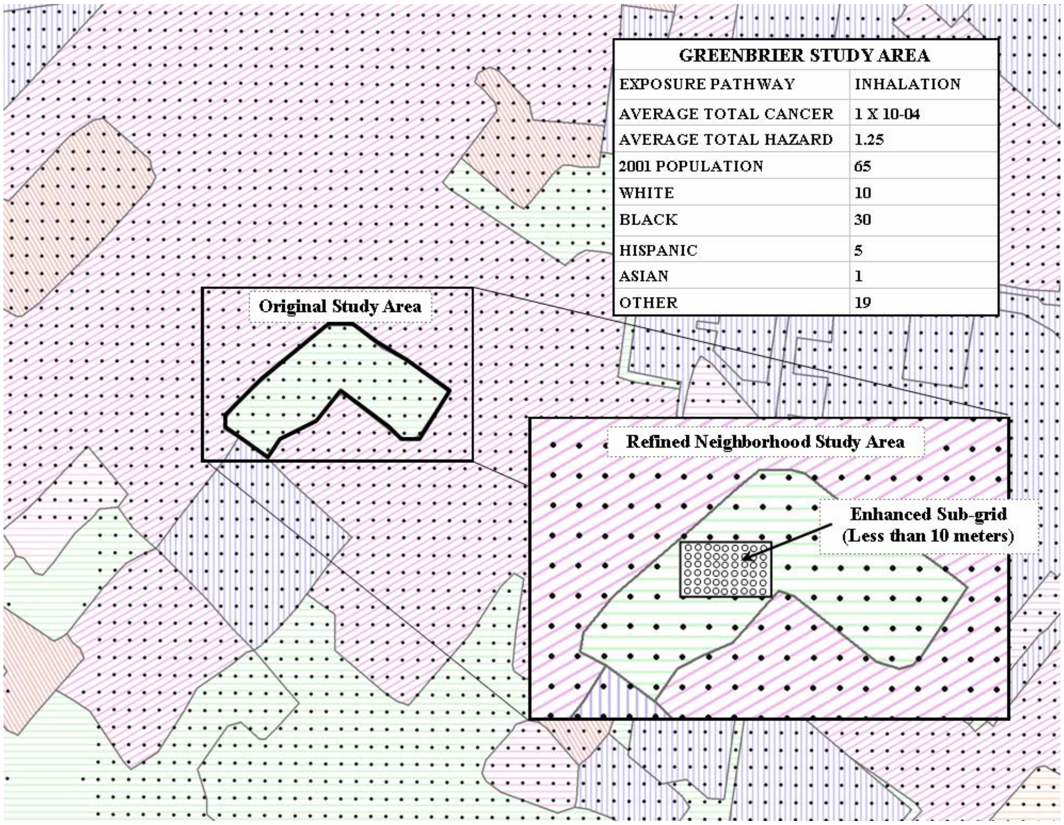
Different graphical presentations can help to effectively convey the risk characterization results to the risk management team members and others in ways particularly suited to the goals and purpose for the overall analysis. Pie charts, bar charts, tabular formats, and other methods that show risk contributions of different sources can be used. Presentation using GIS formats is particularly useful.

For example, the RAIMI Risk-MAP tool can be used to depict both the risk across the study area as a whole or can zoom in to display what is predicted at smaller geographic scales. Exhibit 6-3 illustrates how an analyst has used this tool to focus on one specific neighborhood (Greenbriar) for emphasis. The dots represent the modeling nodes across the neighborhood and the risk results have been highlighted in a box to the side. For this neighborhood, the analyst has decided to display the average risk (i.e., the average risk and hazard across all the modeling nodes) along with relevant demographic data. The analyst could have chosen to display information for this neighborhood in a number of other ways, including information about risk variation across the modeling nodes (e.g., highest to lowest) or providing risk estimates for different segments of the population (e.g., if an exposure model has been used). The way in which the analyst chooses to display the information will depend on the message that is trying to be communicated.

Another important method for displaying risk is graphic presentation of risk "isopleths" to represent study area potential risk gradients. However, analysts need to carefully consider how to select "breaks" in the data (e.g., what risk value they will use to show contour lines) since it is easy to create different impressions about the meaning of the data depending on the way the data breaks are chosen. When using this type of presentation format it is particularly important to clarify there is no risk without the presence of people and a completed exposure pathway. In other words, depicting an isopleth implies risk at every point within the contour lines. It is only when people are present and contacting contaminated air, however, that risk is actually a possibility. Further, the risk shown is particular to the exposure conditions assumed in the analysis. **This is another reminder that it is important to clearly describe assumptions, limitations and uncertainties accompanying such graphical representations in order to convey the intended message and to avoid being misunderstood.** An example of a figure depicting risk isopleths is provided in Exhibit 6-4.

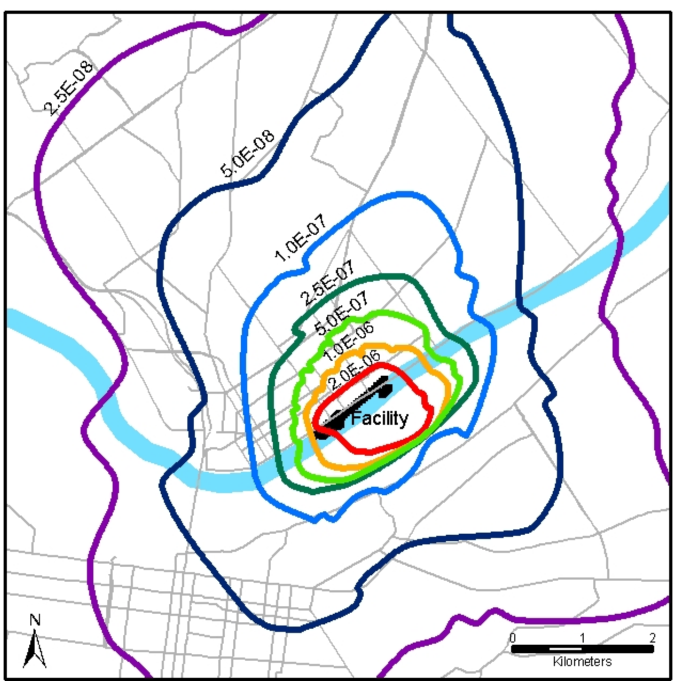
If background concentrations were included as a "source" of air toxics during the risk characterization, a bar chart is usually the most appropriate way to represent their contribution to the overall risk estimate for a study area. Specifically, the background risk is depicted along side the risk attributable to the local source(s) being evaluated (see Exhibit 6-5). It generally is not appropriate to subtract background exposures from exposures associated with local sources because background concentration information is typically limited and may be unrepresentative of all external air contaminants influencing the study area.

Exhibit 6-3. Example Depiction of Average Risk within a Subarea of a Larger Study Area



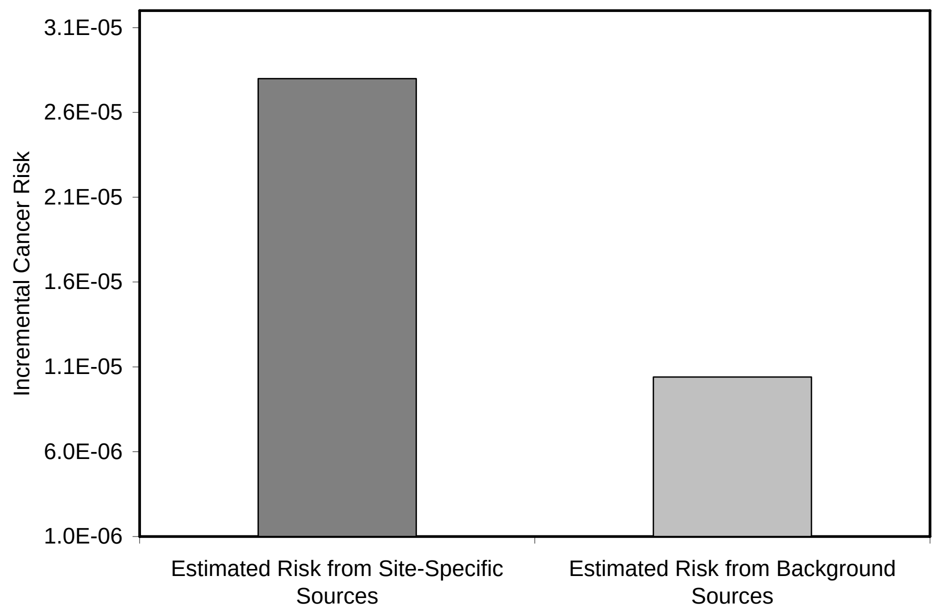
Source: EPA's *Regional Air Impact Modeling Initiative (*see: http://www.epa.gov/Arkansas/6pd/rcra_c/raimi/raimi.htm.

Exhibit 6-4. Example Display of Risk Across a Study Area Using Isopleths



In this example, estimated individual lifetime cancer risk has been estimated for a study area based on modeled ambient air concentrations in the vicinity of a single facility. (See Exhibit 6-9 for an example of isopleths resulting from multiple sources simultaneously impacting an area.)

Exhibit 6-5. Example Comparison of Risk Estimates from Study-Specific and Background Sources



In this example, the estimated risk from the specific sources being evaluated a modeling study (2.8×10^{-5}) and the estimated risk from background sources (1.0×10^{-5}) using upwind monitoring are compared side-by-side. This places the risk estimates from the sources of concern in an appropriate regional context. Note that an individual's total inhalation risk is due to both air contaminants released from all sources impacting the study area (both those in the study area and those more distant). Depending on the situation, risk managers may or may not include background concentrations in the decision making process.

6.3 Identifying Risk Contributors (Source Apportionment)

Once the risk characterization has been performed, a natural follow-on question (particularly if the risk managers indicate the risks are unacceptably high) is to identify the sources and chemicals that are responsible for the majority of the risk, a technique known as **source apportionment analysis**. When ambient concentrations are used as a surrogate for exposure concentrations, the general approach is to work backwards from the ambient concentrations developed in the air dispersion modeling step at points where the risk is unacceptably high.

Specifically, this approach uses the results of an air dispersion model to estimate the relative contribution of each source (or source category) to the ambient concentration estimate at each modeling location of concern. The basic approach conceptually includes the following steps:

- Identify the locations at which source apportionment will be performed (usually selected modeling nodes, groups of modeling nodes, and any special receptors);
- Use an air dispersion model (e.g., ISCST3) estimate of ambient concentrations of each chemical at each location for each source (or source category);
- Sum the ambient concentrations for each chemical at each location; and
- Calculate the percentage contribution of each source to the predicted ambient concentration.

In an assessment in which the exposure concentration is set equal to the ambient concentration and the same exposure scenario is assumed at all locations, the percent of the ambient concentration for a given chemical contributed by a particular source corresponds to the percent risk potentially posed by that chemical from that source at that point.

The results of source apportionment analyses can be presented in a number of ways, including tabular formats (e.g., Exhibit 6-6), bar or pie charts, and GIS overlays. The use of bar charts or pie charts is a particularly simple, effective way to communicate the relative contribution of sources to exposure concentrations or estimated risk (Exhibit 6-7). The height of a bar or size of each "slice" of the pie is proportional to the relative contribution of each source. This technique is most effective when the total number of sources is relatively small.

Additional spatial and temporal details of individual source contributions can be illustrated using GIS overlays (e.g., ambient concentration contribution depicted using the RAIMI tool Risk–MAP). Exhibit 6-8 shows one way to depict the contribution of sources to emissions in the study area (tons per year of a chemical released) while Exhibit 6-9 illustrates how different sources contribute to the cumulative risk (as risk isopleths) across a study area.

Keep in mind that in a multisource cumulative assessment, analysts will typically be apportioning risk among many chemicals emitted from large and small businesses, mobile sources, and other potential sources. Depending on the site-specific circumstances, any of these chemicals or types of sources may be the main risk driver. In other cases, there may be no one particular chemical or source that is the primary contributor to an area's risk.

Source Apportionment Using Monitoring Data

In addition to using air dispersion modeling results to apportion air concentrations among sources, air monitoring data may also sometimes be used. In limited cases, a fairly straightforward analysis of source contribution might be made through evaluation of concentration, time of measurement, meteorological conditions, and other information. More commonly, a process such as *receptor modeling* would need to be used for determining the quantitative impact of a particular air-pollution source on ambient air quality (as measured by a monitoring device). Receptor modeling seeks to avoid the detailed knowledge of emissions inventories and meteorology that is necessary to apply dispersion modeling, the traditional method of predicting the air-quality impact of identifiable sources. Classical receptor models are conservative in nature, so that pollutant species which reach the receptor site are assumed to have been emitted in the same chemical form by a source. More information on receptor modeling can be found at: http://www.epa.gov/scram001/tt23.htm.

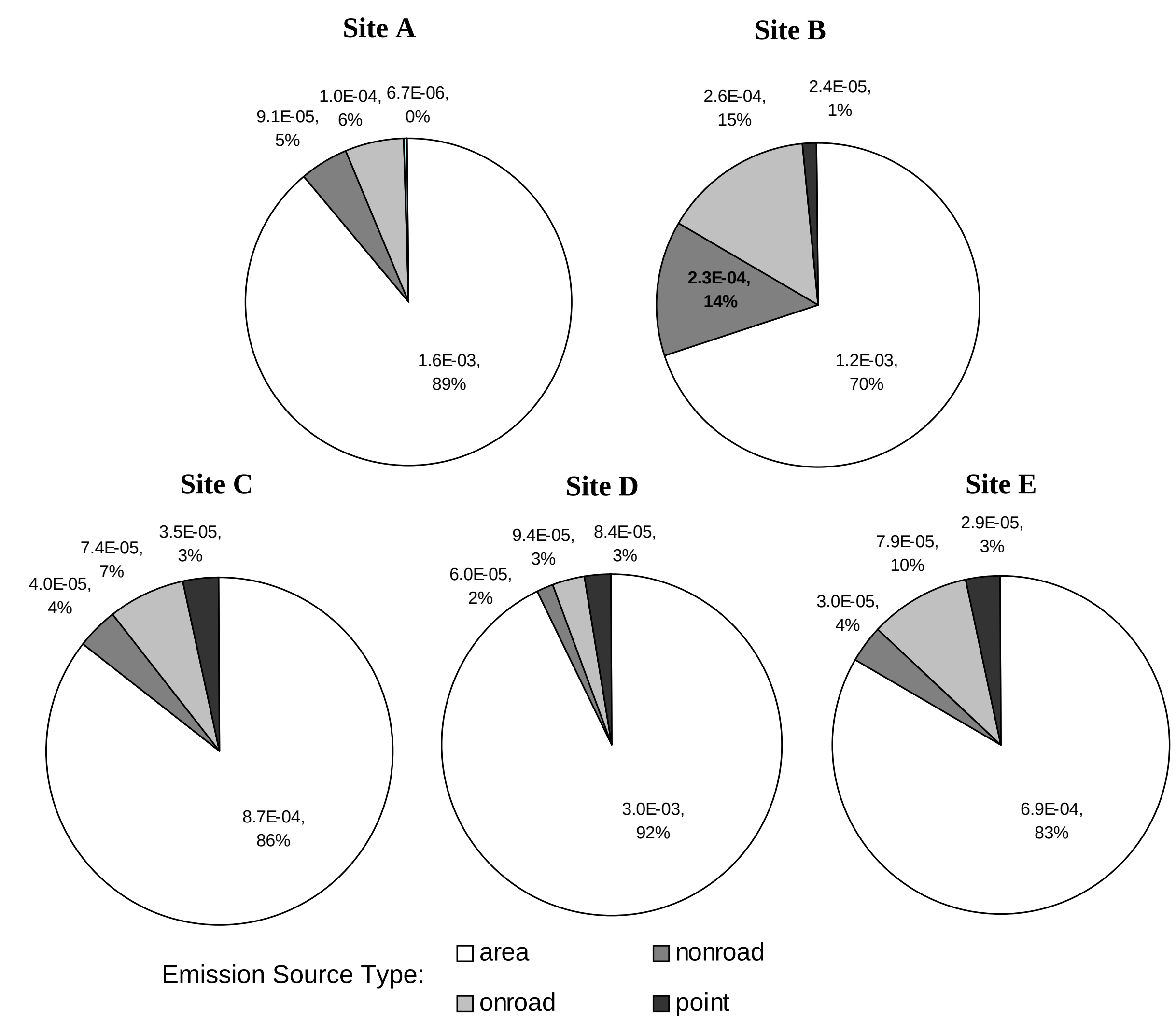
Exhibit 6-6. Example Source Apportionment Profile of 1,3-Butadiene Emissions and Risk-Based Prioritization at a Location of Predicted Maximum Impact In the Happydale Neighborhood

Source Description		Permit Status	Source-Specific Percentage of Pathway Risk Estimate	Cancer Risk Estimate	Chronic Hazard Quotient Estimate
1	*Big Air Corporation, Wastewater JWWDP Blending Station #B4-14* FIN: JWB14 EPN: JWB14	G	23.5%	1×10^{-4}	0.1
2	*Big Air Corporation, Wastewater JWWDP Neutralization Basin #B-16* FIN: JWB16 EPN: JWB16	G	14.9%	7×10^{-5}	0.07
3	*Big Air Corporation, South B.D.E. Equipment Fugitives* FIN: BDFUGS EPN: BDFUGS	P	12.4%	6×10^{-5}	0.06
4	*Big Air Corporation Inventory Name: Fugitives* EPN: C4FU	UN	6.9%	4×10^{-5}	0.04
5	*Big Air Corporation Wastewater JWWTP Primary Clarifier #C*-6 FIN: JWC6 EPN: JWC6	G	6.8%	3×10^{-5}	0.04
Etc.	All Other Modeled Sources • 22 Individual and 14 Grouped Sources • 7 of these individual sources resulted in risk exceeding $1x10^{-5}$ (The remaining rows in this table would provide similar information to rows 1-5 above)	NA	35.4%	2×10^{-4}	0.2
		Total	**100.0%**	**5×10^{-4}**	**0.5**

Notes: Values in this Exhibit are presented for example purposes only and do not represent an actual facility. Totals may vary due to rounding.

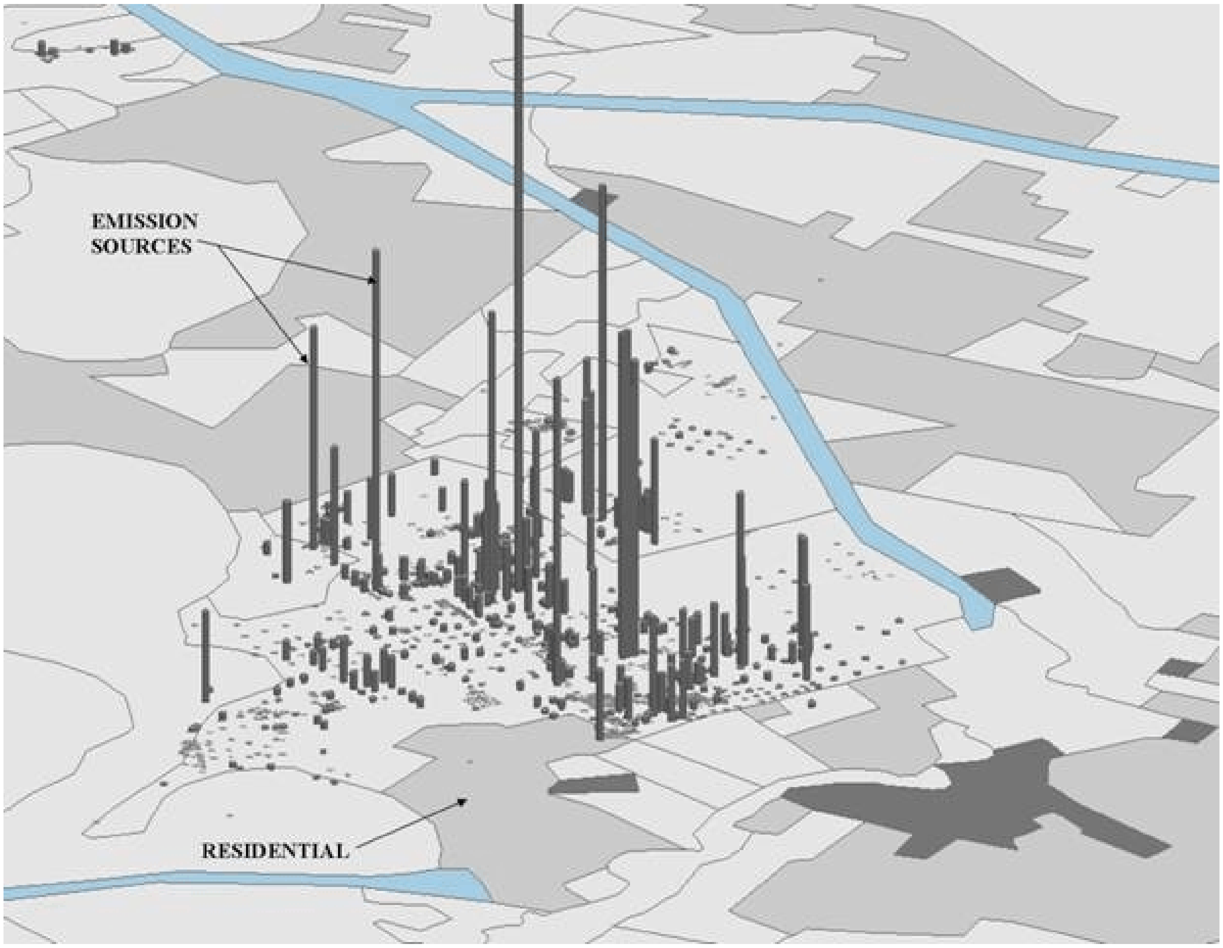
EPN: Emission Point Number FIN: Facility Identification Number
G: Grandfathered Source P: Permitted Source
NA: Not Applicable-grouped source category UN: Unknown

Exhibit 6-7. Example Use of Pie Charts to Illustrate Source Contribution



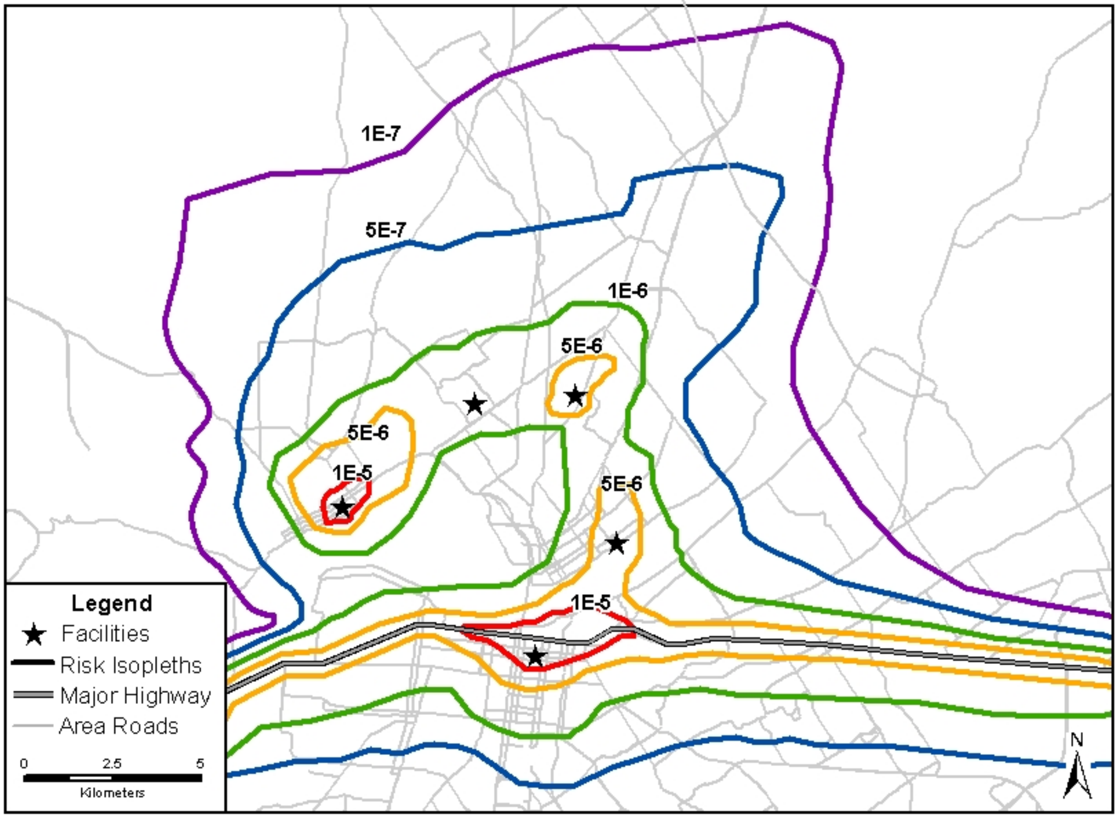
These pie charts indicate the estimated relative emission source contributions to ambient nickel concentrations at five locations in a hypothetical assessment area. The size of each "slice" is proportional to the relative amount (percent of total estimated concentration at a given site) of nickel attributable to each individual source type (e.g., area, onroad), with the concentration and percentage contribution shown for each source type. Note that similar plots could be used for cancer risk estimates (e.g., contribution of each source to total estimated individual cancer risk).

Exhibit 6-8. Tons per Year of Chemical X Released, by Source



Source: EPA's *Regional Air Impact Modeling Initiative* (see: http://www.epa.gov/Arkansas/6pd/rcra_c/raimi/raimi.htm).

Exhibit 6-9. Example of Cumulative Estimated Risk Isopleths from All Modeled Sources for a Hypothetical Study Area



This example illustrates cancer risk isopleths from the combined impact (all air toxics, all sources) of study-area stationary sources (major and area sources). The mobile sources were modeled two different ways. The study-area secondary roads were modeled by allocating mobile emissions uniformly across the study area. This allows the addition of the secondary road impacts to the overall cumulative risk. However, by allocating the emissions evenly over the entire study area, the detail of impacts in the immediate vicinity of any particular secondary road is lost. The major highway in the lower part of the figure, on the other hand, was modeled as a "linked source" [i.e., breaking the length of the highway up into short segments (links) and modeling each segment as an individual source]. This allows the analyst to provide additional detail about the risk posed in the immediate vicinity of that one roadway.

6.4 Characterization of Assumptions, Limitations, and Uncertainties

Some Sources of Uncertainty

- **Scenario uncertainty.** Information to fully define exposure or risk is missing or incomplete
- **Model uncertainty**. Algorithms or assumptions used in models may not adequately represent reality
- **Parameter uncertainty**. Values for model parameters cannot be estimated precisely
- **Decision-rule uncertainty**. Policy and other choices made during the risk assessment may influence risk estimates

Multisource cumulative assessments make use of many different kinds of scientific concepts and data (e.g., in the areas of chemistry, engineering, meteorology, environmental fate and transport, exposure assessment, toxicology, epidemiology, etc.), all of which are used to characterize the expected risk in a particular environmental context. However, pertinent information may or may not be available for many aspects of a risk assessment. Where such information is lacking, the risk assessment framework recognizes the need to employ assumptions or surrogates. In addition, the information used may rely on a variety of professional and science policy judgments (e.g., which models to use, where to locate monitors, which toxicity studies to use as the basis of developing dose-response values). In other words, uncertainty is inherent in the risk assessment process.

The assessment team needs to understand these strengths and the limitations in each assessment, and to be explicit in communicating this information to decision makers and the larger community. They will do this uncertainty analysis during the risk characterization process. Specifically, they will perform an evaluation and presentation of the assumptions, limitations, and uncertainties inherent in the risk assessment. It is critical that this evaluation be thorough and thoroughly explained in order to place the risk estimates in proper perspective.

6.4.1 Documentation of Assumptions

During the course of a risk assessment, a number of assumptions may have been made and used in the development and analysis of the conceptual model, particularly when significant data gaps exist that require a parameter value for the risk assessment to proceed. For example, meteorological data for a specific neighborhood may not have been available so analysts decided to use data from a nearby airport instead. Based on an understanding of the local meteorology, the analysts may have assumed that the airport data was sufficiently representative of the study area to use without question.

All major assumptions made throughout the analysis should be thoroughly documented. Readers of the final report should be able to understand why an assumption had to be made, how it was made, why the assumption was appropriate for the analysis at hand, and the potential influence of the assumption on the final risk estimates.

Transparency, Clarity, Consistency, and Reasonableness (TCCR) – Transparency

The previously noted EPA Risk Characterization Policy states that "A risk characterization should be prepared in a manner that is clear, transparent, reasonable, and consistent with other risk characterizations of similar scope prepared across programs in the Agency." Risk characterization is therefore judged by the extent to which it achieves the principles of **T**ransparency, **C**larity, **C**onsistency, and **R**easonableness (TCCR).

What Are Criteria for Transparency?

Transparency provides explicitness in the risk assessment process. It ensures that any reader understands all the steps, logic, key assumptions, limitations, and decisions in the risk assessment, and comprehends the supporting rationale that lead to the outcome. Transparency achieves full disclosure in terms of :

- The assessment approach employed;
- The use of assumptions and their impact on the assessment;
- The use of extrapolations and their impact on the assessment;
- The use of models vs. measurements and their impact on the assessment;
- Plausible alternatives and the choices made among those alternatives;
- The impacts of one choice vs. another on the assessment;
- Significant data gaps and their implications for the assessment;
- The scientific conclusions identified separately from default assumptions and policy calls;
- The major risk conclusions and the assessor's confidence and uncertainties in them; and
- The relative strength of each risk assessment component and its impact on the overall assessment (e.g., the case for the agent posing a hazard is strong, but the overall assessment of risk is weak because the case for exposure is weak).

Transparency is the principal value among the four TCCR values, because, when followed, it leads to clarity, consistency and reasonableness.

(Other aspects of the TCCR principles are provided in text boxes below.)

Source: EPA's Risk Characterization Policy, which can be found in Appendix A of the following document: http://epa.gov/osa/spc/htm/rchandbk.pdf.

6.4.2 Documentation of Limitations

At the end of the risk characterization, the assessors will have developed both quantitative and qualitative expressions of risk. It is important for the analysts to carefully articulate any important limitations associated with those values. For example, if the risk characterization is performed at the county-level, the results should only be used to make statements about risks at the county-level (i.e., it might be inappropriate to try and extrapolate the results to a finer geographic resolution). As another example, if small, diffuse sources are evaluated in the aggregate, then it might not be possible to draw any conclusions about individual sources in specific locations.

6.4.3 Analysis and Documentation of Uncertainty

TCCR – Clarity

What Are Criteria for Clarity?

Clarity refers to the risk assessment product(s). Making the product clear makes the assessment free from obscurity and easy to understand by all readers inside and outside of the risk assessment process. Clarity is achieved by:

- Brevity;
- Avoiding jargon;
- Using plain language so it's understandable to EPA risk managers and the informed lay person;
- Describing any quantitative estimations of risk clearly;
- Using understandable tables and graphics to present the technical data; and
- Using clear and appropriate equations to efficiently display mathematical relationships (complex equations should be footnoted or referred to in the technical risk assessment).

Uncertainty, within the context of the risk assessment process, is defined as "a lack of knowledge about specific factors, parameters, or models."[7] When applied to the results of a risk assessment, the term "uncertainty" refers to the lack of accuracy in the risk estimate due to unknown values or unavoidable errors in the input assumptions, models and parameter values. Accordingly, one of the key purposes of uncertainty analysis is to provide an understanding of where the estimate of exposure and risk falls within the range of possible values.

There are numerous sources of uncertainties in multisource cumulative assessments, and each merits consideration in the risk characterization step. The degree to which these sources of uncertainty need to be quantified, and the amount of uncertainty that is acceptable, varies considerably from study to study. For a simple screening-level analysis, conservative simplifying assumptions may be used to bias the risk estimate high, but at the expense of certainty that the result is at or near the actual risk posed by the air toxics exposures (i.e., the use of conservative assumptions is intended to result in a health-protective estimate where the risk assessor is confident that the actual risk posed by air toxics exposures is unlikely to be *greater* than the conservative estimate of risk). When the cost to fix an apparent problem is high, this level of uncertainty might not be acceptable.

The uncertainty characterization for many analyses is commonly limited to a qualitative discussion of the major sources of uncertainty and their potential impact on the risk estimate. When the risk manager needs a refined understanding of the uncertainties associated with the risks, sensitivity analysis or other quantitative approaches may be performed to more fully describe the uncertainties associated with the analysis. Specifically, there are two generally used approaches for tracking uncertainty through the risk assessment:

- ***Qualitative Approach.*** In simpler approaches to uncertainty analysis, the assessment uncertainties may be expressed as qualitative statements or even as a subjective confidence interval within which there is a high probability that the true risk will fall.

- ***Quantitative Approach.*** There are several quantitative approaches that can be employed to try to get a more firm handle on the various uncertainties inherent in an assessment. One straightforward approach for expressing uncertainty (particularly for a given parameter) is a

TCCR – Consistency

What Are Criteria for Consistency?

Consistency provides a context for the reader and refers to the presentation of the material in the risk assessment. For example, are the conclusions of the risk assessment characterized in harmony with relevant policy, procedural guidance, and scientific rationales, and if not, why the conclusions differ. Also, does the assessment follow precedent with other EPA actions or why not. However, consistency should not encourage blindly following the guidance for risk assessment and characterization at the expense of stifling innovation. Consistency is achieved by:

- Following statutory requirements and program precedents (e.g., guidance, guidelines, etc.);
- Following appropriate Agency-wide assessment guidelines;
- Using Agency-wide information, where appropriate, from systems such as the Integrated Risk Information System (IRIS);
- Putting the risk assessment in context with other similar risk assessments;
- Defining and explaining the purpose of the risk assessment (e.g. regulatory purpose, or policy analysis, or priority setting, etc.);
- Defining the level of effort (e.g. quick screen, extensive characterization) put into the assessment and the reason(s) why this level of effort was selected; and
- Following established Agency peer review procedures.

"sensitivity analysis." This approach is used to ascertain how much the risk estimate would change as a result of a change to the values of the various input parameters (e.g., emission rate, degradation rate, exposure frequency, etc.). If a small change in a parameter results in relatively large changes in the risk outcomes, the outcomes are said to be sensitive to that parameter (see reference 3). A finding of great sensitivity to a parameter for which the assigned value is highly uncertain may lead to the risk assessment team trying to collect additional information for that parameter so as to provide a sounder base for the value chosen (thus increasing the confidence in the resulting risk estimate). More comprehensive uncertainty analyses may also be considered depending on the needs for the assessment (see below).

When a more thorough investigation of uncertainty (and variability) is necessary, more advanced techniques such as probabilistic techniques (e.g., Monte Carlo simulation analysis) can be used. Using these techniques, important variables (typically those in the exposure assessment) are specified as distributions (rather than as single values) according to what can be expressed about their underlying variability and/or uncertainty. Values are sampled repeatedly from these distributions and combined in the analysis to provide a range of possible outcomes. While this technique can offer a useful summary of complex information, it must be noted that the analysis is only as certain as the underlying data. It is important that the risk assessor clearly expresses individual modeled variables in a way that is consistent with the best information available. While quantitative statistical uncertainty analysis is usually not practical for most multisource cumulative assessments (see Exhibit 6-10), it is nevertheless important that all assessments identify those assessment components for which additional information will likely lead to improved confidence in the estimate of exposure and risk.

TCCR – Reasonableness

What Are Criteria for Reasonableness?

Reasonableness refers to the findings of the risk assessment in the context of the state-of-the science, the default assumptions and the science policy choices made in the risk assessment. It demonstrates that the risk assessment process followed an acceptable, overt logic path and retained common sense in applying relevant guidance. The assessment is based on sound judgment. Reasonableness is achieved when:

- The risk characterization is determined to be sound by the scientific community, EPA risk managers, and the lay public, because the components of the risk characterization are well integrated into an overall conclusion of risk which is complete, informative, well balanced and useful for decision making;
- The characterization is based on the best available scientific information;
- The policy judgments required to carry out the risk analyses use common sense given the statutory requirements and Agency guidance;
- The assessment uses generally accepted scientific knowledge; and
- Appropriate plausible alternative estimates of risk under various candidate risk management alternatives are identified and explained.

Exhibit 6-10. When To Perform a Quantitative Uncertainty Analysis

Quantitative uncertainty analysis is NOT recommended when:

- Conservative, screening-level calculations indicate that the risk from potential exposure is clearly below regulatory or other risk levels of concern;
- The cost of an action to reduce exposure is low; and/or
- Data for characterizing the nature and extent of contamination or exposure are inadequate to permit even a bounding estimate (an upper and lower estimate of the expected value).

Quantitative uncertainty analysis IS recommended when:

- An erroneous result in the exposure or risk estimate may lead to large or unacceptable consequences;
- It is important to understand where a screening-level or point estimate of exposure or risk falls within a range of estimates based on adequate supporting data and credible assumptions; and/or
- It is important to identify those assessment components for which additional information will likely lead to improved confidence in the estimate of exposure or risk.

Source: Adapted from NCRP (1996).[8]

What About Variability in a Multisource Cumulative Assessment?

Variability refers to true heterogeneity or diversity that occurs within a population or sample. Factors that lead to variability in exposure and risk include variability in contaminant concentrations in an environmental medium (e.g., air, water, soil) and differences in other exposure parameters such exposure frequencies.

Temporal and spatial variability in contaminant concentrations is often a very important aspect to consider in multisource cumulative assessments. Spatial variability arises from many factors, including the release forms, physical and chemical dilution and transformation processes, and physical characteristics of the source or surrounding environment. Ecological receptors and humans may exhibit spatial variability in their contact with an exposure medium. Likewise, temporal variability can result from a variety of factors. For example, a source may only emit a chemical at specific times during the year (e.g., during the processing of a batch of product). Meteorological changes between seasons also can cause variable exposure (even though source emissions remain relatively constant). Because variability is an intrinsic property of the quantities being evaluated, it cannot be reduced by data gathering or refinements in models. However, understanding and/or analysis of variability are still important, especially during problem formulation.

Additional discussion of variability in risk assessment is provided in ATRA Volume 1, Chapter 3.

Note that probabilistic analyses and higher levels of uncertainty analysis require special expertise. Accordingly, the way in which uncertainty will be characterized for the assessment should be considered in developing the analysis plan and forming the risk assessment team. Additional discussions of uncertainty analysis, including practical approaches to the assessment and presentation of the principal sources of uncertainty in risk assessments are provided in ATRA Volume 1, Chapters 3 (Section 3.4) and 13, and other documents including the *Residual Risk Report to Congress* (see reference 3); the EPA Risk Assessment Forum's *Guiding Principles for Monte Carlo Analysis* (see reference 7), NARSTO's Improving Emission Inventories for Effective Air Quality Management Across North America (Chapter 8, Appendix C)[9], and the National Research Council's Science and Judgement in Risk Assessment (Chapter 9).[10]

References

1. U.S. Environmental Protection Agency's Risk Characterization Policy can be found in Appendix A of the following document: http://epa.gov/osa/spc/htm/rchandbk.pdf.

2. U.S. Environmental Protection Agency. 2000. *Handbook for Risk Characterization.* Office of Science Policy (EPA 100-B-00-002). December. See http://epa.gov/osa/spc/htm/rchandbk.pdf.

3. U.S. Environmental Protection Agency. 1999. *Residual Risk Report to Congress*. Office of Air Quality Planning and Standards (EPA-453/R-99-001). March. See http://www.epa.gov/ttn/oarpg/t3/reports/risk_rep.pdf.

4. U.S. Environmental Protection Agency. 1986. *Guidelines for the Health Risk Assessment of Chemical Mixtures.* Risk Assessment Forum (EPA/630/R-98/002). September. See http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=22567.

5. U.S. Environmental Protection Agency. 2000. *Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures.* Risk Assessment Forum (EPA/630/R-00/002). August. See http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=20533.

6. U.S. Environmental Protection Agency. 1992. *Risk Characterization Guidelines*.

7. U.S. Environmental Protection Agency. 1997. *Guiding Principles for Monte Carlo Analysis.* Risk Assessment Forum (EPA/630/R-97/001). March. See http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=29596.

8. National Council on Radiation Protection and Measurements. 1996. *A Guide for Uncertainty Analysis in Dose and Risk Assessments Related to Environmental Contamination*. Bethesda, MD, May 1996. NCRP Commentary No. 14.

9. NARSTO. 2005. *Improving Emission Inventories for Effective Air Quality Management Across North America*. NARSTO 05-001. Pasco, Washington, U.S.A. See ftp://narsto.esd.ornl.gov/pub/EI_Assessment/Improving_Emission_Index.pdf

10. National Research Council. 1994. *Science and Judgement in Risk Assessment*. National Academy Press. Washington, D.C.

Chapter 7 Communicating Results

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7.0 Introduction

The purpose of an air toxics **risk assessment** is to evaluate the magnitude and extent of exposure to air toxics and the potential effects on humans and the environment. Risk assessments aid the process of developing risk management alternatives that minimize risk and maximize environmental benefits.

> ***What is Risk Communication?***
> *Risk communication is the way in which decision-makers communicate with various interested parties about the nature and level of risk, and about the risk reduction strategies to reduce the risk.*

The purpose of **risk communication** is to help in the planning of the risk assessment and to convey the results of the risk assessment in a way that effectively supports risk management decisions; this is so that the risk management decisions both meet the goals of the project and provide some comfort level for stakeholders. Good risk communication strategies are a fundamental aspect of developing trust among various stakeholders and the community and are often considered an important first step that can begin even before conducting the risk assessment. Involving the community, establishing and maintaining relationships, and networking with other partners (e.g., agencies, organizations, officials, the media) are key elements in a risk communication strategy. Tailoring communications to the cultural diversity of the community is important because it may help establish the trust necessary to complete a risk assessment that meets all stakeholder and community needs. Risk management rooted in voluntary measures requires effective risk communication to get buy-in.

The subject of risk communication overlaps considerably with related topics discussed in Chapter 6, including EPA's philosophy of transparency, clarity, consistency, and reasonableness (TCCR) as described in its *Policy For Risk Characterization*.[1]

This first part of this chapter (Sections 7.0 through 7.4) provides a general overview of risk communication based on information developed by the Agency for Toxic Substances and Disease Registry (ATSDR)[a] and other authors in order to assist the risk assessment team in communicating the context and results of the risk assessment to the public. The second part of this chapter (Section 7.5 to the end) provides information tailored to communicating about multisource air toxics risks at the local level.

ATSDR has published a handbook on risk communication for its staff.[2] Although directed toward ATSDR staff, this handbook clearly and effectively outlines the detailed steps necessary in order to develop an effective risk communication plan, and is applicable to all risk assessors and risk management teams. The tools and information in the ATSDR handbook (and discussed in this chapter) will help the risk assessment team:

> **Why is Risk Communication Important?**
>
> 1. Provides an opportunity to communicate health risks in a caring, concerned, and well-planned manner
> 2. Involves the community in the risk management process
> 3. Helps alleviate fear or anger and establish trust

[a] ATSDR also has an excellent website on risk communication resources (see http://www.atsdr.cdc.gov/HEC/primer.html).

- Develop a communication strategy;
- Conduct community outreach and evaluation;
- Develop communication messages; and
- Interact effectively with the news media.

Effective Risk Communication:

- Can determine and respond to community concerns;
- Can reduce tension between concerned communities and agency staff; and
- Can explain health risk information more effectively to communities.

It is important to keep in mind that many different people can have a role to play in communicating results, and the stakeholder team performing the overall project can be utilized to help develop a communication strategy specific to the community being examined. This is especially true if there are members of the community taking part in the stakeholder group process. For example, if the stakeholder group includes community residents, it may be useful to have them help communicate results to the community as a whole, particularly if they are trusted by local citizens.

7.1 Risk Perception

If people perceive themselves to be at risk, their perception is unlikely to change even if they are not being exposed or harmed. Elements that affect risk perception include experience, culture, level of education, outrage factors, who is affected/how they are affected (equal treatment), and the level of control exercised on an event or events. People's perceptions of the magnitude of risk also are influenced by factors other than numerical data. According to Covello(3) and other authors:(4)

- Risks perceived to be voluntary are more accepted than risks perceived to be imposed.
- Risks perceived to be under an individual's control are more accepted than risks perceived to be controlled by others.
- Risks perceived to have clear benefits are more accepted than risks perceived to have little or no benefit.
- Risks perceived to be fairly distributed are more accepted than risks perceived to be unfairly distributed.
- Risks perceived to be natural are more accepted than risks perceived to be manmade.
- Risks perceived to be generated by a trusted source are more accepted than risks perceived to be generated by an untrusted source.
- Risks perceived to be familiar are more accepted than risks perceived to be exotic.
- Risks perceived to affect adults are more accepted than risks perceived to affect children.

Two-way risk communication works best. Non-experts want access to information and to gain knowledge. Technical experts and officials also want to learn more about non-experts' interests, values and concerns. The audience includes government, industry, citizens, and both technical and non-technical people. They can all be included in the process as partners.

7.2 Your Risk Communication Strategy - The Overall Plan

In general, planning a risk communication strategy includes the following steps:

- Determine the goals of the communication effort;
- Identify communication restraints;
- Identify the audience(s);
- Identify audience concerns;
- Identify what the audience(s) knows about the issues, both correct information and misinformation;
- Design the message(s) to be sent out to the community;
- Design the "channels"/choose the best methods to reach people;
- Prepare to deliver/present the message;
- Anticipate communication problems;
- Evaluate the program; and
- Modify program as needed.

When working through this process, it is important to know and understand the communication limits and purpose, know your audience, and whenever possible, pretest your message(s). You also should communicate early, often, and fully, and remember that for many of the people in your audience, perception is reality.

A good communication strategy also will use tested principles of good presentation, such as the use of simplified language to present important content and the ability to be objective (not subjective) and balanced. Presentations also should not be limited to just one form or just one medium.

Try to use spokespersons who can communicate knowledgeably, honestly, clearly, and compassionately, and will listen and deal with specific concerns. Finally, it is important to make sure that the information provided in the risk communication strategy is conveyed to all segments of the audience at a level that they can understand and that the communication materials are honest and upfront about uncertainties. It is often better to say "I don't know" than to hedge.

The ability to establish constructive communication will be determined, in large part, by whether or not the audiences perceive the speaker to be trustworthy and believable. Public assessment of how much we can be trusted and believed is based upon four factors:[(1)]

- Empathy and caring;
- Competence and expertise;
- Honesty and openness; and
- Dedication and commitment.

7.3 Risk Comparisons

Many successful risk communication efforts have had one major thing in common – a portrayal that puts the calculated exposure risks from an assessment in perspective, with risk ranges the public can easily relate to and understand.

Risk comparisons can help to put risks into perspective. However, irrelevant or misleading comparisons can harm trust and credibility. Thus, while risk comparisons are commonly used, they should be used with caution, because some kinds of risk comparisons are more likely to be perceived as pre-conceived judgments about the acceptability of risks.(1) Guidelines for risk comparisons have been published(5) and provide rankings of risk comparisons in terms of their acceptability to the community. The highest-ranking comparisons are those that presume a level of trust between the risk communicator and the public, and that consider the factors that people use in their perception of risk. Exhibit 7-1 describes several example risk comparison rankings.

The general rule of thumb is to select from the highest-ranking risk comparisons whenever possible. When there is no choice but to use a low-ranking risk comparison, do so cautiously, being aware that it could backfire. The fifth rank, which risk assessors rarely use, consists of comparisons of unrelated risks (e.g., involuntary vs. voluntary risks). These comparisons have

Exhibit 7-1. Relative Acceptability of Risk Comparisons

- **First-rank risk comparisons (most acceptable)**
  - Of the same risk at two different times
  - With a standard
  - With different estimates of the same risk
- **Second-rank comparisons (less desirable)**
  - Of the risk of doing something versus not doing it
  - Of alternative solutions to the same problem
  - With the same risk experienced in other places
- **Third-rank comparisons (even less desirable)**
  - Of average risk with peak risk at a particular time or location
  - Of the risk from one source of an adverse effect with the risk from all sources of the same effect
- **Fourth-rank comparisons (marginally acceptable)**
  - With cost; or one cost/risk ratio with another
  - Of risk with benefit
  - Of occupational risk with environmental risk
  - With other risks from the same source
  - With other specific causes of the same disease, illness, or injury
- **Fifth-rank comparisons (rarely acceptable – use with caution)**
  - Of risks that may seem unrelated to community members (e.g., smoking, driving a car, lightning)

been found to be very problematic. For example, the risk of driving without a seat belt is a voluntary risk, while exposure to air toxics is generally considered involuntary by community members. Covello et al. [(5)] provide specific examples of each of the comparison ranks, as associated with a manufacturing facility (http://www.psandman.com/articles/cma-4.htm). Risk comparison charts are also provided in Appendix B of that document (http://www.psandman.com/articles/cma-appb.htm), although the authors do not recommend their use in public presentations.

EPA has included risk comparisons in some air toxics analyses. For example, the EPA's NATA National-Scale Risk Characterization (http://www.epa.gov/ttn/atw/natamain) discusses general estimated U.S. background concentrations and risks from air toxics. Additional information on dealing with background risks is provided in Section 5.2.4.

7.4 Implementing Risk Communication Strategies

In order to implement risk communication strategies, agencies may need to plan their messages, approaches to public presentations, and working with the media. The purpose of communication with the public is to inform, educate, and enhance cooperative problem solving and conflict resolution. The strategies for communicating effectively with the public should be written down in a communication plan. This plan should be developed early in the Planning and Scoping process (Chapter 4) and then implemented throughout the process. Communicating early and often with external stakeholders will be key to the overall assessment and risk reduction efforts.

7.4.1 Key Messages and Communication Opportunities

Risk communication strategies also consider the meaning of the information (e.g., will the listener understand how to use the information in forming opinions, making decisions, and taking actions). When risks are calculated for air toxics and the risk results are presented to the public, the community may not be familiar with quantitative risk data and what it means for them. In order to prevent panic and to encourage participation in and buy-in of risk management decisions, risk communication strategies are developed that not only reassure the community, but also explain the potential risks and uncertainties in an understandable, clear, and honest way. Effective communications also provide information in a community-compatible language or form. For example, if the community speaks Spanish, then the communications could be in Spanish as well as English. Similarly, if the community includes Native Americans, the communications could be in the appropriate language and employ appropriate symbolism. The effective communication of risks will allow stakeholders to better participate in management decisions that weigh the benefits of different alternatives against the costs of achieving "acceptable" levels of risks and the costs of disruptions associated with implementation.

When developing messages, it is important to consider the following questions:

- What does the community already know?
- Is this information factual?
- What does the community want to know?
- What does the community need to know?
- Can the information be misunderstood?

When developing a public education campaign, it is generally most effective if the campaign highlights no more than three primary messages. More than three primary messages may convolute the focus of the education campaign. Those developing public education campaigns may wish to test their risk communication messages with trusted audience members before releasing them to the public. This can ensure that the messages are on-target and help avoid community objections that decision-makers may not have anticipated. It also is important to ensure that the message is culturally attuned and fits the language needs of the audience. "Outrage reducers" are outlined by risk communication specialist Peter Sandman (www.petersandman.com).

When developing risk-communication messages, decision-makers should (1) review the concerns and worries of their audience; (2) cover WHO, WHAT, HOW, WHEN, WHERE and WHY; and (3) develop messages that are consistent with their actions.

Different messages and channels may be needed for different audiences. To communicate effectively, the risk communicator should try to understand the audience's values, concerns, and perceptions. Credibility is enhanced by the degree to which the risk communicator correctly identifies, anticipates, and empathizes with the specific concerns of his or her audience(s), which may include:

- Health concerns;
- Safety concerns;
- Environmental concerns;
- Economic concerns;
- Aesthetic concerns;
- Lifestyle/cultural concerns;
- Data and information concerns;
- Fairness/Equity concerns;
- Trust and credibility concerns;
- Process/value concerns (e.g., who makes decisions and how); and
- Risk management concerns.

Audiences May Include:

- Environmental groups;
- Civic organizations;
- Professional and trade organizations;
- Educational and academic groups;
- Religious groups;
- Other government agencies;
- Neighborhood/school organizations;
- Industries; and
- Other organizations.

It may be worthwhile to develop audience profiles for key audiences. Profiles describe the members of the audience, whom they trust and go to for information (decision-makers can seek these people out for advice on communicating with the community), what their prevailing attitudes and perceptions are, and what concerns and worries motivate their actions.

It is important to clearly communicate scientific information and uncertainty:

- Provide all information possible, as soon as possible;
- Communicate when there is progress being made;
- Maintain your relationship with the community;
- Be honest about what you do not know;
- Explain how you will work together to find the answers;
- Help the audience understand the process behind your findings;
- Avoid acronyms and jargon;

- Carefully consider what information is necessary; and
- Use familiar frames of reference to which the audience can relate.

Public interactions may also include availability sessions, informal discussions, or poster sessions. Presentations can occur in a variety of venues some of which are better suited than others to different situations. Determining the best channels for your message depends on understanding when to use which tool and knowing how the community prefers to receive information. Message delivery channels include:

- **Presentations**: Speeches to public groups. Benefit: offers the audience a chance to ask questions; reaches many people at one time. Limitations: if poorly presented, can distort community perception; cannot sufficiently address individual concerns; can become argumentative or confrontational.

- **Open Houses/Availability Sessions**: Informal meeting where public can talk to staff on a one-to-one basis. Benefit: allows for one-to-one conversation; helps build trust and rapport. Limitations: can become argumentative or confrontational.

- **Small Group Meetings**: Sharing information with interested community members and government officials. Benefit: allows two-way interaction with the community. Limitations: may require more time to reach only a few people; may be perceived by community groups as an effort to limit attendance; be sure your information is identical or you may be accused of telling different stories to different groups; can become argumentative or confrontational.

- **Briefings**: Can be held with key officials, media representatives, and community leaders; generally not open to the public. Benefit: allows key individuals to question risk assessment staff before release of public information. Limitations: should not be the only form of community communication; bad feelings may arise if someone feels that they were left off the invite list.

- **Community mailings**: Sends information by mail to key contacts and concerned/involved members of the community. Benefit: delivery of information quickly; may require less planning than a meeting. Limitation: no opportunity for feedback.

- **Exhibits**: Visual displays to illustrate health issues and proposed actions. Benefits: creates visual impact. Limitations: one-way communication tool, no opportunity for community feedback.

- **Fact Sheets**: To introduce new information. Benefit: brief summary of facts and issues; provides background for information discussed during a meeting. Limitations: one-way communication tool; needs to be well-written and understandable.

- **Newsletters**: To inform community of ongoing activities and findings. Benefit: explains findings; provides background information. Limitations: can backfire if community members do not understand or misinterpret contents.

- **News Release**: Statement for the news media to disseminate information to large numbers of community members. Benefit: reaches large audience quickly and inexpensively. Limitations: may exclude details of possible interest to the public; can focus unneeded attention on a subject.

- **Public Meetings**: Large meeting open to the public where experts present information and answer questions, and community members ask questions and offer comments. Benefit: allows community to express concerns and agency to present information. Limitations: can intensify conflicts, rather than resolve controversies.

Presentations require a careful balancing act between effectively conveying key messages and avoiding a range of pitfalls. Important "Dos" and "Don'ts" to avoid presentation pitfalls are outlined in Exhibit 7-2.

7.4.2 Working With the Media

The media can be a primary source of information on risks to the public. Effective news media relations have many benefits, complementing other communication efforts. What people read, see, or hear in news coverage can lend credibility to agencies associated with air toxics risk assessment, and can help to make it a familiar topic for public discussion. News coverage can inform people about air toxics issues and help them ask appropriate questions. Skill in media relations can help risk communications avoid or dispel rumors, respond to criticism, defuse controversy, and even turn adversity to advantage.

News coverage is crucial to engaging the attention of decision-makers and earning the support of opinion leaders. Also, because the news media pay distribution costs, helping journalists cover the issues is a cost-effective way to communicate.

The best approach to the media, as with the public, is to be open and honest, provide information tailored to the needs of each type of media, such as graphics and other visual aids, and provide background material. Journalists also should welcome such materials as fact sheets, press kits, and lists of experts. Establishing an information center also can be an effective way to make materials available to the news media (and to the general public). It also is very important that the material and discussions you have with the media clearly articulate the messages that you want to find their way into print or onto the TV or radio.

Like other communication efforts, working with the news media is done best when it is based on a strategy and follows a systematic process. A good strategy seeks opportunities to match the goals and objectives of the organization with the interests of journalists. As in other communication strategies, assessing the needs of the audience – journalists – is important to reaching them effectively.

After you determine that the rules of your organization concerning contacts with the media have been met, here are a few suggestions on how to deal with news reporters:

- When a reporter calls, be sure to get a name and media affiliation; if what the reporter wants is not clear to you, ask for a clear explanation; if you are uneasy with a reporter's query, decline in a friendly way to continue the conversation.

Exhibit 7-2. Presentation Dos and Don’ts

- **Pitfall**: **Jargon**
  Do: Define all technical terms and acronyms.
  Don’t: Use language that may not be understood by even a portion of your audience.

- **Pitfall**: **Humor**
  Do: Direct it at yourself, if used.
  Don’t: Use it in relation to safety, health, or environmental issues.

- **Pitfall**: **Negative Allegations**
  Do: Refute the allegation without repeating it.
  Don’t: Repeat or refer to them.

- **Pitfall**: **Negative Words and Phrases**
  Do: Use positive or neutral terms.
  Don’t: Refer to national problems (problems unrelated to the issue at hand), i.e., “This is not Love Canal.”

- **Pitfall**: **Reliance on Words**
  Do: Use visuals to emphasize key points, but be culturally correct for the audience.
  Don’t: Rely entirely on words.

- **Pitfall**: **Temper**
  Do: Remain calm. Use a question or allegation as a springboard to say something positive.
  Don’t: Let your feelings interfere with your ability to communicate positively.

- **Pitfall**: **Clarity**
  Do: Ask whether you have made yourself clear.
  Don’t: Assume you have been understood.

- **Pitfall**: **Abstractions**
  Do: Use examples, stories, and analogies to establish a common understanding, but test them out first to make sure they are clear, make your point, and are culturally acceptable.

- **Pitfall**: **Nonverbal Messages**
  Do: Be sensitive to nonverbal messages you are communicating. Make them consistent with what you are saying.
  Don’t: Allow your body language, your position in the room, or your dress to be inconsistent with your message.

- **Pitfall**: **Attacks**
  Do: Attack the issue.
  Don’t: Attack the person or organization.

- **Pitfall**: **Promises**
  Do: Promise only what you can deliver. Set and follow strict orders.
  Don’t: Make promises you can’t keep or fail to follow up.

- **Pitfall**: **Numbers**
  Do: Emphasize performance, trends, and achievements.
  Don’t: Focus on or emphasize large negative numbers.

Exhibit 7-2. Presentation Dos and Don'ts (continued)

Pitfall: **Guarantees**
- **Do**: Emphasize achievements made and ongoing efforts.
- **Don't**: Say there are no guarantees.

Pitfall: **Speculation**
- **Do**: Provide information on what is being done.
- **Don't**: Speculate about worst cases.

Pitfall: **Money**
- **Do**: Refer to the importance you attach to health, safety, and environmental issues; your first obligation is to public health.
- **Don't**: Refer to the amount of money spent as a representation of your concern.

Pitfall: **Organizational Identity**
- **Do**: Use personal pronouns ("I," "we").
- **Don't**: Take on the identity of a large organization.

Pitfall: **Blame**
- **Do**: Take responsibility for your share of the problem.
- **Don't**: Try to shift blame or responsibility to others.

Pitfall: **"Off the Record"**
- **Do**: Assume everything you say and do is part of the public record.
- **Don't**: Make side comments or "confidential" remarks.

Pitfall: **Risk/Benefit/Cost Comparisons**
- **Do**: Discuss risks and benefits carefully (consider putting them in separate communications).

Pitfall: **Risk Comparison**
- **Do**: Use them to help put risks in perspective.
- **Don't**: Compare unrelated risks.

Pitfall: **Health Risk Numbers**
- **Do**: Stress that true risk is between zero and the worst-case estimate. Base actions on federal and state standards, when possible, rather than risk numbers.
- **Don't**: State absolutes or expect the lay public to understand risk numbers.

Pitfall: **Technical Details and Debates**
- **Do**: Focus your remarks on empathy, competence, honesty, and dedication.
- **Don't**: Provide too much detail or take part in protracted technical debates.

Pitfall: **Length of Presentations**
- **Do**: Limit presentations to 15 minutes.
- **Don't**: Ramble or fail to plan the time well.

Source: ATSDR Risk Communication Primer[2]

- Reporters are often under deadline pressure, but you can take enough time to respond effectively; don't get pressured into hasty comments that might backfire.

- Do not hesitate to ask for more information about a story before responding to a request for an interview.

In working with journalists, it is vital to develop good interpersonal relationships. How can you do that? One rule of thumb followed by experienced practitioners is to adhere to the "Five Fs" – Fast, Factual, Frank, Fair, and Friendly (Exhibit 7-3).[6]

Other issues to keep in mind include:

- **Interviews**. Frequently, the best way to get a message out is through an in-person interview. You should generally assume that all statements you make are "on the record." Exhibit 7-4 outlines some techniques to prevent poor transmittal of your message.

- **Press Releases**. Press releases may not be an effective way to transmit a message. However, in some cases, releases that are targeted to particular media outlets and purposes can be useful. For example, the publication of a report on air toxics risk might be newsworthy and of concern to the community, and thus would be sent to local community newspapers. Remember that your press release should emphasize, upfront, the messages that you want to get out to the public.

- **Other Platforms**. You may have the opportunity to communicate your message through other platforms such as:

  – Letters to the Editor. Keep them short, to the point, and prompt.
  – Commentaries. Radio broadcasts and newspapers print a number of opinion pieces each day. Bear in mind that submissions are numerous, acceptances rare.
  – Talk Radio (and TV). Talk shows may request experts to address various environmental issues.

Exhibit 7-3. The "Five Fs" of Media Relations
Fast. Respect journalists' deadlines. If a journalist telephones for information, return the call immediately, even if it is past normal office hours. A phone message returned the next day is often too late. By then, the story already may have been aired or printed.
Factual. Be factual, and make the facts interesting. Stories are to be based on facts. Journalists also appreciate a dramatic statement, creative slogan, or personal anecdote to help illustrate your point. Give the source of any facts and statistics provided.
Frank. Be candid. Never mislead journalists. Be as open as possible and respond frankly to their questions. As long as there is an explanation of the reason, most journalists will understand and respect a source even if he or she is not able to answer a question completely or at all.
Fair. Organizations should be fair to journalists if they expect journalists to be fair to them. Favoring one news outlet consistently, for example, will lose the confidence of the others.
Friendly. Like everyone else, journalists appreciate courtesy. Remember their names; read what they write; listen to what they say; know their interests; thank them when they cover the issues in a factual, unbiased way.

Exhibit 7-4. Interviewing Techniques

- Always think carefully before you answer a question. People often ramble - and say something they wish they hadn't if they answer too quickly. Take a moment to consider what you want to say. If you need more time, ask for the question to be repeated.

- Don't talk just to keep a conversation going with a reporter. Experienced reporters will be silent because often people they interview will talk to fill awkward voids and then say something they don't mean to say.

- Ask the reporter to make your affiliation clear in the story.

- Listen carefully to questions and respond clearly. Avoid jargon. If you have a key idea that you want to get across, repeat it several times, perhaps using different words. This is especially useful for broadcast: no matter how the tape is edited, you will make your point.

