EPA-600/5-79-001e
February 1979

METHODS DEVELOPMENT FOR ASSESSING AIR POLLUTION CONTROL BENEFITS

Volume V

Executive Summary

by

David S. Brookshire, Thomas D. Crocker (Project Director),
Ralph C. d'Arge
University of Wyoming
Laramie, Wyoming 82071

Shaul Ben-David and Allen V. Kneese
University of New Mexico
Albuquerque, New Mexico 87131

William D. Schulze
University of Southern California
Los Angeles, California 90007

USEPA Grant #R805059010

Project Officer
Dr. Alan Carlin
Office of Health and Ecological Effects
Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C. 20460

OFFICE OF HEALTH AND ECOLOGICAL EFFECTS
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

DISCLAIMER

This report has been reviewed by the Office of Health and Ecological Effects, Office of Research and Development, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

PREFACE

This project was initiated in the late fall of 1976 when Drs. Alan Carlin and Roger Cortesi of the USEPA wished to consider the contributions economic analysis might make to assessing the values of EPA's environmental improvement programs. Both men made numerous useful suggestions in the early stages of the project. Dr. Carlin has been a uniquely valuable project officer. He has prodded when prodding (in retrospect) was necessary, has offered encouragement at times when discouragement reigned, and has been a useful technical critic. In short, he has been a highly valued colleague.

In addition to the principal investigators, many individuals have contributed research studies for this project. These include Dr. Richard M. Adams of the University of Wyoming; Drs. Maureen L. Cropper and W. Russell Porter of the University of California, Riverside; and Drs. Robert A. Jones and John G. Riley of the University of California, Los Angeles. Mr. Narongsakdi Thanavibulchai of the University of Wyoming, Dr. Mark A. Thayer of the University of New Mexico, and Mr. Berton J. Hansen of the University of California, Riverside, have also made substantive written research contributions. Mr. Barry Ives and Ms. Kris Kirshner of the University of New Mexico; Mr. Larry Eubanks and Dr. Robert L. Horst, Jr., of the University of Wyoming; and Dr. Osman Bubik of the University of the Bosphorus (Turkey) have contributed their analytical and their organizing talents.

Many research assistants have put in almost countless hours in data collection, preparation and collation. These are, from the University of Wyoming, John Accardo, Rex Adams, Curt Anderson, Julie Berglund, Tony Fest, Steve Furtney, Clive Jones, David Livingston, Mike Miller, Stephanie Morrow, Bulent Paker, Morteza Rahmathan, and Mohammed Saidi; and from the University of New Mexico, David Boldt, Kay Meyer, Lex Tysseling, John Tysseling, and Dolores Willett.

Drs. Dennis Aigner of the University of Southern California, Shelby Gerking of the University of Wyoming, Leon Hurwitz of the Department of Pharmacology at the University of New Mexico, Lester Lave of the Brookings Institution, Roland Phillips of the Department of Epidemiology at Loma Linda University, and Eugene Seskin and V. Kerry Smith of Resources for the Future have provided sound advice and cautions on various aspects of the epidemiological effort. None, however, are responsible for the results obtained.

Finally, Ms. Stephanie Morrow, Ms. Susan Pynn, Mrs. Wendy Clements, and Mrs. Levi Stephenson have provided efficient and timely administrative services.

ABSTRACT

The studies summarized by this volume represent original efforts to construct both a conceptually consistent and empirically verifiable set of methods for assessing environmental quality improvement benefits. While the state-of-the-art does not at present allow us to provide highly accurate estimates of the benefits of reduced human or plant exposure to air pollutants, these studies nevertheless provide a set of fundamental benchmarks on which further efforts might be built. These are: (1) many benefits traditionally viewed as intangible and therefore non-measurable can, in fact, be measured and be made comparable to economic values as expressed in markets; (2) aesthetic and morbidity effects may dominate the measure of benefits as opposed to previous emphases on mortality health effects; and (3) the likely economic benefits of air quality improvements are perhaps as much as an order of magnitude greater than pevious studies had hypothesized.

CONTENTS

FIGURES

TABLES

Introduction

Benefit-cost analysis is a well established mode of applied economics extensively used for the evaluation of public investment projects. It is now also being employed increasingly to evaluate new technologies, scientific programs, and environmental policies. These applications present special difficulties. Before turning to these more explicitly, it will be useful to say a little about the history of benefit-cost analysis.

The technique was developed initially to evaluate water resources investment made by the federal water agencies in the United States, principally the United States Bureau of Reclamation and the United States Army Corps of Engineers. The general objective of benefit-cost analysis in this application was to provide a useful picture of the costs and gains from making investments in water development. The intellectual "father" of benefit-cost analysis is often said to be the 19th Century Frenchman, Jules Dupuit, who in 1844 wrote a study "On the Measure of the Utility of Public Works." In this remarkable article he recognized the concept of consumers surplus and saw that consequently the benefits of public works are not necessarily the same thing as the direct revenues that the public works projects will generate.

