EPA Document# EPA-740-R-24-006
November 2024
Office of Chemical Safety and
Pollution Prevention

United States
Environmental Protection Agency

Risk Evaluation for Asbestos
Part 2: Supplemental Evaluation Including Legacy Uses and Associated Disposals of Asbestos

CASRN 1332-21-4

November 2024

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

LIST OF APPENDIX FIGURES

ACKNOWLEDGEMENTS

The Assessment Team gratefully acknowledges the participation, input, and review comments from U.S. Environmental Protection Agency (EPA or the Agency) Office of Pollution Prevention and Toxics (OPPT) and Office of Chemical Safety and Pollution Prevention (OCSPP) senior managers and science advisors. The Agency is also grateful for assistance from EPA contractors Battelle (Contract No. EPW16017), ERG (Contract No. 68HERD20A0002), ICF (Contract No. 68HERC19D0003), SpecPro Professional Services, LLC (Contract No. 68HERC20D0021), General Dynamics Information Technology, Inc. (Contract No. HHSN316201200013W), and SRC (Contract No. 68HERH19D0022). Special acknowledgement is given for the contributions of technical experts from EPA's Office of Research and Development (ORD), including Thomas Bateson and Leonid Kopylev, for their joint efforts.

As part of an intra-agency review, the Asbestos Part 2 Risk Evaluation was provided to multiple EPA Program Offices. Comments were submitted by EPA's Office of Children's Health Protection (OCHP), Office of General Council (OGC), ORD, and Office of Water (OW). The Asbestos Part 2 Risk Evaluation scope and approaches were discussed with the EPA Offices noted above, as well as other EPA Offices (Office of Air and Radiation [OAR], Office of Land and Emergency Management [OLEM], and Regional Offices) and outside federal stakeholders including the Mine Safety and Health Administration (MSHA), National Aeronautics and Space Administration (NASA), and United States Geological Survey (USGS).

Docket

Supporting information can be found in public docket, Docket ID: (EPA-HQ-OPPT-2021-0254).

Disclaimer

Authors: Collin Beachum, Jennifer Nichols (Management Leads), Brandall Ingle-Carlson, Emily Nolan, Laura Krnavek (Assessment Leads), Marcy Card, Todd Coleman, Ana Corado, Robert Courtnage, Juan Bezares Cruz, Peter Gimlin, Myles Hodge, Christelene Horton, Rachel McAnallen, J. Aaron Murray, Marlyn Rodriguez, Abhilash Sasidharan, Stephanie Schwarz, William Silagi, and Ryan Sullivan.

Contributors: Thomas Bateson and Leonid Kopylev.

Technical Support: Mark Gibson and Hillary Hollinger.

This risk evaluation was reviewed and cleared for release by OPPT and OCSPP leadership.

EXECUTIVE SUMMARY

EPA has evaluated asbestos under the Toxic Substances Control Act (TSCA). Asbestos is a naturally occurring fibrous silicate mineral. Although there are six types of fibers (chrysotile, crocidolite, amosite, anthophyllite, tremolite, actinolite), chrysotile is the only asbestos fiber type known to be currently imported, processed, or distributed for use in the United States. Asbestos was primarily used as a fire retardant in construction but has also been used extensively in manufacturing—including for use in diaphragms used to make chlorine and caustic soda, gaskets, brakes and other friction products, cement water pipes, and in building materials such as floor tiles, insulation (including on hot water and steam pipes), roofing and siding shingles, textured paint, and patching compounds—among other uses. Asbestos fibers known as fibrils can get in the air and eventually into a person's lungs, which may result in adverse health effects such as asbestosis (lung disease) and cancer including mesothelioma (cancer of the mesothelium, the thin tissue that lines many internal organs) as well as lung, ovarian, and laryngeal cancers.

When asbestos was selected for TSCA risk evaluation in December 2016, EPA conducted its initial risk evaluation on ongoing uses of chrysotile asbestos and excluded "legacy uses" (*i.e.,* uses without ongoing or prospective manufacturing, processing, or distribution for use) and "associated disposals" (*i.e.*, future disposal of legacy uses). In late 2019, a U.S. circuit court[1] held that EPA should not have excluded legacy uses or "associated disposals" from the evaluation. Examples of legacy uses include floor and ceiling tiles, pipe wraps, insulation, heat protective textiles containing chrysotile and other fiber types. Following this court ruling, EPA determined that the complete risk evaluation for asbestos would be issued in two parts. The final *Risk Evaluation for Asbestos Part 1: Chrysotile Asbestos* was released in December 2020. This document presents Part 2 of the risk evaluation of asbestos and focuses on supplemental analyses, including legacy uses of asbestos and associated disposals and talc containing asbestos.[2] Under the one-time asbestos reporting rule under TSCA section 8(a), exposure-related information—including information on the presence, types, and quantities of asbestos (including asbestos that is a component of a mixture) and asbestos-containing articles that have been manufactured (including imported) or processed—was provided to the Agency in 2024 and considered in the Part 2 Risk Evaluation consistent with TSCA sections 26(h), (i), and (k), 15 U.S.C. 2625.

The uses of asbestos evaluated in this Part 2 Risk Evaluation include a wide range of exposure scenarios and potentially exposed or susceptible subpopulations (PESS). One legacy use of asbestos is as a fire retardant in building materials, from which asbestos fibers can be released during construction, modification, or demolition of asbestos-containing materials (ACMs) in homes, schools, or commercial buildings. The indoor air assessment showed that asbestos containing building materials do not pose a risk if they are left undisturbed. However, exposure to asbestos can occur when (1) construction workers cut through pipes lined with asbestos, (2) do-it-yourself (DIY) home remodelers remove asbestos-containing ceiling tiles, and (3) fire fighters enter buildings with disturbed asbestos during an emergency. In contrast, asbestos present in undisturbed insulation in a school do not present asbestos exposure to students or teachers, as long as the asbestos remains undisturbed. Relevant uses of imported talc products that may contain asbestos that are subject to TSCA (*i.e.*, fillers and putties with talc containing asbestos and crayons with talc containing asbestos, but not, for example, talc-containing cosmetics that are not subject to TSCA) were also considered, but no reasonably available information

[1] See in *Safer Chemicals, Healthy Families v. EPA*, 943 F.3d 397 (9th Cir. 2019); note that the court upheld EPA's exclusion of "legacy disposals" (*i.e.,* past disposals).
[2] In addition to the final scope and this risk evaluation, EPA released the *White Paper: Quantitative Human Health Approach to be Applied in the Risk Evaluation for Asbestos Part 2 – Supplemental Evaluation including Legacy Uses and Associated Disposals of Asbestos* in August 2023. The White Paper focused on the quantitative human health assessment and dose-response considerations for Part 2 of the risk evaluation.

was identified to provide evidence that import of these products is ongoing. The PESS with greatest risk from asbestos exposure include those with occupational exposure, individuals exposed through DIY activities, children who may develop adverse health effects decades after asbestos exposure, and those who smoke or are especially susceptible to respiratory effects.

Asbestos Part 2 Unreasonable Risk to Human Health

Epidemiologic evidence indicates that exposure to asbestos is associated with a range of health effects including mesothelioma, lung, ovarian, and laryngeal cancers, as well as asbestosis and other non-cancer respiratory effects. EPA evaluated the risks of people experiencing these cancers and harmful respiratory effects from being exposed to asbestos via occupational exposure, "take-home" exposure (workers and others exposed to asbestos fibers that may have been transferred to their homes), people who conduct DIY projects that modify products that can release asbestos (such as home renovation projects that dismantle asbestos-containing tiles), and the general population with asbestos released into the environment (such as ACMs released during a structure fire or demolished in a nearby building). When determining unreasonable risk of asbestos to human health, the Agency also accounted for potentially exposed and susceptible subpopulations—workers, children, individuals exposed through DIY activities, and smokers (see Table 5-25).

The risks from asbestos stem from disturbing asbestos either through direct modification or proximity to the activity or associated materials. EPA expects that the highest asbestos exposure potential exists for workers involved with cutting, sanding, or grinding ACM on a regular basis; for example, construction workers routinely involved in demolition work (Section 5.1.1). Career fire fighters represent another occupationally exposed group that is at risk. Similarly, for take-home exposures, the highest asbestos exposure potential derives from workers with direct asbestos exposure who bring asbestos contaminated clothing back home and expose those cleaning and handling the garments (Section 5.1.2). Next, for consumers engaged in DIY projects, high concentrations of asbestos exposure may arise from activities such as home maintenance, large scale renovations, and removal activities involving asbestos-containing products when modified through sanding, grinding, drilling, etc. (Section 5.1.4). In contrast, general population exposures to asbestos increase with proximity to asbestos emitting activities such as those described above (Section 5.1.4). The highest excess lifetime cancer risk (ELCR) caused by asbestos exposure was found to be associated with occupational exposures, followed by general population exposures located near asbestos disposal activities, then DIY and take-home exposures. The risk of non-cancer effects such as localized pleural thickening (used interchangeably with "pleural plaques") was similar across exposure scenarios evaluated.

Although the exposure scenarios in the risk evaluation did not assume universal compliance with existing federal regulation, the monitoring data used may reflect the existing federal, state, and local regulations requiring proper management of ACMs. Under the Asbestos Hazard Emergency Response Act (AHERA) under Title II of TSCA, EPA issued regulations in the 1980s requiring local education agencies (public school districts and non-profit private schools, including charter schools and schools affiliated with religious institutions) to inspect their school buildings for asbestos, prepare asbestos management plans, and perform asbestos response actions. AHERA also required EPA to develop a model plan for states for training and accrediting persons conducting asbestos inspections and corrective-action activities at schools and public and commercial buildings.

For example, under the Clean Air Act, the asbestos National Emission Standards for Hazardous Air Pollutants (NESHAPs) regulations issued in 1973 specify work practices for asbestos to be followed during renovations and prior to demolitions of all structures, installations, and buildings (excluding residential buildings that have four or fewer dwelling units). The Occupational Safety and Health

Administration (OSHA) regulates asbestos through standards for the construction industry, general industry, and shipyard employment sectors. These standards require exposure monitoring and awareness training. When potential for asbestos exposure is identified, employers are required to establish regulated areas, controlling certain work practices, instituting engineering controls, use administrative controls and, if needed, provide for the wearing of personal protective equipment. OSHA standards also require proper handling of work clothing to prevent take-home" contaminated work clothing. Existing federal, state, and local asbestos regulatory requirements include work practices that reduce the release of asbestos fibers and therefore may reduce exposure to people sufficiently to reduce risk below a level of concern.

However, the aforementioned requirements do not apply to all work situations and EPA's high-end estimates cover those situations where existing regulations do not apply. That is why there are high-end estimates that exceed EPA's standard risk benchmarks: Existing regulations, while assumed to be effective at reducing exposure, do not cover all activities considered in this risk evaluation. The Agency focused on the high-end risk estimates to represent situations where workers, including people hired to perform home renovation work, may not be subject to existing asbestos regulatory requirements or follow work protective practices to reduce asbestos exposure. EPA's risk evaluation showed that there are situations where workers, including self-employed persons hired to perform home renovation work, may not be subject to existing asbestos regulatory requirements, do not follow work practices to reduce asbestos exposure, or may not be aware that asbestos is present at the worksite. Therefore, it is possible that people who live, work, or go to school in buildings that are being renovated in this manner could also be exposed.

In this Part 2 Risk Evaluation, EPA has determined that the following asbestos conditions of use (also called COUs or TSCA COUs) significantly contribute to the unreasonable risks of cancer and non-cancer health effects:

- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – construction and building materials covering large surface areas – paper articles; metal articles; stone plaster, cement, glass, and ceramic articles;
- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – machinery, mechanical appliances, electrical/electronic articles;
- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – other machinery, mechanical appliances, electronic/electronic articles;
- Industrial/commercial use – chemical substances in furnishing, cleaning, treatment care products – construction and building materials covering large surface areas – fabrics, textiles, and apparel;
- Industrial/commercial use – chemical substances in furnishing, cleaning, treatment care products – furniture and furnishings – stone, plaster, cement, glass, ceramic articles, metal articles, and rubber articles;
- Consumer use – chemical substances in construction, paint, electrical, and metal products – construction and building materials covering large surface areas – paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles; and
- Disposal.

The unreasonable risk has been identified in scenarios for (1) people who handle asbestos products, (2) exposed workers taking asbestos home, (3) non-professional DIY exposure scenarios, and (4) the general population located within the vicinity of activities releasing asbestos to the environment.

EPA has determined that the following asbestos COUs do **not** significantly contribute to unreasonable risks of cancer and non-cancer health effects:

- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – fillers and putties;
- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – solvent based/water based paint;
- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – electrical batteries and accumulators;
- Industrial/commercial use – chemical substances in packaging, paper, plastic – packaging (excluding food packaging) – rubber articles; plastic articles (hard); plastic articles (soft):
- Industrial/commercial use – chemical substances in automotive, fuel, agriculture, outdoor use products – lawn and garden care products;
- Industrial/commercial use – mining of non-asbestos commodities – mining of non-asbestos commodities;
- Industrial/ commercial use – laboratory chemicals – laboratory chemicals;
- Industrial/commercial use – chemical substances in products not described by other codes – other (artifacts);
- Industrial/commercial use – chemical substances in products not described by other codes – other (aerospace applications);
- Consumer use – chemical substances in construction, paint, electrical, and metal products – machinery, mechanical appliances, electrical/ electronic articles;
- Consumer use – chemical substances in construction, paint, electrical, and metal products – fillers and putties;
- Consumer use – construction, paint, electrical, and metal products – solvent-based/water-based paint;
- Consumer use – chemical substances in furnishing, cleaning, treatment care products – construction and building materials covering large surface areas, including fabrics, textiles, and apparel;
- Consumer use – chemical substances in furnishing, cleaning, treatment care products – furniture and furnishings – stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles;
- Consumer use – chemical substances in packaging paper, plastic, toys, hobby products – packaging (excluding food packaging) – rubber articles; plastic articles (hard); plastic articles (soft):
- Consumer use – chemical substances in packaging paper, plastic, toys, hobby products – toys intended for children's use (and child dedicated articles) – fabrics, textiles, and apparel; or plastic articles (hard);
- Consumer use – chemical substances in products not described by other codes – other (artifacts);
- Consumer use – chemical substances in automotive, fuel, agriculture, outdoor use products – lawn and garden care products.

Asbestos Part 2 Unreasonable Risk to the Environment

Although asbestos is no longer mined in the United States, releases of asbestos to the environment persist due to legacy uses and associated disposals of asbestos containing materials such as old building materials, brake pads, oil gaskets, and pipe insulation. The strong silicon-oxygen-silicon (Si-O-Si) covalent bonds found within asbestos fibers are responsible for its inherent environmental stability, negligible water solubility, high tensile strength, hardness, and inherent chemical inertness. Small asbestos fibers suspended in the air eventually settle into soils and water bodies, where negligible solubility leads to deposition into sediments and biosolids. EPA assessed exposures to aquatic organisms (surface water and sediment) and terrestrial organisms (air, water, and soil), but found limited uptake of asbestos fibers in these environmental media. Aquatic hazard data were available for asbestos from a total of six fish and aquatic invertebrate (Asiatic clam) studies. No aquatic plant studies were reasonably available. EPA did not characterize hazard to terrestrial species because the toxicological endpoints associated with the ecological assessment of terrestrial species are not relevant for asbestos. Due to limited uptake of asbestos fibers in the environment by animals and plants and limited adverse hazard effects, **EPA has determined that there is no risk of injury to the environment from asbestos that would significantly contribute to the unreasonable risk of asbestos.**

Unreasonable Risk of Asbestos as a Chemical Substance

As further explained in Section 6.1 of this risk evaluation, a single unreasonable risk determination is made for asbestos as a chemical substance that includes both the conditions of use evaluated in the *Risk Evaluation for Asbestos Part 1: Chrysotile Asbestos* (U.S. EPA, 2020c) and the conditions of use evaluated in this Part 2: Supplemental Evaluation Including Legacy Uses and Associated Disposals of Asbestos. The unreasonable risk determination is based on the existing risk characterization section of the 2020 Part 1 Risk Evaluation for Chrysotile Asbestos (Section 4) and does not involve additional technical or scientific analysis. The risk determination for asbestos as a chemical substance is also based on the risk estimates (Sections 4 and 5) presented for the conditions of use (Section 1.1.2) in this Part 2 Risk Evaluation.

1 INTRODUCTION

Asbestos is a naturally occurring fibrous mineral with six types of fibers—chrysotile, crocidolite, amosite, anthophyllite, tremolite, actinolite—however, chrysotile is the only asbestos fiber type known to be imported, processed, or distributed for use in the United States. EPA has recently issued a final rule under TSCA to prohibit the ongoing manufacture (including import), processing, distribution in commerce and commercial use of chrysotile asbestos (89 FR 21970, March 28, 2024 (FRL-8332-01-OCSPP)). Domestically, chrysotile asbestos was primarily used as a fire retardant in construction and building materials but was most recently used in chlor-alkali diaphragms used to produce chlorine and caustic soda, in sheet gaskets used in chemical manufacturing, brake blocks used on drilling rigs, imported brakes and linings, other vehicle friction products and other gaskets. This document presents Part 2 of the Risk Evaluation for Asbestos under the Frank R. Lautenberg Chemical Safety for the 21st Century Act that amended TSCA in June 2016. The Agency began its risk evaluation of asbestos when it was identified as one of the first 10 chemicals for risk evaluation under amended TSCA. Part 2 is a response to the ruling from the court in *Safer Chemicals, Healthy Families v. EPA*, 943 F.3d 397 (9th Cir. 2019) holding that EPA should not have excluded "legacy uses" or "associated disposals" from consideration (see also Section 1.1). Examples of legacy uses include floor and ceiling tiles, pipe wraps, insulation, and heat protective textiles containing chrysotile and other fiber types.

Section 1.1 provides an overview of the scope of Part 2 of the Risk Evaluation for Asbestos, including production volume, life cycle diagram (LCD), conditions of use (COUs), and conceptual models used for asbestos; Section 1.2 includes an overview of the systematic review process; and Section 1.3 presents the organization of this risk evaluation. Figure 1-1 describes the major inputs, phases, and outputs/components of the TSCA risk evaluation process—from scoping to releasing the final risk evaluation.

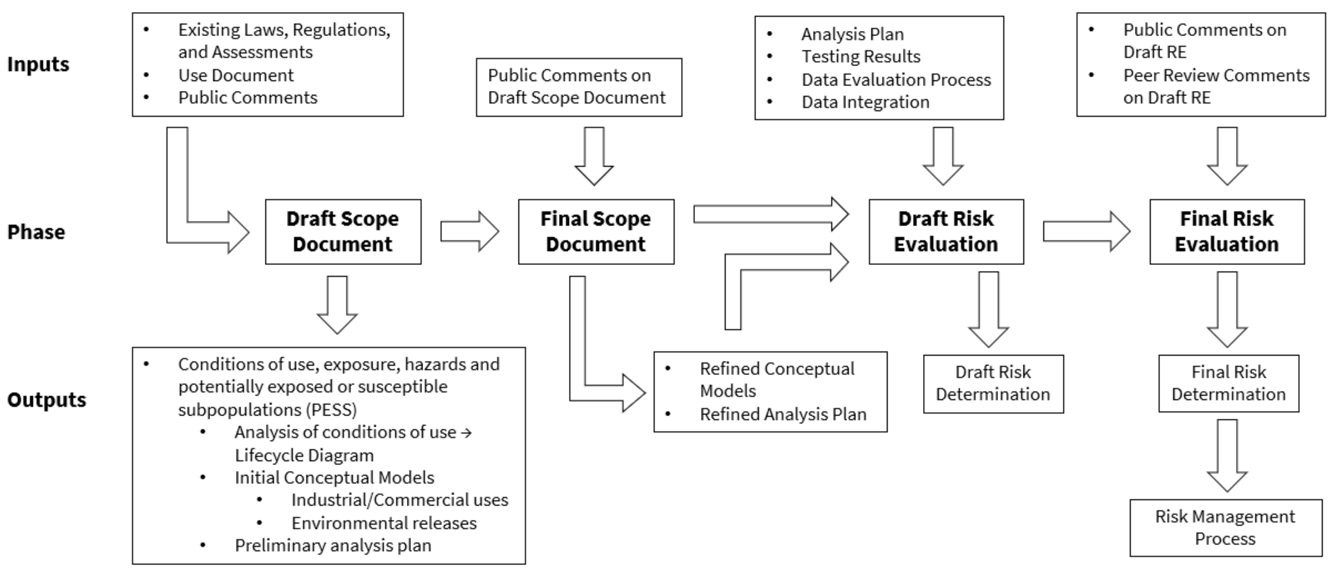


Figure 1-1. TSCA Existing Chemical Risk Evaluation Process

1.1 Scope of the Risk Evaluation

For Part 1 of the Risk Evaluation for Asbestos, EPA initially adopted the definition of asbestos as defined by TSCA Title II (added to TSCA in 1986), section 202 as the "asbestiform varieties of six fiber types – chrysotile (serpentine), crocidolite (riebeckite), amosite (cummingtonite-grunerite), anthophyllite, tremolite, or actinolite." However, a choice was subsequently made to focus Part 1 solely on chrysotile asbestos as this is the only asbestos fiber type that is currently imported, processed, or distributed in the United States. EPA informed the public of this decision to focus on ongoing uses of asbestos and exclude legacy uses and disposals in the *Scope of the Risk Evaluation for Asbestos*, released in June 2017 (U.S. EPA, 2017). However, as noted above, in late 2019, the court in *Safer Chemicals, Healthy Families v. EPA*, 943 F.3d 397 (9th Cir.) held that EPA's Risk Evaluation Rule (82 FR 33726 [July 20, 2017]) should not have excluded "legacy uses" (*i.e.,* uses without ongoing or prospective manufacturing, processing, or distribution for use) or "associated disposals" (*i.e.,* future disposal of legacy uses) from the definition of conditions of use (COUs)—although the court did uphold EPA's exclusion of "legacy disposals" (*i.e.,* past disposals). Following that court ruling, EPA continued development of the risk evaluation for the ongoing uses of chrysotile asbestos and determined that the complete risk evaluation for asbestos would be issued in two parts. The *Risk Evaluation for Asbestos Part 1: Chrysotile Asbestos*—also referred to as the "2020 Part 1 Risk Evaluation for Asbestos," "Part 1 Risk Evaluation," and simply "Part 1"—was released in December (U.S. EPA, 2020c), allowing the Agency to expeditiously move into risk management for the unreasonable risk identified in Part 1 for ongoing chrysotile COUs.

EPA used reasonably available information, defined in 40 CFR 702.33, in a fit-for-purpose approach, to develop a risk evaluation that relies on the best available science and is based on the weight of scientific evidence. EPA evaluated the quality of the methods and reporting of results of the individual studies using the evaluation strategies described in the *Draft Systematic Review Protocol Supporting TSCA Risk Evaluations for Chemical Substances, Version 1.0: A Generic TSCA Systematic Review Protocol with Chemical-Specific Methodologies* (also called the "Draft Systematic Review Protocol") (U.S. EPA, 2021a).

Following the finalization of Part 1 of the Risk Evaluation for Asbestos, EPA OPPT immediately began development of Part 2 of the Risk Evaluation for Asbestos (also called "Part 2 of the risk evaluation," "Part 2 Risk Evaluation," or simply "Part 2"), starting with the issuance of a draft scope document. The *Final Scope of the Risk Evaluation for Asbestos Part 2: Supplemental Evaluation Including Legacy Uses and Associated Disposals of Asbestos* (87 FR 38746) (EPA-HQ-2021-0254-0044; also referred to as "Final Scope") was released in June 2021, reflecting consideration of public comments on a draft scope document. Although Part 1 of the risk evaluation adopted the TSCA Title II definition of asbestos, the consideration of legacy uses and associated disposals that will be evaluated in Part 2 warrant broader considerations as asbestos can be co-located geologically with commercially mined substances. In particular, Libby amphibole asbestos (LAA) is known to have been present with vermiculite, extracted from an open pit mine near Libby, Montana, until the mine closed in 1990. Vermiculite was widely used in building materials which are an important focus of the evaluation of legacy uses of asbestos. Thus, LAA (and its tremolite, winchite, and richterite constituents) were considered in this Part 2 of the risk evaluation. EPA also determined the relevant COUs of asbestos-containing talc, including any "legacy use" and "associated disposal" where asbestos is implicated in Part 2. Where the Agency identifies reasonably available information demonstrating asbestos-containing talc COUs that fall under TSCA authority, these were also evaluated in this Part 2 Risk Evaluation for Asbestos.