- Don't hurry: speak slowly, and in short, concise sentences. State your position in simple, easy-to-understand language. Use everyday examples and analogies, when possible.

- Never talk down to a reporter. You are partners in getting your message across. Arrogance will come across negatively to an audience. An "attitude" can turn an interview into a confrontation.

- Don't lose your temper! No matter how antagonized you feel, recognize that this can be a tactic to get you to say something you do not wish to say.

- If you don't know the answer to a reporter's question, or cannot answer, just refrain from answering. A lie or bad guess will return to haunt you. You will lose credibility.

- Some reporters may ask to tape an interview over the telephone. This is a common practice for radio reporters to obtain "sound bites" and to get accurate quotes. The reporter should inform you of the taping before it begins. Do not repeat an allegation – it could be taken out of context.

Additional Suggested References

Calow, P. 1997. H*andbook of Environmental Risk Assessment and Management*. Blackwell Publishers.

Crawford-Brown, D. 1999. *Risk-based Environmental Decisions: Culture and Methods*. Kluver Academic Publishers.

Johnson, B.B., Sandman, P.M., and Miller, P. 1992. Testing the Role of Technical Information in Public Risk Perception by RISK. *Issues in Health and Safety*, Fall 1992:341-364.

Lundgren, R.E. 1994. *Risk Communication: A Handbook for Communicating Environmental, Safety, and Health Risks*. Battelle Press, Columbus, OH.

Langford, Ian. 2002. An existential approach to risk perception. *Risk Analysis* 22(1):101-120.

U.S. Environmental Protection Agency. 1992. *Air Pollution and the Public: A Risk Communication Guide for State and Local Agencies*. EPA 450/3-90/025.

For an additional list of risk communication references, see http://www.psandman.com/articles/cma-bibl.htm.

7.5 Presenting Basic Information About Multisource Cumulative Risk and Hazard

Depending on the purposes for the assessment, different outputs of the risk assessment process will be the focus of communication. The basic information to be presented to the community and other interested stakeholders may include:

- The range of hazard and/or risk estimated for the study area;
- An estimate of the number of people associated with different hazard and/or risk levels (this may be for the community at large and/or for each exposure area evaluated);
- The chemicals and sources that account for the majority of hazard or risk, or a presentation of chemical or source-specific hazard or risk ordered from highest to lowest;
- A comparison of the hazard or risk estimates to other risks, such as background risk (if evaluated);
- The major assumptions, limitations, and uncertainties associated with the above information (see Section 7.5.2); and
- The community-based expectations of acceptable risk and hazard, and those areas where the expectations are exceeded.

Note that risk assessors acting as risk communicators should be careful to avoid making inferences about whether the results for a particular chemical or source should be the target for risk reduction (that is the realm of the risk manager). One way to do this is to simply provide summary information on all chemicals and all sources, and the percentage they all contribute to overall risks. In subsequent risk communication about the findings of the risk assessment, this information may be focused on those chemicals that "account for the majority of hazard and risk;" however, the risk managers should provide input on how to identify those risk factors that are significant and those that are not (from a risk management perspective).

It should also be noted that negative findings may be as important as positive findings. For example, it may be necessary to contrast specific concerns about elevated exposure and health impacts from a local industry identified during planning and scoping with assessment results that indicate exposure and/or risk levels associated with that industry are likely to be low.

7.5.1 Presentation Formats for Multisource Risk Outputs

Risk characterization results for a multisource assessment can be presented in a wide variety of ways, including tables, bar or pie charts, and maps such as GIS overlays. Chapter 6 provides several general examples of ways to depict multisource risk across a study area. Several additional example presentation formats are provided below and in the RAIMI Case Study provided in Appendix A.

- **Exhibit 7-5** presents an example risk summary table. In this example, the risk or hazard posed by all evaluated carcinogens from all known sources impacting two different neighborhoods is first calculated at each modeling point and then averaged for all the modeling points in a given neighborhood (either Happy Land or Big City neighborhood). For example, Happy Land neighborhood has an overlay of 500 modeling points. The estimated chemical-specific cancer risks posed by all sources impacting the neighborhood at each of these points is determined by multiplying the multisource modeled annual average chemical-specific concentration at each point times the associated chemical-specific IURs (see Chapter 6). In Happy Land, there are a total of 8 carcinogens impacting the neighborhood that are emitted from a mix of local stationary and mobile sources. The annual average concentrations of each of these 8 chemicals is modeled at each of the 500 modeling points. The upper bound cancer risk at each point is then estimated by combining with the appropriate toxicity value. The *average* upper bound cancer risk *across the Happy Land neighborhood* is, for each chemical, the sum of the 500 individual census block risk estimates divided by 500. For example, the average upper bound benzene risk estimate of 9×10^{-6} shown in Exhibit 7-5 is the average of the 500 individual benzene risk estimates for the 500 different modeling points within the Happy Land neighborhood. The sum of the chemical-specific average upper bound risk estimates (on a chemical-by-chemical basis) is the average cumulative upper bound cancer risk for this neighborhood (all chemicals, all sources). A similar exercise could be performed for hazard quotients to determine average chemical-specific hazard quotients and an average cumulative hazard index (all chemicals, all sources). Another way to effectively present some of the information in Exhibit 7-5 might be a pie chart, with different wedges representing individual chemicals and wedge sizes corresponding to the fraction of the cumulative cancer risk or hazard index they pose.

- **Exhibit 7-6** presents an example qualitative approach for displaying information. In this example, the chronic hazard posed by each evaluated chemicals with RfCs from all known sources impacting four different neighborhoods is first calculated at each modeling point and then averaged (by chemical) across all the modeling points in a given neighborhood. The result is then compared to some predetermined decision criteria established by the partnership team during the planning and scoping phase of the assessment. In this example, the partnership team decided that if the chemical-specific neighborhood average hazard was, on a chemical-by-chemical basis, less than HQ = 0.1, the chemical would not be considered further (either for higher levels of analysis or for potential risk mitigation).

  For example, the Mitchell Hill neighborhood has an overlay of 250 modeling points. The estimated chemical-specific hazards posed by all sources impacting the neighborhood at each of the 250 points was determined by dividing the multisource modeled annual average chemical-specific concentration for each chemical at each internal point by the associated chemical-specific RfCs (see Chapter 6). In Mitchell Hill, there are a total of 7 RfC chemicals impacting the neighborhood that are emitted from a mix of local stationary and mobile sources. The annual average concentrations of each of these chemicals is modeled at each of the 250 modeling points. The hazard at each modeling point is then determined by combining the modeled concentration with the appropriate toxicity value. The *average* hazard *across the Mitchell Hill neighborhood* is, for each chemical, the sum of the 250 hazard estimates divided by 250. The average value is then compared to the pre-established decision criteria and the chemical specific hazard labeled appropriately. For this table, the analysts decide to label chemical-specific hazard quotients that are less than 0.1 as "LOW" and chemical-specific hazard quotients that are greater than or equal to 0.1 as "Needs more information," indicating that the chemical will be the subject of additional evaluation or, perhaps, more immediate risk reduction.

  Also note that the focus of this particular table was to provide qualitative information regarding hazard. The table authors also used footnotes to provide information about the chemicals that are carcinogens. In addition, also note that this analysis team has not limited itself to only the federal HAPs (the planning and scoping group expanded their list of chemical for consideration to include ammonia and hydrogen sulfide).

(Also note in this exhibit that color and bolding have been used to emphasize certain elements. This can be a useful technique to help emphasize specific information.)

- In addition to providing information on risks posed by specific chemicals in a particular area, it will also be helpful to display information that shows which sources are responsible for those risks (communicating information about source apportionment). Several examples of how to display source apportionment are provided in Appendix A (RAIMI case study). An additional example is provided in **Exhibit 7-7**.

  In this example, the average cancer risk for the Johnson Creek neighborhood study area ($3{\times}10^{-5}$) has been apportioned among the various modeled local sources contributing to that average value. Here, the analysts have broken out the sources into only four categories. Alternatively, they could have listed each source individually along with the risk posed by the individual chemicals associated with each.

- Another important communication tool is to provide a graphical presentation that provides the "big picture" of what was done and what was found in the analysis (see **Exhibit 7-8**).

- Finally, GIS overlays and other types of maps can be used to visually communicate information in a wide variety of ways (see **Exhibit 7-9** and additional examples in Appendix B). In the Exhibit 7-9 example, GIS has been used to highlight a specific geographic area within a larger study are (the dots are the modeling grid) and highlights specific risk and demographic information about that area. This approach can be modified in a wide variety of ways to help focus attention to one or more aspects of the area in question.

7.5.2 Communicating Uncertainty

Recognizing and explaining the concept of uncertainty is a critical component of risk communication. Scientific uncertainty can complicate communications when officials attempt to satisfy public demand for reliable, accurate, and meaningful information pertaining to the evaluation of risk. Communication with the public regarding uncertainty in risk estimates can also be complicated by the complexity of the information, a lack of understanding of difficult scientific concepts and analyses, and a public perception that correlation and association are equivalent to causation. Ultimately, persons responsible for communicating risk will have the difficult task of explaining the limitations and uncertainties associated with a risk assessment's findings.

That having been said, audiences should be given as much information as possible, so that they can understand that uncertainty is not unexpected and that "answers" may evolve with the availability of new information and science. If stakeholders are making demands of "total certainty," one issue the risk communicator may try to identify is whether they are questioning the scientific process itself, or rather, if their underlying doubts are related to the input values or assumptions used in the assessment process.

Recommendations from government agencies familiar with risk communication, including the Nuclear Regulatory Commission (NRC), suggest using a variety of methods, such as diagrams, outlines, and analogies, when explaining the potentially complex topic of uncertainty. For more information on effective communication of risk results, refer to Chapter 29 of ATRA, Volume 1, as well as the following resources:

- *A Primer on Health Risk Communication Principles and Practices*, published by the Agency for Toxic Substances and Disease Registry (see http://www.atsdr.cdc.gov/HEC/primer.html);

- *The Technical Basis for the NRC's Guidelines for External Risk Communication*, published by the U.S. Nuclear Regulatory Commission (see http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6840/cr6840.pdf);

- EPA's Risk Assessment Guidelines (see http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=55907); and

- *Communicating in a Crisis: Risk Communication Guidelines for Public Officials*, compiled by the U.S. Department of Health and Human Services (see http://www.riskcommunication.samhsa.gov/RiskComm.pdf).

7.6 Risk Trends

Developing trends or projections in risk over time is one approach for putting the assessment results in perspective and is a representation of risks that the public can easily relate to and understand. The presentation of risk trends for a community, however, will usually require multiple years of data and multiple analyses of risk to track the trends. When using a methodology such as RAIMI, the process is simplified since the method's computer tools allow the processing of "what if" scenarios. This means that analysts can also perform trend analyses rather quickly (assuming no major changes other than emissions in the study area from year to year). The reason for this has to do with the use of unit emission rates for the various pollutants (see Section 5.2.3.2). As future years of emissions data are developed, they can be converted into unit emission rates, compared to previous year data and changes to the original risk analysis can be calculated. Risk trends are most easily communicated by a simple bar chart that shows the change in risk estimates to people in a particular geographic area from year to year (Exhibit 7-10).

Exhibit 7-5. Example Risk Summary Presentation								
Contaminant	**Neighborhood Cumulative Individual Risk and Chronic Hazard Values (All chemicals, all sources; averaged across all neighborhood census block internal points) Lifetime constant exposure scenario**							
	Happy Land Neighborhood				**Big City Neighborhood**			
	Estimated Cancer Risk	**Percent Contribution[a]**	**Hazard**	**Percent Contribution[a]**	**Estimated Cancer Risk**	**Percent Contribution[a]**	**Hazard**	**Percent Contribution[a]**
Benzene	**9×10^{-6}**	2	0.1	9	**3×10^{-5}**	11	0.1	23
1,3-Butadiene	**5×10^{-4}**	86	**1**	90	**1×10^{-4}**	36	0.3	68
Ethylene oxide	**2×10^{-5}**	3	0.01	1	**2×10^{-5}**	7	0.03	7
Formaldehyde	**2×10^{-6}**	<1	0.003	<1	**2×10^{-5}**	7	0.01	2
Benzo(a)anthracene	**9×10^{-6}**	2	NC	-	**2×10^{-5}**	7	NC	-
Benzo(a)pyrene	**3×10^{-5}**	5	NC	-	**7×10^{-5}**	25	NC	-
Benzo(b)fluor-anthene	**9×10^{-6}**	2	NC	-	**2×10^{-5}**	7	NC	-
TOTALS	**6×10^{-4}**	100	**1**	100	**3×10^{-4}**	100	0.4	100

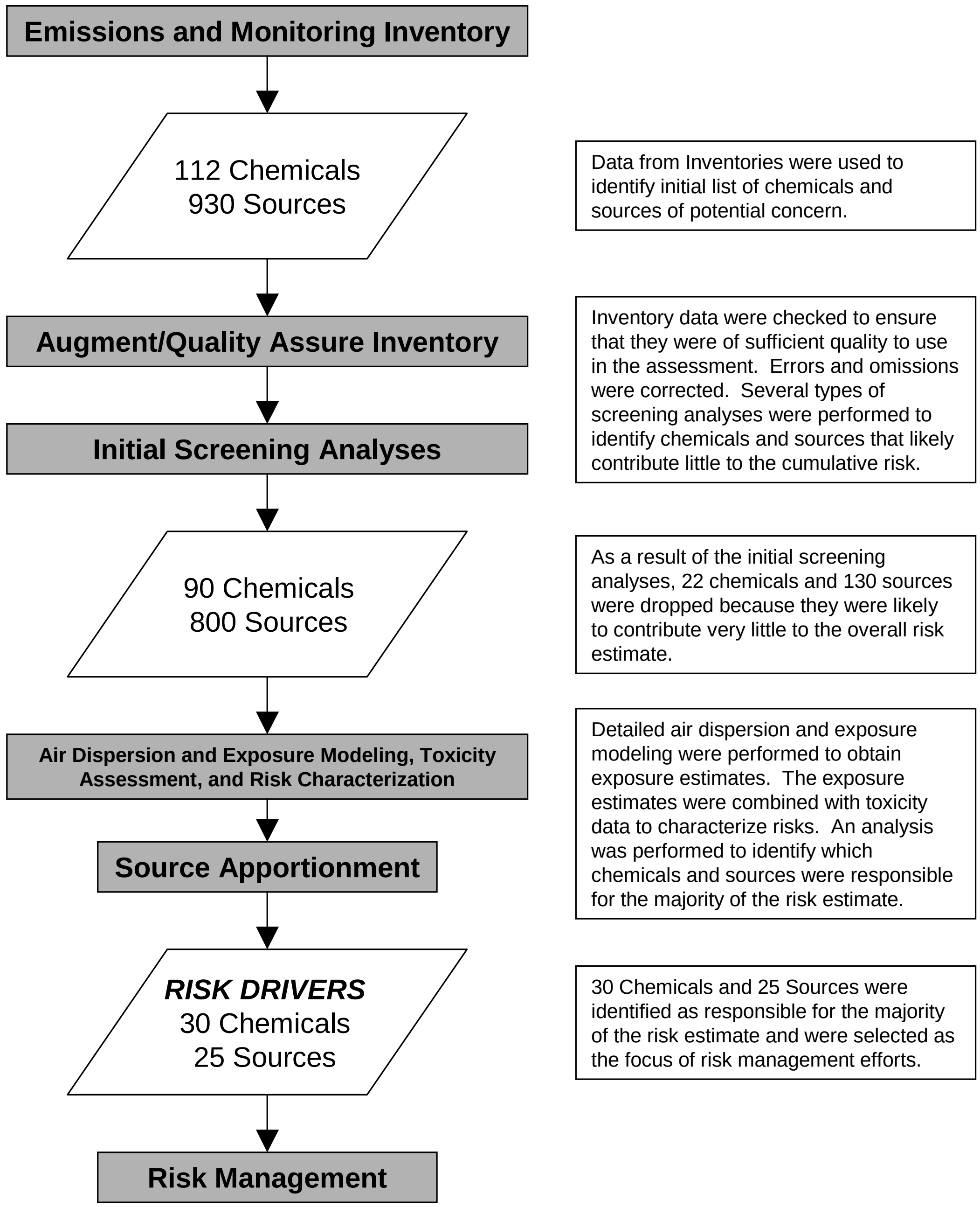
NC Not calculated (RfC not available)
[a] Percent contribution to cumulative cancer risk or hazard for that neighborhood.

Exhibit 7-6. Example Qualitative Presentation of Chronic Hazard Results				
Chemical	**Average Neighborhood Chemical-Specific Hazard (all sources)**			
	Mitchell Hill	**Kramer Heights**	**Manning Acres**	**Wagner's Point**
Ammonia	**Low**[a]	**Low**	**Low**	**Low**
Arsenic[b]	**Low**	**Low**	**Low**	**Low**
Benzene[b]	**Low**	**Low**	**Low**	**Needs more information**[c]
Cadmium[b]	**Low**	**Low**	**Low**	**Low**
Hydrogen sulfide	**Low**	**Low**	**Low**	**Low**
Carbon tetrachloride[b]	**Low**	**Low**	**Low**	**Low**
Chromium (hexavalent)[b]	**Needs more information**[c]	**Needs more information**[c]	**Needs more information**[c]	**Needs more information**[c]

(a) Low means HQ < 0.1
(b) This chemical is also a carcinogen
(c) Areas marked as "needs more information" had a HQ $\geq$ 0.1. These chemicals are candidates for further analysis and possible risk reduction.

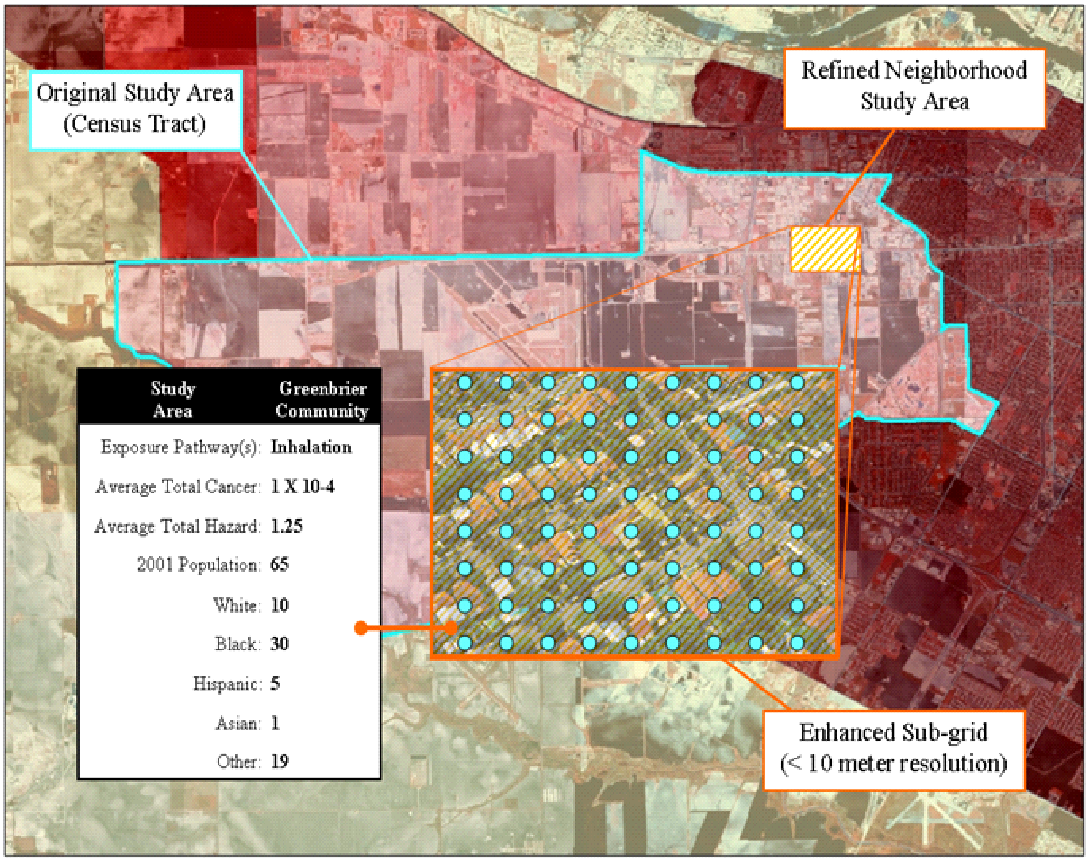
Exhibit 7-7: Example Presentation of Source Apportionment of Average Cancer Risk Johnson Creek Neighborhood			
Source Description		**Estimated Average Cancer Risk for Lifetime Continuous Exposure**	**Source-Specific Percentage of Inhalation Risk**
1	All On-Road Gasoline Vehicles Surrogate: On-Road Mobile	1×10^{-5}	32%
2	Gasoline Distribution Stage 1 Surrogate: Commercial Land Use and Industrial Land Use	1×10^{-5}	32%
3	All Major Stationary Sources	8×10^{-6}	26%
4	All Other Modeled Sources (36 Individual and 25 Grouped Sources)	3×10^{-6}	10%
	TOTALS	3×10^{-5}	100%

Exhibit 7-8. Example Graphical Representation of the Overall Assessment Methodology and Results



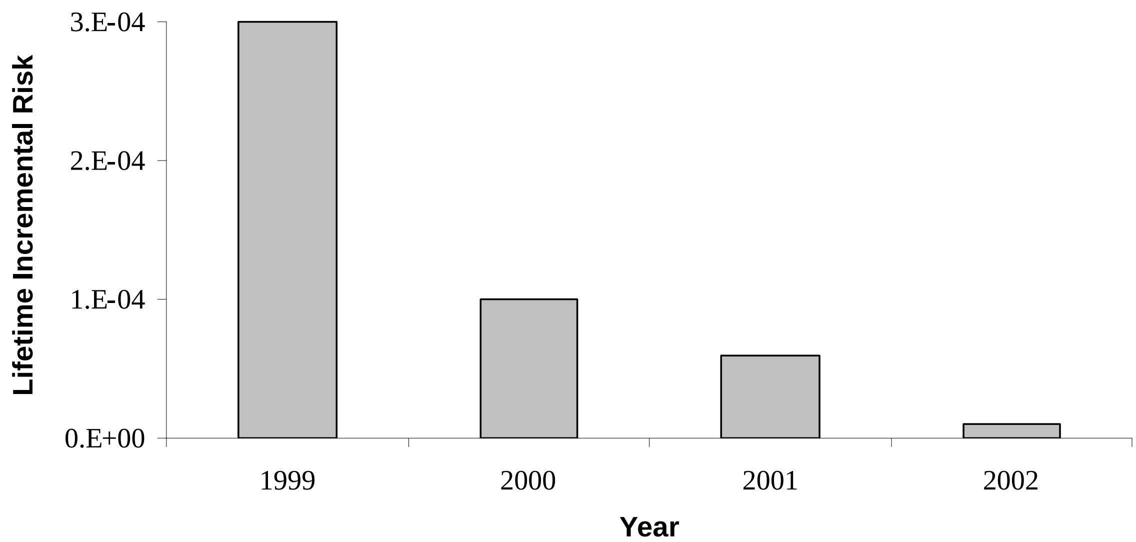
This graphic illustrates each step of a sample multisource cumulative assessment and describes the role each plays in developing the ultimate result – identifying the chemicals and sources responsible for the majority of the risk estimate. This sample assessment also illustrates a tiered or phased approach in which the risk assessment begins with a large set of chemicals and sources of potential concern and narrows the focus (by screening out insignificant contributors) for the more refined tier of analysis.

Exhibit 7-9. Example Use of Maps/GIS Overlays to Communicate Assessment Results (Average Total Cancer Risk, All Sources, All Chemicals)



Source: EPA's *Regional Air Impact Modeling Initiative* (see: http://www.epa.gov/Arkansas/6pd/rcra_c/raimi/raimi.htm).

Exhibit 7-10. Example Risk Trend Bar Chart
All Sources, All Chemicals Impacting Study Area



References

1. U.S. Environmental Protection Agency. 1995. *Policy for Risk Characterization* ("Browner Memorandum"). Science Policy Council, Washington, DC., March 1995. Available at: http://64.2.134.196/committees/aqph/rcpolicy.pdf.

2. Agency for Toxic Substances and Diseases Registry (ATSDR). 1994. *Tools and Techniques for Effective Health Risk Communication*. This is an update of the ATSDR *Primer on Health Risk Communication Principles and Practices*, October 1994. Available at: http://www.atsdr.cdc.gov/HEC/primer.html.

3. Covello, V.T., Sandman, P. 2001. Risk communication: Evolution and Revolution, in Wolbarst A. (ed.). *Solutions to an Environment in Peril*. John Hopkins University Press, Baltimore, MD: pp. 164-178. Available at: http://www.psandman.com/articles/covello.htm.

4. Fischhoff B, Lichtenstein S, Slovic P, Keeney D. 1981. *Acceptable Risk*. Cambridge University Press, Cambridge, Massachusetts.

5. Covello, V.T., Sandman, P.M., Slovic, P. 1988. *Risk Communication, Risk Statistics and Risk Comparisons: A Manual for Plant Managers*. Chemical Manufacturers Association, Washington, D.C., 1988. Available at: http://www.psandman.com/articles/cma-0.htm.

6. Cutlip, S.M., Center, A.H., and Broom, G.M. 1985. *Effective Public Relations*. Prentice-Hall, Englewood Cliffs, New Jersey.

Chapter 8 Risk Reduction Options

Table of Contents

8.0 Introduction

This chapter discusses the process of managing the risks identified in a multisource cumulative assessment (see Exhibit 8-1). This chapter draws on and augments the discussion in ATRA Volume 1, Chapter 27, by providing additional information pertinent to communities assessing and responding to the cumulative impact of numerous sources of air toxics. Risk managers and others with a stake in the risk management process are referred to the ATRA Volume 1 chapter for more information on this subject..

8.1 Role of Risk Management in Multisource Cumulative Assessment

The multisource cumulative assessment will result in a risk characterization that describes the cumulative risk posed by sources in a study area to populations in the study area. The risk managers will have to decide whether the risks are acceptably low or whether risk reduction options should be considered.

In order to help the risk managers with this task, the risk characterization will commonly provide a source apportionment of the risks to identify the percentage that each chemical/source combination contributes to the overall risk. These data, along with other relevant information such as technological feasibility and cost (see Exhibit 8-2) of risk reduction alternatives, are then factored into decisions about how to reduce risk to the exposed populations.

This relationship between risk assessment and risk management has been discussed by a variety of people and institutions. In addition to Exhibit 8-2, another helpful approach to understanding the interplay of risk assessment and risk management is that described by the Presidential/Congressional Commission on Risk Assessment and Risk Management (CRARM) in their Reports *Framework for Environmental Health Risk Management* and *Risk Assessment and Risk Management In Regulatory Decision-Making* (the two-volume "White Book").[(1)] The Commission developed a six-stage integrated framework for environmental health risk management that can be applied to most situations (Exhibit 8-3):

- Define the problem and put it in context;
- Analyze the risks associated with the problem in context;
- Examine options for addressing the risks;
- Make decisions about which options to implement;
- Take actions to implement the decisions; and
- Conduct an evaluation of the action's results.

The Commission noted that the process of examining risk management options does not have to wait until the risk analysis is completed, although a risk analysis often will provide important information for identifying and evaluating risk management options. In some cases, examining risk management options may help refine a risk analysis. The Commission also recommended that all of these steps involve stakeholders (see ATRA Volume 1, Chapter 28).

Exhibit 8-1. The General Multisource Cumulative Assessment Process For Community Assessment – Focus on Risk Management

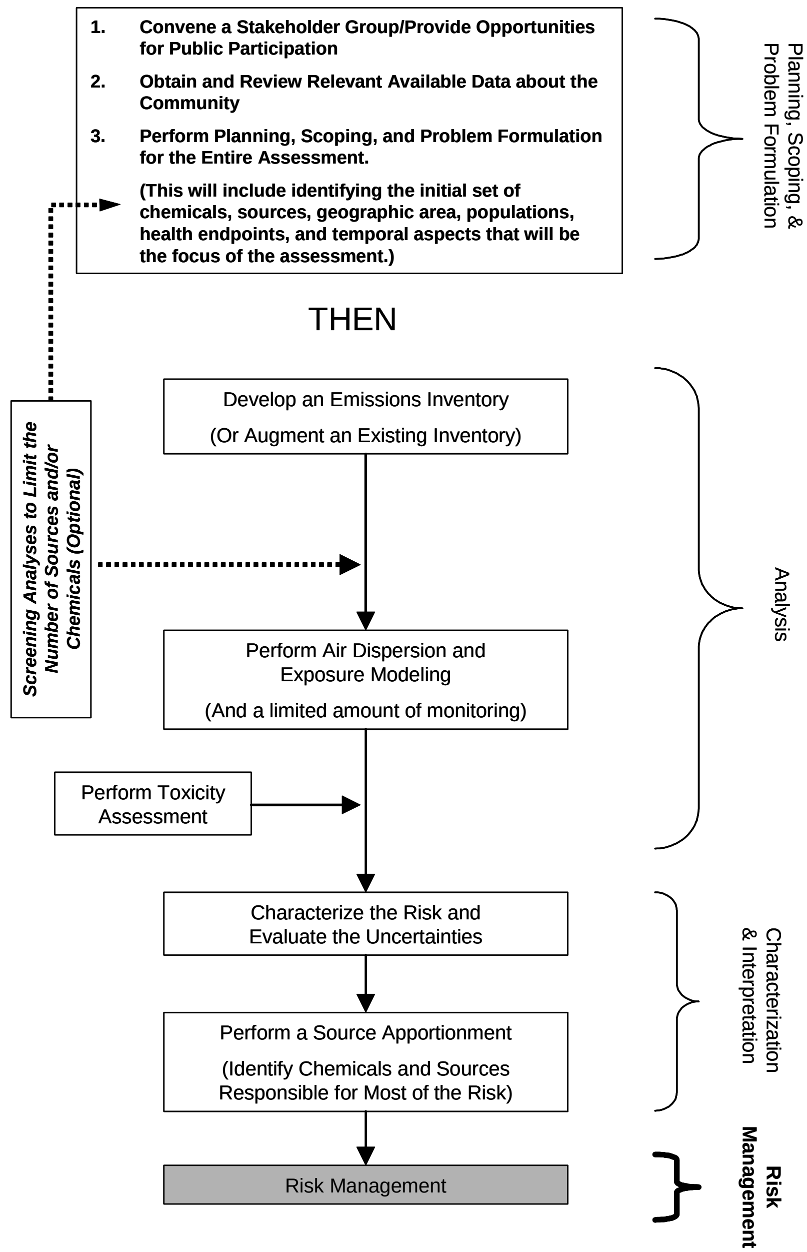


Exhibit 8-2. Illustration of the Relationship Between Risk Assessment and Risk Management[2]

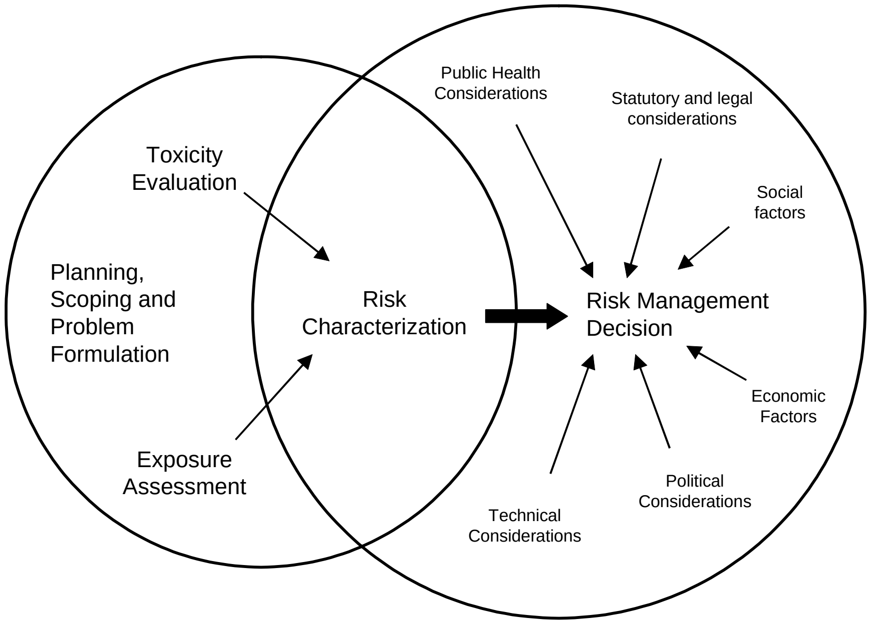
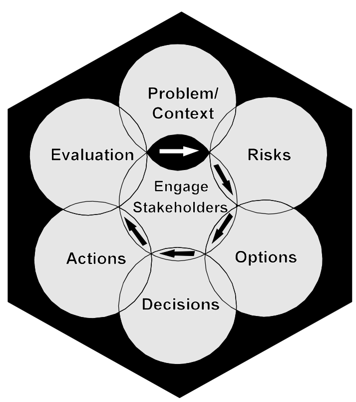


Exhibit 8-3. The CRARM Framework for Risk Management



Other than defining the problem and putting it in context and then analyzing the risks, the remainder of the steps identified by the CRARM constitute the risk management phase. (Note that the risk assessment/risk management framework outlined by the CRARM in Exhibit 8-3 is drawn as a circle, indicating that as stakeholders learn more and as things change in the study area, the process may need to go through a continual set of iterations to achieve and maintain a healthy environment.)

8.2 The Role of Risk Estimates in Decision-Making

Decision-makers have a number of options when deciding what types of risk estimates to consider as inputs to risk management decisions. Estimates of human health risk generally fall into two categories, estimated **cancer risk** and the estimated **noncancer hazard** magnitude of exposure concentration or dietary intake greater than a pre-established reference exposure level), as described in more detail in ATRA Volume 1, Chapters 13 and 22. Non-cancer hazard may be considered for both acute (short-term) and chronic (longer-term) exposures. In some cases, **ecological risk** may be a factor in decision-making.

In some situations, risk managers may choose to consider EPA's approach for assessing an "ample margin of safety." For cancer risks, EPA generally considers incremental risk (or probability) of cancer for an individual potentially exposed to one or more air toxics. In protecting public health with an ample margin of safety, EPA strives to provide maximum feasible protection against risks to health from HAPs by (1) protecting the greatest number of persons possible to an individual lifetime risk level no higher than 1×10^{-6} (one in one million) and (2) limiting to no higher than approximately 1×10^{-4} (one in ten thousand) the estimated risk that a person living near a source would have if exposed to the maximum pollutant concentrations for 70 years. These goals are described in the preamble to the benzene National Emissions Standards for Hazardous Air Pollutants (NESHAP) rulemaking (54 *Federal Register* 38044, September 14, 1989) and are the goals incorporated by Congress for EPA's residual risk program under Clean Air Act (CAA) section 112(f). Exhibit 8-4 describes some of the key steps in the development of the 1×10^{-4} to 1×10^{-6} carcinogenic risk range.

For non-carcinogenic substances, on the other hand, risk managers may consider a reference level that is developed based on data from laboratory animal or human epidemiology studies (see ATRA Volume 1, Chapter 12), and to which uncertainty factors are applied. The reference level is usually an exposure level below which there are not likely to be any adverse effects from exposure to the chemical. Exposures above the reference level may have some potential for causing adverse effects. This concept may also be applied generally to ecological risks.

Risk estimate options generally revolve around estimates of individual risk, the number of people at different risk levels (population risk), and occasionally include the expected incidence of disease in the entire population. Risk estimates can be derived for the current population as currently distributed in an area or for a population size and geographic distribution that might occur in the future; similarly, they may focus on risk estimates for persons currently exposed or possible risks calculated for a hypothetical individual located where exposures are expected to be relatively high. It is important to note that risk estimates should strive to take into account both **indoor** and **outdoor** exposure to toxics, when possible.

Exhibit 8-4. Development of the 10^{-4} to 10^{-6} Carcinogenic Risk Range

The 1970 CAA established Section 112 to deal with hazardous air pollutants. Once the EPA Administrator had identified such a pollutant and "listed" it, he/she was directed to set emission standards for sources emitting it at levels that would "provide an ample margin of safety to protect the public health." The regulation of benzene pursuant to Section 112 illustrates the evolution of risk-based decision-making for carcinogens and the consideration of the "ample margin of safety."

- EPA listed benzene as a HAP in June 1977 and indicated that the "relative risk to the public" would be considered in judging "the degree of control which can and should be required."

- In 1980, the first round of benzene standards followed the proposed procedures in EPA's 1979 draft airborne carcinogen policy, which reflected a technology-based approach to emission standard development with a limited role for quantitative risk assessment in establishing priorities and ensuring that the residual risks following the application of "best available technology" (BAT) were not unreasonable.

- In 1984, after "weighing all factors," EPA made several changes to the proposed benzene rules, arguing that the risks were "too small to warrant federal regulatory action." These decisions were promptly challenged by the Natural Resources Defense Council, who argued about the uncertainties in the risk estimates and the inappropriate consideration of cost in regulatory decisions made under Section 112. The issues raised were similar to litigation already pending on amendments to the original vinyl chloride standards.

- On July 28, 1987, Judge Robert Bork, writing for the D.C. Circuit Court of Appeals, remanded the vinyl chloride amendments to EPA, finding that the Agency had placed too great an emphasis on technical feasibility and cost rather than the provision of an "ample margin of safety" as required by the statute. The opinion also laid out a process for making decisions, consistent with the requirements of the law. The Bork opinion held that EPA must first determine a "safe" or "acceptable" level considering only the potential health impacts of the pollutant. Once an acceptable level was identified, the level could be reduced further, as appropriate and in consideration of other factors, including cost and technical feasibility to provide the required ample margin of safety. The Court also held, however, that "safe" did not require a finding of "risk-free" and that EPA should recognize that activities such as "driving a car or breathing city air" may not be considered "unsafe."

- In September of 1989, after proposing several options and receiving considerable public comment, EPA promulgated emission standards for several categories of benzene sources. EPA argued for the consideration of all relevant health information and established "presumptive benchmarks" for risks that would be deemed "acceptable." The goal, which came to be known as the "fuzzy bright line," is to protect the greatest number of persons possible to an individual lifetime risk no higher than one in 1,000,000 and to limit to no higher than approximately one in 10,000 the estimated maximum individual risk. The selection of even "fuzzy" risk targets placed greater emphasis on the development and communication of risk characterization results.

Source: National Academy of Sciences' *Science and Judgment in Risk Assessment* (The Blue Book).(2)

As introduced in the last chapter, risk managers will often be interested in several different descriptions of risk when evaluating the need for risk reduction. To reiterate, these “risk descriptors” commonly include:

- **Risk to a specified individual**. Most risk assessments focus on estimating individual risk rather than the incidence of adverse effects (e.g., numbers of predicted cancer cases per year) in a population. There are two general estimates of individual risk:

  – **High-end** risk estimates seek to determine a “plausible worst case” situation among all of the individual risks in the population. This estimate is meant to describe an individual who, as a result of where they live and what they do, experiences the highest level of exposure within some reasonable bounds. Reasonable maximum risk estimates are often defined conceptually as “above the 90th percentile of the population”(3) but not at a higher exposure level than the person exposed at the highest level in the population. When calculated using deterministic methods, the high-end individual is calculated by combining upper-bound and mid-range exposure factors (e.g., an average body weight, but high-end ingestion rate) so that the result represents an exposure scenario that is both protective and reasonable, but not higher than the worst possible case.

  – **Central-tendency** risk estimates seek to determine a reasonable “average” or “mid-range” situation among all of the individual risks in the population. Many risk management decisions related to exposure to radioactive substances (e.g., in nuclear power plants) are based on central-tendency risk estimates.

  Note that when calculating deterministic risk estimates, both a high-end and central-tendency estimate of risk give the risk manager some sense of the range of risks in the population. When risks to a population are developed using probabilistic methods, this becomes a moot point, since the result is a distribution of risks across the population, which necessarily includes information about the full variability of risk across the population – including both high-end and central-tendency risks. See ATRA Volume 1, Chapter 31, for more information on probabilistic approaches to risk assessment.

- **Risk to the total population**. Whether or not risk to the total population is considered by EPA may depend on the regulatory authority provided by the CAA. For example, Section 112(k) of the CAA requires EPA to develop an Urban Air Toxics Strategy (see Chapter 2) to reduce HAPs from area sources to achieve a 75 percent reduction in cancer incidences attributable to such sources. Two general types of descriptors are used for population risk. The first type, sometimes termed **population at risk**, is derived by determining the number of people in a population with a particular individual risk level (e.g., “1,340,000 people are exposed at the 1×10^{-6} level, and 320 people are exposed at the 1×10^{-4} level”). This is a useful estimate of the variability of risk in a population.

  Incidence, another descriptor used for population risk, is an estimate of the total number (incidence) of adverse effects in a population over a specified time period (e.g., a period of 70 years). A screening approach to deriving this estimate for a 70-year period involves multiplying the estimate of individual risk (central tendency and/or reasonable maximum) by the number of persons for which that risk estimate was predicted. For example, in a population of 200 million persons, an individual cancer risk of 1×10^{-4} (i.e., one in ten thousand) for everyone in the population would translate to an incidence of hundreds or thousands of excess cancer cases over a 70-year period (depending on the exposure assumptions). However, in a small population (e.g., a town of 200 persons), the same individual cancer risk to everyone would translate to an excess incidence of cancer of less than one over a 70-year period.

- **Present versus future scenarios**. Risks may be characterized using present or future scenarios. Use of present scenarios involves predicting risks associated with the current exposures to individuals (or populations) that currently reside in areas where exposures are predicted to occur. For example, a current population risk estimate would use the existing population within some specified area. The resultant risk estimates are associated with the presumption that the current exposure conditions exist for the current population over the period of time associated with the assessment (e.g., into the future). Use of future population scenarios involves estimating risks associated with exposure conditions to individuals that might reside, at some future point, in areas where potential exposures may occur (e.g., if a housing development were built on currently vacant land).

- **Potential risk**. Risks may sometimes be characterized for hypothetical exposures. For example, in a screening air toxics modeling application, a potential risk estimate may be derived using the location where the maximum modeled exposure concentration occurs, regardless of whether there is a person there or not. This estimate may be considered along with the predicted individual risk associated with a currently populated area, such as the MIR, which reflects risk associated with the maximum exposure concentration at an actual residence or in a census block with a non-zero population (see ATRA Volume 1, Chapter 11).

8.3 Types of Risk Management Decisions Related to Air Toxics

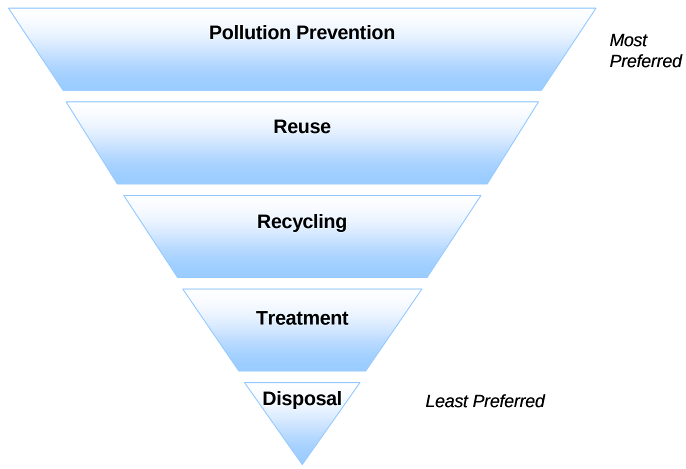
When responding to the results of a multisource cumulative assessment, the natural inclination of many risk managers will be to focus on two broad categories of risk management options: emissions controls and placement/location of sources (e.g., siting).

- **Emissions control**. Emissions control can include either installing some type of emission control equipment, instituting a workplace practice or other technical approach, or eliminating the emission altogether. Emissions controls may be either:

  - "Command-and-control" approaches such as regulatory emissions limits under the MACT program or gasoline formulation requirements; or
  - Voluntary approaches such as anti-idling campaigns, Tools for Schools (see http://www.epa.gov/iaq/schools/), pest management plans, or gas can trade-in campaigns.

  When deciding on an emission control approach, EPA's preference is to encourage pollution prevention over regulatory requirements whenever feasible (see Exhibit 8-5).

Exhibit 8-5. Pollution Prevention Hierarchy
In the Pollution Prevention Act of 1990, Congress established a hierarchy for the handling of pollution (see graphic). The Act established as United States policy that pollution should be prevented or reduced at the source whenever feasible, that pollution which cannot be prevented should be recycled in an environmentally safe manner whenever feasible, and that pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible. Disposal or other release into the environment (e.g., fugitive and stack emissions of air toxics) should be employed only as a last resort and should be conducted in an environmentally safe manner.



Pollution prevention is the reduction or elimination of pollutants at the source. As defined in the Pollution Prevention Act, "source reduction" means any practice which (1) reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal, and (2) reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants. It includes equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control. Examples of the value of pollution prevention for reducing environmental risks at the community level are demonstrated by EPA's Environmental Justice through Pollution Prevention (EJP2) grant program. EPA encouraged community groups, tribes, and local governments to identify environmental problems and generate potential pollution prevention solutions for their communities.

Source: U.S. Environmental Protection Agency. 2002. *Environmental Justice Through Pollution Prevention Program.* Updated July 9, 2002. Available at: http://www.epa.gov/opptintr/ejp2/.

- **Source placement**. These decisions involve where to locate industrial facilities, businesses, waste disposal facilities, transportation routes, and other sources of air toxics. Siting decisions for specific sources are typically made by SLT governments through mechanisms such as zoning, deed restrictions and other property controls, and other regulatory approaches. Many of these decision-making processes include public involvement in which citizens may seek to influence the final decision. These siting decisions may involve assessment of environmental impacts pursuant to the National Environmental Policy Act, other federal statutes, or similar state statutes. Risk management decisions of this type are not relegated only to sources emitting chemicals to outdoor air. Rules affecting indoor air quality may also be imposed, such as ordinances banning smoking in public areas.

Note that while some risk management decisions and mitigation requirements can be made by EPA or SLT regulators pursuant to specific legal authorities, government environmental agencies sometimes have limited authority to effect change and may need to work with other government agencies that do have the jurisdiction to implement a risk reduction strategy. For example, the need to reroute truck traffic to decrease diesel emissions in a residential area may require the assistance of the appropriate municipal or county road authority.

In some cases, there may be no regulatory requirements that can address an identified issue and voluntary approaches might be the best way to achieve environmentally beneficial results. Specifically, some important reasons risk managers may select voluntary approaches include the following:

- The types of problems identified may not lend themselves to regulatory solutions (e.g., they may require changes in the behavior of the exposed population). Examples include commuting choices and smoking in homes.

- Voluntary programs may encourage sources to participate in the risk reduction effort if it can be shown that their upfront costs will save them money in the long run. As an example, a pollution prevention assistance program may be able to show an emitting company that a straightforward change in a process to a cheaper, less toxic material will maintain product integrity and reduce their environmental regulatory burden.

- Money saving incentives such as tax credits or consumer rebates can be used to encourage voluntary risk reduction activities. Some examples include supporting the sale of low emission fuels in a metro area, tax credits on low energy consuming home products, and incentives for small business pollution control upgrades.

An example of one community's approach to reducing air pollution, primarily through voluntary programs (The Cleveland Clean Air Century Campaign), is highlighted on the next page.

The risk management options selected will usually depend, in large part, on the types of sources involved. In a community with multiple types of air toxics emissions, the focus of the risk management will usually be on three types of sources; namely, stationary sources, mobile sources, and indoor sources. The following subsections discusses each of these types of sources in detail. Additional information on air pollution, its potential impacts, and methods for reducing exposures can be found at www.epa.gov/air. The following sections focus on responding to the different types of risks posed by different types of sources. Information on several additional common types of air pollution issues that communities commonly face (e.g., mold) are also provided to give the reader a broader sense of the types of actions that will often been pursued as part of an overall community risk-reduction scheme.

The Cleveland Clean Air Century Campaign

The Cleveland Clean Air Century Campaign (CCACC) is a voluntary, community-based initiative to reduce health and environmental risk from air toxics in urban areas. The U.S. EPA and the city of Cleveland, Ohio are working together on this new approach to air toxics control that will serve as a model for communities nationwide.

A dedicated group of Cleveland residents, organizations, agencies and businesses are coming together with the U.S. EPA and Ohio EPA to begin projects that will protect public health in the city. The projects are addressing pollutants from many sources, both indoors and outdoors. The EPA has made an initial investment in the Campaign, which is administered by the American Lung Association® of Ohio.

The campaign has three goals: (1) reduce air toxics in Cleveland within a year; (2) ensure the project is sustainable over time within the community; and, (3) ensure the approach can be replicated in other counties across the United States. A central component of this campaign was the creation of a Working Group comprised of representatives from a range of interested neighborhoods, organizations, businesses, and government agencies. This Working Group guides the campaign. This project also includes an evaluation of the overall process to help improve the ongoing project as it moves forward and to capture key lessons and findings to ensure the success of future projects in other cities.
For more information on the Cleveland Clean Air Century Campaign, see http://www.ohiolung.org/ccacc.htm and a case study of this project in Appendix A.

Project	Costs	Description
Clean Cleveland heavy duty fleets	$243K	Retrofit school buses and other fleets with technology to reduce diesel PM
Highway diesel fuel for offroad use		Use highway instead of nonroad diesel fuel for nonroad fleets – focus on changing contract and bid specs of major users such as the Airport
Anti-idling campaign		Eliminate excessive vehicle idling within specified fleets through education, policy, and training – clean heavy-duty fleets will be required to implement anti-idling as part of the heavy-duty program; focus on school bus yards in two neighborhoods
Commuter choice		Encourage employers to offer incentives for carpooling, public transit, and other environmentally friendly commuter options
RTA bus/fuel replacement	$25K	Replace older circulator buses for St. Clair-Superior and Slavic Village with new ones and fuel with low-sulfur diesel
Household hazardous waste collection/exchange	$23K	As part of Cuyahoga County and other household hazardous waste collection, exchange toxic mercury thermometers, pesticides, and gas cans for less toxic alternatives; includes letter campaign to ban sale of mercury thermometers in counties, towns, cities
Gas can exchange program	$25K	Gas can exchange program through household hazardous waste collection days. Tools-for-Schools program and other means.
Home indoor air education campaign	$9K	Compile and distribute brochure with information about managing household toxics, including second-hand smoke and radon testing
Tools for schools		Pilot program in four schools; expand pilot program to more public and private schools throughout Cleveland
County to local toxic emissions inventory	$60K	Develop Cuyahoga County-specific inputs to emissions inventory for priority toxics
Electroplaters toxic reduction assessment Working group intern Capaign administration	 $10K $9K	Provide on-site survey and education about options for reducing toxics Data collection Community-based recipient of the EPA grant for project management
Total	**$600K**	

8.3.1 Stationary Sources

EPA has issued a number of rules to control emissions of air toxics from many large industrial and commercial operations like refineries and chemical plants. Once fully implemented, these rules will reduce annual emissions of nearly 200 different air toxics by about 1.7 million tons (from 1990 emissions). EPA is working on rules to reduce emissions from smaller, but numerous operations, like paint stripping and autobody paint shops. Exhibit 8-6 provides an outline of the various types of stationary sources impacting outdoor air and some of the common methods used to address those sources. To learn more about EPA's air toxics rules, see *Taking Toxics Out of the Air* brochure (http://www.epa.gov/oar/oaqps/takingtoxics/index_small.html).

Exhibit 8-6. Common Stationary Sources Impacting Outdoor Air Quality and Associated Risk Reduction Options

Emissions of chemicals to outdoor air can come from large stationary sources such as chemical plants, steel mills, oil refineries, and hazardous waste incinerators. These sources may release chemicals from equipment leaks, when materials are transferred from one location to another, or during discharge through emissions stacks or vents. Chemical releases can also come from a wide variety of smaller stationary sources such as neighborhood dry cleaners, gas stations, forest fires, autobody shops, backyard burning, and wood burning fireplaces. Although emissions from these individual small sources are often relatively small, collectively their emissions can be of concern—particularly where large numbers of these types of sources are located in heavily populated areas.

Given the wide array of types of stationary sources and chemicals emitted, a wide array of source control options may need to be considered. In general, the source control options that risk managers will commonly pursue in a multisource risk reduction effort include one or several of the following:

- Installing pollution control equipment;
- Implementing pollution reducing work habits (e.g., keeping containers closed when not in use);
- Instituting process changes to substitute one chemical with a less toxic alternative; and
- Providing education and outreach to sources on both the things they can do to reduce pollution and (hopefully) the money they may be able to save by doing so.

More information about EPA's programs to address stationary sources of air pollution can be found at www.epa.gov/air.

8.3.2 Mobile Sources

Mobile sources pollute the air through combustion and fuel evaporation. These emissions contribute greatly to air pollution nationwide and are the primary cause of air pollution in many urban areas. The most significant air pollutants from mobile sources include:

- Carbon monoxide;
- Hydrocarbons;
- Nitrogen oxides; and
- Particulate matter.

Mobile sources also emit several other important toxic air pollutants, such as benzene (see Section 3.2.3). Nationwide, mobile sources represent the largest contributor to air toxics. Air toxics are pollutants known or suspected to cause cancer or other serious health or environmental effects.

Successful pollution solutions for mobile sources involves a variety of approaches. From better engine design to better transit options, programs to reduce mobile source pollution must address not only vehicles, engines, and equipment, but also the fuels they use and the people who operate them. In some cases, straightforward solutions such as increasing the distance from a roadway can be effective in reducing exposure to mobile sources. The road to clean air also depends on extensive collaboration between EPA; vehicle, engine, and fuel manufacturers; state and local governments; transportation planners; and individual citizens.

This integrated approach to mobile source emission control is responsible for greatly reducing mobile source air pollution during the last 30 years. Technological advances in vehicle and engine design, together with cleaner, higher-quality fuels, have reduced emissions so much that EPA expects the progress to continue, even as people drive more miles and use more power equipment every year.

Of course, growth in the use of vehicles, engines, and equipment works against the improvements gained by making individual vehicles or engines cleaner. If our reliance on mobile sources keeps growing without further action, overall mobile source pollution will eventually start to increase again. EPA, therefore, continues to promote even cleaner technology as well as voluntary programs to reduce vehicle, engine, and equipment activity.

More information on the various types of mobile sources impacting outdoor air and the common methods used to address those sources is provided in Exhibit 8-7. In addition, a partial bibliography of near roadway health effects and exposure studies has been compiled by EPA's Office of Transportation and Air Quality (see http://www.westcoastcollaborative.org/files/outreach/Health%20Effects%20and%20Exposure%20Studies.pdf).

8.3.3 Indoor Sources

Air pollutants indoors can come from a wide variety of sources, including:

- Radon gas from the soil;
- Secondhand tobacco smoke;
- Mold and other biological contaminants;
- Carbon monoxide and other combustion gases;
- Pollution in outdoor air permeating indoor spaces; and
- Chemicals from indoor sources such as certain consumer products (e.g., glues and adhesives, floor polishes, hair care products, air fresheners).

The best solution for all of these problems is to control the source; use a radon removal system, for example, or ban smoking indoors. For mold, control the moisture that allows it to grow. Ventilation may also solve these problems. Air cleaners are never a complete solution, but may help lower levels.

Exhibit 8-7. Common Mobile Sources Impacting Outdoor Air Quality and Associated Risk Reduction Options

Pollution sources that move, such as cars, trucks, snowblowers, bulldozers, and trains, are known as "mobile sources." Mobile sources pollute the air through combustion of fuel and fuel evaporation. These emissions contribute greatly to air pollution nationwide and are the primary cause of outdoor air pollution in many urban areas. There are a wide array of risk reduction activities that stakeholder teams can pursue to help reduce mobile source emissions. Example projects include:

- Encouraging people to drive less (encouraging the use of alternative means of transportation such as buses, trains, or bicycles and commuting to work by carpooling, vanpooling, or telecommuting);
- Discourage the use of drive-through windows or ATMs;
- Encouraging the adoption of driving practices that improve mileage;
- Encouraging people to maintain vehicles on a regular basis to keep them in good shape;
- Encouraging the use of cleaner fuels (e.g., low sulfur diesel for construction equipment, natural gas for city buses);
- Encouraging the availability and purchase of energy efficient methods of transportation;
- Retrofitting diesel engines (e.g., in older school buses) with pollution reducing control devices;
- Anti-idling campaigns, especially for diesel engines that commonly idle for long periods of time (school buses, long-haul commercial trucks). This can also help with indoor air quality, especially of the idling occurs near buildings;
- Truck stop electrification to encourage anti-idling by long-haul commercial trucks;
- Discourage use of gasoline powered lawn mowers, leaf blowers, etc.;
- Transportation control measures such as timing stoplights to improve traffic flow; and
- Providing education and outreach to mobile source operators on both the things they can do to reduce pollution and (hopefully) the money they may be able to save by doing so.

More information about EPA's programs to address mobile sources of air pollution can be found at http://www.epa.gov/oms/transport.htm.

Exhibit 8-8 provides an outline of some of the various types of sources impacting indoor environments and some of the common methods used to address those sources. Several specific indoor air contaminant sources are highlighted below.

8.3.3.1 Radon

Radon is a radioactive gas found all over the U.S., and the second leading cause of lung cancer, causing an estimated 21,000 lung cancer deaths a year. Radon enters buildings from the soil beneath the building. EPA is concerned about homes because we spend more time there than anywhere else. Because radon is odorless and invisible, a test must be performed to determine if it is present above acceptable levels. For more information on radon, see www.epa.gov/radon.

Exhibit 8-8. Common Indoor Air Pollution Sources and Risk Reduction Options

There are many sources of indoor air pollution in any home. These include combustion sources such as oil, gas, kerosene, coal, wood, and tobacco products; building materials and furnishings as diverse as deteriorated, asbestos-containing insulation, wet or damp carpet, and cabinetry or furniture made of certain pressed wood products; products for household cleaning and maintenance, personal care, pesticides, or hobbies; central heating and cooling systems and humidification devices; and outdoor sources such as radon and outdoor air pollution.

There are three basic approaches to enhancing the quality of indoor air:

Source Control. Usually the most effective way to improve indoor air quality is to eliminate individual sources of pollution or to reduce their emissions. Some sources, like those that contain asbestos, can be removed, sealed or enclosed; others, like gas stoves, can be adjusted to decrease the amount of emissions. In addition, the choice of consumer products brought into the home and the ways in which they are stored and used can help reduce emissions. In many cases, source control is also a more cost-efficient approach to protecting indoor air quality than increasing ventilation because increasing ventilation can increase energy costs.

Ventilation Improvements. Another approach to lowering the concentrations of indoor air pollutants is to increase the amount of outdoor air coming indoors. Most home heating and cooling systems, including forced air heating systems, do not mechanically bring fresh air into the house. Opening windows and doors, operating window or attic fans, when the weather permits, or running a window air conditioner with the vent control open increases the outdoor ventilation rate. Local bathroom or kitchen fans that exhaust outdoors remove contaminants directly from the room where the fan is located and also increase the outdoor air ventilation rate. As noted above, there are potential tradeoffs between increasing ventilation and increasing energy costs.

Air Cleaners. There are many types and sizes of air cleaners on the market, ranging from relatively inexpensive table-top models to sophisticated and expensive whole-house systems. Some air cleaners are highly effective at particle removal, while others, including most table-top models, are much less so. Air cleaners are generally not designed to remove gaseous pollutants. (Note that there is a large body of written material on ozone and the use of ozone indoors. The results of some controlled studies show that concentrations of ozone considerably higher than public health standards are possible even when a user follows the manufacturer's operating instructions. For more information about the use of indoor ozone generators, see http://www.epa.gov/iaq/pubs/ozonegen.html#if%20i%20follow%20manuf.%20directions%20will%20i%20be%20harmed).

For more information on sources and control of indoor air pollutants, see http://www.epa.gov/iaq/index.html.

8.3.3.2 Secondhand Smoke

Secondhand smoke may be a community concern, because people who did not choose to smoke breath the secondhand smoke. Secondhand smoke is a known cause of lung cancer. It also causes many irritant effects, especially among children, annually causing the hospitalization of thousands of children under the age of 18 months. Both adults and children with asthma find their symptoms triggered by smoke exposure.

Some communities have used EPA materials to promote smoke-free homes and cars to protect children. Others have invested in helping people to stop smoking, since this also keeps homes and cars smoke-free. More information is available from U.S. EPA (http://www.epa.gov/iaq) or from a local chapter of the American Lung Association (http://www.lungusa.org/site/pp.asp?c=dvLUK9O0E&b=22542).

Asthma

Asthma affects millions of Americans by narrowing their airways during an asthma attack, so that they don't get enough air in their bodies. Such attacks kill thousands each year. Attacks typically occur due to exposure to indoor air "triggers;" such triggers include secondhand smoke, dust mites, molds, cockroaches and pests, pet dander, and some combustion products. Asthma can also be triggered by numerous outdoor pollutants such as ozone and pollen.

Asthma can be controlled by medications; both adults and children with asthma should see a physician to create an asthma action plan to help avoid these triggers, and to use both preventive and rescue medications. Visit http://www.epa.gov/asthma to learn more about asthma and what can be done to prevent it.

8.3.3.3 Mold

Molds and other biological contaminants will grow whenever there is enough moisture. In community settings, these conditions may occur with floods, storms, or other natural disasters. Individual homes may also be affected by leaks, condensation, or activities which raise indoor humidity.

Molds cause allergic and irritant effects, and can also affect asthmatics. Given the prevalence of molds and the sensitivities of many people to molds, it is prudent to avoid exposure to molds and mold spores. Community-based environmental risk reduction projects will almost always have mold as an opportunity for attention and success. For more information, go to http://www.epa.gov/mold.

8.3.3.4 Carbon Monoxide

Carbon monoxide and other products of combustion will appear whenever something is burned, whether gasoline in a vehicle or power generator; candles in the dining room; an unvented heater in the fireplace; charcoal in the grill, or a forest fire a few miles away. Proper venting of combustion equipment removes these contaminants from home water heaters and furnaces.

Tools for Schools

Schools of all sorts may have indoor air problems. These can cause health problems and absentees, and interfere with education and student performance.

EPA created the Indoor Air Quality Tools for Schools Action Kit to help schools improve their indoor air quality, using in-house personnel and low-and no-cost actions. For more information, visit http://www.epa.gov/iaq/schools.

Many combustion products are irritants, but one, carbon monoxide, is deadly and odorless. Symptoms of carbon monoxide exposure include headache, dizziness, nausea, confusion, chest pain in people with heart disease, and even a lethargy or flu-like symptoms. Because none of these symptoms is respiratory, most people do not recognize that their symptoms are due to the air quality.

Carbon monoxide kills hundreds of Americans every year. Many deaths are caused by malfunctioning heating equipment, but some are due to vehicles running in an attached garage, and more each year come from use of improperly located power generators after a storm. Other deaths come from burning charcoal in a tent or house. Community efforts might publicize these dangers to warn citizens to be cautious. Another possible community project is to provide carbon monoxide sensors to homes and schools.

8.3.3.5 Consumer Products and Building Materials

Chemicals may be given off (or "outgas") from various building materials and consumer products brought into the home. We are all familiar with many of these chemical odors. Some people enjoy the "new car smell" or the fragrances in our cleaning supplies. The ability of these chemicals to cause health effects varies greatly, from those that are highly toxic, to those with no known health effects. Eyes and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment are among the immediate symptoms some people have experienced soon after exposure to some chemicals. To reduce exposures, follow label instructions carefully on household products; properly dispose of old or unneeded chemicals; buy limited quantities; and limit your exposure by using the chemicals in a well ventilated area.