Early contributions to development of benefit-cost analysis as a practical technique generally did not come from the academic or research communities but rather from government agencies. The agencies responsible for water development in this country have for a long time been aware of the need for economic evaluation of projects. In 1808 Albert Gallatin, Jefferson's Secretary of the Treasury, produced a report on transportation programs for the new nation. He stressed the need for comparing the benefits with the costs of proposed waterway improvements. The Federal Reclamation Act of 1902 which created the Bureau of Reclamation and was aimed at opening western lands to irrigation required economic analysis of projects. The Flood Control Act of 1936 proposed a feasibility test based on classical welfare economics which requires that the benefits to whomsoever they accrue must exceed costs. In 1946 the Federal Interagency River Basin Committee appointed a subcommittee on benefits and costs to reconcile the practices of federal agencies in making benefit-cost analyses. In 1950 the subcommittee issued a landmark report entitled "Proposed Practices for Economic Analysis of River Basin Projects." While never fully accepted either by the parent committee or the federal agencies, this report was remarkably sophisticated in its use of economic analysis and laid an intellectual foundation for research and debate which set it apart from other major reports in the realm of public expenditures. This document also provided general guidance for the routine development of benefit-cost analysis of water projects which persists to the present day.

Even while the benefit-cost technique was limited largely to the relatively straightforward problem of evaluating water resources investments there was much technical debate among academic economists about the proper way of handling both empirical and conceptual difficulties with the technique. Some of the discussion surrounded primarily technical issues, e.g. ways of computing consumer surplus and how best to estimate demand functions for various outputs. Others were more clearly value and equity issues, e.g., whether the distribution of benefits and costs among individuals needed to be accounted for or whether it was adequate to consider only aggregates, and what is the appropriate rate of time discount to use on water projects.

Benefit Analysis and the New Generation of Environmental Problems

The next large task of environmental regulation in this country is to manage the flow of toxic and hazardous materials into our environment in some socially optimum manner. To the extent that this effort is to be aided by explicit benefit-cost analyses, the capabilities of the technique will be stretched to its limits. Both the empirical and value issues which have existed in the traditional water resource applications are aggravated. While water resource applications often involve the evaluation of public goods (in the technical economic sense of goods exhibiting jointness in supply) the bulk of outputs pertain to such things as irrigation, navigation, flood control and municipal and industrial water supplies which usually could be reasonably evaluated on the basis of some type of market information. In the newer applications we are dealing almost entirely with public goods where market surrogates are much more difficult to establish. The problem of finding justifiable monetary values, on outcomes of the projects or regulatory decisions is a very difficult one.[1/] In most instances there will be two central questions: How does one obtain a dose-response function, and what value does one place on risks to life, health, and aesthetic phenomena?

The research efforts reported in the four volumes synthesized in this executive summary represent a variety of attempts to elevate the state-of-the-art in assessing the benefits of environmental quality enhancement. There are two primary areas of emphasis. First, new experimental techniques for measuring the value of air quality improvements and other environmental amenities are developed and tested for a specific area, the South Coast Air Basin of southern California. However, the study of the South Coast Air Basin is not holistic in that some types of effects such as oxidant damage to materials and forests have not been evaluated. Second, the analytical and empirical methods of economics are used to develop hypotheses on disease etiologies and to value labor productivity and consumer losses due to air pollution-induced mortality and morbidity. Since the major focus for each area of emphasis has been on methodological development and experimentation, all the reported empirical results are only properly regarded as tentative and ongoing rather than definitive and final. For policy applications, these results require further refinement. Nevertheless, these results do suggest that previous commentaries may have substantially underestimated the economic losses caused by the aesthetic and the morbidity impacts of air pollution, and, by implication, benefits of improvements inair quality. We turn first to what we call the epidemiology experiments.

Epidemiology Experiments

Volume I focuses on developing methodology for valuing the benefits to human health associated with air pollution control. Air pollution may affect human health in three ways: (1) by increasing mortality rates; (2) by increasing the incidence and severity of chronic illness (morbidity); and (3) by increasing the incidence and severity of acute illness (morbidity).

A number of approaches for determining health effects and valuing them in economic terms are developed within the study. First, if a dose-response relationship is known between mortality rates and air pollution or between days lost from work due to illness (productivity loss) and air pollution, economic losses can be approximated. In the former case, one must know how consumers value increased safety. Thus, if air pollution control reduces risk of death from air pollution related disease, studies of the value consumers place on safety in other situations -- on the job, in transportation, etc. -- can be applied to measuring the benefits of pollution control programs. Note, however, that valuing safety for small changes in risk is very different from the alternative of valuing human life through lost earnings. The latter approach is rejected in this study. Rather, the focus is on examining the value of safety to individuals. That is, how much are consumers willing to pay for the reduced risks to health obtained through pollution control? For morbidity losses, lost time from work and lost productivity during hours of work can be relatively easily valued by using observed wage rates.

A second approach for valuing the effects of air pollution on human health is to attempt to observe the direct effect of air pollution on economic factors, thus avoiding the necessity of developing dose-response relationships. If one can develop relationships employing data on wages, wealth, and socioeconomic and health status characteristics as well as pollution exposures, consumer willingness to pay to avoid illness can be derived. We term this second methodology the willingness to pay approach. It is based on traditional macroeconomic theory.