In addition to the Final Scope and prior to this Part 2 Risk Evaluation, EPA released the *White Paper: Quantitative Human Health Approach to be Applied in the Risk Evaluation for Asbestos Part 2 – Supplemental Evaluation including Legacy Uses and Associated Disposals of Asbestos* in August 2023 (U.S. EPA, 2023g) (also referred to as the "White Paper) for a 60-day comment period and an external letter peer review. The White Paper focused on the quantitative human health assessment and dose-response considerations for Part 2 of the risk evaluation. EPA is using the terms dose-response and exposure-response relationship interchangeably to describe the amount of exposure/dose a person is exposed to. EPA has continued to focus the human health assessment in Part 2 on epidemiologic evidence, evaluating cancer and non-cancer evidence and conclusions from the existing EPA assessments in addition to other studies identified from a recently conducted systematic review approach. The White Paper described the systematic review considerations and criteria for identifying studies for dose-response analysis, evaluated, and compared existing cancer inhalation unit risks (IURs) and the non-cancer point of departure (POD) with the results of the new systematic review, and proposed a cancer IUR and non-cancer POD for use in Part 2. Several key findings and conclusions from EPA's White Paper are provided below:

- OPPT conducted systematic review to identify the reasonably available information relevant for consideration in the quantitative human health approach to be applied in Part 2 of the Risk Evaluation for Asbestos. This included identification of cancer and non-cancer epidemiologic studies from oral, dermal, and inhalation routes of exposure.
- OPPT has not identified any cancer or non-cancer epidemiologic studies from oral or dermal exposures that support dose-response analysis; therefore, OPPT did not use cancer or non-cancer values for these routes.
- For inhalation exposures, OPPT has identified several inhalation epidemiologic studies (or cohorts) for non-cancer effects, including some that were considered in the IRIS LAA Assessment (U.S. EPA, 2014c). However, none of those studies warranted an updated dose-response analysis for the non-cancer POD. OPPT is using the existing POD of 2.6×10^{-2} fiber/cc from the IRIS LAA Assessment to assess non-cancer risks in Part 2 with application of appropriate uncertainty factors (UFs).
- OPPT did not identify any inhalation cancer cohorts beyond those considered by previous EPA assessments, including for cancers other than mesothelioma and lung cancer, which would warrant an updated dose-response assessment.
- The existing EPA-derived IURs—0.23, 0.17, and 0.16 per fiber/cc—are based on lung cancer and mesothelioma with quantitative adjustment for laryngeal and ovarian cancers in the development of the IUR of 0.16 per fiber/cc in the Part 1 Risk Evaluation. Despite each value being derived from different information and epidemiologic cohorts, and therefore having different strengths and uncertainties, the values are notably similar and round to 0.2 per fiber/cc. OPPT is using an IUR of 0.2 per fiber/cc in Part 2 of the Risk Evaluation for Asbestos.

An additional expansion of considerations in Part 2, pertains to the evaluation of human health effects, consideration of risk from take-home exposures and general population exposures from environmental releases. Although Part 1 focused on certain cancer outcomes known to be causally related to asbestos exposure (IARC, 2012a, 1977), Part 2 considers non-cancer outcomes at the system level or higher. Historically, there has been a focus on inhalation exposures in asbestos health assessments conducted by the EPA and other organizations, but there has also been interest in the updated literature on dermal and oral exposures. These routes of exposure are being considered in Part 2. A broad range of health effects are examined in the asbestos epidemiologic literature including cancer (*e.g.*, mesothelioma, lung, ovarian, laryngeal, gastrointestinal cancers) and non-cancer (*e.g.*, asbestosis, lung function decrements, pleural plaques/abnormalities, immune-related effects, cardiovascular effects) outcomes. This range of human health outcomes was presented in Figure 2-10 in the Final Scope, and an interactive version of this diagram is available: Heat Map of Hazard Screening Results for Asbestos.

1.1.1 Life Cycle and Production Volume

The Life Cycle Diagram (LCD)—which depicts the COUs that are within the scope of the risk evaluation during various life cycle stages, including industrial, commercial, and consumer uses of legacy asbestos materials, as well as talc and vermiculite products that may contain asbestos—was previously included in the *Final Scope of the Risk Evaluation for Asbestos Part 2* (U.S. EPA, 2022b).

The LCD has been updated since it was included in the Scope document. Specifically, the relevant uses of imported talc products that are subject to TSCA that may contain asbestos (*e.g.*, fillers and putties with talc containing asbestos, crayons with talc containing asbestos, and toy crime scene kits with talc containing asbestos) have been combined into a singular LCD shown in Figure 1-2. However, there was limited data identified that provide evidence that import of these products is ongoing. Under the one-time asbestos reporting rule under TSCA section 8(a), exposure-related information, including information on the presence, types, and quantities of asbestos (including asbestos that is a component of a mixture) and asbestos-containing articles that have been manufactured (including imported) or processed was provided to the Agency in 2024 and considered in the final risk evaluation consistent with TSCA sections 26(h), (i), and (k), 15 U.S.C. 2625.

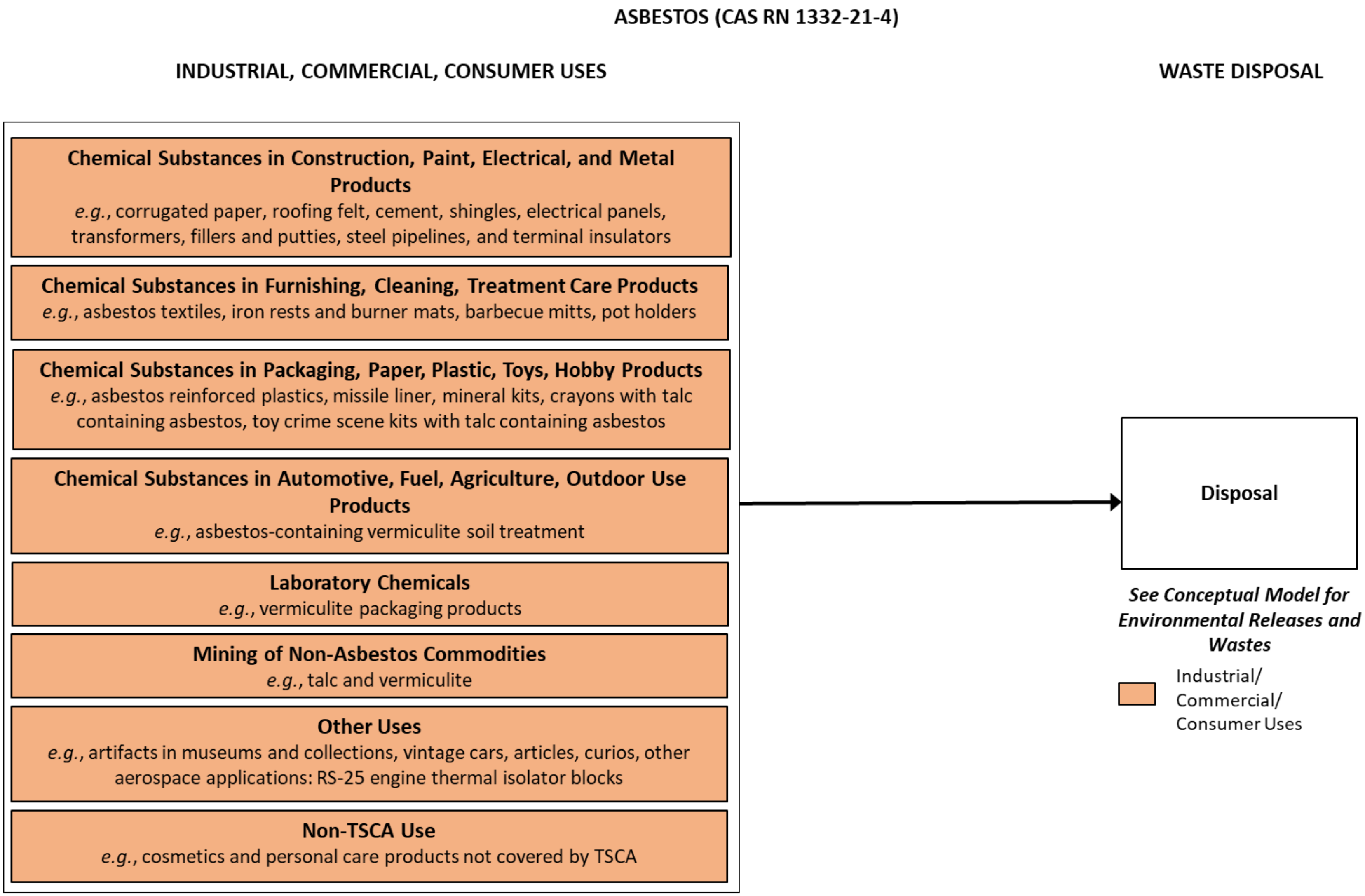


Figure 1-2. Asbestos Part 2 Life Cycle Diagram

See Table 1-1 for categories and subcategories of conditions of use. Potential exposures to fillers and putties with talc that contains asbestos are captured within the occupational and consumer exposure assessments and are not assessed separately. An evaluation of trace amounts of asbestos is considered separately.

Descriptions of the industrial, commercial, and consumer use categories identified from the *Instructions for Reporting 2020 TSCA Chemical Data Reporting* (U.S. EPA, 2020b) were used in the characterization of legacy asbestos uses shown in the Life Cycle Diagram (Figure 1-2). The CDR descriptions provide a brief overview of each use category; Appendix G contains more detailed descriptions (*e.g.*, process descriptions, worker activities, process flow diagrams, equipment illustrations) for each industrial and commercial use.

1.1.2 Conditions of Use Included in the Risk Evaluation

Since the release of the Draft Part 2 Risk Evaluation for Asbestos, additional data on ongoing import, processing and use of asbestos were provided to EPA. Conditions of use associated with the newly received data are described in the discussion of asbestos in trace amounts in Section 1.1.2.2. No other conditions of use were modified substantially. Table 1-1 presents the COUs that were included and evaluated in this Part 2 Risk Evaluation. Appendix D describes the updates made to the COUs after the Final Scope (U.S. EPA, 2021b), and Appendix E contains a description of the conditions of use.

The conditions of use included in the risk evaluation are those reflected in the life cycle diagram and conceptual models. These conditions of use were evaluated for chronic, and lifetime exposures, as applicable based on reasonably available exposure and hazard data as well as the relevant routes of exposure for each.

Table 1-1. Conditions of Use (Life Cycle, Categories, and Subcategories) and Examples of Items/Applications in the Risk Evaluation for Asbestos Part 2

Life Cycle Stage[a]	Category[b]	Subcategory[c]	Item/Application[d]	Reference(s)
Industrial/ Commercial Uses	Chemical substances in construction, paint, electrical, and metal products	Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles*	Siding; corrugated paper (for use in pipe wrap insulation and appliances); commercial papers, millboard; rollboard; specialty paper; roofing felt; cement; shingles; corrugated cement; ceiling tiles; loose-fill insulation (asbestos-containing vermiculite); asbestos cement pipes and ducts (water, sewer and air); asbestos (wallboard & joint compound); wall protectors; air duct insulation; soldering and welding blocks and sheets; gaskets; stove gaskets and rings; asbestos-coated steel pipelines; flooring felt; vinyl floor tiles	U.S. EPA (1989) EPA 2021 (vermiculite webpage)
		Machinery, mechanical appliances, electrical/ electronic articles	Corrugated commercial and specialty papers; reinforced plastics for appliances such as ovens, dishwashers, boilers, and toasters; miscellaneous electro-mechanical parts for appliances including deep fryers, frying pans and grills, mixers, popcorn poppers, slow cookers, washers and dryers, refrigerators, curling irons, electric blankets, portable heaters, safes, safety boxes, filing cabinets, and kilns and incinerators	U.S. EPA (1989)
		Other machinery, mechanical appliances, electronic/ electronic articles	Braking and gear-changing (clutch) components in a variety of industrial and commercial machinery including combines, mining equipment, construction equipment such as cranes and hoists, heavy equipment used in various manufacturing industries (*e.g.*, machine tools and presses), military equipment, marine engine transmissions, and elevators; gaskets, packings/seals in rotary, centrifugal, and reciprocating pumps, valves, expansion joints, soot blowers, and other types of mechanical equipment; electro-mechanical parts including commutators, switches, casings, and thermoplugs; arc chutes; electrical panels; transformers (high grade electrical paper)	U.S. EPA (1989)
		Fillers and putties	Adhesives and sealants; extruded sealant tape; rubber and vinyl sealants; epoxy adhesives;	U.S. EPA (1989)
		Solvent-based/water-based paint*	Coatings; corrugated coatings; textured paints; vehicle undercoating	U.S. EPA (1989)

Life Cycle Stage[a]	Category[b]	Subcategory[c]	Item/Application[d]	Reference(s)
Industrial/ Commercial Uses		Electrical batteries and accumulators*	Insulator for terminals	U.S. EPA (1989)
	Chemical substances in furnishing, cleaning, treatment care products	Construction and building materials covering large surface areas, including fabrics, textiles, and apparel	Asbestos textiles including yarn, thread, wick, cord, rope, tubing (sleeving), cloth, and tape	U.S. EPA (1989)
		Furniture & furnishings including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles*	Iron rests; burner mats; barbecue mitts; pot holders	CPSC-EPA 1979 (44 FR 60056)
	Chemical substances in packaging, paper, plastic	Packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft)*	Asbestos reinforced plastics	U.S. EPA (1989)
	Chemical substances in automotive, fuel, agriculture, outdoor use products	Lawn and garden care products*	Asbestos-containing vermiculite soil treatment	U.S. EPA (2000a)
	Mining of non-asbestos commodities**	Mining of non-asbestos commodities	Metal and nonmetal mines, surface coal mines, and surface areas of underground coal mines	MSHA 2008 (41 FR 11284)
	Laboratory chemicals	Laboratory chemicals	Vermiculite packaging products	U.S. EPA (2000a) (IHC World, 2023)
	Chemical substances in products not described by other codes	Other (artifacts)	Artifacts in museums and collections	
		Other (aerospace applications)	Other aerospace applications including RS-25 engine thermal isolator blocks; high-performance plastics for aerospace including heat shields, rocket motor casings, and rocket motor liners	U.S. EPA (1989)

Life Cycle Stage[a]	Category[b]	Subcategory[c]	Item/Application[d]	Reference(s)
Consumer uses	Chemical substances in construction, paint, electrical, and metal products	Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles	Siding; corrugated paper (for use in pipe wrap insulation and appliances); commercial papers; millboard; rollboard; specialty paper; roofing felt; cement; shingles; corrugated cement; ceiling tiles; loose-fill insulation (asbestos-containing vermiculite); asbestos cement pipes and ducts (water, sewer, and air); Galbestos; fireplace embers; stove gaskets and rings; flooring felt; vinyl floor tiles	U.S. EPA (1989) EPA 2021 (vermiculite webpage)
		Machinery, mechanical appliances, electrical/ electronic articles	Corrugated commercial and specialty papers; reinforced plastics for appliances such as ovens, dishwashers, boilers and toasters; miscellaneous electro-mechanical parts for appliances including deep fryers, frying pans and grills, mixers, popcorn poppers, slow cookers, washers and dryers, refrigerators, curling irons, electric blankets, portable heaters, safes, safety boxes, filing cabinets, and kilns and incinerators	U.S. EPA (1989)
		Fillers and putties	Adhesives and sealants; extruded sealant tape	U.S. EPA (1989)
		Solvent-based/water-based paint*	Coatings; textured paints; vehicle undercoating	U.S. EPA (1989)
	Chemical substances in furnishing, cleaning, treatment care products	Construction and building materials covering large surface areas, including fabrics, textiles, and apparel	Asbestos textiles including yarn, thread, wick, cord, rope, tubing (sleeving), cloth, tape	U.S. EPA (1989)
		Furniture and furnishings, including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles*	Iron rests; burner mats; barbecue mitts; potholders, and similar items	CPSC-EPA 1979 (44 FR 60056)
	Chemical substances in packaging, paper,	Packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft)	Asbestos reinforced plastics	U.S. EPA (1989)

Life Cycle Stage[a]	Category[b]	Subcategory[c]	Item/Application[d]	Reference(s)
Consumer uses	plastic, toys, hobby products	Toys intended for children's use (and child dedicated articles), including fabrics, textiles, and apparel; or plastic articles (hard)	Mineral kits	(QDOE, 2023) (WST, 2019)
	Chemical substances in automotive, fuel, agriculture, outdoor use Products	Lawn and garden care products	Asbestos-containing vermiculite soil treatment	U.S. EPA (2000a)
	Chemical substances in products not described by other codes	Other (artifacts)	Vintage artifacts in private collections; vintage cars, articles, curios	CPSC-EPA 1979 (44 FR 60056)
Disposal	Disposal	Disposal	Articles containing asbestos, demolition debris	

[a] Life Cycle Stage Use Definitions (40 CFR 711.3)

- "Industrial use" means use at a site at which one or more chemicals or mixtures are manufactured (including imported) or processed.
- "Commercial use" means the use of a chemical or a mixture containing a chemical (including as part of an article) in a commercial enterprise providing saleable goods or services.
- "Consumer use" means the use of a chemical or a mixture containing a chemical (including as part of an article, such as furniture or clothing) when sold to or made available to consumers for their use.
- Although EPA has identified both industrial and commercial uses here for purposes of distinguishing scenarios in this document, the Agency interprets the authority over "any manner or method of commercial use" under TSCA section 6(a)(5) to reach both.

[b] These categories of conditions of use appear in the Life Cycle Diagram, reflect CDR codes, and broadly represent conditions of use of asbestos in industrial and/or commercial settings.

[c] These subcategories reflect more specific conditions of use of asbestos.

[d] The listed items/applications are examples identified by EPA within the specific subcategories; these lists of examples are not exclusive and other items/applications not listed may fall within the subcategories' conditions of use of asbestos.

* These industrial/commercial and consumer COUs are supported by data from the 8(a) rule and are therefore considered both legacy uses of asbestos and uses covered by the discussion of trace amounts in Section 1.1.2.2.

** For purposes of this COU table, mining was listed as an industrial/commercial COU, even though mining is considered manufacturing under TSCA.

1.1.2.1 Conceptual Models

The conceptual model in Figure 1-3 presents the exposure pathways, exposure routes and hazards to human populations from industrial and commercial activities and uses of asbestos. Figure 1-4 presents the conceptual model for consumer activities and uses, Figure 1-5 presents general population exposure pathways and hazards for environmental releases and wastes, and Figure 1-6 presents the conceptual model for ecological exposures and hazards from environmental releases and wastes.

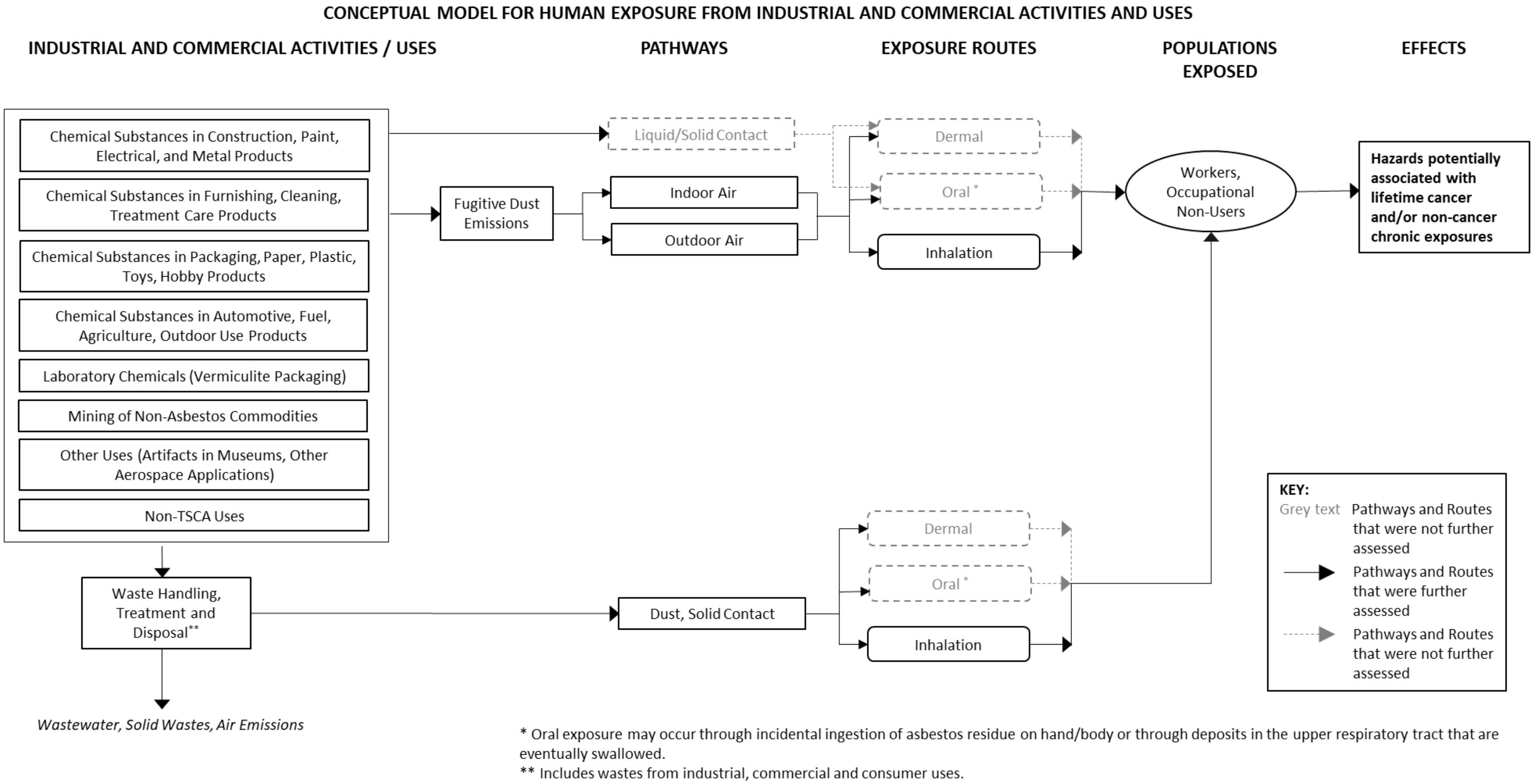


Figure 1-3. Conceptual Model for Industrial and Commercial Activities and Uses: Potential Exposure and Hazards
Some products are used in both commercial and consumer applications. See Table 1-1 for categories and subcategories of conditions of use. Distribution in commerce not included in LCD. For the purposes of the risk evaluation, distribution in commerce is the transportation associated with moving chemical substances in commerce. Unloading and loading activities are associated with other conditions of use. When data and information were available to support the analysis, EPA also considered the effect that engineering controls and/or personal protective equipment have on occupational exposure level.