8.4 Developing the Risk Management Strategy

An air toxics risk management strategy (also called a risk management plan) is a written statement of the specific set of goals and activities aimed at reducing exposures to toxic chemicals in the air (the plan will also need to carefully outline the time frames for implementation and the roles and responsibilities of the various people and organizations responsible for implementation of the plan and efforts to monitor progress). The specific chemicals and sources that become the focus of the risk management plan will depend on the mix of sources, chemicals, exposures and population characteristics of the study area.

Many times an initial "Framework for Risk Management" document is prepared and agreed to by the risk managers **prior** to the risk assessment to set the stage for how the results of an assessment will be judged and how to lay out the general strategies that may be used to identify and implement risk reduction options. A key benefit of this approach is to keep the risk estimates from automatically becoming the de facto acceptable risk levels. An obvious benefit to this approach is to build trust with the study-area community. A drawback is that it can set a "line in the sand" that becomes unreasonably inflexible in light of analysis uncertainties. If the partnership team develops a framework document for risk management, they should carefully consider the pros and cons, and ensure that all affected stakeholders understand the need for some flexibility in the risk management process, given the potential (and as yet, unknown) uncertainties in the risk estimates as well as other factors that can affect the risk management decision (cost, technical feasibility, etc.).

The multisource assessment may find that only a limited number of sources are responsible for most of the local risk (for example, in areas with a dense collection of heavy industry abutting a residential area). In other cases, the assessment may point to a variety of important chemicals and sources, some of which may be industry related and some of which may not be. For example, a typical urban area may have little or no “smokestack” industries and the majority of the risks will be associated with mobile sources, small area sources such as gas stations and autobody shops, and indoor sources such as consumer products and combustion. In addition, most communities will identify a variety of sources (e.g., diesel emissions from older school buses, second hand smoke) that are already well characterized in terms of the risks they pose and the options for reducing those risks. Communities may decide to address some or all of those sources, regardless of the timing or the findings from the multisource assessment.

In short, every study area will have a unique mix of sources, population characteristics, and other factors (e.g., meteorology, building stack characteristics, etc.) that will result in a unique set of exposure and risk conditions. To respond to these study area-specific conditions, the risk reduction strategy will need to be tailored to these circumstances.

The CRARM noted that a variety of stakeholders can play an important role in all facets of identifying and analyzing risk reduction options. They can help risk managers:

- Develop methods for identifying risk-reduction options;
- Develop and analyze options; and
- Evaluate the ability of each option to reduce or eliminate risk, along with its feasibility, costs, benefits, and legal, social, and cultural impacts.

Involved stakeholders are more likely to understand the decisions made by risk managers and are more likely to accept and implement a risk management decision they have participated in shaping. They will also have developed the relationships, knowledge, communication channels, and administrative mechanisms to help all the parties work together on implementing the risk reduction activities. Another way to look at it is that involving stakeholders and incorporating their recommendations where possible reorients the decision-making process from one dominated by regulators to one that includes those who must live with the consequences of the decisions. This not only fosters successful implementation, but can promote greater trust in government institutions.

The following discussion describes the process for developing a strategy for a study area and follows the risk management steps of the overall risk assessment/risk management framework articulated by the CRARM (see Section 8.1 above):

- Examine options for addressing the risks;
- Make decisions about which options to implement;
- Take actions to implement the decisions; and
- Conduct an evaluation of the action’s results.

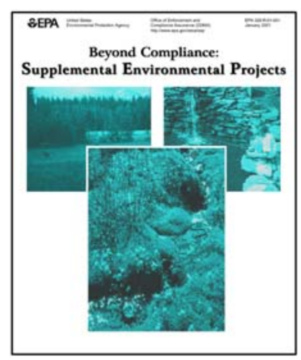
8.4.1 Examine Options for Addressing the Risks

This stage of the risk management process involves identifying potential risk management options and evaluating their effectiveness, feasibility, costs, benefits, unintended consequences, and cultural or social impacts. Specifically, the following factors (and perhaps others) will temper the actions the risk management group decides to take, when and how they will take action, or whether they will take no action at all.

- The type of emissions sources impacting the community and the contribution of those sources to overall risk;
- Existing regulatory programs (existing and upcoming regulations) that will reduce the risk over time;
- Technical feasibility of reducing emissions;
- Cost of risk reduction options such as the cost to install and operate pollution control equipment;
- Community support for risk reduction options;
- Industry support for risk reduction options;
- The desire to include known risk factors not quantitatively included in the multisource assessment (e.g., tobacco use, certain indoor air sources); and
- Background concentrations.

Alternative Solutions to Unique Problems

Project XL, which stands for "eXcellence and Leadership," is a national pilot program that allows state and local governments, businesses, and federal facilities to develop (with EPA) innovative strategies to test better or more cost-effective ways of achieving environmental and public health protection. In January 2001, EPA signed the 50th XL Final Project Agreement. Although EPA is no longer accepting proposals for new XL projects, EPA will continue to fulfill each of its commitments under Project XL and will track and monitor the progress of each XL pilot for the duration of the project. See www.epa.gov/projectxl for more information.



Supplemental Environmental Projects (SEPs) are part of enforcement settlements connected with violations of an environmental statutory or regulatory requirement. As part of the enforcement settlement, a violator voluntarily agrees to undertake an environmentally beneficial project in exchange for a reduction in the penalty. See http://www.epa.gov/compliance/civil/seps/index.html for more information.

8.4.2 Make Decisions About Which Options to Implement

In most risk management situations, decision-makers will have a number of options from which to choose. Which option is optimal depends on the particular situation (and in some cases, may be driven by statutory requirements, or public "buy-in"). When choosing among a variety of options, decision makers should consider the following useful principles:

- Base the decision on the best available scientific, economic, and other technical information;
- Be sure the decision accounts for the problem's multisource, multichemical context;
- Give priority to preventing risks, not just controlling them (see Exhibit 8-4 above);
- Use alternatives to command-and-control regulation (i.e., voluntary approaches), where applicable;
- Be sensitive to social and cultural considerations; and
- Include incentives for innovation, evaluation, and research.

> **Sustaining the Risk Reduction Effort Over Time**
>
> A critical element to consider in the evaluation of the overall risk reduction effort is the sustainability of the project. Most risk reduction efforts are only meaningful when there is a sustained effort to reduce risk over the long term, and the stakeholder group will need to identify the impediments that may keep this from happening. For example, will community interest in the project or money to pay for risk reduction efforts dwindle over time? What types of things can be done now to ensure continued progress into the future? A discussion of risk reduction sustainability is provided in Section 12.5.

As noted above, decision makers will often have to also consider a variety of administrative and legals issues such as existing rules, regulations, policies, and standards in making their decision about what course to take. Several additional considerations are highlighted in the text box on the following page.

8.4.3 Take Actions to Implement the Decisions

Once a risk reduction plan is in place, the partnership team will move forward to implement the identified risk reduction options. It is this stage at which the goodwill that has been developed through the project will be rewarded. Stakeholders who have been involved from the beginning of the project and who have come to trust one another are more apt to accept the risk management plan and work to carry it out.

8.4.4 Conduct an Evaluation of the Action's Results

At an appropriate point after implementation of risk reduction actions, decision-makers and other stakeholders review how effective they have been at reducing risk. Evaluating effectiveness involves an analytical approach to measure results, as well as comparing the actual benefits and costs to estimates made in the decision-making stage. The effectiveness of the process leading to implementation should also be evaluated at this stage.

Example Factors to Consider When Evaluating Risk Management Options

- **Background concentrations**. Air toxics risk management decisions usually focus on the *incremental* risk associated with specified sources in the study area in the absence of background risks. However, background risk may be important in certain situations. For example, if a monitoring program measures concentrations of air toxics being transported into a given study area that result in risks above an "acceptable" level, no level of emissions control within the study area will be able to reduce risk to an "acceptable" level, and the community may wish to address the incoming air toxics via discussions beyond the local community.

- **Level of uncertainty in the analysis**. In the face of highly uncertain risks, decision-makers have to carefully weigh the consequences of two or more options: making a decision to control emissions or exposures only to find out later that there was little actual risk (e.g., incurring unnecessary "cost" to the community), or making a decision *not* to control emissions or exposures only to find out later that the risks were real and large (e.g., incurring potentially preventable harm to the community).

- **Implementation costs**, both for voluntary approaches (e.g., marketing, process changes, tax incentives) as well as to regulatory agencies, the regulated community, and the general community (consumers, employees). Are the benefits reasonably related to the costs?

- **Technical feasibility**. Short of removing the emission source altogether, is there an available technology to reduce or eliminate emissions?

- **Effectiveness/timing**. Will the risk reduction option provide effective management of the problem within a reasonable timeframe?

- **Political feasibility**. Does the option have the necessary political support?

- **Community acceptance**. Do the stakeholders buy-in to the proposed risk reduction alternatives?

Each of these factors may be more or less important depending on the context for the risk management decision. For example, the risk manager may be required by statute to weigh economic factors less than technical factors.

Evaluation provides important information about:

- Whether the actions were successful, whether they accomplished what was intended, and whether the predicted benefits and costs were accurate. For example, in a multisource analysis where several chemicals and sources have been targeted for risk reduction, yearly emissions estimates (as unit emissions rates) may be rerun through the risk model to recalculate risks, and risk trends are plotted over time. Risk managers will then be in a position to decide whether risk mitigation targets are adequately being addressed;

- Whether any modifications are needed to the risk management plan to improve success;

- Whether any critical information gaps hindered success;

- Whether any new information has emerged that indicates a decision or a stage of the process should be revisited. Examples include filling data gaps identified during the original assessment or the subsequent construction of a new emissions source;

- Whether the process was effective and how stakeholder involvement contributed to the outcome; and

- What lessons can be learned to guide future risk management decisions or to improve the decision-making process.

Reviewing and evaluating the results of a risk management effort is a critical first step in addressing an important challenge: how to ensure that the community's risk management efforts are sustainable over time. Section 12.5 discusses the challenges associated with sustainability and opportunities for a community to develop the institutional capability that can help maintain sustainability over long periods of time.

Environmental Public Health Indicators

Environmental Public Health Indicators are useful tools to help establish goals and assess progress in achieving these goals. Indicators may help show whether risk reductions are having the desired effects on public health, the economy, quality of life, or any other specific goals. In particular, effective indicators can:

- Tell the community how well strategies are working – what is going well or what might need to be changed;

- Help the community see the full effects of the risk reduction strategy on public health, quality of life, the economic health of the community; and

- Help the community decide how to focus community efforts and resources more efficiently and equitably.

Some useful resources on environmental indicators include the following:

- Environmental Indicators Initiatives (http://www.epa.gov/indicators/);
- Check Your Success: A Community Guide to Developing Indicators (http://www.uap.vt.edu/checkyoursuccess/);
- Fact Sheets and Tools for Evaluation (http://www.epa.gov/evaluate/tools.htm); and
- The Centers for Disease Control maintains a website that provides useful information on environmental public health indicators that can be used to assess our health status or risk as it relates to our environment (http://www.cdc.gov/nceh/indicators/default.htm).

References

1. Presidential/Congressional Commission on Risk Assessment and Risk Management.1997. *Framework for Environmental Health Risk Management* (Final Report, Volume 1). Available at www.riskworld.com/Nreports/1996/risk_rpt.

   Presidential/Congressional Commission on Risk Assessment and Risk Management. 1997. *Risk Assessment and Risk Management In Regulatory Decision-Making* (Final Report, Volume 2). Available at www.riskworld.com/Nreports/1996/risk_rpt.

2. Adapted from the National Research Council (NRC). 1983. *Risk Assessment in the Federal Government: Managing the Process (The "Red Book").* National Academy Press, Washington, D.C.

3. U.S. Environmental Protection Agency. 1995. *Guidance for Risk Characterization*. Science Policy Council, Washington, D.C., February 1995. Available at: http://www.epa.gov/osa/spc/pdfs/rcguide.pdf.

PART III

MULTISOURCE MULTIPATHWAY RISK ASSESSMENT

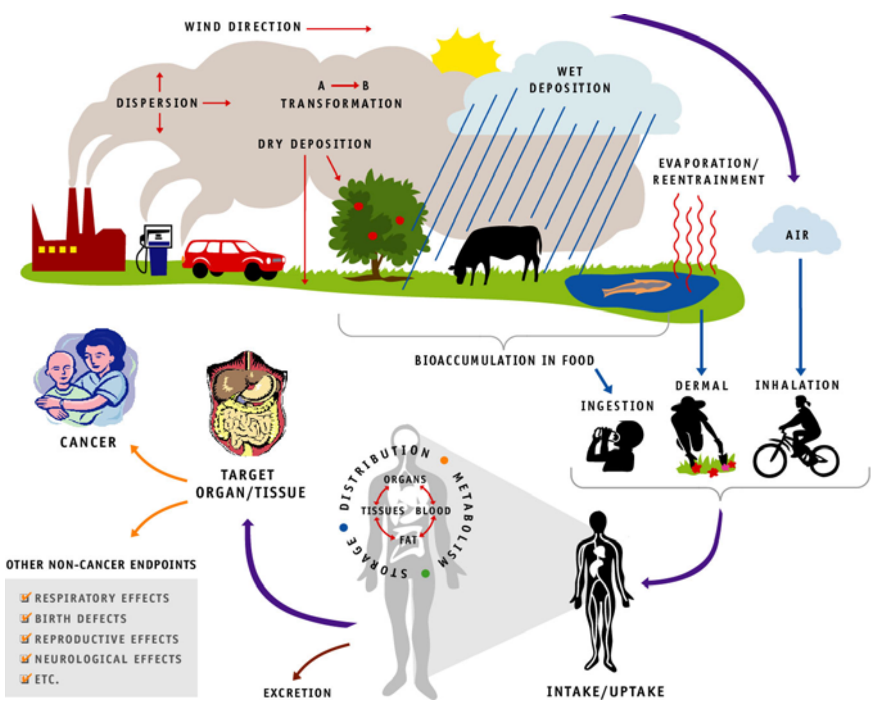
Chapter 9 Overview of Multisource Multipathway Risk Assessment

Table of Contents

9.0 Introduction

Part II of this Reference Manual discussed how to plan for and conduct a multisource cumulative human health risk assessment via the direct inhalation pathway. Part III provides the same general discussion of the various aspects of the risk assessment process; however, the discussion is focused specifically on multisource *multipathway* (sometimes also called *multimedia*) risk assessment for both humans and ecosystems. Such multipathway risk assessments may be appropriate when air toxics that persist and which may also bioaccumulate or biomagnify are present in releases to ambient air (the HAPs which have these properties are described in the next section). When performed, a multipathway risk assessment will usually involve an assessment of the deposition of air toxics onto soil, plants, and water, any subsequent uptake of the chemicals by biota, and potential exposures by organisms via contact with the contaminated soils, waters, and foods. This is illustrated generically, for a human health multipathway analysis, by the following figure.

Overview of Multisource Multipathway Exposure Pathways



(Note that for human health risk assessments, a multipathway analysis will usually include the inhalation pathway plus any additional relevant exposure pathways. A lack of available data on inhalation exposure pathways for ecological receptors may preclude inclusion of this pathway in ecological multipathway risk assessments.)

The remainder of this chapter presents an overview of multisource multipathway risk assessment for both human and ecological receptors. Detailed information on the various elements of multipathway assessment is provided in ATRA Volume 1, Part III (for human health assessment) and Part IV (for ecological risk assessment).

9.1 Toxic Chemicals That Persist and Which May Also Bioaccumulate

Some toxic compounds have the ability to persist in the environment for long periods of time and may also have the ability to build up in the food chain to levels that are harmful to human health and the environment. More specifically, a chemical that is a persistent bioaccumulator is a substance that partitions to water, sediment, or soil and is not removed at rates adequate to prevent its bioaccumulation in aquatic or terrestrial species.

For example, releases of metals from a source may deposit out of the air onto the ground where they remain in surface soils for long periods of time. Children playing in the area may ingest this contaminated soil through hand-to-mouth behaviors. The chemicals in the soil may also be taken up into plants through the roots and accumulate in foraging animals.

> **The PBT Chemical Program**
>
> **PBT pollutants** are chemicals that are toxic, persist in the environment and bioaccumulate in food chains and, thus, pose risks to human health and ecosystems. The biggest concerns about PBTs are that they transfer rather easily among air, water, and land, and span boundaries of programs, geography, and generations.
>
> The EPA is forging a new approach to reduce risks from and exposures to priority PBT chemicals through increased coordination among EPA national and regional programs. This PBT chemicals program has been established to overcome the remaining challenges in addressing priority PBT pollutants. EPA is committing, through this program, to create an enduring cross-office system that will address the cross-media issues associated with priority PBT pollutants.
>
> For more information on EPA's PBT Chemical Program, see http://www.epa.gov/pbt/.

EPA's challenge in reducing risks from this category of toxic air pollutants stems from this ability to transfer from air, to sediments, water, land, and food; to linger for long periods of time in the environment; and for some substances, their ability to travel long distances. Many of these chemicals (e.g., DDT) have been banned for use in the U.S. As such, there should be no active air emissions of these chemicals (although releases into the air are still possible, e.g., by resuspension of previously contaminated soil). However some chemicals, such as mercury, are still in use today. A number of lists of these persistent and bioaccumulative chemicals have been developed through international and internal EPA efforts (see Exhibit 9-1). Notably, a number of the HAPs appear on one or more of these lists.

Exposure to persistent and bioaccumulative air toxics through a pathway other than inhalation of contaminated air is termed **an indirect exposure pathway** because contact with the chemical occurs in a medium that is not the original medium to which the chemical was released (i.e., air). In contrast, a **direct exposure pathway** is one in which contact occurs with the chemical in the medium to which it was originally released. When exposure of a organism (e.g., a person, plant, or animal) to a chemical (or chemicals) occurs through more than one pathway, a **multipathway analysis** may be considered. When the releases in question come from multiple sources, the analysis is termed a **multisource multipathway** analysis.

As noted above, in air toxics risk assessment, the inhalation pathway is commonly assessed for human receptors and less frequently for ecological receptors. However, indirect exposure pathways are usually assessed for both humans and ecological receptors for a limited set of chemicals released to the air. EPA has identified a preliminary set of HAPs for which indirect exposure pathway analyses should generally be conducted for situations involving significant emissions of these chemicals in a study area. This list of chemicals is termed **Persistent Bioaccumulative HAP Compounds (PB-HAP Compounds**; see Exhibit 9-2); however, all of the PB-HAP compounds occur on one or more of EPA's existing lists of PBT chemicals. The designation "PB-HAP" was developed to distinguish this list from the existing lists of PBT chemicals (Exhibit 9-1) and specifically to clarify that chemicals on this new list are:

- HAPs;
- Relatively persistent in the environment; and
- For some chemicals, have a strong propensity to bioaccumulate or biomagnify.

This preliminary list of PB-HAPs was derived primarily on the basis of human health concerns. It does not consider direct contact by plants or inhalation by animals. Additional HAPs may be identified as EPA gains more familiarity with ecological risk assessments for air toxics. Study area-specific circumstances may indicate a need to consider other air toxics posing potential risk via non-inhalation pathways. ATRA Volume 1, Appendix D, more fully describes the process by which EPA identified the list of PB-HAPs.

Some Key Terms for Multipathway Analysis

Persistence refers to the length of time a compound stays in the environment, once introduced. A compound may persist for less than a second or indefinitely.

Bioconcentration is the net accumulation of a substance by an organism as a result of uptake directly from an environmental medium (e.g., net accumulation by an aquatic organism as a result of uptake directly from ambient water, through gill membranes or other external body surfaces).

Bioaccumulation is the net accumulation (storage in tissue and/or organs) of a substance by an organism as a result of uptake from all environmental sources – the medium in which they live, the water they drink, and the diet they consume – over a period of time.

Biomagnification or Biological Magnification is the process whereby certain substances, such as pesticides or heavy metals, transfer up the food chain and increase in concentration. For example, a biomagnifying chemical deposited in rivers or lakes absorbs into algae, which are ingested by aquatic organisms, such as small fish, which are in turn eaten by larger fish, fish-eating birds, terrestrial wildlife, or humans. The chemical tends to accumulates to higher concentration levels with each successive food chain level. Depending on the circumstances, chemicals that biomagnify often are the primary contributors to risk among all the PBT chemicals impacting a study area. Biomagnification is illustrated in ATRA Volume 1, Chapter 23.

Exhibit 9-1. "Lists" of Toxic Chemicals that Persist and Which Also May Bioaccumulate

LRTAP chemicals – The United States signed protocols on Persistent Organic Pollutants (POPs) and heavy metals pursuant to the Convention on Long-Range Transboundary Air Pollution (LRTAP) in June 1998 at a ministerial meeting in Aarhus, Denmark. Sixteen POPs and three metals are regulated (http://www.epa.gov/oppfead1/international/lrtap2pg.htm):

1. aldrin
2. cadmium
3. chlordane
4. dieldrin
5. endrin
6. hexabromobiphenyl
7. kepone (chlordecone)
8. mirex
9. toxaphene
10. hexachlorobenzene
11. heptachlor
12. lead
13. mercury
14. polychlorinated biphenyls (PCBs)
15. dichlorodiphenyltrichloroethane (DDT)
16. lindanedioxins (polychlorinated dibenzo-p-dioxins)
17. furans (polychlorinated dibenzofurans)
18. hexachlorobenzene
19. polycyclic aromatic hydrocarbons

PBT Chemicals – EPA has identified the following priority persistent, bioaccumulative, and toxic (PBT) chemicals and has developed the PBT program to address the cross-media issues associated with these chemicals (http://www.epa.gov/pbt/):

1. aldrin/dieldrin
2. mercury and its compounds
3. benzo(a)pyrene
4. mirex
5. chlordane
6. octachlorostyrene
7. DDT
8. dichlorodiphenyldichloroethane (DDD)
9. dichlorodiphenyldichloroethylene (DDE)
10. PCBs
11. hexachlorobenzene
12. dioxins and furans
13. alkyl-lead
14. toxaphene

Great Lakes Priority Substances. In keeping with the obligations of the Great Lakes Water Quality Agreement, Canada and the United States on April 7, 1997, signed the "Great Lakes Binational Toxics Strategy: Canada-United States Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes" (http://www.epa.gov/glnpo/p2/bns.html). This Strategy seeks percentage reductions in targeted persistent toxic substances so as to protect and ensure the health and integrity of the Great Lakes ecosystem. The list of "Level 1" substances is identical to EPA's priority PBT pollutants.

Great Waters Pollutants of Concern. The 1990 Clean Air Act Amendments established research and reporting requirements related to the deposition of hazardous air pollutants to the Great Lakes, Lake Champlain, Chesapeake Bay, and certain other "Great Waters." The Program has identified the following pollutants of concern (http://www.epa.gov/airprogm/oar/oaqps/gr8water/index.html):

1. cadmium and cadmium compounds
2. chlordane
3. DDT/DDE
4. dieldrin
5. hexachlorobenzene
6. α-hexachlorocyclohexane
7. lindane (γ-hexachlorocyclohexane)
8. lead and lead compounds
9. mercury and mercury compounds
10. PCBs
11. polycyclic organic matter
12. tetrachlorodibenzo-p-dioxin (dioxins)
13. tetrachlorodibenzofuran (furans)
14. toxaphene
15. nitrogen compounds

Exhibit 9-1 (continued)

TRI PBT chemicals. EPA has published two final rules that lowered the Toxics Release Inventory (TRI) reporting thresholds for certain persistent bioaccumulative and toxic (PBT) chemicals and added certain other PBT chemicals to the TRI list of toxic chemicals (http://www.epa.gov/tri/lawsandregs/pbt/pbtrule.htm). The following PBT chemicals are subject to reporting at lowered thresholds:

1. dioxin and dioxin-like compounds
2. lead compounds
3. mercury compounds
4. polycyclic aromatic compounds
5. aldrin
6. benzo(g,h,i)perylene
7. chlordane
8. heptachlor
9. hexachlorobenzene
10. isodrin
11. lead
12. mercury
13. methoxychlor
14. octachlorostyrene
15. pendimethalin
16. pentachlorobenzene
17. PCBs
18. tetrabromobisphenol A
19. toxaphene
20. trifluralin

Waste Minimization Priority Chemicals. EPA's National Waste Minimization Partnership Program focuses on reducing or eliminating the generation of hazardous waste containing any of 30 Waste Minimization Priority Chemicals (WMPCs). This list replaces the list of 53 chemicals EPA identified in 1998 (*Notice of Availability: Draft RCRA Waste Minimization Persistent, Bioaccumulative and Toxic (PBT) Chemical List*, Federal Register 63(216): 60332-60343, November 9, 1998). Twenty six of the chemicals in the current list were also in the draft list published in 1998. The remaining four chemicals on the current list were added in response to comments and new information EPA received from the public regarding the Agency's methodology for selecting the 53 chemicals in the draft list (http://www.epa.gov/epaoswer/hazwaste/minimize/chemlist.htm).

1. 1,2,4-trichlorobenzene
2. 1,2,4,5-tetrachlorobenzene
3. 2,4,5-trichlorophenol
4. 4-bromophenyl phenyl ether
5. acenaphthene
6. acenaphthylene
7. anthracene
8. benzo(g,h,i)perylene
9. dibenzofuran
10. dioxins/furans
11. endosulfan, alpha and endosulfan, beta
12. fluorene
13. heptachlor and heptachlor epoxide
14. hexachlorobenzene
15. hexachlorobutadiene
16. hexachlorocyclohexane, gamma-
17. hexachloroethane
18. methoxychlor
19. naphthalene
20. PAH group (as defined in TRI)
21. pendimethalin
22. pentachlorobenzene
23. pentachloronitrobenzene
24. pentachlorophenol
25. phenanthrene
26. pyrene
27. trifluralin
28. cadmium and cadmium compounds
29. lead and lead compounds
30. mercury and mercury compounds

Exhibit 9-2. PB-HAP Compounds			
PB-HAP Compound	**Pollution Prevention Priority PBTs**	**Great Waters Pollutants of Concern**	**TRI PBT Chemicals**
Cadmium compounds		X	
Chlordane	X	X	X
Chlorinated dibenzodioxins and furans	X[(a)]	X	X[(b)]
DDE	X	X	
Heptachlor			X
Hexachlorobenzene	X	X	X
Hexachlorocyclohexane (all isomers)		X	
Lead compounds	X[(c)]	X	X
Mercury compounds	X	X	X
Methoxychlor			X
Polychlorinated biphenyls	X	X	X
Polycyclic organic matter	X[(d)]	X	X[(e)]
Toxaphene	X	X	X
Trifluralin			X

[(a)] "Dioxins and furans" ("" denotes the phraseology of the source list)
[(b)] "Dioxin and dioxin-like compounds"
[(c)] Alkyl lead
[(d)] Benzo[a]pyrene
[(e)] "Polycyclic aromatic compounds" and benzo[g,h,i]perylene

9.2 Overview of Multisource Multipathway Human Health Air Toxics Risk Assessment

The multisource multipathway risk assessment for human health is organized in the same way as the multisource cumulative inhalation risk assessment (describe above in Part II) into three general phases:

1. Planning, scoping, and problem formulation;
2. Analysis, consisting of exposure assessment and toxicity assessment; and
3. Risk characterization.

The following sections provide an overview of these various steps in the assessment. Details of the various elements are provided in ATRA Volume 1, Part III.

9.2.1 Planning, Scoping, and Problem Formulation

The planning, scoping, and problem formulation phase of multisource multipathway risk assessment focuses on developing a common understanding of what needs to be included in the risk assessment (beyond the direct inhalation assessment) to assess risks associated with pathways involving deposition (i.e., transfer of the compounds to soil, water, sediment, and biota), bioaccumulation, and biomagnification, and subsequent exposure. Some of the more common exposure pathways considered for a multisource multipathway analysis are illustrated in Exhibit 9-3.

Exhibit 9-3. Human Exposure Pathways Considered for Multisource Multipathway Air Toxics Assessments

Incidental Ingestion Pathways:

- air → soil → human
- air → surface water → human

Food Chain Pathways:

- air → water → human
- air → soil → water → human
- air → vegetation → human
- air → animal → human
- air → vegetation → animal → human
- air → soil → vegetation → human
- air → soil → animal → human
- air → soil → water → animal → human
- air → soil → water → fish → human
- air → soil → water → sediment → fish → human
- air → water → animal → human
- air → water → fish → human
- air → water → sediment → fish → human

In particular, it is noted that the scope of the multisource multipathway risk assessment generally will be more extensive than that for inhalation assessment, and therefore significant additional effort will be likely. EPA is currently working to develop methodologies to support the efficient analysis of multisource multipathway risk assessments and analysts are referred to EPA's Fate, Exposure, and Risk Analysis (FERA) website (http://www.epa.gov/ttn/fera/) and Regional Air Impact Modeling Initiative (RAIMI) website (http://www.epa.gov/Arkansas/6pd/rcra_c/raimi/raimi.htm) for new information in this evolving area.

Keep in mind that, in reality, the planning, scoping, and problem formulation phase for the multisource multipathway assessment would be integrated with that of the inhalation analysis as early as feasible.

It may be necessary to include on the **planning and scoping team** experts in multimedia modeling, bioaccumulation, human exposure factors, and ingestion toxicology. The focus on additional exposure pathways may influence many aspects of the risk assessment, including the size of the study area; emission sources to be considered; the temporal and spatial resolution required; the appropriate level of detail and documentation; trade-offs between depth and breadth in the analysis; QA/QC requirements; analytical approaches to be used; and the staff and monetary resources to commit. The **study-specific conceptual model** would also reflect the specific concerns of air toxics that persist and which also may bioaccumulate. As with the inhalation risk assessment, the planning, scoping, and problem formulation process is an iterative process that reflects changing information and concerns as the multimedia risk assessment unfolds.

9.2.2 Analysis

The analysis phase of the multisource multipathway assessment is divided into two components: exposure assessment and toxicity assessment. **Exposure assessment** for a multisource multipathway analysis is likely to be considerably more complicated than the corresponding inhalation exposure assessment for several reasons:

- People can be exposed to air toxics in many more ways, including in the food they eat, the milk they drink, and the soils on which they play.

- Time is a critical variable. Air toxics that persist and which also may bioaccumulate can slowly build up in soils, sediments, and biota over time. With sufficient time, even relatively small releases have the potential to result in high exposures.

- The spatial distribution of the air toxics can be complex. Chemicals can move away from deposition points due to runoff, erosion, and the movement of contaminated animals. Chemicals deposited over a wide area (e.g., a watershed) can concentrate in smaller areas (e.g., a pond).

- Multimedia models often rely on more extensive list of input variables.

- Sampling and analysis may involve a wider range of media (e.g., soil, sediment) and different types of biota (e.g., fish, shellfish, plants). Each type of sampling and analysis has its own methods, protocols, and QA/QC procedures.

- Whereas the exposure concentration in air is the quantitative metric of exposure for inhalation, intake (usually on a per kg-day basis) is the quantitative metric of ingestion exposure in multipathway analyses. To quantify intake, it is necessary to (1) estimate the concentrations of chemicals of potential concern (COPC) in water, soil, sediment, and/or food items; (2) determine how much water, soil, sediment, and food are ingested; (3) determine the duration and temporal patterns over which ingestion occurs; and (4) adjust for body weight, to account for the different types of people in the population who interact with the contaminated media. Multipathway exposure assessment uses a number of different **exposure factors** that provide quantitative estimates of the physical and behavioral attributes of potentially exposed populations (e.g., how much fish a person eats per day). Exposure factors can be treated as either constants or variables in the exposure assessment, depending on whether a deterministic or probabilistic analysis is being performed.

The multipathway **toxicity assessment** is similar to the toxicity assessment for inhalation. It considers the same general information: (1) the types of potential adverse health effects associated with chemical exposures; (2) dose-response relationships; and (3) related uncertainties such as the weight of evidence for carcinogenic effects. There are two primary differences:

- A chemical's toxicity is influenced by the route of exposure. That is, the same chemical can result in different toxic effects (and have different dose-response values) depending on whether the chemical is inhaled or ingested. There are a number of reasons why this may occur. For example, when a chemical is inhaled into the respiratory tract, the primary toxic effect may occur in the respiratory tract as a result of inhaling the chemical (a portal of entry effect) and/or the chemical may be absorbed into the bloodstream and subsequently circulated throughout the body (including eventually making its way to the liver). When swallowed, on the other hand, chemicals can also cause a portal of entry effect and/or be absorbed into the bloodstream through the gastrointestinal tract where they are carried directly to the liver. Chemicals in the liver are often metabolized extensively (either to more or less toxic substances) before being transported by the bloodstream to other parts of the body.

- The specific dose-response values used for the ingestion pathway – reference doses (RfDs) for non-cancer (and, in some cases, cancer) effects and oral cancer slope factors (CSFs) – differ in form and derivation from those used for inhalation assessments. Specifically, RfDs and CSFs are developed to match the metric of exposure for ingestion and are expressed (usually) in terms of amount of chemical ingested per unit of body weight per day (i.e., mg/kg-d for RfDs) and risk per amount of chemical ingested per unit body weight per day (i.e., $(mg/kg\text{-}d)^{-1}$ for CSFs).

9.2.3 Risk Characterization

The risk characterization for multipathway assessments also may be more complicated than that for the inhalation risk assessment.

- Ingestion risk estimates are first added across all ingestion pathways and then added to inhalation risk estimates. Where this addition is done across multiple chemicals, the sum is referred to as a cumulative risk estimate. Although the summation process is relatively simple for screening-level analyses, it can become complex for more advanced tiers of risk assessment.

- The uncertainty analysis for multisource multipathway risk assessments may be considerably more complex if multiple sources and pathways are important because many more source characteristics, exposure factors and variables will be involved in the quantification of risk.

As noted earlier, many more specific exposure factors can be treated as variables for probabilistic multipathway risk assessments.

- The uncertainty analysis for multisource multipathway analysis is also much more complex due to the larger number of pathways assessed and the larger number of inputs that are needed.

Analysis of Groundwater Pathways

EPA's Office of Solid Waste has considerable experience in modeling and monitoring the movement of contaminants in groundwater. Much of that experience is based on exposure assessments associated with land-based disposal units (i.e., where the source of contamination is in the subsurface). For example, EPA's Center for Exposure Assessment Modeling (CEAM) distributes multimedia models designed to quantify the movement and concentration of contaminants (from land-based releases at hazardous waste sites) traveling through groundwater, surface water, and food chain media (available at http://www.epa.gov/ceampubl/). In these models, releases to the atmosphere from the subsurface may be considered, but transfer from the air through the subsurface is not.

EPA has limited experience with air toxics multipathway analysis that involve situations in which the groundwater may become contaminated from air releases. EPA's *Methodology for Assessing Health Risks Associated With Multiple Pathways of Exposure to Combustor Emissions* (http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=55525) identifies three site-specific conditions that might lead to greater groundwater impacts:

- Deposition rates that are several times greater than the average;
- The existence of more soluble HAPs in emissions; and
- Higher recharge rates such as would occur in areas with very permeable soil and bedrock near the surface.

9.2.4 Tiered Multisource Multipathway Risk Assessments

EPA guidance generally recommends that a tiered approach to risk assessments be taken to identify the key chemicals, sources, and pathways that contribute most to the risk being evaluated.[1] A tiered approach can be particularly valuable for multisource multipathway risk assessments because of the potential complexity commonly associated with such analyses. Often, screening-level analyses assume relatively high exposure factors (e.g., all of the fish a person eats comes from a potentially contaminated pond) to determine whether risk associated with a specific pathway appears to be significant enough to warrant more robust analysis. Subsequent tiers of analysis, using more realistic exposure factors and perhaps involving more complex modeling and perhaps sampling and analysis, are generally undertaken only if lower-tier analyses continue to indicate the potential for evaluated risk. As with inhalation risk assessments, an iterative process of evaluation, deliberation, data collection, work planning and communication is used to decide:

- Whether or not the risk assessment, in its current state, is sufficient to support the risk management decision(s); and

- If the assessment is determined to be insufficient, whether or not progression to a higher tier of complexity (or refinement of the current tier) would provide a sufficient benefit to warrant the additional effort.

More information on tiered approaches to risk assessment can be found in ATRA Volume 1, Section 3.3.3, and ATRA Volume 2.

9.3 Multisource Multipathway Ecological Risk Assessment

A Note to the Reader

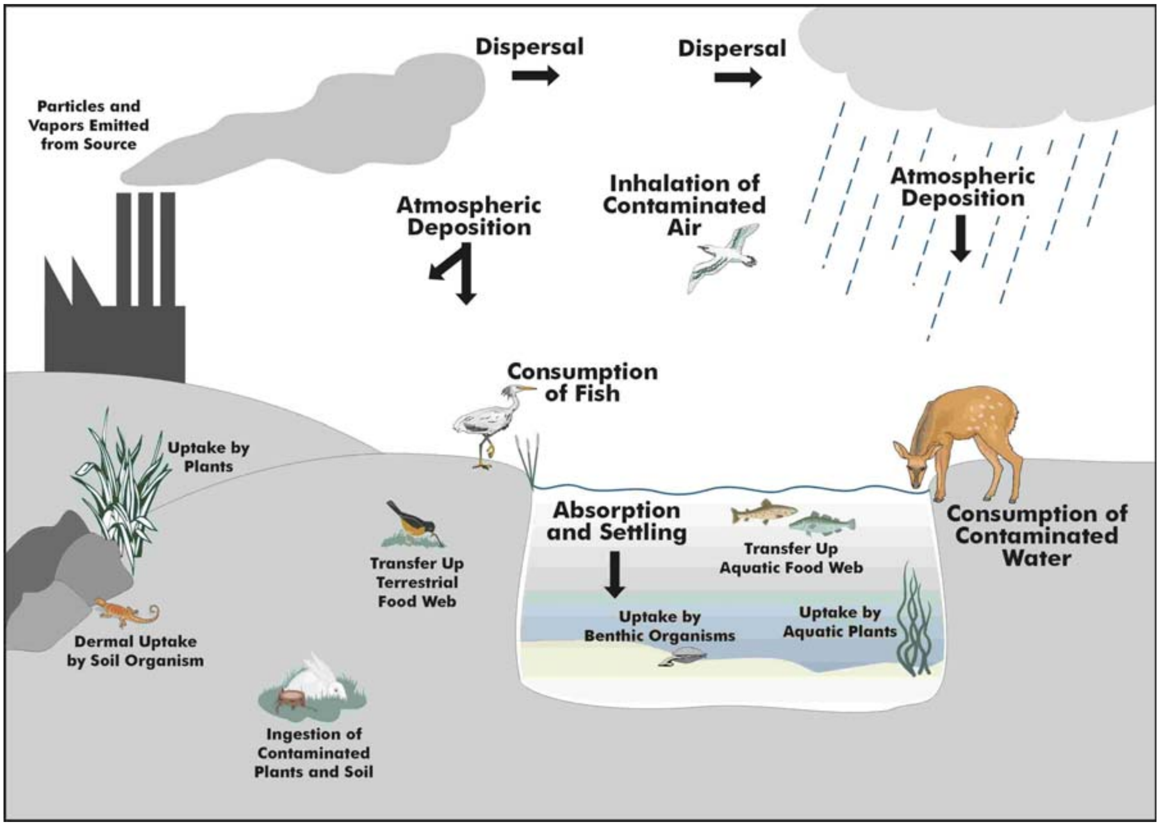
ATRA Volume 1, Part IV (and this Section 9.3), constitutes a snapshot of EPA's current thinking and approach to the adaptation of the evolving methods of ecological risk assessment in the context of Federal and state control of air toxics. While inhalation risk assessment has been increasingly used in regulatory contexts over the last several years, ecological risk assessment tools for air toxics are less well developed and field tested in a regulatory context. The information provided in the ATRA reference library should be considered a living document for review and input. By publishing this information in its current state of development, EPA continues to solicit the involvement of persons with experience in this field to help improve assessment methods for use in a future regulatory context. EPA anticipates ongoing revision to ecological risk assessment methods provided in ATRA.

Section 9.2 discusses how to plan for and conduct a multisource multipathway human health risk assessment when air toxics that persist and which may also bioaccumulate are released to the air. These substances may also pose risks to ecological receptors from exposure to contaminated media or through exposure via aquatic and terrestrial food chains (see Exhibit 9-4).

This section introduces the basic concepts of ecological risk assessment and describes their application to air toxics. The discussion of ecological risk assessment follows the same general framework as that presented for human health in Section 9.2 since the overall concept is the same; however, there are several important differences between the terminology of human health and ecological risk assessment with which readers are encouraged to become familiar (see text box below and ATRA Volume 1, Part IV). In addition, professional expertise will always be required to apply the ecological risk assessment principles and tools identified in this document to specific assessment areas or problems. This document is not a substitute for a working familiarity with ecological principles, their application, and the field of ecological risk assessment.

In addition to the information presented here, readers are also encouraged to become familiar with EPA's *Guidelines for Ecological Risk Assessment* (http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=12460) which provides a more complete understanding of EPA's recommended approach to ecological risk assessment. Interested readers are also referred to *EPA's Ecological Risk and Decision Making Workshop* materials which provide detailed information on the definition of ecological risk assessment, how it relates to human health assessment, the ecosystem protection place-based approach, and the basis for ecological protection and risk assessment at EPA.[2]

Exhibit 9-4. Air Toxics Exposure Pathways of Potential Concern for Ecological Receptors



This graphic illustrates some of the potential multimedia pathways of concern for air toxics exposure to ecological receptors. Air toxics released from a source disperse through the air and eventually fall to the earth (atmospheric deposition) via settling and/or precipitation. Air toxics deposited to soil may be absorbed or ingested by plants and soil invertebrates (uptake). Terrestrial animals may be exposed to air toxics via ingestion of contaminated plants and soil, or by consuming contaminated terrestrial animals (for those air toxics that bioaccumulate and transfer up the terrestrial food web). Air toxics deposited to water may be dissolved in the water column and/or may settle and be absorbed into aquatic sediments. Air toxics in sediments may be absorbed or ingested by benthic organisms (uptake); those in sediments and the water column may be absorbed by aquatic organisms (uptake). Aquatic organisms (e.g., fish) may be exposed directly to air toxics in the water column and/or by consuming contaminated aquatic organisms (for those air toxics that bioaccumulate and transfer up the aquatic food web). Terrestrial animals may be exposed to air toxics by eating contaminated fish or shellfish and/or by drinking contaminated water. Note also that, while in the atmosphere, air toxics may also have direct impacts on plants (direct exposure) and terrestrial animals (inhalation).

9.3.1 Overview of Air Toxics Ecological Risk Assessment

The ecological risk assessment process has three main steps that broadly correspond to the four basic steps in human health risk assessment methodology (Exhibit 9-5; see http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=12460):

- **Problem formulation**, which corresponds to the problem formulation step of the human health risk assessment methodology (planning and scoping activities similar to human health risk assessment are also integrated with this step; however, they are discussed separately below to maintain the operational structure of the ecological risk assessment as described in EPA's ecological risk assessment guidelines);

- **Analysis**, which corresponds to the exposure assessment and toxicity assessment steps of the human health risk assessment methodology; and

- **Risk characterization**, which corresponds to the risk characterization step of the human health risk assessment methodology.

Some Important Differences Between Ecological Risk Assessment and Multipathway Human Health Risk Assessment

- **Planning and scoping**. The ecological risk assessment requires more preliminary analysis and deliberation regarding endpoints to be assessed and toxicity values to be used because ecological systems are more complex and are not as well understood biologically as human health systems. The planning and scoping team should include individuals with specific expertise in ecological risk assessment.

- **Assessment area**. It may be necessary to evaluate additional portions of the assessment area that are not of concern from a human health perspective.

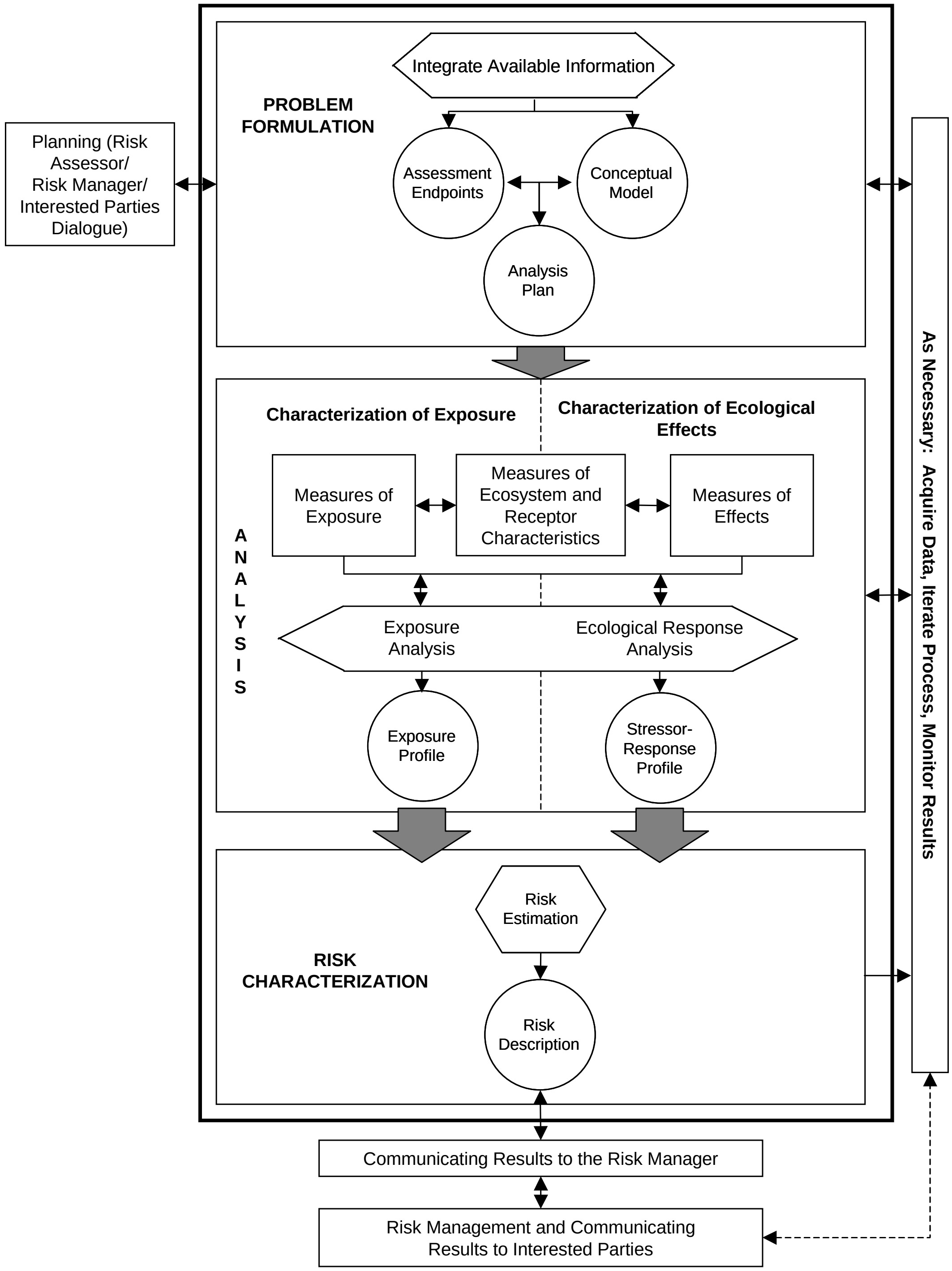
- **Potentially exposed populations**. The focus shifts from potentially exposed individual humans to potentially exposed populations and species of ecological receptors of concern. In many cases, the exposure assessment may need to address multiple species and life-stages, many of which have physiological and biochemical processes that differ significantly from humans. (When threatened or endangered species are present, the assessment may also include an evaluation of those organisms as individuals.)

- **Exposure pathways and exposure routes**. It may be necessary to assess different exposure pathways and routes that are not of concern for human health.

- **Ecological effects assessment**. Ecological systems have traits and properties that are different from humans and, thus, the ecological effects assessment (comparable to toxicity assessment for human health) may consider a wider range of potential causal relationships.

- **Risk characterization**. While risks may be assessed at multiple levels of ecological organization (i.e., organism, population, community, and ecosystem), they generally are assessed at the population level in air toxics assessments. (Nevertheless, when appropriate, consideration should be given to assessments at high levels of ecological organization, such as at the landscape level.)

Exhibit 9-5. Ecological Risk Assessment Framework



From: *Guidelines for Ecological Risk Assessment.* U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC, EPA/630/R095/002F, 1998 (http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=12460)

9.3.2 Problem Formulation

Problem formulation provides the foundation for the entire ecological risk assessment. This step includes:

- Identifying risk management goals from an ecological perspective, ecological receptors of concern (e.g., wetlands, fish populations, keystone species that impact the overall ecosystem), and assessment endpoints (explicit expression of the environmental value that is to be protected, operationally defined by an ecological entity and its attributes);

- Developing the ecological risk part of the conceptual model as necessary to account for ecological exposure pathways and receptors; and

- If necessary, developing the sampling and analysis plan and associated quality assurance project plan to collect data on exposures and measures of effects that are needed to support the ecological risk assessment.

As with human health risk assessments, problem formulation is often an iterative process, in which substantial re-evaluation may occur as new information and data become available. Data collection in subsequent iterations often is triggered by identification of major data gaps and uncertainties in the risk characterization that prevent confident decision-making by risk managers.

The problem formulation process for ecological risk assessment for air toxics focuses on developing a common understanding of what needs to be done to assess *ecological* risks associated with pathways involving the transfer of compounds from the air to soil, water, sediment, and biota, and subsequent exposure. While the ecological risk assessment may build on the foundation of the human health multipathway assessment (e.g., using the same emissions data and multimedia models), the problem formulation step is particularly critical for the ecological risk assessment because of the effort needed to understand and identify important ecological receptors, exposure pathways, endpoints, and management goals. The ecological risk assessment is not simply an "add-on" to the human health multipathway risk assessment. The problem formulation effort will need to consider a wide variety of possible ecological receptors that are not similar to humans. For example:

- Different species (and life stages) may have very different responses to the same exposure. Therefore, knowledge of the exposure-response of many species, including those that may be particularly sensitive to the air toxic, is needed.

- There may be many different types of ecosystems present in the assessment area, and sensitivity likely varies among them. Therefore, the particular features of the ecosystem(s) that occur in areas where high exposures are predicted may be particularly important.

Planning and Scoping the Multisource Ecological Risk Assessment

To ensure that the ecological risk assessment will provide information useful to the risk managers who will be making the risk management decisions, EPA's *Guidelines for Ecological Risk Assessment* recommends a planning and scoping dialogue occur between the risk assessors, risk managers, and where appropriate, interested stakeholders at the very start of the risk assessment process. The outcome of the planning and scoping phase is an agreement on the basic goals, scope, and timing of the risk assessment. Important goals of the dialogue are the identification of the risk management goals and risk management options that the risk assessment will be designed to inform. This 'kick-off' dialogue sets the stage for the problem formulation phase, when the plans for the ecological risk assessment are finalized. Ultimately, the planning and scoping process is a helpful tool to get the right people involved and talking so that the risk questions, expectations, and plans in place to make the overall assessment go smoothly and in a scientifically responsible manner.

9.3.3 Analysis

Analysis includes two principal steps **– characterization of exposures** and **characterization of ecological effects** to the **contaminants of potential ecological concern** (COPECs).

9.3.3.1 Characterization of Exposures

During this step, the analysts will characterize the spatial and/or temporal pattern of stressor concentrations in environmental media (including certain body burden levels) and analyze the level of contact or co-occurrence between the stressors and the ecological receptors. This often is done using the multimedia models such as those identified in ATRA Volume 1, Chapter 18; however, different models or approaches may be appropriate.

It should be noted that the ecological exposure characterization is likely to differ significantly from the corresponding multipathway exposure assessment for human health. For example:

- In addition to food chain (ingestion) exposures, many ecological receptors can be exposed to air toxics via direct contact with contaminated soils (e.g., earthworms) or sediments (e.g., sediment-dwelling invertebrates, bottom-feeding fish); direct exposure to surface water (e.g., free-swimming invertebrates and fish); or direct exposure to contaminated air via inhalation (e.g., birds), dermal contact (e.g., amphibians), deposition to plant surfaces, etc.

- Particular geographic areas of concern may differ because ecological receptors may occur in areas rarely used by human populations (e.g., large wetland areas, ponds where people rarely fish).

- Sampling and analysis may involve a wider range of media (e.g., sediment) and different types of biota (e.g., earthworms, aquatic invertebrates). Each type of sampling and analysis has its own methods, protocols, and Quality Assurance/Quality Control (QA/QC) procedures.

- Quantitative metrics of exposure may include both direct and indirect exposures for ecological receptors, including an evaluation of ambient concentrations of COPECs in soil, water, sediment, and or food stuffs. Quantification of exposure via ingestion is similar to that for human health ingestion analyses, except that different food items may be involved, and the appropriate ecological **exposure factors** (e.g., diet, body weight) will be different. As with human health analyses, many exposure factors can be treated either as constants or as distributions in the exposure assessment. Ecological exposure assessments for ingestion pathways frequently use bioenergetic models to more explicitly relate intake to adverse effects.[3]

9.3.3.2 Characterization of Ecological Effects

Characterization of ecological effects includes identifying the types of effects that different stressors may have on ecological receptors, along with characterizing the **stressor-response relationship** (the relationship between the level of exposure to the stressor and the expected biological or ecological response). A common result is the identification of **ecological toxicity reference values (TRVs)**, which are concentrations of chemicals in environmental media (including biota such as fish tissues) below which no significant ecological effects are anticipated. TRVs are similar, in concept, to RfDs (reference doses) and RfCs (reference concentrations) for human health noncancer evaluations. TRVs may be screening level (i.e., conservative, generic values) or more refined values for use in higher levels of analysis. They may be point values, ranges, or developed using more advanced probabilistic methods (such as Monte Carlo techniques).

There are two primary differences between the characterization of ecological effects for ecological risk assessment and toxicity assessment for human health risk assessment.

- Adverse effects of concern generally focus at the population, community, or ecosystem level. With rare exceptions (e.g., threatened or endangered species), effects to individual organisms are not the primary concern. Note, however, that ecological risk assessments often use estimates of impacts to individual organisms (e.g., mortality, reproductive effects) to infer impacts at higher levels of organization because exposure-response data for populations, communities, or ecosystems often are lacking. Some approaches are available, however, for incorporating population-level analysis in ecological risk assessments.[4]

- A distinction is made between **assessment endpoints**, which are the environmental values to be protected, and **measures of effects**, which are the specific measures used to evaluate risk to the assessment endpoints (assessment endpoints and measures of effects are defined in ATRA Volume 1, Section 23.3.4.2).

9.3.4 Ecological Risk Characterization

Similar to human health risk characterization, ecological risk characterization combines information concerning exposure to chemicals with information regarding effects of chemicals to estimate risks. Human health risk assessments consider health effects in the bodies of individual people. Ecological risk assessments consider various “health” issues that can range from actual health effects in the bodies of individual ecological receptors to something more attuned to the “health” of the ecosystem as measured by species richness and diversity.

An Ecological Risk Assessment Case Study: Ozone Risks To Agroecosystems

The case study summarized here provides an example of how EPA has assessed environmental risks from an air pollutant (ozone) as part of EPA's effort to promulgate National Ambient Air Quality Standards (NAAQS) for criteria air pollutants (see ATRA Volume 1, Chapter 2). Note that this example is for ozone, a criteria air pollutant; however, the concepts presented here are relevant to air toxics risk assessment. In addition, an agroecosystem, such as the system discussed here, is more of a human construct than a natural ecosystem and is provided here only for illustration of general principles. An actual air toxics ecological risk assessment of a natural system would have to consider site-specific characteristics of the system in question.

Problem Formulation. Pursuant to the Clean Air Act (CAA), EPA is required to set NAAQS for "any pollutant which, if present in the air, may reasonably be anticipated to endanger public health or welfare and whose presence in the air results from numerous or diverse mobile and/or stationary sources." EPA develops public health (primary) and welfare (secondary) NAAQS. According to section 302 of the CAA, the term welfare "includes ... effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values ...." A secondary standard, as defined in section 109(b)(2) of the CAA, must "specify a level of air quality the attainment and maintenance of which in the judgment of the Administrator, based on such criteria, is requisite to protect the public welfare from any known or anticipated adverse effects associated with the presence of such air pollutant in the ambient air."

This case study focuses on an assessment endpoint for agricultural crops (e.g., the prevention of an economically adverse reduction in crop yields). Yield loss is defined as an impairment of, or decrease in, the value of the intended use of the plant. This concept includes a decrease in the weight of the marketable plant organ, reduction in aesthetic values, changes in crop quality, and/or occurrence of foliar injury when foliage is the marketable part of the plant. These types of yield loss can be directly measured as changes in crop growth, foliar injury, or productivity, so they also serve as the measures of effect for the assessment.

Exposure Analysis. EPA used ambient ozone monitoring data across the U.S. and a Geographic Information System (GIS) model to project national cumulative, seasonal ozone for the maximum three month period during the summer ozone season. This allowed EPA to project ozone concentrations for some rural parts of the country where no monitoring data were available but where crops were grown, and to estimate the attainment of alternative NAAQS scenarios. The U.S. Department of Agriculture's (USDA's) national crop inventory data were used to identify where ozone-sensitive crop species were being grown and in what quantities. This information allowed the Agency to estimate the extent of exposure of ozone-sensitive species under the different scenarios.

Ecological Effects Analysis. Stressor-response profiles describing the relationship between ozone and growth and productivity for 15 crop species representative of major production crops in the U.S. (e.g., crops that are economically valuable to the U.S., of regional importance, and representative of a number of crop types) had already been developed from field studies conducted from 1980 to 1986 under the National Crop Loss Assessment Network (NCLAN) program. The NCLAN studies also included secondary stressors (e.g., low soil moisture and co-exposure with other pollutants like sulfur dioxide), which helped EPA interpret the environmental effects data for ozone.

Risk Characterization. Under the different NAAQS scenarios, the Agency estimated the increased protection from ozone-related effects on vegetation associated with attainment of the different NAAQS scenarios. Monetized estimates of increased protection associated with several alternative standards for economically important crops were also developed. This analysis focused on ozone effects on vegetation since these public welfare effects are of most concern at ozone concentrations typically occurring in the U.S. By affecting commercial crops and natural vegetation, ozone may also indirectly affect natural ecosystem components such as soils, water, animals, and wildlife.

Source: U.S. Environmental Protection Agency. 1999. *Residual Risk Report to Congress*. Office of Air Quality Planning and Standards, Research Triangle, NC, March 1999. EPA-453/R-99-011.

Other Key Ecological Risk Assessment Resources

- NCEA's Ecological Risk Assessment webpage http://cfpub.epa.gov/ncea/cfm/ecologic.cfm
- The Oak Ridge National Laboratory Ecological Risk Assessment webpage on tools, guidance, and applications http://www.esd.ornl.gov/programs/ecorisk/ecorisk.html
- The Superfund Ecological Risk Assessment Program http://www.epa.gov/oswer/riskassessment/ecorisk/ecorisk.htm
- Navy Guidance for Conducting Ecological Risk Assessments http://web.ead.anl.gov/ecorisk/
- EPA's Watershed Ecological Risk Assessment program http://cfpub.epa.gov/ncea/cfm/weracs.cfm?ActType=default

References

1. U.S. Environmental Protection Agency. 2001. *Risk Assessment Guidance for Superfund (RAGS). Volume III - Part A. Process for Conducting Probabilistic Risk Assessment*. Office of Emergency and Remedial Response, Washington, D.C., December 2001. EPA/540/R-02/002. Available at: http://www.epa.gov/oswer/riskassessment/rags3adt/index.htm

2. U.S. Environmental Protection Agency. 1995. *Ecological Risk and Decision Making Workshop.* December 1995. EPA 230/B96/004B.

3. Moore, D.W.J., et al. 1999. A probabilistic risk assessment of the effects of methylmercury and PCBs on mink and kingfishers along East Fork Poplar Creek, Oak Ridge, Tennessee, USA. *Environmental Toxicology and Chemistry* 8:2941-2953.

4. Suter II, G.W., et al. 2000. *Ecological Risk Assessment of Contaminated Sites*. Lewis Publishers, Boca Raton, FL. (see pages 228-231).

PART IV

OTHER ENVIRONMENTAL RISK FACTORS OF CONCERN TO COMMUNITIES

Chapter 10 Organizing and Involving the Community

Table of Contents

10.0 Introduction

> **The Basic Elements of the Process Described in Part IV**
>
> **Organize** a broad partnership needed to reach community goals;
> **Collect** the information needed to understand community risk factors, potential impacts and vulnerabilities;
> **Analyze** the information to identify community priorities and to identify options for reducing risks;
> **Mobilize** the community and its partners to take action; and
> **Evaluate** the work of community, measure progress, and begin new effort to address remaining risks.

As a complement to the multisource air toxics focus of the first part of this resource document, this chapter and the chapters that follow, are designed to help communities work together to develop a more complete picture of many environmental problems they may potentially face (i.e., issues beyond indoor and outdoor air toxics) and respond effectively to those issues. The chapters incorporate the perspectives of the National Environmental Justice Advisory Council (NEJAC) report on cumulative risk,[(1)] EPA's Framework for Cumulative Risk Assessment,[(2)] the Community Environmental Health Assessment Workbook published by the Environmental Law Institute,[(3)] EPA's *Community Air Screening How To Manual*,[(4)] and other sources. The chapters also incorporate input from the participants in the training session on community risk held at EPA's National Community Involvement Conference, Denver, CO, June 19, 2004.[(5)] Chapters 10-12 discuss how to:

- Improve the understanding of environmental risk factors that may impact community health;
- Build the consensus among all sectors of the community that will be needed to take effective action through use of *collaborative partnerships*;
- Mobilize all sectors of the community and its partners to take effective actions to reduce risks; and
- Build the long term capacity of all sectors of the community to understand and reduce environmental risks.

This type of information can act as a "roadmap" for communities working to create a healthier environment. For example, communities working on a toxics reduction project under EPA's *Community Actions for a Renewed Environment* or CARE program can use this Part to guide their efforts to organize, evaluate risks and risk reduction options, and implement risk mitigation projects (see Exhibit 10-1).

Exhibit 10-1. Community Action for a Renewed Environment (CARE)

What is CARE?

The Community Action for a Renewed Environment (CARE) program is designed by the EPA to help communities work at the local level to address the risks from multiple sources of toxics in their environment. Through CARE various local organizations, including non-profits, citizens, businesses, schools and federal, state, and tribal or local government agencies create collaborative partnerships to address toxics in their local environment. CARE helps communities to improve their environment through local action, providing technical support and federal funding directly to the collaborative partnerships working at the local level.

What Are the Goals of the CARE Program?

- Exposure to toxic pollutants will be reduced through collaborative action at the local level.
- A comprehensive understanding of all sources of risk from toxics will be developed and prioritized for action.
- Self-sustaining community-based partnerships will be created that will continue to improve the local environments.

Why Should a Community Consider CARE?

If a community wants to work together to reduce levels of toxic pollution - the CARE program can help.

- CARE promotes local consensus-based solutions that address risk comprehensively.
- CARE helps communities by providing information about the pollution risks they face, and the funding to address them.
- Through the CARE program, EPA also provides technical assistance and serves as a resource broker, helping the communities identify and access opportunities and resources to reduce toxic exposures, especially through a broad range of voluntary programs.
- As communities create local stakeholder groups that successfully reduce risks, CARE helps them build the capacity to understand and address toxics in their environment.