In regard to these approaches two experiments were conducted. First, a data set on sixty U.S. cities was explored to determine if some of the problems of aggregate epidemiology -- epidemiology using aggregate data on groups of individuals as opposed to data on individuals -- can be overcome. The study attempted to estimate a human dose-response expression in which 1970 city-wide mortality rates for major disease categories are statistically associated with population characteristics such as doctors per capita, cigarettes per capita, information on dietary patterns, race, age, and air pollution. The study is unusual in two respects. First, it is the first aggregate epidemiological study of the effect of air pollution on mortality to include dietary variables, which along with smoking and medical care, prove to be highly significant statistically. Second, the study accounts for the fact that human beings will attempt to adjust to disease by seeking out more medical care. Thus, cities with higher mortality rates are likely to have more physicians per capita. This adjustment process has in the past prevented an estimate of the direct effect of physicians on the prevention of disease. An estimation technique capable of accounting for the actual contribution medical care makes to reducing mortality rates is employed. The impact upon the analysis of including these new variables and employing the heretofore epidemiologically unused estimation technique is striking. In fact, the total effect of air quality on mortality is about an order of magnitude smaller than other estimates.[2/] Rather small but important associations are found between pneumonia and bronchitis and particulates in air and between early infant disease and sulfur dioxide air pollution. The direction of the associations which were found among all the variables are shown in Table 1.

The sixty city study does, however, have a number of remaining problems. These incluse biases introduced by using aggregate as opposed to individual data, the exclusion of data on radiation, exercise, and migration of individuals between cities, and the possibility that individuals may die from combinations of causes.

Given these qualifications, it is possible to construct benefit measures using the methodology briefly summarized in Table 2.

First, to obtain national estimates, it is necessary to know the population at risk. Since the sixty city sample is entirely urban, and since toxic air pollution is principally an urban problem, a population at risk for 1970 of 150 million urban dwellers was used. As a range for the value of safety, Thaler and Rosen's (1975) estimate of $340,000 (in 1978 dollars) was used as a lower bound and Smith's (1977) estimate of $1,000,000 as an upper bound. Finally, to provide an estimate of reduced risk from air pollution control, an average 60 percent reduction in ambient urban concentrations was assumed for both S02 and particulates. Then, using the mean concentration of these pollutants in the sixty city sample as a basis for calculation, it was possible to derive the average reduction in risk of pneumonia mortality for a 60 percent reduction in particulates and the average reduction in risk of infant diseases for a 60 percent reduction in S02 from the estimated dose-response functions for these diseases.

Multiplying the population at risk by the assumed value of safety and then by the <u>average</u> reduction in risk given a crude approximation of the benefits for a 60 percent reduction in national urban ambient concentrations of particulates and S02 respectively. National urban totals and the value of the average individual risk reduction are shown in Table 3.

The second major experiment focused on morbidity rather than mortality. It employed data on the health and the time and budget allocations of a random sampling of the civilian population nationwide. The sample, which was collected by the Survey Research Center of the University of Michigan, consisted of approximately 5,000 heads of households for nine years starting in 1967. Generalized measures of acute illness, stated in terms of annual work-days ill, and chronic illness, stated in terms of years of illness duration, were available. The measures of illness were substantially less than ideal. For example, individuals who died between the reference year

Table 1

Summary of Two-Stage Linear Estimates of Factors in Human Mortality
Hypotheses not Rejected at the 97.5% Confidence Level
(One-tailed t-test, t $\geq$ 2.0)

Variable (Sign of Hypothetical Effect)		Total Mortality Rate	Vascular Disease	Heart Disease	Pneumonia and Influenze	Emphysema and Bronchitis	Cirrhosis	Kidney Disease	Congenital Birth Defects	Early Infant Diseases	Cancer
Doctors/Capita*	(-)	-	-	-		-		-			-
Median Age	(+)	+	+	+	+		+	+			+
% Nonwhite	(+)	+		+			+	+		+	+
Cigarettes	(+)	+	+	+							+
Room Density	(+)	+			+		+	+			
Cold	(+)	+			+						+
Animal Fat	(+)			+							
Protein	(+)	+				+					+
Carbohydrates	(?)					-					
NO_2	(+)										
SO_2	(+)									+	
Particulates	(+)				+						
R^2		.82	.60	.77	.54	.39	.64	.54	.22	.55	.86

*Two-stage estimator employed.

Table 2

Methodology for Health Benefits Assessment

Benefits = (Population at Risk) x (Value of Safety) x (Reduction in Health Risk)

<u>Value of Safety Based on Consumer's Willingness to Pay</u>

Low estimate:	$340,000
Source:	Thaler & Rosen (1975)
High estimates:	$1,000,000
Source:	Robert Smith (1977)

Table 3

Urban Benefits from Reduced Mortality:
Value of Safety for 60 Percent
Air Pollution Control

Disease	Pollutant	Average Individual Safety Benefit (1978 Dollars/Year)	National Urban Benefits (1978 Billion Dollars/Year)
Penumonia	Particulates	29 - 92	4.4 - 13.7
Early Infant Disease	SO_2	5 - 14	.7 - 2.2
Total		34 - 106	5.1 - 15.9

of the interview and the time of the interview are not included, and years of illness duration are defined in terms of dissimilar multiples of years rather than the actual number of years.