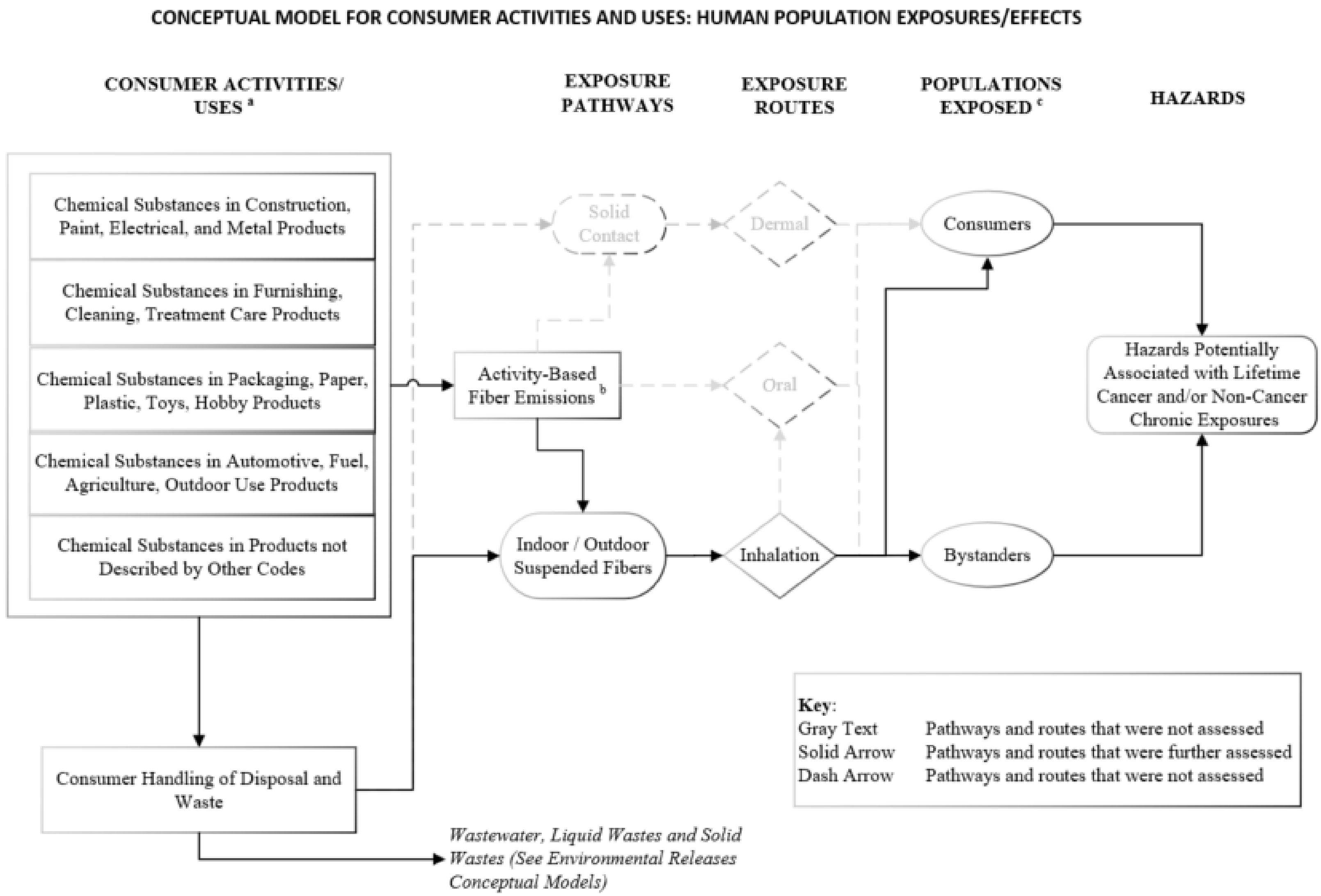


Figure 1-4. Asbestos Conceptual Model for Consumer Activities and Uses: Potential Exposures and Hazards

The conceptual model presents the exposure pathways, exposure routes and hazards to human from consumer activities and uses of asbestos.

[a] Some products are used in both commercial and consumer applications. See Table 1-1 for categories and subcategories of conditions of use.

[b] Human exposure occurs through inhalation of asbestos fibers released during activity-based scenarios.

[c] Populations for estimating exposure include potentially exposed or susceptible subpopulations (PESS).

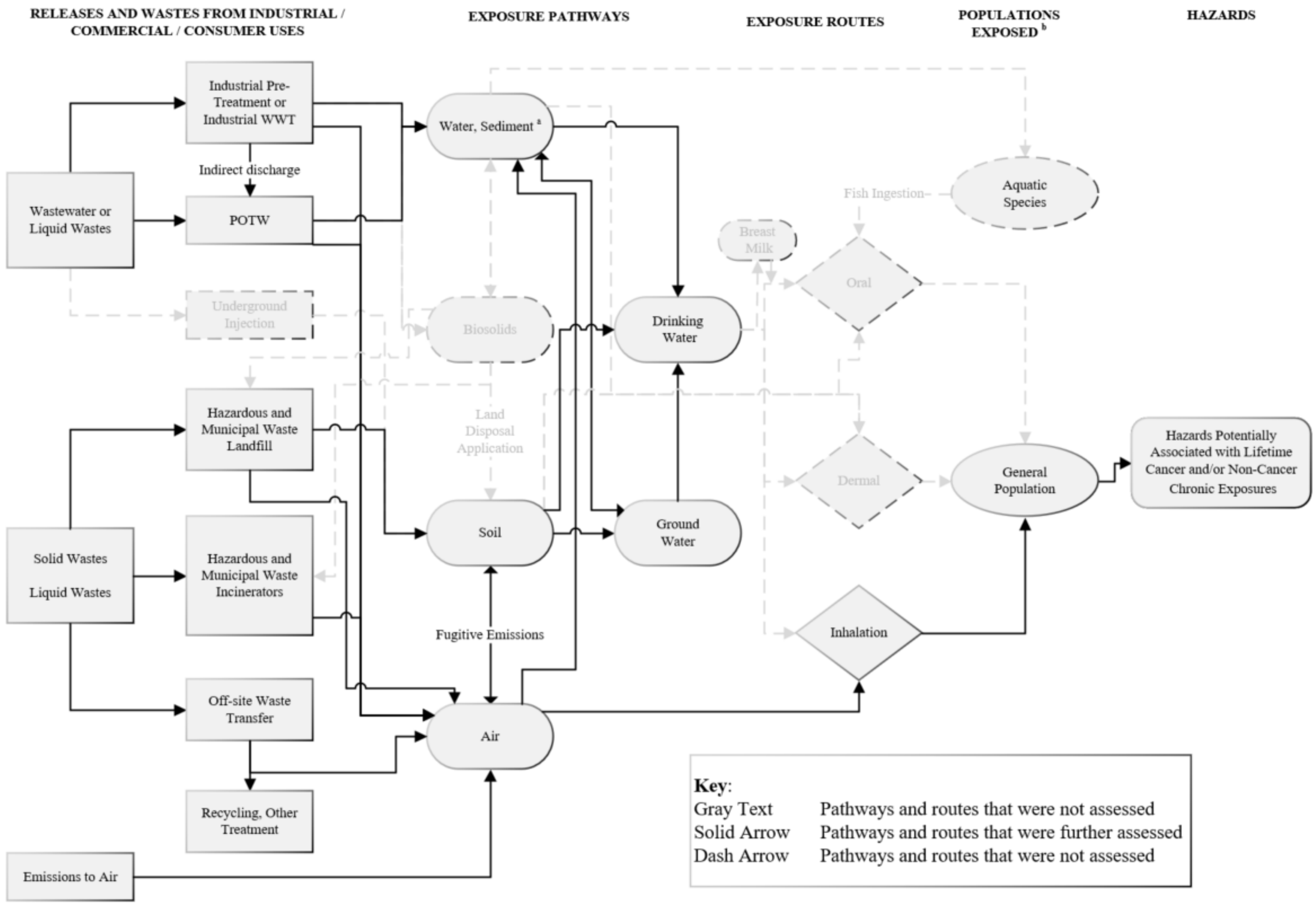


Figure 1-5. Asbestos Conceptual Model for Environmental Releases and Wastes: General Population Exposures and Hazards

The conceptual model presents the exposure pathways, exposure routes and hazards to humans from releases and wastes from industrial, commercial, and/or consumer uses of asbestos.

[a] Industrial wastewater or liquid wastes may be treated on-site and then released to surface water (direct discharge), or pre-treated and released to publicly owned treatment works (POTW) (indirect discharge). For consumer uses, such wastes may be released directly to POTW (*i.e.*, down-the-drain).

[b] Populations for estimating exposure include potentially exposed or susceptible subpopulations.

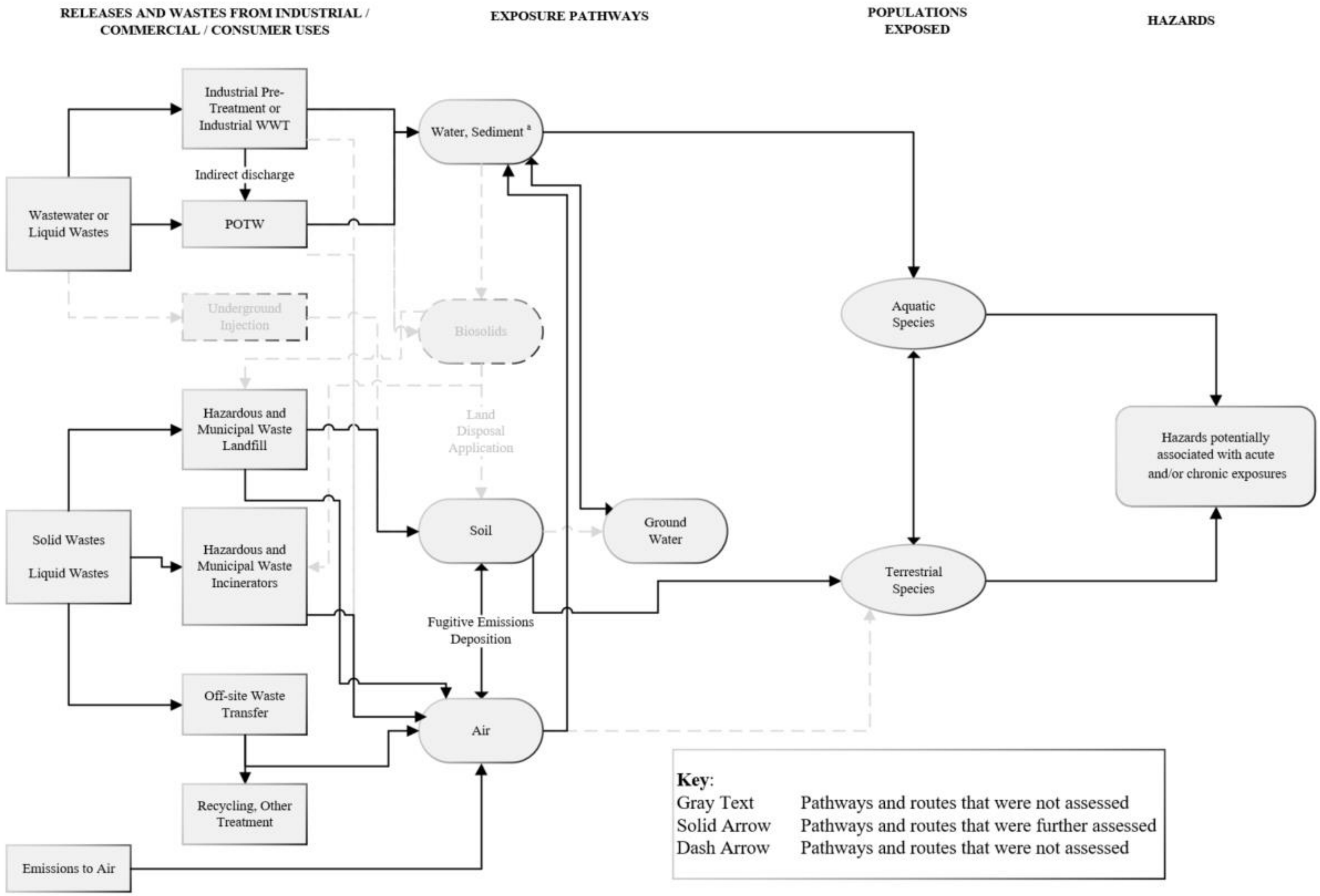


Figure 1-6. Asbestos Conceptual Model for Environmental Releases and Wastes: Ecological Exposures and Hazards

[a] Industrial wastewater or liquid wastes may be treated on-site and then released to surface water (direct discharge), or pre-treated and released to POTW (indirect discharge). For consumer uses, such wastes may be released directly to POTW (*i.e.*, down-the-drain).

1.1.2.2 Asbestos Unintentionally Present in Trace Amounts in Other Mined Materials and Manufactured/Processed Articles from Such Materials

Pursuant to the settlement agreement in *Asbestos Disease Awareness Organization v. EPA*, No. 19-CV-00871; *State of California et al. v. EPA*, No. 19-CV-03807, EPA agreed to publish a notice of proposed action to promulgate a rule pursuant to TSCA section 8(a), 15 U.S.C. 2607(a), for the maintenance of records and submission to EPA of reports by manufacturers (including importers) and processors of asbestos (including asbestos that is a component of a mixture), and articles containing asbestos (including as an impurity) that addressed the information-gathering deficiencies identified for asbestos in these cases.[3]

Under this one-time asbestos reporting rule under TSCA section 8(a), exposure-related information—including information on the presence, types, and quantities of asbestos (including asbestos that is a component of a mixture) and asbestos-containing articles that have been manufactured (including imported) or processed—was provided to the Agency in 2024. In total, 71 submissions were received and considered in the final Part 2 Risk Evaluation consistent with TSCA sections 26(h), (i), and (k), 15 U.S.C. 2625. The information reported to the Agency covers activities previously determined to be conditions of use, and further clarified conditions of use discussed in the scope document. As EPA noted in the scope, depending on where reasonably available information implicates the presence of asbestos, the conditions of use could include manufacturing (including import), processing, and distribution. Based on the TSCA section 8(a) data, new processing and importing COUs have been added to cover the additional activities identified with the new submissions. Although not added to COU Table 1-1 in Section 1.1.2, these conditions of use include Manufacturing (including import), Processing, Distribution in commerce, Use, and Disposal of asbestos unintentionally present in trace amounts in other mined materials, including products/articles from such materials. It is important to note that asbestos unintentionally present in trace amounts in products not subject to TSCA, such as cosmetics, was not assessed by EPA.

One submission indicated a previously unknown and ongoing use of asbestos in battery separators. The company self-disclosed to EPA that they used chrysotile asbestos electrical insulation paper purchased in the 1980s to produce battery separators for specific military purposes. The product was still used in military applications at the time of submission in the summer of 2024. As part of discussions held with EPA the submitter confirmed they had discontinued the manufacturing and processing of this product. Thus, the manufacturing and processing of battery separators will not be addressed further in this final Part 2 risk evaluation. The assessment of the legacy use and disposal of battery separators is already included in this Part 2 Risk Evaluation for Asbestos.

The remaining 70 submissions indicated that asbestos unintentionally present in trace amounts (referred to as "trace asbestos" for the remainder of the risk evaluation)—either confirmed through direct measurement or acknowledged as possible—may be present in other mined materials (*e.g.*, vermiculate, talc, wollastonite, stone) and downstream consumer or industrial products (*e.g.*, automotive plastic parts, paints, insulation materials). Approximately 84.5 percent of submissions did not include data to support the presence of asbestos and stated that trace amounts of asbestos could be present based on indications from suppliers or general knowledge. The vast majority of submissions with exposure or weight fraction

[3] In 2019, EPA promulgated a Significant New Use Rule on asbestos (SNUR) (84 FR 17345, April 25, 2019 (FRL-9991-33)), in which the Agency determined that the manufacturing (including import) or processing of asbestos for certain uses and any other use of asbestos that was not already prohibited under TSCA or under evaluation in the *TSCA Risk Evaluation for Asbestos Part 1: Chrysotile Asbestos* were significant new uses. However, the SNUR does not cover manufacturers or processors of asbestos only as an impurity. 40 CFR 721.45(d).

data showed asbestos levels below the limit of detection or non-detects. Submissions that detected asbestos in a product found weight fractions less than 0.1 percent. The low detection rates and levels of asbestos identified across the data submitted under TSCA section 8(a) indicate that although trace amounts of asbestos may be present in mined products, such trace asbestos is uncommon and appears at low levels (<0.1%) when it occurs. Examples of trace asbestos are highlighted below.

One submission with monitoring data detected asbestos levels of approximately 0.001 f/cc in the air surrounding the processing of specialty paper products, which is among the lowest values previously identified in the occupational exposures in this Part 2 risk evaluation.

Several submissions indicated that tremolite and actinolite asbestos fibers may be present as a trace impurity in the mining and smelting of copper ore (quantitative data not provided). Smelting of copper occurs at temperatures well above the thermal degradation of asbestos (900 °C); thus, asbestos is not anticipated to be present in downstream products. Asbestos as an impurity in mining is described in Appendix G.15 below.

In another example, a manufacture of stone tiles sampled for asbestos contamination twice a year for the 4 years covered under the TSCA section 8(a) reporting period. One sample detected a single asbestos fiber in the stone tiles and the rest were below the limit of detection (1.0×10^{-6} to 1.3×10^{-5} weight percent in bulk or 0.001–0.006 f/cc in air monitoring samples). The low detection rate and low level of asbestos identified in the product through this consistent analysis of one product at one site provides insight into the high number of non-detects and samples below the limit of detection in the overall data landscape of trace asbestos.

Potential for exposure to trace asbestos was previously identified by EPA in the industrial mining of non-asbestos commodities. Asbestos air monitoring data from personal air samples collected by the Mine Safety and Health Administration (MSHA) from 2005 to 2022 showed a limited number of non-zero values (~0.01%) across approximately 2,500 samples from 200 mining sites post-2008 (MSHA, 2022a), when MSHA lowered the permissible exposure limit (PEL) for asbestos from 2 fibers per cubic centimeter of air (f/cc) to 0.1 f/cc. None of the reported TWA from personal air sampling from 2008 to 2022 exceeded the PEL. There is strong evidence that exposure to trace asbestos in mined commodities occurs infrequently and at low levels. Based on the available data and consultations with federal partners and outside stakeholders, EPA has determined a qualitative assessment of industrial mining of non-asbestos commodities is appropriate for this risk evaluation, as described in Appendix G.15

The potential of trace asbestos in toys intended for children's use, including mineral kits and crayons, was assessed qualitatively by the EPA as described in Section 3.1.3 and Appendix J.1.3. During the scraping, sanding, and breakdown of mineral kits, it is expected that particulate can be uplifted and exposure via inhalation of asbestos containing particulate could occur. However, EPA did not identify studies measuring asbestos fibers releases during the modification of mineral kits nor studies providing asbestos concentrations in these products. In contrast, a study of crayons with trace asbestos (up to 0.03%) by the Consumer Product Safety Commission (CPSC) (Saltzman and Hatlelid, 2000) did not identify the release of any asbestos in air samples collected during 30 minutes of aggressive use, leading authors to conclude that risk of exposure to asbestos through crayons is "extremely low."

While there are historical examples of higher levels of asbestos unintentionally present in other mined materials, such as vermiculite originating from the mine in Libby, Montana, which ceased operations in 1990, the current evaluation of unintentionally present trace amounts of asbestos is informed by more recent data submissions under TSCA section 8(a) and exposure data from MSHA. The reasonably available information on ongoing manufacturing (including importing and mining), processing, use, and disposal practices suggests trace amounts of asbestos in other mined materials and associated manufactured/processed materials appears infrequently and at low levels (<0.1%). EPA did not conduct a quantitative assessment of all of these uses, as the existing exposure scenarios are protective of uses of the trace amounts of asbestos identified here. The Agency retained the qualitative assessments of certain subcategories of these uses with unique exposure profiles: mining (Appendices G.15), mineral kits, and crayons (Appendix J.1.3).

1.1.3 Populations Assessed

Based on the conceptual models presented in Section 1.1.2.1, Figure 1-7 presents the human and ecological populations assessed in this Risk Evaluation. Specifically for humans, EPA evaluated risk via inhalation route to workers and ONUs; to do-it-yourself (DIY) consumers and bystanders; and to the general population from environmental releases, disposals, and take-home exposures. After a thorough and comprehensive investigation of the reasonably available evidence on the hazards and risks associated with asbestos, the epidemiological studies continue to show that asbestos exposure is associated with lung cancer, mesothelioma, laryngeal cancer, and ovarian cancer (Section 5). Thus, EPA determined that the human health hazards identified in its previous reports as well as those from other agencies are still relevant and valid. The White Paper further summarizes the human health approach taken for Part 2 (U.S. EPA, 2023g).

For environmental populations, EPA evaluated potential risk to aquatic species via water and sediment, and risk to terrestrial species via inhalation exposure routes. Environmental risks were evaluated for acute and chronic exposure scenarios, as applicable based on reasonably available exposure and hazard data as well as the relevant populations for each.

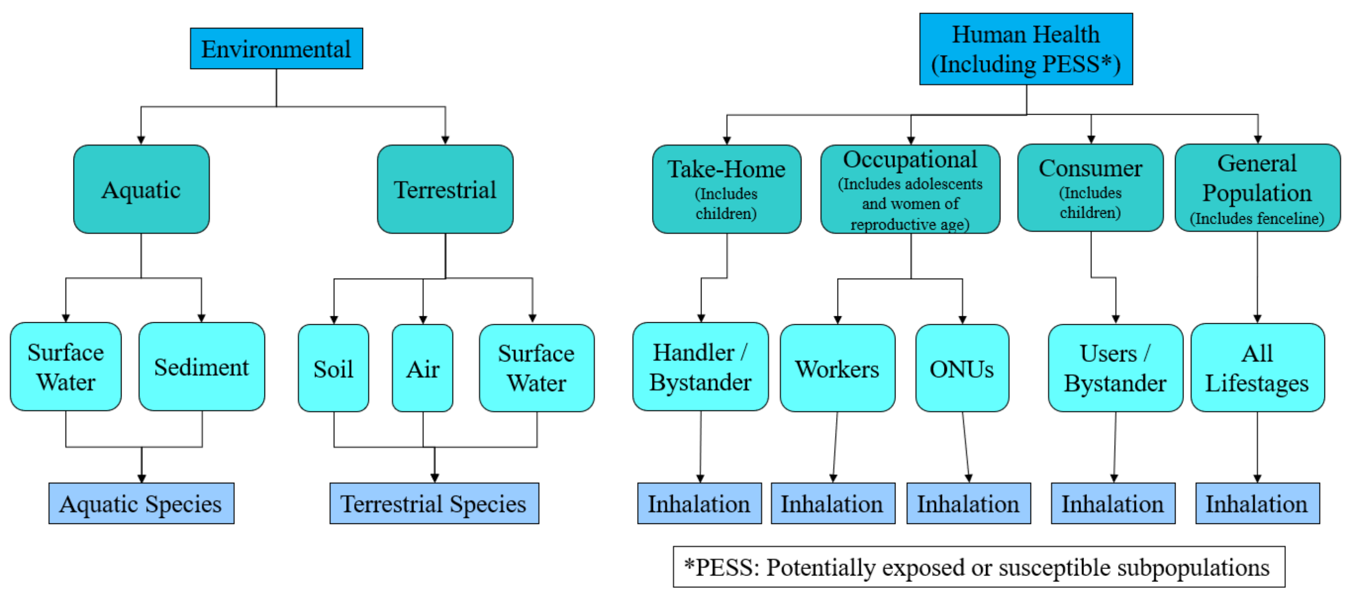


Figure 1-7. Exposures and Populations Assessed in this Risk Evaluation

1.1.3.1 Potentially Exposed or Susceptible Subpopulations

TSCA requires that risk evaluations "determine whether a chemical substance presents an unreasonable risk of injury to health or the environment, without consideration of costs or other non-risk factors, including an unreasonable risk to a potentially exposed or susceptible subpopulation identified as relevant to the risk evaluation by the Administrator, under the conditions of use." 40 CFR 702.33states that "the term '*potentially exposed or susceptible subpopulation*' means a group of individuals within the general population identified by the Administrator who, due to either greater susceptibility or greater exposure, may be at greater risk than the general population of adverse health effects from exposure to a chemical substance or mixture, such as infants, children, pregnant women, workers, the elderly, or overburdened communities."

This risk evaluation considers potentially exposed or susceptible subpopulations (PESS) throughout the human health risk assessment (Section 5). Considerations related to PESS can influence the selection of relevant exposure pathways, the sensitivity of derived hazard values, the inclusion of particular subpopulations, and the discussion of uncertainties throughout the assessment.

1.2 Systematic Review

The U.S. EPA's Office of Pollution Prevention and Toxics (EPA/OPPT) applies systematic review principles in the development of risk evaluations under the amended TSCA. TSCA section 26(h) requires EPA to use scientific information, technical procedures, measures, methods, protocols, methodologies, and models consistent with the best available science and base decisions under section 6 on the weight of scientific evidence.

Systematic review supports the risk evaluation in data searching, screening, evaluation, extraction, and evidence integration and is used to develop the exposure and hazard assessments based on reasonably available information. EPA defines "reasonably available information" to mean information that EPA possesses or can reasonably generate, obtain, and synthesize for use in risk evaluations, considering the deadlines for completing the evaluation (40 CFR 702.33).