CARE Program Strategies

- Through CARE, communities are empowered to address toxic pollution issues at the local level.
- Effective stakeholder groups will be created that include the community, non-profit organizations, businesses, government agencies and other appropriate partners.
- Toxic risks from multiple sources in the community will be examined and understood. Subsequently, these risks will be prioritized so that effective action is taken.
- Focused on action, CARE will use information and analysis to build consensus and help target the greatest risks.
- The CARE program will make use of voluntary programs in order to find approaches to best solve and reduce risks.
- Local resources will be mobilized and long term community capacity to understand and address environmental risks will be built.

CARE formally began in 2005. During the first year, EPA will work with its partners to improve the program for the future. For more information on the CARE program, see http://www.epa.gov/care/.

Some Key Terms for Part IV

Risk is used to mean the likelihood that exposure to an environmental risk factor will result in harm to a specific population. For example, *carcinogenic risk* would be the probability of people in a community developing cancer from exposure to an airborne pollutant (the environmental risk factor).

Environmental risk factor (or risk factor, for short) is used generically to mean a thing in the community that can potentially harm human health, the environment, or both. Pollution from factories, cars, and trucks, pesticides used in the home, and discharge of chemicals from pipes to local water bodies are all examples of environmental risk factors. A risk factor that may negatively affect human health or ecosystems is said to have a potential *adverse impact*. In order for a risk factor to pose a risk, the risk factor has to be inherently dangerous (e.g., a highly toxic pesticide) and there must be an appropriate interaction (usually called an "exposure") between the risk factor and a person or the environment. For example, for a chemical that causes a toxic effect when inhaled, the chemical has to be in the air a person is breathing for there to be a risk of an adverse impact.

Cumulative risk. When the community has more than one risk factor, it may be appropriate to consider the *cumulative risk* posed by all the factors simultaneously. EPA has developed a *Framework for Cumulative Risk Assessment* which defines cumulative risk assessment as an analysis, characterization, and possible quantification of the combined risks to human health or the environment from multiple agents or stressors (see: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=54944).

The term **Impact** is used in two different ways. First, it is used to mean the people and ecological receptors that are potentially affected by a risk factor. For example, if part of a community lives in housing of a certain age, they may be exposed to old lead based paint. The "potentially impacted community" are those people who live in older homes that contain the risk factor "lead paint." Second, impact is used to mean the negative outcome of interaction with a risk factor. For example, the lead exposure people may experience in older homes can result in, among other things, neurological damage in children. Neurological damage from lead exposure is said to be an "adverse impact."

Vulnerability is a concept that recognizes that disadvantaged, underserved, and overburdened communities have pre-existing deficits of both physical and social natures that make the effects of environmental pollution more, and in some cases unacceptably, burdensome. Another way of saying this is that a community or sub-population of a community may be vulnerable if it is more likely to be adversely affected by a stressor than the general population. The concept of vulnerability is discussed further in Section 10.4.

This Part also elaborates further on the usefulness of developing strong community partnerships that evaluate local risk factors from the community perspective in a *collaborative* way (see text box below). The discussion also focuses on developing as comprehensive an understanding as possible of local environmental risk factors and their potential to cause harm, including considerations of both potential harm posed by individual risk factors as well as the potential harm posed by a number of risk factors in combination (i.e., a cumulative risk). Included is a consideration of the influence of community vulnerabilities in the overall analysis (see Section 10.4). This more comprehensive view of community concerns gives the partnership team the information needed to better ensure that risk reduction efforts improve the health of the community and its environment.

What is "Collaboration?"

Collaboration can be defined "as a mutually beneficial and well-defined relationship entered into by two or more organizations or individuals to achieve common goals. The relationship includes a commitment to a definition of the mutual relationships and goals, a jointly developed structure and shared responsibility, mutual authority and accountability for success, and sharing of resources and rewards."

Paul W. Mattessich. 1992. *Collaboration: What Makes it Work*. Amherst H. Wilder Foundation. St. Paul, MN.

This Part also incorporates the "bias for action" perspective of the NEJAC report on cumulative risk by encouraging partnerships to take actions to reduce risks as soon as possible. Note that the "bias for action" approach does not mean that collecting and analyzing information are not important. Instead, the community's work to improve its understanding of risk is an essential part of a "bias for action" because without a shared understanding of potential risks, mobilizing all sectors of the community will not be possible. Likewise, an unclear understanding of community risks may lead to community actions that are not focused where they can do the most good.

The "Bias for Action" Approach

The bias for action approach encourages communities to take action on known risk factors at the outset of the process while also encouraging the use of practical approaches for collecting and analyzing the information needed to build consensus and target additional risk reduction efforts where they will do the most good.

EPA's Guidebook to Comparing Risks and Setting Environmental Priorities

All environmental problems pose various types and degrees of risks to human health, to ecological systems, and to society's quality of life. Federal, state, and local government officials have found *comparative risk assessment* (see Chapter 11) to be a powerful management tool that helps them determine how to best allocate limited resources for reducing or preventing these risks. Comparative risk assessment is both an analytical process and a set of methods used to systematically measure, compare, and rank environmental problems, and provide important input to the priority-setting and budget process. With the assistance of staff from EPA, comparative risk projects have been conducted by over 20 states, several Native American Tribes, and nearly a dozen localities. The comparative risk approach has also been applied in Bangkok, Thailand, Quito, Equador, and Tetouen, Morocco, and in other cities around the world, with assistance from the Agency for International Development.

To assist stakeholders understand the details of performing a comparative risk assessment, EPA developed a workbook called the ***"Guidebook to Comparing Risks and Setting Environmental Priorities."*** It discusses the major technical and managerial issues inherent in comparative risk projects and explains the mechanics of conducting the risk analysis and risk management phases of a project. While Chapters 10-12 of this ATRA Volume 3 resource document provide an introduction to environmental priority setting and risk reduction using the comparative risk process, the *Guidebook* provides additional important details that partnership teams will find helpful when performing an actual assessment. Team members are encouraged to obtain and review the *Guidebook* for helpful information as they work through the process of identifying and mitigating local priority risks. The *Guidebook* can be obtained from EPA's National Environmental Publications Information System at http://nepis.epa.gov/.

10.1 How Is Part IV Organized and How Can It Be Used Effectively?

This Part is organized around ten specific steps communities can take to build a healthier environment (the ten step process is outlined in Exhibit 10-2). Keep in mind that not all communities are the same and each will need to make choices about how to apply these steps in a way that will best meet local circumstances. For example, some communities will choose to work on only one or a few known community risk factors while others will work on known risk factors while collecting and evaluating information on additional issues. Still others may choose to put off action until all analyses are complete.

Exhibit 10-2. Ten Steps to a Healthier Environment
1. Build a collaborative partnership that is able to identify environmental risk factors and potential impacts, build consensus, and mobilize all the resources necessary to achieve community goals; 2. Identify the environmental, health, and related social and economic concerns of the community; 3. Identify community vulnerabilities that may increase risks from environmental stressors; 4. Identify community assets; 5. Identify the concerns and vulnerabilities that everyone agrees need immediate action and begin work to address these concerns and vulnerabilities; 6. Collect and summarize available information on risk factors, potential impacts, and vulnerabilities to estimate levels of concern. Identify information gaps where the information on stressors, concerns and vulnerabilities is missing or inadequate; 7. Identify priorities for possible community action; 8. Identify and analyze options for reducing the priority concerns and for filling information gaps; 9. Decide on an action plan to address concerns and to fill gaps in information and mobilize all sectors of community and community partners to carry out the action plan; and 10. Evaluate the results of community action, analyze any new information that has been collected, and reevaluate the process to reset priorities as needed.

There are several important issues that communities should keep in mind from the outset and throughout implementation of the ten step process, including:

- **Work in a way that helps to build an effective partnership.** Broad and effective partnerships are the key to getting things done. Partnerships are the source of resources and information and they are the key to mobilizing the whole community to take action to improve environmental health. Because strong partnerships are a key ingredient in the process, all the activities described in this Part should be done in a way that continuously strives to build and maintain the partnership and the trust among the partners. This can be accomplished if everyone in the partnership has the opportunity to be heard and to participate fully as equals in the work and decisions of the partnership. Since members of the partnership will come to the partnership with different backgrounds and resources, the partnership may have to find ways to compensate for these differences. That having been said, all the upfront time and effort needed to build trust and a strong partnership will pay off in the long run because a strong partnership whose members trust each other is much more likely to succeed at mobilizing the community to take actions that make a difference.

"Environmental Health" What Does That Mean?

In this document, *environmental health* is used generically to mean the health of the people and ecosystem in a particular place. Depending on the community needs and concerns, the partnership team may choose to work on issues related to human health, ecosystem health, or both.

- **Decide whether an assessment is needed.** Taking a comprehensive approach to environmental assessment is especially valuable as a tool to get everyone in a community on the same page in their understanding of community risks. A comprehensive assessment also helps a community to set priorities and focus resources where they will do the most good. But some communities may already agree on the need to address a particular priority risk. Or some communities may need a fairly long trust building process before they can agree to work with all stakeholders to get the more complete view of risk. Thus, making the judgment about when (or if) to do an assessment and how comprehensive it will be will depend on the situation in each community.

- **Use the ten step process in a way that meets community needs.** The order in which a community takes the steps listed in Exhibit 10-2 will vary depending on the situation in the community. For example, in some communities, residents will want to begin with step two and develop a first draft summary of environmental and health concerns and community assets (possibly in the form of a community risk/impacts/assets matrix; see for example Exhibit 10-6) before starting the work to form a partnership. In other communities, the work to form a partnership will come first and all sectors of the community will work together to complete Step 2. Communities will have to use their judgment to decide on how to sequence the steps, choosing the approach that best helps to compile the necessary information and build the consensus and broad partnership that will be needed to reach community goals.

- **Establish a "scope" that meets community needs.** The definition of "environment" will vary from community to community as will the scope of the partnership activities (i.e., the limits of what the partnership will work on). For example, in communities that have ongoing development, crime prevention, or education projects, the scope of the partnership activities may be limited to traditional environmental pollution concerns. However, some communities may want to use a broader definition of "environment" to include things such as jobs, lack of adequate health care, and crime. In such cases, the process will need to be flexible in order to meet community needs, accept the community definition of environment, and (usually) bring in additional partners that can help on these other issues. (Note that even in communities with a focus on traditional environmental pollution concerns, the need to address community vulnerabilities may require assistance from partners outside the traditional environmental arena - see Section 10.4).

- **Incorporate a bias for action.** As noted previously, the approach presented in this Part generally recommends that the ten steps be completed from existing data and the knowledge of the participants in a short time frame. This will allow a relatively quick identification of priorities that everyone can agree on as well as actions that can be taken to reduce risks and impacts. The initial review of existing information will also identify data gaps and areas where there will not be consensus. Once the preliminary priorities and risk reduction actions are identified and underway, the partnership can organize its efforts to fill significant gaps. Once the community has new information, the assessment steps will need to be repeated using the more complete information so that the priorities and actions can be refined or redirected as needed.

The remainder of this chapter provides information to help communities organize into effective partnerships to carry out the work (Step 1),[(a)] identify the community's concerns (Step 2), and identify the community's vulnerabilities (Step 3) and assets (Step 4). It also provides information on identifying issues that should get immediate action (Step 5) and tips on engaging and communicating effectively with the larger community.

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[a] Although a discussion of how to involve the community and organize a stakeholder group was presented in Part I (Sections 2.4 and 2.5) and Part II (Chapter 4), that discussion is repeated and expanded in this chapter. The discussion is repeated for readers who may not have an air toxics focus, and consequently may not have read Parts I and II of this document. The discussion in this chapter also provides details that are likely to be particularly important for the type of risk reduction efforts discussed in this Part.

Chapter 11 provides information on collecting and summarizing information about important environmental risk factors, community concerns, and vulnerabilities in a local area, along with how to identify and respond to data gaps (Step 6). The chapter also discusses techniques to prioritize the identified issues from those of most concern to those of lesser concern, and selecting a short list of specific issues to work on to bring about positive change in the local environment (Step 7).

Once the partnership group has chosen specific issues to work on, they will need to identify a set of specific risk reduction projects to perform. Chapter 12 provides information on how to identify and analyze options for addressing the priority concerns and for filling information gaps (Step 8). It goes on to discuss the development of an action plan and mobilizing the community (Step 9) as well as how to evaluate the results of the actions taken (Step 10). Also provided is information on some common risk reduction projects and strategies that the partnership team is likely to draw from as they work to improve their environment.

The CARE Resource Guide

The Community Action for a Renewed Environment (CARE) program (see Exhibit 10-1) has developed a Resource Guide (http://cfpub.epa.gov/care/index.cfm?fuseaction=Guide.showIntro) to help communities in the CARE program, but it can be used by anyone interested in any aspect of working with communities to reduce risks. In the CARE program, communities go through a multi-step process: getting organized, analyzing risks, reducing risks, and tracking progress. The Resource Guide enables stakeholder groups to find the EPA on-line resources that can help their community through every step of the process as they move from getting organized to becoming stewards of their own environment. The first four parts of the Resource Guide track the CARE process and are roughly organized in order of the steps a community would go through as it moves through that process:

Part I Getting Started and Building Partnerships

Part II Understanding the Risks in Your Community

Part III Methods to Reduce Your Exposure

Part IV Tracking Progress and Moving Forward

Partnership teams are encouraged to use the Resource Guide to help them locate important guidance documents and other information they will need to draw on as they work to perform an analysis of risk factors in their community, select risk reduction projects, and evaluate their efforts over time.

PACE EH: A Tool for Community Environmental Health Assessment

An excellent resource for communities looking to evaluate and respond to environmental health concerns is the Protocol for Assessing Community Excellence in Environmental Health (PACE EH). PACE EH is an innovative tool created in collaboration with the National Association of County and City Health Officials and the CDC's National Center for Environmental Health at the Centers for Disease Control and Prevention that allows communities and local governments to identify environmental health issues, rank local environmental health concerns, and prioritize environmental health program activities. The PACE EH process mobilizes the community to take an active role throughout the entire environmental health assessment process.

PACE EH helps local health agencies integrate community concerns into their programs. PACE EH redefines the way agencies practice environmental health by enabling them to be advocates for the communities that they serve. PACE EH offers a way to integrate data-driven assessments of environmental health concerns with the values and perceptions of communities. Initial users of PACE EH report that the process enables them to:

- Be more responsive to community environmental health concerns;
- Gain visibility in the community as leaders in environmental health;
- Work for environmental justice with disenfranchised communities;
- Have community-based coalitions that lobby for local environmental health ordinances;
- Have a health department staff that is comfortable being engaged with communities;
- Become more effective in engaging community members in environmental health issue identification and problem solving;
- Educate communities on the importance of science-based decision making; and
- Provide state and national policy-makers with community-driven findings that could be used to shape environmental health policies and resource allocation.

More information on the PACE-EH program can be found at: http://www.cdc.gov/nceh/ehs/PIB/PACE.htm

10.2 STEP 1 - Building a Collaborative Partnership

STEP 1
Building a Collaborative Partnership

Building a strong collaborative partnership of interested stakeholders is an important aspect of a risk identification and risk reduction program at the local level. Participation of local stakeholders in a partnership can help ensure a better understanding of the process and will help to promote buy-in to the selected risk reduction strategies. It follows that partnership members should consist of a broad cross-section of the community who are concerned as well as involved with the environment, human health and socioeconomic health and well being of the community.[b] Exhibit 10-3 provides a list of organizations that are common candidates for participation in a community-based collaborative partnership.

[b] ATRA Volume 1, Chapter 28, also provides an introduction to community involvement.

Exhibit 10-3. Potential Recruitment Pools for Membership in a Local Partnership
• Community members from the focus community, including minority members • Local environmental justice organizations • Local, regional and national environmental NGO organizations • Faith based organizations • Local economic organizations • Educational Institutions (Schools, Universities and Colleges) • Community civic, environmental, and economic development organizations and associations • Local business representatives, including those representing potential toxics sources • Housing associations • School teachers and staff • Community students and student organizations or environmental clubs • Youth organizations • Local library staff • Local and national business associations • Unions representing local employees • Local government, including elected officials and agency representatives from planning, permitting, development, public works, parks, police and fire departments • Local, state, tribal, and federal government agency representatives from transportation, environment, housing, energy, and other relevant agencies, such as forestry agencies and natural resources departments • National, state, and tribal environmental organizations • Public health organizations (local, state, tribal, and federal) and health care providers • Local foundations concerned with the environment or public health

So, how does a collaborative partnership form? From a practical standpoint, a partnership will commonly evolve from one of several types of existing organized efforts already associated with the community. In some communities, an existing citizen grassroots organizing effort will provide the basis for a collaborative partnership. In other communities, it may be chartered by a local governmental entity. In still others, a non-profit environmental organization may be the catalyst of the effort, just to name a few.

Business and Industry as Part of the Partnership

Industrial facilities and other smaller business located in or around a community study area may be possible sources of emissions in a multisource community-based assessment, and these stakeholders should not be overlooked when forming a collaborative partnership. In some places, a framework may already exist to help foster relationships between local business and the community. For example, Clean Air Minnesota is a voluntary partnership of businesses, environmental groups, government agencies, and citizens working together toward a common goal of cleaner air in the Twin Cities and elsewhere in Minnesota (see http://www.mn-ei.org/air/index.html). If such a framework does not exist, communities may want to contact local industries or trade groups directly to inquire about their willingness and ability to contribute to a partnership. In many cases, businesses can be an excellent resource for a community.

The effort needed to understand and improve the quality of the local environment may be complex and may require a wide range of skills and resources. No single sector of the community or government will commonly have the ability or resources to do all this work alone. An effective partnership, on the other hand, will have the ability to bring together the required resources, information, and skills that will be needed to reach an agreement on the questions to be evaluated, the approach to be taken, and an effective plan for action once the assessment is complete. Some of the skills that are commonly needed to perform a community risk reduction project include:

Keeping Everyone Informed and Involved

The partnership team should make special efforts to ensure that all sectors of the community are given the opportunity to participate fully in the effort, especially when there are sectors of the community that are not used to being involved in partnership efforts (e.g., affected residents or small businesses in the community). Partnership teams should lay out clear plans for involving these members of the community and provide the support they need to participate fully in all aspects of the partnership's work and in the leadership of the partnership. The success of the partnership will depend on its ability to fully engage all sectors of the community.

- **Leadership**. Successful completion of the assessment will depend on leaders with a clear understanding of the partnership's goals and the skills to lead the community toward those goals.

- **Dialogue**. The willingness and ability to exchange information and to learn from others is essential to maintaining a functioning partnership.

- **Data collection**. Members who are familiar with or have access to available information.

- **Technical knowledge**. Depending on the type and level of analysis that will be performed, certain technical skills will be helpful. Some of the skills and knowledge that may be needed include environmental regulation and environmental data sources, risk analysis, certain engineering skills, data base management, and toxicology. The partnership may have access to this expertise directly (e.g., from local government or university staff) or may need the aid of consultants to perform the technical analysis. Once the risks have been evaluated, identifying and implementing meaningful risk reduction measures may require specialized expertise such as environmental engineering and pollution prevention.

- **Communication**. Because the work of the partnership depends on community support and participation, the ability to explain the work of the partnership to the community is essential. This will require both communication skills and knowledge of the community. The ability to communicate the science used in the assessment to non-scientists is especially important. ATRA Volume 1, Chapter 29, discusses the fundamentals of risk communication.

- **Fundraising skills.** Depending on the scope of the effort, more or less resources may be needed to fund partnership activities. Section 10.2.2 provides information on common sources of resources for the effort.

- **Organizational skills**. Logistics such as chairing meetings, keeping records, organizing community events and actions, developing budgets, handling and raising funds, and other related administrative skills will be needed over the course of the process.

- **Facilitation skills**. The ability to foster a process that will build trust, improve communication, clarify goals, and develop participation in the partnership is essential.

- **Ability and willingness to implement risk reduction strategies**. Members of the partnership and others (e.g., business, citizens) may need to implement the risk reduction strategies.

The strategy for getting a partnership started will be different for each community and will depend on factors such as the kinds of established organizations, the ability to access technical resources, and local interest in environmental issues.

The Benefits of Facilitation

Facilitation is a process used to help a group of people or parties have constructive discussions about complex, or potentially controversial issues. The facilitator provides assistance by helping the parties set ground rules for these discussions, promoting effective communication, eliciting creative options, and keeping the group focused and on track. Facilitation can be used even where parties have not yet agreed to attempt to resolve a conflict.

As the partnership team for a community-based project forms and begins to have meetings, they may find that bringing in a facilitator will be beneficial, particularly when the partnership team consists of a diverse set of individuals with strong opinions and different ideas about "what should be done." If meeting facilitation is needed, the partnership may decide to use someone from the community with facilitation experience or a professional meeting facilitator. A neutral facilitator is particularly effective in communities where some controversy is anticipated.

Building Collaboration through Community-Based Participatory Research (CBPR)

Community-based participatory research (CBPR) is one approach to engaging the broader community by including community members along with researchers and organizational representatives as active participants in the research process targeted at a public health issue (such as air toxics in a community). In CBPR, all of the partners involved contribute expertise and share decision-making and responsibilities. In doing so, the partnership's collective understanding of the issue at hand can be enhanced and leveraged to broaden the pooled knowledge of the investigative team, ensure that the research is relevant, increase the quality and validity of the research results, break down the barriers that have sometimes existed in more traditional studies (where a community was the "subject" of the research), and ultimately improve the health and quality of life of the involved community.

A number of books and articles regarding the principles, benefits, components, and challenges of CBPR projects have been published. See, for example, the mini-monograph entitled "Community-Based Participatory Research: Lessons Learned from the Centers for Children's Environmental Health and Disease Prevention Research." *Environmental Health Perspectives* (volume 113, pages 1463-1471) October 2005; available at http://ehp.niehs.nih.gov/members/2005/7675/7675.html.

10.2.1 Who Will Do the Day-to-day Work of the Partnership?

A successful partnership for a community risk reduction effort will usually require an organization to take the lead and act as a consistent champion of working together to improve local environmental quality. Commonly, the community will decide to establish some form of a partnership team steering committee to lead, organize, and oversee the day-to-day work of the overall effort. If this approach is chosen, the steering committee should include a balanced representation from as many different sectors of stakeholders in the community as possible. A broad representation will help ensure that all views are considered and that the partnership has access to the information and support needed for a successful outcome. The steering committee should also include individuals who have specialized skills and resources needed to help complete the project. A larger group of community members, or the entire community, would then be encouraged to participate on occasion in activities organized by the steering committee (e.g., public meetings to allow the larger community to provide input). Because the scope of partnership activities will depend on the specific goals that are chosen, the tasks and membership in the steering committee may evolve as goals are clarified.

If the community puts the day-to-day work into the hands of some form of a steering committee, that committee should, at a minimum:

- Represent the views of the community residents, businesses, and organizations in partnership decisions;
- Exchange information so that all partnership members have the understanding necessary to participate fully in the work;
- Consider the views of all members of the partnership and work to develop a collaborative decision-making process;
- Participate in the technical analysis of risk factors, potential impacts, and community vulnerabilities;
- Help to communicate the work and results to the larger community;
- Help to develop and lead the implementation of an action plan to make improvements in environmental quality;
- Help with group logistics such as organizing, chairing, and keeping meeting records; and
- Act as the fundraising arm for the effort (see Section 10.2.2 for information on funding a community risk reduction project).

Depending on the needs of a given community effort, the partnership team steering committee might decide to establish a number of topic-specific workgroups to help perform specific tasks

The Important and Synergistic Roles of Regulatory and Public Health Agencies in Identifying and Reducing Environmental Health Risks

The effort to sustain our gains in public health and environmental health protection will be most effective if regulatory and public health agencies work together. Both regulatory and public health agencies have important and complementary roles to play in setting policies for environmental health protection and risk management.

The likely synergy between environmental and public health agencies is a reservoir of untapped potential for environmental risk management. Many environmental pollution problems can be identified by their public health contexts. For example, construction of an asphalt batch plant was proposed in Boston. The residents of the urban community in which it was to be constructed were found by public health officials to have a relatively high incidence of asthma and cardiovascular disease. The public health findings signaled a potential environmental health problem that could have been exacerbated by emissions from the asphalt plant. On that basis, construction of the plant was opposed by citizens and by the public health agency, and a decision was made to try to locate the plant elsewhere.

Environmental, public health, and social agencies can work together with community activists to define problems and to develop and implement strategies to manage environmental risks in the full context of poverty, poor schools, and inadequate housing. As our society works to reduce risks in an era of diminishing resources, it is vital that environmental and public health agencies collaborate in deploying the tools of public health-epidemiology, exposure assessment, surveillance, nutrition, genetics, and behavior change-to identify and evaluate the most cost-effective ways to reduce risks and improve public health in all segments of the population. The public health community should accept the challenge to play an influential role in setting national, state, and local priorities and in developing strategies to understand, manage, and prevent environmental risk.

Source: CRARM Report, Volume 1; available at www.riskworld.com/Nreports/1996/risk_rpt.

and to report back to the steering committee on an established schedule. Example teams could include:[c]

- **Risk Analysis Team** to gather environmental and community data and rank risk factors, potential impacts, and community vulnerabilities;
- **Communications Team** to be the primary interface with the larger community;
- **Quality Assurance/Quality Control Team** to help establish data quality requirements, and audit technical analyses;
- **Recommendations Team** to make recommendations on whether risks are unacceptable for specific risk factors, recommend specific risk factors for the partnership to work on, and to develop and present recommended risk reduction options; and

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[c] The members of the partnership should be careful not to influence the scientific process in such a way as to achieve a predetermined outcome. The reason for this is simple. The analysis of community risks results must be viewed by the larger community as having been based on good science and science judgment. Stakeholders with an interest in the outcome of the analysis must not be seen as having unduly influenced it.

- **Implementation Team** to implement selected risk reduction strategies and measure results.

Depending on the circumstances, some of the functions of these workgroups could be combined, with the exact set of workgroups formed varying from one community to another.

10.2.2 Funding Sources for Community Assessments

Effectively conducting some aspects of a community-level air toxics assessment may require financial support beyond what is readily available within the community. As a result, an effort toward acquiring funding may need to be included in the planning phases of a risk assessment. Fundraising, or lack thereof, can greatly enhance or limit the viability of an assessment. It is important to have an idea of the available sources of funding as well as an estimate of the funds needed to effectively achieve the goals and scope set for the assessment and, if desired, to sustain the project over the long-term.

Funding for projects and research proposals related to community-level air toxics risk assessments is available in a variety of forms and from numerous sources. Financial support for such projects may come in the form of grants, which award money for a specific purpose, finance much of today's research and are available through a number of organizations, including federal, state, and local government institutions, nonprofit foundations, and industries and corporations. Grant recipients may be required to share or publish results, attend conferences, or write summary reports as part of the agreement with the funding source. The federal government is the primary resource for project-related grant money. Loans, which provide money temporarily, are also available but not as popular a choice for funding, since the provider must generally be compensated within some time frame. Additionally, volunteers and in-kind services can be organized for particular types of projects located in certain areas or serving the mutual interest of several communities or organizations.

Some Terms of the Grants Business

Application Package	A group of specific forms and documents for a specific funding opportunity which are used to apply for a grant.
Cooperative Agreement	An award of financial assistance that is used to enter into the same kind of relationship as a grant; and is distinguished from a grant in that it provides for substantial involvement between the federal agency and the recipient in carrying out the activity contemplated by the award.
Grant	An award of financial assistance, the principal purpose of which is to transfer a thing of value from a federal agency to a recipient to carry out a public purpose of support or stimulation authorized by a law of the United States (see 31 U.S.C. 6101(3)). A grant is distinguished from a contract, which is used to acquire property or services for the federal government's direct benefit or use.
Project Period	The period established in the award document during which awarding agency sponsorship begins and ends.

For a list of grants terminology, see the Grants.gov website at: http://www.grants.gov/GrantsGov_UST_Grantee/!SSL!/WebHelp/glossary.html.

The U.S. government is perhaps the most extensive and comprehensive domestic provider of grant and program money for research and study. An online listing of all federal government grant programs is available at http://www.cfda.gov. A search-and-apply grant database is also available at http://grants.gov. Some potential sources of funding are listed here (see Exhibit 10-4); many studies related to environmental and public health receive funding from one or more of the organizations listed here.

EPA offers a significant portion of grant money for environmental health concerns, but the National Institute of Environmental Health Sciences, the National Institute of Health, and the Department of Health and Human Services, among others, also offer funding opportunities for projects and research related to environmental and public health assessment. A description of the EPA grant funding program, including its advantages and limitations, as well as a list of grants to choose from, can be found at http://www.epa.gov/seahome/grants_disclaim.html.

Each study must secure its own financial support from federal, state, or local government, industry, foundations, non-profits, or other organizations. Determining the purpose, scope, and focus will help narrow the search for potential sources of funding to organizations with sufficient financial resources to satisfy the scope and whose interests are similar to the purpose and focus specific of the study.

Additional References

EPA Office of Environmental Justice: Compliance and Enforcement at http://www.epa.gov/compliance/about/offices/oej.html.

Environmental justice-related request for applications, programs, and grant opportunities can be found at http://grants.nih.gov/grants/guide/index.html and http://www.epa.gov/compliance/environmentaljustice/grants/index.html

Catalog of Federal Funding Sources for Watershed Protection www.epa.gov/watershedfunding

EPA Clean School Bus USA Program at http://www.epa.gov/otaq/schoolbus/funding.htm

EPA Voluntary Diesel Retrofit Program at www.epa.gov/otaq/retrofit/

The Environmental Finance Program operates as a referral service for those soliciting funding for environmental projects, but does not supply grants or loans. This program provides *A Guidebook of Financial Tools* as well as a Catalog of Federal Domestic Assistance, EPA Regional Sources of Funding, and State Sources (via each state's environmental department). See http://www.epa.gov/efinpage/ for details.

Exhibit 10-4. Potential Funding Sources for Community Assessments	
U.S. EPA	
Environmental Justice Cooperative Agreements Program	This program was established in 2003 to help community-based organizations finance the planning and implementation of projects addressing local environmental and public health concerns. In 2004, 30 cooperative agreements were awarded to organizations that will use EPA's "environmental justice collaborative problem-solving model" to address their issue(s). See http://www.epa.gov/compliance/environmentaljustice/grants/ej-cps-grants.html.
Office of Environmental Justice Small Grant Program	This program was established in 1994 and also provides assistance to community groups addressing environmental justice issues in the form of local environmental or public health concerns. Interested community groups must meet all requirements of an affected local community-based organization (LCBO) to be eligible. See http://www.epa.gov/compliance/environmentaljustice/grants/ej_smgrants.html.
Brownfields Program	This program was established in 1995 for the rehabilitation of property which contains a hazardous substance or pollutant. Communities with brownfields sites often have difficulty revitalizing such properties due to the potential presence of harmful substances and the costs associated with their removal. Brownfields properties waiting for redevelopment, in addition to those sites which have already undergone rehabilitation, are located throughout the United States. See http://www.epa.gov/swerosps/bf/index.html.
Supplemental Environmental Projects (SEPs)	This program provides grant money generated by the civil penalties defendants often pay in the settlement of environmental enforcement cases. Generally, recommended SEPs are proposals with potential for detectable environmental or health benefits, including but not limited to: operation and maintenance of health clinics in minority and/or low-income populations, control of lead-based paint in child-occupied housing, replacement or retrofit engines for diesel buses, and aquatic resource preservation. See http://www.epa.gov/compliance/resources/publications/civil/programs/sepbrochure.pdf
Community-Based Environmental Protection (CBEP)	This programs integrates human needs and environmental management, taking into consideration ecosystem health and emphasizing the positive correlation between a healthy environment and economic prosperity. See http://www.epa.gov/ecocommunity/.
Smart Growth Program	This program offers a variety of grants focused on working with tribal, state and local governments, businesses, and industry to influence land use and growth plans to minimize the potential impact on environmental, economic, and community health. See http://www.epa.gov/piedpage/index.htm.
Community Action for a Renewed Environment (CARE)	This program provides two different levels of grant funding to help communities determine local pollution risks and, if necessary, take steps to reduce toxic pollutants. See http://www.epa.gov/care.

Exhibit 10-4. Potential Funding Sources for Community Assessments (continued)	
Office of Air and Radiation	Multiple grants are offered by this department, including several specifically for tribal communities, related to air quality monitoring, environmental education and outreach programs, and training in methods for reducing exposure risk to toxic pollutants. See http://www.epa.gov/air/grants_funding.html#oad.
Department of Health and Human Services	
Office of Minority Health	This office was established in 1985 with the task of eliminating health disparities by improving and protecting the health of racial and ethnic minorities. Funds to achieve this goal are provided in the form of Cooperative Agreements, Research Funding, Educational Funding, and Community Grants. See http://www.omhrc.gov/omh/whatsnew/2pgwhatsnew/funding.htm.
National Institutes of Health	NIH funds various projects focused on reducing the health disparities in minority and low-income communities. See http://grants.nih.gov/grants/guide/pa-files/index.html?sort=ac&year=active.
National Institute of Environmental Health Sciences (NIEHS)	
Environmental Justice: Partnerships for Communication	This program works to establish communication within communities between scientists assessing exposure to pollution, regulators, and affected residents. The projects also emphasize minority participation in the research studies. See http://www.niehs.nih.gov/translat/envjust/envjust.htm.
Department of Housing and Urban Development	
Lead-Based Paint Hazard Control Grant Program	This program provides funding to state and local governments for the control of lead-based paint hazards in low-income housing, particularly those with young children. See http://www.hud.gov/offices/adm/grants/nofa05/grplead.cfm.
Community Development Block Grant Program for Indian Tribes and Alaska Native Villages	This program provides grants promoting the development of Indian and Alaska Native communities, which includes construction of housing, suitable living environments, and creation of economic opportunities. This program is aimed at persons with low and moderate incomes. See http://www.hud.gov/offices/adm/grants/nofa05/grpicdbg.cfm.
U.S. Congress	
Morris K. Udall Foundation	The Udall Foundation was established in 1992 by the U.S. Congress to honor Morris Udall's achievements and service in the House of Representatives. The Foundation awards undergraduate merit-based scholarships to college students who have shown potential and commitment to pursuing careers related to the environment. Additionally, the Foundation includes a Native Nations Institute, which helps develop curriculum materials for tribal educational institutions, supports business skills camps for Native American high school students, and provides Native American congressional internships. More information is available at http://www.udall.gov/prog.htm.

10.2.3 How Can the Partnership Effectively Involve the Larger Community?

Whatever structure the local partnership team initially takes, it should consider communicating with and including the general public as soon as possible in the process. If the community members participate early on and throughout the process, they will be in a better position to understand what the partnership group is doing, they will have had more opportunity to provide input and, ultimately, will feel the work being done is in their best interest and be willing to support the selected risk reduction projects. The process works best when the community members appreciate that the partnership group is working with them and respecting their input (keeping them informed and involved). In contrast, excluding the public from the process may result in community resentment and rejection of even a sound risk reduction approach. A "guardian-like" attitude toward the community that treats people as unknowledgeable and incapable of meaningful participation does not foster trust and can eventually undermine the process.

Another important reason to involve the community early in the process is that the people who live in the community are the people who can provide some of the best advice about the important risk factors actually present. They are also the people who best understand the types of solutions that will be most accepted.

The level of participation that community members have in some of the more technical phases (e.g., assessing the relative importance of various risk factors) of the process may be tailored to their background, expertise, and interest; however, this does not mean the community cannot serve an important role in the technical phase, as well. The technical approach taken, as well as the assumptions and limitations of the analysis, should be clearly explained to the community members and their input should be valued in return.

What Is "the Community?"

Many people commonly think of the community as only the people who live within the area. For a community risk-reduction effort, however, it is helpful to think of the community as comprised of more than just the people who live there. The "community" (in this more inclusive sense) can include people who work in the area but live elsewhere, local businesses that operate in the area, neighborhood schools, etc.

In addition to the people and groups who actually live and work in an area, a number of other stakeholders also may have an interest in the community's concerns (e.g., local officials, health professionals, local media). It is helpful, therefore, when organizing a risk reduction effort within a community, to keep in mind that many different people (not just the people who live there) may have an interest in the work being undertaken (even though they may choose not to participate in the day-to-day work of the partnership).

10.2.3.1 Understanding the Goals, Objectives, and Responsibilities for Effective Community Involvement

At a minimum, goals and objectives for effective community involvement should include the following items (note that all study areas are different and this list is just a suggested starting point that may need to be expanded):

- Earning trust and credibility through open and respectful communications;

- Including the community in the design and implementation of risk evaluation and risk reduction efforts;
- Ensuring that community members understand the entire risk reduction process including any possible health impacts of the risk factors;
- Updating communities about all current risk reduction activities; and
- Promoting collaboration between decision-makers, communities, and other agencies and stakeholders when carrying out risk reduction activities.

To reach these goals and objectives, the following key principles are important:

- Be aware of confidentiality and privacy issues. Any personal information that the partnership receives from community members should be respected, as appropriate.
- Be aware of special needs and cultural differences. When conveying information about risk factors and risk reduction activities, partnership groups should be aware of non-English speaking community members and other citizens who may need help in understanding complicated messages. Also, be sure to consider cultural symbolism. There are notable examples of the use of a symbol that is acceptable in one culture but that has an unacceptable meaning in another.
- Maintain effective communication. As part of the trust-building process, the stakeholder group should keep community members informed of progress, opportunities for community involvement, how community input will be used, how community members can participate in the selected risk reduction efforts, and upcoming issues and events.
- Respect community knowledge and values. It is important to recognize that community knowledge can provide valuable information for the deliberative processes and to help address data gaps. It is particularly important to try to understand people's interests (what they care about) during the process (more discussion of this subject is provided in the next section).

10.2.3.2 Plan Community Involvement Strategy and Activities

Planning a community involvement strategy and activities is one of the most critical components for effective community involvement. The type and nature of communication and involvement activities will depend on:

- The needs and interests expressed by the community during the previous stages;
- The potential risk factors the community faces; and
- The resources available for communication and involvement activities.

Exhibit 10-5 provides a broad list of issues to be considered when developing a community involvement strategy. Not all of these issues must have solutions initially; however, they may need to be addressed eventually. Exhibit 10-6 illustrates some tips developed by the Agency for Toxic Substances and Disease Registry (ATSDR) for effective community involvement.

10.2.3.3 Provide Opportunity for Continued Public Interaction

While an evaluation of risk factors is underway, continuing communication and involvement goals will include updating the community on the status of the assessment, obtaining ongoing feedback on the process, obtaining additional information as needed or available from the community for the assessment, and recommending public health actions, if needed, about how community members can reduce risks now while the assessment goes forward. Throughout this process, the partnership team should continue to listen to community concerns and clearly explain how they will respond to these concerns. The team also should leverage community outreach resources whenever possible. For instance, federal agencies, state health and environmental agencies, local health departments, citizens' advisory groups, and medical advisory groups may have funds for involving community members in the process. Collaborating with partner organizations can strengthen community outreach depth and coverage.

Exhibit 10-5. Issues to Consider When Developing Community Involvement Strategies

Community health concerns

- How many community members are concerned about the study area?
- What is the level of the community's concern?
- Is the level of community concern higher (or lower) than the actual risk would suggest?
- Are community concerns unknown?
- Would a physician enhance outreach at community meetings?
- Is information/outreach/health education available now or can this wait until reports are generated?

Demographics

- How many community members are potentially affected?
- Are there any potentially sensitive populations that may be exposed?
- Do socio-demographic data suggest need for additional resources, such as translation?
- How do the community members receive information (e.g., newspaper, radio, word-of-mouth)?

Community interest in the risk analysis and management process

- How involved in the process would the community like to be?
- How would the community like to be kept updated and informed (e.g., newsletters, e-mails)?
- How many community groups or activist groups are involved? How active are they?
- Should the risk stakeholder group facilitate the creation of a community group if one has not been formed?
- Can information be disseminated at cultural centers? Informal gatherings?

Media support

- What has the community already heard from the media? Are there misconceptions that need to be dispelled?
- Will media support require more community involvement resources than usual?

Support of the community

- Are there Native American communities affected by the risk factors? Should a relevant tribal agency be involved?
- Does a risk factor involve an environmental justice issue or other type of special sites?
- What experiences has the community had with "the government"? Other agencies?

Exhibit 10-5. Issues to Consider When Developing Community Involvement Strategies (Continued)

- Is there a higher than average need for resources, such as for more frequent community updates?
- How active will any regional agency representatives or other agencies be in community involvement efforts?

Non-English speakers and other special needs

To ensure the participation of everyone in the community, agencies often use one or more of the following strategies:

- Offer translators and signers at community meetings, and check for wheelchair accessibility.
- Provide additional sessions of meetings that are offered exclusively in the community's secondary language(s).
- Seek out advocates for the severely disabled or others with special needs.
- Provide education and outreach materials in both English and secondary languages.
- Develop understandable and culturally appropriate messages and materials.

Public health

- Is the study area designated as being of public health concern? Is hazard acute or chronic?
- Are environmental health risks largely unknown?
- Is the study area considered a high priority? By whom?
- Are there already some risk or health outcome results? Are biological data available?
- Is a health connection plausible between contaminant exposures and community health concerns?
- Are data available for review now? When will they be available?
- Are there toxics reduction steps already in process?

Community culture and setting

- What are the current community priorities and projects?
- What are the community organizations?
- Who are the community leaders (unelected)?
- What activities constitute community life?

Other

- How many people are in the stakeholder group? Does everyone know their role?
- What is the timeframe for report development and communication?
- Will any special clearances be required? At what levels?
- Will document or graphics development resources be needed?
- Are there schools or locations where community meetings can be held?

Exhibit 10-6. ATSDR's Components of Effective Community Involvement

In identifying community concerns and interests, it often is useful to develop a "conceptual map" of the key organizations and decision-making processes in a community. The map should include information such as who speaks for various parts of the community, who serves in formulating perspectives, and what the process is for obtaining consensus within the community.

TIP: Identify local associations or groups by asking community members, respected "elders," or other associations. This also can go a long way in demonstrating a commitment to involving and mobilizing all stakeholder groups, which helps to build trust and creates a more successful community-involvement process.

But In seeking out community members, do not rely solely on existing community organizations. Very often community members are not well organized or represented by existing groups. Just because there is not an organization or group in the study area does not mean that you can bypass that part of the community.

TIP: Local public health providers, such as county health departments and hospitals can be a key partner in understanding and evaluating the risk factors a community faces and risk reduction solutions that will work well in a particular place. These organizations often have resources (staff and funding) that can be used in community health activities. Because they are locally based, involving them as key partners in the process can create strong local leaders to promote sustainable activities once risk reduction projects are in place.

Source: U.S. Agency for Toxics Substances and Diseases Registry (ATSDR) *Public Health Assessment Guidance Manual* (http://www.atsdr.cdc.gov/HAC/PHAManual/cover.html).

Generally, community involvement strategies are situation-specific and partnership teams should determine which community involvement strategies are appropriate given the potential seriousness of the risk factors, the abilities and involvement of the community, and the resources available for communication, training, and outreach. If resources for community outreach are limited, the team may wish to consider how they can best prioritize resources for community involvement. In such instances, the team should look for community outreach opportunities during other community activities, if it would be culturally acceptable. For a determination of cultural acceptability, ask community leaders or "trusted elders."

Finally, some community analyses foster highly interactive relationships with community members. For example, the partnership team may establish ad hoc working groups to evaluate specific issues. These groups may include advisory members from the community or their representatives (e.g., community consultants) and may be more or less formal, as the circumstances require.

10.2.3.4 Providing Risk Evaluation Documents and Risk Reduction Project Selection Documents to the Larger Community

At the end of any analysis phase, the next stage of community involvement generally begins. Since the process of data gathering, analysis, and risk factor, potential impact, and vulnerabilities evaluation can take some time, community interest may have decreased. However, once the risk reduction options are ready for release and implementation, public interest often peaks again.[d] The partnership team may consider using a more formal process to communicate this information to the public. For example, the team may release the draft for a period of time for people to read and comment. During the review period, meetings may be held to help describe how the analysis was done and how the risk reduction options were selected. The partnership team may also need to communicate the key results, limitations, and recommendations through a variety of communication materials including fact sheets, press releases, and websites. If an agency or other parties will be conducting any follow-up activities in the area, then additional appropriate community involvement may be planned.

Tips for Involving the Community

An enormous number of tools and activities exist that stakeholder groups can use to plan for and encourage meaningful community involvement. They range from the simple phone call, to block parties (at which food may be provided), to the mapping of risk factors, demographics, and other geographic data. How many and which tools and activities should be used or initiated for a given situation depends on the phase of the process, the level of community interest, and the number and degree of important risk and vulnerability factors a community has. The formation of strong relationship between the partnership and the larger community can be an effective way to access local knowledge and other assets, achieve consensus, leverage resources, and obtain results.

The CARE Resource Guide provides a number of examples for effective community involvement (http://cfpub.epa.gov/care/index.cfm?fuseaction=Guide.showIntro).

10.2.3.5 Talking to the Public about Risk

Throughout the entire process, the partnership team will need to both become familiar with concepts that are unfamiliar to them, such as risk analysis and risk management. Throughout the process, the group will also need to be able to effectively communicate this type of information to the general public.

What is Risk Communication?

Risk communication is the way in which decision-makers and others communicate with various interested parties about the nature and level of risk, and about the risk reduction strategies to reduce the risk.

The purpose of risk communication is to help describe the results of the risk and vulnerability analyses and to convey the results in a way that both effectively supports the goals of the project and provides an ample level of understanding for community members. Having a good risk communication strategy is a fundamental aspect of developing trust among all the various stakeholders. Planning for risk communication should begin before conducting the analysis of community risk factors.

[d] The partnership group may wish to release the results of the risk analysis phase with the risk reduction projects or prior to selecting the risk reduction projects.

Involving the community, establishing and maintaining relationships, and networking with other partners (e.g., agencies, organizations, officials, the news media) are key elements in a risk communication strategy. Tailoring communications to the cultural diversity of the community is also important because it may help establish the trust necessary to complete a risk analysis that meets the needs of all stakeholders. Risk management rooted in voluntary measures will particularly require effective risk communication in order to get buy-in.

ATRA Volume 1, Chapter 29, and Chapter 7 of this document provide an overview of the basics of risk communication. The stakeholder group is encouraged to review and use that information at the very outset of any community risk reduction effort.

10.3 STEP 2 - Identify Community Concerns and Interests

STEP 2
Identify Community Concerns & Interests

There is a wide array of environmental risk factors that may exist in any community. Some risk factors are relatively common (e.g., smoking, chemicals in consumer products, pesticides for yard use), while others are found less frequently (e.g., an abandoned hazardous waste site in the community).

One important activity that the partnership team will need to do at the outset of any risk reduction effort is to identify the environmental risk factors present in the community, the potential impacts the factors may pose, and community vulnerabilities (discussed in Section 10.4 below). A good way for the partnership to begin this process is to provide ample opportunity for both the members of the partnership and the larger community to voice their specific individual concerns. (Note that it is likely that the concerns expressed during this initial conversation may not all be the same and a fair amount of listening and discussion will be needed to help develop a common understanding of the members' concerns. It will also set the stage for deciding what issues will ultimately be the overall focus of the project.)

As noted previously, some community stakeholders may consider certain issues to be outside the bounds of improving "environmental health" (e.g., they may have a focused view of environmental health that centers on exposures of people or ecosystems to chemical or radiological pollutants). Other people may have a different perspective on the definition of "environment" and the partnership will need to discuss and resolve how to work through such contrasting views. In those instances where certain concerns raised by partnership members are ultimately found to be outside the scope of what can be addressed (e.g., due to limited resources), a willingness on the part of all partnership members to at least help identify resources or make connections to agencies that can help address these concerns will go a long way to building trust and credibility among all the partnership members. By not listening or responding to the concerns of partnership members, the overall process will run the risk of failing to implement meaningful reduction efforts.[e]

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[e] Note that some community efforts may decide at the outset that they want to work on one or a few specific areas. They may decide upfront that they want to work on "just indoor environments" or "just solid waste issues" or they may limit themselves to risk factors that are already well characterized both in terms of the risk they pose and the methods to reduce the risks (e.g., retrofitting diesel engines, replacing leaded pipes in home drinking water systems). Regardless of the approach taken to arrive at a course of action, the partnership is encouraged to be transparent about why and how both their initial and ongoing choices were made.

10.3.1 What Are the Issues that Commonly Concern Stakeholders?

Parts II and III of this document discuss the risks posed to communities from toxic air pollution both outside and inside, and things that can be done to help reduce those risks. In addition to air toxics, a number of other environmental risk factors may impact community health. The stakeholder group will usually begin by making a laundry list of these risk factors in their community. In order to do this efficiently and effectively, they will need to have an understanding of the common types of risk factors and where information about those risk factors is kept. (An example table of a laundry list of potential risk factors is provided in Exhibit 10-6.)

Broadly speaking, the most common environmental pollution risk factors (other than toxic air contaminants) that may adversely impact the health of people in the community fall into the following general categories:

<u>Chemical Risk Factors</u>

- Chemicals in indoor environments (e.g.,, lead paint in older homes, pesticide use);
- Chemicals in water used for drinking, bathing, cooking, recreation, etc.;
- Chemicals in soils and sediments (e.g., spills of toxic chemicals, crumbling lead paint from building exteriors);
- Chemicals in foods (e.g., mercury in fish, pesticides); and
- Chemicals in wastes (e.g., spent batteries in trash).

<u>Biohazards</u>

- Microbes in drinking water and recreational waters (e.g., beaches); and
- Infectious wastes (e.g., from health care facilities).

<u>Radiation Hazards</u>

- Radon and other naturally occurring ground-based radiation sources;
- Ultraviolet radiation; and
- Other electromagnetic sources (e.g., power lines).

<u>Miscellaneous Risk Factors</u>

- Vermin (e.g., rats);
- Mold in indoor environments;
- Noise; and
- Odors.

Each of these categories can be further subcategorized into a number of specific risk factors which may or may not be present in a specific geographic area. For example, consider the generic risk factors "Chemicals in Foods" and "Chemicals in Indoor Environments." Virtually every community can place these broad categories on their initial list of risk factors and can start making lists of specific risk factors they think might be a problem for each of these broad categories. For example, the partnership team might decide to begin by creating an initial list of potential risk factors along with the potentially impacted parts of the community and the adverse outcome that the risk factor may be causing. An example of such a table is provided in Exhibit 10-7. Information on how to refine this initial list by gathering existing information about community risk factors and potential impacts is provided in Chapter 11. Information on developing new information is provided in Chapter 12.

Additional risk factors may be present in a given community to a greater or lesser degree. For example, communities that have aggressive recycling ordinances may have already solved the problem of hazardous materials in municipal trash. As another example, some older urban areas may have numerous abandoned light-industrial areas that are contaminated from past use, while newer communities may have no such areas. Some stakeholders are also likely to raise other concerns including disease incidence in the community (e.g., existing cancer rates).

Exhibit 10-7. Example Table for Developing an Initial List of Potential Risk Factors

Risk Factor	**Location/Prevalence (i.e., Potentially Impacted People)**	**Potential Adverse Outcomes (e.g., Negative Health Impacts)**
Indoor Environments		
Mold in schools	All Pleasantville schools	Respiratory problems (allergic responses, sinus infections)
Pesticides	All Pleasantville homes and schools	Various health effects, depending on the pesticide
Water Pollution		
Pathogen contamination of recreational water body	Lake Pleasantville following major storm events (due to overflow of combined sewer lines)	Infectious disease (e.g., gastrointestinal illness)
Lead in drinking water	All Pleasantville households	Neurological impacts (children are particularly susceptible)
Land Pollution		
Contaminated soils and groundwater	Pleasantville industrial park (abandoned)	Health effects to children playing on contaminated land, and adjacent residents consuming contaminated groundwater (cancer and other effects)

What About Risks to the Local Ecosystem?

An *ecosystem* is defined as place having unique physical features, encompassing air, water, and land, and habitats supporting plant and animal life (see http://www.epa.gov/ebtpages/ecosystems.html). Ecosystems can vary dramatically from place to place and each community will have its own unique ecosystem setting.

In addition to environmental pollutants that may affect human health in the community, stakeholders will often be concerned about their local ecosystem and want to take action to protect it. An example of protecting an ecosystem is the watershed approach in which all pollution sources and habitat conditions in a watershed are considered in developing strategies for restoring and maintaining a healthy ecosystem.

There are a variety of actions communities can take to protect ecosystems in order to support plant, animal, and aquatic life, including voluntary efforts designed to reduce the amount of pollutants entering their environment. Information on how to gather existing information (and potentially develop new information) on environmental concerns is provided in Chapter 11. Chapter 12 discusses some of the activities partnerships can do to help maintain a healthy local ecosystem. EPA's *Community-Based Environmental Protection (CBEP)* program provides information on integrating environmental management with human needs, considers long-term ecosystem health, and highlights the positive correlations between economic prosperity and environmental well-being (for more information on CBEP, see http://www.epa.gov/ecocommunity/about.htm).

10.4 STEP 3 - Identify Community Vulnerabilities that May Increase Risks from Environmental Stressors

STEP 3
Identify Community Vulnerabilities

The concept of vulnerability recognizes that disadvantaged, under served, and overburdened communities have pre-existing deficits of both physical and social natures that make the effects of environmental pollution more, and in some cases unacceptably, burdensome. Another way of saying this is that a community or sub-population of a community may be vulnerable if it is more likely to be adversely affected by a stressor than the general population. While vulnerability assessment is an added dimension in the understanding of risks or impacts to a population and may be unfamiliar to some, an attempt to investigate and address community vulnerabilities can allow for the identification of better, more effective options for risk reduction. Community vulnerability factors are divided into four categories:

- **Susceptibility/sensitivity.** Sub-populations may be susceptible or sensitive to a stressor if it faces an increased likelihood of sustaining an adverse effect due to a life stage, an impaired immune system, or a pre-existing condition.

- **Differential exposure.** Sub-populations may experience differential exposure due to living or working near a source of pollution that causes exposure to a higher level of pollution than the general population.

- **Differential preparedness.** Sub-populations that are less able to withstand environmental insults experience differential preparedness.

- **Differential ability to recover.** Sub-populations that experience differential preparedness have differential abilities to recover.

Information on how to gather information about existing community vulnerabilities if provided in Chapter 11. Information on how to develop new information on community vulnerabilities is provided in Chapter 12.

Some Example Vulnerability Factors

- Genetic predisposition to disease
- Effects on fetus, infants and children
- Effects of aging
- Compromised immune system
- Preexisting health conditions
- Proximity to pollution sources (differential exposure)
- Employment in high exposure/dangerous jobs
- Past exposures
- Multiple routes of exposure to one chemical
- Exposures to multiple pollutants
- Subsistence consumption
- Poor nutrition
- Cultural practices
- Lack of recreational facilities
- Differential access to community services
- Low income
- Low education
- Dilapidated housing
- Emotional stress
- Crime
- Vermin (insects and rodents)
- Unemployment or underemployment
- Discrimination
- Lack of information
- Lack of social capital
- Differential preparedness/ability to recover
- Differential access to health care

Information on how to develop data on community vulnerabilities is provided in Chapter 11.

10.5 STEP 4 - Identify Community Assets

STEP 4
Identify Community Assets

Communities with large numbers of environmental (including environmental justice), social, and economic problems and stressors are still communities with a large number and variety of assets. In order to build on the existing foundation of the communities, a list of community assets should be developed. Knowing and understanding these assets will be a key element in developing the community's plan for reducing risks. Some examples of community assets include:

- Technical and Organizational Skills
- Communication Channels
- Leadership
- Coalition Building
- Neighborhood Associations
- Financial Resources
- Businesses
- Civic and Community Leaders
- Political Abilities
- Outreach, Including the Ability to Mobilize Actions
- Historical Information
- Religious Institutions

10.6 STEP 5 - Identify the Concerns and Vulnerabilities that Everyone Agrees Need Immediate Action

STEP 5
Identify Concerns

Step 2 identified an initial list of risk factors present in the community along with information about the impacts they may have on the community. Step 3 developed an understanding of community vulnerabilities that may increase risks from the identified factors from Step 2. Working as a group, the risk factors, potential impacts, and vulnerabilities should be evaluated and those that everyone (or the majority) agrees need immediate action should move forward as quickly as possible to identify, evaluate, and implement options for action. Concurrently, the remaining risk factors, potential impacts, and vulnerabilities (and data gaps) will be analyzed further to identify additional priorities for action (discussed in the next chapter). Once additional priorities are identified, the risk reduction work that has already begun on the initial key issues of concern can be adjusted, as necessary, to add new issues.

Will Community Risk Reduction Efforts Have to "Start from Scratch?"

No. A number of federal, state, tribal, and local programs are already in place to help identify and reduce many of the environmental risks in communities. Some of these programs are required by law while some are more voluntary in nature. Voluntary efforts often take the form of outreach and education activities to help business and citizens understand what they can do to help enhance their community's environmental health.

For example, EPA's *Community Action for a Renewed Environment* or CARE program supports a series of multi-media, community-based and community-driven projects to reduce local exposures to toxic pollution (see Exhibit 10-1). Another example is EPA's *Tools for Schools* program which helps to create healthy indoor environments in the classroom (http://www.epa.gov/iaq/schools/).

References

1. National Environmental Justice Advisory Council Cumulative Risks/Impacts Work Group. 2004. *Ensuring Risk Reduction in Communities with Multiple Stressors: Environmental Justice and Cumulative Risks/Impacts*, Draft Report, January 31. See http://www.epa.gov/compliance/resources/publications/ej/nejac/nejac-cum-risk-rpt-122104.pdf.

2. U.S. Environmental Protection Agency. 2003. *Framework for Cumulative Risk Assessment*. Office of Research and Development, National Center for Environmental Assessment (EPA/600/P-02/001F). See http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=54944.

3. Environmental Law Institute. 2000. *Community Environmental Health Assessment Workbook, A Guide to Evaluating Your Community's Health and Finding Ways to Improve It*. With the permission of the author.

4. U.S. Environmental Protection Agency. 2004. *Community Air Screening How-To Manual, A Step-by-Step Guide to Using Risk-Based Screening to Identify Priorities for Improving Outdoor Air Quality*. EPA-744/B-04-001. Available at http://www.epa.gov/ttn/fera/risk_atra_main.html

5. How to Participate and Lead New Community Based Efforts to Address Environmental Health Concerns, Part 2: Identifying, Understanding, and Addressing Risks. Sessions presentations included in conference proceedings at: http://www.epancic.org/2004/proceedings.cfm.

Chapter 11 Identifying and Ranking Community Risk Factors

Table of Contents

11.0 Introduction

As introduced in Chapter 10, there are a number of environmental risk factors that may exist in any community. Some risk factors are relatively common (e.g., smoking, chemicals in consumer products, pesticides for house and yard use), while others are found less frequently (e.g., an abandoned hazardous waste site). The number and types of people potentially impacted as well as the type of adverse impacts they may experience from these risk factors also can vary significantly. Likewise, the number, type, and potential importance of community vulnerabilities can also widely vary from place to place.

This chapter provides an introduction to collecting and summarizing information on community risk factors, potential impacts, and vulnerabilities (Step 6). The chapter concludes with a discussion of some of the tools and techniques commonly used to evaluate and rank these identified concerns and how to select priority issues for community action from the list of ranked concerns (Step 7). This set of community priority issues of concern will be carried forward to the next step of the process (described in Chapter 12) in which risk reduction options are evaluated and specific risk reduction projects selected, implemented, and evaluated over time.

Note that there will be uncertainties associated with both the data the partnership team collects about the risk factors, potential impacts, and vulnerabilities in the community as well as assessing what those data may mean. A discussion of some ways to assess uncertainty inherent in the assessment process is provided below and some ways to fill important data gaps is provided in Chapter 12.

11.1 STEP 6 - Collect and Summarize Available Information and Identify Information Gaps

STEP 6
Collect & Summarize Available Information - Identify Data Gaps

In this step of the process, the partnership will gather and evaluate existing information on the risk factors, potential impacts, and vulnerabilities identified during Steps 2 and 3. This information will be used in the next step (Step 7) to help identify the risk factors that may have the greatest potential to affect the health of the community or its environment.

To estimate the magnitude of each of the identified environmental, health, and socioeconomic issues, the partnership should collect all available information on risk factors, observed impacts, potential risks posed by the risk factors, and vulnerabilities. Some sources of information include:

- Members of the partnership, especially those directly affected by a risk factor;
- Databases with information on the amounts and sources of releases of pollutants to the community's environment;
- Information on levels of chemicals measured in the environment;
- Formal studies of risk in the community, if they are available;
- Studies done to estimate the risk for similar communities;
- Studies done to estimate the health and vulnerability of the community; and
- National studies of risk.

Residents of the community, local businesses, and local doctors and public health staff can help locate and collect available information. Government and university staffs can identify any existing studies of the community and of similar communities. The partnership will require the participation of all of its members to complete this part of the process. Further information on collecting and summarizing this type of information is discussed below.

If there is not enough information available to estimate the level of concern resulting from a risk factor, the partnership may either use its best judgement to evaluate a risk factor or it could highlight the risk factor as an item needing additional data. (Keep in mind that using judgment in lieu of actual data will usually increase the uncertainty of the overall assessment's conclusions.) For example, if there are a significant number of older homes in the community (a potential source of lead exposure from lead-containing paint), the partnership team might go ahead and identify the potential concern from lead paint as relatively high based on very limited data. Their rationale might be that:

- Lead paint in older homes is a known environmental threat (see http://www.epa.gov/lead);
- The community is primarily made up of older homes (thus, there is the potential for a large number of people exposed to lead); and
- It is believed that many of these homes are occupied by children who are likely to have inadequate access to quality healthcare, including routine screening for lead exposure (a vulnerability).

In contrast, they might decide to identify this risk factor as a data gap that needs more information (e.g., number and age of homes potentially affected, number of children in the homes, results of community blood lead testing) before a decision can be made about potential action (see Step 9 - filling information gaps).

Indeed, partnership teams are likely to identify several areas of concern where they will not have the needed information to adequately evaluate the risk factors, the potential impacts, or the presence and influence of vulnerabilities. In such cases, identifying the information gaps and developing a plan to fill them is an essential part of the overall process. Depending on the circumstances, these data gaps may even be identified as a high priority for taking action (i.e., to fill the gaps as quickly as possible).

The CARE Resource Guide
Understanding the Risks in Your Community

As introduced in Chapter 10 of this volume, the Community Action for a Renewed Environment (CARE) program (http://www.epa.gov/care/) has developed a Resource Guide to help communities go through the multi-step process of assessing and addressing risk factors in their community.

Part II of the Resource Guide (Understanding the Risks in Your Community) is particularly helpful for identifying information on the various types of risk factors, potential impacts, and vulnerabilities that may be present in the community.

11.1.1 What Existing Data Are Available on Community Risk Factors, Potential Impacts, and Vulnerabilities?

In order to evaluate the importance of the various risk factors, potential impacts, and the role of community vulnerabilities, the partnership team will first need to collect all relevant and readily available information on all of these issues. This will include information from members of the partnership team and information from the larger community, especially those directly potentially affected by a given risk factor. Information on risk factors, potential impacts, and vulnerabilities could come from existing studies done in the community, studies done in other similar communities, national studies, or a wide array of other data sources.