For most of the dose-response expressions estimated in this part of the study, air pollution appears to be significantly associated with increased time being spent acutely or chronically ill. Air pollution, in addition, appears to influence labor productivity, where the reduction in productivity is measured by the earnings lost due to reductions in work time and effort. The reduction in productivity due to air pollution-induced chronic illness seems to be much larger than any reductions due to air pollution-induced acute illness.

Figure 1 is a hueristic representation of the structure forming the basis of our estimate of potential labor productivity gains from air pollution control. Air pollution is viewed as increasing directly both chronic and acute illness. In addition, it causes an indirect increase in acute illness via its positive effect on chronic illness. Acute illness reduces hours worked, but, because of its passing nature, it has no impact upon the worker's long-term productivity that determines the level of his wages. However, chronic illness, which does reduce long-term productivity, exerts a direct negative influence on both wages and hours worked. It also influences hours worked in an indirect manner through its effect upon wages.

Table 4 is a succinct list of the major assumptions underlying our empirical implementation of the structure depicted in Figure 1 and its extrapolation to a national aggregate. We divide these assumptions into four classes: specification, measurement, estimation, and aggregation. The table also indicates the probable direction of bias, if any, the assumption introduces. However, we do not now know the sensitivity of our estimates and calculations to any particular assumption or to the entire set of assumptions. Upon reviewing Table 4, the judicious reader will immediately become aware that our listing is sufficiently strenuous to raise some questions about whether our estimates and calculations are yet sufficiently compelling to warrant their serious use.

In spite of the lengthy listing of assumptions, we emphasize that our treatment of the system in Figure 1 has several positive distinguishing features. To balance any negative impressions established from Table 4, we list these positive features in Table 5. Our estimates of the system in Figure 1 are presented in Volume I, Table 6.3. As a result of a one-unit (ug/m3) increase in air pollution utilizing the relationships in Table 6.3, we estimate that the representative person will have his annual work hours reduced by 0.547 hours. Of this reduction, only 0.046 hours will be due to acute illness. The loss in labor productivity suffered by this person can be calculated by (where ^ stands for change):

$$\frac{\Delta(\text{Work hours} \quad \text{Wage})}{\Delta(\text{Pollution})} = \frac{\Delta(\text{Work hours})}{\Delta(\text{Pollution})} \cdot \text{Wage} + \frac{\Delta(\text{Wage})}{\Delta(\text{Pollution})} \cdot \text{Work hours}$$

Upon performing this calculation, we obtain:

$$= (0.547)(\$3.225) + (\$0.071)(1560.895)$$
$$= \$2.86.$$

Figure 1

A Representation of the Effect of Air Pollution
Upon Labor Productivity

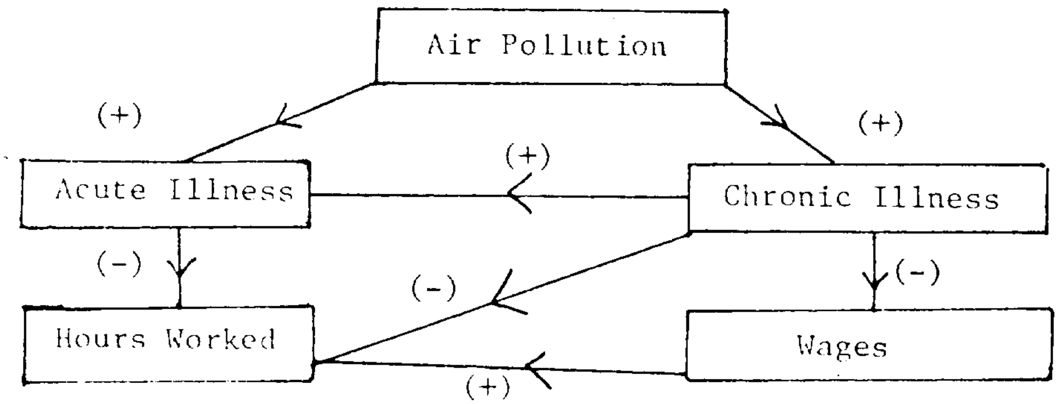

Table 4

Major Assumptions Limiting Generality of Results

Specification

1. Air pollution affects only the duration of chronic illness. Our inattention to the severity of chronic illness tends to reduce the estimated impact of air pollution on labor productivity.

2. Occupational exposures to hazards and environmental pollutants other than air pollution do not influence either acute or chronic illness. If air pollution is moderately and positively associated with these hazards and polutants, this assumption tends to increase the estimated impact of air pollution on labor productivity.