In response to comments received by the National Academies of Sciences, Engineering, and Medicine (NASEM), TSCA Scientific Advisory Committee on Chemicals (SACC) and public, EPA developed the *Draft Systematic Review Protocol Supporting TSCA Risk Evaluations for Chemical Substances* (U.S. EPA, 2021a) (also referred to as "2021 Draft Systematic Review Protocol") to describe systematic review approaches implemented in TSCA risk evaluations. In response to recommendations for chemical specific systematic review protocols, the Risk Evaluation for Asbestos Part 2 – Systematic Review Protocol (U.S. EPA, 2023f) (also referred to as the "Asbestos Part 2 Systematic Review Protocol") describes clarifications and updates to approaches outlined in the 2021 Draft Systematic Review Protocol that reflect NASEM, SACC and public comments as well as chemical-specific risk evaluation needs. For example, EPA has updated the data quality evaluation process and will not implement quantitative methodologies to determine both metric and overall data or information source data quality determinations. Screening decision terminology (*e.g.*, "met screening criteria" as opposed to "include") was also updated for greater consistency and transparency and to more appropriately describe when information within a given data source met discipline-specific title and abstract or full-text screening criteria. Additional updates and clarifications relevant for Asbestos Part 2 data sources are described in greater detail in the Asbestos Part 2 Systematic Review Protocol (U.S. EPA, 2023f).

The systematic review process is briefly described in Figure 1-8, below. Additional details regarding these steps are available in the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021a). Literature inventory trees for each discipline (*e.g.*, human health hazard) displaying results of the literature search and screening, as well as sections summarizing data evaluation, extraction, and evidence integration are included in the Asbestos Part 2 Systematic Review Protocol (U.S. EPA, 2023f).

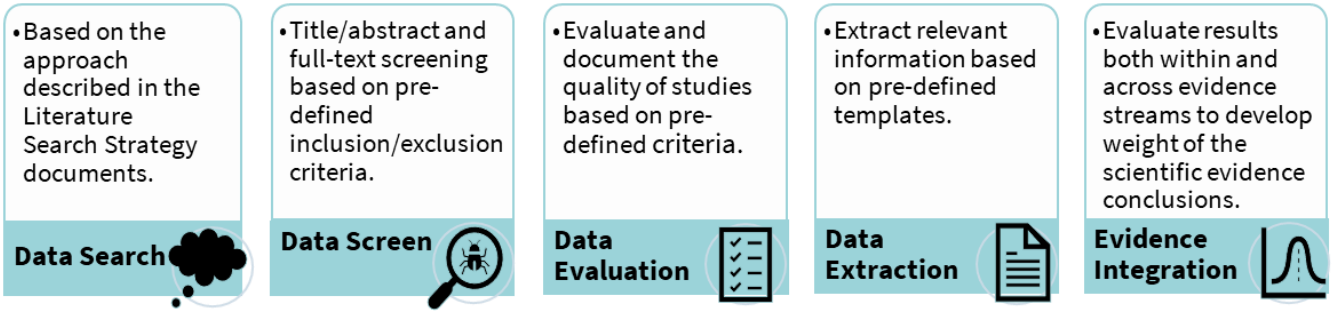


Figure 1-8. Diagram of the Systematic Review Process

EPA also conducted a search of existing major domestic and international laws, regulations and assessments pertaining to asbestos. The Agency compiled this summary information from available federal, state, international, and other government data sources Appendix B. EPA also identified key assessments conducted by other EPA programs and other U.S. and international organizations. Depending on the source, these assessments may include information on conditions of use (or the equivalent), hazards, exposures, and potentially exposed or susceptible subpopulations (PESS). Some of the most recent and pertinent assessments that were consulted include the following: U.S. EPA (2014c), U.S. EPA (1986a), U.S. EPA (1989), and CPSC (1977).

1.3 Organization of the Risk Evaluation

This Part 2 Risk Evaluation for Asbestos includes five additional major sections, a list of references, and several appendices. Section 2 summarizes basic physical and chemical properties as well as the fate and transport of asbestos. Section 3 includes an overview of releases and concentrations of asbestos in the environment. Section 4 provides a discussion and analysis of the environmental risk assessment—including the environmental exposure, hazard, and risk characterization based on the conditions of use for asbestos. Section 5 presents the human health risk assessment, including the exposure, hazard, and risk characterization based on the conditions of use. Section 5 also includes a discussion of PESS based on both greater exposure and susceptibility, as well as a description of aggregate and sentinel exposures. Sections 4 and 5 both discuss any assumptions and uncertainties and how they impact the asbestos risk evaluation. Finally, Section 6 presents EPA's determination of whether the chemical presents an unreasonable risk under the TSCA COUs.

Appendix A includes the key abbreviations and acronyms used within the document and appendices as well as a glossary of select terms. Appendix B summarizes the details of asbestos regulatory and assessment history. Appendix C provides a list of supplemental documents such as spreadsheets and risk calculators. All subsequent appendices include more detailed analysis and discussion than are provided in the main body of this Part 2 Risk Evaluation for Asbestos.

2 CHEMISTRY AND FATE AND TRANSPORT OF ASBESTOS

Physical and chemical properties determine the behavior and characteristics of a chemical that inform its condition of use, environmental fate and transport, potential toxicity, exposure pathways, routes, and hazards. Environmental fate and transport include environmental partitioning, accumulation, degradation, and transformation processes. Environmental transport is the movement of the chemical within and between environmental media, such as suspension and deposition of asbestos fibers. Thus, understanding the environmental fate of asbestos informs the specific exposure pathways, and potential human and environmental exposed populations that EPA considered in this Part 2 of the risk evaluation.

Asbestos – Chemistry and Fate and Transport (Section 2):
Key Points

EPA considered all reasonably available information identified by the Agency through its systematic review process under TSCA to characterize the chemistry and fate and transport of asbestos fibers. The following bullets summarize the key points of this section:

- The strong Si-O-Si covalent bonds found within the silicate tetrahedra of asbestos fibers are responsible for its inherent environmental stability, negligible water solubility, high tensile strength, hardness, and inherent chemical inertness.
- Small asbestos fibers (<1 μm) can remain suspended in air and water and their deposition is expected to be higher closer to the asbestos source and eventually settle to soils, water bodies, and sediments.
- When in water, asbestos fibers will eventually settle into sediments and biosolids from wastewater treatment processes.
- Uptake of asbestos fibers is not expected in terrestrial and aquatic organisms, under normal environmental conditions.
- Incineration of asbestos fibers will result in morphological changes during recrystallization yielding non-asbestos fibers and negligible releases to air.

2.1 Physical and Chemical Properties

EPA gathered and evaluated physical and chemical property data and information according to the process described in the Asbestos Part 2 Systematic Review Protocol. During the evaluation of Asbestos EPA considered both measured and estimated property data/information set forth in Table 2-1, as applicable.

Asbestos is a generic commercial designation for a group of naturally occurring mineral silicate fibers of the serpentine and amphibole series (IARC, 2012b). The Chemical Abstracts Service (CAS) definition of asbestos is a grayish, non-combustible fibrous material. It consists primarily of impure magnesium silicate minerals. EPA initially adopted the TSCA Title II definition of asbestos (added to TSCA in 1986), as the asbestiform varieties of six fiber types—chrysotile (serpentine), crocidolite (riebeckite), amosite (cummingtonite-grunerite), anthophyllite, tremolite, or actinolite. The latter five fiber types are amphiboles, while chrysotile is of the serpentine class. The Part 1 Risk Evaluation focused on chrysotile, which is the only asbestos fiber with ongoing use. Part 2 focuses on other fiber types, including LAA. Table 2-1 shows the physical and chemical properties for the six asbestos fiber types, as well as LAA. LAA is a mixture of amphibole fibers identified in the Rainy Creek complex and present in ore from the vermiculite mine near Libby, Montana (U.S. EPA, 2014c). These fiber types are hydrated magnesium silicate minerals with relatively long crystalline fibers.

In general, amphibole asbestos fibers have less surface area, and are more brittle and inflexible than serpentine asbestos fibers (Badollet, 1951). Asbestos fibers used in most commercial applications consist of aggregates and usually contain a broad distribution of fiber lengths. Amphibole asbestos fiber bundle lengths usually range from a fraction of a millimeter to several centimeters, and diameters range from 0.1 to 1.4 μm (NLM, 2021; U.S. EPA, 2014c; Hwang, 1983; Le Bouffant, 1980).

The variations between serpentine and amphibole asbestos fiber types are likely due to differences in their chemical compositions, leading to differences in microcrystalline surface structure. The amphibole asbestos fiber types can be better understood as being a series of minerals in which cations are progressively replaced (Na, Mg, replaced by Fe) (Virta, 2004). Amphibole asbestos fibers exhibit surface charges either less than −20 mV, or greater than 24 mV indicating at least moderately stable suspensions in water, however, more filamentous fiber types exhibit zeta potentials ranging further from 0 as those stated above, indicating a tendency for more stable suspension (Virta, 2004; Schiller and Payne, 1980). These differences in surface charge are due to the substitution of Mg and Ca ions with divalent Fe at varying ratios in the mineral assemblage. Amphibole asbestos fibers are insoluble in both water and organic solvents but do tend to form stable suspensions in water. The fibers do not appear to undergo physical or chemical changes due to hydrolysis or photolysis but can undergo morphological changes due to weathering and extreme conditions as described in Section 2.2.2.

Table 2-1. Physical and Chemical Properties of Asbestos Fiber Type

Property	Chrysotile	Crocidolite	Amosite	Anthophyllite	Tremolite	Actinolite	Libby Amphibole
Essential Composition	Silica sheet (Si_2O_5), with a layer of brucite ($Mg(OH)_2$) with every 3 hydroxyls replaced by oxygens [1]	Na, Fe silicate with some water [5]	Fe, Mg silicate [5]	Magnesium and iron silicates [11]	Ca, Mg silicate with some water [5]	Ca, Mg, Fe silicate with some water [5]	Winchite (84%), richterite (11%), and tremolite (6%). [16]
Color	Usually white to grayish green, may have tan coloring [1]	Lavender, blue, greenish [5]	Ash gray, greenish, or brown [5]	Grayish white, brown-gray, or green [5]	White to light-green [11]	Greenish [5]	–
Luster	Silky [1]	Silky to dull [5]	Vitreous to pearly [5]	Vitreous to pearly [5]	Silky [5]	Silky, greasy to vitreous [5]–[17]	–
Surface Area (m^2/g)	13.5 to 22.4 [2]	4.62 to 14.80 [2]	2.25 to 7.10 [2]	4.4 to 14.4 [12]	0.66 to 9.2 [12]	–	1.1 to 7.4 [16]
Individual Fiber Diameter (µm)	0.02 to 0.03 [1]	0.09 [7] (Median true diameter)	0.26 (median true diameter) [7]	<0.10 to 1.4 [13]	0.2 to 0.42 [16]	–	0.61 ± 1.22 [16]
Average fiber outer diameter (A)	200 [1]	–	–	–	–	–	–
Particle Dimension (µm) Largest Dimension (L) Smallest Dimension (S) Aspect Ratio L/S	(L): 1.00 ± 0.44 µm; (S): 0.07 ± 0.02 µm; L/S: 13.8 ± 5.1 [3]	(L): 5.33 ± 2.77 µm; (S): 0.248 ± 1.60 µm; L/S: 21.478 ± 2.667 [8]	(L): 4.63 µm; (S): 0.258 µm; L/S: 17.99 [10]	–	–	(L): 0.8 to 36.0 µm; (S): 0.2 to 12.0 µm; L/S: 3 to 4 [18]	(L): 0.220 to 23.598 (1.95 mean) (S): 0.0244 to 2.593 (0.316 mean) (L/S): 1.0 to 128.9 (7.1 mean) [20]
Hardness (Mohs)	2.5 to 4.0 [1]	4.0 [6]	5.5 to 6.0 [6]	5.5 to 6.0 [5]	5 to 6 [11]	6.0 [5]	–
Density (g/mL)	2.19 to 2.68 [4]	3.2 to 3.3 [6]	3.1 to 3.25 [6]	3.09 [14]	2.9 to 3.2 [6]	2.9 to 3.1 [19]	–
Optical Properties	Biaxial positive parallel extinction [1]	Biaxial negative oblique extinction [6]	Biaxial positive parallel extinction [6]	Biaxial positive extinction parallel [5]	Biaxial negative oblique extinction [6]	Biaxial negative extinction inclined [5]	–
Refractive Index	1.53 to 1.56 [1]	1.654 to 1.701[9]	1.635 to 1.696 [9]	1.596 to 1.652 [9]	1.599 to 1.668 [9]	1.599 to 1.668 [9]	–
Flexibility	High [1]	Fair to Good [5]	Good [5]	Poor (very brittle, non-flexible) [5]	Poor, generally brittle, sometimes flexible [5]	Poor, brittle, and non-flexible [5]	–
Texture	Silky, soft to harsh [1]	Soft to harsh [5]	Coarse, but somewhat pliable [5]	Harsh [5]	Generally harsh, sometimes soft [5]	Harsh [5]	–

Property	Chrysotile	Crocidolite	Amosite	Anthophyllite	Tremolite	Actinolite	Libby Amphibole
Spinnability	Very good [5]	Fair [5]	Fair [5]	Poor [5]	Generally poor, some are spinnable [5]	Poor [5]	–
Tensile Strength (MPa)	1,100 to 4,400 [1]	1,400 to 4,600 [6]	1,500 to 2,600 [6]	≤30 [5]	<500 [6]	≤7 [5]	–
Resistance to: Acids Bases	Weak, undergoes fairly rapid attack Very good [5]	Fair Good [5]	Fair, slowly attacked Good [5]	Fair Very good [5]	Resistance to acids: fair Resistance to bases: good [5]	Fair Fair [5]	–
Zeta Potential (mV)	+13.6 to +54 [6]	−32 [6]	−20 to −40 [6]	blocky particles = 39±2 and elongated particles = 49±2 at pH 7 [15]	blocky particles = 24±1 and elongated particles = 35±3 at pH 7 [15]	–	–
Decomposition Temperature (°C)	600 to 850 [6]	400 to 900 [6]	600 to 900 [6]	1,150 to 1,340 [14]	950 to 1,040 [6]	1,140 to 1,296 °C [19]	–

Notes: source; overall data quality determination
1 = (NLM, 2021); High
2 = (Addison et al., 1966) ; Medium
3 = (Thorne et al., 1985); High
4 = (Elsevier, 2021c); High
5 = (Badollet, 1951); High
6 = (Virta, 2004); High
7 = (Hwang, 1983); High
8 = (Siegrist and Wylie, 1980); High
9 = (Lott, 1989); High
10 = (Snyder et al., 1987); High
11 = (Larrañaga et al., 2016); High
12 = (Pollastri et al., 2014); High
13 = (Le Bouffant, 1980); High
14 = (Elsevier, 2021b); High
15 = (Schiller and Payne, 1980); High
16 = (U.S. EPA, 2014c); High
17 = (Zhong et al., 2019); High
18 = (Virta et al., 1983); High
19 = (Elsevier, 2021a); High
20 = (Lowers and Bern, 2009), High

2.2 Environmental Fate and Transport

2.2.1 Fate and Transport Approach and Methodology

Reasonably available environmental fate data, including fiber dissolution in water, bioconcentration, biodegradation rates, removal during wastewater and drinking water treatment, suspension and resuspension, and incineration are among selected parameters for consideration in the current risk evaluation. In assessing the environmental fate and transport of asbestos, EPA considered the full range of results from sources that were rated as high and medium confidence. Information on the full data quality evaluation and data extraction data set is available in the supplemental file *Risk Evaluation for Asbestos Part 2 – Systematic Review Supplemental File: Data Quality Evaluation and Data Extraction Information for Environmental Fate and Transport* (U.S. EPA, 2024c).

Table 2-2 provides selected environmental fate data that EPA considered while assessing the fate of asbestos. The data in Table 2-2 were updated after publication of *Final Scope of the Risk Evaluation for Asbestos Part 2: Supplemental Evaluation Including Legacy Uses and Associated Disposals of Asbestos* (87 FR 38746) (EPA-HQ-2021-0254-0044) with additional information identified through the systematic review process.

Table 2-2. Environmental Fate Properties of Asbestos

Property or Endpoint	Value[a]	Reference	Overall Data Quality Determination
Aqueous dissolution	Rate of dissolution is a function of surface area and temperature. Mg^{2+} may be continuously liberated from fibers leaving a silica skeleton. Smaller particles liberated more magnesium.	Choi and Smith (1972)	High
Air transport	Asbestos fibers of 0.1 to 1 um aerodynamic diameters can be transported thousands of miles in air.	ATSDR (2001)	Medium
Removal from water with direct filtration	Chrysotile asbestos; Mean removal: 90–99.89%	McGuire et al. (1983)	High
Removal from wastewater for reuse application	Removal >99% Water reuse with flocculation, filtration, reverse osmosis, and disinfection	Lauer and Convery (1988)	High
Removal in surface water	Chrysotile asbestos; Removal of fibers (%): >90% removal at reservoirs with detention times >1 year Reported removals: Lake Silverwood: 27%; detention time 0.1 year Lake Skinner: 88%; detention time 0.5 year Lake Perris: 96%; detention time 1.5 years Lake Pyramid-Castaic: 99.8%; detention time 3.0 years	Bales et al. (1984)	Medium
Aerobic biodegradation	Half-life in water >200 days	NICNAS (1999)	Medium
Bioconcentration factor (BCF)	Asbestos fibers were found in the asbestos-treated fish by transmission electron microscopy (TEM). Sunfish lost scales and had epidermal	Belanger et al. (1986c)	High

Property or Endpoint	Value[a]	Reference	Overall Data Quality Determination
	tissue erosion. Asbestos fibers were not identified in control or blank samples.		
Incineration	Incineration (combustion chamber target 850–900 °C): Asbestos was not detected in solid product or in exhaust gas; asbestos reduction due to morphological changes.	Osada et al. (2013)	High

[a] Measured unless otherwise noted

2.2.2 Summary of Fate and Transport Assessment

Asbestos is a group of persistent and naturally occurring hydrated silicate mineral fibers that can be found in soils, sediments, lofted in air and windblown dust, surface water, ground water and biota (ATSDR, 2001) as depicted in Figure 2-1. The basic building block of asbestos fibers are silicate tetrahedra in a variety of polymeric structures through formation of very strong Si-O-Si covalent bonds and cationic sites that are occupied by either magnesium (chrysotile asbestos) or a combination of magnesium, iron, calcium, and/or sodium (amphibole asbestos). The strong Si-O-Si covalent bonds are responsible of many chemical properties that makes asbestos very stable in most environmental conditions, have high tensile strength and hardness, and its inherent chemical inertness. The ionic bonds where metals attach within the crystal lattices in the main silicate chain of asbestos fibers are weaker than covalent bonds, leading to metal leaching in aqueous media. Under extreme conditions (*e.g.*, 50 mM oxalic acid) asbestos fibers have been reported to undergo minor morphological changes such as changes in fiber length or leaching of cations from the surface of the crystal lattice (Favero-Longo et al., 2005; Gronow, 1987; Schreier et al., 1987; Choi and Smith, 1972). In general, asbestos fibers do not evaporate, significantly dissolve, burn, undergo significant reactions, or otherwise degrade in the environment (ATSDR, 2001).

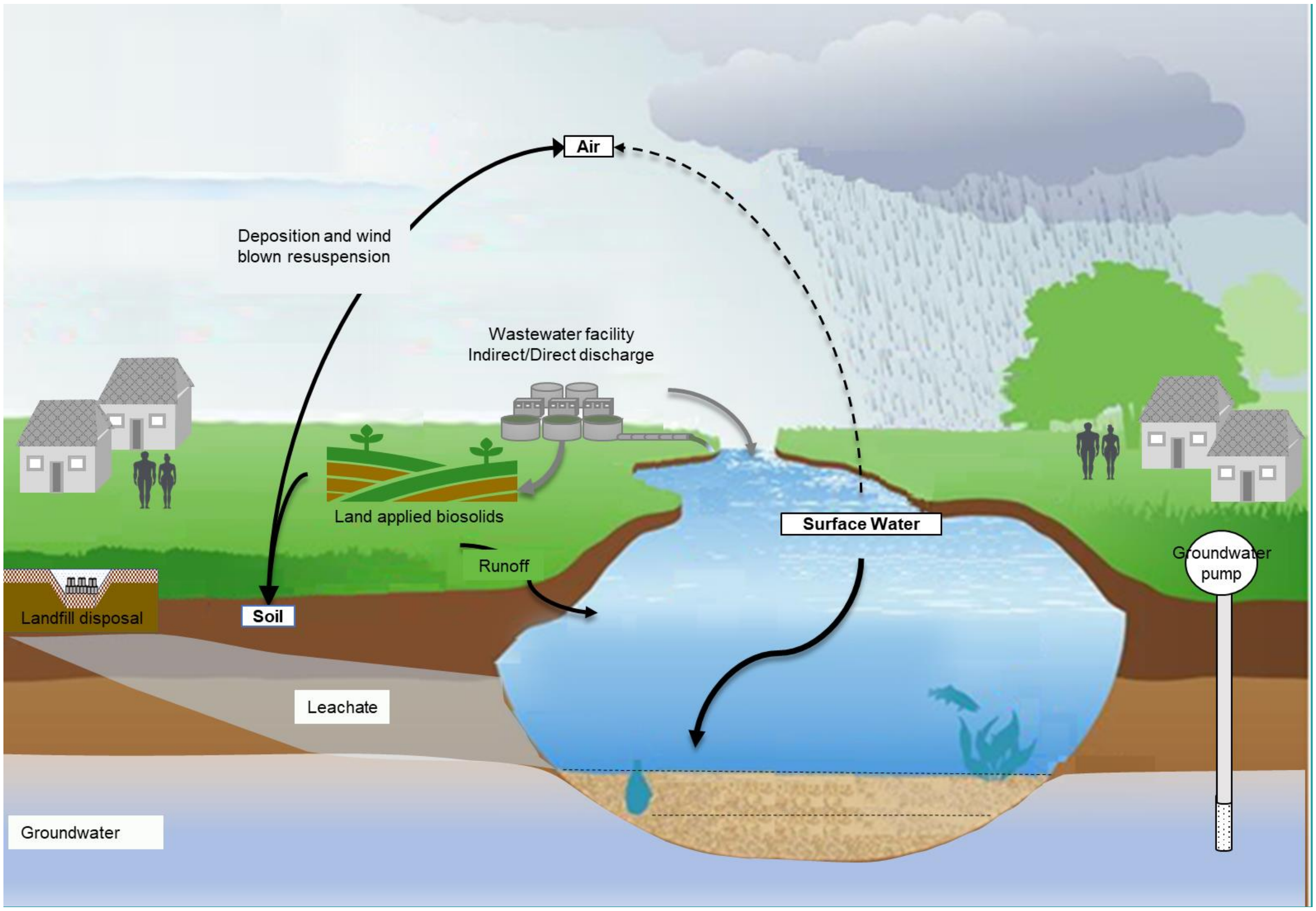


Figure 2-1. Fate and Transport of Asbestos in the Environment[a]

[a] The diagram depicts the distribution (grey arrows) and transport (black arrows) of Asbestos in the environment. The width of the arrow is a qualitative indication of the likelihood that the indicated partitioning will occur (*i.e.*, wider arrows indicate more likely partitioning and dashed arrows negligible transport).

Despite the durability of asbestos fibers in the environment, the accumulation of asbestos fibers is not generally observed in terrestrial and aquatic organisms (ATSDR, 2001). Limited studies are available on the bioconcentration or bioaccumulation of asbestos in environmental organisms. In field studies, exposure to high concentrations of chrysotile asbestos (10^4 to 10^8 fibers/L) has been documented to result in embedment of fibers into tissues in clams (*Corbicula* sp.) (Belanger et al., 1990; Belanger et al., 1986c; Belanger et al., 1986a, b). However, under controlled laboratory experiments, 30-day aqueous exposure to 10^8 fibers/L (10^5 f/cc) chrysotile asbestos resulted in negligible accumulation of fibers in clams (Belanger et al., 1987). However, high fiber burdens were reported in clams with a lifelong asbestos exposure of 10^9 fibers/L (10^6 f/cc) (Belanger et al., 1987). In general, asbestos fibers are not expected to bioaccumulate within aquatic organisms under environmentally relevant conditions.

Asbestos fibers usually contain a broad distribution of fiber lengths. Small asbestos fibers (<1 μm) remain suspended in air and water and their deposition is expected to be higher closer to the asbestos source as described in Section 3.3.4. In surface water, the concentration of suspended asbestos fibers are reported to decrease more than 99 percent in water reservoirs with hydraulic retention times greater than 1 year (Bales et al., 1984). Storm events may increase the deposition and resuspension of asbestos fibers (Schreier and Lavkulich, 2015). During water treatment processes, the use of coagulation and flocculation treatment processes have been reported to remove 80 to 99 percent of asbestos fibers, with higher removal rates reported with use of filtration treatment units (Kebler et al., 1989; Lauer and

Convery, 1988; Bales et al., 1984; McGuire et al., 1983; Lawrence and Zimmermann, 1977; Schmitt et al., 1977; Lawrence and Zimmermann, 1976). As stated in the Risk Evaluation for Asbestos Part 1, once in water it will eventually settle into sediments (or possibly be present in biosolids from wastewater treatment processes) (U.S. EPA, 2020a).