When researching information about community risk factors, potential impacts, and vulnerabilities, the stakeholder group will benefit from engaging both average citizens and organizations with expertise in the area of environmental and public health assessment and management. Government agencies such as the local health department, local and state environmental agencies, and EPA Regional offices are particularly helpful resources for identifying and evaluating existing information since they work with these issues on a day-to-day basis and are also the institutions who collect and maintain much of the important data on the community. Other groups, such as universities and environmental non-profit organizations may also be able to help identify important data.

"Environmental Media"
What Does That Mean?

In its simplest sense, an "environmental medium" is a naturally occurring material such as soil, sediment, air, surface water, or ground water. When human activities result in the release of a pollutant to the environment, the resulting mixture of environmental medium plus pollutant is commonly referred to as a "contaminated environmental medium" or simply a contaminated medium.

As the partnership team goes about collecting information, it will commonly find (particularly when the data come from government agencies such as EPA) that data can be located according to the structure of the agency. For example, environmental information is often organized by *environmental medium* (see adjacent text box) with the different offices within an environmental agency overseeing (and maintaining) the data for each medium (e.g., data about contaminated air will generally be collected and maintained by an environmental agency's "Air Program," data on water contamination will be maintained by an agency's "Water Program," etc.).

Finding Information on Community Risk Factors, Impacts, and Vulnerabilities

Many of the websites and other resources presented in Section 11.1.1 provide access to information about community environmental risk factors and their potential impacts. For example, many EPA Offices provide citizen-oriented information on their websites about common risk factors found in and around the home. The National Library of Medicine's Tox Town (Exhibit 11-1) allows users to navigate around a typical town to see the common types of chemical hazards communities face. Potential impacts are also usually straightforward to find. For example, the Census Bureau provides access to information on the number and types of people living in specific geographic area. However, gathering information on community vulnerabilities (e.g., poverty, crime, access to health care) may be a more difficult task, and in some cases, the data may not be available for a specific community.

EPA has created the Environmental Justice Graphic Assessment Tool (see text below) to help map out a variety of these types of community related data (e.g., number and location of people living below the poverty line). However, this tool may not provide a full picture about all the potential issues in a given place. Particularly with respect to community vulnerability, other information sources such as the local public health departments, local land use planning organizations, and community surveys may need to be relied on to help identify and quantify potential community vulnerabilities.

While the concept is straightforward, the nuances of organizational structure and data management can be complex and accessing data specific to a community can take some time and effort (particularly since some data are not readily accessible through the internet). This is one of the reasons why the partnership team will benefit from the participation of environmental and health professionals who understand the structure of key agencies and how/where those agencies maintain their data.

To help partnership teams navigate the wide variety of available information sources, the following sections provide basic information on some of the key federal, state, and local organizations which may have information relevant to the community-based risk reduction effort.

11.1.1.1 The Overall Federal Information Gateway - FirstGov

A useful starting point for finding information maintained by the federal government on a given community is the FirstGov internet site (http://www.USA.gov/). FirstGov is the official U.S. gateway to government information that transcends the traditional boundaries of separate government agencies. Specifically, FirstGov has a powerful search engine and ever-growing collection of topical and customer-focused links that can connect citizens to millions of web pages from the federal government, state, tribal, and local governments, and foreign nations.

11.1.1.2 U.S. Environmental Protection Agency

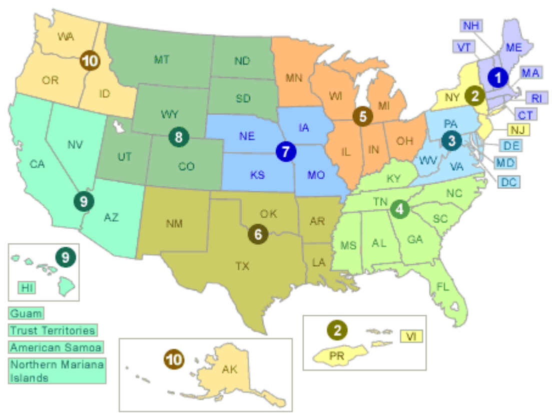
The U.S. EPA (http://www.epa.gov/) is one of the main federal agencies tasked with protecting the environment. The Agency does this by implementing a number of federal laws such as the Clean Air Act, the Clean Water Act, and the Superfund and waste management laws. EPA is also involved in a number of voluntary efforts to help communities achieve a healthy and sustainable environment. EPA will generally be one of the key information sources that the partnership team will use to identify information about risk factors in their air, water, land, and waste.

EPA maintains a vast array of data and tools that can be used in a community-based risk reduction program. In order to help citizens access and use this information effectively and efficiently, the Agency has developed several internet-based gateways and other tools to help in the navigation of EPA resources. Several important internet-based tools include:

How Do I Contact EPA?

EPA is a large organization that oversees a variety of laws, programs, and research. Partnership teams that want to work with EPA are encouraged to begin by contacting the EPA Regional Office that includes their state.

Information on how EPA is organized can be found at http://www.epa.gov/epahome/aboutepa.htm. The location, organization, and contact information for EPA Regional offices can be found at http://www.epa.gov/epahome/locate2.htm.



- **EnivroFacts**
(http://www.epa.gov/enviro/)
This website provides access to several EPA databases that provide information about environmental activities that may affect air, water, and land anywhere in the United States. Partnership teams can also use EnviroFacts to generate maps of environmental information.

- **EnviroMapper** (http://www.epa.gov/enviro/html/em/)
EnviroMapper is a powerful tool used to map various types of environmental information, including air releases, drinking water, toxic releases, hazardous wastes, water discharge permits, and Superfund sites. Users can select a geographic area within EnviroMapper and view the different facilities that are present within that area. EnviroMapper can be used to create maps at the national, state, and county levels, and link them to environmental text reports. Users can even insert dynamically created maps in their own webpages.

- **Window to My Environment** (http://www.epa.gov/enviro/wme/)
Window To My Environment (WME) is a powerful web-based tool that provides a wide range of federal, state, and local information about environmental conditions and features in a specific area. This internet tool is provided by EPA in partnership with federal, state and local government and other organizations.

- **The CARE Resource Guide**
  (http://www.epa.gov/care/)
  As noted in Chapter 10, the CARE program has developed this resource guide to help anyone interested in working with communities to evaluate and reduce environmental risk. The Resource Guide enables stakeholder groups to find on-line resources that can help their community through every step of the risk evaluation and risk reduction process.

- **Environmental Justice (EJ) Graphic Assessment Tool** (http://www.epa.gov/enviro/ej/)
  EPA's EJ Graphic Assessment Tool can be used to map EPA environmental data in relation to available demographic data (e.g., population density, percent minority population).

For partnership teams new to EPA databases and tools, the gateways and tools listed above are a good place to start to find general information. As needs increase for more in-depth information, access to the databases and tools that underlie these gateways and tools will be important.

For example, the gateway resources use data from a number of environmental databases managed by EPA, such as the National Contaminant Occurrence Database (NCOD), which contains information about contaminants in drinking water supplies, and the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS), which contains information about Superfund sites. If the data provided through the gateway is not at the level of detail necessary, internet users can usually access more in-depth data directly from the individual databases. A list of many of EPA's databases and software is available at http://www.epa.gov/epahome/data.html.

11.1.1.3 The Agency for Toxic Substances and Disease Registry (ATSDR)

ATSDR (http://www.atsdr.cdc.gov/about.html) is an agency of the U.S. Department of Health and Human Services. Its mission is to serve the public by taking public health actions and providing health information to prevent harmful exposures and disease related to toxic substances. ATSDR is directed by Congressional mandate to perform specific functions concerning the effect on public health of hazardous substances in the environment. These functions include public health assessments of waste sites, health consultations concerning specific hazardous substances, health surveillance and registries, response to emergency releases of hazardous substances, applied research in support of public health assessments, information development and dissemination, and education and training concerning hazardous substances.

ATSDR also has published more than 250 draft or final toxicological profiles for hazardous substances found at Superfund sites. Toxicological profiles provide chemical-specific information on health effects, physical and chemical properties, production, use, and disposal. Toxicological profiles generally summarize available information about the levels of a substance monitored or estimated in the environment, general population and occupational exposure, and populations with potentially high exposure. (The Toxicological Profiles can be accessed at http://www.atsdr.cdc.gov/toxpro2.html.)

ATSDR has published numerous studies on various public health risk factors, including exposure to lead, asbestos, radon gas, and others. These publications include national-level exposure studies, as well as local or regional exposure assessments and case studies. Partnership teams may be able to use this information to obtain data or methods useful for assessing risk in their particular community.

For example, ATSDR is required by the Superfund law to conduct public health assessments (PHAs) of all Superfund sites. ATSDR's PHAs evaluate information on the release of hazardous substances into the environment in order to assess the impact on public health, to develop health advisories or other recommendations, and to identify studies or actions needed to evaluate and mitigate or prevent human health effects. PHAs evaluate three primary types of information: environmental data, community health concerns, and health outcome data (See ATRA Volume 1, Chapter 30). If a health assessment has already been done in the community, this might provide excellent background information for the community risk reduction effort (for a list of PHAs, see http://www.atsdr.cdc.gov/HAC/PHA/). More information on ATSDR's community support activities and resources is available at http://www.atsdr.cdc.gov/COM/commhome.html.

11.1.1.4 National Center for Environmental Health (NCEH)

The National Center for Environmental Health (NCEH) is part of the Centers for Disease Control and Prevention (http://www.cdc.gov/nceh/). NCEH plans, directs, and coordinates a national program to maintain and improve the health of the American people by promoting a healthy environment and by preventing premature death and avoidable illness and disability caused by non-infectious, non-occupational environmental and related factors. For example, NCEH provides data on:

- Air pollution;
- Healthy places;
- Asthma;
- Cancer clusters;
- Weather (extreme cold and heat, hurricanes, tornados, floods);
- Harmful algal blooms;
- Lead poisoning;
- Mold;
- Noise; and
- Tracking environmental public health.

11.1.1.5 National Institute of Environmental Health Sciences (NIEHS)

The mission of the National Institute of Environmental Health Sciences (NIEHS; http://www.niehs.nih.gov/external/welcome.htm) is to reduce the burden of human illness and dysfunction from environmental causes by understanding each of these elements and how they interrelate. The NIEHS achieves its mission through multidisciplinary biomedical research programs, prevention and intervention efforts, and communication strategies that encompass training, education, technology transfer, and community outreach.

NIEHS also publishes the peer-reviewed journal Environmental Health Perspectives (EHP), an important vehicle for the dissemination of environmental health information and research findings. EHP's mission is to serve as a forum for the discussion of the interrelationships between the environment and human health by publishing in a balanced and objective manner the best peer-reviewed research and most current and credible news of the field. This journal, which is available for free online (http://ehp.niehs.nih.gov/), may be of interest to those conducting community-scale assessments.

11.1.1.6 United States Geological Survey (USGS)

The U.S. Geological Survey (USGS; www.usgs.gov) is the nation's largest water, earth, and biological science and civilian mapping agency. USGS collects, monitors, analyzes, and provides scientific understanding about natural resource conditions, issues, and problems. The diversity of their scientific expertise enables the Survey to carry out large-scale, multi-disciplinary investigations and provide impartial scientific information to resource managers, planners, and other customers. Some of their many products include:

- **USGS Library.** Access to over 300,000 book, map, and serial records in the U.S. Geological Survey Library online catalog. Includes information on library borrowing policies, locations, and a link to ASK-A-LIBRARIAN, an electronic reference service.

- **USGS Store.** Purchase USGS published products (including maps, books, and general interest publications), as well as products of other agencies that are available from the USGS.

- **Publications Warehouse.** Search 60,000 bibliographic citations and obtain USGS series publications. Availability of content ranges from USGS Store purchase, to full text, to bibliographic citation only.

- **Biological Information on the Web – The National Biological Information Infrastructure.** The National Biological Information Infrastructure (NBII) is an electronic gateway to biological data and information developed and maintained by the USGS and other NBII partners and contributors in government agencies, academic institutions, non-government organizations, and private industry.

- **Geologic Information.** National Clearinghouse for geologic maps, datasets, and related geoscience information. Includes links to major USGS geoscience databases and programs as well as resources for creating digital geologic maps.

- **National Water Data – NWISWeb.** NWISWeb provides a comprehensive gateway to water-resources data collected at approximately 1.5 million sites in all 50 states, the District of Columbia, and Puerto Rico.

- **The National Map.** The Nation's Topographic Map for the 21st Century – Access to high-quality, geospatial data and information from the USGS as well as federal, state, and local partners.

- **National Atlas of the United States.®** Explore or download a comprehensive collection of small scale geospatial data from federal agencies.

- **Geodata.gov – Geospatial-One-Stop.** Web-based portal for one-stop access to maps, data, and other geospatial services from across all levels of government, including the USGS. Geodata.gov is a component of the National Spatial Data Infrastructure.

Other offerings from the Survey include:

- **Research.** Researchers can also locate, view, download, or order scientific and technical articles and reports as well as general interest publications such as booklets, fact sheets, pamphlets, and posters resulting from the research performed by USGS scientists and partners.

- **Map Information.** Learn about, locate, view, download, or order topographic, geologic, and other special purpose maps and charts in a variety of printed and digital formats.

- **General Aerial Photograph Information.** Locate, view, download, or order photographs showing such features as landforms, vegetation cover, and other natural and man-made features and phenomena.

- **Digital Satellite Data.** Locate, view, download, or order global land remote sensing data derived from a variety of air- and satellite-borne sensors, including Landsat satellite imagery and data from the Advanced Very High Resolution Radiometer carried aboard National Oceanic Atmospheric Administration's polar orbiting weather satellites.

- **Digital Data Sets.** Locate and download or order a vast array of biologic, geographic, geologic, and hydrologic scientific data collected or created by USGS scientists and partners.

- **Scientific Software.** Public-domain software developed by USGS scientists and partners to support a wide variety of natural science research and mapping activities.

- **Real-Time Monitoring and Data.** Measurements of natural phenomena such as earthquakes and floods collected, distributed, and displayed for immediate analysis following their occurrence as well as "live" scientific monitoring via video technology.

- **Graphics, Photograph, and Video Collections.** Collections of photographs and other visual media, most copyright-free, derived from the work of USGS scientists and partners.

11.1.1.7 United States Census Bureau

The Census Bureau (www.census.gov) is the main source of information on demographics in the United States. The Bureau also provides a range of economic information. The data and tools provided by the Bureau are particularly useful for communities trying to understand the relationship between risk factors and the people who live and work in an area. Some of the many community-relevant tools provided by the Bureau include:

- **The American FactFinder** - This interactive application supports the Economic Census, the American Community Survey, the 1990 Census, Census 2000 and the latest Population Estimates;

- **Censtats** - Applications available include: Census Tract Street Locator, County Business Patterns, Zip Business Patterns, International Trade Data, and more;

- **QuickFacts** - State and County QuickFacts provides frequently requested Census Bureau information at the national, state, county, and city level;

- **Online Mapping Tools** - Using TIGER and the American FactFinder;

- **US Gazetteer** - Place name and ZIP code search engine; and

- **DataFerrett** is a tool and data librarian that searches and retrieves data across federal, state, and local surveys, executes customized variable recoding, creates complex tabulations and business graphics. Current Population Survey, Survey of Income and Program Participation, American Community Survey, American Housing Survey, Small Area Income Poverty Estimates, Population Estimates, Economic Census Areawide Statistics, National Center for Health Statistics data, Centers for Disease Control data, and more.

11.1.1.8 State, Local, and Tribal (SLT) Agency Data

SLT government agencies may be able to provide public health, environmental quality, or other data that go beyond what is available from EPA and other federal agencies and it is usually a good idea to evaluate both federal government and more locally developed data sources to help capture all relevant information. For example, a SLT may collect one level of required information for transmission to the federal government, while at the same time developing more in-depth information for its own purposes. In addition, local government agencies (usually at the county or city level) are often a source of information about community concerns that may not be required by state or federal governments (e.g., odors, noise). In addition, local authorities usually have unique knowledge about the community that cannot be found in any organization's database of information.

Depending on the circumstances, the agency with responsibility for a particular issue (e.g., hazardous waste) may reside with the state or tribe's environmental agency or some other institution such as a health department. FirstGov (www.USA.gov - see Section 11.2.1 above) provides convenient links to state government internet sites. In addition, EPA provides links to state environmental agencies (http://www.epa.gov/epahome/state.htm).

11.1.1.9 Epidemiological and Other Medical Studies

Health information may be available from cancer or other disease registries, public health assessments, or other public health, medical, or epidemiological surveys or studies of the local community. Sources of such data include the local public health department, federal government agencies, state health departments, Indian Health Service, academic researchers, or the medical community, such as local hospitals. (See Section 11.1.1.3 above for examples this type of information collected by ATSDR.)

11.1.1.10 The National Library of Medicine

The National Library of Medicine (NLM; http://www.nlm.nih.gov/), on the campus of the National Institutes of Health (NIH) in Bethesda, Maryland, is the world's largest medical library. The Library collects materials in all areas of biomedicine and health care, as well as works on biomedical aspects of technology, the humanities, and the physical, life, and social sciences.

The collections stand at more than 7 million items – books, journals, technical reports, manuscripts, microfilms, photographs and images. For partnership teams, the library has a wealth of relevant information that can be accessed easily through the internet. A particularly useful tool is called "ToxTown" which provides users with an interactive town or city with links to the types of hazards they might find there (see Exhibit 11-1). Other example relevant collections include:

- MedlinePlus is the National Library of Medicine's web site for consumer health information (http://medlineplus.gov/). MedlinePlus is also available in Spanish (http://medlineplus.gov/esp/). Information in MedlinePlus includes:
  - Health topics pages link to health information from NIH and other authoritative sources and also include a MEDLINE/PubMed® search, current news items about the topic, and links to related topics;
  - Medical Encyclopedia - an extensive library of medical images as well as 4,000 articles about diseases, tests, symptoms, injuries, and surgeries;
  - Interactive Health Tutorials - programs that use animated graphics and sound to explain conditions and procedures in easy-to-read language;
  - Current Health News - late-breaking stories about medicine and health;
  - Dictionary - spellings and definitions of medical terms;
  - Directories - locations and credentials of doctors, dentists and hospitals; and
  - Other Resources include:
    - ✓ Organizations - a collection of organizations providing health information;
    - ✓ Libraries - consumer health libraries providing services to local residents; and
    - ✓ Databases - resources beyond MedlinePlus covering special topics and collections.
- MEDLINE - access to millions of articles published in biomedical journals, including special collections of easy-to-read materials, low vision resources, and health check tools.

11.1.1.11 Information Provided by the Community

The people who live in the community are often the best source of information. Even though the partnership team will have community representatives, not all community members are likely to be involved in the day-to-day work of the effort. As such, the partnership team may wish to hold informational meetings or use other techniques to solicit concerns and information from citizens and other local stakeholders. In addition to obtaining important information, this will also help to build trust in the process and buy-in to the selected risk reduction efforts.

Exhibit 11-1. The NLM's Tox Town

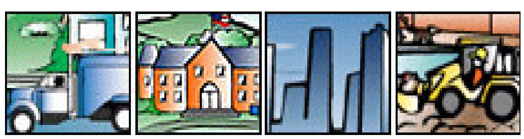
The National Library's **Tox Town** (http://toxtown.nlm.nih.gov/index_content.html#) is designed to give you information on:

- Everyday locations where you might find toxic chemicals;
- Non-technical descriptions of chemicals;
- Links to selected, authoritative chemical information on the internet;
- How the environment can impact human health; and
- Internet resources on environmental health topics.

Tox Town uses color, graphics, sounds and animation to add interest to learning about connections between chemicals, the environment, and the public's health. Tox Town's target audience is students above elementary-school level, educators, and the general public. It is a companion to the extensive information in the TOXNET (http://toxnet.nlm.nih.gov/) collection of databases that are typically used by toxicologists and health professionals.

Users can explore Tox Town by selecting Neighborhoods, Location links or Chemical links (Chemicals are described in non-technical language supplemented with internet links about a chemical and its possible impact on human health). The City, the Town, or the US-Mexico Border neighborhoods give an overview of environmental health concerns in those settings. The website gives selected internet resources about a location's environment and possible effects on human health. Toxic chemicals that might be found in a location are also listed. Some buildings display an interior view.

Tox Town also offers some resources in Spanish (http://toxtown.nlm.nih.gov/espanol/), and has a text version (http://toxtown.nlm.nih.gov/text_version/index.html).



11.1.2 Summarizing the Information Collected in Step 6

During Step 6, the partnership team has collected information about the community's identified risk factors, potentially impacted people and environmental resources, the potential adverse outcomes of exposure to the risk factors, and vulnerabilities that may further influence how the community may respond to the exposures. At this point it is a good idea to summarize all this information in a table, along with any other relevant information that has been developed during the information development process. (This is an expansion and refinement of the initial risk factor table shown in Exhibit 10-7.)

For example, consider the following summary table (Exhibit 11-2) in which the partnership team identified four community risk factors along with information about the potential number of people exposed to the risk factors, the types of adverse outcomes (some health, some quality of life) that may occur because of the exposure, and the key information sources where they got this information. They also noted some of the data gaps that they found along the way. Providing a summary of what they have found so far will be helpful when they go to the next step of the process – identifying community priorities.

11.2 STEP 7 - Identify Priorities

STEP 7
Identify Priorities

Once the partnership team has identified and summarized existing information on risk factors, potential impacts, community vulnerabilities, and other relevant information (e.g., quantitative estimates of risk), they will need to combine all this information in some way to rank the risk factors from most concern to least concern. If for no other reason, the ranking is necessary since resource considerations will likely constrain the partnership from selecting all identified risk factors as priorities for action.[a]

The discussion in this section provides information on some of the ways that partnership teams can use rank the identified risk factors. The chapter concludes with a discussion about how to select specific risk factors from the ranked list as targets for potential risk reduction projects.

Gathering Information for Identifying Priorities

In conducting analyses on data collected for priority-setting, the team should incorporate a "bias for action" (as described in Chapter 10). As feasible, existing data and the knowledge of the participants should be leveraged so that the analyses can be completed in a short time frame. This will allow a relatively quick identification of priorities that everyone can agree on as well as actions that can be taken to reduce risks and impacts. Once additional information has been gathered, later efforts can be organized to fill any significant gaps and other needs that are identified.

[a] In rare cases, the partnership may be interested in considering the availability, feasibility and acceptability of risk reduction measures for all of the risk factors they have identified.

Exhibit 11-2. Example Summary Data for Identified Community Risk Factors				
Identified Risk Factor	**Location/ Prevalence**	**Potential Adverse Outcomes (e.g., Negative Health Impacts)**	**Vulnerabilities**	**Information Sources (Gaps in Information)**
Breathing on- and off-road diesel particulates (Risk to human health)	Potentially affects all members of community High exposure along truck routes Elderly, children, and asthmatics especially impacted	Impacts respiratory and cardiac function, carcinogenic outcomes	Inadequate access to health care Proximity to pollution sources (Proximity to roadways) Community populations of children and the elderly	Evaluated national studies of similar exposures and resulting health outcomes Number and types of people exposed from Census Bureau Limited survey of community about access to adequate health care (Need more detailed information on local truck traffic)
Drinking contaminated water from community wells (contamination due to abandoned waste site) (Risk to human health)	Potentially affects 50 households on private well water; ~25 children; <5 elderly	Contaminants cause both cancer and noncancer health effects	Inadequate access to health care Proximity to multiple pollution sources (populations potentially exposed to contaminated wells also exposed to adjacent industrial complex emissions) Contaminants cause both cancer and noncancer health effects	Identified this risk factor based on perceived threat to neighbors of a nearby waste site Surveyed these residents about their access to adequate health care (Insufficient monitoring data available on well water)
Exposure of children to lead in water, paint, and soil (Risk to human health)	Potentially affects most households in the community (80% of homes built before 1970)	Causes neurological problems in children	Inadequate access to health care and blood lead screening Neurological effects on fetus, infants, and children	Based on limited childhood blood level data; national studies of similar exposure conditions Number and type of people potentially exposed from census data, local housing authority, and state environmental hazardous sites clean-up program (No household sampling of contaminated media; no blood lead data available)
Odor from wastewater treatment plant (Affects quality of life)	Potentially affects all members of community	Emotional stress Reduced recreational opportunities Reduced property values	Emotional stress	Community complaints No identified information on potential health impacts

But What About Quantitative Information on Risk?

Up to this point, the partnership team has gathered information on the presence of environmental risk factors in its area, the people and ecological systems potentially impacted by the factors, the negative outcomes that can result from contact with the risk factors, and community vulnerabilities. But what about taking this information to the next step by developing quantitative estimates of actual risk posed by the factors? Shouldn't that also be an important piece of information to be included in the overall ranking process?

The answer is yes it can be, but depending on the needs, desires, and resources of the partnership team, it may or may not actually be done (e.g., resource considerations, available data, access to needed expertise, a desire to "move ahead" rather than have "analysis paralysis," etc. may lead the partnership team to base its ranking on readily available information and to avoid the development of quantitative risk estimates).

If the partnership team wants to develop quantitative estimates of risk as a way of further informing the ranking process, it will likely need to seek out experts in the field of risk assessment (EPA, state, tribal, and local public health and environmental agencies, and local universities can usually provide this aid). For example, consider a partnership team that has identified the risk factor "Chemical X in the air we breathe" as a potential problem in the community. From their evaluation of readily available data, they were able to find:

- There is a monitor located in the community, the data from which can be used to estimate the long-term average concentration of the cancer causing Chemical X in the air;
- From the Census Bureau, it is able to estimate how many people are potentially exposed to Chemical X, and;
- There is readily available, peer reviewed data that establishes how toxic (i.e., how potent) Chemical X is in its ability to cause cancer through inhalation.

Using this information, they decide to develop an estimate of the potential for the exposed population to develop cancer over time based on an assumption of continuous (24 hours per day, 7 days a week) inhalation exposure over a lifetime to Chemical X at the monitored concentration. The team does this by using the following equation:

$$\textbf{Cancer Risk} = [\textbf{X}] \div \textbf{IUR}$$

Where the cancer risk is a statistical probability of developing cancer (because of exposure to Chemical X) over a lifetime of exposure by inhaling the chemical in air, [X] is the concentration of Chemical X in the air at the point of exposure (in micrograms of Chemical X per cubic meter of air or ug/m^3), and IUR is the upper bound estimate of the inhalation unit risk, a number that mathematically represents how potent Chemical X is at causing cancer [IUR is given in units of $(ug/m^3)^{-1}$].

The partnership team may or may not be able to develop such analyses for all the identified risk factors in its community (e.g., it would likely not be able to develop an estimate of the likelihood a person would develop "emotional stress" from a nuisance odor and the ranking for this factor might have to rely more on anecdotal information from community residents). Ultimately, the ranking process will likely have to rely on a variety of different types of data for the different risk factors that are not perfectly matched in either the type or quality (i.e., comparing one risk factor to another is not always an "apples to apples" comparison). A discussion of the various techniques that partnership teams can use to deal with this issue is provided in the next section.

11.2.1 Methods for Evaluating and Ranking Community Concerns

As introduced in Chapter 10, partnership teams will commonly use a *Comparative Risk Assessment* or CRA process to help them compare risk factors to one another and to rank them using a *common scale of concern* (e.g., by putting all risk factors on the same scale such as a numerical 1-10 scale of concern or a high/medium/low scale of concern).

Keep in mind that the data gathered or developed about individual factors in Step 6 may be more or less fact-based whereas the ranking process discussed here will likely rely to a greater degree on the distinctive characteristics of the partnership team. For example, the team may have a strong quantitative analysis of the potential risks posed by a given risk factor, but during the ranking process, the relative level of concern developed for that factor may be influenced by team members' values, feelings, and experience with the factor. As such, the results of a CRA in one community may be different from the results of a CRA in another community for a similar set of circumstances.

What Exactly Are We Ranking in Step 7?

In Step 7, we are ranking the community's identified risk factors from highest concern to lowest concern using a common scale. For example, on a scale of one to ten (with ten being "most concern" and one being "least concern"), pesticide exposure in homes might be scored as a "higher concern" issue than, say, exposure to lead paint in older homes.*

In this approach, the partnership will use all of the information it gathered in Step 6 (information on the risk factors, the potential impacted populations, the potential adverse effects,
community vulnerabilites, quantitative estimates of risk, etc.) to develop the final ranking.

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*The level of concern for an array of risk factors put into a "common scale of concern" can mask important information such as the probability of an individual developing cancer, the number of people living with a certain level of noncancer hazard, or the level of stress experienced by an odor problem. As such, efforts should be made to use the common scale for its intended purpose and, when possible, to retain and communicate other important information to decision makers.

Once the CRA has been completed, the partnership team will have a sense of the relative concern (using the common scale adopted by the community) of the community risk factors. The process may also result in a list of data gaps that may need to be filled for the ranking effort to be completed.

Keep the Community Involved

During the process of gathering information on risk factors, potential impacts, and community vulnerabilities, the partnership team will have made efforts to keep the larger community involved. Likewise, residents of the community, local businesses, local doctors and public health staff, and others should also be engaged in the next step of the process – ranking the risk factors. Continued involvement by these stakeholders early on and throughout the process will help ensure success over the long run.

The following section discusses the general approach to using the CRA process to rank community risk factors. Readers should keep in mind that the CRA process is necessarily a flexible approach that will need to be adapted to local circumstances.

What About the Combined Impact of Multiple Risk Factors?

In addition to the information developed for each individual factor, the partnership team may also consider the cumulative level of concern posed by combining information on more than one risk factor together. For example, the combined potential impact from multiple risk factors that all result in the same adverse endpoint (e.g., all emission sources of chemicals that cause irritation of the respiratory tract) would provide useful information for setting priorities.

However, given the limits of science in this area, developing estimates of cumulative risk may be difficult (particularly when issues such as health status and vulnerabilities are folded into the evaluation). That having been said, once the information on known concerns has been collected, the partnership may, nevertheless, be able to develop at least a qualitative sense of the combined concerns affecting the community. One way to do this might be to develop a matrix displaying all the environmental risk factors along with the potentially affected community subgroups, the expected impacts, the health status of those affected, and other relevant vulnerabilities. The matrix would also point out the potential relationship (or lack of relationship) of the various risk factors to one another.

For example, the risk from breathing particulate matter in the air from a local industry may be compounded by particulate matter releases from local traffic as well as particulate matter releases from local use of wood burning fireplaces for heat. If everyone in the study area has the potential for simultaneous exposure to particulate matter from all three of these sources, it would be helpful for the partnership to recognize this potential for cumulative risks. This information can also help in determining the types of steps that will be needed to bring about meaningful change in the community as well as the level of effort and resources that will be needed to bring about that change. Similarly, the partnership should also attempt to look at the cumulative impacts of multiple chemicals being released from the same source. (In contrast, contaminated ground water affecting only a few households in one part of the community would not be considered in the cumulative risk analysis for other parts of the community.) A matrix format for displaying this type of information would essentially be an expanded and refined version of Exhibit 11-2.

As noted above, performing a scientifically sound cumulative analysis of risk (either quantitative estimates or more qualitative evaluations) is technically challenging and the scientific approaches for doing so are still developing. Partnership teams are encouraged to engage people who are knowledgeable in this area to help them as they work to develop an understanding of the potential cumulative risk issues in their community. Understanding issues such as the composition of complex mixtures released to the environment or the potential for different pollutants to result in the same health effect generally require the help of environmental engineers and toxicologists. More information on performing a cumulative risk assessment is provided on EPA's Cumulative Risk Assessment Program webpage (http://www.epa.gov/OSA/spc/2cumrisk.htm).

Comparative Risk Analysis

Comparative risk analysis (CRA) is a methodology to identify and address the issues of greatest environmental risks and provide a framework for prioritizing environmental problems. The results of a CRA can be used to provide a technical basis for targeting activities or managing priorities and resources. EPA's Comparative Risk Analysis Website (http://www.epa.gov/seahome/comprisk.html) contains the history and overall methodology of comparative risk, as well as several case studies and other information. Partnership teams are encouraged to download and run the comparative risk analysis tutorial provided on this webpage to help them further understand how risk ranking efforts are performed.

In addition, EPA's workbook called the *"Guidebook to Comparing Risks and Setting Environmental Priorities"* discusses the major technical and managerial issues inherent in comparative risk projects and explains the mechanics of conducting the risk analysis and risk management phases of a project (the *Guidebook* can be obtained from EPA's National Environmental Publications Information System at http://nepis.epa.gov/).

CRAs may have important limitations. For example, subjectivity is commonly needed to score and rank different kinds of risk. In addition, because the quality of data is likely to vary among risk factors, different risk scores may have varying levels of uncertainty. The initial ranking of risk factors using the CRA process should be performed, inasmuch as possible, without consideration of cost, technical feasibility of correcting the problem, or other non-health and safety issues. The reason for this is that the community will commonly consider that it is entitled to a transparent, health and safety-based ranking of risk factors even though some of those factors may not ultimately be selected for risk reduction projects (e.g., because of cost, technological impediments, or other reasons – see Chapter 12). Without this initial "health and safety-only" analysis, the entire effort may be seen by the community as arbitrary, skewed, or biased towards one or a few stakeholders' needs. This can lead to community apathy and an unwillingness to accept the ranking outcome or participate in the subsequent risk reduction activities.

Estimates of concern developed in the CRA process can be based on information that is quantitative, such as an estimate in the form of a statistical probability (e.g., a "three in one hundred thousand" risk of developing cancer), or qualitative, such as qualitative estimates of concern using a "high-medium-low" scale and this level of detail may influence how the risk factor is viewed within the CRA analysis. For example, a community might consider quantitative estimates cancer risks to be a more important or "weighty" indicator of potential concern than anecdotal data about a low-level odor problem.

11.2.2 What Is the Basic CRA Framework?

When performing a CRA, the partnership team will evaluate and develop a relative ranking of the risk factors it has identified using a common scale of concern. Typically it will use some form of voting, negotiated consensus, or a formula[(1)] to do this (see below). Regardless of the approach taken, the partnership team may either base its ranking on perceptions, feelings, or direct experience of a factor[(b)] or it may work to make its analysis more objective by relying on

[b] While this is the easiest and fastest way to perform the analysis, it can also lead to a result that is subject to a high level of uncertainty.

scientific methods and facts.[c] (It should also be noted that when the cost to correct a problem is high, decision makers will commonly require a scientific fact-based analysis to release any funds needed for risk reduction activities.[d])

That having been said, it is best not to think of these two approaches to performing a CRA as the only options. Instead, a comparative risk project may use a series of refinements that begin with a relatively perception/experience-based ranking analysis and proceed to a more scientific fact-based evaluation. In some cases, part of a ranking analysis will have a strong science/fact-based underpinning while other parts of the effort will rely more on perception and experience. Ultimately, these two approaches are best thought of as points along a spectrum of increasing complexity and detail that move from a ranking that is based solely on how people feel about a risk factor to a ranking that is more fact-based. Typically, a ranking effort will be a combination of both types of information.

As noted above, ranking risk factors in the CRA process is normally done in one of three ways:

- By negotiated consensus;
- By voting; or
- By the application of some sort of formula.

These various methods for ranking risk factors progresses from relatively straightforward, simplistic approaches to more complex analytical approaches. Each has it strengths and weaknesses that the stakeholder group should attempt to understand and articulate in its written description of the process. Exhibit 11-3 describes some of the characteristics of these ranking methods.

Using a "Common Scale of Concern"

It may not be immediately obvious whether or how to compare the a quantitative risk estimate of getting cancer (expressed as a statistical probability) from exposure to a nearby air pollution source to the impact on a community's quality of life from a local sewage plant. As noted previously, this problem is resolved by putting all the risk factors "on the same footing" by developing a score for each factor using a common scale of concern (e.g., assigning each factor a score of one to ten – with ten being the most concern – or a score of high, medium, or low concern).

However, even when the factors are made to be directly comparable by assigning them to the same scale, other issues with the comparison process can arise. For example, Factor A might be labeled "High Concern," but information on which this is based is judged "very uncertain" while the underlying data for Factor B – also labeled "High Concern" – is judged to be "highly certain." While the comparison of Risk Factors A and B is now straightforward on the one hand (they are both "High Risk"), when uncertainties are taken into account, this seemingly easy comparison becomes questionable.

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[c] This approach takes the most time and resources, but may provide more certainty about the level of concern posed by a factor and may contradict the community's perception of the most significant risks.

[d] Partnership members may or may not derive detailed, community-specific estimates of risk for each risk factor. When an in-depth risk analysis is not pursued for a given factor, the team will commonly obtain, evaluate, and use existing estimates of risk and other relevant data to allow the comparative analysis of the risk factor to proceed.

Exhibit 11-3. Example Risk Ranking Methods
Negotiation In this approach, the partnership team negotiates how to rank the various factors. This is the least structured of the risk ranking methods and generally involves the following steps: • Review the data; • Take proposals for how to rank the individual factors; • Discuss/debate any objections and make alterations to the proposals; • Discuss/debate any objections and rank the remaining factors; and • Review the results and make remaining alterations as necessary. **Voting** As the name implies, this approach allows one vote for each member of the partnership team. This is the most familiar method of ranking and is the most frequently used. However, there is a temptation in voting to cut off discussion too early which may result in ignoring complex issues, magnifying biases, and overlooking data. There are single vote and multiple voting techniques that can be used to express voter's preferences and each technique has its advantages and disadvantages. One example of how to organize and run a meeting where voting is used as a decision making tool is provided at: http://instruction.bus.wisc.edu/obdemo/readings/ngt.html. **Application of a Formula** This will usually be the least familiar option for the partnership team, but may provide a more objective, science-based approach to ranking risk factors. As an example of this approach, environmental issues could be broken down into component parts, weighted and recombined to provide an overall ranking score. The scores are then listed from highest to lowest. Note that even in this type of approach, value judgements (e.g., selecting the weighting factors) may still cause some uncertainty in the overall ranking. Issues also arise when the risk endpoints differ (e.g., statistical probability of developing cancer vs. probability of exceeding an established public heath criterion).

The following is a simple example of a partnership team that is considering how to rank three identified risk factors in their community:

- Secondhand cigarette smoke;
- Living next to an abandoned industrial site; and
- School buses idling in front of schools.

The team begins the ranking exercise by simply asking each team member to rank the factors based on his or her own experience, feelings, and perceptions about these risk factors using all the data they gathered and summarized in Step 6. When the results of the exercise are reviewed, it was determined that some members of the partnership team rated the abandoned site the factor of most concern while others considered secondhand smoke the more pressing problem. Still others identified school bus emissions as the most important issue. When they discussed how they came to their conclusions, they found that their reasons for their choices differed for a wide variety of reasons, such as:

- Perceived threat of a risk factor based on their personal relationship to the risk factor (e.g., how close a person lived to the abandoned site, whether a team member had children who attend school);

- A focus on community vulnerabilities (e.g., children are especially vulnerable to school bus exhaust and secondhand cigarette smoke and most children in the area are poor); and

- Perceptions about potential impacts (e.g., the abandoned site once used cancer-causing chemicals which influenced how people felt about the issue, most children take the bus to school making the impact of bus emissions a community-wide problem, etc.).

In short, by simply asking individuals to rank the factors using the available information, the outcome may vary from person to person based on individual perceptions and feelings about a given factor. That having been said, some partnership teams may willingly choose this approach as a first step in ranking community concerns (e.g., in order to give maximum consideration of individual team members' personal concerns).

After this "exploratory exercise" in ranking the factors, the team considers its options. At this point, the team could simply vote on how to rank the risk factors. Alternatively, it could negotiate (or "talk it out") to come to consensus about how to rank the factors. In this example, the team decides to move past simplistic voting and negotiating options in order to try to rank the factors by relying more on empirical data and refined analysis methods. Specifically, it hopes to make the analysis more "fact-based" by developing and applying a formula to develop a numerical ranking of the three factors.

This is a particularly useful approach since its first attempt at ranking the factors, had it stopped at that point, would have led to disagreements among team members. By moving to a more fact-based analysis, the team hopes to develop a rationale for its ranking that is based on considerations other than differences of opinion and personal preferences. Hopefully, the outcome will be a more robust analysis on which most of the partnership team can come to agree.

To develop and apply a formula to rank the three identified risk factors, the partnership members begin by looking at the information they have already developed for each of these three items and, based on that information and in consultation with public health experts, use negotiation skills to place each risk factor into a "High Concern, Medium Concern, or Low Concern" grouping. For example, the team has established, based on existing scientific literature, that breathing secondhand smoke should be ranked as a "High Concern" (secondhand smoke is a known human carcinogen). It also concludes from an evaluation of available literature that children breathing school bus exhaust should also be ranked a "High Concern." For the abandoned site, the state has sampled both soils and groundwater on and around the site and found insignificant contamination. The facility's grounds are fenced and guarded and neighboring residents are all on city water. The partnership team members, therefore, rank the hazard associated with this factor a "Low

The Interplay of Voting, Negotiating, and Formulas

The CRA process is not an entirely "either/or" process and there may be an interplay of the various CRA approaches (voting, negotiating, and use of formulas) throughout the process. For example, the team may decide to use a "formula" to calculate relative rankings for the risk factors, but in the process of performing this analysis it needs to make decisions about which formula to use and which inputs to include. Making such decisions will commonly require the advice of experts from various scientific and engineering fields, and will commonly include some negotiation and perhaps even some voting.

Concern" since all the facts point to limited or no exposure to contaminated media by local residents.

At this point, the partnership team members could use a very simple formula to rank the factors, such as:

Formula (1)

Risk Ranking = Initial Concern Grouping
(i.e., High Concern, Medium Concern, or Low Concern)

Using this approach results in the following relative ranking of the various concerns:

INITIAL RANKING

Secondhand smoke = School bus exhaust **= High Risk**

Abandoned Site **= Low Risk**

However, this analysis is based solely on a review of the scientific literature and other general factual information about the hazards generally believed to be posed by the these three risk factors. The potential impacts to the actual surrounding community and the community's existing vulnerabilities have not been taken into account. To better account for these additional variables, the partnership members decide to refine their formula to include information on the potential number of people potentially impacted by each of these three risk factors.

To do this, the partnership team first uses negotiation techniques to select a numerical representation for each of its original concern groups (High Concern, Medium Concern, and Low Concern), with a larger numerical value representing a higher concern (these numerical values are referred to as "weights;" the larger the number, the more "weight" or importance it represents). It then uses negotiation techniques to develop three new groupings to represent the number of people that are potentially impacted by the risk factors (i.e., less than 100, 100 to 1000, and more than 1000 people potentially impacted). As it did with the concern groupings, it then assigns each of these population groups a numerical weighting value (see Exhibit 11-4).

Exhibit 11-4. Example Risk Ranking Scheme Using Groupings and Numerical Weights				
Grouping Number	**If the Concern for a risk factor is ranked...**	**...then the weight for the risk factor will be...**	**If the number of potentially impacted persons is...**	**...then the weight for the impacted population will be...**
Group Number 1	HIGH	100	Less than 100	1
Group Number 2	MEDIUM	50	Between 100 and 1,000	50
Group Number 3	LOW	1	Greater than 1,000	100

The next step is to determine the revised "Formula" it will use to perform the re-ranking of the risk factors. So to continue the example, the partnership decides that the revised formula should be:

Formula (2)

Revised Ranking Score = (Weight for a Risk Factor) × (Weight for the number of people potentially impacted)

In the example, the partnership team members reviewed demographic and other relevant information for the community and found that only 50 people live within a half-mile of the abandoned facility, smoking is banned in public places in the community, and there are 1,200 children enrolled in community schools. According to the formula above, the revised ranking score for each risk factor would be:

REVISED RANKING

Second hand smoke = 100 × 1 = 100

School bus exhaust = 100 × 100 = 10,000

Abandoned facility = 1 × 1 = 1

On the face of it, the revised ranking of the risk factors indicates that school bus exhaust ranks higher than secondhand smoke which ranks higher than the abandoned facility.

At this point the team needs to consider where it is in the analysis. Has this revised analysis helped it sort out which risk factors are of most concern? Has it done it in a more factual, scientifically supportable manner? What information has yet to be considered? Are the important uncertainties inherent in the analysis up to this point that should be taken into consideration?

For example, the partnership team factually knew that the local government for the community outlaws smoking in public places, but the partnership team had no data on the number of people who smoke in non-public places such as homes (thus, putting the number of people potentially impacted arbitrarily into the lowest population group in Exhibit 11-4). In other words, there is likely substantial uncertainty in the ranking of the secondhand smoke ranking leading the team to decide to identify this as a data gap that should be clarified before developing the final ranking (see Chapter 12 for information on filling data gaps). Other potential issues that they note at this point include:

- Formula (2) includes a measure of potential hazard and potential impact, but does not explicitly take community vulnerabilities into account. In this example, the partnership team decides to qualitatively include information about community vulnerabilities (by use of a negotiation process) to convert the revised risk rankings developed using formula (2) into a final ranking.

- Other uncertainties in the analysis include whether the assignment of risk factors to a common scale (high/medium/low) was appropriate and whether the selection of the weighting factors is a reliable representation of the relative importance of each weighted element.

This simple example illustrates how the partnership team can use the various options of voting, negotiating, and application of formulas (or more than one of these activities simultaneously) to develop a ranking of risk factors. As the team works to refine its analysis, it may even bring in additional relevant data to further augment the ranking process (e.g., quantitative estimates of risk posed by a given factor).

Throughout all these efforts, partnership teams should strive to use the best information available. Having said that, it is important to realize that it is impossible to eliminate all uncertainty no matter how much time and money you spend. However, using the best information available within a transparent process will give the partnership a framework to inform a real discussion of priorities. This kind of candid and open communication often results in true consensus and a strong and lasting partnership.

The next step of the process – selecting the priority issues for community action – is discussed in the following section.

11.2.3 Selecting Priority Concerns for the Community

As noted above, the partnership team will have, at this point, developed a ranked list of community risk factors (using CRA) and developed a written report of how the analysis was performed along with important uncertainties and outstanding data gaps. The team will now proceed to take this information and identify which of the ranked factors are of most importance and which will be carried forward to the next step of the process (discussed in Chapter 12) – evaluating and selecting risk reduction projects. The partnership team can do this in a variety of ways. For example, it can use methods similar to those used in the CRA process (e.g., voting, negotiation, or a formula) to decide which factors to select from among the ranked list as community priorities.

It is important to keep in mind that a factor which scored high in the Step 7 CRA may not ultimately be selected for a risk reduction project. For example, the uncertainty in the risk ranking of a given factor may be so great that the partnership can only identify it as a data gap that requires more information before a decision can be made. As another example, a factor that ranks high on the list may be slated for imminent regulatory risk reduction that would render community actions superfluous. In addition, it may be very expensive to reduce the risks from the source ranked as the highest in the CRA process. In such instances, the community might be able to get more total risk reduction by reducing the second-, third-, and fourth-highest risk factors for the same money and in less time than pursuing the most risky factor alone.

What Are We Doing at this Point in the Analysis?

Up to this point, we have done several things simultaneously. First we collected information about community risk factors, potential impacts, and vulnerabilities. Next we used a process called Comparative Risk Analysis or CRA to rank the identified risk factors from most concern to least concern using a common scale of concern.

The output of these Steps is a summary of all the collected information about each risk factor, the final ranking, and a written description of how this work was done. Now, we will take all of this information to develop a final priority list of issues that will be the focus of actions to bring about risk reduction in the community.

That having been said, considerations of whether or not something *can be done about a particular issue and how much it will cost* should be set aside at this point. This initial priority setting exercise should be based as strictly as possible on how important the concern is to the health and quality of life of the community and its environment. This is because it is important for a community to know about significant concerns, even if it is not possible to do something about some of those concerns immediately. Considerations of the practicality of doing something about the priorities will be a key part of the next step (Step 8), the development and implementation of an action plan.

Finally, it should be noted that the exercise of selecting community priority risk factors will depend heavily on the community's goals and values, resulting in different communities making unique choices and the overall discussion of choices difficult to quantify. Only good common sense and a clear view of community values will provide a basis for making the judgments necessary to set community priorities. It will also be important, as the discussion proceeds, for members of the partnership team to keep in mind that the goal is to reach agreement on the priorities that best meet community needs and that help build the consensus needed for mobilizing everyone to take action. Remember, it will usually not be possible to respond to all community risk factors at once. However, the partnership team will need to establish a way to deal with those concerns that were not agreed on. If some members of the partnership team identify an issue as a high priority concern and others disagree, the action plan will need to include a process for coming to agreement on these issues.

In summary, at this point in the process, partnership team members will have:

- Identified the risk factors of concern, their potential impacts, community vulnerabilities, and other relevant information;
- Summarized all this data together (e.g., as in Exhibit 11-2);

- Reviewed the data and performed their ranking analysis using voting, negotiation, a formula, or some combination of the three techniques (commonly in an iterative approach);
- Selected priority concerns for possible action; and
- Presented the overall results of the data gathering, ranking analysis, and priority selection process in easy to read table formats along with a thorough description of every step of the process, including discussions about the logic used for decisions, where data came from, how the ranking was performed, how priorities were chosen, and important uncertainties and remaining data gaps in the analysis.

References

1. U.S. Environmental Protection Agency Region 5 and Purdue University. 1995. *Software for Environmental Awareness: Comparative Risk Assessment*. Available at http://www.epa.gov/seahome/comprisk.html.

Chapter 12 Options for Reducing Priority Risk Factors

Table of Contents

12.0 Introduction

Chapter 11 discussed the process of identifying the priority risk factors on which the community will focus its risk reduction efforts. This chapter discusses the process of identifying, evaluating, and selecting the risk mitigation options that the community will pursue for each of these priority concerns (Step 8) and developing a plan of action to both implement the selected risk reduction options and fill data gaps (Step 9). The chapter concludes with a discussion of an ongoing evaluation of the effectiveness of the process and sustaining community efforts over time (Step 10).

Risk Management
An Overview

The process of identifying a problem requiring action as well as the action(s) to reduce the risk is called **risk management**. ATRA Volume 1, Chapter 27, provides a general overview of this topic and Chapter 8 of this Volume provides information specific to managing air toxics risks when multiple sources of emissions are present in a community. Stakeholders are referred to these chapters for more information on this subject.

Another excellent reference for understanding the process of managing environmental risk is the Presidential/Congressional Commission on Risk Assessment and Risk Management's *Framework for Environmental Health Risk Management* (available at: http://www.riskworld.com/Nreports/1996/risk_rpt/Rr6me001.htm).

12.1 STEP 8 - Identify and Analyze Options for Reducing the Priority Risks

STEP 8
Identify Options for Reducing Priority Risks

Once the partnership has identified its priority concerns and outstanding information needs, the next step will be to find out what can be done to address these issues. For priority risk concerns, the partnership will need to explore the available options for reducing risk. For example, if diesel particulates were identified as a priority, the community will need to do some research to identify approaches that have been developed to address this issue, such as retrofitting diesel engines on public and private truck and bus fleets, changing traffic routes, or restricting idling.

For each of the identified options, it will also need to identify additional relevant information such as technical feasibility, cost of the control measure, benefits, unintended consequences, existing or upcoming regulatory requirements, likelihood of community acceptance and participation, and cultural or social impacts of implementation for each option. The partnership will also need to identify resources that will be needed to implement the various approaches along with the assets and resources already available in the community.

The resources needed to reduce risks will vary depending on the source. For example, some risks, such as indoor exposure to tobacco smoke, might be effectively addressed through low-cost education and outreach efforts while other risks, such as diesel retrofits, will require significant investments for purchasing and installing new technology.

Some risks factors may not be able to be addressed by a single community and require a longer term effort to work with other communities. For example, the siting of major highways or the cleanup of a river, stream, or lake shared by other communities may require efforts by multiple communities. A similar effort will be needed to develop options for filling identified data gaps (discussed below).

Protecting Ecosystems

Community risk reduction projects will commonly focus on protecting human health. However, many communities will also be interested in assessing and addressing risks to their local ecosystem as well. EPA's *Community-Based Environmental Protection (CBEP)* program provides information on integrating environmental management with human needs, considers long-term ecosystem health, and highlights the positive correlations between economic prosperity and environmental well-being.

Communities considering ecosystem protection projects should consult the CBEP webpage - http://www.epa.gov/ecocommunity/about.htm, as well as EPA's Ecosystems webpage - http://www.epa.gov/ebtpages/ecosystems.html.

Once all the information on the options for addressing the community's priority risk factors and filling data gaps has been collected, it can be put together and summarized to help the community choose the actions it will take. Each community will have to use its best judgment to find the proper balance between the work to collect information on options and the work to reduce risk and fill information gaps. For example, requiring too much information on available options may delay the start of risk reduction actions. On the other hand, too little time spent on developing and evaluating options may result in taking actions that are not as effective as they could be in reducing risk.

It should be reemphasized that risk management does not always have to wait until the risk analysis and ranking process is completed (although the risk analysis and ranking will usually provide important information for effectively guiding the project). For example, some communities may wish to begin risk reduction projects for common, well characterized risk factors with little up-front analysis. In addition, some risk factors may be so obviously hazardous that even a minor amount of evaluation can confirm an important concern. Risk mitigation work may proceed on such factors while a more in-depth process evaluates additional concerns.

The partnership will find that risk reduction options generally fall into the following categories:

- **Regulatory approaches**. Many risk factors are already regulated by federal, state, tribal, or local government requirements. In some cases, the risk factor is not currently regulated (or only partially regulated), but statutory requirements call for further regulation at a specified time in the future. Regulatory approaches include enforceable requirements that must be met (or else are subject to legal action, such as fines).

- **Permits and related authorities**. Permits may offer opportunities for both regulatory and voluntary risk-management strategies. For example, many sources release chemicals to the environment pursuant to permits and related authorities. Permits generally must be renewed periodically and/or modified if conditions at the source change beyond some specified amount. This may provide an opportunity to amend permit conditions so as to reduce high-risk emissions. This might be coupled with voluntary measures or other flexible solutions to result in overall risk reduction.

> **The CARE Resource Guide**
> ***Identifying Risk Reduction Alternatives***
>
> As introduced in Chapter 10 of this volume, the Community Action for a Renewed Environment (CARE) program (http://cfpub.epa.gov/care/) has developed a Resource Guide (http://cfpub.epa.gov/care/index.cfm?fuseaction=Guide.showIntro) to help communities go through the multi-step process of assessing and addressing risk factors in their community.
>
> **Part III** of the Resource Guide (Methods to Reduce Your Exposure) is particularly helpful for identifying risk reduction options for community risk factors.

- **Voluntary approaches**. EPA and other regulatory agencies are looking beyond regulatory approaches to reduce risks from a variety of factors. Non-regulatory (voluntary) approaches are frequently the preferred option (or the only option) for meeting risk reduction goals, particularly if government agencies do not currently have specific regulatory authority to address a given risk factor. In addition, the types of problems identified may not lend themselves to regulatory solutions. Voluntary programs may also allow businesses to significantly reduce risks at much lower cost than regulatory options. Incentives such as tax reductions or consumer rebates can be used to encourage voluntary responses.

  In addition to voluntary activities on the part of the regulated community, a substantial amount of risk reduction can be achieved through voluntary activities on the part of average citizens. Voluntary changes in a variety of activities ranging from commuting choices to the way people discard waste can have a meaningful impact on both a person's immediate environment and the health of the community at large.

Information about potential risk reduction options for different types of risk factors can be obtained from EPA, the environmental management literature, searching the internet, and other sources. The following sections briefly describe some of the general approaches used by the EPA to address some of the common risk factors that may be identified as priority concerns in a community-based risk reduction program.

12.1.1 Indoor and Outdoor Air Pollution

In many communities, poor air quality can result from the release of toxic chemicals to both indoor and outdoor air from a wide variety of sources. In a community setting, the number and types of sources can be very large, making it difficult to know which sources and chemicals should be the focus of efforts to achieve meaningful improvement in air quality. Parts II and III of this book address this issue in detail and provide approaches to mitigating unacceptable air toxics risks identified in the process. In particular, readers interested in approaches to reducing toxic air pollution and several other important common community air pollutants are referred to

Part II, Chapter 8. Additional information on air pollution, its potential impacts, and methods for reducing exposures can be found at www.epa.gov/air.

The Criteria Air Pollutants
Six Pollutants Of National Concern

EPA has set national ambient air quality standards (NAAQS) for six common pollutants referred to as "criteria" pollutants. These standards are required by law to be met everywhere in the nation. When an area exceeds these standards, the area is said to be in "nonattainment" with the standard and the state is required to develop and implement a plan to bring the area back into attainment.

Carbon Monoxide	**Particulate Matter**
Ozone	**Sulfur Dioxide**
Nitrogen Dioxide	**Lead**

Given the substantial amount of work that is being put into this effort at the state and national level, further information on these pollutants is not provided here. Stakeholders interested in learning more about the criteria pollutant program are referred to: http://www.epa.gov/air/urbanair/6poll.html. Parties interested in participating in the criteria pollutant program should contact their state or local air pollution control agency.

12.1.2 Water Pollution

With the exception of certain pollutants that deposit out of the air (e.g., mercury), most surface water pollution results from direct pollution discharges from industrial or identifiable sources and runoff from diffuse activities (e.g., pesticides runoff in storm water from yards and fields). Groundwater pollution is usually caused by spills, leaking storage tanks, or other land-based releases. EPA regulates these water quality issues primarily under the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA). However, other environmental laws may also come into play (e.g., when groundwater is contaminated from mismanagement of hazardous waste, the hazardous waste law called RCRA may also apply). Depending on the source, the pollutant of concern in water may be a chemical, a pathogen such as bacteria found in sanitary sewage, or garbage. Exhibit 12-1 provides a description of a number of common water pollution sources and risk reduction options.

EPA's Clean Beaches Program

Beaches are a place to play, watch wildlife, fish, and swim. With beaches giving us so much, we have to protect them from a variety of potential problems.

Pollution can arrive at a beach simply by people dropping trash. Storms are also a major problem; some sewer systems overflow directly into rivers, which eventually carry pollution and bacteria to beach waters. In addition, pollution can come from heavy concentrations of animals like pigs and chickens. EPA is working with states, tribes, territories, local governments, sources of pollution, and the public to reduce pollution from all of these.

To learn more about beach pollution and things communities can do to protect beaches, see http://www.epa.gov/beaches/.

Exhibit 12-1. Common Water Pollution Sources and Risk Reduction Options
EPA divides water pollution sources into two categories: point and non-point. Point sources of water pollution are stationary locations such as sewage treatment plants, factories and ships. Non-point sources are more diffuse and include agricultural runoff, mining activities and paved roads. Under the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. EPA works with state and local authorities to monitor pollution levels in the nations water and provide status and trend information on a representative variety of ecosystems. ***Recommended EPA Web pages*** *Watershed Information Network* - A roadmap to information and services for protecting and restoring water resources (http://www.epa.gov/OWOW/win/index.html). Additional information about EPA's water pollution control activities is available at: http://www.epa.gov/ebtpages/water.html.

12.1.3 Land Pollution and Solid Waste

Sites contaminated by improperly disposed hazardous substances can release contaminants to the land, air, surface water, groundwater or the food chain. EPA's programs to addresses land pollution are authorized primarily by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as Superfund) and the Resource Conservation and Recovery Act (RCRA). The Superfund program was created in 1980 to locate, investigate, and clean up the worst hazardous sites nationwide. Clean up activities may include removal or containment (e.g., capping) of the sources of contamination, treating contaminated media, and institutional controls (e.g., fences, fishing restrictions) to limit exposures. Superfund also requires reporting of spills of hazardous substances. EPA's Superfund home page is http://www.epa.gov/superfund/index.htm.

RCRA is the nation's primary law directing the routine management of solid and hazardous wastes. RCRA's goals are to protect human health and the environment from the hazards posed by waste disposal, to conserve energy and natural resources through waste recycling and recovery, to reduce or eliminate the amount of waste generated, including hazardous waste, and to ensure that wastes are managed in an environmentally safe manner. RCRA has three main regulatory programs: solid waste (i.e., non-hazardous waste), hazardous waste, and underground storage tanks (USTs). RCRA requires or encourages many approaches to prevent or clean up land pollution, such as protective design standards for landfills and underground storage tanks, treatment or protective disposal of hazardous wastes, and remediation of spills and other contamination at hazardous waste facilities or from USTs. For more information about RCRA and related waste management programs at EPA, visit: http://www.epa.gov/epaoswer/osw/index.htm.

Household Hazardous Wastes

Some jobs around the home may require the use of products containing hazardous components. Such products may include certain paints, cleaners, stains and varnishes, car batteries, motor oil, and pesticides. The used or leftover contents of such consumer products are known as "household hazardous waste."

Americans generate 1.6 million tons of household hazardous waste per year. The average home can accumulate as much as 100 pounds of household hazardous waste in the basement or garage and in storage closets. When improperly disposed of, household hazardous waste can create a potential risk to people and the environment. EPA's webpage http://www.epa.gov/epaoswer/non-hw/househld/hhw.htm describes steps that people can take to reduce the amount of household hazardous waste they generate and to ensure that those wastes are safely stored, handled and disposed of.

In addition to Superfund and RCRA, EPA's Brownfields Program promotes the expansion, redevelopment, or reuse of properties hindered by the presence or potential presence of a hazardous substance or other pollutants. The Brownfields Program is designed to empower states, communities, and other stakeholders to work together in a timely manner to prevent, assess, safely clean up, and sustainability reuse brownfields. More information about the Brownfields Program is available at: http://www.epa.gov/swerosps/bf/index.html.

Exhibit 12-2 provides a list of some of the common waste pollution sources likely to be identified in a community risk reduction program and some of the common risk reduction options used to address those risk factors.

What Are Brownfields?

Brownfields are real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant. Cleaning up and reinvesting in these properties takes development pressures off of undeveloped, open land, and both improves and protects the environment.

12.1.4 Pesticides

Although pesticides can be beneficial to society, they can also be dangerous if stored or used carelessly. Improper pesticide use has the potential to result in excessive human or animal exposure via direct contact or from contaminated drinking water, food, air, or soil. Risks from pesticides can occur on the farm, on the job, or at home (e.g., lawn care, pest control), and proper storage can be just as important as proper use. EPA regulates the manufacture and use of pesticides primarily through the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

Exhibit 12-3 provides a list of some of the common pesticide risk factors likely to be identified in a community risk reduction program and some of the common risk reduction options used to address those risk factors.

Exhibit 12-2. Common Waste Sources and Risk Reduction Options
Nearly everything we do leaves behind some kind of waste. Households create ordinary garbage (and some household hazardous waste). Some example types of residential wastes include batteries, old paint and pesticides, scrap tires, and used oil. Industrial and manufacturing processes create both hazardous and nonhazardous wastes as well. There are a wide array of options a community can pursue to address waste issues, including: **Reducing wastes** through "source reduction" (i.e., consuming and throwing away less). This includes purchasing durable, long-lasting goods; seeking products and packaging that are as free of toxics as possible; and redesigning products to use less raw material in production, have a longer life, or be used again after its original use. **Reusing items** by repairing them, donating them to charity and community groups, or selling them – also reduces waste. Reusing products, when possible, is even better than recycling because the item does not need to be reprocessed before it can be used again. **Recycling** turns materials that would otherwise become waste into valuable resources. In addition, it generates a host of environmental, financial, and social benefits. Materials like glass, metal, plastics, and paper are collected, separated and sent to facilities that can process them into new materials or products. **Buying recycled products**, such as packaging, is necessary in order to make recycling economically feasible. When we buy recycled products, we create an economic incentive for recyclable materials to be collected, manufactured, and marketed as new products. Buying recycled has both economic and environmental benefits. Purchasing products made from or packaged in recycled materials saves resources for future generations. **Composting** is another form of recycling. Composting is the controlled biological decomposition of organic matter, such as food and yard wastes, into humus, a soil-like material. Composting is nature's way of recycling organic waste into new soil, which can be used in vegetable and flower gardens, landscaping, and many other applications. To learn more about what communities can do to help reduce and deal with wastes, visit EPA's "What You Can Do About Wastes" website at: http://www.epa.gov/epaoswer/osw/citizens.htm.