3. Annual geometric mean ambient concentrations of total suspended particulates serve as an adequate proxy for all forms of air pollution. The effect of this assumption upon the estimated effect of air pollution on labor productivity is unknown.

4. All relationships depicted in Figure 1 are linear. It is unknown what effect this assumption has on the estimated effect of air pollution on labor productivity.

5. Air pollution-induced health effects do not cause the voluntary substitution of leisure for work. This assumption tneds to reduce the estimated impact of air pollution on labor productivity.

Measurement

6. Air pollution exposures for each individual in the sample are adequately represented by a single annual average of ambient concentrations obtained at a single monitoring station within the individual's county of residence. Since pollution monitoring stations in the early part of the 1970's were predominantly in downtown urban locations, individuals' air pollution exposures probably tend to be exaggerated. This will reduce the estimated health effects of air pollution.

7. The duration of any air pollution-induced chronic illness cannot exceed ten years. This will reduce the estimated effect of air pollution upon the duration of chronic illness.

8. Housewives, retirees, and students, who together constitute about twenty percent of our samples, do not contract air pollution-induced acute illnesses. This assumption will tend to reduce the estimated impact of air pollution upon labor productivity.

9. Air pollution-induced chronic and acute illnesses are a constant proportion of all illnesses. The effect of this assumption is unknown.

(continued)

Table 4

(continued)

10. The quality of preventive and ameliorative medical care an individual consumes is adequately measured by whether or not he has medical insurance. This assumption has an unknown effect upon our estimates.

11. Relative air pollution concentrations across the U.S. have been fairly constant. This assumption has an unknown effect upon our estimates of air pollution-induced chronic illness.

12. When interviewed, the individuals in the sample had no incentive to bias their answers nor did they have difficulty accurately recalling their personal medical histories of the previous twelve to sixteen months. The effect of this assumption upon our estimates is unknown.

13. No individual who would otherwise have been included in the sample died between the time for which information was to be gathered and the time of the interview. In fact, about five percent of the potential respondents died each year. The effect of this assumption is to reduce the effects of air pollution upon labor productivity.

Estimation

14. With the available data, classical linear regression procedures provide consistent and unbiased estimates of the structure depicted in Figure 6.1. The effect of this assumption upon our estimates is unknown.

Aggregation

15. The response of the health state of each individual in the U.S. to any given change in ambient air pollution is a constant. The effect of this assumption upon the calculation for the aggregate effect of air pollution upon labor productivity is unknown.

16. The response of the health state of every individual in the U.S. to ambient air pollution changes is identical. The effect of this assumption upon the calculation for the aggregate effect of air pollution upon labor productivity is unknown.

Table 5

Distinguishing Features that Enhance the Generality of Results

1. The acute illness and chronic illness dose-response estimates used to calculate the aggregate impact of air pollution-induced morbidity upon U.S. labor productivity are representative of estimates obtained from many different independent samples drawn from the same data set. In effect, substantial quasi-replication of the dose-response estimates has been performed.

2. The system is estimated only for people who have always lived in one state. We believe this restriction enhances the extent to which we capture the effect of the history of air pollution exposures upon the chronic illness dose-response function.

3. Our estimated expressions for wages and hours worked are very similar to those obtained by other economists.

4. We include more information on life-styles and genetic and social endowments than is usually included in dose-response expressions estimated from epidemiological data.

That is, a one-unit reduction in air pollution would have increased this representative person's 1970 earnings by $2.86. Only $0.15 of this sum represents the gain from a reduction in acute illness.

The above $2.86 sum represents our "best" estimate at this point of the representative person's gain in 1970 earnings from a one-unit reduction in air pollution. Lower and upper bounds for this estimate can be established by making use of the confidence intervals for the effect of pollution on chronic and acute illness; that is, we wish to calculate the gain in earnings when the pollution coefficient in Table 6.3, equation 1 is 0.0028 + 0.0011, and when the pollution coefficient in equation 2 is 0.623 + 0.317. At least for the chronic illness expression, this confidence interval captures nearly all the range of the values for the pollution coefficients estimated in twelve different chronic illness expressions, each of which was estimated from a separate sample. Upon performing this calculation for the lower bound, we obtain $1.88, and for the upper bound, we obtain $3.84.

Assume that the average exposure of the U.S. 1970 urban population to annual geometric mean total suspended particulates was 100 ug/m3 and that the standard deviation of these exposures was 30 ug/m3. Throughout this study, total suspended particulate measures have been highly correlated with other air pollutants so that total suspended particulates probably serve as an adequate proxy for all air polution. Further assume that the national urban population is approximately 150 x 10 6 people, of whom 75 percent, or 112.5 x 10 6, are 16 years or older. At age 16, each of these adults has a lifespan of 56 years and any air pollution induced chronic illnesses he contracts are distributed rectangularly over the 56 years. The annual earnings he loses due to the presence of an acute or chronic illness do not vary over the 56 years.

If the medium household size is 2.0, there are then 56.25 x 10 6 urban household heads. There is thus a $160.88 x 10 6 = ($2.86) (56.25 x l0 6) gain in the labor productivity for household heads from a one unit reduction in air pollution.