The inherent insulation properties of asbestos fibers are related to the fiber's potential to undergo dehydration and dehydroxylation as a function of temperature. For example, the thermal insulation property of chrysotile is due to its capability to remain stable up to 550 °C via dehydration, then dehydroxylation of the brucite layer that occurs from 550 to 750 °C followed by decomposition at 850 °C. Thermally decomposed chrysotile fibers recrystalizes at 800 to 850 °C as forsterite and silica (Virta, 2004). Recent studies have investigated the use of destructive treatment approaches such as incineration as an alternative for the disposal of asbestos containing materials. The use of incineration and other thermal treatments of asbestos containing materials have been reported to transform asbestos fibers into non-asbestiform types during recrystallization with very low to non-detectable concentrations of asbestos fibers released to air (Carneiro et al., 2021; Obmiński, 2021; Witek et al., 2019; Osada et al., 2013; Porcu et al., 2005; Jolicoeur and Duchesne, 1981).

Overall, asbestos may be released to the environment through industrial or commercial activities, such as processing raw chrysotile asbestos, fabricating/processing asbestos containing products, or the lofting of friable asbestos containing materials during use, disturbance and disposal of asbestos containing materials.

A detailed summary of physical and chemical properties and a fate and transport assessment is available in Appendix D and the fate assessment supplemental document.

2.2.3 Weight of Scientific Evidence Conclusions for Fate and Transport

2.2.3.1 Strengths, Limitations, Assumptions, and Key Sources of Uncertainty for the Fate and Transport Assessment

During the data extraction and evaluation of data collected in the systematic review process, the results from multiple high- and medium quality studies were selected for this risk evaluation to represent the range of the identified environmental fate endpoints. The available information was measured under field monitoring conditions or controlled laboratory experiments. These studies are subject to several sources of variability including variability inherent in the methodology, inter-laboratory variability and variability due to factors such as the temperature, pH ranges, and test substance concentrations. Because of these factors, no single value is universally applicable. However, the weight of scientific evidence shows asbestos fibers are expected to be very stable under most environmental conditions.

Given the similarity of results from multiple high and medium quality studies, there is robust weight of evidence about the dissolution and removal in water and the incineration of asbestos fibers. Asbestos fibers are stable and persistent in water under normal environmental conditions. Once in water, asbestos fibers are expected to settle into sediments and biosolids, thus aquatic or terrestrial organisms are unlikely to be exposed to asbestos fibers suspended in water. Lastly, the industrial incineration of asbestos results in morphological changes resulting in the formation of non-asbestos fibers (such as forsterite, amorphous silica, and enstatite during the recrystallization process). In addition, very low to non-detectable concentrations of asbestos fibers released to air have been reported during incineration processes.

Due to the limited number of high and medium quality studies there is moderate weight of evidence about the bioconcentration, biodegradation, and air transport of asbestos fibers. Overall, there is no evidence to suggest bioaccumulation in food webs (ATSDR, 2001), but it is very persistent under most environmental conditions (NICNAS, 1999). Furthermore, fiber deposition is expected to be greater closer to asbestos sources as described in Section 3.3.4.

3 RELEASES AND CONCENTRATIONS OF ASBESTOS

3.1 Approach and Methodology

3.1.1 Industrial and Commercial

EPA categorized the COUs listed in Table 1-1 into occupational exposure scenarios (OESs) as shown in Table 3-1. EPA developed the OESs to group processes or applications with similar sources of release and occupational exposures that occur at industrial and commercial workplaces within the scope of the risk evaluation. For each OES, occupational exposure and environmental release results are provided and are expected to be representative of the entire population of workers and sites involved for the given OES in the United States. In some cases, only a single OES is defined for multiple COUs, while in other cases multiple OESs are developed for a single COU. This determination is made by considering variability in release and use conditions and whether the variability can be captured as a distribution of exposure or instead requires discrete scenarios. Further information on specific OESs is provided in Appendix G.

Table 3-1. Crosswalk of Conditions of Use to Occupational Exposure Scenarios Assessed

Life Cycle Stage[a]	Category[b]	Subcategory[c]	Occupational Exposure Scenario (OES)
Industrial/ Commercial Uses	Chemical substances in construction, paint, electrical, and metal products	Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities; (Appendix G.10) Handling of asbestos-containing building materials during firefighting or other disaster response activities (Appendix G.11)
		Machinery, mechanical appliances, electrical/electronic articles	Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos (Appendix G.12)
		Other machinery, mechanical appliances, electronic/electronic articles	
		Electrical batteries and accumulators	Handling articles or formulations that contain asbestos (Appendix G.13)
		Solvent-based/water-based paint	
		Fillers and putties	
	Chemical substances in furnishing, cleaning, treatment care products	Construction and building materials covering large surface areas, including fabrics, textiles, and apparel	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities; (Appendix G.10) Handling of asbestos-containing building materials during firefighting or other disaster response activities

Life Cycle Stage[a]	Category[b]	Subcategory[c]	Occupational Exposure Scenario (OES)
Industrial/ Commercial Uses			(Appendix G.11)
		Furniture & furnishings including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles	Handling articles or formulations that contain asbestos (Appendix G.13)
	Chemical substances in packaging, paper,	Packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft)	Handling articles or formulations that contain asbestos (Appendix G.13)
	Chemical substances in products not described by other codes	Other (artifacts)	
		Other (aerospace applications)	
	Chemical substances in automotive, fuel, agriculture, outdoor use products	Lawn and garden products (vermiculite soil treatment)	Handling of vermiculite-containing products (Appendix G.14)
	Laboratory chemicals	Laboratory chemicals (vermiculite packaging products)	
	Mining of non-asbestos commodities	Mining of non-asbestos commodities	Mining of non-asbestos commodities (Appendix G.15)
Disposal, including Distribution for Disposal	Disposal, including distribution for disposal	Disposal, including distribution for disposal	Waste handling, disposal, and treatment (Appendix G.16)

[a] Life Cycle Stage Use Definitions (40 CFR 711.3)

- "Industrial use" means use at a site at which one or more chemicals or mixtures are manufactured (including imported) or processed.
- "Commercial use" means the use of a chemical or a mixture containing a chemical (including as part of an article) in a commercial enterprise providing saleable goods or services.
- "Consumer use" means the use of a chemical or a mixture containing a chemical (including as part of an article, such as furniture or clothing) when sold to or made available to consumers for their use.
- Although EPA has identified both industrial and commercial uses here for purposes of distinguishing scenarios in this document, the Agency interprets the authority over "any manner or method of commercial use" under TSCA section 6(a)(5) to reach both.

[b] These categories of conditions of use appear in the Life Cycle Diagram, reflect CDR codes, and broadly represent conditions of use of asbestos in industrial and/or commercial settings.

[c] These subcategories reflect more specific conditions of use of asbestos.

3.1.1.1 General Approach and Methodology for Environmental Releases

For each OES, daily releases to air, land, and water were estimated based on annual releases, release days, and the number of sites (Figure 3-1). The blue boxes represent primary sources of release data that were used to develop annual releases, release days, and number of sites. The information in the green boxes is aggregated by OES to provide daily release estimates. Generally, EPA used 2016 to 2020 TRI (U.S. EPA, 2022a), 2014 to 2017 National Emissions Inventory (NEI) (U.S. EPA, 2022d), and 2015 to 2022 National Response Center (NRC, 2022) to estimate annual releases. Where available, EPA used literature search data for estimation of associated release days. To estimate the number of sites using asbestos within a condition of use, EPA relied on U.S. Census Bureau data, as well as literature search data. Generally, information for reporting sites in NEI was sufficient to accurately characterize each reporting site's condition of use. However, information for determining the condition of use for reporting sites in TRI is typically more limited. The approach and methodology for estimating daily releases is described in Appendix G, which also includes detailed facility-level results.

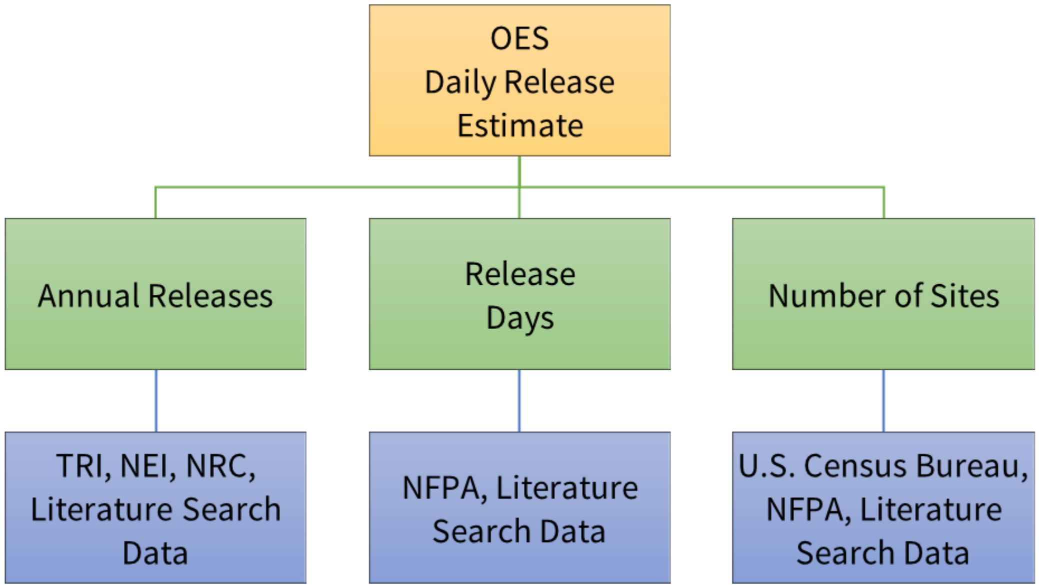


Figure 3-1. An Overview of How EPA Estimated Daily Releases for Each OES
TRI = Toxics Release Inventory; NEI = National Emissions Inventory; NRC = National Response Center; NFPA = National Fire Protection Association

3.1.2 Take-Home

Workers performing job-related activities (*e.g.*, demolition and asbestos removal) that expose them to asbestos fibers can transfer asbestos fibers from the working environment to the home environment via contaminated clothes or surfaces. This creates the potential for take-home exposures. Demolition and asbestos removal workers go to great lengths to avoid asbestos exposure to themselves, those around them, and the environment when they follow National Emission Standards for Hazardous Air Pollutants (NESHAP) rules and regulations, 40 CFR Part 61, subpart M. However, take-home exposures from contaminated clothes/surfaces can occur when asbestos is not handled following NESHAP guidance or when personal protective equipment (PPE, protective clothing) is unavailable. This section summarizes take-home exposures scenarios and the data and methods used to evaluate scenarios not following NESHAP.

3.1.2.1 Methods and Key Assumptions to Determine Asbestos Concentrations

Figure 3-2 provides a diagram of the mechanism of exposure for the take-home scenario. On the left, the diagram depicts an occupational worker on three consecutive days of work, where each day the worker is exposed to the same 8-hour time-weighted average (TWA) asbestos concentration. In addition to their inhalation exposure during the workday, the fibers may settle onto the clothing worn by the worker, referred to as the "occupational loading." This fiber loading dictates the quantity of asbestos available for resuspension at home during laundry preparation. Although current Occupational Safety and Health Administration (OSHA) regulations (29 CFR 1926.1101) prohibit taking contaminated clothing home, this exposure pathway was included to account for workers who may not follow all OSHA guidelines and incur exposures due to lack of knowledge about asbestos identification, removal, handling, and disposal of contaminated clothes or a personal choice. Thus, on the right, when the clothing worn on those three days is prepared for laundering, shaking/folding/unfolding the clothes will tend to resuspend a fraction of the loaded fibers into the residential indoor air, resulting in inhalation exposure for the clothes handler and any bystanders.

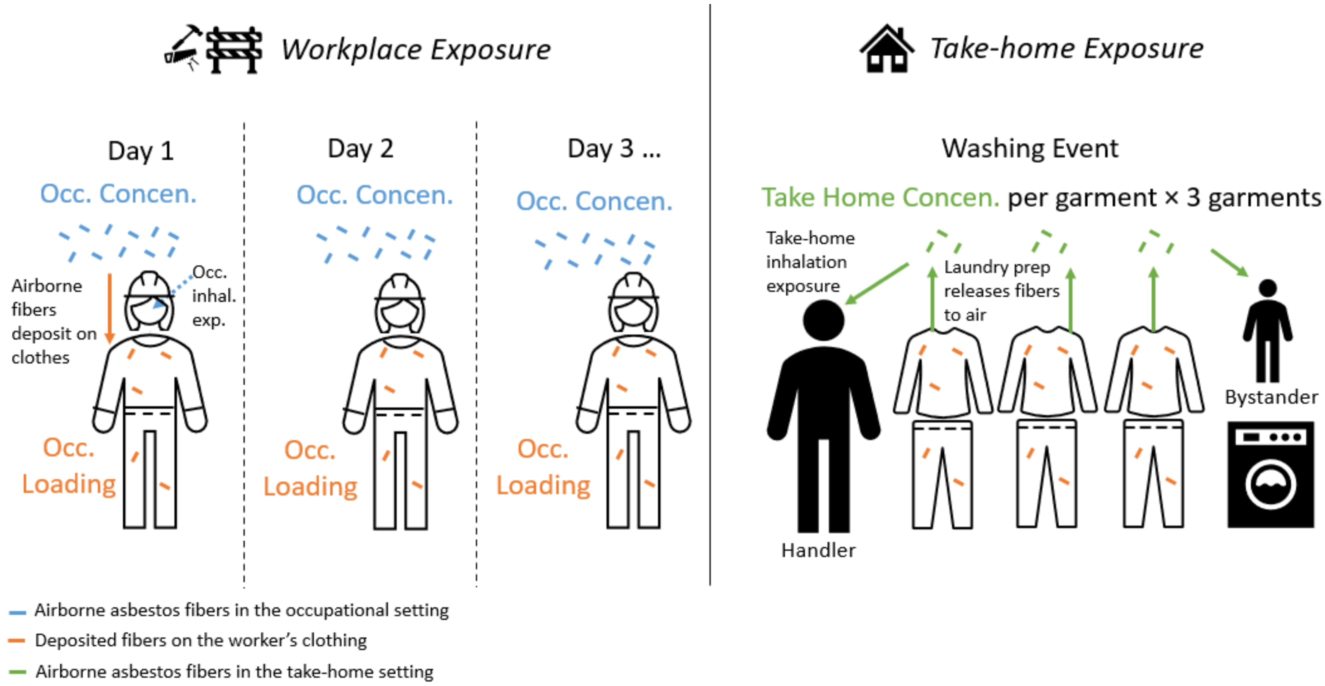


Figure 3-2. Take-Home Scenario Mechanism of Exposure

In considering the take-home scenarios, exposures across days could happen in many ways depending on the number of work garment sets worn, the pattern of workdays when asbestos exposure occurs, the frequency of washing events, and the number of garment sets per washing event. For example, (1) a worker may wear one garment set for three consecutive days and then launder, or (2) a worker may wear a different garment set each day and launder all three together (see Figure 3-2). Because the occupational concentrations and take-home concentrations are linked via the occupational loading process, EPA defined a "unit" of take-home exposure, as depicted in Figure 3-3.

Key Assumption: Unit Exposure for Take-Home Scenarios		
one *occupational* exposure day where a *single garment* is loaded based on an *8-hr TWA conc.*	corresponds to ➡	one *take-home* exposure day where a *single garment* is washed leading to a *proportional 24-hr TWA conc.*

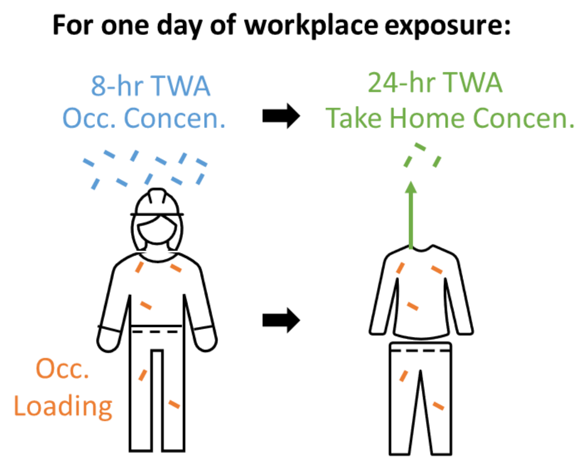


Figure 3-3. Take-Home Exposure Scenarios Key Assumptions Summary

This approach assumes all garment sets are ultimately washed, and one unit is 1 day of loading at the 8-hour TWA concentration. Then, the 24-hour TWA take-home concentration when that garment is washed is given by an empirically derived "take-home slope factor" (second term in Equation 3-1**).** The empirical data to derive the take-home slope factor are described in Section 3.1.2.2 and Table 3-2. In this proposed approach, a specific scenario where the actual 8-hour TWA concentration is "[X] f/cc" (first term in Equation 3-1) results in a 24-hour take-home exposure concentration of [*Y*] multiplied by the take-home slope factor. The intercept should be zero because if there is no occupational fiber loading then there is no take-home exposure.

Equation 3-1. Equation to Calculate Take-Home Exposures 24-Hour TWA Concentrations

$$24hr\ TWA\ Concentration\ = 8hr\ TWA\ Concentration \times Take\ home\ slope\ factor + Intercept$$

$$Take\ home\ slope\ factor = \frac{24hr\ TWA\ Concentration\ [Y]}{8hr\ TWA\ Concentration\ [X]}$$

3.1.2.2 Data Sources and the Take-Home Slope Factor Estimation

The 8-hour TWA occupational exposure concentration [X] and 24-hour TWA take-home exposure concentration [Y] are data taken from the identified studies. The take-home slope factor uses studies that jointly monitor the workplace exposure and subsequent handling of asbestos-contaminated clothing ("take-home studies") and represents the ratio between (1) the 24-hour TWA take-home exposure concentrations during laundry preparation activities (Equation 3-1, numerator), and (2) the 8-hour TWA occupational exposure concentrations during the loading period (Equation 3-1, denominator).
To select these studies, all experimental, monitoring, and/or modeling studies with a low, medium, or high overall quality determination were examined for applicability using the following criteria:

- **Keyword:** Title or abstract mention "take-home" exposures

- **Scenario:** Asbestos fibers released from clothing or other items brought home from the work site during routine handling of clothes.
- **Country:** United States or Canada
- **Timeframe:** Sampling conducted since 2000, although prior years are considered given limited availability of data
- **Media Type:** Indoor air or personal inhalation
- **Microenvironment:** Living area of houses (test houses or simulated via experimental chambers)
- **Analytical Method/Units:** PCM or TEM measured as fibers/cc

Following application of these criteria, eight experimental studies were selected for further review; one study, upon further full-text review, was excluded, leaving seven studies for use in determining the take-home slope factor. The included studies were selected because they represent occupational loading to clothing and subsequent handling of that garment. EPA uses these data as a proxy for workers that are unaware of asbestos presence or health effects and bring those garments home. If the workers follow the existing guidelines (AHERA 40 CFR Part 763), take-home exposures would likely not happen. The excluded study, Weir et al. (2001), was not considered representative of residential clothes handling scenarios because they used small 150 L dynamic flow chambers in the experiments. There is high uncertainty in how representative the experimental method (small chamber) is to real-world samples collected via personal breathing zone or area samples. Table 3-2 and Table_Apx L-1 in Appendix L provide the study activity type, job-related loading event information, take-home exposure event information, and sampling details of the seven studies. Table 3-2 also summarizes the measured levels of asbestos during the loading and take-home clothes preparation used in the regression analysis. Calculations and slope factor approaches are available in *Asbestos Part 2 RE - Risk Calculator for Take Home – November 2024* (U.S. EPA, 2023e) (see also Appendix C).

Table 3-2. Asbestos 8-Hour TWA Loading Concentrations and 24-Hour TWA Take-Home Concentrations Used in Regression

Study	Analytical Method	Event Duration (minutes)		Number of Garments per Handler Event	Loading Event Concentration (f/cc)	8-hr TWA Avg. Loading Event Concentration (f/cc)	Avg. Take-Home Event Concentration (f/cc)		24-hr TWA Take-Home Event Concentration Normalized to One Garment (f/cc)	
		Load[a]	Handler[b]				Handler	Bystander	Handler	Bystander
Abelmann et al. (2017)	PCM	30	30	2	8.8E01	5.50E−01	5.20E−01	3.40E−01	5.42E−03	3.54E−03
Madl et al. (2014)	PCME	30	30	6	1.3E−02	8.13E−04	5.00E−03	1.50E−03	1.74E−05	5.21E−06
Madl et al. (2009)	PCME	30	30	11	2.4E−02	1.50E−03	3.60E−02	1.00E−02	6.82E−05	1.89E−05
Madl et al. (2008)	PCME	30	15	3	1.98E−01	1.24E−02	1.10E−02	1.00E−02	3.82E−05	3.47E−05
Jiang et al. (2008)	PCME	30	15	3	1.19E−01	7.44E−03	3.00E−03	2.00E−03	1.04E−05	6.94E−06
Sahmel et al. (2014) Low	PCME	30	15 handler, 30 bystander	6	5.0E−02	3.13E−03	7.00E−03	1.00E−03	1.22E−05	3.47E−06
Sahmel et al. (2014) Medium					2.235E00	1.40E−01	9.40E−02	3.75E−03	1.63E−04	1.30E−05
Sahmel et al. (2014) High					3.125E00	1.95E−01	1.29E−01	9.50E−03	2.24E−04	3.30E−05
Sahmel et al. (2016)	PCME	390	15 handler, 45 bystander	3	1.14E01	9.26E00	2.94E00	6.20E−01	1.02E−02	6.46E−03

[a] Load refers to occupational loading that is the fibers that settle onto the clothing worn by the worker. This fiber loading dictates the quantity of asbestos available for resuspension at home during laundry preparation.
[b] Refers to amount of time in minutes the handler of clothing handled the clothing, which can include activities like undressing, shaking, and folding
PCM = phase contrast microscopy; PCME = PCM-equivalent

Using the 8-hour TWA loading event concentrations in Table 3-2 as the independent variable and the 24-hour TWA take-home concentrations as the dependent variable, linear regression slopes (the take-home slope factor), intercepts, and R^2 were estimated in three different ways:

- included in this risk evaluation all 7 studies in a single regression;
- included Abelmann et al. (2017), Madl et al. (2014), and Madl et al. (2009) together; and
- included Madl et al. (2008), Jiang et al. (2008), Sahmel et al. (2014), and Sahmel et al. (2016) together; the three different target loading concentrations in Sahmel et al. (2014) were treated as three different points in the regression.