12.1.5 Other Common Toxic Substances

In addition to the typical hazardous materials discussed previously (e.g., pesticides and household hazardous wastes), many communities will have some amount of older building that contain one or both of two toxic chemicals of particular concern; namely, asbestos and lead.

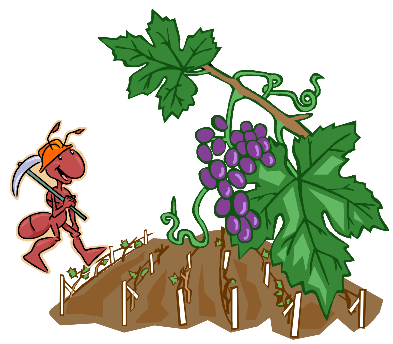
12.1.5.1 Asbestos

Asbestos is a naturally-occurring mineral fiber; so fibrous in fact that it can be woven like a fabric. Asbestos fibers have been added to over 3,000 products. Asbestos is fire-resistant, chemical-resistant and heat resistant so it was a poplar additive in all types of insulation, fire

Exhibit 12-3. Common Pesticide Risk Factors and Risk Reduction Options

A *pesticide* is any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest. Though often misunderstood to refer only to insecticides, the term pesticide also applies to herbicides, fungicides, and various other substances used to control pests. Pesticides are used by homeowners, businesses and others (especially agricultural uses). Some common household pesticides include:

- Cockroach sprays and baits;
- Insect repellents for personal use;
- Rat and other rodent poisons;
- Flea and tick sprays, powders, and pet collars;
- Kitchen, laundry, and bath disinfectants and sanitizers;
- Products that kill mold and mildew;
- Some lawn and garden products, such as weed killers; and
- Some swimming pool chemicals.



One method of reducing risks from pesticides is to implement an ***Integrated Pest Management*** (IPM) program. IPM is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment.

The IPM approach can be applied to both agricultural and non-agricultural settings, such as the home, garden, and workplace. IPM takes advantage of all appropriate pest management options including, but not limited to, the judicious use of pesticides. In contrast, *organic* food production applies many of the same concepts as IPM but limits the use of pesticides to those that are produced from natural sources, as opposed to synthetic chemicals.

For more information about pesticides, see: http://www.epa.gov/pesticides/. For information on things communities can do to help reduce exposures to pesticides, see: http://www.epa.gov/pesticides/controlling/index.htm.

doors, building products and firemen's suits. Asbestos has great strengthening properties. Asbestos-containing building materials include fireproofing material (sprayed on steel beams), insulation material (on pipes); acoustical or soundproofing material (sprayed onto ceilings and walls), and in miscellaneous building materials such as resilient floor coverings (linoleum), asphalt and vinyl floor tile, roofing shingles, roofing felts, siding, wallboard, etc. Friable asbestos material (asbestos material that when dry can be crumbled, pulverized, or reduced to powder by hand pressure) is of the most concern because these fibers can be released into the air more readily and inhaled into the lungs.

The presence of asbestos in a building does not mean that the health of the building occupants is endangered. If asbestos-containing material remains in good condition and is unlikely to be disturbed, exposure will be negligible. However, when asbestos-containing material is damaged or disturbed - for example by maintenance, repairs or remodeling/renovations conducted without proper controls - asbestos fibers are released. When asbestos fibers are released into the air there is a potential health risk because people breathing the air may breathe in asbestos fibers. Continued exposure can increase the amount of asbestos fibers that remain in the lungs. Fibers that remain embedded in lung tissue over time may cause serious lung diseases including: asbestosis, lung cancer, or mesothelioma.

In 1986, the Asbestos Hazard Emergency Response Act (commonly referred to as AHERA) was signed into law. AHERA requires public and private non-profit primary and secondary schools to inspect their buildings for asbestos-containing building materials. EPA has published regulations that require schools subject to AHERA to:

- Perform an original inspection and periodic re-inspections every 3 years for asbestos containing material;
- Develop, maintain, and update an asbestos management plan and keep a copy at the school;
- Provide yearly notification to parent, teacher, and employee organizations regarding the availability of the school's asbestos management plan and any asbestos abatement actions taken or planned in the school;
- Designate a contact person to ensure the responsibilities of the local education agency are properly implemented;
- Perform periodic surveillance of known or suspected asbestos containing building material; and
- Provide custodial staff with asbestos awareness training.

People that work with asbestos in public and commercial buildings and schools must be accredited and various worker protection requirements apply. For more information on Asbestos, see http://www.epa.gov/region4/air/asbestos/, or call the Asbestos hotline at (800) 368-5888.

12.1.5.2 Lead

Lead is a highly poisonous metal that was used for many years in things found in and around our homes. Lead may be in the paint in homes built before 1978. If the paint is chipped or peeling, it may cause health problems if paint chips or dust from the paint are breathed in or eaten. Children often put hands, toys and other things in their mouth. Children playing on floors or outside in the dirt where there are paint chips or dust may be eating lead by putting their fingers and toys in their mouth. Many children in America are poisoned by lead. As many as three million children under 6 years old may have some lead poisoning and the problem is worse in minority and low-income communities.

EPA and other federal, state and local government agencies are working to protect our children from lead poisoning. EPA wants to lower and soon stop lead poisoning by giving out information and talking to people about lead poisoning. Laws have also been made to help stop lead poisoning. Companies that break these laws may be fined by EPA.

Since the 1980's, EPA and other federal agencies have worked together to stop lead poisoning from not only lead in paint, but other things like gasoline, water, and the air from manufacturing plants. States and communities have developed programs to find and take care of children that have been poisoned by lead and fix up old houses that have paint with lead. Many parents have helped stop lead poisoning by keeping their homes clean and watching for paint that is chipping and peeling, by having their children tested for lead poisoning, and by feeding their children healthy food.

To combat childhood lead poisoning, the EPA requires landlords and property owners to give renters and buyers of houses built before 1978 a pamphlet titled *Protect Your Family from Lead in Your Home* (http://www.epa.gov/lead/leadprot.htm). Landlords and sellers must also inform renters and buyers if there are known lead-based paint in the home. Buyers also have the option to have the property inspected by a certified lead-hazards firm at their own expense. Information, including rules and regulations on certified lead inspectors and risk assessors, can be obtained by checking EPA's Lead web page http://www.epa.gov/lead/, or by contacting the National Lead Information Center at 1-800-424-LEAD (TDD: 1-800-526-5456).

12.1.6 Noise Pollution and Odors

Odors can impact health and quality of life. Odors or the substances eliciting them may cause, for example, headaches or nausea. Common odor sources include sewage treatment, composting, landfills, land application of sewage sludge, industrial emissions, and animal waste management. For some odor sources, chemical treatment or emission control equipment may be used to reduce odors at the source. Workplace practices and other operational controls may also be effective. For example, RCRA solid waste landfill operators are required to place a cover layer (usually soil) on the active face of the landfill at the end of each operating day. Daily cover reduces odors as well as the potential for fires, blowing litter, and other problems.

Like odors, noise can cause headaches and other health and quality of life problems. Examples of noise sources include traffic, airplanes (especially low flying planes found near flight paths), lawn equipment, recreational equipment (jet skis), and construction equipment (e.g., construction vehicles, power generation equipment, and activities such as jack hammering, sawing, blasting, pounding, and grinding). Common options for controlling noise impacts are erecting physical sound barriers, installing noise control equipment (e.g., mufflers), and using institutional or operational controls (e.g., redirecting flight paths, restricting loud noises to certain times of the day). The National Institute for Environmental Health Sciences maintains an website of useful resources on community noise issues and noise reduction options (http://ehp.niehs.nih.gov/topic/noisepol.html).

Many noise and odor problems are addressed primarily by local or state authorities instead of EPA or other federal agencies. For example, some communities have local noise ordinances and rules regulating nuisance odors. Some EPA rules, such as RCRA solid waste regulations describe above, and rules for land application of sewage sludge, also include provisions to minimize odor problems.

12.1.7 Radiation

Radiation is everywhere in the environment and partnership teams will need to be aware of the various sources, when to be concerned, and when protections from harmful exposures are needed. Some of the most common sources of radiation are:

- Radon gas that infiltrates homes from naturally occurring radium in soil;
- Nuclear power plants;
- Radiological waste sites;
- Consumer products which may contain, have been treated with, or emit either non-ionizing or ionizing radiation;

- Security devices and processes often involve ionizing radiation. Many of these devices are regulated by federal and state agencies (e.g., airport luggage x-ray machines and irradiated mail);
- Foods and food containers may be exposed to the high energy of ionizing radiation to kill bacteria and other pathogens (note that this exposure does not make the food or containers radioactive). Naturally occurring radionuclides can remain in glazes used on food containers;
- Medical procedures are the major sources of radiation exposure for many people;
- Commonly used household devices such as cell phones, microwaves, and televisions; and
- Other naturally occurring radiation such as UV radiation from sunlight.

An example of a radiation risk reduction project, a stakeholder group might decide to perform a SunWise project (http://www.epa.gov/sunwise/), especially if community members are likely to become overexposed by the sun. SunWise is an environmental and health education program that aims to teach the public how to protect themselves from overexposure to the sun through the use of classroom-based, school-based, and community-based components.

EPA's Radiation Protection Program (http://www.epa.gov/radiation/index.html) provides an overview of various radiation sources and helpful information on reducing exposures.

Radon

Radon is a cancer-causing, radioactive gas that comes from the natural (radioactive) breakdown of uranium in soil, rock and water and gets into the air people breathe. Radon can be found all over the U.S. and can get into any type of building - homes, offices, and schools - and result in a high indoor radon level. People are most likely to get their greatest exposure at home, where they spend most of their time. Radon is invisible and has no smell or taste.

Radon is estimated to cause many thousands of deaths each year from lung cancer. In fact, the Surgeon General has warned that radon is the second leading cause of lung cancer in the United States today. Only smoking causes more lung cancer deaths. If a person smokes and their home has high radon levels, their risk of lung cancer is especially high.

For more information on radon and things communities can do to test for radon and mitigate exposures, see: http://www.epa.gov/radon/. Additional information on radon is discussed in Section 3.2.4.1.

12.1.8 Lifestyle Risk Factors

Many studies have demonstrated an association between environmental exposures and certain diseases or other health problems. Examples include radon associated with lung cancer and disease-causing bacteria (e.g., in contaminated meat and water) associated with gastrointestinal illness. However, not all health problems are caused by environmental pollution. Diet, exercise, alcohol consumption, smoking habits, and genetic make-up can all influence the health status of an individual. When external pollutants are introduced into the picture, these same issues of health status and lifestyle choices may further influence the likelihood of an individual contracting disease from the exposure.

Further complicating the picture are several segments of the population that may be at higher risk of disease from environmental pollutants. Potentially sensitive groups (due to either greater potential for exposure or a greater susceptibility to the same exposure) may, depending on the pollutant, include very young children, the elderly, and people with existing health problems such as respiratory or heart disease. In addition, poor or other disadvantaged populations may live in more polluted environments that expose them to higher concentrations of pollutants. (A discussion of environmental justice issues is provided in Section 2.1.3, a discussion of community vulnerabilities is provided in Chapter 10.)

Sorting out the roles and interactions of lifestyle, environmental, and demographic risk factors is a major area of scientific research. For the partnership team, assessing interactions of these factors may overly complicate the development of a risk management strategy, especially if the community believes that its health status is the fault of someone else. That having been said, addressing common sense lifestyle risk factors in addition to environmental risk factors will almost always be beneficial (if it is appropriate to do so within the context of the community). For example, if the risk reduction plan includes public education about radon exposure in the home (an exposure that can cause lung cancer), the educational materials could also discuss other pollutants (e.g., cigarette smoking) that cause lung cancer.

12.1.9 Conserving Energy

Conserving our energy sources such as fossil fuels is important because of their nonrenewable nature and because their use impacts the environment. The impacts may be direct or indirect. Direct impacts include those from the pollutants released by the combustion (e.g., particles, metals including mercury, PAHs, etc). Some of the pollutants released may exert their impact indirectly (e.g., by causing chemical or physical reactions in the atmosphere which then lead to environmental impacts). For example, carbon dioxide is produced when oil, coal, and gas are combusted in power stations, heating systems, and car engines. Carbon dioxide in the atmosphere acts as a transparent blanket, that contributes to the global warming of the earth (the "greenhouse effect"). Possible impacts include a threat to human health, environmental impacts such as rising sea levels that can damage coastal areas, and major changes in vegetation growth patterns that could cause some plant and animal species to become extinct. As another example, sulfur dioxide is also emitted into the air when coal is burned. The sulfur dioxide reacts with water and oxygen in the clouds to form precipitation known as "acid rain." Acid rain can alter ecosystems, kill fish and other aquatic life, as well as damage or kill trees and other plant life. Acid rain can also damage buildings and statues.

In the U.S., the average family's energy use generates over 11,200 pounds of air pollutants each year. Every unit (or kilowatt) of electricity conserved can thus help reduce the environmental impact of energy use.[a] Partnership teams may want to consider an energy conservation project even though the reduction in the release of pollution (e.g., from a power plant) may occur far distant from the community.

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[a] Unless it was generated through nuclear power, which has its own set of issues.

There is a wealth of educational resources that explain the wide range of projects that can be implemented to protect the environment through conserving energy. In particular, the EnergyStar® program (http://www.energystar.gov/) encourages homeowners to improve energy efficiency through advice on energy efficient consumer products and building projects that can reduce energy bills and improve home comfort.

Because a strategic approach to energy management can produce twice the savings – for the bottom line and the environment – as typical approaches, EnergyStar® offers businesses a proven energy management strategy that helps in measuring current energy performance, setting goals, tracking savings, and rewarding improvements. For example, EPA provides an innovative energy performance rating system which businesses have already used for more than 21,000 buildings across the country. EPA also recognizes top performing buildings with the EnergyStar® program.

Additional approaches to energy conservation include the use of alterative and renewable energy sources, encouraging public transportation and other transportation alternatives, waste reduction and recycling, and encouraging smart growth. More information about EPA's energy conservation initiatives may be found at: http://www.epa.gov/ebtpages/pollenergy.html.

12.2 Select Risk Reduction Options

As noted previously, partnership teams working to select risk reduction options for implementation will want to consider all the relevant information related to each option. They will also need to keep in mind their team's overall objectives and capacity to carry out the risk reduction projects in making their selections. In sorting through the various risk reduction options for a given risk factor, stakeholder groups should be particularly mindful of the following seven fundamental characteristics of sound risk management decision making:

- Base the decision on the best available scientific, economic, and other technical information;
- Be sure the decision accounts for the problem's multisource, multimedia, multichemical, and multirisk contexts;
- Give priority to preventing risks, not just controlling them;
- Use alternatives to command-and-control regulation, where applicable;
- Be sensitive to social and cultural considerations; and
- Include incentives for innovation, evaluation, and research.

Additional items to be considered when evaluating risk reduction options are discussed in Exhibit 12-4.

Similar to the process used to rank the community's risk factors, the partnership team can use a variety of methods to select actual risk reduction projects from among the list of potential options. As discussed in 11.2.2, the stakeholder group may work to achieve consensus by:

- Negotiated consensus;
- Voting; or
- Application of a more analytical process.

Exhibit 12-4. Factors to Consider When Evaluating Risk Management Options
Risk reduction benefits to be realized. Risk management decisions often focus on the *incremental* risk associated with the specific risk factor without regard to the risk from other factors. When the risk reduction option provides little risk reduction in light of the overall risk from other factors, the stakeholder group may wish to rethink which factors it wants to pursue. That having been said, the impediments to risk reduction for these more important factors may preclude the community from creating meaningful change and the partnership team may chose to pursue the less important risk factors anyway since realizing a risk reduction will usually have some positive influence on community health, even when the risk reductions are relatively small. **Level of uncertainty in the analysis**. In the face of a highly uncertain understanding of the risk posed by a factor, the partnership team will have to carefully weigh the consequences of selecting or not selecting a factor for risk mitigation. Specifically, it could make a decision to control a risk factor only to find out later that there was little actual risk (e.g., incurring unnecessary "cost" to the community), or making a decision *not* to control a risk factor only to find out later that the risks were real and large (e.g., incurring potentially preventable harm to the community). **Implementation costs**. What are the costs of the risk reduction approaches, including costs to regulatory agencies, the regulated community, and the general community (consumers, workers). Are the benefits reasonably related to the costs? **Technical feasibility**. Is there a readily available tried and tested technology to otherwise reduce or eliminate the risk? **Legal feasibility**. Are their existing or upcoming legal authorities to establish and enforce requirements? Are their other legal impediments to pursuing the risk reduction option? **Effectiveness/timing**. Will the option provide effective management of the problem within a reasonable time frame? **Political feasibility**. Does the option have the necessary political support? **Community acceptance**. Will the larger community support the proposed risk reduction alternatives? Each of these issues may be more or less important depending on the context for the risk management decision.

12.3 STEP 9 - Decide On an Action Plan and Mobilize to Carry Out the Plan

STEP 9
Develop/Implement an Action Plan
Fill Data Gaps

Once the community partnership has prioritized its concerns and information needs and collected and summarized relevant information, the next step will be to decide on a plan of action and mobilize the community to begin work. Choosing the plan for work will depend on many factors particular to each community. Depending on the resources that can be mobilized in a community, the partnership may want to organize a number of teams to address multiple priorities.

The partnership may also need to develop a short-term plan to begin some immediate actions and a long term plan to address priorities that will require more time to collect needed resources. Some communities may decide to put information collection first to help build consensus or to make sure that significant risks have not been overlooked. Others may focus primarily on risk reduction and put less emphasis on filling gaps in information. Developing a plan that allows the community to get some early successes while pursuing longer term goals may help to build community support for the work of building a healthy community and environment. To achieve the best results, the partnership should make sure that the plan takes advantage of all the local assets and mobilizes as many members of the community as possible.

It should be emphasized that historically, much of the risk reduction efforts realized over the past decades has been driven primarily by requirements of regulatory agencies. Businesses and governments (e.g., local municipalities) have generally been the focus of these risk reduction efforts. However, it is likely that in community-based risk reduction efforts, the partnership group may identify and select risk reduction projects that could target business activities, citizen activities, or (more likely) both. For example, a community might select risk reduction projects that focus on unregulated water emissions from small business, household hazardous waste, and indoor environments in public schools.

12.3.1 Filling Data Gaps by Developing New Information About the Community

Depending on the risk factor, potential impact, or vulnerability in question, there may be little or no data to evaluate or characterize an issue and the stakeholder group may wish to develop new information to support the community reduction effort. New research or data collection should be carefully planned and executed to ensure that the resulting information is credible, accurate, and relevant to the concerns of the community.[b]

12.3.1.1 Collecting Environmental Samples for Analysis

Methods for collecting samples and measuring chemicals in the environmental media are well developed. EPA has formulated hundreds of test methods and offers guidance and related information on the internet (http://www.epa.gov/epahome/Standards.html; see also ATRA Volume 1, Chapters 10 and 19). Testing for some basic indicators (e.g., water quality indicators such as pH) is relatively simple and inexpensive, and EPA offers guidance to support certain citizen volunteer monitoring efforts (for example, see http://www.epa.gov/owow/monitoring/vol.html#methods). However, testing for many chemicals in water, air, and soil can be complex and generally requires trained professionals and sophisticated laboratory equipment. In addition, testing can also be expensive and time consuming. Partnership teams will need to carefully weigh whether they want (or need) to collect environmental monitoring data as part of the risk reduction project.

If the partnership team for a community-scale risk assessment does not have the skills and equipment to perform the testing themselves, it may be able to obtain assistance from

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[b] Chapter 4 of this volume provides an overview of planning and scoping a multisource cumulative evaluation, including planning for the collection of new data. While the chapter's focus is multisource cumulative assessment, the underlying concept of how to plan and scope an environmental data development effort is essentially the same. Stakeholder groups that intend to develop new data are encouraged to familiarize themselves with this process prior to developing any new data for a project.

government laboratories, academic researchers, or private-sector testing services. Several governmental programs and private foundations offer grants to support environmental and public health testing. Many environmental health and occupational health and safety resources available to community-based organizations are identified in Section V of *Operations Manual for Hispanic Community-Based Organizations* (http://www.epa.gov/ecocommunity/pdf/hispopman-all2.pdf). Chapter 10 also provides an overview of developing resources for a project.

12.3.1.2 Using Computer Models to Evaluate Chemicals in the Environment

EPA and others have developed a number of computer models for evaluating chemicals in the environment (see http://www.epa.gov/epahome/models.htm). Examples of the potential uses of these models include:

- Estimating pollutant concentrations in environmental media (e.g., groundwater) or the food chain based on measured or estimated pollutant concentration in releases or other media; and

- Estimating exposures and risks to people or ecosystems potentially exposed to chemicals in the environment, or affected by other risk factors (e.g., microbial drinking water contamination).

Similar to collecting actual environmental samples and sending them to the lab, computer modeling generally requires special expertise to perform. However, unlike monitoring, computer modeling is generally cheaper and faster and, thus, may be a more attractive option for partnership teams. A drawback is that the output of a model is only as good as the data that go into it. If available input data are lacking or inadequate, new input data might need to be developed before running the model, perhaps by monitoring which will add to the time and cost of the modeling option. (Note that Part II of this resource document as well as ATRA Volume 1, Chapter 9, provide information regarding computer models used for air toxics evaluations.)

12.3.1.3 Surveys

For some community concerns, it may be helpful to conduct a survey to gather new data. Surveys are particularly helpful for learning about the occurrence of potential problems (e.g., complaints of noxious odors), to learn about risk factors related to human activities (e.g., consumption of contaminated sport fish), and help develop an understanding of potential impacts and vulnerabilities. In addition, surveys may be a useful way to rank community concerns about a list of specific risk factors.

Surveys may be conducted by various means, including:

- Meetings or focus and advocacy groups;
- Mail surveys;
- Telephone surveys;
- Newspaper surveys;
- Email or internet form surveys; and
- Door-to-door or other field surveys (e.g., angler surveys).

Choosing a survey method will depend on several factors, including the resources and labor available for conducting the survey; level of scientific rigor needed (e.g., informal or statistically based); time available before results are needed; and amount of information needed from survey participants.

A Note of Caution about Surveys

Performing a survey in a manner that produces useful results will usually require the community to engage people with specialized expertise to help in the design, administration, and evaluation of the survey. Specifically, the community will need expertise in the science of surveys and statistics as well as in the topic area that will be the focus of the survey.

For example, consider a community that wants to perform an angler survey to determine what kinds of fish people catch and eat. The community would need help from experts in the field of designing, administering, and evaluating survey results as well as biologists familiar with the water bodies in question (i.e., people who know the local fish populations).

By not engaging people with the right types of expertise in order to perform a sound survey, the survey results may be of little use to people making decisions.

Surveys must be designed with care to ensure that they are unbiased and precisely address questions of concern. In addition, survey methods and designs can greatly affect response rates (i.e., participation in the survey), and it may be important to provide anonymity to survey participants. Except in the case of very simple or informal surveys, it is important to develop the survey design with the help of a knowledgeable professional. To do a survey properly, expertise will usually be needed in the fields of statistics, surveys, and the topic on which the survey is being conducted. With regard to conducting surveys involving the collection of personal information, the government and other reputable organizations follow established protocols, such as the requirement of informed consent, confidentiality, and review by institutional boards or committees. Partnership teams are encouraged to consider these protocols when developing the survey program.

12.4 STEP 10 - Evaluate the Results of Community Action, Analyze New Information, and Start the Process Again to Reset Priorities

STEP 10
Evaluate Results and Adjust as Needed

To make sure that community efforts are getting the desired results, it will be important for the partnership to find effective ways to measure progress. For each priority in the action plan, the partnership should develop a measure(s) that can be used to gauge progress and evaluate the effectiveness of community action. Reductions in releases, exposures, and risk, and reductions in health effects can all be used to measure progress (a plan for measuring progress should be agreed upon at the time of selecting the projects).

Evaluating effectiveness involves monitoring and measuring, as well as comparing the actual benefits and costs estimates made in the analysis stage. The effectiveness of the process leading to implementation and in building community capacity to understand and address risks should also be evaluated at this stage. To be successful, communities will need to not only measure their progress, but to learn from their experiences, and adjust their work to build on their successes and learn from their mistakes.

Specifically, evaluation provides important information about:

- Whether the actions were successful, whether they accomplished what was intended, and whether the predicted benefits and costs were accurate;
- Whether any modifications are needed to the risk reduction plan to improve success;
- Whether any critical information gaps hindered success;
- Whether any new information has emerged that indicates a decision or a stage of the process should be revisited;
- Whether the process was effective and how stakeholder involvement contributed to the outcome; and
- What lessons can be learned to guide future risk management decisions or to improve the decision-making process.

> **The CARE Resource Guide**
> ***Evaluating the Effectiveness of Risk Reduction Activities***
>
> As introduced in Chapter 10 of this volume, the Community Action for a Renewed Environment (CARE) program (http://cfpub.epa.gov/care/) has developed a Resource Guide (http://cfpub.epa.gov/care/index.cfm?fuseaction=Guide.showIntro) to help communities go through the multi-step process of assessing and addressing risk factors in their community.
>
> **Part IV** of the Resource Guide (Tracking Progress and Moving Forward) contains information on tracking and evaluating the effectiveness of a risk assessment.

As these bullet points indicate, the management of risks does not stop with the implementation of the risk reduction projects. There needs to be an ongoing effort to review the results of the risk mitigation efforts and to adjust the process as necessary to stay on target for achieving risk reduction goals.

12.5 Sustaining the Effort Over Time

A critical element to consider in the evaluation of the overall risk reduction effort is the **sustainability** of the project. Most risk reduction efforts are only meaningful when there is a sustained effort to reduce risk over the long term, and the partnership team will need to identify the impediments that may keep this from happening. For example, will community interest in the project or money to pay for risk reduction efforts dwindle over time? What types of things can be done now to ensure continued progress into the future?

It is important to be cognizant of the challenges associated with the sustainability of a community-based risk management strategy over many years or decades. This section discusses these challenges and opportunities for a community to develop the institutional capability that can help maintain sustainability over long periods of time.

12.5.1 What is Needed for Sustainability?

If a community-based risk management effort is not designed and managed to be enduring, human health and the environment may be endangered through a variety of means. For example:

- The commitment to risk management among the stakeholders within the community may gradually fade away or be eliminated, causing monitoring and/or mitigation activities to lapse.

- Opportunities for improving community health and any monitoring and/or mitigation strategies may be missed in communities where risk management strategies become neglected.

- The public may come to believe that risks and hazards within the community have been eliminated.

- If residual risks or hazards are rediscovered, the community's ability to address the problems may have declined and the cost needed to do so may increase.

To design long-term risk management strategies that can adapt to changes, the community must address two primary questions:

- **Ensuring survival**. How can implementation be structured to ensure that robust and adaptable long-term strategies endure?

- **Maintaining focus**. How can the community ensure that implementation remains reliable over time?

Each of these is discussed in a separate subsection below.

12.5.1.1 Ensuring that Risk Management Strategies Remain Relevant to the Community

As noted previously, the long-term survivability of a risk management strategy can be bolstered by local involvement in decision-making, active involvement of a wide range of affected parties, and frequent communication across parties with a stake in the community. The affected parties within the community have the greatest stake in the success and survival of the risk management effort. They also will have the best access to certain types of information that should influence evolving strategies, such as information on changes in land use patterns and social values. For these and other reasons, the risk management strategy should rely considerably on local involvement in decision-making in addition to centralized institutions such as EPA or a state or tribal environmental protection agency that have access to other types of relevant information, such as advances in science and technology.

A certain degree of redundancy could also be beneficial. A wide range of parties within the community may have an interest in the risk management effort, including community residents and businesses; various state, tribal, local, and federal agencies; business owners; technology vendors; and advocacy groups. When these parties are directly involved in the risk management effort, communicate frequently, and understand the importance, goals, and responsibilities associated with the risk management strategy, they can help counteract threats to the overall long-term sustainability of the effort. For example, if a local government agency that has played a key role in a risk management effort loses relevant funding, the remaining interested parties in the community that have been conducting similar activities can ensure that the functions performed by that agency are transferred or assumed by others.

Some Characteristics of an Effective Long-Term Risk Management Effort

- *Layering and redundancy*. Layering means using several measures to carry out roughly the same function; redundancy means creating a situation in which several entities are responsible for or have a vested interest in the effectiveness of the risk reduction measures.
- *Ease of implementation*. A risk management activity must be capable of being put into effect, and it also should be reasonably easy to keep in effect.
- *Monitoring commensurate with risks*. Monitoring progress and the schedule for doing so need to be commensurate with the harm that could be caused if there is a failure of risk mitigation efforts.
- *Oversight and enforcement*. To the extent that the risk management effort involves an enforcement agency or party, the enforcer must have teeth.
- *Appropriate incentive structures*. Attention needs to be devoted to assuring that all participants in the risk management effort continue to be appropriately motivated for carrying out the needed tasks over time.
- *Adequate funding*. Implementing, monitoring, and appropriately modifying risk management activities will require adequate and reliable financial resources throughout the activities' required lifetimes.
- *Durability and replaceability*. A risk management activity should endure either for as long as the an issue remains hazardous or until the activity can be refreshed or replaced by an equally reliable substitute activity.

Adapted from: *Long-term Institutional Management of U.S. Department of Energy Legacy Waste Sites*. National Academy of Sciences, National Research Council, August 2000.

Frequent communication among stakeholders within the community also can help ensure that new information is widely distributed and its implications are understood and incorporated into future decisions. Likewise, interaction and communication among different communities involved in similar risk management activities may help bring necessary expertise and resources to bear if the survival of the risk management effort is threatened within one community. This benefit may be particularly valuable in communities with few resources. Maintaining trust and credibility will be a key challenge. Public confidence in the institutions or groups involved in the risk management effort will depend on the ability of the institutions/groups to demonstrate a commitment to the mission and carry out their responsibilities openly and fairly.[1]

12.5.1.2 Ensuring that Risk Management Strategies Remain Focused

Institutions or groups engaged in the risk management efforts need to avoid the perception that risk levels within the community are less than they are. These organizations also should avoid merely continuing to implement existing monitoring and mitigation strategies. Instead, the organizations should continually seek better solutions and incorporate new developments in science, technology, land use patterns, and societal values. The organizations also should continually learn and reinvent themselves, adapting to changing circumstances, or they will risk becoming ineffective and lose support.

Education and Training

Education and training will be a critical part of a sustainable risk management strategy, particularly among community stakeholders, and will serve to continually reinforce concepts and keep the concepts familiar and pertinent. Enhancing the awareness of: (1) why risk reduction efforts are necessary; (2) how to implement risk management activities; (3) how to evaluate and interpret change; and (4) how to modify activities in response to changing circumstances. This will enhance the ability of risk management strategies to survive and adapt to the changing cultural and natural environment.

Education of the public, particularly within the community, can enhance the effectiveness and protectiveness of a risk management strategy. Communities that are well educated and trained with respect to risk and risk management issues are more likely to implement voluntary measures and take other actions to prevent unnecessary risks.

12.5.2 The "Rolling Risk Management" Strategy

Efforts to improve community health and welfare may require an extended amount of time to accomplish and, for some risk factors, need to have a risk management strategy that goes on in perpetuity. In such situations, a key challenge is to set in place a long-term risk management framework that ensures protection of human health and the environment for future generations. This hazard management framework might address possibilities such as: (1) the original strategies to reduce risks within the community will fail; (2) changing circumstances within and around the community will need corresponding changes in risk management strategies; and (3) future generations will want to change land and resource uses within the community. To help ensure long-term sustainability, the current generation should strive to provide the next generation with the skills, resources, and opportunities to cope with any problems that may result from changes or failures in risk management efforts (i.e., a "rolling risk management" strategy).[2]

Why is a "rolling risk management" strategy useful? The main reason is that conditions change over time, and these changes may affect the relevance and effectiveness of current risk management strategies. For example:

- Applicable laws, regulations, and standards may change over time. Voluntary strategies today may become mandatory, and vice-versa.

- Demographic changes within the community may change exposure pathways or levels of concern. People may move into areas that currently are not inhabited or move away from areas where current exposure levels are relatively high.

- Future advances in science and technology may make source control more effective at less cost.

- Advances in science and medicine may identify new hazards. Several decades ago, links between many substances and adverse health effects such as cancer were largely unknown and unsuspected; therefore, a risk management strategy developed then would not have considered such hazards.

Finally, given the need to re-evaluate and perhaps modify risk management strategies over time, the community should always have as many options available as possible. Decisions should seek solutions that address near-term needs and concerns but preserve long-term flexibility to the greatest extent possible. For example, partnership teams might not be able, at the present time, to find a permanent solution for some of the risk factors within the community. New and different solutions may be developed in the future as a result of technological and societal advances the team will need to keep aware of evolving technology and have the flexibility to incorporate it through their “rolling risk management” strategy.

References

1. *Long-term Stewardship of Contaminated Sites, Trust Funds as Mechanisms for Financing and Oversight*. Carl Bauer and Katherine Probst, Resources for the Future Discussion Paper 00-54, December 200, page 380; *Long-term Institutional Management of U.S. Department of Energy Legacy Waste Sites*. National Academy of Sciences, National Research Council, August 2000, page 86.

2. *Deciding for the Future: Balancing Risks, Costs, and Benefits Fairly Across Generations*, National Academy of Public Administration, June 1997.

Appendix A Case Studies

Table of Contents

1.0 Introduction

This Appendix describes several case studies that illustrate approaches for conducting the types of analyses described in this volume. First, presented in Section 2 is an application of EPA's RAIMI approach in Port Neches, Texas, that illustrates a cumulative multisource assessment (Part II of this volume). Following this in Section 3 is a brief description of a similar air quality modeling case study conducted for Houston, Texas. In Section 4, the Cleveland Clean Air Century Campaign is summarized as an illustration of how a community can take action to identify and reduce exposures to toxics from a variety of sources (Part IV of this volume). Brief summaries of three additional examples of community action toward identifying and reducing air toxics exposures are presented in the final section.

2.0 Application of RAIMI in Port Neches, Texas

EPA Region 6 developed the Regional Air Impact Modeling Initiative (RAIMI) as a technical approach that utilizes existing guidance and tools to evaluate the potential for health impacts as a result of exposure to emissions from multiple sources. The RAIMI approach employs a methodology that allows the user to systematically and efficiently conduct a localized assessment that covers the "big picture" of risk for a community from sources of air toxics, rather than an analysis focusing on a single (or very limited number of) emission sources.

Port Neches: An Example Application of the RAIMI Methodology

The Port Neches Case Study described in this appendix describes the application of RAIMI as a methodology for performing localized cumulative multisource assessment. The primary interests and goals of an assessment will differ from community to community, so the exact methodology used should depend on and be tailored to local circumstances. As always, the needs of the community in terms of the assessment's purpose, scope, and methodology must be well defined to produce useful results. In addition, this case study reflects the application of RAIMI at Port Neches as a "pilot study" of the methodology; some details related to the application of RAIMI have changed since the pilot study, and other aspects of RAIMI may be modified in the future as the methodology evolves and is improved.

The EPA Region 6's pilot study of the RAIMI approach was performed in the community of Port Neches, Jefferson County, Texas because the area exhibited the source characteristics, receptor characteristics, and other practical considerations that were deemed desirable for an optimal pilot study area. The information provided below is a summary of the pilot study. More detailed information about RAIMI, including a full description of the Port Neches case study, can be obtained on EPA's web page at http://www.epa.gov/earth1r6/6pd/rcra_c/raimi/raimi.htm.

Jefferson County is located in southeast Texas on the gulf coast and is bounded to the east by the Neches River and to the south by the Gulf of Mexico. Jefferson County has a population of 241,322, according to 1999 census estimates.[(1)] There are two main urban areas in the county, both of which are included in the Beaumont-Port Arthur Metropolitan Statistical Area. The City of Beaumont is located in the north-central part of the county, and has a population of 109,697, based on 1999 census estimates.[(2)] The second urban area is located about 20 kilometers southeast of Beaumont, and includes the cities of Port Arthur (1999 estimated population 56,574), Port Neches (13,981), Nederland (17,599), and Groves (16,362).[(3)] Numerous local industrial complexes are interspersed with surrounding residential and commercial areas of single and multi-family dwellings, including schools, parks, child and elderly care centers, and hospitals. A significant portion of Jefferson County land area, mostly in the west half of the county, is comprised of undeveloped, rural, and agricultural land use.

Jefferson County, Texas

The Port Neches Assessment Area is located south of Beaumont and north of Port Arthur, centered among the cities of Port Neches, Groves, and Nederland. The Port Neches Assessment Area covers an area 23 kilometers west to east and 12 kilometers south to north (276 sq. km.). The area is characterized by several large industrial facilities located within Port Neches, Groves, and Nederland, in close proximity to several residential neighborhoods (Exhibit A-1).

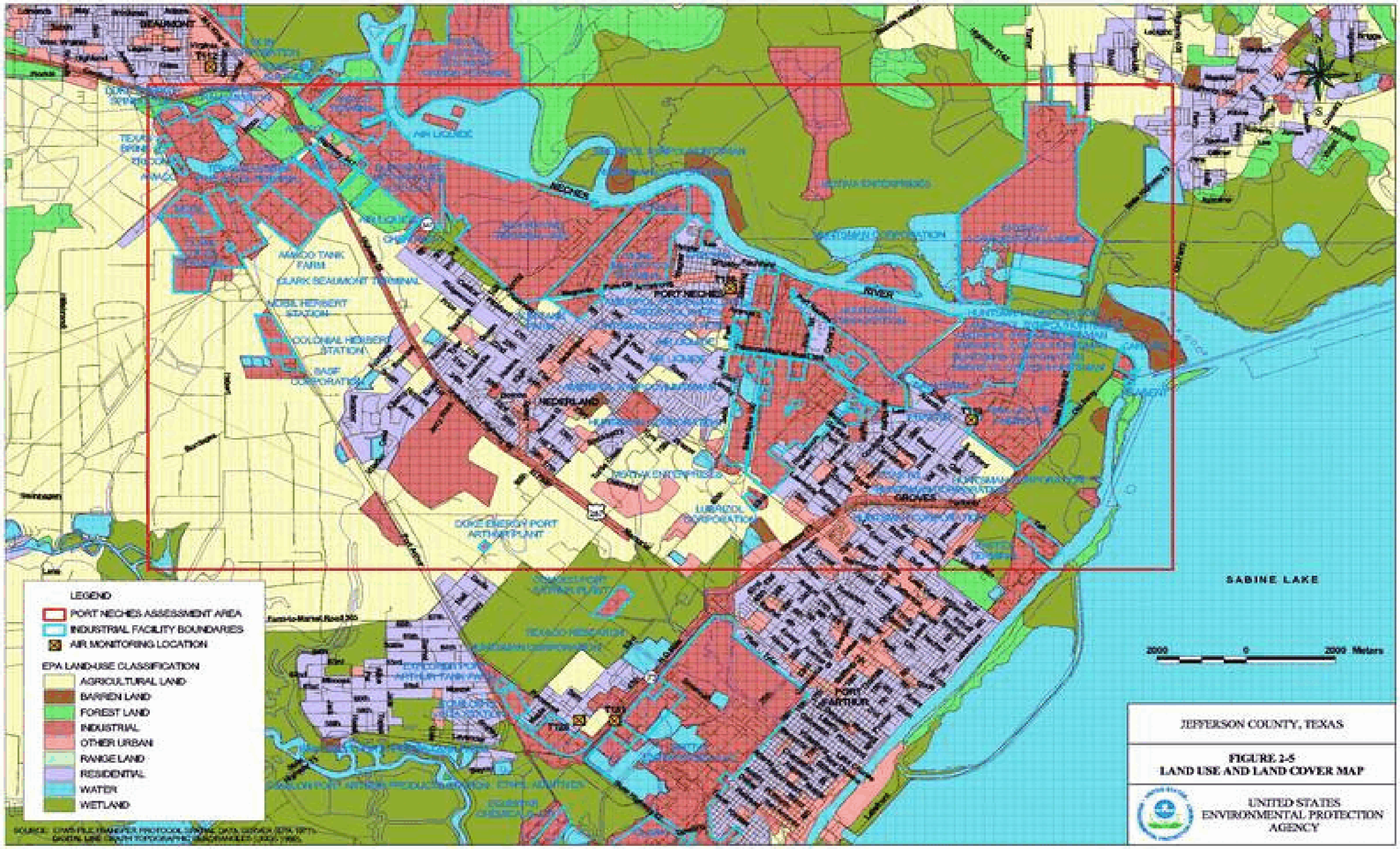
For the pilot study, EPA followed the basic procedure for multisource assessment presented in this resource document, by characterizing air toxics sources within the study area, modeling air concentrations, and calculating cancer risks and non-cancer hazards for residents in the study area. Overall, the Port Neches Pilot Study was a successful test of the capabilities of the RAIMI as a tool for use in risk-based multisource assessments. The study was effective in providing site-specific ranking of risk concerns, as well as identification of important data gaps. In addition, the pilot identified the need for more robust analytical and data management capabilities to conduct large scale and high-resolution multisource assessments, which has been the primary focus of RAIMI developers in the follow-up to the Port Neches Phase study (a Phase II study) and county-wide RAIMI Screen assessments.

2.1 Planning, Scoping and Problem Formulation

EPA conducted the Pilot Study primarily to test – in a "real-life" situation – the practical utility of RAIMI as a technical tool for examining and ranking the potential impacts of multiple emission sources on a localized scale. The Pilot Study was also designed to provide useful, site-specific risk results that could be used to determine potential health risks and (if appropriate) inform local risk management decisions.

With these objectives in mind, EPA carried out the planning, scoping, and problem formulation phase of the study to set the bounds of the assessment and establish a way to focus their resources. The Jefferson County, Texas, area was first subdivided into five separate zones based on density of emission sources and the presence of neighborhoods and people. One of these assessment areas, Port Neches, was then selected as the specific study area for the Pilot Study because it contains various air toxics sources (including local industrial complexes and non-industrial sources) interspersed with residences and neighborhoods both directly adjacent to and more distant from the major industrial sources. The study area is large enough to support a diversity of sources and receptors without being so large as to be burdensome for data collection and analysis.

Exhibit A-1. Land Use and Land Cover in Port Neches Study Area



EPA specified that the assessment would focus on both cancer risks and non-cancer hazards from direct human inhalation exposures (a later phase of the RAIMI Pilot Study may address multipathway exposures). Only releases of contaminants to outside air were considered, and ambient concentrations were predicted using an air dispersion model. EPA also confirmed that several readily-available and relevant emissions inventory data sources were available for this area. Risks would be calculated for people in Port Neches with estimated average annual ambient concentrations used as a surrogate for chronic exposure (i.e., with no exposure model used), with several years of data considered to account for temporal variability.

2.2 Emissions Characterization

Once the problem formulation was completed, EPA identified relevant emissions sources within the study area and collected necessary data on source and emission specific parameters for air dispersion and risk modeling. As an initial step, the source types of interest were defined for the purposes of ISCST3 air dispersion modeling (for this study, stack, fugitive, and mobile sources), and the source-specific emissions data to be collected for each of these source types were specified (e.g., stack height, release location, emission rate; see Exhibit A-2). This up-front analysis helped to focus EPA's data collection and processing efforts.

A variety of federal and state emission data sources were evaluated for their potential utility for the case study. Two primary data sources were selected (Exhibit A-3). The Texas Natural Resource Conservation Commission (TNRCC) Point-Source Database (PSDB) was used for individual emission sources (e.g., industrial facilities), and the National Emissions Inventory (NEI) was used for grouped emission sources (e.g., gas stations, dry cleaners, mobile sources, and other sources, where overall emissions across the study area have been estimated and aggregated). Information from these two data sources was supplemented by additional data from EPA's Toxics Release Inventory (TRI) and other federal and state data files for specific emissions sources.

To carry out the assessment rapidly and efficiently, emission sources were prioritized before moving on to more in-depth assessment, allowing EPA to focus resources on the most significant emission sources in terms of the potential to impact neighborhood receptors in the Port Neches area. Different prioritization schemes were employed for individual and grouped emission sources.

- About 1,529 **individual emission sources** were identified in the TNRCC PSDB for the Port Neches Assessment Area; therefore, modeling every source would have been extremely resource-intensive. Individual emission sources were prioritized first on the basis of total mass emitted annually. Specifically, only those sources reporting emissions of at least 1 ton of a speciated contaminant were carried on to the next step of the assessment (i.e., about 113 of the 1,529 original sources).[a]

[a] Analysts should use caution when screening out persistent chemicals that bioaccumulate or biomagnify since relatively small emissions may lead to high levels in non-air media, such as biota, over time.

Exhibit A-2. Source-Specific Emissions Data Needs for ISCST3 Air Dispersion Model Input			
	Stack Source	**Fugitive Source**	**Mobile Source**
Physical Characteristics	Stack height [m] Base elevation [m] Stack diameter [m] Stack gas exit velocity [m/s] Stack gas exit temp. [K] Control device description Location [NAD 83]	Area [m^2] Release height [m] Base elevation [m] Location [NAD-83]	Area [m^2] Release height [m] Base elevation [m] Location [NAD-83]
Emissions Characteristics	Contaminant CAS number and name Speciated emission rate [g/s]	Contaminant CAS number and name Speciated emission rate [g/s]	Contaminant CAS number and name Speciated emission rate [g/s]

Notes:
m meters
m/s meters/second
K Kelvin
NAD-83 North American Datum 1983
g/s grams/second
CAS Chemical Abstract Service

Exhibit A-3. Potential Sources of Emissions Information for Port Neches Assessment		
Source	**Maintained/ Administered By**	**Data Characteristics**
National Emissions Inventory (NEI)	EPA	Digital
Toxic Release Inventory	EPA	Digital
Aerometric Information Retrieval System (AIRS)	EPA	Digital
RCRA Hazardous Waste Permit Files	EPA and TNRCC	Hard copy
RCRA Information System	EPA	Digital
Point-Source Database	TNRCC	Digital
New Source Review Permit Files	TNRCC	Hard copy
Title V Permit Applications Table 1-A forms	TNRCC	Hard copy
Facility files and records	Facility	Unknown

- Data from the NEI for **grouped emission sources** indicated that there were about 74 subcategories of these sources for the Port Neches area. To prioritize these subcategories, a worst-case hypothetical emissions scenario was used as a basis for screening. Under this scenario, all emissions (county-wide totals) for a given subcategory were assumed to occur in the geographically smallest census tract in the Port Neches area, thereby generally resulting in a situation with the highest possible density of emissions and receptors. "Pseudo-point source locations" were used as the release points for grouped emission sources to simulate their emissions throughout the census tract.[b] Air and risk modeling were then conducted (following the procedures described in the next sections) to determine which source subcategories exceed certain risk and hazard prioritization levels. This resulted in 42 subcategories of grouped emission sources that were carried on through more refined air and risk modeling, in which county-wide emissions were allocated to census tracts using an appropriate allocation scheme (e.g., based on land use, population, SIC employment).

2.3 Air Dispersion Modeling

For the air quality modeling phase of the Port Neches assessment, EPA used the ISCST3 air dispersion model. (Note that the RAIMI technical approach allows for the use of a range of models.) Five years of meteorology data representative of the Port Neches area were obtained for the modeling to account for year to year variability in weather patterns. A receptor grid (i.e., the specific points in space where ambient concentration of air toxics are estimated by the dispersion model) was designed with 500-meter intervals between grid points to cover the entire study area (Exhibit A-4). In addition, for five areas of high industrial activity (those with numerous emissions sources and nearby residential areas), a denser grid using 100-meter spacing was used to provide more refined results in these areas (Exhibit A-5).

[b] For grouped emission sources, "pseudo-points" were located at the geographic center of the census tract and at the four main compass point directions (north, east, south, west) at a distance of one-half the radius of a circle with an area equivalent to the census tract. Emissions were then allocated to these locations, with one-ninth of the total emissions assigned to the center point and two-ninths assigned to each of the surrounding sources.

Exhibit A-4. Receptor Grid and Node Array Map for Port Neches Assessment Area

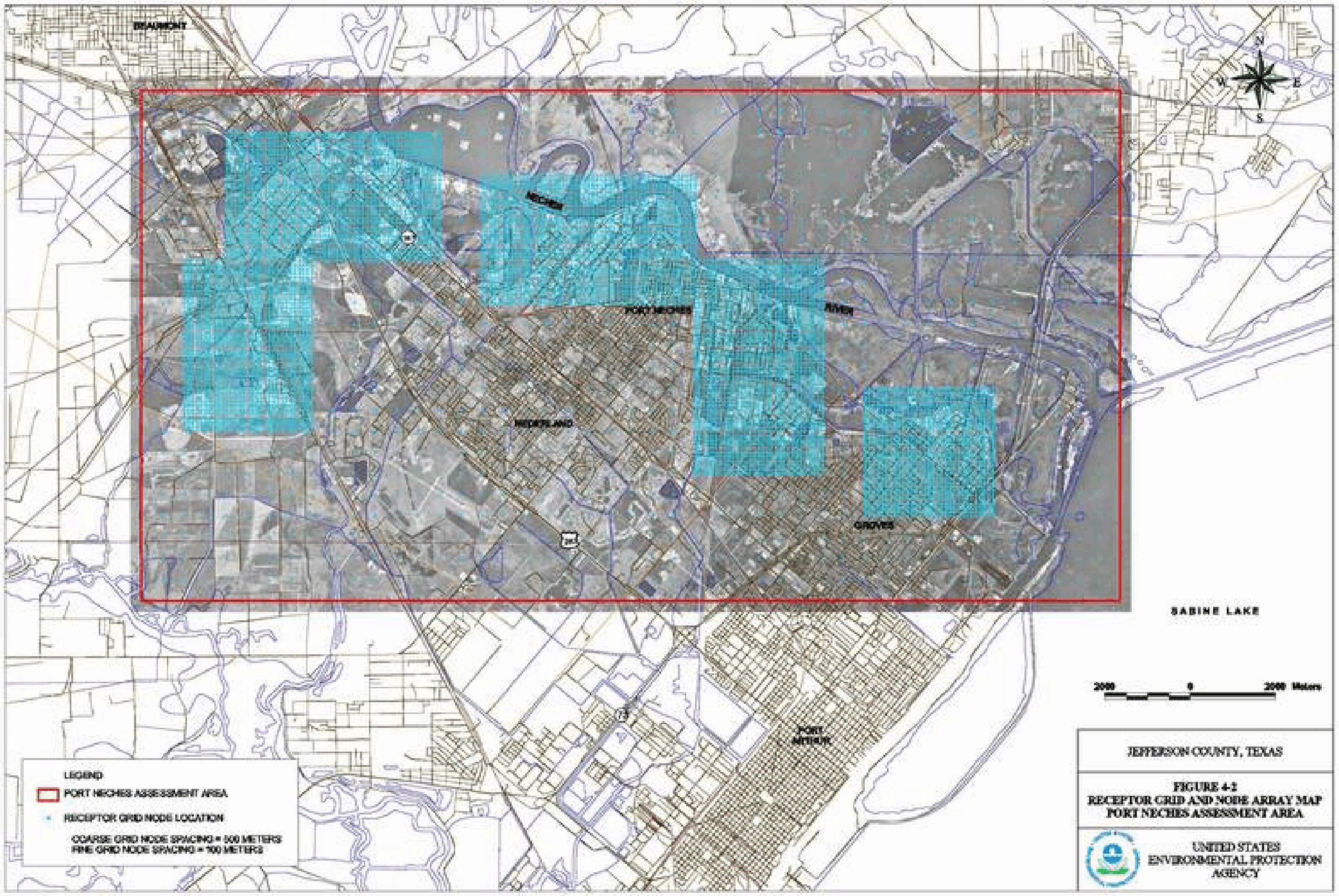


Exhibit A-5. Grid Node Array Areas for Port Neches Assessment Area [a]						
Grid Name	**Spacing**	**Minimum UTM X (m)**	**Maximum UTM X (m)**	**Minimum UTM Y (m)**	**Maximum UTM Y (m)**	**Dimensions (km)**
395-3311	500-meter	395,000	418,000	3,311,000	3,323,000	23 x 12
397-3319	100-meter	397,000	402,000	3,319,000	3,322,000	5 x 3
403-3318	100-meter	403,000	408,000	3,318,000	3,321,000	5 x 3
408-3314	100-meter	408,000	411,000	3,314,000	3,319,000	3 x 5
412-3313	100-meter	412,000	415,000	3,313,000	3,316,000	3 x 3
396-3315	100-meter	396,000	399,000	3,315,000	3,319,000	3 x 4

[a] For this application, the Universal Transverse Mercator (UTM) coordinate system was used to define the grid node locations. Refer to Section 5.2.4.3 for a description of the UTM system.

To generate adequate and useful results, minimize the production of unnecessary data, and accommodate the flexible design of site-specific risk evaluation, a "single-pass" air modeling approach was used in the Pilot Study. In this approach, each source and each potential contaminant phase (e.g., vapor, particle) from that source are modeled individually (i.e., 2,500 sources take 2,500 model runs). Emissions from each source are modeled at a unitized emission rate (e.g., 1 gram/second). Every model run is source-specific (i.e., weather is source-specific, using regional weather station data modified for each source location by local surface roughness determined by land use surrounding the source). The set of air concentration and deposition estimates that are completed using a unitized emission rate can then be adjusted to actual source and contaminant specific air concentrations and deposition rates by multiplying the concentration found in the unitized analysis by the actual emission rate of each contaminant from each source. Because each source is modeled to a Universal Grid of points, the estimated air concentration and deposition values at each modeling point (also referred to a receptor location or "node") for each source and contaminant can be summed across all of the modeling runs to provide exposure concentrations for that location. The single-pass approach has the following advantages:

- Updated or revised emissions data can be readily incorporated into analysis and new exposure concentrations determined without re-air modeling (i.e., if more refined or additional emissions data are obtained during the study, or at some point after the study). Unitizing the emission rates allows the air dispersion modeling analysis to be done only once for a source. Since air dispersion modeling is a computer intensive step, having the ability to model each source only once saves a great deal of time when modeling a large number of sources, as is typically found in community-scale assessments.

- The potential impact on estimated exposures and risks from reducing (or increasing) emissions from one or more sources can be assessed by multiplying the modeled air concentration estimates by the new emissions rates.

The end result is a scalable set of model results that can be used for current and future anticipated risk modeling needs (i.e., "what if" scenario evaluation, evaluation of pollution control measures). Key results of air quality modeling for the Port Neches case study included estimated air concentrations for both vapor and particle phases.

2.4 Exposure Assessment and Risk Characterization

The risk modeling component of the RAIMI estimates potential human health exposures at the neighborhood level by using a relatively simple inhalation exposure scenario in conjunction with the modeled air concentrations. Specifically, the case study used estimated ambient air concentrations as surrogates for the exposure concentration (EC). Estimated ambient air concentrations were then combined with toxicity factors to develop estimates of chronic cancer risk and hazard. Because an exposure model was not used in this study, the risk results are necessarily screening-level estimates of risk.

As noted above, an exposure model could have been applied to further refine the exposure assessment (using different microenvironments) and resulting risk and hazard estimates. Volume 1, Chapter 11 provides a more detailed discussion of available approaches for developing refined estimates of exposure.

Exposure and risk modeling for the Port Neches study generally followed the guidance presented in EPA's *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (HHRAP).[4] Although the HHRAP was initially developed for the assessment of a single combustion facility, it can be applied in a multi-source assessment, and it met the goals of the Port Neches Pilot Study at the time the study was performed. Exposure and risk calculations and analyses were carried out with the assistance of several software applications, including ACCESS™ database software (Microsoft Corporation) for doing the bulk of the computations, IRAP-*h* View™ risk modeling software (Lakes Environmental Software, Inc.) for tabulating results, and a GIS platform utilizing ArcView™ software (Environmental Systems Research Institute, Inc.) for spatial analyses. (Note that all of these functions have now been automated within the current RAIMI software suite - see Chapters 5 and 6.)

A Note on the RAIMI Port Neches Case Study

Assessors should note that the original case study materials for the Port Neches area provided on the RAIMI website indicate that inhalation exposure scenarios and risk calculation approaches (including selection of toxicity values) were used that may differ from those recommended by Volume 1 of this series. As such, this case study should be considered an example of only the concept of how to perform a cumulative multisource assessment. When performing an actual assessment in a community, EPA recommends that assessors follow the guidelines for inhalation exposure assessment and risk calculations as provided in ATRA Volume 1. While the RAIMI software has subsequently been modified to match the recommended risk calculation approaches recommended in ATRA Volume 1, the toxicity values in the RAIMI software currently do not match those recommended in ATRA Volume 1. Analysts can modify the toxicity values for a given RAIMI software run as needed to match the current recommended EPA values.

These tools provided semi-automated methods for importing the air modeling results from ISCST3 output files, calculating risks at receptor locations from multiple sources and chemicals, performing additional iterations (e.g., to re-evaluate risks for different inputs), and graphically displaying risk results. Inputs needed for the ISCST3 model included speciated emission rates for each emission source, fate and transport parameters for each exposure location, and chemical-specific properties (see Exhibit A-6). Toxicity factors were obtained from EPA's IRIS database and other sources. This setup allowed EPA to calculate cancer risks and hazards for individuals and populations in the Port Neches study area.

2.5 Presentation of Results

To develop the risk results of interest, information on land-use (residential, commercial, etc.) was combined with the basic risk modeling results to identify the neighborhoods with the highest potential risks. Two distinct residential neighborhoods – the Port Neches/Nederland and Groves neighborhoods – were identified as the exposure areas with the highest cancer risks and hazards, taking into account where people are located and population density. The results were further analyzed to identify the chemicals (i.e., risk drivers) and sources (including both industrial facilities and categories of mobile sources) responsible for the largest part of the estimated cancer risks and hazards. Maps and tables were created to display where and how high modeled risk levels were predicted to be within these modeling domains. For example, Exhibit A-7 presents a summary table of average risk estimates for the Nederland neighborhood. Exhibit A-8 presents a summary graphic displaying isopleths of areas where risk estimates were within specified ranges. Exhibit A-9 presents and example of how to display the results of a source apportionment analysis. Exhibits A-10 and A-11 illustrate examples of how to use the results of source apportionment analyses to support risk management decisions (refer to the text box below for a more detailed description of the examples presented in Exhibits A-9 through A-11). Similar tables were generated to show risks for the Groves neighborhood. In addition, EPA developed an evaluation of uncertainties affecting the results of the Pilot Study. Finally, EPA summarized how the results of the RAIMI Pilot Study could be useful to regulatory agencies and facilities in identifying and prioritizing risk management opportunities.

Overall, the Port Neches Pilot Study was a successful test of the capabilities of the RAIMI as a tool for use in cumulative multisource assessment. In addition, the study was effective in providing site-specific prioritization of risk concerns, as well as identification of important data gaps. Complete documentation of the Pilot Study is available at the RAIMI website (http://www.epa.gov/earth1r6/6pd/rcra_c/raimi/raimi.htm).

Exhibit A-6. Air Modeling Input Parameter Values for Port Neches Study		
Parameter Description	**Units**	**Value**
Met preprocessor: Surface station	--	Jefferson County Airport, TX (WBAN 12917)
Met preprocessor: Upper air station	--	Lake Charles, LA (WBAN 03937)
Met preprocessor: Years selected	yr	1984, 1985, 1988, 1989, 1990
Met preprocessor: Minimum M-O Length	m	2.0
Met preprocessor: Surface roughness length (measurement site)	m	0.10
Met preprocessor: Surface roughness length (application site)	m	1.0
Met preprocessor: Noontime albedo	--	0.18
Met preprocessor: Bowen ratio	--	0.70
Met preprocessor: Anthropogenic heat flux	--	0.0
Met preprocessor: Fraction of net radiation absorbed at ground	--	0.15
ISC COntrol: Model options	--	DFAULT CONC DEPOS DDEP WDEP DRYDPLT WETDPLT URBAN
ISC COontrol: Averaging times	--	1 ANNUAL
ISC COntrol: Terrain heights	m	ELEV
ISC SOurce: Location	m	UTM coordinates (NAD-83)
ISC SOurce: Base elevation	m	(Above mean sea level)
ISC SOurce: Emission rate	g/s	1.0
ISC SOurce: Particle diameter	µm	1.0 (or use stack test data)
ISC SOurce: Mass fraction	--	1.0 (or use stack test data)
ISC SOurce: Particle density	µg/m3	1.0 (or use stack test data)
ISC SOurce: Scavenging coefficients	1/(s-mm/hr)	Liquid: 0.45E-04; Ice: 0.15E-04
ISC SOurce: Source groups	--	ALL
ISC TG: Terrain grid	--	Special terrain grid array not used (terrain elevation at each grid location entered in Receptor pathway)

Notes:

--	Unitless	1/(s-mm/hr)	Inverse of (seconds-millimeters/hour)
g/s	Grams/second	µg/m3	Microgram per cubic meter
m	Meter	µm	Micrometer
		yr	Year

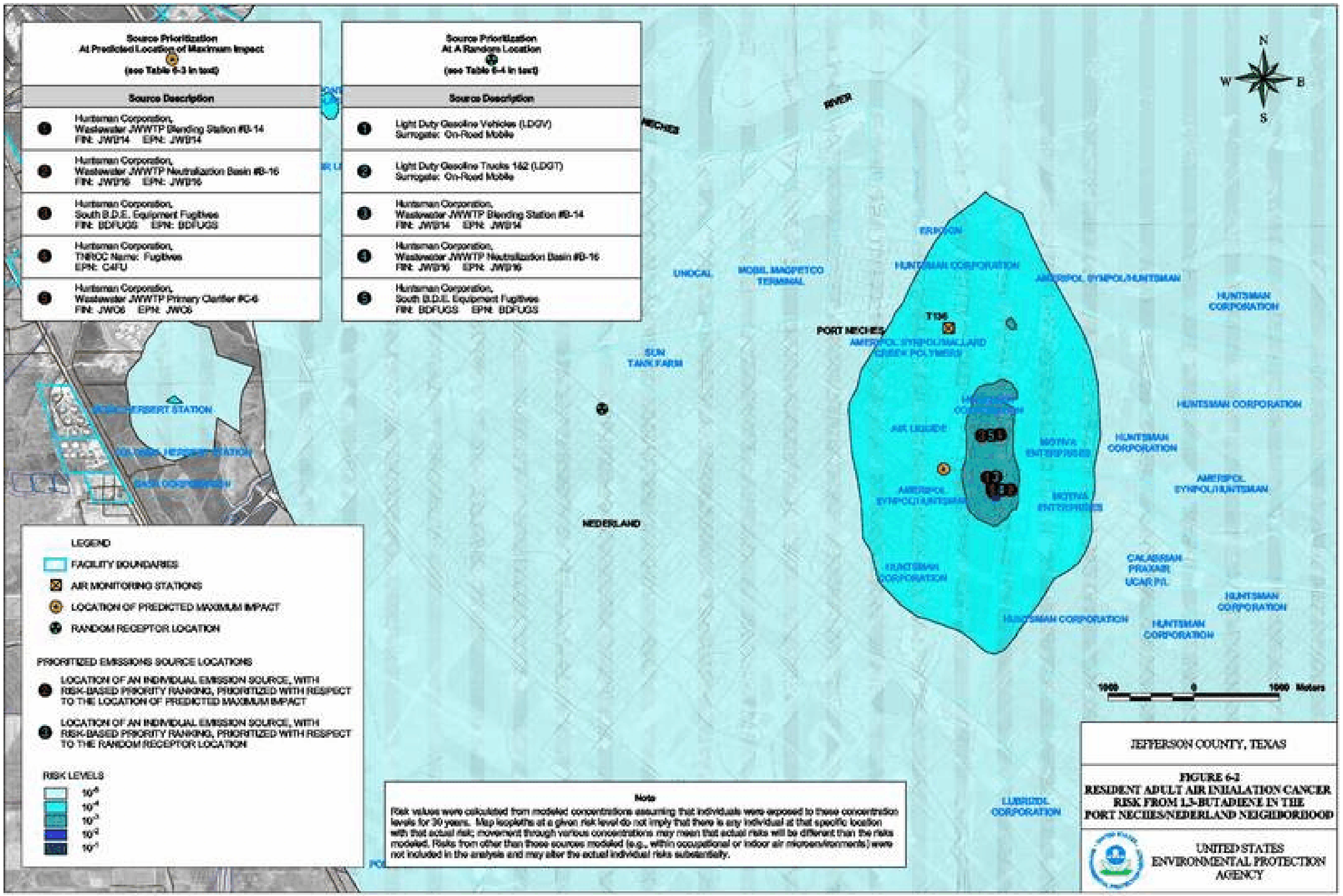
Exhibit A-7. Risk Summary for Nederland Neighborhood by Contaminant		
Contaminant	**Port Neches/Nederland Neighborhood**	
	Average Risk	**Hazard**
Benzene	$9x10^{-6}$	NC
1,3-Butadiene[(a)]	**$5x10^{-4}$**	NC
1,3-Butadiene[(b)]	$7x10^{-6}$	**1**
Ethylene Oxide	**$2x10^{-5}$**	NC
Formaldehyde	$5x10^{-6}$	0.0
Benzo(a)anthracene	$9x10^{-6}$	NC
Benzo(a)pyrene	**$3x10^{-5}$**	NC
Benzo(b)fluoranthene	$9x10^{-6}$	NC

Notes:
[(a)] Risk values calculated using what was the current unit risk factor contained in EPA's Integrated Risk Information System (IRIS).
[(b)] Risk and hazard values calculated using what had been proposed toxicity benchmarks as recommended by EPA's National Center for Environmental Assessment.