If two-thirds of the household heads are married, if 35 percent of these households have working wives, and if working wives earn 60 percent as much as their male counterparts, there would then be a $22.58 x 10 6 = ($2.86) (0.6) (13-13 x 10 6) gain in the labor productivity of working wives.

If the value of household services provided by all household members in each urban household is 40 percent of the market earnings of the household head, there would then be a $64.35 x 10 6 = ($2.86) (0.4) (56.25 x 10 6) gain in the household labor productivity of all urban households. Adding the results for household heads, working wives, and household labor, we obtain a $247.81 x 10 6 gain in labor productivity for a one unit reduction in air pollution. A 60 percent reduction in 1970 air pollution would then, in August 1978 dollars, increase the value of 1970 urban labor productivity by $25.28 x 10 9 dollars. This "best" estimate and its upper and lower bounds are presented in Table 6. Most of the gain would accrue due to reductions in air pollution-induced chronic illness. If one performs

Table 6

Estimated Aggregate Gains in 1970 U.S. Urban Labor Productivity Due to a 60 Percent Reduction In Air Pollution

(August 1978 Dollars)

	Aggregate
Lower Bound	16×10^9
"Best" Estimate	25×10^9
Upper Bound	34×10^9

these identical calculations in precisely the same fashion for a 1977 U.S. total population of 216.1 x 10^6, one obtains a "best" estimate of \$36.4 x 10^9.

It must be strongly emphasized that the magnitudes exhibited in Table 6 are extremely sensitive to the assumptions we have made. Nevertheless, given any reasonable set of assumptions about air pollution exposures, size of the population exposed, etc., the estimates of labor productivity gains in Table 6 are much larger than previous estimates of all types of annual gains from air pollution control in the United States. No gains in labor productivity, via reductions in air pollution-induced health effects, have previously been developed. It thus appears that the economic gains from the morbidity reduction effects of air pollution control may have been greatly undervalued, perhaps because most prior research efforts have concentrated upon mortality rather than morbidity.

The South Coast Air Basin Urban Experiment

The South Coast Air Basin of southern California was selected to test some benefit measures of air pollution control. In this case both health and aesthetic considerations were involved. For the household sector, two rather distinct approaches to valuation of environmental quality have emerged from recent research. The first involves the analysis and observation of how some pertinent actual market prices, such as real property prices, are influenced by environmental quality attributes. The second tries to induce individuals to reveal directly their actual preferences, in monetary terms, for environmental attributes. Clearly, there should be a well-defined relationship between what people do pay through differences in property values and what they say they will pay, provided there are no incentives for them to distort their bids. New survey techniques include ways of testing whether there are distortions in what people say they will bid.[3/]

During the past few decades, in general, air quality in the Los Angeles area has deteriorated substantially. However, in some neighborhoods deterioration has been slight, e.g., communities adjacent to the Pacific Ocean, while in others, the deterioration has been relatively severe as measured by concentrations of N02 or total oxidants. The researchers believed the Los Angeles are, therefore, would be a good location to make test comparisons of the effects of air quality on housing prices and individual stated preferences where the comparisons could be contained within a single large metropolitan area.

The South Coast Air Basin urban experiment consisted of an attempt to value air quality through examination of differences in property values and through an interview survey instrument designed to elicit willingness to pay for improved air quality.

Six pairs of neighborhoods were selected for comparison purposes. The pairings were made on the basis of similarities of housing characteristics, socioeconomic factors, distance to beach and services, average temperature, and subjective indicators of the "quality" of housing. Thus, for each of the pairs, an attempt was made to exclude effects on property values other than differences in air quality. A survey of randomly selected residents of single-family dwellings was then conducted for each paired neighborhood to discover attitudinal preferences and valuation responses.

A naive statistical comparison of these paired neighborhoods indicates that property value differentials between poor and fair air quality locales may be as high as $140 per month per household. Utilizing more advanced economic models, which better take into account factors other than pollution such as distance to ocean and differences in tastes which may influence property values, willingness to pay inferred from the property value differentials is about $40 per month. As a reasonably comparable estimate, the survey results,showed an average bid of slightly less than $30 per month. Thus, there is comparability between the magnitudes obtained between the survey and property value study estimates. Given various assumptions on income, location, aggregation by areas, specific housing characteristics, and knowledge on the health effects of air pollution, both the survey and property value studies will yield estimates ranging from $20 to $150 per month per household. These preliminary results indicate that air quality deterioration in the Los Angeles area has had substantial effects on housing prices and that these negative price effects on housing are comparable in magnitude to what people say they are willing to pay for improved air quality.

Crude estimates can be made to deduce willingness to pay for improved air quality throughout the South Coast Air Basin. Difficulties are encountered in making data sets or groups of diverse individuals exactly comparable. Differences are observed between the survey and property valuation groups in average income, age (the mean age in the survey exceeded 42 years) and other socioeconomic factors. These differences have not been controlled for in the following estimates of the aggregate willingness to pay for air quality improvement in the South Coast Air Basin.