Table 3-3 presents the results from this analysis and Figure 3-4 regression analysis makes clear that the different studies cluster into two different take-home slope factors, where Abelmann et al. (2017), Madl et al. (2014), and Madl et al. (2009) give a slope factor of approximately 0.0098 for handlers while Madl et al. (2008), Jiang et al. (2008), Sahmel et al. (2014), and Sahmel et al. (2016) give a slope factor of 0.0011 for handlers. The factor in Regression 3 is roughly an order of magnitude lower than in Regression 2 and generally in line with the conclusion in Sahmel et al. (2014) and Sahmel et al. (2016) that the 8-hour TWA take-home concentrations are about 1 percent of the 8-hour TWA loading concentrations. Both Regression 2 and 3 have R^2 near 1, and no specific study experimental set-up or method descriptions indicated why the two groups of studies cluster into two distinct groups. Without additional information to indicate which studies may provide the best experiments from which to estimate these slope factors, the two groups were used to determine a central tendency (CT) and high-end (HE) take-home slope factor:

- CT Slope Factor, Regression 3
  - Handler: 0.0011; bystander: 0.00070
- HE Slope Factor, Regression 2
  - Handler: 0.0098; bystander 0.0064

Table 3-3. Regression Coefficients for Three Regression Equations

Regression	Handler Regression			Bystander Regression		
	Slope	Intercept	R^2	Slope	Intercept	R^2
Regression 1, All Studies	0.0011	0	0.8059	0.00067	0	0.7916
Regression 2, 3 Studies, "HE"	0.0098	0	0.9999	0.0064	0	0.9999
Regression 3, 4 Studies, "CT"	0.0011	0	1.0000	0.00070	0	0.9995
24-hour TWA take-home concentration as a function of 8-hour TWA loading concentration						

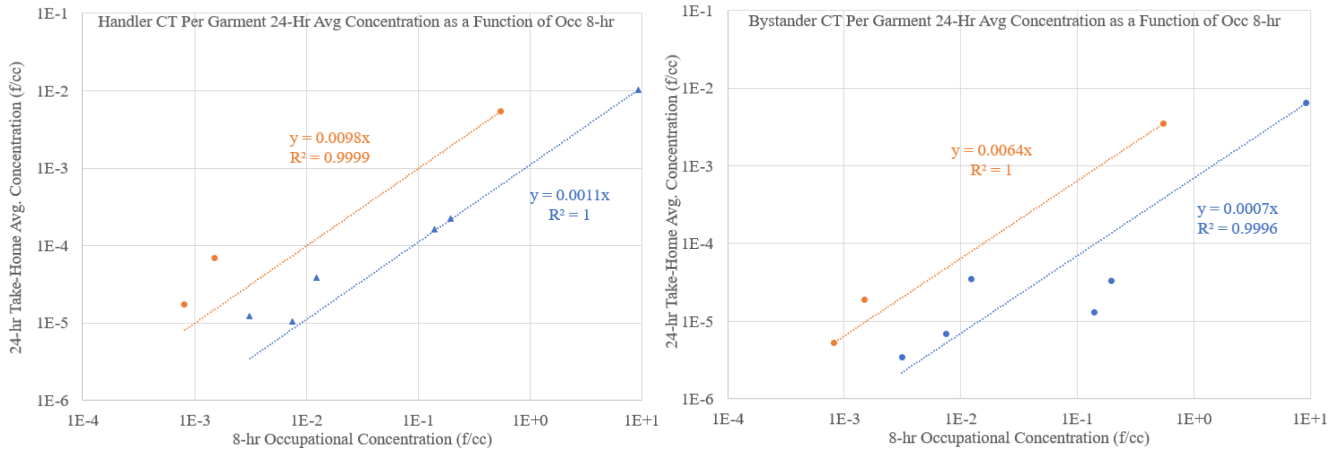


Figure 3-4. Take-Home Exposure Slope Factor Regression for Handler and Bystander
Orange circles are Regression #2 representing the high-end studies; blue and circles triangles are Regression #3 representing the central tendency studies.

3.1.2.3 Take-Home Scenario Concentration Data Uncertainties and Variability

EPA targeted studies that aimed to replicate common working and laundry activities that followed acceptable sampling and analytical methods. This section explores the uncertainty associated with the data used to build take-home scenarios for all OESs.

The approaches described in Section 3.1.2 to obtain take-home asbestos fiber loading concentrations onto worker clothes was developed because EPA did not identify studies that measured take-home exposures for all COUs and asbestos containing products. Although EPA has high confidence in the regression approach, there are sources of uncertainty in the assumptions and approximations used.

The overall data quality evaluation for all but one of the studies was medium, and the remaining study was high (see Table_Apx L-1). All studies used PCM and PCME for asbestos concentration and identification which decreases uncertainty from mixing in non-asbestos fibers in the reported measurements. None of the studies reported fiber size which increases uncertainty in the reported concentrations as smaller particles could have been included and could result in increased concentrations and subsequently overestimate risk. Simulations of fiber releases during an activity were different for all studies where different sources of asbestos products were used or various simulated asbestos emission concentrations were used with no link to an actual asbestos containing product or activity. However, sampling duration was stable within 15 and 30 minutes for six of the studies; one study used 45 minutes for the bystander simulation. Similar sampling times minimizes uncertainties when aiming to harmonize all studies into a regression approach.

The regression approach to use one garment (unit) to a loading event and eventual laundry activity minimizes uncertainties and variability while decreasing complexity. One garment loading to a laundry activity assessment can then be extended to other garment use choices and laundry handling practices.

Overall uncertainty and variability in the take-home exposure scenario are moderate and high respectively indicating that estimates are robust and represent a wide range of exposure scenarios.

Table 3-4. Qualitative Assessment of the Uncertainty and Variability Associated with Concentration Data Used in Take-Home Exposure Analysis

Variable Name	Effect	Uncertainty (L, M, H) [a]	Variability (L, M, H) [a]
Asbestos fiber sizes	Concentration data used may include smaller particle sizes and hence overestimate risk.	H	H
Overall sample analysis method such as TEM, PCM, and PCME	Methods may include non-asbestos fiber concentrations and overestimate risk. Most studies used PCME to confirm asbestos fibers.	M	M
Simulations of fiber releases during an activity	Increase uncertainty and variability because products and asbestos concentrations vary for different activities and asbestos containing products.	H	H
Sampling time	Similar sampling times decreases variability and uncertainty as these were representative of usual occupational activity durations.	L	L
One garment per loading approximation	Decreases complexity so results can be used for all take-home and working scenarios.	M	M
Overall take-home concentration data	**Concentrations used in risk calculation estimates.**	**M**	**H**[b]

PCM = phase contrast microscopy; PCME = PCM-equivalent; TEM = transmission electron microscopy
[a] L = low; M = moderate; H = high
[b] Low-end to high-end concentration ranges 3–4 orders of magnitude difference

3.1.3 Consumer

The consumer COUs include categories related to chemical substances in

- Construction, paint, electrical, and metal products;
- Furnishing, cleaning, treatment care products;
- Packaging, paper, plastic, toys, hobby products;
- Automotive, fuel, agriculture, outdoor use products; and
- Products not described by other codes.

Specifically, these categories are associated with subcategories and specific product examples, as shown in Table 1-1. These product examples are no longer manufactured or available for purchase; however, asbestos is still found in a variety of consumer and commercial products that remain in use. The consumer scenarios in this evaluation are for legacy uses in which all scenarios are task- or activity-based DIY scenarios in which the user is not a professional nor acting in a professional setting. They perform an activity involving an asbestos product that modifies the product leading to the release of asbestos fibers. Product modification can occur when it is disturbed/repaired (*e.g.*, sanded, grinded, drilled, scraped, cut, shoveled, or moved) or replaced; these activities may occur during normal home maintenance and/or when users perform small or large renovations. These activities can release asbestos fibers that can be inhaled.

Section 3.1.3.1 first reviews example products that may contain asbestos and be used in DIY activities for the COU categories and subcategories. Then, in Section 3.1.3.2, the products that have the potential to release asbestos are mapped to specific activity-based scenarios, where each product is generally linked to both a "disturbance/repair" and "replacement" activity. Where possible, the releases and exposures to users and bystanders (discussion in Section 3.1.3.3 with a summary of scenario concentrations in Section 3.1.3.4) and associated risks are quantified (Section 5); for scenarios where literature is not available to quantify exposure, risks are discussed qualitatively.

3.1.3.1 Friable Asbestos Fibers and Products Prioritized for Assessment

Section 3.1.3.1 outlines specific product examples containing friable asbestos for the different COU categories and subcategories. The NESHAP for asbestos, 40 CFR part 61, subpart M defines "friable asbestos material" as "any material containing more than 1 percent asbestos by weight that, when dry, can be crumbled, pulverized, or reduced to powder by hand pressure." 40 CFR 61.141. Exposure to asbestos fibers from the product examples depends on the potential release of fibers during intended use or while performing some activity that modifies the product.

As described in the scope document, products containing friable asbestos were primarily identified from three sources:

- regulatory impact analysis of controls on asbestos and asbestos products: Final report: Volume III (U.S. EPA, 1989);
- review of asbestos use in consumer products (final report) (CPSC, 1977); and
- sampling and analysis of consumer garden products that contain vermiculite (U.S. EPA, 2000a).

Through systematic review, additional papers were also identified for consumer uses that provided specific product asbestos weight fractions. Table 3-5 summarizes the COU categories/subcategories, product examples, and respective weight fractions. To assess friability, all identified products, other than crayons, have upper weight fraction ranges above 1 percent; however, not all products are friable by hand pressure. Generally, products containing asbestos will not release asbestos fibers unless the materials are modified, as previously discussed (*e.g.*, mechanical manipulations). It was determined that construction materials are subject to activities that can release fibers under dry conditions, such as sanding, cutting, and removal and hence are considered to have friable fibers. Fiber friability for products that are subject to activities in which fibers are expected to become friable by hand was assigned using expert personal opinions, for example, asbestos reinforced plastics are not expected to crumble under hand pressure.

Table 3-5 includes a column that notes the "priority for evaluation for DIYers." All products that were determined to be friable by hand are considered to be high priority, expected asbestos fiber releases and subsequent exposures. Products that have a "No" for hand friability and a "Yes" for "sanding/cutting" friability where consumer DIYers are judged less likely to perform sanding and cutting activities (compared with, for example, commercial workers working with the products) are assigned a low priority (see footnote "j"). Examples include metal gaskets, cement, electro-mechanical parts in appliances, and plastics used in appliances and toys. Because these products are not friable and are unlikely to be modified by consumers, EPA concludes asbestos fibers are not to be released and hence no exposure is expected. In addition, while some products/articles are friable, any product with a lifetime less than 30 years is unlikely to remain in current use, where 30 years reflects the fact that most products no longer used asbestos by the late 1980s (U.S. EPA, 1989). EPA deprioritized products such as textiles, burner mats, wicks, and soil treatment products on this basis (see footnote "k") and recognizes that these products may remain in people's possession and not in use for the original intended purpose. Because these products are unlikely to remain in use EPA concludes that exposure to asbestos is unlikely. Remaining products with a "High" in the "Priority for Consumer Exposure Evaluation" column in Table 3-5 are evaluated either qualitatively or quantitatively in the consumer exposure assessment, as discussed in the next section.

Table 3-5. Conditions of Use, Product Examples, Weight Fractions, and Friable Fibers

COU Subcategory	Product Type	Product Examples	Weight Fraction – Percent Asbestos by Weight (%)	Friable by Hand	Friable by Sanding, Cutting	Priority for Consumer Exposure Evaluation	Studies and Evaluation Rating	Exposure Estimate Type
Chemical substances in construction, paint, electrical, and metal products COU								
Construction and building materials covering large surface areas: paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles	Paper articles	Corrugated paper (for use in pipe wrap insulation and appliances)	95–98% [a]	Yes	Yes	High	None	Qualitative, J.1.1
		Commercial papers, millboard; rollboard; specialty paper	Up to 90% [b]	Yes	Yes	High	None	Qualitative J.1.1
	Metal articles	Stove gaskets and rings, fireplace embers, Galbestos	Up to 90% [b]	No	Yes	Low [j]	None	Qualitative J.1.1
	Stone, plaster, cement, glass, and ceramic articles	Plaster and mastic	5–15% [c]	Yes	Yes	High	(Lange et al., 2008), M	Quantitative J.1.1
		Cement, corrugated cement, cement pipes and ducts (air, water, or sewer)	Air duct joint sealing cement, 1–5% [b]	No	Yes	Low [j]	None	See Plaster and mastic
			Cement pipe for airduct, 10–20% [b]	No	Yes	Low [j]	None	See Plaster and mastic
			Cement sheet, 15–45% [a,b]	No	Yes	Low [j]	None	See Plaster and mastic
			Cement pipe for water, 10–25% [b]	No	Yes	Low [j]	None	See Plaster and mastic
	Roofing and siding materials	Roofing felt	85–87% [a]	No	Yes	High	(Lange et al., 2008), M	Quantitative J.1.1
		Roofing cement	3–15% [c]	No	Yes	High	(Mowat et al., 2007), H; (Lange et al., 2008), M	Quantitative J.1.1
		Roofing shingles	13–18% [a]	No	Yes	High	(Lange et al., 2008), M	Quantitative J.1.1
		Siding	13–18% [a]	No	Yes	High	(Lange et al., 2008), M	Quantitative J.1.1
	Ceiling materials	Acoustical ceiling tiles	1–5% [b,d]	Yes	Yes	High	(Boelter et al., 2016), M; (Lange et al., 1993), M	Quantitative J.1.1
	Flooring materials	Flooring felt	Up to 85% [a]	No	Yes	High	None	Quantitative J.1.1
		Flooring tile (vinyl)	10–20% [b]	No	Yes	High	(Lundgren et al., 1991), M	Quantitative J.1.1
	Insulation	Loose-fill insulation	Unknown	Yes	Yes	High	(Ewing et al., 2010), M	Quantitative J.1.1
	Plastics	Reinforced plastics for appliances such as ovens,	17% [a]	No	Yes	Low [j]	None	Qualitative J.1.1

COU Subcategory	Product Type	Product Examples	Weight Fraction – Percent Asbestos by Weight (%)	Friable by Hand	Friable by Sanding, Cutting	Priority for Consumer Exposure Evaluation	Studies and Evaluation Rating	Exposure Estimate Type
Machinery, mechanical appliances, electrical/ electronic articles		dishwashers, boilers, and toasters						
	Electro-mechanical parts	Miscellaneous electro-mechanical parts for appliances including deep fryers, frying pans and grills, mixers, popcorn poppers, slow cookers, refrigerators, curling irons, electric blankets, portable heaters, safes, safety boxes, filing cabinets, and kilns and incinerators	Appliance wiring, up to 100% [b]	No	Yes	Low [j]	None	Qualitative J.1.1
			Slow cooker, 65–75% [b]	No	Yes	Low [j]	None	Qualitative J.1.1
			Toasters, 95% [b]	No	Yes	Low [j]	None	Qualitative J.1.1
			Hair dryers, 85–90% [b]	No	Yes	Low [j]	None	Qualitative J.1.1
			Refrigerators, 14–50% [e]	No	Yes	Low [j]	None	Qualitative J.1.1
			Washing machines, 8–20% [e]	No	Yes	Low [j]	None	Qualitative J.1.1
			Gas boiler, 2–25% [e]	No	Yes	Low [j]	None	Qualitative J.1.1
Fillers and putties	Adhesives	Glues and epoxies	Up to 5% [a b]	No	Yes	Low [j]	None	See adhesives, mastics and cements
		Adhesives, mastics, and cements to bond surfaces such as brick, lumber, mirror, and glass	1– 9% [a f]	No	Yes	Low [j]	(Paustenbach et al., 2004), M	Quantitative J.1.1
	Sealants	Semi-liquid glazing and caulking compounds applied with a caulking gun or putty knife, to seal around glass in windows, joints in metal ducts, and bricks	0.5–25% [a b]	No	Yes	Low [j]	(Lange et al., 2008), M	Quantitative J.1.1
		Joint compound, patching, spackling material	0.25–12% [b g]	Yes	Yes	High	(Rohl et al., 1975), M	Quantitative J.1.1
		Liquid sealants used for waterproofing and sound deadening interior walls	1–5% [a]	No	Yes	Low [j]	None	See adhesives, mastics and cements
		Butyl rubber and vinyl sealants applied over welds for corrosion protection and aesthetics	1–5% [a f]	No	Yes	Low [j]	(Paustenbach et al., 2004), M	Quantitative J.1.1

COU Subcategory	Product Type	Product Examples	Weight Fraction – Percent Asbestos by Weight (%)	Friable by Hand	Friable by Sanding, Cutting	Priority for Consumer Exposure Evaluation	Studies and Evaluation Rating	Exposure Estimate Type
Fillers and putties		Extruded sealant tape used as a gasket for sealing building windows, automotive windshields, and mobile home windows	Up to 20% [a]	No	Yes	Low [j]	None	See Butyl rubber and vinyl sealants applied over welds for corrosion protection and aesthetics
	Coatings	Asphalt based coatings, used to prevent decay and corrosion of underground pipes and structural steel	5–10% [a f]	No	Yes	Low [j]	(Paustenbach et al., 2004), M	Quantitative J.1.1
		Vehicle undercoating to prevent corrosion	5–30% [b]	No	Yes	Low [j]	None	See Asphalt based coatings, used to prevent decay and corrosion
Solvent-based/water-based paint	Coatings; textured paints	Coatings; textured paints	1–5% [b]	Yes	Yes	High	(Sawyer, 1977), L	See adhesives, mastics and cements
Chemical substances in furnishing, cleaning, treatment care products COU								
Construction and building materials covering large surface areas, including fabrics, textiles, and apparel	Asbestos textiles including yarn, thread, wick, cord, rope, tubing (sleeving), cloth, tape	Wicks for oil burning	Up to 100% [b]	No	Yes	Low [k]	None	Qualitative J.1.2 and see Textiles and cloth (including gloves and mittens)
Furniture and furnishings, including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles	Fabrics, textiles, and apparel	Burner mats	85% [b]	No	Yes	Low [k]	None	Qualitative J.1.2 and see Textiles and cloth (including gloves and mittens)
		Textiles and cloth (including gloves and mittens)	75–100% [a b]	No	Yes	Low [k]	(Cherrie et al., 2005), M	Quantitative J.1.2

COU Subcategory	Product Type	Product Examples	Weight Fraction – Percent Asbestos by Weight (%)	Friable by Hand	Friable by Sanding, Cutting	Priority for Consumer Exposure Evaluation	Studies and Evaluation Rating	Exposure Estimate Type
Chemical substances in packaging, paper, plastic, toys, hobby products COU								
Packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft)	Plastic articles, Asbestos reinforced plastics	Asbestos reinforced plastics (*e.g.*, ash trays)	20–25% [b]	No	Yes	Low [j]	None	Qualitative J.1.3
		Child dedicated articles or plastic articles (hard)	5–50% [b]	No	Yes	Low [j]	None	Qualitative J.1.3
Toys intended for children's use (and child dedicated articles), including fabrics, textiles, and apparel; or plastic articles (hard)	Toys	Mineral kits	Unknown	No	Yes	High	None	Quantitative J.1.3
		Crayons	0.03% [h]	Yes	Yes	High	(Saltzman and Hatlelid, 2000), M	Quantitative J.1.3
Chemical substances in automotive, fuel, agriculture, outdoor use products COU								
Lawn and garden care products	Lawn and garden care products	Vermiculite soil treatment	0.1–3% [i]	Yes	Yes	Low [k]	(U.S. EPA, 2000a), H	Quantitative J.1.4
Chemical substances in products not described by other codes COU								
Chemical Substances in Products not Described by Other Codes	Vintage artifacts in private collections; vintage cars, articles, curios	Metal dedener	10% [b]	No	Yes	Low	None	Qualitative J.1.4

COU Subcategory	Product Type	Product Examples	Weight Fraction – Percent Asbestos by Weight (%)	Friable by Hand	Friable by Sanding, Cutting	Priority for Consumer Exposure Evaluation	Studies and Evaluation Rating	Exposure Estimate Type

[a] (U.S. EPA, 1989)
[b] (CPSC, 1977)
[c] (Mowat et al., 2007)
[d] (Boelter et al., 2016)
[e] (Hwang and Park, 2016)
[f] (Paustenbach et al., 2004)
[g] (Rohl et al., 1975)
[h] (Saltzman and Hatlelid, 2000)
[I] (U.S. EPA, 2000a)
[j] Limited exposures for DIY consumers because consumers are assumed to unlikely sand or cut materials
[k] Reduced exposure potential due to expected lifetime of product/article

3.1.3.2 Activity-Based Scenarios and Data Sources

For prioritized products/articles in Table 3-5 that a consumer may encounter, EPA searched the systematic review references tagged to identify experimental, monitoring or modeling studies that measured asbestos fibers released during potential activity-based scenarios. The studies and data used in this evaluation were selected for applicability using the following criteria:

- **Keyword:** Within articles screened at full text, the title or abstract mention the targeted friable consumer products listed in Table 3-5.
- **Scenario:** Asbestos fibers released from specific tasks or activities that a DIY user may perform. Studies evaluating workers were included.
- **Country:** United States, Canada, and high-income foreign countries.
- **Timeframe:** Sampling conducted since 2000, although prior years are considered given limited availability of data and most likely timeframe of use of asbestos-containing products.
- **Media Type:** Personal breathing zone data for a DIY user; indoor or outdoor area air data for a bystander.
- **Analytical Method/Units:** PCM or TEM measured as fibers/cc with the identification of asbestos fiber type and size within the scope of this evaluation (*i.e.*, fibers >5 µm and 3:1 aspect ratio).

Table 3-5 includes columns noting the relevant references for each product/article, including the study quality evaluation rating: high ("H"), medium ("M"), or low ("L"). Studies with quantitative information are further assessed to provide quantitative exposure concentrations; these studies all had high or medium ratings. For products where quantitative information was not available in the literature, exposure and risk potential is either discussed qualitatively or unable to perform a full quantitative assessment ("None" in last column). Products that are not likely to result in fiber releases from routine use or modifying activity was deemed qualitative analysis and no further analysis was performed ("None" in last column). For the scenarios evaluated quantitatively, the activity-based scenarios include scenarios where the product/article is either disturbed or replaced (or both).

3.1.3.3 Concentrations of Asbestos in Activity-Based Scenarios

Studies identified in Table 3-5 were used to estimate exposure concentrations for each activity-based scenario. The concentrations identified for bystanders were reported area air concentrations or approximated concentrations using a reduction factor (RF). For activity-based scenarios that have reported both personal data (which represents DIY users) and area data (which represents bystanders), RFs were calculated by dividing the personal exposure concentration by the area exposure concentration. The resulting RFs were averaged across all activity-based scenarios to obtain an overall average default RF value of 6. This RF was used to approximate concentrations for activity-based scenarios that did not have bystander (area) data reported. For these scenarios, the reported personal exposure concentration for DIY users was divided by 6 to obtain the bystander exposure concentration. The scenarios evaluated quantitatively extracted data are summarized in Table 3-6.

3.1.3.4 Summary of Inhalation Data Supporting the Consumer Exposure Assessment

Table 3-6 summarizes the activity-based asbestos concentration data from the above studies identified by the systematic review process for each subcategory evaluated quantitatively for consumers and bystanders. The low-end (LE), central (CT), and high-end (HE) tendency concentrations for each DIY activity-based scenario for users and bystanders are summarized by specific product examples and by COU. The references identified via the systematic review process are also described by year of sampling or performed activity, method used to characterize asbestos fibers, and the systematic review rating result for the specific reference. All but one reference had ratings of medium and the one reference was rated as high, indicating that the studies had a few minor faults, but overall appropriate to use in this analysis. The year sampled also provides confidence in application of the data for current exposure scenarios considering legacy uses of asbestos containing products. These inhalation concentrations are used to calculate the risk estimates in Sections 5.1.3 and 5.3.2.3.