The use of multiple toxicity values for 1,3-butadiene in this case study illustrates an example of what the analyst may want to do when multiple or proposed toxicity values are available. Assessors should note that the original case study materials for the Port Neches area provided on the RAIMI website (and reprinted here) are indicative of toxicity values that were available at the time and, in some cases, differ from those currently recommended by Volume 1 of this series. When performing an actual assessment in a community, EPA recommends that assessors follow the current guidelines for inhalation exposure assessment, risk calculations, and toxicity values as provided in ATRA Volume 1. While the RAIMI software has subsequently been modified to match the recommended risk calculation approaches recommended in ATRA Volume 1, the toxicity values in the RAIMI software currently do not match those recommended in ATRA Volume 1. Analysts can modify the toxicity values for a given RAIMI software run as needed to match the current recommended EPA values. EPA's current list of recommended toxicity values are provided at: http://www.epa.gov/ttn/atw/toxsource/summary.html.

NC = Not calculated.
Bold type indicates risk greater than $1x10^{-5}$ or hazard greater than 0.25, the limits used in this particular pilot study to identify risk drivers.

Exhibit A-8. Graphic Illustrating Geographic Areas Where Cancer Risk Estimates are Within Specified Ranges



Description of Exhibits A-9 through A-11: Illustration of Results from a Source Apportionment Analysis

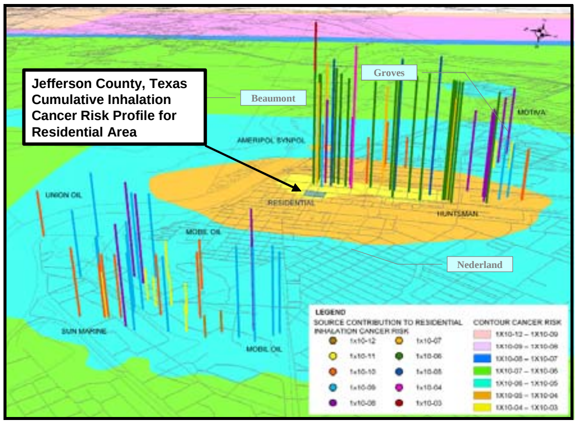
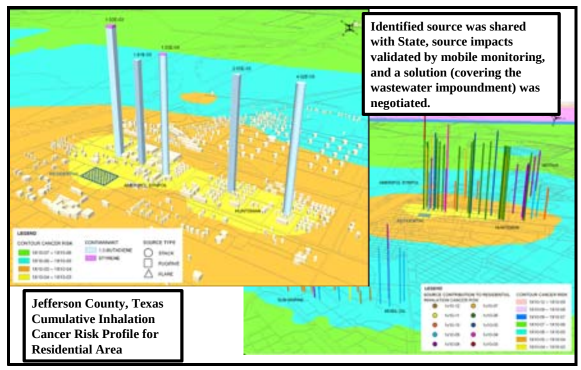
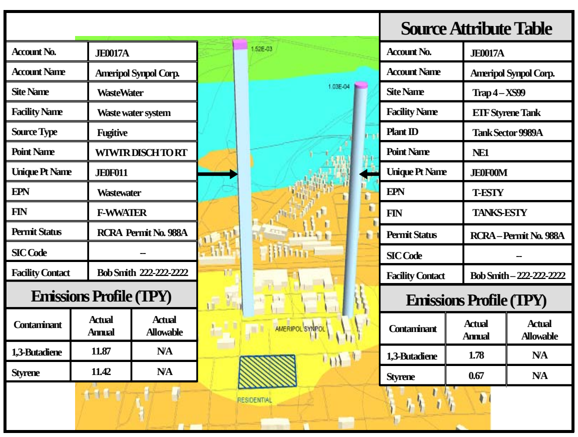


Exhibit A-9 is an example of how RAIMI can display results of a source apportionment analysis. Each bar represents a source, with the height of the bar proportional to the amount of air toxics it emits. The color of a bar represents the incremental inhalation cancer risk due to emissions from that source to residents of the indicated residential area. Shaded isopleths on the surface indicate the cancer risk to residents in each area due to the cumulative effect of all the modeled sources.

Exhibit A-10 presents a closer look at the five sources causing the highest cancer risk impacts for the modeled residential area. The height of each bar represents the cancer risk attributable to that source, and shape of the bar indicates which type of source it is (i.e., stack, fugitive, or flare).





Account No.	JE0017A
Account Name	Ameripol Synpol Corp.
Site Name	WasteWater
Facility Name	Waste water system
Source Type	Fugitive
Point Name	WTWTR DISCH TO RT
Unique Pt Name	JE0F011
EPN	Wastewater
FIN	F-WWATER
Permit Status	RCRA Permit No. 988A
SIC Code	--
Facility Contact	Bob Smith 222-222-2222

Emissions Profile (TPY)

Contaminant	Actual Annual	Actual Allowable
1,3-Butadiene	11.87	N/A
Styrene	11.42	N/A

Source Attribute Table

Account No.	JE0017A
Account Name	Ameripol Synpol Corp.
Site Name	Trap 4 – XS99
Facility Name	ETF Styrene Tank
Plant ID	Tank Sector 9989A
Point Name	NE1
Unique Pt Name	JE0F00M
EPN	T-ESTY
FIN	TANKS-ESTY
Permit Status	RCRA – Permit No. 988A
SIC Code	--
Facility Contact	Bob Smith – 222-222-2222

Emissions Profile (TPY)

Contaminant	Actual Annual	Actual Allowable
1,3-Butadiene	1.78	N/A
Styrene	0.67	N/A

Exhibit A-11 zooms in further to highlight the two sources whose emissions result in the highest cancer risks. Detailed information about these two sources is provided in the exhibit to aid in risk management decisions.

Exhibit A-9. Example Presentation of Source Apportionment Analysis

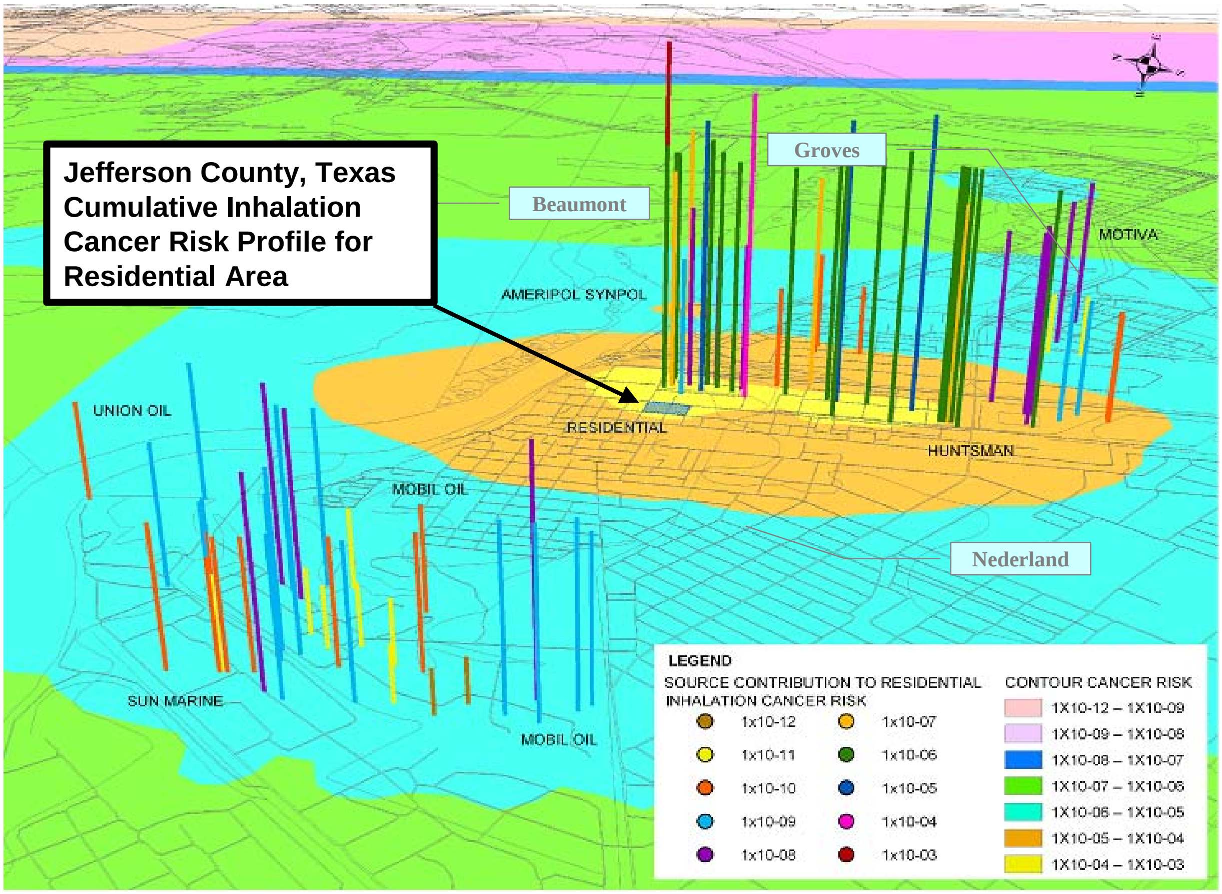


Exhibit A-10. Example Use of Source Apportionment Results

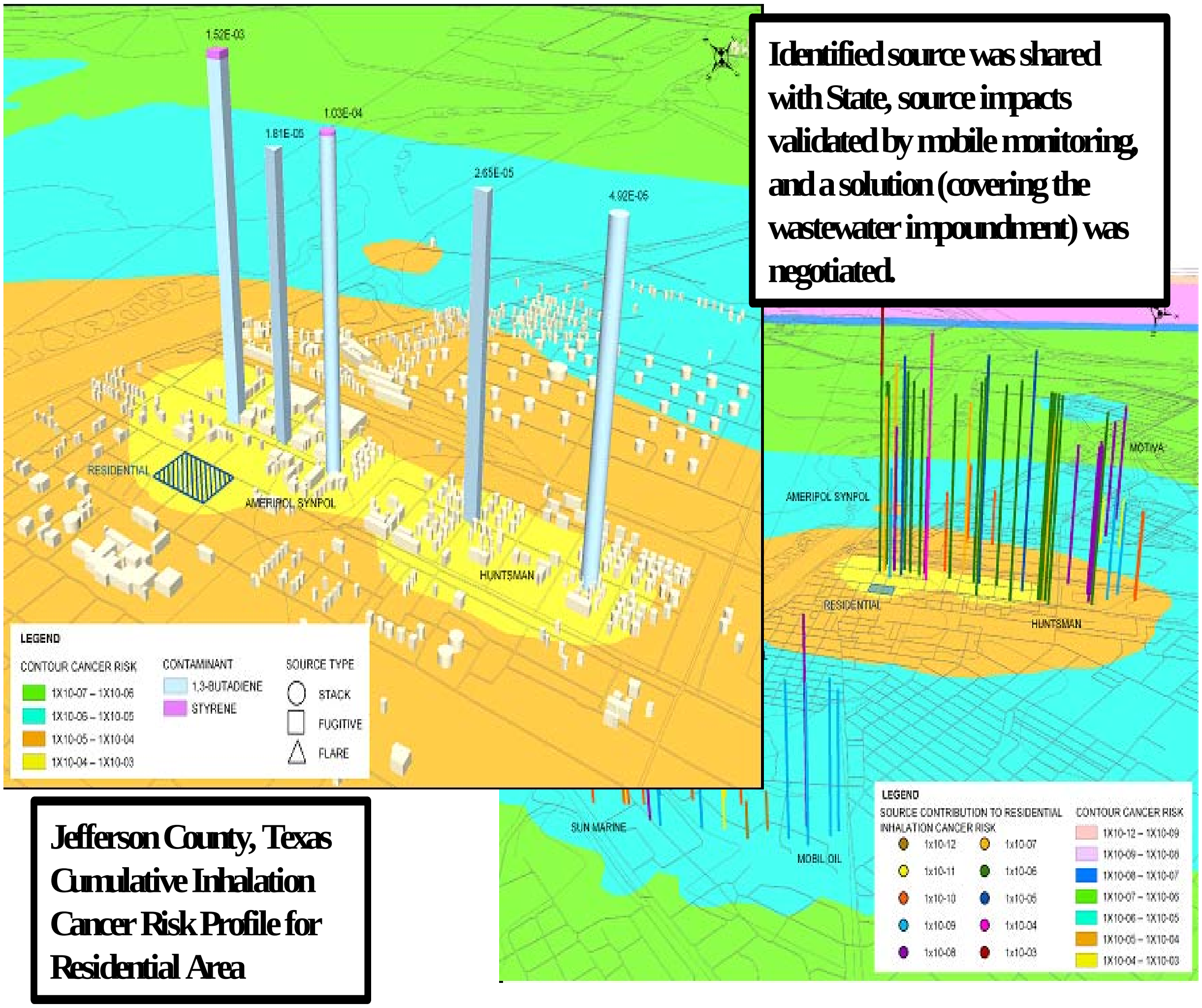
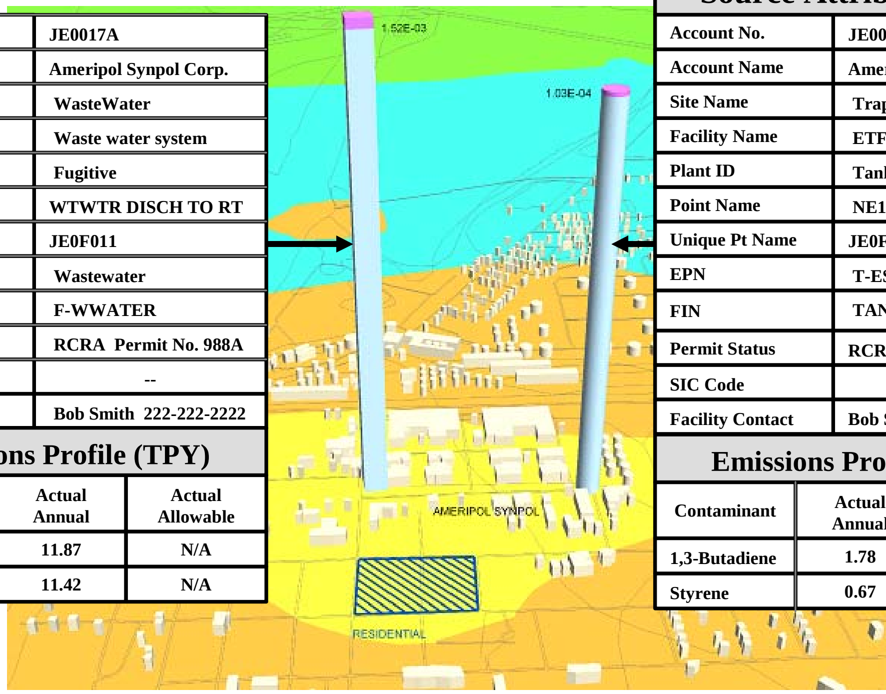


Exhibit A-11. Example Use of Source Apportionment Results



Account No.	JE0017A
Account Name	Ameripol Synpol Corp.
Site Name	WasteWater
Facility Name	Waste water system
Source Type	Fugitive
Point Name	WTWTR DISCH TO RT
Unique Pt Name	JE0F011
EPN	Wastewater
FIN	F-WWATER
Permit Status	RCRA Permit No. 988A
SIC Code	--
Facility Contact	Bob Smith 222-222-2222

Emissions Profile (TPY)

Contaminant	Actual Annual	Actual Allowable
1,3-Butadiene	11.87	N/A
Styrene	11.42	N/A

Source Attribute Table

Account No.	JE0017A
Account Name	Ameripol Synpol Corp.
Site Name	Trap 4 – XS99
Facility Name	ETF Styrene Tank
Plant ID	Tank Sector 9989A
Point Name	NE1
Unique Pt Name	JE0F00M
EPN	T-ESTY
FIN	TANKS-ESTY
Permit Status	RCRA – Permit No. 988A
SIC Code	--
Facility Contact	Bob Smith – 222-222-2222

Emissions Profile (TPY)

Contaminant	Actual Annual	Actual Allowable
1,3-Butadiene	1.78	N/A
Styrene	0.67	N/A

3.0 The Houston Case Study for Urban Air Toxics Modeling

Another example of a multisource assessment is a modeling application completed by OAQPS for the Houston urban area. This assessment was carried out to demonstrate an air quality modeling methodology for air toxics in an urban area, highlight specific issues related to air quality modeling of an urban area, and provide an example of the application of several of EPA's publically-available air quality and emissions tools. The analysis differs from the application of RAIMI for the Port Neches case study in that it focuses on only the emissions characterization and dispersion modeling aspects of a multisource assessment and does not include any assessment of toxicity and exposure or characterization of human health risks.

For this case study, the model domain was defined to include several counties comprising the Houston urban area centered on Harris County, Texas. EPA's 1996 National Toxics Inventory (NTI) was used to compile emissions data for benzene, cadmium, chromium, formaldehyde, and lead from sources in the Houston area (i.e., all stationary and on-road and non-road mobile sources). EPA's Emissions Modeling System for Hazardous Pollutants (EMS-HAP) was used as an emissions processor to interface with NTI, perform QA/QC, and convert the NTI data into a format for ISCST3.

ISCST3 was selected as the primary air quality model for the application, and was used to calculate ambient concentrations for air toxics other than formaldehyde. For formaldehyde, two modeling steps were applied: (1) dispersion of formaldehyde emissions was modeled using ISCST3, with simple atmospheric decay accounted for by a user-supplied half-life; and (2) formation of formaldehyde from emissions of precursor pollutants was modeled using EPA's OZIPR model, a screening-level, one-dimensional photochemical box model (see http://www.epa.gov/scram001/tt22.htm#ozipr). Concentration outputs from ISCST3 and OZIPR were then added together to estimate total ambient formaldehyde concentrations. For all pollutants, census tract centroids and monitoring station locations were selected as receptor locations for ISCST3 modeling, and annual average concentrations were defined as the modeling endpoint.

Three sets of model results were generated. In the first set, the modeling was performed with all types of emissions allocated to 1-km grid cells. In the second set of results, on-road mobile source emissions were allocated to road segments in the Houston area. A third set of model runs was executed using a set of receptor locations spaced 500 m apart in one part of the modeling region containing a high density of emission sources to determine the impact of using a finer (i.e., denser) results grid. These sets of results were compared to each other and to available monitoring data.

Several conclusions were drawn from the results of the Houston case study.

- Higher concentrations were located in eastern and northern Harris County, near the higher density of emission sources for the five HAPS studied.

- Increasing the receptor density near emission sources changed the location of maximum concentrations, illustrating that concentration gradients can occur near high emission sources and highlighting the importance of receptor placement and density to modeling results.

- Allocating onroad mobile emissions to road segments can improve the model-predicted concentrations when compared to observations from monitoring data.

In addition, the authors of the study noted that refinements in the emissions inventory would aid in predicting accurate model concentrations for assessing exposure to toxic pollutants.

This case study is described in detail in the *Example Application of Modeling Toxic Air Pollutants in Urban Areas*, available at http://www.epa.gov/scram001/guidance/guide/uatexample.pdf (EPA 454-R-02-003, June 2002).

4.0 The Cleveland Clean Air Century Campaign in Cleveland, Ohio

The case study presented in this section illustrates how a community can work together to identify toxics risk factors in a community, identify issues of concern, and select and work on projects to reduce the risks posed by these factors. Although the Cleveland effort focuses primarily on air pollution issues, the approach used in Cleveland can be applied in any community to assess and address the wide array of environmental risk factors faced by the community. Several examples of other community-based projects are also summarized following this section.

4.1 Overview of the Campaign

The Cleveland Clean Air Century Campaign (CCACC) is a voluntary, community-based initiative administered by the American Lung Association of Ohio with the goal of reducing health and environmental risk from air toxics in the Cleveland area. With the aid of U.S. EPA and the City of Cleveland, the stakeholders are working together on an approach to air toxics control that serves as a model for communities nationwide. The City of Cleveland was chosen for this initiative because the area has typical levels of air toxics in both the indoor and outdoor environments, contains a local EPA Cleveland Field Office, and is home to strong community groups. More detailed information about CCACC can be found at the main web page for this project at http://www.ohiolung.org/ccacc.htm.

This partnership between the City of Cleveland and EPA was a pilot study for EPA's Community Action for a Renewed Environment (CARE) program, an EPA initiative designed to establish a series of multi-media, community-based, and community-driven projects to reduce local exposure to toxic pollution (see http://www.epa.gov/care/). CARE empowers communities by responding to their needs, helping to reduce risk, and working with them to solve problems identified within their community. The Cleveland project demonstrates this approach in which local stakeholders, with advice and support from the EPA, can work collaboratively to achieve reductions in air toxics.

Cleveland Clean Air Century Campaign Working Group Members

Environmental Groups
- Environmental Health Watch
- Cleveland Green Building Coalition
- Earth Day Coalition

Government Agencies
- Cleveland Department of Public Health, Division of Air Quality
- Ohio Environmental Protection Agency
- US Environmental Protection Agency

Neighborhoods/Citizens
- St. Clair Superior
- Slavic Village
- Lee-Seville-Miles
- Tremont
- Congressman Kucinich's Office

Indoor Sources
- Schools
- American Lung Association of Ohio

Stationary Sources
- Goodrich Landing Gear
- RPM
- Northeast Ohio Regional Sewer District
- City of Cleveland Division of Waste Collection & Disposal
- Alcoa

Mobile Sources
- BP Products North America Inc.
- Regional Transit Authority (RTA)
- Northeast Ohio Areawide Coordinating Agency

Other
- Cuyahoga Community College

Under the CCACC, community members have collaborated to implement measures designed to reduce exposure to air toxics from important outdoor and indoor sources. The methods employed in implementing these measures and a description of some of the results achieved under CCACC are described below.

4.2 Goals and Organization

The CCACC was initiated in March 2001 with three primary goals:

- Reduce air toxics in Cleveland within a year;

- Ensure the project is sustainable over time within the community; and
- Ensure the approach can be replicated in other counties across the United States.

A central component of this campaign was the creation of a **Working Group** comprised of representatives from a range of interested neighborhoods, organizations, businesses, and government agencies to guide the campaign. Members of the Working Group are implementing projects to reduce air toxics in Cleveland. These projects address pollutants from many sources, both indoors and outdoors, and put into place an innovative risk reduction program in the city to help address important urban toxic air pollutants. The project also includes an evaluation of the overall process to help improve the ongoing project as it moves forward and to capture key lessons and findings to ensure the success of future projects in other cities.

4.3 Consideration of Air Toxics Risks

The project plan for this initiative recognized the role of data analysis to identify candidates for risk reduction; however, given the goal of implementing air toxics reduction actions within a year of initiation, there was commitment to a streamlined assessment process. This objective for the streamlined assessment was to help identify a set of "risk-drivers" for air toxics in Cleveland to inform reduction action decisions that would benefit Cleveland.

A report was prepared by the consultant early in the project that examined available studies and information on air toxics pertinent to Cleveland for both indoor and outdoor sources and arrived at several preliminary findings regarding this short list of air toxics of concern. This early information, accompanied by presentations and discussions on this and on basic air toxics and risk concepts and methods, allowed the stakeholder group to quickly move from a focus on information and analysis to consideration of air toxics projects and actions.

4.4 Exposure Reduction Projects and Results

In March 2002, the CCACC Working Group identified and selected the first set of projects to be undertaken in reducing exposure to air toxics in the Cleveland area. These reduction projects targeted a range of sources, including indoor and outdoor sources, mobile and stationary sources, and air toxics produced by industrial and non-industrial (e.g., domestic) sources. Projects were also initiated that were designed to increase awareness and/or acquire additional knowledge regarding exposures to air toxics in Cleveland. Risk reductions were underway and making a difference in Cleveland by the summer of 2002.

Exhibit A-12 provides descriptions of the projects currently under way in Cleveland as a part of the Campaign and notes selected accomplishments associated with some projects (costs associated with some of these projects are provided in Section 8.3). It is important to note that while aspects of CCACC projects benefit Cleveland as a whole, the Campaign has focused

Exhibit A-12. CCACC Risk Reduction Projects	
Project	**Description and Selected Results**
Smoke-Free Home Pledge Campaign	Encourage people to designate their homes and automobiles "Smoke-Free." This campaign is designed to protect children as well as adults from the health risks of secondhand smoke. ***Result*:** Smoke-free home pledges from 251 families.
Highway diesel fuel for off-road use	Reduce emissions of diesel particulate matter by encouraging low-sulfur fuel use as part of major construction contracts and increase community knowledge about options for reducing emissions from diesel vehicles. If all off-road equipment switched to highway-grade diesel fuel, there would be an approximate particulate matter (PM) emission reduction of 13%, or 80 tons. ***Result*:** For only construction equipment with 20% participation, the reduction is approximately 10 tons, or 2.5 lb of PM eliminated per 100 gallons of fuel, or for every 100 hours of use.
Anti-idling campaign	Eliminate unnecessary vehicle idling throughout the City of Cleveland by both private citizens and business/public fleets by achieving widespread recognition that avoiding idling is a smart, effective, accessible, immediate, and money-saving way to reduce pollution including air toxics. ***Result*:** The institution of the Cleveland Municipal School District Anti-idling Campaign. Vehicles departing from all school garages are restricted to the maximum of five minutes of running time after vehicle start up.
Cleaner Diesel Fleets for Cleveland	Reduce emissions of diesel exhaust, reduce school children's exposure to diesel exhaust, and increase community knowledge about options for reducing emissions from diesel vehicles by providing funding to fleets for retrofitting vehicles. ***Result*:** Catalyst mufflers installed on 29 Cuyahoga County Board of Mental Retardation & Developmental Disabilities buses, and three new engines installed in City of Cleveland Heights vehicles. These technologies reduce particulate matter by 20-50%, carbon monoxide by 40%, and hydrocarbons by 50%. In addition, 23 (out of 600) school buses in the Cleveland Municipal School District (CMSD) were upgraded with new particulate filters. This technology reduces emissions of particulates, hydrocarbons, and carbon monoxide by 90% when used in conjunction with ultra-low sulfur diesel fuel. CMSD was awarded a U.S. EPA "Clean School Bus USA" grant; the Ohio EPA redirected secured funds to support the District's retrofit project for an additional 41 school buses.
Cleveland local emission source inventory	Develop local inventory of emissions of priority air toxics. ***Result:*** Developed a cost-effective, reliable, baseline inventory for individual sources of risk driver hazardous air pollution (HAP) emissions in and around the Cleveland area.

Exhibit A-12. CCACC Risk Reduction Projects	
Project	**Description and Selected Results**
Gas Can Exchange Program	Reduce toxic air emissions caused by residential/facility usage, storage and /or improper disposal of gasoline. ***Result*:** CCACC funded the replacement of older cans with 656 5-gallon and 368 2.5-gallon lower-emission cans. The estimated potential reduction of VOCs for all of these cans over their five-year functional life span is 10.6 to 18.5 tons. The corresponding estimated benzene reduction is 420 to 720 lb.
Household Hazardous Waste (HHW) Collection/Exchange	Reduce toxic air emissions caused by residential usage, storage and/or improper disposal of hazardous household products by coordinating HHW collection events. ***Result*:** CCACC coordinated two household hazardous waste (HHW) collection events. In 2002, 8.38 tons of HHW were recycled and 12.7 tons of waste was collected from 88 households, with a total reduction of 270 grams of mercury. In 2003, 117 households participated and 13.59 tons of HHW were collected.
Electroplating toxics emissions reduction	Provide information and resources to local electroplaters to manage and reduce toxics. ***Result*:** CCACC funded an electroplater workshop that gives local electroplaters the information, skills, and resources to manage and reduce toxic emissions.
Tools for Schools	Provide schools with information, skills, and equipment/materials to manage air quality in a low-cost, practical manner. ***Result*:** CCACC funded Tools for Schools assessments for 4 Cleveland schools and held Tools for Schools training workshops for 98% of the building maintenance personnel. In addition, CCACC funded the purchase of equipment/materials for the improvement of indoor air quality in 48 schools and a Healthy Indoor Air In Schools workshop for 50 environmental health professionals.
Commuter Choice	Address emissions from mobile sources incurred through commuting practices. ***Result:*** Employers are encouraged to offer incentives for carpooling, public transit, and other environmentally-friendly commuter options.
RTA Bus/Fuel Replacement	Address unhealthy emissions from older commuter buses. ***Result:*** Replaced older circulator buses for St. Clair/Superior and Slavic Village neighborhoods with new buses and fuel for low-sulfur diesel.

Exhibit A-12. CCACC Risk Reduction Projects	
Project	**Description and Selected Results**
Home Indoor Air Education Campaign	Provide information to citizens regarding indoor air quality. ***Results:*** Created the "Home Air Pollution Resource Guide" (a 21-page home indoor education booklet) for Cleveland residents that provides educational information and resources on indoor air quality (IAQ) issues. Disseminated 4,000 home indoor air education booklets. Expected results include potential risk reduction from lead and mold, increased awareness and knowledge of IAQ issues, and less improper disposal of household hazardous waste in landfills or sewers.

particular attention to the St. Clair/Superior Slavic Village, Tremont, and Lee-Seville-Miles neighborhoods of the City, so that the Working Group can more easily measure progress and target local resources. These neighborhoods were selected because they met criteria developed by the EPA in conjunction with the City, such as a diverse mix of industry and sources, a significant amount of residential housing, and active community groups. It is hoped that the initiatives begun in these areas will be undertaken in other Cleveland neighborhoods.

5.0 Additional Examples of Community-Based Projects

In this section, three additional examples are presented that are similar to the Cleveland campaign. Each of these illustrates community-based action toward reducing exposures and risks from air toxics and other pollutants.

5.1 Multi-Media Toxics Reduction Project – South Phoenix, Arizona

The Arizona Department of Environmental Quality (ADEQ) was awarded an EPA grant to build on the success of the Cleveland project (discussed above) to reduce toxic pollutants in South Phoenix. The purpose of this project is to develop and implement a plan to reduce air, water and soil pollution and improve public health in the South Phoenix community. The project will identify sources of toxic pollutants, analyze those source contributions and their potential health and environmental effects, and develop a prioritized action plan to lower public exposures to these toxics substances. The project will also require an extensive communication and public outreach effort.

Some of the steps that are being taken include:

- Convening a Community Action Council (CAC) to oversee the process;
- Review of historical and current data to identify problematic toxics;
- Select the pilot area for the analysis;
- Develop science-based strategies to reduce public exposure; and
- Implement the strategies.

The organization of the CAC includes a wide variety of members chosen to reflect the diversity of the community, to serve as liaisons to their constituent groups, and to participate in the decision making process. The process is structured to be open and inclusive with access to the advice and technical expertise of persons knowledgeable about environmental issues (including federal, state, and local government authorities). The CAC is working to emphasize a facilitated consensus-based process that is reflective of the diversity of community's views. More information about the South Phoenix project can be found at: http://www.azdeq.gov/function/about/spco.html and http://yosemite.epa.gov/oar/CommunityAssessment.nsf/0/bfdaf1b8469667ec85256c6e005c79cb?OpenDocument.

5.2 The Chelsea Creek Action Group Comparative Risk Assessment – Chelsea and East Boston, Massachusetts

The Chelsea Creek Action Group (CCAG) is a coalition of Chelsea and East Boston residents, led by the Chelsea Green Space and Recreation Committee and the East Boston Neighborhood of Affordable Housing. Together, CCAG members on both sides of the Creek work to gain access to the waterfront, to get land owners to remediate contaminated land, and to help residents appreciate the value of this natural resource. CCAG works to connect the two communities through newsletters, events and fairs, environmental workshops, boat tours, and walks.

As part of their efforts, the CCAG is working to perform a comparative risk assessment for the local area. The Comparative Risk Assessment has three interrelated goals:

- To collect information from Chelsea and East Boston residents on their greatest environmental and health concerns stemming from activities along Chelsea Creek;
- To collate the scientific data on the environmental hazards present in and around Chelsea Creek; and
- To create a way for neighbors, agencies, and government to work together and create action plans to tackle those problems.

As a first step, a Resident Advisory Committee solicited input on environmental and health concerns from residents on both sides of Chelsea Creek. By holding public meetings and conducting surveys, the Committee found that people's top environmental concerns are:

- Air quality and respiratory illnesses;
- Water quality in Chelsea Creek; and
- Truck traffic and noise.

In response, the CRA Technical Committee is gathering and processing scientific information about those concerns. The Committee is composed of scientists, public health professionals, attorneys, and other concerned people. At the end of the study, the Committee will write a report that will guide public policy in the community. To learn more about the Green Space and Recreation Committee and their efforts, see http://www.chelseacollab.org/greenspace/.

5.3 Air Toxics/Environmental Justice Pilot Project – West Oakland, California

The goal of this project is to work with the community and other stakeholders to identify and implement reductions in air toxics in West Oakland. While the initial core of the project is assessment of the impacts of, and mitigation measures for, diesel truck emissions, the scope is expanding to multi-media. The community has identified specific needs in the following areas:

- Red Star Yeast;
- Air monitoring;
- Community health assessment;
- Asthma center;
- Truck/diesel relief;
- Clean-up of a Superfund site;
- Indoor and school air quality; and
- Transit and access issues.

The approach of the project is based on the following tasks:

- Build on the community's ongoing work, which has identified key indicators and a comprehensive list of desired solutions;
- Work with the community and other key stakeholders (the city, city council, Port of Oakland, the county) and state and local partner agencies to assess the problems, refine the issue list, identify solutions and facilitate their implementation; and
- Identify potential EPA points of access to these issues and solutions and integrate EPA's programs and available tools.

More information on the West Oakland project can be found at: http://yosemite.epa.gov/oar/CommunityAssessment.nsf/d2cea01886a35f4085256e1900591902/6d201b0c720741fd85256c6f005d91c4!OpenDocument.

References

1. U.S. Census Bureau. 2001. *Population Estimate Program: Online Database*. http://www.census.gov/population/estimates/county/co-99-1/99C1_48.txt. Accessed January 24, 2005.

2. U.S. Census Bureau. 2001. *Population Estimate Program: Online Database.* http://www.census.gov/population/estimates/metro-city/SC100K-T1.txt. Accessed January 24, 2005.

3. U.S. Census Bureau. 2001. *Population Estimate Program: Online Database.* http://www.census.gov/population/estimates/metro-city/SC10K-T3.txt. Accessed January 24, 2005.

4. U.S. Environmental Protection Agency. 1998. *Methodology for Assessing Health Risks Associated with Multiple Pathways of Exposure to Combustor Emissions*. Update to EPA/600/6-90/003 *Methodology for Assessing Health Risks Associated With Indirect Exposure to Combustor Emissions*. National Center for Environmental Assessment. EPA-600/R-98-137, available at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=55525.

Appendix B Overview of Screening-level Approaches

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1.0 Introduction

Community-scale assessments can be expensive, time-consuming, and complex. As such, many planning teams will apply a variety of *screening techniques* to try and limit the analysis to only those chemicals and sources that are likely to contribute significantly to the overall risk. Conversely, some analysts will purposefully not perform any screening in order to keep the overall analysis as true to the notion of a *cumulative* assessment as possible. The approach ultimately selected for any given project will depend on the stated goals of the assessment, the needs of the analysts and decision makers, the established data quality objectives, and the resources available to perform the analysis.

Screening-Level Approaches - Use the Right Approach for the Situation

The screening-level approaches described in this appendix are generalized examples of techniques that may be applicable for a given community-scale assessment. However, depending on the needs, goals, and data quality objectives of an assessment, the approaches described here may not be feasible, appropriate, or even necessary. Analysts should consider the circumstances of their particular assessment and employ the approaches (or modifications) appropriate for the assessment.

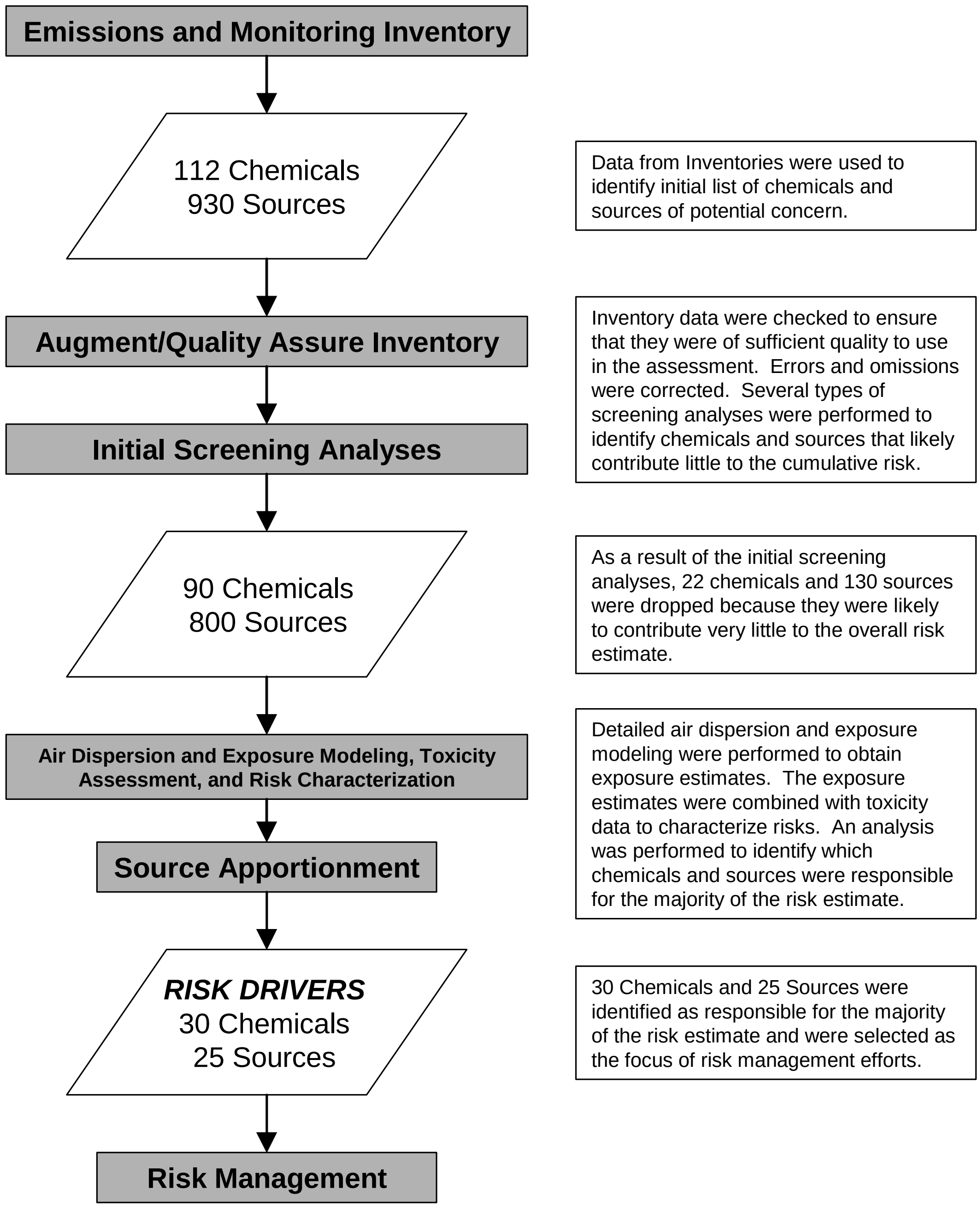
The screening-level approaches used by analysts commonly incorporate a variety of simplifying, yet conservative assumptions that allow the assessment team to hone in on the chemicals and sources that are most likely to "drive" the risk in the study area. Likewise, if the screening-level analysis indicates that the potential risk of a specific emission is relatively low, it might be appropriate to remove it from further analysis (see Exhibit B-1 for an illustration of how screening can be used in the overall analytical approach to focus in on the most likely significant contributors to area risks).

This Appendix describes several screening-level approaches that may be useful for community-scale assessments. Note that each community assessment will be different and that the screening techniques actually used may closely match the examples provided here, they may be a modification of one of these approaches, or analysts may select and implement a different approach entirely (i.e., there is no "one size fits all" approach to selecting and applying screening techniques in a community-scale multisource analysis). Under all circumstances, analysts should be careful to fully describe why they selected a screening technique, how they performed the analysis, and why the removal of chemicals or sources from further consideration was appropriate and justifiable.

What About PBT Chemicals?

Analysts should use caution when screening out persistent chemicals that bioaccumulate and biomagnify since relatively small emissions may lead to high levels in non-air media such as biota over time. (See ATRA Volume 1, Parts III and IV for a discussion of PBT chemicals.)

Exhibit B-1. Example of the Use of a Screen to Reduce the Scope of an Assessment.



This graphic illustrates each step of a sample cumulative multisource assessment and describes the role each plays in developing the ultimate result – identifying the chemicals and sources responsible for the majority of the risk estimate. This sample assessment also illustrates a tiered or phased approach in which the risk assessment begins with a large set of chemicals and sources of potential concern and narrows the focus (by screening out insignificant contributors) for the more refined tier of analysis.

2.0 Overview of Screening-Level Approaches

As introduced in Chapter 3, **screening** is a process by which analysts apply a series of criteria to a group of chemicals and sources to determine which of the chemicals and sources may be of sufficient concern to be considered for additional action. For example, in a community impacted by a large number and variety of emission sources and chemicals (a common scenario), analysts will often apply one or more techniques to try and "narrow the field" to those chemicals and sources that are probably the most important in terms of study-area cumulative risk. This "short list" of sources and chemicals would then become the focus of a more robust analysis. (In some cases, the screening results may provide sufficient information for risk management to begin - see 3.3.1.) The benefit of screening is that it can help reduce unnecessary work, it can speed up the analysis, and it can help to clarify the important issues for a community. One drawback is that, if not done properly, important information can be lost. Another drawback is the community members are sometimes suspicious of screening as a way to "hide" important information. The amount of time it takes to develop, explain, and obtain buy-in to a screening level analysis may negate any benefits of performing the screening in the first place.

There are any number of "screening techniques" that could theoretically be employed to limit the number of sources and chemicals in a community multisource analysis with the possibilities ranging from fairly arbitrary in nature (and, thus, questionable) to more scientifically objective. From a practical standpoint, the screening process usually takes shape in the form of an analysis that is performed in a "tiered" or "phased" approach (discussed in Chapter 3) that generally progresses from simple approaches that rely on reasonably conservative inputs and assumptions to more complex approaches that attempt to provide both more realistic estimates of risk and a

What Are Some Screening-Level Approaches Other People Have Developed?

There are several existing air toxics-specific documents that provide insight into the concept of screening and possible approaches to screening level analysis. Analysts are encouraged to familiarize themselves with these documents prior to implementing screening assessments in a community-level multisource assessment.

- U.S. EPA. 1992. *A Tiered Modeling Approach for Assessing the Risks Due to Sources of Hazardous Air Pollutants.* Office of Air Quality Planning and Standards (EPA-450/4-92-001). March. (http://www.epa.gov/reg3artd/airquality/mod.htm)
- U.S. EPA. 2004. Air Toxics Risk Assessment Reference Library, Volume 2, Facility-Specific Assessment. Office of Air Quality Planning and Standards (EPA-453-K-04-001B). April. (http://www.epa.gov/ttn/fera/risk_atra_vol2.html)
- U.S. EPA Region 6. 2003. *Regional Air Impact Modeling Initiative (RAIMI) Pilot Study in Port Neches, TX*. May. (http://www.epa.gov/earth1r6/6pd/rcra_c/raimi/raimi.htm)
- U.S. EPA. *Draft Community Assistance Technical Team Air Screening How To Manual*. Office of Pollution Prevention and Toxics, Washington, D.C. (http://www.epa.gov/opptintr/cahp/howto.html)
- U.S. EPA. 2006. *A Preliminary Risk-Based Screening Approach for Air Toxics Monitoring Data Sets.* Region 4 Air, Pesticides, and Toxics Management Division (EPA-904-B-06-001). February. (http://www.epa.gov/region4/air/airtoxic/Screening-020607-KM.pdf)

(Note that these screening techniques address inhalation-only exposures. EPA is working to develop better screening techniques for multi-media impacts of pollutants that deposit out of the atmosphere.)

better understanding of community variability and risk estimate uncertainties. Within each tier of analysis, any one or more screening techniques may be employed to further reduce the number of chemicals and sources evaluated in that tier. (Note that the tiered risk assessment approach provided in Exhibit 3-10 is not meant to imply that there is a clear distinction between tiers of analysis. For example, a series of refinements in a lower tier analysis might be indistinguishable from a higher tier analysis. Instead, these tiers of analysis are best thought of as points along a spectrum of increasing complexity and detail. The important focus is the specific ways in which a given assessment is refined in successive iterations, including the application of screening level approaches, rather than whether or not it would be considered a lower or higher tier of analysis.)

Analysts that are developing and/or using screening approaches should keep in mind that a good technique will usually need to meet three criteria:

(1) The screening technique will be a relatively simple, straightforward approach;

(2) The inherent simplicity of the screening approach will be counterbalanced with reasonably conservative inputs and assumptions; and

(3) The decision criteria used to evaluate the screening results (i.e., to either "screen out" or "retain" a chemical or source) will also be reasonably conservative.

If the analyst is not reasonably confident that the technique will not lose or "screen out" important information, the technique may not justify removing sources or chemicals from further consideration. Analysts should be particularly cautious about screening techniques that are based on arbitrary decisions about what to keep in and what to leave out (e.g., "we will keep in only major stationary sources and leave out all area sources"). Unless such techniques can be shown to reliably remove only insignificant sources and chemicals, their use may not be justifiable.[a]

The following sections illustrate some common screening techniques for air toxics assessments. As noted previously, the needs, goals, and data quality objectives of a specific study will drive the selection, use, and timing of a screening technique.

2.1 Toxicity Weighted Screening Approach (TWSA)

This example TWSA approach uses a cutoff of 99 percent of total toxicity-weighted emissions. ***This is not intended as a suggested value***, as others (e.g., 90 or 95 percent) may be appropriate for focusing a given risk assessment on the subset of air toxics that are likely to drive the risk management decision.

The TWSA approach is referred to as *hazard-based approach* because it is intended to be entirely emissions- and toxicity-based, without considering dispersion, fate, receptor locations, and other exposure parameters. This type of approach is usually employed as a "first cut" screen during the early exploratory phase of an assessment to quickly get a sense of emissions that are

[a] One example of where this type of technique would be justifiable is when the planning and scoping team decides on a scope that purposefully omits specific sources and chemicals (e.g., their stated purpose it to evaluate "only major stationary sources," "only mobile sources," etc.). However, when such is the case, the analysis is no longer a "multisource assessment" and the stated purpose and goals of the assessment should acknowledge this fact.

potentially important (and can also be used to quickly get a sense of potential risk reduction strategies). The benefit of this type of approach is that it is quick, easy, and cheap to perform. The drawback is that it does not provide any information about exposure and risk. Another important drawback is that any clues about the importance of a given source or chemical emission to local impacts that it does provide may be subject to substantial uncertainty.

Toxicity weighting of emissions or ambient concentrations is a process whereby air toxics emissions data (and, less frequently monitored air toxics concentrations) are combined with *weighting factors* developed from toxicity values such as carcinogenic potency estimates (e.g., inhalation unit risk factors) and reference concentrations (RfCs) to account for differences in relative toxicity among air toxics (see ATRA Volume 1, Section 6.3.2.1). Other weighting factors could also potentially be developed and included to account for differences in dispersion characteristics or variations in population density or behavior.

One way to perform the toxicity weighting (using emissions data as an example) is to place all emissions amounts for different chemicals on the same scale of relative hazard potential. For example, the IUR for acrylamide indicates that it is approximately 160 times more potent a carcinogen than benzene. Knowing only this, the analyst could consider one ton of acrylamide emissions equivalent to 160 tons of benzene for purposes of potential to cause cancer. In other words, the TWSA essentially normalizes the emissions rates of each toxic air pollutant to a hypothetical substance with an inhalation unit risk value of 1 per $\mu g/m^3$ for carcinogenic effects and/or a reference concentration (RfC) of 1 mg/m^3 for noncancer (and in some cases, cancer) effects. It requires emissions information as well as the applicable dose-response values (see ATRA Volume 1, Chapter 12). This technique is especially helpful when the number of HAPs and/or the number of emission points is large.

Risk-Screening Environmental Indicators (RSEI)

RSEI is a fast and effective toxicity-weighting screening tool for evaluating releases from industrial facilities reporting to the TRI. RSEI considers the amount of chemical released (using TRI data), the location of that release, the toxicity of the chemical, its fate and transport through the environment, the route of human exposure, and the number of people affected. This information is used to create numerical values that can be added and compared in a variety of ways to assess the relative risk of chemicals, facilities, regions, industries, etc. (see http://www.epa.gov/opptintr/rsei/).

Following this logic, emissions of each toxic air pollutant would be weighted according to their relative potencies to allow for direct comparison of potential risk across air toxics (with IUR and RfC estimates evaluated separately). For example, this type of analysis permits comparisons of the relative risk posed by pollutants with large mass emissions and low toxicity against pollutants with small mass emissions but high toxicity. Once the toxicity weighted values have been determined, they can be parsed a number of ways to identify chemicals and sources for more in-depth evaluation.

The steps for emissions-based toxicity weighted screening would include the following steps (see Exhibit B-2 for an example calculation):

1. Identify all the inhalation unit risks (IURs) and RfCs for the air toxics in all facility/source emissions.

2. Determine the total tons/year of each toxic air pollutant emitted from facility/source emissions.
3. Multiply the emission rate of each toxic air pollutant by its IUR to obtain a toxicity-emissions product.
4. Rank-order the toxicity-emissions products and obtain the sum of all products.
5. Starting with the highest ranking product, proceed down the list until the cumulative sum of the products reaches a large proportion (e.g., 99 percent) of the total of the products for all the air toxics. Include in the assessment all the air toxics that contributed to this proportion of the total.
6. Repeat steps 3 through 5, but instead divide the emissions rate by the RfCs to obtain "hazard equivalent tons"/year (see Exhibit B-3).

Keep in mind that the TWSA does not provide a quantitative estimate of risk. All it provides is a screening level perspective of potential hazard posed by emissions or ambient concentrations. Nevertheless, emissions and ambient concentrations clearly have a strong influence over exposure and risk, and therefore the toxicity-weighting approach, while a crude yardstick, could help inform a risk management decision if a more refined assessment is not feasible.

Some Notes of Caution When Using the TWSA Approach

The TWSA approach should generally be used to rank pollutants within sources, but not between sources. That is, TWSA should generally not be used to remove a source from the multisource assessment at the screening level. Proceeding in this manner will insure that each source goes into the multisource assessment with at least its potentially most risky pollutants. Other issues that should be considered when performing a TWSA include:

- **Stack vs. Fugitive Emissions**: Impacts to receptors exposed to releases from tall stacks versus impacts to receptors exposed to fugitive releases from very localized, poorly dispersed emission sources could be very different. As such, if the TWSA approach is to be used for sources in a community, they should, at a minimum, be segregated into stack emissions and fugitive emissions and the TWSA performed separately for each type.

- **Emissions Characterization Quality**: The TWSA will typically be based on existing, not refined, emissions data. Some of these data may be fairly crude for some sources and chemicals, while more accurate information may be available for others (e.g., stack test data), resulting in a variable mix of emission estimates with different levels of accuracy. Unless a concerted effort is made to use only emissions of the same caliber and accuracy level, mixing the level of certainty around emissions could lead to artificially ranked chemicals. Specifically, pollutants could be retained because emissions were estimated high in order to be conservative (in light of uncertainties in the existing emissions inventory), while other pollutants with more robust emissions characterization may be eliminated because the estimates were more accurate.

- **Multipathway Exposures.** If persistent, bioaccumulative toxics (the PB-HAPs, see Chapter 9) are to be included in the assessment, they should be the subject of a separate TWSA based on ingestion dose-response values and bioconcentration factors to avoid the problem of eliminating ingestion hazards with an inhalation TWSA.

Exhibit B-2. Example TWSA Calculation for Cancer Effects					
Air Toxic (all Facility/Source Emissions)	**Emissions (tons/year)**	**IUR**	**Cancer Equivalent Tons/year**	**Percent of Total**	**Cumulative Percent**
1,3-butadiene	8.2×10^{1}	3.0×10^{-5}	2.5×10^{-3}	23.8%	23.8%
carbon tetrachloride	1.5×10^{2}	1.5×10^{-5}	2.2×10^{-3}	21.3%	45.1%
beryllium compounds	8.6×10^{-1}	2.4×10^{-3}	2.1×10^{-3}	19.8%	64.9%
arsenic compounds	4.2×10^{-1}	4.3×10^{-3}	1.8×10^{-3}	17.5%	82.4%
2,3,7,8-TCDD	2.0×10^{-5}	3.3×10^{1}	6.6×10^{-4}	6.4%	88.8%
chromium (VI) compounds	3.7×10^{-2}	1.2×10^{-2}	4.4×10^{-4}	4.3%	93.1%
polycyclic organic matter[(a)]	6.7	5.5×10^{-5}	3.7×10^{-4}	3.6%	96.7%
cadmium compounds	1.0×10^{-1}	1.8×10^{-3}	1.8×10^{-4}	1.8%	98.4%
formaldehyde	2.2×10^{4}	5.5×10^{-9}	1.2×10^{-4}	1.1%	99.5%
1,3-dichloropropene	5.2	4.0×10^{-6}	2.1×10^{-5}	0.2%	99.7%
allyl chloride	2.8	6.0×10^{-6}	1.7×10^{-5}	0.2%	99.9%
methylene chloride	1.9×10^{1}	4.7×10^{-7}	8.7×10^{-6}	0.1%	100.0%
benzene	9.3×10^{-2}	7.8×10^{-6}	7.3×10^{-7}	0.0%	100.0%
Total			1.0×10^{-2}	100.0%	

Heavy line denotes 99% cutoff. In this example, 1,3-dichloropropene, allyl chloride, methylene chloride, and benzene might be dropped from the cancer analysis.
[(a)] Cancer equivalent tons/year and IUR are based on the assumption that benzo(a)pyrene represents 5% of emissions.

Exhibit B-3. Example TWSA Calculation for Noncancer (and Some Cancer) Effects					
Air Toxic	**Emissions (tons/year)**	**RfC**	**Noncancer Equivalent Tons/year**	**Percent of Total**	**Cumulative Percent**
beryllium compounds	8.6×10^{-1}	2.0×10^{-5}	4.3×10^{4}	38.3%	38.3%
1,3-butadiene	8.2×10^{1}	2.0×10^{-3}	4.1×10^{4}	36.7%	75.0%
arsenic compounds	4.2×10^{-1}	3.0×10^{-5}	1.4×10^{4}	12.6%	87.6%
cadmium compounds	1.0×10^{-1}	2.0×10^{-5}	5.1×10^{3}	4.6%	92.1%
carbon tetrachloride	7.0×10^{2}	1.9×10^{-1}	3.7×10^{3}	3.3%	95.4%
allyl chloride	2.8	1.0×10^{-3}	2.8×10^{3}	2.5%	97.9%
formaldehyde	8.9	9.8×10^{-3}	9.1×10^{2}	0.8%	98.7%
2,3,7,8-TCDD	2.0×10^{-5}	4.0×10^{-8}	5.0×10^{2}	0.4%	99.1%
chromium (VI) compounds	3.7×10^{-2}	1.0×10^{-4}	3.7×10^{2}	0.3%	99.5%
toluene	1.3×10^{2}	4.0×10^{-1}	3.2×10^{2}	0.3%	99.8%
1,3-dichloropropene	5.2	2.0×10^{-2}	2.6×10^{2}	0.2%	100.0%
methylene chloride	1.9×10^{1}	1	1.9×10^{1}	0.0%	100.0%
benzene	4.8×10^{-2}	3.0×10^{-2}	1.6	0.0%	100.0%
		Total	1.1×10^{5}	100.0%	
Heavy line denotes 99% cutoff. In this example, chromium (VI) compounds, toluene, 1,3-dichloropropene, methylene chloride, and benzene might be dropped from the analysis.					

2.2 Comparisons Between Ambient Concentrations and Risk-Based Concentrations (RBCs)

A second type of hazard-based screening approach is the comparison of ambient air toxics concentrations to risk-based concentrations (RBCs). RBCs for cancer effects (developed from IURs) are ambient concentrations associated with specific levels of cancer risk and usually assume 70 years of continuous exposure. RBCs based on RfCs are ambient concentrations that pose no appreciable hazard to humans (also assuming continuous lifetime exposure). An example of this type of methodology has recently been developed by EPA for screening air toxics monitoring data sets (see http://www.epa.gov/region4/air/airtoxic/Screening-020607-KM.pdf).

Comparisons of estimated concentrations to RBCs can provide indicators of potential public health impacts but should not be considered a characterization of actual health risks.

What If I Had Better Data?

In a higher level of analysis where actual exposure and risk data have been developed, an analysis of this type can be used to further focus the assessment on the significant air toxics of concern. This approach would be similar to the TWSA, except that the analyst would use the estimates of individual cancer risk and hazard instead of toxicity-weighted emissions. An example of this type of risk-based approach would commonly include the following steps:

1. Using applicable input data, run a simple dispersion and/or exposure model (with conservative assumptions) and calculate cancer risk at a selected point (e.g., maximum exposed individual location).
2. Rank-order the individual risk estimates for each emitted toxic air pollutant and obtain the sum of the cancer risk.
3. Starting with the highest ranking cancer risk, proceed down the list until the individual air toxics contributing a large proportion (e.g., 99 percent) of the total risk estimate are included. Include those air toxics in subsequent tiers of analysis.
4. Repeat steps 1 through 3 for hazard.

2.2.1 Example Derivation of Chronic RBCs

In this example, the starting point for the derivation of RBC values for chronic exposures is the Office of Air Quality Planning and Standards' (OAQPS) list of recommended chronic inhalation toxicity values for the Hazardous Air Pollutants (HAPs).[(1)] Specifically, the methodology uses the OAQPS recommended cancer IUR values and chronic inhalation reference concentrations (RfCs) as starting points and performs the following manipulations to derive a final chronic screening value:

- **Chronic RBC for "noncancer" (and in some cases, cancer) health endpoints.** For the "noncancer" RBC value [which in some cases (e.g., chloroform), is also a cancer screening value], the chronic RfCs are used as a starting point since chronic RfCs are, by definition, an estimate of the concentration of a chemical in the air to which continuous exposure over a lifetime is expected to result in little appreciable deleterious effects to the human population, including sensitive subgroups. However, most ambient air contains a mixture of chemicals which may result in a cumulative hazard that is not accounted for by assessing chemicals on an individual basis. To account for possible simultaneous exposure to multiple contaminants, the noncancer chronic RBC value for each chemical is lowered by a preselected amount. In this example, the amount by which the RfC is lowered is selected to be a ten-fold reduction of the RfC [i.e., (0.1) × (RfC)].

  Calculating the "noncancer" RBC values in this fashion is conservative since it is unlikely that a person would be continuously exposed over a lifetime to 10 chemicals that behave in a toxicologically similar manner.

- **Chronic RBC value for cancer health endpoints.** The IUR for a carcinogenic chemical is used as a starting point to derive an air concentration corresponding to a specific individual cancer risk level. Commonly, the cancer RBC risk level is selected as one in one million (written 1E-06 or $1\text{x}10^{-6}$) which is the lower end of the cancer risk range cited in the 1989

Benzene NESHAP (1E-04 to 1E-06) as an acceptable range of risk for the air toxics program.[(2)] The 1E-06 level of risk also takes into account the potential for simultaneous exposure to multiple carcinogens. Specifically, one would have to experience the unlikely scenario of continuous lifetime exposure to 100 cancer-causing agents (all at a concentration corresponding to a risk level of 1E-06) to approach the upper limit of the acceptable risk range (1E-04). The chronic RBC value for cancer is calculated by simply dividing a risk of one in a million by the IUR [(1E-6)/(IUR)].

- **Final chronic RBC value for both cancer and noncancer (and in some cases, cancer) effects.** The final chronic RBC value for a chemical is simply the lower of the concentration values calculated above.

The example methodology for the development of chronic RBCs has precedent in other risk-based environmental programs (e.g., Superfund risk assessors have commonly used similar screening levels to narrow the focus of hazardous site investigations).[(b)] If analysts decide to use different RBC levels, they are encouraged to document why they chose an alternate value and why the alternate value is in line with the screening level concept (i.e., a simple approach counterbalanced with highly conservative inputs and decision criteria).

2.2.2 Examples of the RBC Approach

Example applications of this approach include the following:

- Suppose a single VOC monitor is placed in the center of a neighborhood that is surrounded by heavy industry and major highways. Twenty-four-hour composite samples are collected every six days for a year (approximately 60 samples). Analysts compile all of the data and then compare the maximum value found for each chemical detected to its final chronic RBC value. Those chemicals that are above their respective RBC values (i.e., the chemicals that "fail the screen") are selected for a follow-on air modeling risk assessment study.