In Table 7 are recorded estimates of monthly bids by households and, by aggregation, estimates of the benefits for an approximate 30 percent improvement in air quality within the South Coast Air Basin. It should be noted that these experimental measures, while reflecting approximate valuations, need further refinement before they can even cautiously be applied to environmental policymaking. Nevertheless, they do suggest that dollar benefits from an improvement in air quality in the South Coast Air Basin are very large.

From the methodological standpoint it appears from these preliminary results and comparisons that survey studies will tend to give a lower valuation of air quality improvement than observations based on what happens in an extremely volatile property market. However, only after substantial further statistical examination and comparability checks between the two methods will the researchers be able to state unequivocably how these relationships may turn out. The results compiled in this study, however, suggest that survey instruments, when compared to property value techniques, provide a reasonable mechanism to obtain environmental quality benefit estimates. The survey approach has the advantages that: (1) data can be

Table 7

Alternatives Estimates of Monthly Bids by Household, and Aggregate Benefits for Air Quality Improvement in the South Coast Air Basin

(Approximate 30 Percent Improvement in Ambient Air Quality)

	1977 Dollars		
	Property Value Study		Survey Study
	Paired Communities	Calculated Marginal Willingness to Pay*	Mean Bid
Bid per household per month (in dollars)	$135	$42**	$29***
Annual benefits (in billions of dollars) (selected areas and groups of the South Coast Air Basin)	$3.96	$.95	$.65

*This benefit calculation is considered an improvement over the paired sample approach since explicit account is made for a number of housing and neighborhood variables not captured in the paired communities comparison.

**Best estimate. The possible range is $26-63 per month.

***Based on maximum total bid with an adjustment for the number of years to achieve improvements in air quality.

collected at low cost on specific environmental problems (the investigator is not tied to the availability of existing data sets); and (2) benefit measures can be disaggregated across individuals and sources of benefits from various characteristics such as aesthetic experiences and perceived health can be obtained.

As a final caution, it should be kept in mind that the South Coast Air Basin studies were conducted in an area where individuals have both an exceptionally well-defined pollution situation that they have experienced and a well-developed property value market for clean air. The effect of clean air on property values, and in turn, on the degree to which people are aware of increased housing prices in high air quality areas appears to be exceptionally well specified at this time in the South Coast Air Basin. Also worthy of note is that 1970 property values on the basis of earlier studies have shown a much weaker association with.air quality than those that were obtained utilizing the 1977-78 air quality data set used here. We feel that this change reflects a substantial shift in interest and concern over air quality for this regional population. Therefore, it should be recognized that the results of this experiment may well not generalizable to other situations where the environmental commodity, i.e., air quality, is not so well specified, either through actual market prices or human perception.

The South Coast Air Basin Agricultural Experiment

The fact that air pollution can damage vegetation has been well documented. Procedures for the measurement of the economic costs associated with these damages, however, have not been clearly defined. The primary purpose of the agricultural assessment component of the research effort is to address and remove some conceptual and empirical limitations of past studies dealing with economic damages to agricultural crops arising from air pollution. Specific objectives included: (1) the conceptualization of an analytic framework for measuring economic damages to agricultural crops; (2) application of this framework to an actual production region with poor ambient air quality - namely southern California; and (3) measurement of agricultural damages for a selected group of 14 annual crops within this region.

A detailed review of the economic damage assessment literature for agricultural crops revealed some conceptional weaknesses inherent in previous studies. These weaknesses pertain to potential effects on both production and consumption of agricultural commodities. From the standpoint of consumption, a major issue is possible changes in prices of a commodity due to the adverse effects of air pollution. That is, if air pollution damages are widespread or if agricultural production of specific commodities is concentrated in areas of high pollutant levels, as is the case for many vegetable crops, then reductions in yield due to air pollution may translate into changes in respective commodity prices at the local and national retail level.

The analytical framework proposed in this study, while by no means definitive, includes price effects directly in the measurement of damages. Also, the "comparative advantage" nature of the analysis allows for a wider range of potential producer strategies in the face of rising levels of pollutants. The output provides an approximation of the net distributional effects of changes in air pollution.

The research reported in Volume III provides a detailed discussion of the analytical framework. Yield-response relationships measuring the decrease in yield due to levels of pollutants and the price-forecasting equations quantifying the increase in consumer prices accompanying a yield decrease are evaluated. The fact that yield reductions within southern California may increase retail prices at the national level is due to the importance of southern California in the overall production of selected crops, such as fresh vegetables on a seasonal basis.

The results of the assessment to date cover only the consumer effects of southern California oxidant pollution, and then only for twelve vegetable crops (beans, broccoli, cantalopes, carrots, cauliflower, celery, lettuce, fresh and processed onions, potatoes and fresh and processed tomatoes) and two field crops (cotton and sugar beets). Total annual economic losses for each year in the period 1972 through 1975 averaged $15 million. In 1976, the loss fell to $11 million. Ninety-nine percent of the 1976 losses are attributable to four crops: celery (68%); fresh tomatoes (12%); potatoes (10%); and cotton (9%). Similar proportions were obtained for 1972-1975.