Table 3-6. Summary of Activity-Based Scenario Studies and Exposure Point Concentrations

Product Example	Activity-Based Scenario	Systematic Review Studies				Activity-Based Scenario Concentrations (f/cc)					
		Source	Year	Method	Rating	DIY User			Bystander		
						LE	HE	CT	LE	HE	CT
Construction, paint, electrical, and metal products COU: construction and building materials covering large surface areas subcategory											
Roofing materials	Outdoor, disturbance/repair (sanding or scraping) of roofing materials	(Mowat et al., 2007)	2005	PCME	High	0.0044	0.0097	0.0069	0.00074 [a]	0.0016 [a]	0.0012 [a]
	Outdoor, removal of roofing materials	(Lange et al., 2008)	2000	PCM	Medium	0.005 [b]	0.01 [b]	0.005 [b]	0.005 [b]	0.01 [b]	0.005 [b]
Plaster	Indoor, removal of plaster	(Lange et al., 2008)	2000	PCM	Medium	0.01	0.05	0.02	0.005 [b]	0.01 [b]	0.005 [b]
Ceiling tiles	Indoor, disturbance (sliding) of ceiling tiles	(Boelter et al., 2016)	2016	PCME	Medium	0.023 [b]	0.045 [b]	0.023 [b]	0.023 [b]	0.045 [b]	0.023 [b]
	Indoor, removal of ceiling tiles	(Lange et al., 1993)	1991	PCM, TEM	Medium	0.005	0.019	0.009	0.0008 [a]	0.0032 [a]	0.0015 [a]
Flooring tiles	Indoor, removal of vinyl floor tiles	(Lundgren et al., 1991)	1990	PCM, SEM	Medium	0.0056 [c]	0.0056 [c]	0.0056 [c]	0.0004 [c]	0.0004 [c]	0.0004 [c]
Loose-fill Insulation	Indoor, disturbance/repair (cutting) of attic insulation.	(Ewing et al., 2010)	2010	PCM	Medium	1.16 [c]	1.16 [c]	1.16 [c]	0.493 [c]	0.493 [c]	0.493 [c]
	Indoor, moving and removal (with vacuum) of attic insulation	(Ewing et al., 2010)	2010	PCM	Medium	0.97	9.27	5.12	0.455	1.543	0.999
Construction, paint, electrical, and metal products COU: fillers and putties subcategory											
Spackle	Indoor, disturbance (pole or hand sanding and cleaning) of spackle	(Rohl et al., 1975)	1979	PCM	Medium	1.25	25.87	13.9	1.95	9.55	5
Coatings, mastics, adhesives	Indoor, disturbance (sanding and cleaning) of coatings, mastics, and adhesives	(Paustenbach et al., 2004)	2004	PCME	Medium	0.023	0.04	0.023	0.003	0.008	0.003
Mastic	Indoor, removal of floor tile/mastic	(Lange et al., 2008)	2000	PCM	Medium	0.005 [b]	0.01 [b]	0.005 [b]	0.005 [b]	0.01 [b]	0.005 [b]

Product Example	Activity-Based Scenario	Systematic Review Studies				Activity-Based Scenario Concentrations (f/cc)					
		Source	Year	Method	Rating	DIY User			Bystander		
						LE	HE	CT	LE	HE	CT
Caulking	Indoor, removal of window caulking	(Lange et al., 2008)	2000	PCM	Medium	0.005 [b]	0.01 [b]	0.005 [b]	0.005 [b]	0.01 [b]	0.005 [b]
Furnishing, cleaning, treatment care products COU: construction and building materials covering large surface areas, including fabrics, textiles, and apparel subcategory											
Oven mittens and potholders	Use of mittens for glass manufacturing, (proxy for oven mittens and potholders)	(Cherrie et al., 2005)	2005	PCM	Medium	0.12	0.53	0.29	0.02 [a]	0.088 [a]	0.049 [a]

[a] No area data was reported for bystanders; default average RF of 6 was used to estimate bystander exposure concentrations.
[b] Non-detect scenario; LOD was used for HE and ½ LOD was used for CT and LE.
[c] Study only reported one value; this was used for LE, HE and CT.
f/cc = fibers per cubic centimeter; LE = low-end; HE = high-end; CT = central tendency; PCM - phase contrast microscopy; PCME = PCE equivalent; RF = reduction factor of 6; TEM = transmission electron microscopy

3.1.3.5 Consumer DIY Scenarios Concentration Uncertainties and Variability

EPA targeted studies that aimed to replicate common activities with asbestos-containing materials and followed acceptable sampling and analytical methods. This section explores the uncertainty associated with the data used to build DIY activity-based scenarios for all product examples. Table 3-7 summarizes the discussion points in this section.

As discussed in Section 3.1.3.1, there are numerous legacy asbestos-containing friable products that a consumer might be able to encounter. However, the SR did not identify appropriate literature for every potentially friable product expected to have some legacy use, and therefore, EPA could not quantify activity-based scenarios for every friable product. In the absence of product or activity-based specific data, EPA used proxies, approximations, and assumptions in some instances. In other instances, the product was not quantitatively evaluated, and was either qualitatively discussed in terms of the low likelihood of exposures to consumers or linked to another quantitative analysis as a proxy. .

For bystander exposures, only one paper Boelter et al. (2016) directly measured potential exposures to a bystander (a person who was observing the ceiling panel work). For all other scenarios, area data were used to approximate bystander exposure, and a default average RF of 6 was used to estimate bystander exposure concentrations when studies did not report area data. Various factors may impact the magnitude of exposures for bystanders. Particle deposition due to indoor air dynamics can reduce particle transportation away from the activity. Additionally, distance from the activity can reduce bystander exposures. As no adjustments were made to the RF to account for deposition or distance, using the average value of 6 may potentially overestimate bystander exposures. Conversely, in the studies reviewed, there was one instance in Rohl et al. (1975) where area measurements for sanding and/or spackling were greater than the personal measurements, suggesting it is possible for a bystander to have greater exposures than a DIY user.

Due to the lack of specific information on DIY consumer exposures, occupational studies measuring exposure to professionals were often used as proxies. There is uncertainty in using occupational data for consumers due to differences in building volumes, air exchange rates, available engineering controls, and potential use of PPE. If available, EPA used data under certain environmental conditions expected to be more representative of a DIY user (*i.e.,* no engineering controls and no PPE use). For example, in Ewing et al. (2010), the authors studied attic insulation removal using both wet and dry methods, and EPA only used the dry method data to evaluate DIY user exposures. It is assumed that DIY users still use work practices that have been discontinued in professional settings and do not use practices too sophisticated for typical DIYers' available resources.

There is uncertainty associated with studies that did not report asbestos size. Although EPA targeted studies that reported asbestos concentrations for fibers exceeding 5 µm and 3:1 ratio (the "respirable" size range), several of the identified studies did not report fiber size: Ewing et al. (2010), Lange et al. (1993), Lundgren et al. (1991), Cherrie et al. (2005), Boelter et al. (2016), Mowat et al. (2007), Paustenbach et al. (2004), and Lange et al. (2008). Generally, 50 to 98 percent of asbestos fibers are less than 5 µm, according to Wilson et al. (2008) and Lee and Van Orden (2008). Including asbestos concentrations < 5 µm would result in the use of larger concentrations values, this means that the reported concentrations of asbestos may overestimate risk.

Any air sampling measured only using PCM analysis may overestimate asbestos exposures as PCM measures total fibers and does not determine the composition of fibers. The method on its own cannot distinguish among different non-asbestos and asbestos fiber types. In the consumer evaluation, two papers only utilized PCM analyses, Lange et al. (2008) and Cherrie et al. (2005), so the selected exposure point concentrations for the activity-based scenarios associated with these papers may result in overestimates of asbestos exposure.

Table 3-7. Qualitative Assessment of the Uncertainty and Variability Associated with Concentrations Data Used in Consumer Assessment

Variable Name	Effect	Uncertainty (L, M, H) [a]	Variability (L, M, H) [a]
Friable asbestos classification [b]	Determination of products with potential to release asbestos fibers.	M	L
Asbestos fiber sizes [c]	Concentration data used may include smaller particle sizes and hence overestimate risk.	H	H
Overall sample analysis method such as TEM, PCM, SEM, PCME [c]	Non asbestos fibers specific methods may include non-asbestos fiber concentrations and overestimate risk. Most studies used TEM to confirm asbestos fibers.	L	L
Overall consumer DIY concentration data	**Concentrations used in risk calculation estimates.**	**M**	**M** [d]

[a] L = low; M = moderate; H = high
[b] Data sources for this information originated from this risk assessment assessor's professional judgment and NESHAP, 40 CFR Part 61, subpart M "friable asbestos" definition interpretation.
[c] Data sources for this information originated from the systematic review identified studies measurements.
[d] Low-end to high-end concentration ranges were within the same or one order of magnitude difference for all scenarios concentrations.

3.1.4 Indoor Air

Asbestos-containing materials are still found in indoor environments such as residences, offices, schools, and other public places that people frequent, primarily from the legacy use of in-service building materials at the end of their life cycle. These exposures contribute to the totality of indoor air exposure and correspond to the COU for (1) construction, paint, electrical, and metal products and (2) furnishing, cleaning, treatment care products. Asbestos indoor air exposures can include indirect exposures from minor uses and disturbances of legacy consumer products (*e.g.*, attic insulation) in the home (Section 3.1.2), job-related take-home exposures (Section 3.1.4), and infiltration of outdoor air in urban/rural areas or areas of naturally occurring asbestos (Section 3.3.1). The relative contribution of different sources of asbestos to the indoor environment is not well characterized. The indoor air exposure assessment in this section focuses only on passive asbestos levels in buildings that have known or unknown asbestos-containing materials in the building structure, not associated with the activity-based consumer and take-home scenarios in which the materials are disturbed in some form. EPA searched the systematic review extraction results for representative data to use in a quantitative assessment, using the following criteria:

- **Country:** United States or Canada
- **Timeframe:** Sampling conducted since 2000
- **Media Type:** Indoor air or suspended dust
- **Microenvironment:** Living or common areas of residential buildings and public and commercial buildings (including schools)
- **Scenario/Source:**
  - Includes with or without the confirmed presence of ACM in the home or building, such as attic insulation.
  - Excludes monitoring of activity-specific consumer tasks and take-home exposure tasks (see Section 3.1.2 and 3.1.4).

    - Excludes monitoring following disasters because these are not representative of indoor air (*e.g.*, fallout from World Trade Center [WTC] terrorist attack in September 2001) and monitoring influenced by legacy activities not under assessment in Part 2, such as intentional mining.
- **Sampling Duration:** Durations close to daily time spent indoors preferred (*i.e.*, 8 hours).

No studies were identified which meet all of the above criteria for residential buildings, public buildings, or school buildings. Some studies met all the criteria except the timeframe cutoff at year 2000. Four U.S. studies which met most of the criteria for residential buildings are discussed in more detail below, including rationale for not continuing with quantitative analysis.

Tang et al. (2004) – Residential indoor concentrations of asbestos were measured in living rooms and bedrooms of 25 apartment residences, as well as from 9 building-interior common areas in upper Manhattan, New York, in 2002. While these indoor spaces were sampled following the WTC terrorist attack in 2001, their location (5 to 12 miles from the WTC) was minimally impacted by dust fallout, and the concentrations of various contaminants were intended to represent non-apportioned levels due to building-related materials and combustion byproducts in urban residential dwellings. The targeted asbestos fiber size for those quantified using PCM were greater or equal to 5 µm and a ratio of greater or equal to 3:1, and sample duration was 8 hours. Quantification was also conducted by TEM-AHERA (Asbestos Hazard Emergency Response Act; ≥0.5 µm and a ratio of ≥5:1) and PCME (≥5 µm and a ratio of ≥5:1). This study was not designed for specifically detecting asbestos in indoor air and the presence of asbestos-containing material was not reported. PCM was used to identify 21 samples out of 50 (42%) as containing fibers. Forty-eight samples were also analyzed using TEM and PCME. For this further analysis, only two samples detected asbestos, and both were at the same level as the detection limit of 0.004 structures per cubic centimeter (s/cc). In addition, neither method used the preferred fiber size criteria (≥5 µm) and a ratio of greater or equal to 3:1. Common areas of the apartment buildings were also sampled with similar results. This study is not being used for a quantitative risk evaluation because there were no detections above the detection limit, and it does not satisfy the fiber size criteria.

Hoppe et al. (2012) – Asbestos fibers in indoor air were sampled from the family room of flood-damaged residences after remediation (n = 47), following the cresting of the Cedar River in Cedar Rapids, Iowa, in June 2008. Homes were originally built between 1890 and 2008. According to the study, remediation followed "mucking and gutting" and generally entailed removal and replacement of cabinetry, drywall, flooring, and insulation with a drying-out period between removal and replacement. Asbestos samples were collected using active samplers for a 24-hour period and were analyzed using PCM (fiber size and ratio not reported). Fibers were found via PCM in 27/47 samples, but this analytical method only captures total fibers, and is not specific to asbestos. There was no confirmation of asbestos in materials nor by confirmatory TEM sampling, likely because asbestos sampling was only one contaminant on a more comprehensive list of indoor air contaminants, with the primary purpose of identifying mold.

Lee and Van Orden (2008) – In the United States, indoor air samples were collected from 752 various types of buildings, including 5 residential buildings and 234 public/commercial buildings, over a 10-year period. The exact time period of sampling was not provided but was presumed to primarily occur in the 1990s. The buildings sampled were the subject of litigation related to suits alleging the general building occupants were exposed to a potential health hazard as a result of the presence of asbestos-containing materials. Samples were collected under conditions of normal occupancy over a 2-day period for at least an 8-hour sample duration. Sample analysis was conducted by TEM and results were provided for various fiber definitions. However, this study did not report specific results and provided no statistical information on the sampling such as minimum, maximum, or frequency of detection. Only one average result was reported: 0.00005 f/mL via TEM. EPA did not use this concentration for a quantitative risk evaluation because the data are not likely to represent current exposures, since some asbestos materials may have been removed from public and commercial buildings (bulk of the sampled environments) and there is limited sampling data and methods reported—the one average residential sample reported was calculated from other averages.

Spear et al. (2012) – Asbestos in indoor air of living spaces was measured in 46 homes in Montana with the confirmed presence of asbestos in vermiculite attic insulation or other ACM. High-volume samples were collected for a mean of 2 hours. All samples (n = 248) were analyzed by PCM, while only those with a concentration exceeding 0.01 f/ mL by PCM or the two highest in each home (n = 158) were further analyzed by TEM. Fiber size and ratio were not reported for either method. TEM results found 15 samples (9.5%) detected asbestos and one exceeded 0.01 structures/cc, which is the Montana clearance level. This sample was from a basement with asbestos containing structures, but the actual concentration was not reported.

(ATSDR, 2006) – In 2003 and 2004, the El Dorado Hill, CA school district sampled air in classrooms and other indoor areas of the school after the areas had been cleaned. The data obtained were assumed to represent potential exposures to students and staff in classrooms at present. Air samples were analyzed using transmission electron microscopy (TEM) with a modified Asbestos Hazard Emergency Response Act (AHERA) method (counting structures longer than 0.5 μm and with aspect ratios greater than 3:1; structures refer to asbestos fibers, bundles, clusters, and matrices). Indoor air sampling of classrooms in the summer and fall of 2003 indicated that the average level of asbestos in three air samples from most rooms was lower than 0.0009 f/cc. Classrooms tested in the summer of 2004 all had asbestos air levels below 0.0009 f/cc with one exception. This classroom, a science classroom, was found to be contaminated with chrysotile asbestos from countertops used for lab counters, which were encapsulated per AHERA standards and no further exposure is expected.

For U.S./Canadian studies with public building data collected since 2000 containing exposure measurements from activity-based modifications of ACMs were assessed and evaluated under the consumer DIY scenarios in Section 3.1.3. While studies with public building data collected since 2000 containing respirable and suspended asbestos fibers concentrations from in-place ACMs were used to evaluate indoor exposures in this section.

The Asbestos-Containing Materials in Schools Rule pursuant to the Asbestos Hazard Emergency Response Act (AHERA) was promulgated in 1987 with the purpose of inspecting schools for asbestos-containing material, preparing asbestos management plans and conducting needed asbestos response actions (*i.e.*, asbestos removal, encapsulation, enclosure, or repair) to prevent or reduce asbestos hazards. The focus of the AHERA program is to manage the identified asbestos-containing material in place and undisturbed if non-friable (preferred approach) or perform asbestos response actions to address damaged or friable asbestos. The associated AHERA data were not used in this indoor evaluation as most of it is not representative of non-occupational exposures. The AHERA data relate to occupational exposures during abatement efforts in which engineering and administrative controls along with PPE are required and careful approaches are used to prevent exposure to the general population.

3.1.4.1 Conclusions for Indoor Air

The indoor air assessment considered suspended dust and particulate as the driver of inhalation exposures. The indoor air assessment studies presented in Section 3.1.4 provide air sampling descriptions, air samples that contain suspended asbestos fibers containing dust and particulate. Settled dust data identified was not used in the exposure estimates. EPA used the available air (suspended dust and fibers) asbestos concentrations for inhalation exposure estimates during normal occupancy of the indoor environment. The available information regarding passive or non-source attributed asbestos concentrations in indoor air (suspended fibers) of residential and public buildings (including schools) is not sufficient for EPA to conduct a quantitative exposure assessment. This is not unexpected, as literature suggests that asbestos levels in indoor air are not typically detected unless the asbestos-containing material is disturbed in some way that allows fibers to become airborne; the mere presence of ACM in a building does not equate to asbestos exposure, as shown in Tang et al. (2004) and (ATSDR, 2006). As such, most studies determine asbestos concentrations from activity-based sampling conducted during disturbances of ACM. EPA has evaluated handler (user) and bystander (non-user) activity-based scenarios in Section 3.1.1 for occupational exposures, Section 3.1.2 for consumer exposures, and in Section 3.1.3 for take-home exposures.

3.2 Environmental Releases

3.2.1 Industrial and Commercial

EPA combined its estimates for annual releases, release days, and number of sites to estimate a range of daily air, water, and land releases for each OES. A summary of releases across sites is presented in Table 3-8. These release estimates are for total releases from a site and may include multiple points of release, such as multiple outfalls for discharges to surface water or multiple points sources for air emissions. Site-specific releases, estimation methodology, and details on deriving the overall confidence score for each OES in Table 3-8 are presented in Appendix G. It is important to note that EPA provides qualitative assessments of potential releases for the Handling of vermiculite-containing products OES (Appendix G.14.2) and the Mining of non-asbestos commodities OES (Appendix G.15.2); therefore, releases and number of sites are not quantified for the two aforementioned OESs.

3.2.1.1 Summary of Daily Environmental Release Estimates

Table 3-8. Summary of Daily Environmental Release Estimates for Asbestos

Occupational Exposure Scenario (OES)	Type of Discharge, Air Emission,[a] or Transfer for Disposal[b]	Number of Sites with Releases[c]	Estimated Daily Release Range across Sites (kg/site-day)		Estimated Release Frequency across Sites (days)[d]	Weight of Scientific Evidence Conclusion	Sources
			Min	Max			
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities	Fugitive air	46,789	7.6E−04	0.15	12	Moderate to Robust	TRI, NEI
	Stack air	46,789	0	0			TRI, NEI
	Surface water	46,789	0.11	4.0			NRC
	Landfill	46,789	411	814			TRI
Handling asbestos-containing building materials during firefighting or other disaster response activities	Fugitive air	97,920	9.1E−03	1.8	1	Moderate	Surrogate OES Data[e]
	Stack air	97,920	0	0			
	Surface water	97,920	1.4	45			
	Landfill	97,920	4,935	9,764			
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	Fugitive air	29,211	9.1E−05	9.0E−02	250	Moderate to Robust	TRI, NEI
	Stack air	29,211	0	6.6E−05			TRI, NEI
	Surface water	29,211	0	0			TRI, Professional Judgment[f]
	Landfill	29,211	67	627			TRI
Handling articles or formulations that contain asbestos	Fugitive air	15,592	2.7E−04	0.35	250	Moderate to Robust	TRI, NEI
	Stack air	15,592	8.5E−03	1.4E−02			TRI, NEI
	Surface water	15,592	0	0			TRI, Professional Judgment[f]
	Landfill, transfer to waste broker	15,592	56	233			TRI

Occupational Exposure Scenario (OES)	Type of Discharge, Air Emission,[a] or Transfer for Disposal[b]	Number of Sites with Releases[c]	Estimated Daily Release Range across Sites (kg/site-day)		Estimated Release Frequency across Sites (days)[d]	Weight of Scientific Evidence Conclusion	Sources
			Min	Max			
Waste handling, disposal, and treatment	Fugitive air	4,972	6.3E−03	7.4E−02	250	Moderate to Robust	TRI, NEI
	Stack air	4,972	9.1E−04	9.5E−02			TRI, NEI
	Surface water	4,972	0	0			TRI, Professional Judgment[f]
	Landfill, off-site management	4,972	765	1.0E04			TRI

[a] Emissions via fugitive air; stack air; or post-incineration emissions.
[b] Transfer to surface impoundment, land application, or landfills.
[c] Where available, EPA used U.S. Census Bureau data and literature search data to provide a basis to estimate the number of sites using asbestos within an OES.
[d] Where available, EPA used literature search data and assumptions to provide a basis to estimate the number of release days of asbestos within an OES.
[e] For this OES, EPA assumed that the releases from an uncontrolled fire/clean-up would be similar to releases from demolition. Therefore, this estimate uses the calculated air releases from maintenance, renovation, and demolition activities.
[f] The TRI data gathered shows no discharges of asbestos to water. There may be incidental discharges of asbestos from this OES; however, EPA expects those releases to be low.

3.2.1.2 Weight of Scientific Evidence Conclusions for Environmental Releases from Industrial and Commercial Sources

For each OES, EPA considered the assessment approach, the quality of the data and models, and uncertainties in assessment results to determine a level of confidence as presented in Table 3-8. The Agency considered factors that increase or decrease the strength of the evidence supporting the release estimate—including quality of the data/information, applicability of the release data to the COU (including considerations of temporal relevance, locational relevance) and the representativeness of the estimate for the whole industry. The best professional judgment is summarized using the descriptors of robust, moderate, slight, or indeterminant, according to EPA's Asbestos Part 2 Systematic Review Protocol. For example, a conclusion of moderate is appropriate where there is measured release data from a limited number of sources such that there is a limited number of data points that may not cover most or all of the sites within the OES. A conclusion of slight is appropriate where there is limited information that does not sufficiently cover all sites within the OES, and the assumptions and uncertainties are not fully known or documented. See EPA's Draft Systematic Review Protocol (U.S. EPA, 2018a) for additional information on weight of scientific evidence conclusions.

For air, water, and land releases, all monitoring data had data quality ratings of medium/high. For releases modeled with TRI/NEI/NRC, the weight of scientific evidence conclusion was moderate to robust since information on the conditions of use of asbestos at sites in TRI and NEI is limited, and NRC does not provide the condition of use of asbestos at sites. For the handling asbestos-containing building materials during firefighting or other disaster response activities OES, the weight of scientific evidence conclusion was moderate since surrogate data from a different OES were utilized. While the surrogate monitoring data had data quality ratings of medium/high, use of surrogate data may introduce uncertainties related to the extent to which the surrogate OES and the OES being assessed are similar. See Appendix G for a summary of EPA's overall weight of scientific evidence conclusions for its release estimates for each of the assessed OESs.

3.2.1.2.1 Strengths, Limitations, Assumptions, and Key Sources of Uncertainty for the Environmental Release Assessment

EPA estimated air, water, and land releases of asbestos using various methods and information sources, including TRI, NEI, and NRC data, surrogate OES data, and best professional judgement.

The Agency estimated air and land releases using reported discharges from the 2016 to 2020 TRI. TRI datum for asbestos were determined to have an overall data quality rating of medium through EPA's systematic review process. However, TRI data are self-reported and have reporting requirements that exclude certain sites from reporting. Due to these limitations, some sites that handle asbestos may not report to these data sets, are not included in this analysis and therefore actual environmental exposures may be underestimated. Sites are only required to report to TRI if the facility has 10 or more full-time employees, is included in an applicable North American Industry Classification System (NAICS) code, and manufactures, processes, or uses the chemical in quantities greater than a certain threshold (25,000 lb for manufacturers and processors and 10,000 lb for users). In addition, facilities are only required to disclose asbestos waste management practices and releases for the portion of asbestos that is friable. TRI reporting is not required for other forms of asbestos (*e.g.*, non-friable asbestos, asbestos in aqueous solutions), which is a limitation of this assessment. Information on the use of asbestos at sites in TRI is limited; therefore, there is some uncertainty as to whether the number of sites estimated for a given OES do in fact represent that specific OES. While annual releases for a given site or facility are the same regardless of the OES under investigation, the daily discharge of the site or facility depends on the number of release days per year for the OES.

EPA estimated air releases using reported discharges from 2014 and 2017 NEI data. NEI was determined to have an overall data quality rating of high through EPA's systematic review process. NEI is a comprehensive and detailed estimate of air emissions of criteria pollutants, criteria precursors, and hazardous air pollutants from air emissions sources. The NEI is released every 3 years based primarily upon data provided by state, local, and tribal air agencies for sources in their jurisdictions and supplemented by data developed by EPA. While state, local, and tribal air agencies are required to report for criteria pollutants, reporting of hazardous air pollutants, such as asbestos, is voluntary. Therefore, NEI may not include data from all emission sources. Like TRI, information on the use of asbestos at sites in NEI is limited. Consequently, there is some uncertainty as to whether the number of facilities estimated for a given OES do in fact represent that specific OES. While annual releases for a given site or facility are the same regardless of the OES under investigation, the daily discharge of the site or facility depends on the number of release days per year for the OES.

EPA estimated water releases using reported discharges from 2016 to 2022 NRC data. NRC was determined to have an overall data quality rating of medium through EPA's systematic review process. The NRC is a part of the federally established National Response System and staffed by the U.S. Coast Guard. It is the designated federal point of contact for reporting all oil, chemical, radiological, biological, and etiological discharges into the environment. However, the NRC only fields the initial incident reports that have not been validated or investigated by federal/state response agencies. Therefore, there is some uncertainty in the accuracy of the information in the NRC data. For example, spill quantities are often estimated or unknown. It is also possible that not all spill incidents are reported to the NRC such that the available data likely does not encompass all spill related releases of asbestos.

Regarding estimation of the number of release sites, EPA relied on data from the U.S. Census for the following three OESs: Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos; Handling articles or formulations that contain asbestos; and Waste handling, disposal, and treatment. In such cases, the average daily release calculated from sites reporting to TRI, NEI or NRC was applied to the total number of sites reported in (U.S. BLS, 2023). It is uncertain how accurate this average release is to actual releases at these sites; therefore, releases may be higher or lower than the calculated amount.