  In this example, the analysts have used the screening technique to weed out chemicals that are unlikely to be present at levels that pose significant chronic risk. The benefit of this approach is that the effort needed in the ensuing detailed modeling assessment may be dramatically reduced. For example, the emissions inventory needed for the modeling study could focus only on sources known to emit "failing" chemicals.

  A potential drawback to this approach relates to whether or not the single monitoring site provides data adequate to meet the necessary risk-based data quality objectives. For example, if the monitoring data are not representative of community exposures (e.g., if there are "hotspots" not captured by the single monitor), important chemicals could be erroneously removed from further consideration. Another potential pitfall is inadequate detection limits. Specifically, if the RBC is lower than the analytical detection limit, ambient concentrations could be higher than the RBC, but not be detected due to an inadequate monitoring procedure.

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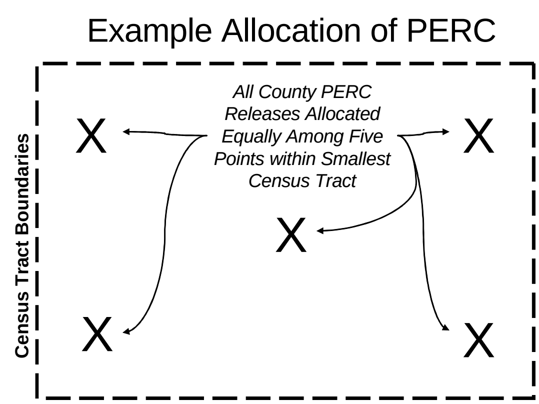
[b] This rationale has been previously employed by Region III Superfund program in their table of risk based concentrations (see http://www.epa.gov/reg3hwmd/risk/human/index.htm).

- Suppose the question is whether or not to include a particular set of diffuse sources in the analysis (e.g., nonpoint sources which have been aggregated up to one total emission amount in the emissions inventory for the county in which the study area is located). Performing a thorough analysis of such sources can require significant resources to determine their precise spatial location. It can also take significant computational time to predict their impact if there are many individual emission points.

  In order to evaluate whether or how to include these diffuse nonpoint sources, the analysts decide to perform an air dispersion modeling run on these sources using the conservative assumption that all the sources are located at five "pseudo-points" evenly distributed within the smallest populated census tract in the modeling domain (refer to Appendix A for a description of the use of pseudo-points). The analyst would perform the air dispersion modeling and compare the resulting ambient concentrations to the chemical-specific RBCs. If the analysis indicates that the potential for risk is sufficiently low (all annual average values are below their respective RBCs), this source type might reasonably be removed from further analysis. If some of the chemicals "fail the screen" (i.e., exceed their respective RBC) and others "pass the screen" (i.e., are below their respective RBC), the analyst may be able to reasonably remove the passing chemicals from further analysis.

  For example, consider a study area (a metropolitan county) with an unknown number of dry cleaners which release perchloroethylene or PERC. The NEI for the county provides only one single total annual amount of PERC released from all dry cleaners in the county. The analysts decide that it would be too resource intensive to locate and map all the dry cleaners; in addition, allocating the emissions around the county (e.g., according to population at the census block level) is not acceptable to the planning and scoping team. How might they resolve this dilemma?

  The analysts decide to perform an exploratory screening analysis of potential PERC risks to determine whether the dry cleaning emissions are a significant issue in the first place. To do this, they make the simplifying, yet conservative assumption that all dry cleaning emission are released from five points within the smallest census tract in the county (see figure) in order to simulate a likely high-end estimate of possible exposures in the study area. They decide to then use the dispersion model ISCST3 to estimate the point of maximum annual average PERC concentration using conservative modeling options [to meet screening criteria (1) and (2) above]. The estimated concentration is then used, as is, as an estimate of lifetime exposure concentration (no exposure model is employed which is, again, simple and, usually, conservative) and the results compared against RBC values. In this analysis, the analysts select the RBC to be concentrations representative of a cancer risk level of one in one million and a hazard quotient = 0.1 [to meet screening criterion (3) above]. If the maximum concentration is below both the cancer RBC and the hazard RBC, the analysts might consider it justifiable to remove this source type and its PERC releases from further consideration in the multisource analysis.

While the RBC approach is more complex than emissions-weighting, it brings two significant advantages to the overall evaluation. First, it may allow analysts to more confidently identify air toxics that are likely to pose insignificant risk for which further reductions may not carry significant health benefits. Depending on whether an air dispersion model is used, one may also be able to account for variation in exposure (and potential risk) across an exposed population.

That having been said, this approach does not take into account other factors that can influence exposure (and risk), such as the activities that people engage in (e.g., working, jogging) and where these activities occur (e.g., at home, school, and work) since an exposure model was not employed, making it subject to greater uncertainty than an approach that does include an estimate of exposure through application of an exposure model.(c) Nevertheless, ambient concentrations are important determinants of exposure and risk, making the concentration/RBC approach a possible basis for risk management decisions if a more refined assessment is not feasible. (Also keep in mind that issues such as secondary formation and other fate and transport phenomena may have a strong influence on exposure and risk. As such, any gains in conservativeness from using a restrictive RBC may be offset by not having fully evaluated all important fate and transport issues.)

2.3 Comparisons Between Estimated Exposures and RBCs that May Yield Quantitative Estimates of Risk

This approach is similar to described in Section 2.2 with the exception that the ambient concentrations predicted through air dispersion modeling are further refined by the application of an exposure model (see ATRA Volume 1, Chapter 11). These refined estimates of exposure are then compared to RBCs in the same way as previously described. The benefit of taking the time to apply the exposure model is that the analyst can usually be more certain that a chemical which is removed from further consideration poses insignificant risk (or that a chemical that is above the RBC may pose significant risk).

[c] As discussed in Exhibit 5-2, long term average estimates of ambient air concentrations (from either dispersion modeling or air quality monitoring) are sometimes used as a surrogate for the chronic exposures people in a study area actually experience. This approach is considered to provide only a screening level estimate of chronic "risk" since it does not take into account either the actual locations of people in the study area or how those people move around during the course of the day. Risk analysts frequently use this approach to assess risk and risk managers commonly base their decisions on such results. That having been said, there are obvious pros and cons to this approach. Avoiding the development of more detailed information on exposures experienced by people in the study area (e.g., via use of an exposure model that takes into account the activity patterns of the people in the study area) is generally faster, easier and requires less knowledge regarding exposure assessment. On the other hand, using ambient concentration as a surrogate for exposure to outdoor air toxics provides answers that are likely to overestimate risk. This can result in taking action when the risks are actually acceptably low. Ultimately, the planning and scoping team will need to evaluate the level of detail that will be needed in the assessment results in order for the risk managers to be able to do their job. Commonly, this will result in the planning and scoping team designing an iterative approach to the risk assessment wherein a screening assessment is done first. If the results of the screening approach are sufficient for the risk managers, the assessment is complete. In contrast, the screening results may be insufficient for decision making and a reassessment of part or all of the risk analysis using more advanced techniques may be undertaken. For more information on planning and scoping, see Chapter 4.

2.4 Quantitative Estimates of Hazards and Carcinogenic Risk for Individuals and Populations

In a higher tier of analysis, in which predicted concentrations of air toxics are refined by the application of an exposure model and then combined with dose-response values (IURs) to develop quantitative estimates of cancer risk,[(d)] all or some of the previous screening methods described above may have been used to identify the exact chemicals and sources that are carried forward to this more formal risk assessment process. However, even within this level of analysis, additional layers of screening may be employed to further refine a specific aspect of the analysis. Consider the following example:

> A risk assessment being performed in a community that is simultaneously impacted by multiple chemicals and sources. The analysts perform a variety of conservative screening techniques to arrive at a set of chemicals and sources that will be the subject of a rigorous emissions inventory development, air dispersion modeling, and exposure modeling study to derive deterministic (i.e., single value or "point") estimates of chronic risk and hazards at specific points throughout the study area.
>
> At the end of this phase of the study, the analysts have identified a subset of chemicals and sources which appear to be responsible for most of the risk based on the deterministic results. However, the level of analysis provided by the deterministic risk characterization is still insufficient for risk management decision making. In particular, the risk managers indicate that they need to have a more full accounting of variability of exposure and risk as well as better understanding of the uncertainties surrounding these estimates for those chemicals and sources responsible for 95% of the risk (as determine by the deterministic analysis). They need this information in order to better judge whether the estimated risks should be mitigated given the costs associated with the available risk reduction options or whether additional data needs to be developed to reduce uncertainty to acceptably low levels. In response, the analysts develop a probabilistic characterization of risk for this subset of chemicals and sources (see ATRA Volume 1, Chapter 31). They also use probabilistic techniques to quantitatively assess uncertainty.

This example illustrates a process by which simplistic, yet conservative screening techniques were used to narrow the focus of a deterministic analysis down to a short list of chemicals and sources that are likely to contribute most to cumulative risk estimates. The results of the deterministic risk assessment are then used to identify chemicals and sources that are carried forward to an even higher level of analysis (probabilistic analysis of risk and uncertainties).

In summary, there are any number of screening techniques that can be used to limit the scope of an analysis and only a few of the more common approaches have been highlighted in this Appendix. Analysts are cautioned to remember that the more screening out of chemicals and sources that takes place, the more the analysis necessarily moves away from being "cumulative" in nature. When weighed against the need to describe to stakeholders why screening was done and why it is "ok," it may be ultimately be time well spent to simply include as many sources

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[d] There are not readily available approaches for quantitatively predicting ***risks*** of effects other than cancer. A hazard quotient approach (which is not a quantitative prediction of the statistical probability of disease outcome) is commonly used for these "other effects."

and chemicals as possible in the analysis. Depending on the scope of the analysis, this may be feasible; in some communities, the shear number and types of sources and chemicals may make screening a necessity. If screening steps are used to narrow the focus of an analysis, the screening steps should be conservative in nature so as to avoid removing chemicals and sources that may significantly contribute to risk. In all cases, the description of the screening process must be carefully detailed in the risk assessment documentation to clarify why the screening was done, how it was done, and why the analysts are reasonably confident that no important information was lost in the process.

References

1. OAQPS Toxicity Values Table - http://www.epa.gov/ttn/atw/toxsource/summary.html (note that these values are updated from time to time and changes in the OAQPS toxicity tables may not be reflected in the current version of this screening level methodology).

2. U.S. EPA. 1989a. National Emission Standards for Hazardous Air Pollutants; Benzene. *Federal Register* 54(177):38044-38072, Rule and Proposed Rule. September 14.

Appendix C Emissions Inventory Database Structure Used in the RAIMI Process

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1.0 Primary Inventory Table for RAIMI

The table presented in this appendix is a sample Primary Inventory Table for RAIMI. This represents one example of the format for the emission inventory for a cumulative multisource assessment; other processes and models may require different formats.

State field names are included in this table for illustration purposes only. Database field names from a particular State or Federal regulatory emissions databases would most likely be different.

Source: EPA's Regional Air Impact Modeling Initiative (RAIMI). See http://www.epa.gov/earth1r6/6pd/rcra_c/raimi/raimi.htm.

Project Inventory Field Name	Field Type	Data Description	Corresponding State Field Name
Emission Source Attributes - Industrial Facility References			
Acct_No.	Text (7)	Unique identifier assigned by the state for each industrial facility at which activities produce air-polluting contaminants. The definition of an account is "an all encompassing entity which includes the plants, facilities, emission points, and abatements at a single geographic location under a single ownership."	AC-ACCOUNT
Acct_Name-1	Text (12)	First 12 characters of the account name (company name).	AC-FIRST-12
Acct_Name-2	Text (24)	Last 24 characters of the account name (company name).	AC-LAST-24
Sitename	Text (25)	The name of the industrial facility covered by the account.	AC-SITENAME
County	Text (13)	The county in which the account's industrial facility is located.	CCD-COUNTY-NAME
Nearest_City	Text (15)	The city nearest to the account's industrial facility.	AC-NEARCITY
Emissions Data			
Last_EI_Date	Long Integer	Date for which the most recent emissions inventory data was supplied. Julian date format - yyddd	AC-LAST-EI-DATE
CAS_No	Long Integer	A number assigned to a chemical by Chemical Abstract Service (CAS) as a unique identifier for that chemical.	CN-CAS-NO
Long_Term_Allow	Double	Allowable (permitted) emissions rate reported as amount per unit time [tons/yr].	CE-LONGTRM-ALLOW
Actual_Annual	Double	Actual annual speciated emission rate reported as volume of emissions actually entering the atmosphere per year [tons/yr].	CE-ACTUAL

Project Inventory Field Name	Field Type	Data Description	Corresponding State Field Name
Emission Source Parameters			
Unique_Point_Name	Text (32)	Unique identifier assigned by analyst for each source (not a regulatory database field).	(Not applicable)
EPN	Text (10)	Emission point number; a company or state number designating an emission point (the point or area at or from which contaminant emissions enter the atmosphere). The number is unique to each account (company name).	PT-EPN
Point_Name	Text (25)	Emission point name; assigned by the company or state.	PT-POINT-NAME
Point_Type	Text (2)	Emission point type: St = stack source, Fl = flare source, Fu = fugitive source.	PT-POINT-TYPE
UTM_Zone	Integer	Abbreviated number of the UTM zone (the universal transverse Mercator coordinate system): 3 = zone 13, 4 = zone 14, 5 = zone 15.	PT-UTMZONE
UTM_E	Long Integer	The east coordinate of an emission point location in meters from a particular reference line in the UTM coordinate system.	PT-EASTMETERS
UTM_N	Long Integer	The north coordinate of an emission point location point in meters from a particular reference line in the UTM coordinate system.	PT-NORTHMETERS
Height	Integer	Stack height as the vertical height of the emission point above base elevation (ground level) [feet].	PT-HEIGHT
Temp	Integer	Stack gas exit temperature of the gas stream exiting the emission point [degrees Fahrenheit].	PT-TEMP
SCFM	Double	Gas flow rate of the gas stream feeding a flare [thousands of standard cubic feet per minute at 68 degrees Fahrenheit].	PT-SCFM
LHV	Long Integer	Average of lowest heats of combustion for flare feed stream constituents [BTU/SCF].	PT-LOWHEATVAL
Mol_Wt	Double	Molecular weight: the average value of constituents of a stream feeding a flare.	PT-MOLWT
Length	Integer	Length of the longest side of a rectangular area encompassing a fugitive source [feet] (applicable for fugitive sources only).	PT-LENGTH
Width	Integer	Length of the shortest side of a rectangular area encompassing a fugitive source [feet] (applicable for fugitive sources only).	PT-WIDTH
Rt_Degrees	Integer	Degree rotation from north of the long axis of a fugitive point [degrees].	PT-DEGREES

Project Inventory Field Name	Field Type	Data Description	Corresponding State Field Name
Rt_Dir	Text (1)	Direction of the offset of the long axis of the rectangle encompassing a fugitive point from a north-south line: 0 = no data, 1 = east, 2 = west.	PT-OFNORTH
Hordischarge	Text (1)	Direction of stack discharge: 0 = vertical discharge, 1= horizontal discharge, default is vertical discharge (applicable for stack sources only).	PT-HORDISCHARGE
Diameter	Double	Stack diameter of the emission point opening [feet] (for non-circular openings it is the diameter of a circle with the same area as the emission point opening; applicable for stack sources only).	PT-DIAMETER
Velocity	Double	Stack gas exit velocity of the gas stream exiting the emission point [feet per second] (applicable for stack sources only).	PT-VELOCITY
Emission Source Attributes - Source References			
FIN	Text (10)	Facility identification number; the number used to identify the smallest unit of equipment which generates contaminants. This number will be supplied by the company in permit applications or during inventory updates, or will be assigned by the state if not supplied by the company, and is unique to each account (company name).	FC-FIN
Facility_Name	Text (48)	Name of the facility; supplied by the company during permit application or inventory update, or by the state if not supplied by the company.	FC-FAC-NAME
Permit	Text (8)	Permit designation assigned; unique in itself. Legal documents (permits & exemptions) governing the air-polluting activities of an account.	CE-PERMIT
SCC	Long Integer	Source classification code; an EPA promulgated code typifying a process.	FC-SCC-CODE

Appendix D Glossary

This list of glossary terms was compiled from existing EPA definitions and supplemented, where necessary, by additional terms and definitions. The wording of selected items may have been modified from the original in order to assist readers who are new to risk assessment more readily comprehend the underlying concept of the glossary entry. As such, these glossary definitions constitute neither official EPA policy nor preempt or in any way replace any existing legal definition required by statute or regulation. A more extensive list of glossary terms can be found in ATRA Volume 1.

A

Acceptable Risk - The likelihood of suffering disease or injury that will be tolerated by an individual, group, or society. The level of risk that is determined to be acceptable may depend on a variety of issues, including scientific data, social, economic, legal, and political factors, and on the perceived benefits arising from a chemical or process.

Accuracy - The measure of the correctness of data, as given by the difference between the measured value and the true or standard value.

Activity Patterns - A series of discrete events of varying time intervals describing information about an individual's lifestyle and routine. This information typically includes the locations visited, the amount of time spent in the locations, and a description of what the individual was doing in each location.

Acute Effect - Any toxic effect produced with a short period of time following an exposure, for example, minutes to a few days

Acute Exposure - One dose (or exposure) or multiple doses (or exposures) occurring within a short time relative to the life of a person or other organism (e.g., approximately 24 hours or less for humans).

Adjusted Exposure Concentration - Also called a refined exposure concentration, an estimate of exposure concentration that has been refined, usually by application of an exposure model, to better understand how people in a particular location interact with contaminated media.

Adverse Environmental Effect - Defined in the CAA section 112(a)(7) as "any significant and widespread adverse effect, which may reasonably be anticipated, to wildlife, aquatic life, or other natural resource, including adverse impacts on populations of endangered or threatened species or significant degradation of environmental quality over broad areas."

Adverse Health Effect - A health effect from exposure to air contaminants that may range from relatively mild and temporary (e.g., eye or throat irritation, shortness of breath, or headaches) to permanent and serious conditions (e.g., birth defects, cancer or damage to lungs, nerves, liver, heart, or other organs), and which negatively affects an individual's health or well-being, or reduces an individual's ability to respond to an additional environmental challenge.

Affected (or Interested) Parties - Individuals and organizations potentially acted upon or affected by chemicals, radiation, or microbes in the environment or influenced favorably or adversely by proposed risk management actions and decisions.

Aggregate Exposure - The combined exposure of an individual (or defined population) to a specific agent or stressor via relevant routes, pathways, and sources.

Aggregate Risk - The risk resulting from aggregate exposure to a single agent or stressor.

AirData - An EPA website (http://www.epa.gov/air/data/info.html) that provides access to yearly summaries of United States air pollution data, taken from EPA's air pollution databases. The data include all fifty states plus District of Columbia, Puerto Rico, and the U. S. Virgin Islands. AirData has information about where air pollution comes from (emissions) and how much pollution is in the air outside our homes and work places (monitoring).

Air Emissions - The release or discharge of a pollutant into the air.

Air Toxic - Any air pollutant (other than a criteria pollutant) that causes or may cause cancer, respiratory, cardiovascular, or developmental effects, reproductive dysfunctions, neurological disorders, heritable gene mutations, or other serious or irreversible chronic or acute health effects in humans or adverse effects on the environment. See hazardous air pollutant and criteria pollutant.

Ambient Medium (e.g., Ambient Air) - Material surrounding or contacting an organism (e.g., outdoor air, indoor air, water, or soil), through which chemicals can reach an organism.

AMTIC - Ambient Monitoring Technology Information Center. An EPA website that contains information and files on ambient air quality monitoring programs, details on monitoring methods, monitoring-related documents and articles, information on air quality trends and nonattainment areas, and federal regulations related to ambient air quality monitoring. [http://www.epa.gov/ttn/amtic/, 2003]

Analysis - The systematic application of specific theories and methods, including those from natural science, social science, engineering, decision science, logic, mathematics, and law, for the purpose of collecting and interpreting data and drawing conclusions about phenomena. It may be qualitative or quantitative. Its competence is typically judged by criteria developed within the fields of expertise from which the theories and methods come.

Analysis Plan - A plan that provides all the details of exactly how each part of the risk assessment will be performed. It usually describes in detail what analyses will be performed, how they will be performed, who will perform the work, schedules, resources, quality assurance/quality control requirements, and documentation requirements.

AP-42 - A compilation of air pollutant emission factors. Volume I of the fifth edition addresses stationary point and area source emission factors. AP-42 is accessible on the Air CHIEF website (http://www.epa.gov/ttn/chief/ap42/) and is also included on the Air CHIEF CD-ROM.

Area of Impact - The geographic area affected by a facility's emissions (also known as the zone of impact).

Area Source (legal sense) - A stationary source that emits less than 10 tons per year of a single hazardous air pollutant (HAP) or 25 tons per year of all HAPs combined.

Area Source (modeling sense) - An emission source in which releases are modeled as coming from a 2-dimensional surface. Emissions from the surface of a wastewater pond are, for example, often modeled as an area source.

Assessment Questions - The questions asked during the planning/scoping phase of the risk assessment process to determine what the risk assessment will evaluate.

ATSDR (Agency for Toxic Substances and Disease Registry) - An Agency of the U.S. Department of Health and Human Services, whose goal is to serve the public by using the best science, taking responsive public health actions, and providing health information to prevent harmful exposures and diseases to toxic substances. Its website (www.atsdr.cdc.gov) includes information on hazardous substances [e.g., toxicological profiles, minimal risk levels (MRLs)], emergency response, measuring health effects, hazardous waste sites, education and training, publications, and special issues (e.g., Children Health).

B

Background Levels - The concentration of a chemical already present in an environmental medium due to sources other than those under study. Two types of background levels may exist for chemical substances: (a) Naturally occurring levels of substances present in the environment, and (b) Anthropogenic concentrations of substances present in the environment due to human associated activities (e.g., automobiles, industries).

Background Source - Any source from which pollutants are released and contribute to the background level of a pollutant, such as volcano eruptions, windblown dust, or manmade source upwind of the study area.

Best Available Control Technology (BACT) - An emission limitation based on the maximum degree of emission reduction (considering energy, environmental, and economic impacts) achievable through application of production processes and available methods, systems, and techniques. BACT does not permit emissions in excess of those allowed under any applicable Clean Air Act provisions. Use of the BACT concept is allowable on a case by case basis for major new or modified emissions sources in attainment areas and applies to each regulated pollutant.

Best Professional Judgement - Utilizing knowledge based on education and experience to determine the best course of action during the course of performing a risk assessment project.

Bias - systematic error introduced into sampling or analysis by selecting or encouraging one outcome or answer over others.

Bioaccumulation - The net accumulation of a substance by an organism as a result of uptake from and or all routes of exposure (e.g., ingestion of food, intake of drinking water, direct contact, or inhalation).

Bounding Estimate - An estimate of exposure or risk that is higher or lower than that incurred by any person in the population. Bounding estimates are useful in developing statements that exposures or risks are within an estimated range.

Breathing Zone - Air in the vicinity of an organism from which respired air is drawn. Personal monitors are often used to measure pollutants in the breathing zone.

Bright Line - Specific levels of risk or of exposure that are meant to provide a practical distinction between what is considered "safe" and what is not.

Building Downwash (Plume Downwash) - The interaction of a plume with a structure, such as a building, which causes the plume to fall to ground.

C

Cancer - A group of related diseases characterized by the uncontrolled growth of abnormal cells.

Cancer Incidence - The number of new cases of a disease diagnosed each year.

Cancer Risk Estimates - The probability of developing cancer from exposure to a chemical agent or a mixture of chemicals over a specified period of time. In quantitative terms, risk is expressed in values ranging from zero (representing an estimate that harm certainly will not occur) to one (representing an estimate that harm certainly will occur). The following are examples of how risk is commonly expressed: 1.E-04 or 1×10^{-4} = a risk of 1 additional cancer in an exposed population of 10,000 people (i.e., 1/10,000); 1.E-5 or 1×10^{-5} = 1/100,000; 1.E-6 or 1×10^{-6} = 1/1,000,000.

Cancer Slope Factor (CSF) - An upper bound (approximating a 95% confidence limit) on the increased cancer risk from a lifetime exposure to an agent. This estimate, usually expressed in units of proportion (of a population) affected per mg/kg/day, is generally reserved for use in the low-dose region of the dose-response relationship; that is, for exposures corresponding to risks less than 1 in 100. This term is usually used to refer to oral slope factors (i.e., slope factors used for assessing ingestion exposure).

Carcinogen(ic) - An agent capable of inducing cancer.

Carcinogenesis - The origin or production of a benign or malignant tumor. The carcinogenic event modifies the genome and/or other molecular control mechanisms of the target cells, giving rise to a population of altered cells.

Census Bureau (Bureau of the Census) - A Bureau within the Department of Commerce, this is the country's preeminent statistical collection and dissemination agency of national demographic information. It publishes a wide variety of statistical data about people, housing, and the economy of the nation. The Census Bureau conducts approximately 200 annual surveys and conducts the decennial census of the United States population and housing and the quinquennial economic census and census of governments.

Census Block - An area bounded by visible and/or invisible features shown on Census Bureau maps. A block is the smallest geographic entity for which the Census Bureau collects and tabulates 100-percent decennial census data.

Census Tract - A small, relatively permanent statistical subdivision of a county or statistically equivalent entity, delineated for data presentation purposes by a local group of census data users or the geographic staff of a regional census center in accordance with Census Bureau guidelines. Designed to be relatively homogeneous units with respect to population characteristics, economic status, and living conditions at the time they are established, census tracts generally contain between 1,000 and 8,000 people, with an optimum size of 4,000 people. Census tract boundaries are delineated with the intention of being stable over many decades, so they generally follow relatively permanent visible features. However, they may follow governmental unit boundaries and other invisible features in some instances; the boundary of a state or county (or statistically equivalent entity) is always a census tract boundary.

Census Tract (or Census Block) Internal Point - A set of geographic coordinates (latitude and longitude) that is located within a specified geographic entity such as a Census Tract or Census Block. For many Census Tracts or Blocks, this point represents the approximate center of the Census Tract or Block; for some, the shape of the entity or the presence of a body of water causes the central location to fall outside the Census Tract or Block or in water, in which case the point is relocated to land area within the Census Tract or Block. The geographic coordinates are shown in degrees to six decimal places in census products.

Chemical Abstracts Service Registry Number (CASRN) - A unique, chemical-specific number used in identifying a substance. The registry numbers are assigned by the Chemical Abstract Service, a division of the American Chemical Society. (Note that some mixtures of substances, such as mixtures of various forms of xylene, are also given CAS numbers.)

Chemicals of Potential Concern - Chemicals that may pose a threat to the populations within the study area. These are the chemicals which are carried through the risk assessment process.

Chemical Speciation - Detailed identification of the specific identities and forms of chemicals in a mixture.

Chemical Transformation - The change of one chemical into another.

Chronic Exposure - Continuous exposure, or multiple exposures, occurring over an extended period of time or a significant fraction of the animal's or the individual's lifetime.

Chronic Health Effects - An effect which occurs as a result of repeated or long term (chronic) exposures.

Cohort - A group of people within a population that can be aggregated because the variation in a characteristic of interest (e.g., exposure, age, education level) within the group is much less than the group-to-group variation across the population.

Community - The persons associated with an area who may be directly affected by area pollution because they currently live in or near the area, or have lived in or near the area in the past (i.e., current or past residents), members of local action groups, local officials, tribal governments, health professionals, and local media. Other entities, such as local industry, may also consider themselves part of the community.

Comparative Risk Assessment - The process of comparing and ranking various types of risks to identify priorities and influence resource allocations.

Conceptual Model - A written description and/or a visual representation of actual or predicted relationships between humans or ecological entities and the chemicals or other stressors to which they may be exposed.

Control Technology/Measures - Equipment, processes or actions used to reduce air pollution at the source.

Cost-Benefit Analysis - An evaluation of the costs which would be incurred versus the overall benefits of a proposed action, such as the establishment of an acceptable exposure level of a pollutant.

Criteria Air Pollutant - One of six common air pollutants determined to be hazardous to human health and regulated under EPA's National Ambient Air Quality Standards (NAAQS). The six criteria air pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, sulfur dioxide, and particulate matter. The term "criteria pollutants" derives from the requirement that EPA must describe the characteristics and potential health and welfare effects of these pollutants. It is on the basis of these criteria that standards are set or revised.

Cumulative Risk - The combined risk from aggregate exposures to multiple agents or stressors.

Cumulative Risk Assessment - An analysis, characterization, and possible quantification of the combined risks to health or the environment from multiple agents or stressors.

D

Data Quality - The encompassing term regarding the quality of information used for analysis and/or dissemination. Utility, objectivity, and integrity are constituents of data quality.

Data Quality Objectives (DQOs) - Qualitative and quantitative statements derived from the DQO process that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support the decisions.

Data Quality Objectives Process - A systematic planning tool to facilitate the planning of environmental data collection activities. Data quality objectives are the qualitative and quantitative outputs from the DQO Process.

Deposition (Wet and Dry) - The removal of airborne substances to available surfaces that occurs as a result of gravitational settling and diffusion, as well as electrophoresis and thermophoresis in the absence of active precipitation (Dry) or in the presence of active precipitation (Wet).

Deterministic - A methodology relying on point (i.e., exact) values as inputs to estimate risk; this obviates quantitative estimates of uncertainty and variability. Results are also presented as point values. Uncertainty and variability may be discussed qualitatively, or semi-quantitatively by multiple deterministic risk estimates.

Direct Exposure - Contact between a receptor and a chemical where the chemical is still in the medium to which it was originally released. For example, direct exposure occurs when a pollutant is released to the air and a person breathes that air.

Dispersion - Pollutant or concentration mixing due to turbulent physical processes.

Disease Cluster - An unusual number, real or perceived, of health events (i.e., reports of cancer) grouped together in time and location.

Dose-Response Assessment - A determination of the relationship between the magnitude of an administered, applied, or internal dose and a specific biological response. Response can be expressed as measured or observed incidence, percent response in groups of subjects (or populations), or as the probability of occurrence within a population.

E

Ecological Risk Assessment - The process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors.

Emission Factor - The relationship between the amount of pollution produced and the amount of raw material processed or product produced. For example, an emission factor for a blast furnace making iron could be the number of pounds of particulates released per ton of raw materials used.

Emission Inventory - A listing, by source, of the amount of air pollutants discharged into the atmosphere in a particular place. Two of the more important publicly available emissions inventories for air toxics studies are the National Emissions Inventory (NEI) and the Toxics Release Inventory (TRI).

Emission Rate - The amount of a given substance discharged to the air per unit time, expressed as a fixed ratio (e.g., tons/yr).

Emissions Monitoring - The periodic or continuous physical surveillance or testing to determine the pollutant levels discharged into the atmosphere from sources such as smokestacks at industrial facilities and exhaust from motor vehicles, locomotives, or aircraft.

Emissions Tracking System (ETS) - This EPA system contains all emissions data submitted under various clean air market programs. Data from Continuous Emissions Monitoring Systems at utilities sends the emission data to the utility's computer system, which then compiles the data for submission to EPA on a quarterly basis. At the end of each calendar year, EPA compares tons of emissions emitted with the allowance holdings of the utility unit to ensure that it is in compliance with the relevant program.

Environmental Data - Any measurements or information that describe environmental processes, location, or conditions; ecological or health effects and consequences; or the performance of environmental technology. Environmental data include information collected directly from measurements, produced from models, and compiled from other sources such as data bases or the literature.

Environmental Medium - Any one of the major categories of material found in the physical environment (e.g., surface water, ground water, soil, or air), and through which chemicals or pollutants can move.

Epidemiology - The study of disease patterns in human populations.

Exposure - Contact made between a chemical, physical, or biological agent and the outer boundary of an organism.

Exposure Assessment - An identification and evaluation of a population exposed to a toxic agent, describing its composition and size, as well as the type, magnitude, frequency, route and duration of exposure.

Exposure Concentration - The concentration of a chemical in its transport or carrier medium (i.e., an environmental medium or contaminated food) at the point of contact.

Exposure Factors - Any of a variety of factors that relate to how an organism interacts with or is otherwise exposed to environmental pollutants (e.g., ingestion rate of contaminated fish). Such factors are used in the calculation of exposure to toxic chemicals.

Exposure Investigation (in Public Health Assessment) - The collection and analysis of site-specific information and biologic tests (when appropriate) to determine whether people have been exposed to hazardous substances.

Exposure Modeling - The mathematical equations simulating how people interact with chemicals in their environment.

Exposure Pathway - The course a chemical or physical agent takes from a source to an exposed organism. An exposure pathway includes a source and release from a source, an exposure point, and an exposure route. If the exposure point differs from the source, a transport/exposure medium (e.g., air) or media (in cases of intermedia transfer) also is included.

Exposure Route - The way a chemical enters an organism after contact (e.g., by ingestion, inhalation, dermal absorption).

Exposure Scenario - A set of conditions or assumptions about sources, exposure pathways, concentrations of toxic chemicals, and populations (numbers, characteristics and habits) which aid the investigator in evaluating and quantifying exposure in a given situation.

Exposure Unit (in Geographical Information System applications) - The geographical area in which a receptor moves and contacts the contaminated medium during the period of exposure.

F

Factor Information Retrieval System (FIRE) - A database management system containing EPA's recommended emission estimation factors for criteria and hazardous air pollutants. FIRE includes information about industries and their emitting processes, the chemicals emitted, and the emission factors themselves. FIRE allows easy access to criteria and hazardous air pollutant emission factors obtained from the Compilation of Air Pollutant Emission Factors (AP-42), Locating and Estimating (L&E) documents, and the retired AFSEF and XATEF documents.

Fate and Transport - A description of how a chemical is carried through and changes in the environment.

Fate and Transport Analysis - The general process used to assess and predict the movement and behavior of chemicals in the environment.

Fate and Transport Modeling - The mathematical equations simulating a physical system which are used to assess and predict the movement and behavior of chemicals in the environment.

Fence Line - Delineated property boundary of a facility.

Field Study - Scientific study made in the ambient air to collect information that can not be obtained in a laboratory.

Fugitive Release - Emission of a chemical to the air that does not occur from a stack, vent, duct, pipe or other confined air stream (e.g., leaks from joints).

Future Scenario - A scenario used in risk assessment to anticipate potential future exposures of individuals (e.g., a housing development could be built on currently vacant land).

G

Geographic Information Systems (GIS) - A computer program that allows layering of different types of spatial information (i.e., on a map) to provide a better understanding of the characteristics of a certain place.

Generally Available Control Technology (GACT) Standard - These standards are less stringent standards than the Maximum Available Control Technology (MACT) standards, and are allowed at the Administrator's discretion for area sources according to the 1990 Clean Air Act Amendments for area sources.

Guidelines (human health and ecological risk assessment) - Official documentation stating current U.S. EPA methodology in assessing risk of harm from environmental pollutants to human populations and ecological receptors.

H

Hazard - In a general sense, "hazard" is anything that has a potential to cause harm. In risk assessment, the likelihood of experiencing a noncancer health (and in some cases a cancer) effect is called hazard (not risk).

Hazard Identification - The process of determining whether exposure to an agent can cause a particular adverse health effect (e.g., cancer, birth defect) and whether the adverse health effect is likely to occur in humans at environmentally relevant doses.

Hazard Index (HI) -The sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways. The HI is calculated separately for chronic, subchronic, and shorter-term duration exposures.

Hazardous Air Pollutants (HAP) - Defined under the Clean Air Act as pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects. Currently, the Clean Air Act regulates 187 chemicals and chemical categories as HAPs.

Hazard Quotient (HQ) - The ratio of a single substance exposure level over a specified time period (e.g., chronic) to a reference value (e.g., an RfC) for that substance derived from a similar exposure period.

Health Endpoint - An observable or measurable biological event used as an index to determine when a deviation in the normal function of the human body occurs.

Health Outcome Data (in Public Health Assessment) - Community-specific health information such as morbidity and mortality data, birth statistics, medical records, tumor and disease registries, surveillance data, and previously conducted health studies that may be collected at the local, state, and national levels by governments, private health care organizations, and professional institutions and associations.

Health Outcomes Study (in Public Health Assessment) - An investigation of exposed persons designed to assist in identifying exposure or effects on public health. Health studies also define the health problems that require further inquiry by means of, for example, a health surveillance or epidemiologic study.

Health Education (in Public Health Assessment) - Programs designed with a community to help it know about health risks and how to reduce these risks.

Health Consultation (in Public Health Assessment) - A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical.

High-End Exposure Estimate - A plausible estimate of individual exposure or dose for those persons at the upper end of an exposure or dose distribution, conceptually above the 90th percentile, but not higher than the individual in the population who has the highest exposure or dose.

Human Exposure Model (HEM) - An EPA model combining the Industrial Source Complex Short Term air dispersion model (ISCST) with a national set of meteorology files, U.S. census data, and a risk calculation component that can be used to estimate individual and population risks.

I

Indirect Exposure Pathway - An indirect exposure pathway is one in which a receptor contacts a chemical in a medium that is different from the one to which the chemical was originally released (an example occurs with dioxin, which is emitted into the air, deposited on soil and accumulated in plants and animals which are then consumed by humans).

Individual Risk or Hazard - The risk or hazard to an individual in a population rather than to the population as a whole.

Indoor Source - Objects or places within buildings or other enclosed spaces that emit air pollutants.

Industrial Source Complex (ISC) Model - A steady-state Gaussian plume model which can be used to assess pollutant concentrations from a wide variety of sources associated with an industrial complex. This model can account for the following: settling and dry deposition of particles; downwash; point, area, line, and volume sources; plume rise as a function of downwind distance; separation of point sources; and limited terrain adjustment. ISC3 operates in both long-term (ISCLT) and short-term (ISCST) modes.

Ingestion - Swallowing (such as eating or drinking).

Ingestion Exposure - Exposure to a chemical by swallowing it (such as eating or drinking).

Inhalation - Breathing.

Inhalation Exposure - Exposure to a chemical by breathing it in.

Inhalation Unit Risk (IUR) - The upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 $\mu g/m^3$ in air. The interpretation of unit risk would be as follows: if unit risk = 2×10^{-6} $\mu g/m^3$, 2 excess tumors may develop per 1,000,000 people if exposed daily for a lifetime to a concentration of 1 µg of the chemical in 1 m^3 of air.

Intake - The process by which a substance crosses the outer boundary of an organism without passing an absorption barrier, e.g., through ingestion or inhalation.

Integrated Risk Information System (IRIS) - An EPA database which contains information on human health effects that may result from exposure to various chemicals in the environment. IRIS was initially developed for EPA staff in response to a growing demand for consistent information on chemical substances for use in risk assessments, decision-making and regulatory activities. The information in IRIS is intended for those without extensive training in toxicology, but with some knowledge of health sciences.

Iterative Process - Replication of a series of actions to produce successively better results, or to accommodate new and different critical information or scientific inferences.

Isopleths - A delineated line or area on a map that represent equal values of a variable.

L

Line Source - A theoretical one-dimensional source from which releases may occur (e.g., roadways are often modeled as a one-dimensional line).

M

Major Source - Under the Clean Air Act, a stationary source that emits more than 10 tons or more per year of a single hazardous air pollutant (HAP) or 25 or more tons per year of all HAPs.

Maximum Achievable Control Technology (MACT) - Under the Clean Air Act, a group of technology based standards, applicable to both major and some area sources of air toxics, that are aimed at reducing releases of air toxics to the environment. MACT standards are established on a source category by source category basis.

Maximum Exposed Individual (MEI) - The MEI represents the highest estimated risk to an exposed individual, regardless of whether people are expected to occupy that area.

Maximum Individual Risk (MIR) - An MIR represents the highest estimated risk to an exposed individual in areas that people are believed to occupy.

Metric (or Measure) of Exposure - The quantitative outcome of the exposure assessment. For air toxics risk assessments, personal air concentration (or adjusted exposure concentration) is the metric of exposure for the inhalation route of exposure and intake rate is the metric of exposure for the ingestion route of exposure.

Measurement - In air toxics assessment, a physical assessment (usually of the concentration of a pollutant) taken in an environmental or biological medium, normally with the intent of relating the measured value to the exposure of an organism.

Media Concentrations - The amount of a given substance in a specific amount of environmental medium. For air, the concentration is usually given as micrograms (µg) of substance per cubic meter (m^3) of air; in water as µg of substance per L of water; and in soil as mg of substance per kg of soil.

Meteorology - The science of the atmosphere, including weather.

Microscale Assessment - An air monitoring network designed to assess concentrations in air volumes associated with area dimensions ranging from several meters up to about 100 meters.

Microenvironment - A small 3-dimensional space (e.g., an office, a room in a home) that can be treated as homogeneous (or well characterized) with regard to exposure concentration of a chemical.

Middle Scale Assessment - An air monitoring network designed to assess concentrations typical of areas up to several city blocks in size with dimensions ranging from about 100 meters to 0.5 kilometer.

Minimal Risk Levels (MRL) - Derived by ATSDR, an MRL is defined as an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (noncancer) over a specified duration of exposure. MRLs can be derived for acute, intermediate, and chronic duration exposures by the inhalation and oral routes.

Mixtures - Any set of multiple chemical substances occurring together in an environmental medium.

Mobile Source Air Toxics - Air toxics that are emitted from non-stationary objects that release pollution. Mobile sources include cars, trucks, buses, planes, trains, motorcycles and gasoline-powered lawn mowers. Another example is a portable generator.

Model - A mathematical representation of a natural system intended to mimic the behavior of the real system, allowing description of empirical data, and predictions about untested states of the system.

Model Uncertainty - Uncertainty due to necessary simplification of real-world processes, mis-specification of the model structure, model misuse, or use of inappropriate surrogate variables or inputs.

Modeling - An investigative technique using a mathematical or physical representation of a system or theory that accounts for all or some of its known properties.

Modeling Node - In air quality modeling, the location where impacts are predicted.

Monitoring - Periodic or continuous physical surveillance or testing to determine pollutant levels in various environmental media or in humans, plants, and animals.

Monte Carlo Technique- A repeated random sampling from the distribution of values for each of the parameters in a generic exposure or risk equation to derive an estimate of the distribution of exposures or risks in the population.

Multipathway Assessment - An assessment that considers more than one exposure pathway. For example, evaluation of exposure through both inhalation and ingestion would be a multipathway assessment. Another example would be evaluation of ingestion of contaminated soil and ingestion of contaminated food.

Multipathway Exposure - When an organism is exposed to pollutants through more than one exposure pathway. One example would be exposure through both inhalation and ingestion. Another example would be ingestion of contaminated soil and ingestion of contaminated food.

Multipathway Risk - The risk resulting from exposure to pollutants through more than one pathway.

N

National Ambient Air Quality Standards (NAAQS) - Maximum air pollutant standards that EPA has set under the Clean Air Act for attainment by each state. Standards are set for each of the criteria pollutants.

National Air Toxics Assessment (NATA) - EPA's ongoing comprehensive evaluation of air toxics in the U.S. Activities include expansion of air toxics monitoring, improving and periodically updating emission inventories, improving national- and local-scale modeling and risk characterization, continued research on health effects and exposures to both ambient and indoor air, and improvement of assessment tools.

National Emissions Inventory (NEI) - EPA's primary emissions inventory of HAPs.

National Emissions Standards for Hazardous Air Pollutants (NESHAPs) - Emissions standards set by EPA for hazardous air pollutants. Also commonly referred to as the MACT standards.

National Emissions Trends (NET) Database - The NET database is an emission inventory that contains data on stationary and mobile sources that emit criteria air pollutants and their precursors. The database also includes estimates of annual emissions of these pollutants from point, area, and mobile sources. The NET is developed every three years (e.g., 1996 and 1999) by EPA, and includes emission estimates for all 50 States, the District of Columbia, Puerto Rico, and the Virgin Islands.

Natural Source - Non-manmade emission sources, including biological (biogenic sources such as plants) and geological sources (such as volcanoes), and windblown dust.

Neighborhood Scale Assessment - An air monitoring network designed to assess concentrations within some extended area of the city that has relatively uniform land use with dimensions in the 0.5 to 4.0 kilometers range.

New Source Performance Standards - Uniform national EPA air emission standards which limit the amount of pollution allowed from new sources or from modified existing sources.

Noncarcinogenic Effect - Any health effect other than cancer. Note that, while not all noncancer toxicants cause cancer, all carcinogens exhibit noncarcinogenic effects.

Nonpoint Source (NEI sense) - Diffuse pollution sources that are not assigned a single point of origin (e.g., multiple dry cleaners in a county which are only described in an inventory in the aggregate).

Nonroad Mobile Sources - Sources such as farm and construction equipment, gasoline-powered lawn and garden equipment, and power boats and outdoor motors that emit pollutants.

Non Steady-state Model - A dynamic model; a mathematical formulation describing and simulating the physical behavior of a system or a process and its temporal variability.

North American Industry Classification System (NAICS) - NAICS replaced the Standard Industrial Classification (SIC) beginning in 1997. This industry-wide classification system has been designed as the index for statistical reporting of all economic activities of the U.S., Canada, and Mexico. NAICS industries are identified by a 6-digit code. The international NAICS agreement fixes only the first five digits of the code. The sixth digit, where used, identifies subdivisions of NAICS industries that accommodate user needs in individual countries.

O

Office of Air and Radiation (OAR) - EPA's Office responsible for providing information about air pollution, clean air, air quality and radiation. OAR develops national programs, technical policies, and regulations for controlling air pollution and radiation exposure. OAR is concerned with pollution prevention, indoor and outdoor air quality, industrial air pollution, pollution from vehicles and engines, radon, acid rain, stratospheric ozone depletion, and radiation protection.

Office of Air Quality, Planning, and Standards (OAQPS) - An EPA Office within OAR whose primary mission is to preserve and improve air quality in the United States. As part of this goal, OAQPS monitors and reports on air quality, air toxics, and emissions. They also respond to visibility issues, as they relate to the level of air pollution. In addition, OAQPS is tasked by the EPA with providing technical information for professionals involved with monitoring and controlling air pollution, creating governmental policies, rules, and guidance (especially for stationary sources), and educating the public about air pollution and what can be done to control and prevent it.

OAQPS Toxicity Table - The EPA Office of Air and Radiation recommended default chronic toxicity values for hazardous air pollutants. They are generally appropriate for screening-level risk assessments, including assessments of select contaminants, exposure routes, or emission sources of potential concern, or to help set priorities for further research. For more complex, refined risk assessments developed to support regulatory decisions for single sources or substances, dose-response data may be evaluated in detail for each "risk driver" to incorporate appropriate new toxicological data. (http://www.epa.gov/ttn/atw/toxsource/summary.html)

Office of Radiation and Indoor Air (ORIA) - An EPA Office within OAR whose mission is to protect the public and the environment from the risks of radiation and indoor air pollution. The Office develops protection criteria, standards, and policies; works with other programs within EPA and other agencies to control radiation and indoor air pollution exposures; provides technical assistance to states through EPA's regional offices, and to other agencies having radiation and indoor air protection programs; directs an environmental radiation monitoring program; responds to radiological emergencies; and evaluates and assesses the overall risk and impact of radiation and indoor air pollution.

Office of Transportation and Air Quality (OTAQ) - An EPA Office within OAR whose mission is to reconcile the transportation sector with the environment by advancing clean fuels and technology, and working to promote more liveable communities. OTAQ is responsible for carrying out laws to control air pollution from motor vehicles, engines, and their fuels. Mobile sources include: cars and light trucks, large trucks and buses, farm and construction equipment, lawn and garden equipment, marine engines, aircraft, and locomotives.

Onroad Mobile Source - Any mobile source of air pollution such as cars, trucks, motorcycles, and buses that travels on roads and highways.

Open Pit Source - Large, open pits, such as surface coal mines and rock quarries.

Operating Permit Program - A program required by the Clean Air Act; requires existing industrial sources to obtain an"operating permit". The operating permit program is a national permitting system that consolidates all of the air pollution control requirements into a single, comprehensive "operating permit" that covers all aspects of a source's year-to-year air pollution activities.

P

Particle-bound - Reversibly absorbed or condensed onto the surface of particles.

Particulates/Particulate Matter (PM) - Solid particles or liquid droplets suspended or carried in the air.

Partitioning - The separation or division of a substance into two or more compartments. Environmental partitioning refers to the distribution of a chemical into various media (soil, air, water, and biota).

Partitioning Model - Models consisting of mathematical equations that estimate how chemicals will divide (i.e., partition) among abiotic and biotic media in a given environment based on chemical- and site- specific characteristics.

Pathway Specific Risk - The risk associated with exposure to a chemical agent or a mixture of chemicals via a specific pathway (e.g., inhalation of outdoor air).

Persistent, Bioaccumulative, and Toxic (PBT) Chemicals - Highly toxic, long-lasting substances that can build up in the food chain to levels that are harmful to human and ecosystem health. They are associated with a range of adverse health effects, including effects on the nervous system, reproductive and developmental problems, cancer, and genetic impacts.

Persistence - Refers to the length of time a compound stays in the environment, once introduced. A compound may persist for very short amounts of time (e.g., fractions of a second) or for long periods of time (e.g., hundreds of years).

Personal Monitoring - A measurement collected from an individual's immediate environment using active or passive devices to collect the samples.

Photolysis - The breakdown of a material by sunlight; an important mechanism for the degradation of contaminants in air, surface water, and the terrestrial environment.

Physical Factors - Manmade and/or natural characteristics or features that influence the movement of pollutants in the environment (e.g., settling velocity, terrain effects).

Planning and Scoping - The process of determining the purpose, scope, players, expected outcomes, analytical approach, schedule, deliverables, QA/QC, resources, and document requirements for the risk assessment.

Point of Exposure - The location of potential contact between an organism and a chemical or physical agent.

Point of Release - Location of release to the environment.

Point Source (NEI sense) - A source of air pollution which can be physically located on a map.

Point Source (non-NEI sense) - A stack, vent, duct, pipe or other confined air stream from which chemicals may be released to the air.

Population Risk or Hazard - Population risk refers to an estimate of the extent of harm for the population or population segment being addressed. It often refers to an analysis of the number of people living at a particular risk or hazard level.

Potential Risk - Estimated likelihood, or probability, of injury, disease, or death resulting from exposure to a potential environmental hazard.

Precision - A measure of the reproducibility of a measured value under a given set of circumstances.

Present Scenario - Risk characterizations using present scenarios to estimate risks to individuals (or populations) that currently reside in areas where potential exposures may occur (e.g., using an existing population within some specified area).

Primary Standard - A pollution limit based on health effects. Primary standards are set for criteria air pollutants.

Probabilistic - A type of statistical modeling approach used to assess the expected frequency and magnitude of a parameter by running repetitive simulations using statistically selected inputs for the determinants of that parameter (e.g., rainfall, pollutants, flows, temperature).

Probabilistic Risk Assessment/Analysis - Calculation and expression of health risks using multiple risk descriptors to provide the likelihood of various risk levels. Probabilistic risk results approximate a full range of possible outcomes and the likelihood of each, which often is presented as a frequency distribution graph, thus allowing uncertainty or variability to be expressed quantitatively.

Probability Density Function (PDF) - The PDF is alternatively referred to in the literature as the probability function or the frequency function. For continuous random variables, that is, the random variables which can assume any value within some defined range (either finite or infinite), the probability density function expresses the probability that the random variable falls within some very small interval. For discrete random variables, that is, random variables which can only assume certain isolated or fixed values, the term probability mass function (PMF) is preferred over the term probability density function. PMF expresses the probability that the random variable takes on a specific value.

Problem Statement - A statement of the perceived problem to be studied by the risk assessment. Problem statements often also include statements about how the problem is going to be studied.

Public Health Consultation (Public Health Assessment) - See health consultation.

Public Health Assessment (PHA) - An evaluation of hazardous substances, health outcomes, and community concerns at a hazardous waste site or other potential source of pollutants to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health.

Public Health Advisory (in Public Health Assessment) - A statement made by a regulatory agency that a release of hazardous substances or contamination by microbial pathogens poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public Health Hazard Category (in Public Health Assessment) - Statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. ATSDR's five public health hazard categories are no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

Q

Qualitative Uncertainty Estimate - A detailed examination, using qualitative information, of the systematic and random errors of a measurement or estimate.

Quality Assurance Project Plan - A document describing in comprehensive detail the necessary quality assurance, quality control, and other technical activities that must be implemented to ensure that the results of the work performed will satisfy the stated performance criteria.

Quality Assurance - An integrated system of activities involving planning, quality control, quality assessment, reporting and quality improvement to ensure that a product or service meets defined standards of quality with a stated level of confidence.

Quality Control - The overall system of technical activities whose purpose is to measure and control the quality of a product or service so that it meets the needs of its users. The aim is to provide data quality that is satisfactory, adequate, and dependable.

R

Receptor (modeling sense) - In fate/transport modeling, the location where impacts are predicted.

Receptor (non-modeling sense) - The entity which is exposed to an environmental stressor.

Reference Concentration (RfC) - An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.

Reference Dose (RfD) - An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.

Reference Media Evaluation Guides (RMEG) - A type of comparison value derived by ATSDR to protect the most sensitive populations. They do not consider carcinogenic effects, chemical interactions, multiple route exposure, or other media-specific routes of exposure, and are very conservative concentration values designed to protect sensitive members of the population.

Regional/National Scale Assessment - An air monitoring network designed to assess from tens to hundreds of kilometers, up to the entire nation.

Relative Potency Factor - The ratio of the toxic potency of a given chemical to that of an index chemical.

Release Parameters - The specific physical characteristics of the release (e.g., stack diameter, stack height, release flow rate, temperature).

Representativeness - The degree to which one or a few samples are characteristic of a larger population about which the analyst is attempting to make an inference.

Residual Risk - The extent of health risk from air pollutants remaining after application of the Maximum Achievable Control Technology (MACT).

Resources - Money, time, equipment, and personnel available to perform the assessment.

Risk (in the context of human health) - The probability of injury, disease, or death from exposure to a chemical agent or a mixture of chemicals. In quantitative terms, risk is expressed in values ranging from zero (representing the certainty that harm will not occur) to one (representing the certainty that harm will occur). (Compare with hazard.)

Risk Assessor(s) - The person or group of people responsible for conducting a qualitative and quantitative evaluation of the risk posed to human health and/or the environment by environmental pollutants.

Risk Assessment - For air toxics, the scientific activity of evaluating the toxic properties of a chemical and the conditions of human or ecological exposure to it in order both to ascertain the likelihood that exposed humans or ecological receptors will be adversely affected, and to characterize the nature of the effects they may experience.

Risk Assessment Work Plan - A document that outlines the specific methods to be used to assess risk, and the protocol for presenting risk results. The risk assessment workplan may consist of one document or the compilation of several workplans that, together, constitute the overall risk assessment workplan.

Risk Characterization - The last phase of the risk assessment process in which the information from the toxicity and exposure assessment steps are integrated and an overall conclusion about risk is synthesized that is complete, informative and useful for decision-makers. In all cases, major issues and uncertainty and variability associated with determining the nature and extent of the risk should be identified and discussed. The risk characterization should be prepared in a manner that is clear, transparent, reasonable and consistent.

Risk Communication - The exchange of information about health or environmental risks among risk assessors and managers, the general public, news media, and other stakeholders.

Risk Management - The decision-making process that uses the results of risk assessment to produce a decision about environmental action. Risk management includes consideration of technical, scientific, social, economic, and political information.

Risk Manager(s) - The person or group responsible for evaluating and selecting alternative regulatory and non-regulatory responses to risk.

S

Sample - A small portion of something designed to evaluate the nature or quality of the whole (for example, one or several samples of air used to evaluate air quality generally).

Sampling and Analysis Plan - An established set of procedures specifying how a sample is to be collected, handled, analyzed, and the data validated and reported.

Science Advisory Board (SAB) - A group of recognized, non-EPA experts who advise EPA on science and science policy.

Scenario Uncertainty - Uncertainty due to descriptive errors, aggregation errors, errors in professional judgment, or incomplete analysis.

SCREEN3 - An air dispersion model developed to obtain conservative estimates of air concentration for use in screening level assessments through the use of conservative algorithms and meteorology.

Screening-level Risk Assessment - A risk assessment performed with few data and many conservative assumptions to identify exposures that should be evaluated more carefully for potential risk.

Secondary Production/Pollutant - Formation of pollutants in the atmosphere by chemical transformation of precursor compounds.

Secondary Standard - A pollution limit based on environmental effects (e.g., damage to property, plants, visibility). Secondary standards are set for criteria air pollutants.

Sensitive Subgroups - Identifiable subsets of the general population that, due to differential exposure or susceptibility, are at greater risk than the general population to the toxic effects of a specific air pollutant (e.g., depending on the pollutant and the exposure circumstances, these may be groups such as subsistence fishers, infants, asthmatics, or the elderly).

Simulation - A representation of a problem, situation in mathematical terms, especially using a computer.

Source - Any place or object from which pollutants are released.

Source Category - A group of similar industrial processes or industries that are contributors to releases of hazardous air pollutants. The 1990 amendments to the Clean Air Act (CAA) requires that the EPA publish and regularly update a listing of all categories and subcategories of major and area sources that emit hazardous air pollutants.

Source Characterization - The detailed description of the source (e.g., location, source of pollutant releases, pollutants released, release parameters).

Spatial Variability - The magnitude of difference in contaminant concentrations in samples separated by a known distance.

SPECIATE - EPA's repository of Total Organic Compound (TOC) and Particulate Matter (PM) speciated profiles for a variety of sources for use in source apportionment studies. The profiles in the system are provided as a library of available profiles for source-receptor and source apportionment type models, such as Chemical Mass Balance 8 (CMB8).

Stack - A chimney, smokestack, or vertical pipe that discharges used air.

Stack Release - The release of a chemical through a stack.

Stack Testing - The monitoring, by testing, of chemicals released from a stack.

Stakeholder(s) - Any organization, governmental entity, or individual that has a stake in or may be impacted by a given approach to environmental regulation, pollution prevention, energy conservation, etc.

Standard Industrial Classification (SIC) - A method of grouping industries with similar products or services and assigning codes to these groups.

Standard Operating Procedure (SOP) - A established set of written procedures adopted and used to guide the work of for a specific project. For example, an air monitoring study would include SOPs on sample collection and handling and SOPs on analytical requirements and data validation and reporting.

Stationary Source - A source of pollution that is fixed in space.

Steady-state Model - Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving media concentrations.

Stochastic - Involving or containing a random variable; involving probability or chance.

Stressor - Any physical, chemical, or biological entity that can induce adverse effects on ecosystems or human health.

Support Center for Regulatory Models (SCRAM) - An EPA website that is a source of information on atmospheric dispersion models (e.g., ISCST3, SCREEN 3, and ASPEN) that support regulatory programs required by the Clean Air Act. Documentation and guidance for these computerized models are a major feature of this website. This site also contains computer code, data, and technical documents that deal with mathematical modeling for the dispersion of air pollutants.

Susceptibility - Increased likelihood of an adverse effect, often discussed in terms of relationship to a factor that can be used to describe a human subpopulation (e.g., life stage, demographic feature, or genetic characteristic).

Susceptible Subgroups - A susceptible subgroup exhibits a response that is different or enhanced when compared to the responses of most people exposed to the same level of the same substance. It may refer to life stages, for example, children or the elderly, or to other segments of the population, for example, asthmatics or the immune-compromised, and will vary with and be particular to the chemical or type of chemical.

T

Target Organ - The biological organ(s) most adversely affected by exposure to a chemical substance (e.g., the site of the critical effect).

Target Organ Specific Hazard Index (TOSHI) - The sum of hazard quotients for individual air toxics that affect the same organ/organ system or act by similar toxicologic processes

Temporal Variability - The difference in contaminant concentrations observed in samples taken at different times.

Terrain Effects - The impact on the airflow as it passes over complex land features such as mountains.

Threshold Effect - An effect (usually an adverse health effect) for which there is an exposure level below which the effect is not expected to occur.

Threshold Toxicant - A chemical for which there is an exposure level below which an adverse health outcome is not expected to occur.

Tiered Analysis - An analysis arranged in layers/steps. Risk assessments/analyses are often conducted in consecutive layers/steps that begin with a reliance on conservative assumptions and little data (resulting in less certain, but generally conservative answers) and move to more study-area specific data and less reliance on assumptions (resulting in more realistic answers). The level of effort and resources also increases with the development of more realistic data.

Toxic Air Pollutants - see hazardous air pollutant.

Toxicity - The degree to which a substance or mixture of substances can harm humans or environmental receptors.

Toxicity Assessment - Characterization of the toxicological properties and effects of a chemical, with special emphasis on establishment of dose-response characteristics.

Toxicology - The study of harmful interactions between chemicals and biological systems.

Toxic Release Inventory (TRI) - Annual database of releases to air, land, and water, and information on waste management in the United States of over 650 chemicals and chemical compounds. This data is collected under Section 313 of the Emergency Planning and Community Right to Know Act.

Trajectory - The track taken by a parcel of air as it moves within the atmosphere over a given period.

Transformation - The change of a chemical from one form to another.

Transparency - Conducting a risk assessment in such a manner that all of the scientific analyses, uncertainties, assumptions, and science policies which underlie the decisions made throughout the risk assessment are clearly stated (i.e., made readily apparent).

Turbulence - Irregular motion of the atmosphere, as indicated by gusts and lulls in the wind.

U

Uncertainty - Uncertainty represents a lack of knowledge about factors affecting exposure/toxicity assessments and risk characterization and can lead to inaccurate or biased estimates of risk and hazard. Some of the types of uncertainty include scenario uncertainty, parameter uncertainty, and model uncertainty.

Uncertainty analysis - A detailed examination of the systematic and random errors of a measurement or estimate (in this case a risk or hazard estimate); an analytical process to provide information regarding the uncertainty.

Uncertainty Factor (UF) - One of several, generally 10-fold factors, used in operationally deriving the RfD and RfC from experimental data. UFs are intended to account for (1) the variation in sensitivity among the members of the human population; (2) the uncertainty in extrapolating animal data to humans, i.e., interspecies variability; (3) the uncertainty in extrapolating from data obtained in a study with less-than-lifetime exposure to lifetime exposure, i.e., extrapolating from subchronic to chronic exposure; (4) the uncertainty in extrapolating from a LOAEL rather than from a NOAEL; and (5) the uncertainty associated with extrapolation from animal data when the data base is incomplete.

Unit Risk Estimate (URE) - The upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1μ g/L in water, or 1 $\mu g/m^3$ in air. The interpretation of unit risk would be as follows: if the water unit risk = 2 x 10^{-6} μg/L, 2 excess tumors may develop per 1,000,000 people if exposed daily for a lifetime to 1 μg of the chemical in 1 liter of drinking water.

Urban Scale Assessment - An air monitoring network designed to assess the overall, citywide conditions with dimensions on the order of 4 to 50 kilometers. This scale would usually require more than one site for definition.

V

Vapor - The gas given off by substances that are solids or liquids at ordinary atmospheric pressure and temperatures.

Variability - Refers to the observed differences attributable to true heterogeneity or diversity in a population or exposure parameter. Examples include human physiological variation (e.g., natural variation in body weight, height, breathing rate, drinking water intake rate), weather variability, variation in soil types and differences in contaminant concentrations in the environment. Variability is usually not reducible by further measurement of study, but it can be better characterized.

Volume Source - In air dispersion modeling, a three dimensional volume from which a release may occur (e.g., a gas station modeled as a box from which chemicals are emitted).

W

Watershed - The land area that drains into a stream; the watershed for a major river may encompass a number of smaller watersheds that ultimately combine at a common point.

Wind Rose - A graphical display showing the frequency and strength of winds from different directions over some period of time.

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