From a policy standpoint, the results are perhaps most meaningful in terms of distributional effects. These results represent damages or costs borne by all consumers (nationwide), through the higher prices each must pay for these crops. The effects of air pollution are therefore felt even by those individuals not residing in areas of high pollution.

Related Studies

The research presented in Volume IV explores various facets of the two central project objectives: the development of new experimental techniques for measuring the value of improvements in environmental quality; and the use of macroeconomic methods to develop hypotheses on disease etiologies, and to value labor productivity and consumer losses due to air pollution-induced mortality and morbidity. The emphasis is on factors that are not completely treated in previous volumes. The valuations developed in the previous volumes were all based on a partial equilibrium framework; that is, economic events are assumed to be isolated from each other. W.R. Porter considers the adjustments and changes in underlying assumptions these values would require if they were to be derived in a more general framework. In a second theoretical paper, Robert Jones and John Riley examine the impact upon the aforementioned partial equilibrium valuations of variations in consumer uncertainty about the health hazards associated with various forms of consumption.

Two empirical efforts conclude the volume. M.L. Cropper employs and empirically tests a new model of the variations in wages for assorted occupations across cities in order to establish an estimate of willingness to pay for enviromental amenities. The valuation she obtains for a 30% reduction in air pollution concerntrations accords very closely with the valuations reported in the earlier volumes.

The volume concludes with a report of a small experiment by W.R. Porter and B.J. Hansen intended to test a particular way to remove certain biases that bidding game respondents have available to distort their true valuations.

All of these studies tend to qualify the results of the experimental procedures discussed in earlier volumes. In addition to assorted empirical weaknesses, further research will require: (1) an adequate specification of the mobility decision in response to degraded air quality; (2) consideration of relative price changes not directly related to air pollution as set forth in Volume II and discussed by Porter; and (3) the manner in which consumers evaluate a multitude of risks simultaneously, both in eating habits and pollution exposures where their economic and physical losses are uncertain.

General Conclusions

This compliation of studies represents original efforts to construct both a conceptually consistent and empirically verifiable set of methods for assessing benefits of environmental quality improvement. While the state-of-the-art does not at present allow us to provide highly accurate estimates of the benefits of reduced human or plant exposure to air pollutants, it is intended to provide a set of fundamental benchmarks. These are: (1) many benefits traditionally viewed as intangible and thereby non-measurable can, in fact, be measured and be made comparable to economic values as expressed in markets; (2) aesthetic experiences and morbidity (illness) effects may dominate the measure of benefits as opposed to previous emphases on mortality health effects; and (3) the likely economic benefits of air quality improvements are perhaps as much as an order of magnitude greater than previous studies had hypothesized.

The researchers in this study have viewed man as a purposeful, if imperfectly informed, individual who chooses to respond to both well-defined market and non-market characteristics of his/her environment. In each experiment we have discovered that he attempts to respond to the deleterious effects of air pollution. These reponses have provided at least a partial roadmap toward identifying how he values the environment in which he must always live.

EXECUTIVE SUMMARY

FOOTNOTES

1/ Other major problem areas are as follows:

First, such matters as nuclear radiation and toxic materials relate to exposure of the whole population or large sub-population to very subtle influences of which they may be entirely unaware. It is difficult to know what normative value individual preferences have under these circumstances.

Second, we are in some cases dealing with long lived effects which could extend to hundreds of thousands of years and many, many human generations. This raises the question of how the rights and preferences of future generations can be represented in this decision process. Realistically, the preferences of the existing generation must govern. The question is whether simple desires of existing persons are to rule or whether it is necessary to persuade the present generation to adopt some ethical rule or rules of a constitutional nature in considering questions of future generations. Such a proposed rule is found in Rawls (1971). Another, related, question of great importance is whether it is legitimate to discount benefits and costs over these long periods thus effectively ruling out the future beyond a relative few years, and if it is legitimate what the proper rate is.

These issues are being studied by several members of the team that produced the research sketched in this paper under a grant from the National Science Foundations's Ethics and Values in Science and Technology program.

2/ See, for example, Lave and Seskin (1977).

3/ For example one possible form of bias is known as “starting point bias." This is the possibility that the final bid will be influenced by the starting bid suggested by the interviewers -- the higher the latter the higher the former. A test for this is to start with several different initial bids for different interviewees and then test to see whether the final bids are different in a statistically significant sense. Such tests indicated that starting point bias was not a large problem in the research reported here.

REFERENCES

Lave, L. and E. Seskin, Air Pollution and Human Health, Baltimore: Johns Hopkins University Press (1977).

Rawls, J., A Theory of Justice, Cambridge: Harvard University Press (1971).

Smith, R., "The Feasibility of an 'Injury Tax' Approach to Occupational Safety," Law and Contemporary Problems, (Summer-Autumn, 1974).

Thaler, R. and S. Posen, "The Value of Saving a Life: Evidence from the Labor Market," in N.E. Terlecky J., (ed) Household Production and Consumption, Columbia University Press, New York (1975), 265-297.