For the Handling asbestos-containing building materials during maintenance, renovation, and demolition activities OES, EPA estimated number of sites through literature data. In the late 1980s, it was estimated that 20 percent of buildings contain friable asbestos (U.S. EPA, 1988). Similarly, for the Handling Asbestos-Containing Building Materials During Firefighting or Other Disaster Response Activities OES, one source estimated that 489,600 structure fires take place each year (NFPA, 2022a). This figure in combination with the estimate of buildings with friable asbestos was used to estimate the number of sites for this OES. Since the percentage of buildings with asbestos was estimated nearly 40 years ago and asbestos use in construction has reduced since then, there is uncertainty resulting from this conservative estimate. In addition, there is adding uncertainty in the assumption that all structure fires are building fires. This could lead to an over or underestimation of the number of sites for these OESs. In addition, the number of release days for these OES was estimated through literature data. For the Handling asbestos-containing building materials during maintenance, renovation, and demolition activities OES, four literature sources were compiled, averaging 12 release days/yr. For Handling asbestos-containing building materials during firefighting or other disaster response activities, one source was identified that stated 1 day/yr. There is uncertainty whether the compiled literature is representative of all demolition and firefighting sites. This could lead to an over or underestimation of the number of sites for these OESs.

3.3 Concentrations of Asbestos in the Environment

The environmental exposure characterization focuses on air, land, and aquatic releases of asbestos from activities that use or dispose asbestos under industrial and/or commercial conditions of use in this risk evaluation. To characterize environmental exposure, EPA assessed point estimate exposures derived from both measured and predicted concentrations of asbestos in ambient air, surface water, and sediments in the United States.

3.3.1 Ambient Air Pathway

Sources of asbestos fibers in ambient air can be from construction materials that are damaged by demolitions and remodeling projects, disposal of asbestos containing materials, activities under all OESs and COUs, and disturbance of natural sources containing asbestos. The following sections summarize the data used to evaluate environmental and general population exposures from available studies that have measured asbestos in ambient air (Section 3.3.1.1) and modeling efforts for environmental releases from activity-based scenarios (Section 3.3.1.2).

3.3.1.1 Measured Concentrations in Ambient Air

Table 3-9 Ambient air scenarios are matched to COUs that best fit under the description provided by the study. One or several COUs can be matched to a scenario depending on the activities performed or materials identified as sources of asbestos by the studies.

Table 3-9. Summary of Published Literature for Measured Ambient Air Concentrations

COU	Ambient Air Scenario	Source Description	Summary Stats Per Proposed Scenario (f/cc)		
			LE[a]	CT[b]	HE[c]
Construction, paint, electrical, and metal products	Near source in public urban space during remodeling and demolition activities	(Lange et al., 2008) Location: Eastern U.S. Sampling Date: 2000 Rating: Medium	3.1E−03	1.1E−02	2.0E−02
Furnishing, cleaning, treatment care products		(Neitzel et al., 2020) Location: Detroit, MI Sampling Date: 2017 Rating: Medium			
Construction, paint, electrical, and metal products	Near source urban public space with fireproofing material	(Nolan and Langer, 2001) Location: Various U.S. Sampling Date: 2001 Rating: Medium	1.0 E−03	1.7E−03	2.2E−03
Furnishing, cleaning, treatment care products					
Disposal, including distribution for disposal[d]	Perimeter to asbestos disposal and waste locations	(ATSDR, 2015) Location: Ambler, Montgomery County, Pennsylvania, BoRit Site Sampling Date: 2008 and 2010 Rating Medium	3.0E−04	5.3 E−03	6.3 E−03

[a] LE is low-end tendency, usually the 10th percentile values if multiple data points are available or the minimum value of one range reported.
[b] CT is the central tendency, 50th percentile if ranges are reported.
[c] HE is the high-end tendency, 95th percentile if multiple data points are available or the maximum value of one range reported.
[d] EPA matched this ambient air scenario to the disposal COU because it is relevant to fiber releases and distribution from the source.

EPA identified studies that reported measured asbestos concentrations in ambient air via the systematic review process summarized in Table 3-9. A detailed description of reported data sources and statistics is available in Appendix H.1. The studies are from the year 2000 and after to evaluate asbestos exposure concentrations using data that best represents current asbestos fiber releases in the United States.

- Lange et al. (2008) – The goal of this study is to determine exposure to airborne asbestos during abatement of ceiling material, window caulking, floor tile and roofing materials. Perimeter and other types of samples were collected within 10 ft of the containment structure that was under abatement. The building was a school in the eastern part of United States with asbestos containing materials. The type of samples used in this ambient air analysis was the perimeter samples. The samples were a composite of at least 2 hours and were analyzed with PCM. The study reported minimum, maximum, arithmetic mean, and geometric mean values of the five types of products getting removed. All were under the detection limit. The study description was linked to emissions of asbestos near the source during remodeling/demolition activities.
- Neitzel et al. (2020) – The objective of this study is to report asbestos measurements taken during the demolition of abandoned residential dwellings in urban locations. Investigators collected air samples about 60 ft from around the demolition of 25 abandoned residential dwellings and used TEM and PCM to analyze the samples. The study reported the number of samples above the limit of detection, and the median, 75th percentile and 90th percentile concentrations. Only the 90th percentile reported a value for 2 samples (out of 46) that contained asbestos fibers. The study description was linked to emissions of asbestos near the source during remodeling/demolition activities.
- Nolan and Langer (2001) – Asbestos fibers were measured inside and outside buildings containing asbestos from fireproofing materials, during normal occupancy and no modifying activities were performed. The goal of this study was to characterize the airborne concentrations of asbestos fiber at twelve sites in and around buildings in diverse geographical locations in the United States. The sampling strategy involved collecting both area samples (where the sampling pump remained in one location during the entire period of sampling) and personal samples (where the pump was attached to an individual). The various locations are public spaces, such as airport terminals, convention centers, and schools. Samples were analyzed with ATEM (analytical transmission electron microscope). The study reported the average of nine samples that were below the detection limit. Only area samples were used for this analysis and were linked to emissions of asbestos near sources such as asbestos containing construction and fireproofing material.
- ATSDR (2015) – The goal of this study was to evaluate exposure of a community to potentially harmful contaminants and make any necessary recommendations to prevent and mitigate exposures, as well as to ensure that the community has the best information possible to protect their health. Sampling was conducted at the BoRit Asbestos Site, historically used to dispose of asbestos-containing materials from the Keasbey & Mattison Company (K&M). The site is no longer active, yet waste material remains in place. Each sampling event was 24 hours in duration, and samples were analyzed via TEM. Fiber sizes corresponding to PCM, AHERA, and Berman-Crump (TEM particle size and type) protocol fibers were documented. The study reported for years 2008 and 2010, a minimum from one sample that was below detection limit, and a maximum from the average of two samples that were above the detection limit. The data used for this section of the RE were collected outside the perimeter of the BoRit site and are considered non-source attributed asbestos disposal and waste handling activities. However, EPA used this data as a guidance to understand asbestos fiber releases and distribution from sources.

3.3.1.2 Modeled Concentrations in Ambient Air

Releases of asbestos fibers to ambient air from various industrial/commercial activities, described by occupational exposure scenarios (OES), were used to estimate environmental concentrations and general population exposure to these releases in Section 3.1.1.1. Table 3-1 and Table 3-10 summarize the OES mapping to COUs and product examples. EPA used the Integrated Indoor-Outdoor Air Calculator (IIOAC), and the American Meteorological Society (AMS)/EPA Regulatory Model (AERMOD) to estimate ambient air concentrations and particle deposition of asbestos from facility releases and activity-based releases. IIOAC uses pre-run results from a suite of AERMOD dispersion scenarios at a variety of meteorological and land-use settings, as well as release emissions, to estimate particle deposition at different distances from sources that release chemical substances to the air. AERMOD, a higher tier model, was utilized to incorporate refined parameters for asbestos particles suspended in air as well as asbestos particle deposition.

The full inputs and results of IIOAC and AERMOD are described and presented in Appendix H and *Asbestos Part 2 RE - AERMOD Inputs and Outputs – November 2024* Supplemental File (see also Appendix C). Briefly, AERMOD is a steady-state Gaussian plume dispersion model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources and both simple and complex terrain. AERMOD can incorporate a variety of emission source characteristics, chemical deposition properties, complex terrain, and site-specific hourly meteorology to estimate air concentrations and deposition amounts at user-specified distances points of exposure and at a variety of averaging times. Readers can learn more about AERMOD, equations within the model, detailed input and output parameters, and supporting documentation by reviewing the AERMOD users guide (U.S. EPA, 2018c).

A full description of the input parameters selected for AERMOD and details regarding post-processing of the results are provided in the Appendix H.2. EPA reviewed available literature to select input parameters for deposition, particle sizes, meteorological data, urban/rural designations, and physical source specifications (stack and fugitive releases). The ambient air environmental releases scenarios by OES are for annual emissions for specific and generic facilities, fugitive and stack releases, rural and urban populations (generic facilities only), and high-end and central tendency releases and meteorological conditions (generic facilities only).

- The term facilities in this RE applies to permanent locations as well as temporary because activities that release asbestos can be transitory, such as demolition, removal, and repair of asbestos containing structures and materials, use and repair of appliances and machinery, and firefighting activities. EPA developed scenarios for TRI facilities with ranges of emission rates for unknown and transitory activities and are referred to as "generic facilities." Specific facilities are those that reported TRI and NEI emission data and description of asbestos release activities which are matched to an OES. In addition, Table 3-10 summarizes OES for which EPA estimated released concentrations for specific and generic facilities.
- Fugitive and stack releases are two source types. Stack releases are a point source, and fugitive releases are area source releases. These source types have different plume and dispersion characteristics that are accounted for differently within the model. Because AERMOD stack modeling is for real stack emissions and requires inputs for stack operation, see Section H.2.3, EPA deemed this modeling effort to not be representative of asbestos point source emissions for activities performed at the temporary or stationary locations in which asbestos fibers are released.

- All generic facilities were simulated as rural and urban. A facility is in an urban area if it had a population density greater than 750 people per square kilometer (km) within a 3-km radius.
- All modeling scenarios utilized several rings of estimating exposures at distances 10, 30, and 60 m from the source for co-located general populations and 100 to 1,000, 2,500, 5,000, and 10,000 m from the source for non-co-located general population.
- Specific facilities meteorological data used the same AERMOD-ready meteorological data that EPA's Risk and Technology Review (RTR) program uses for risk modeling in review of National Emission Standards for Hazardous Air Pollutants (NESHAP). The RTR 2019 meteorological data set was used to model emission years 2018 and 2019. Meteorological data from 2016 were used for emission years 2014 to 2017, covering 824 stations, which the RTR program used prior to the updates to the 2019 data set. Generic facilities meteorological data were modeled twice with two different meteorological stations. EPA's IIOAC utilized a meteorological station for each region of the country, and from this data set, it was determined that meteorological conditions from Sioux Falls, South Dakota, led to central tendency (CT) modeled concentrations and particle deposition. Meteorological conditions from Lake Charles, LA led to high-end (HE) modeled concentrations relative to the other regional stations.
- Central tendency and high-end annual air concentrations were calculated for generic facilities releases using the central tendency and high-end release rate data, which corresponds to the average and the 95th percentiles.

Table 3-10. Release Scenarios Considered for Ambient Air and Deposition Modeling

OES	COU and Subcategory	Facility Specific Fugitive Analysis	Generic Facility Fugitive Analysis
Handling articles or formulations that contain asbestos	COU: Construction, Paint, Electrical, and Metal Products Subcategory: Solvent-based/water-based paint, fillers, and putties COU: Furnishing, Cleaning, Treatment Care Products Subcategory: Furniture & furnishings including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles COU: Packaging, Paper, Plastic, Toys, Hobby Products Subcategory: Packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft) and Toys intended for children's use (and child dedicated articles), including fabrics, textiles, and apparel; or plastic articles (hard)	✓	
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities	COU: Construction, Paint, Electrical, and Metal Products Subcategory: Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles COU: Furnishing, Cleaning, Treatment Care Products Subcategory: Construction and building materials covering large surface areas, including fabrics, textiles, and apparel	✓	✓
Use, repair, or disposal of industrial and commercial appliances or	COU: Construction, Paint, Electrical, and Metal Products Subcategory: Machinery, mechanical appliances, electrical/electronic articles and other machinery, mechanical appliances, electronic/electronic articles	✓	✓

OES	COU and Subcategory	Facility Specific Fugitive Analysis	Generic Facility Fugitive Analysis
machinery containing asbestos			
Waste handling, disposal, and treatment fugitive annual ambient air risk	COU and subcategory: Disposal, including Distribution for Disposal	✓	
Handling asbestos-containing building materials during firefighting or other disaster response activities	COU: Construction, Paint, Electrical, and Metal Products Subcategory: Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles COU: Furnishing, Cleaning, Treatment Care Products Subcategory: Construction and building materials covering large surface areas, including fabrics, textiles, and apparel		✓

Specific Facilities

The modeled asbestos air concentrations for annual releases for specific facilities by OES tables are available in Asbestos Part 2 RE - Ambient Air Specific Facilities Released Concentrations - November 2024 Supplemental File (see Appendix C) and a description of the outputs is available in Appendix H. Figure 3-5 shows overall annual air asbestos fiber concentration patterns for specific facilities by OES. The range bars show the low and high-end tendencies, which were calculated from the average of the 10th and 95th percentiles for each OES.

- Figure 3-5 shows an overall pattern of decreasing ambient air asbestos fiber concentrations (f/cc) away from the source for all OES for all fugitive emissions from specific facility.
- The decreasing pattern also shows that each OES concentration decreases about one order of magnitude from one distance marker to the next. The asbestos concentrations in air have a sharp drop for fugitive emissions between the co-located distances and general population, after the 100 m mark (not visible in the figures due to the log scale).
- The figures also show a wide range of asbestos concentrations among OES at the same distance from the source ranging from 1 to 3 orders of magnitude difference.
- The cascading decreasing pattern for each distance shows the order of larger to smaller concentrations by OES:
    - Area emissions from activities related to handling asbestos-containing building materials during maintenance, renovation, and demolition
    - Area emissions from activities related to use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos
    - Area emissions from waste handling, disposal, and treatment
    - Area emissions from activities handling articles or formulations that contain asbestos

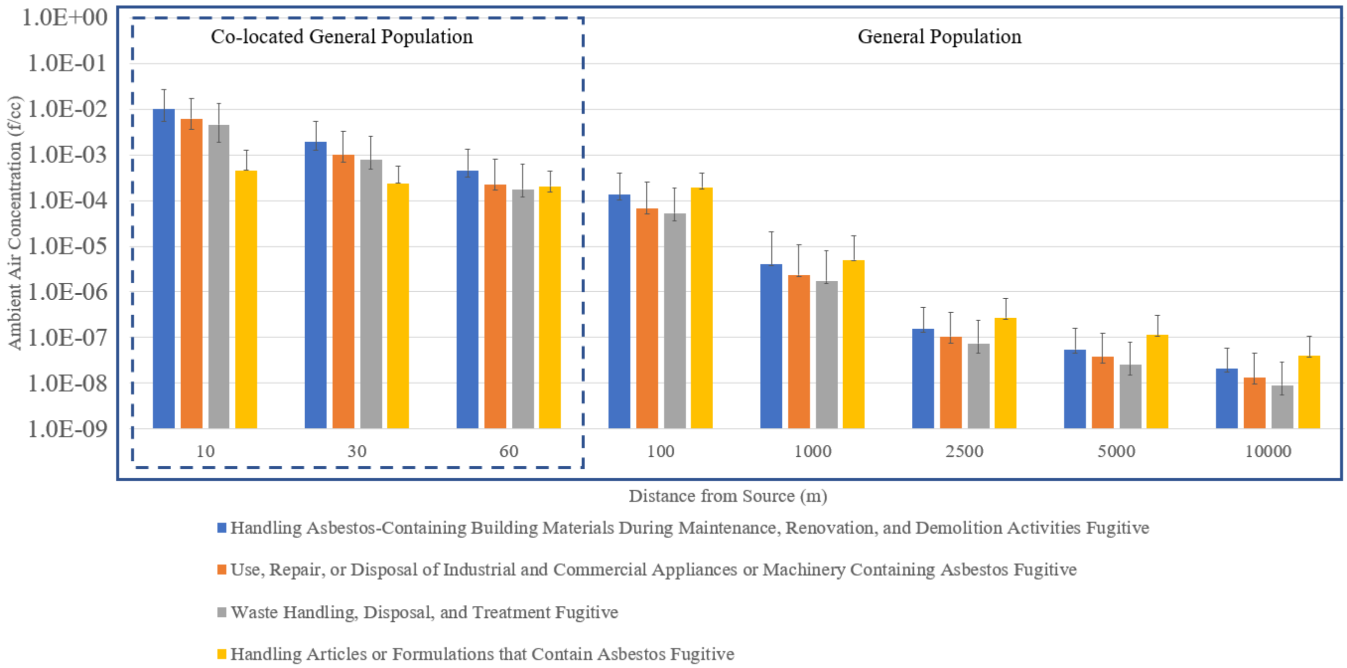


Figure 3-5. Specific Facilities Ambient Air Concentrations by Distance from Source for Each OES

Figure 3-5 depicts the summary of the specific facilities ambient air concentrations by OES, and each OES bar in Figure 3-5 is composed of releases from multiple specific facilities with a wide range of descriptions available in Appendix H (Figure_Apx H-4, Figure_Apx H-5, Figure_Apx H-6, and Figure_Apx H-7). The overall pattern of each figure in Appendix H is the same as that from Figure 3-5, and the difference in concentrations among facilities under the same OES at the same distance from the source can range from 3 to 6 orders of magnitude.

Generic Facilities

The modeled asbestos air concentrations for annual releases for generic facilities by OES tables are available in *Asbestos Part 2 RE - Ambient Air Generic Facilities and Depo Concentrations - November 2024* Supplemental File (see Appendix C) and in Appendix H. Figure 3-6 shows simulated overall annual air asbestos fiber concentration patterns for generic facilities by OES for fugitive emissions.

- Like specific facilities, the simulated generic facilities show a pattern of decreasing ambient air asbestos fiber concentrations (f/cc) away from the source for all OES.
- Like specific facilities, the generic facilities also show a difference of 1 to 2 orders of magnitude from distance marker to the next for the same generic facility simulation.
- There is no marked difference between rural and urban populations for concentrations within the same distance marker.
- Fugitive emission concentrations for all OES at the same distance marker are all within the same order of magnitude.
- There is a 2 orders of magnitude difference between HE and CT emissions (HE is shown by the lined bars in the figures). The main difference driver is the use of meteorological data from Lake Charles, Louisiana, for the HE emissions estimates and Sioux Falls, South Dakota, for CT emissions estimates simulations.

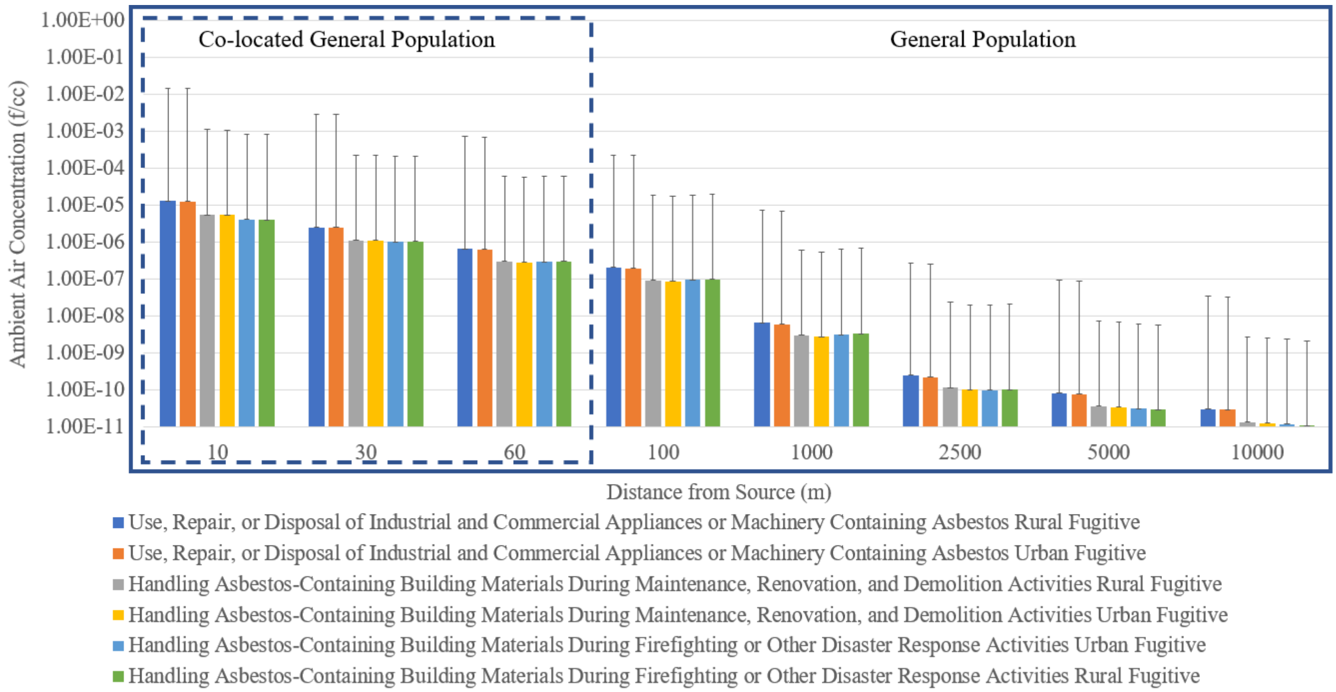


Figure 3-6. Generic Facilities Ambient Air Concentrations by OES for Rural and Urban Fugitive Emissions

3.3.1.3 Concentrations of Asbestos in Ambient Air Summary

The ambient air scenarios built using literature studies monitoring data and the modeled ambient air specific and generic facilities aim to capture an overall general picture of asbestos released to ambient air in the United States from asbestos sources matched to OES and COUs. The measured concentrations scenarios are commonly used to ground truth portions of the results from the ambient air modeled scenarios for specific and generic facilities when describing similar distances from the source. Because the transient nature of the activities performed under three of the OESs and the stationary nature of two of the OESs there are wide ranges in asbestos fibers release concentrations within each COU and its matching OES. Comparisons between measured and modeled data are to be used as a guidance rather than ground truth. For example, the firefighting and fireproofing activities/products related scenarios. Nolan and Langer (2001)'s ambient air samples distance from buildings containing these materials was not specified.

EPA assumes from the study description that sampling was performed near the source, and hence within the co-located region (0 to 100 m from source). The measured LE, CT, and HE concentrations from Nolan and Langer (2001) are 1.0×10^{-3}, 1.7×10^{-3}, and 2.2×10^{-3} f/cc respectively, while the modeled concentrations for HE scenarios range from 8.4×10^{-4} to 2.2×10^{-9} f/cc and for CT scenarios range from 4.2×10^{-6} to 1.1×10^{-11} f/cc. The measured concentrations are an order of magnitude higher than the highest HE value of the modeled concentrations closest to the source distance, 10 m, rather than any other distance. Similar comparisons can be done to the HE measured concentrations for the demolition, renovation, maintenance of asbestos-containing building materials OES. The measured HE value is 2.0×10^{-2} f/cc and the specific and generic facilities HE 10 m values range from 1.1×10^{-3} to 1.7×10^{-2} f/cc. The measured HE value is within the modeled HE range for this OES. Finally, EPA can compare the HE measured concentration to the HE modeled concentration range for the waste handling, disposal, and treatment OES. The measured value is 6.3×10^{-3} f/cc and the generic and specific facility modeled concentrations ranged from 3.1×10^{-5} to 8.7×10^{-3} f/cc at 10 m distance from the source. The measured value for this OES is on the higher side of the modeled concentrations range, but within the range.

Modeled generic and specific asbestos air concentrations from occupational activity-based scenarios are grouped and averaged by OES and divided by low-end, central, and high-end tendencies in Table 3-11 and Figure 3-7, for a detailed grouping by ambient air analysis summary see Appendix H.3. The concentration values in Figure 3-5 and Figure 3-6 will be used to estimate risk to asbestos fiber inhalation by the general population, Section 5.1.4 and environmental exposures in Section 4.

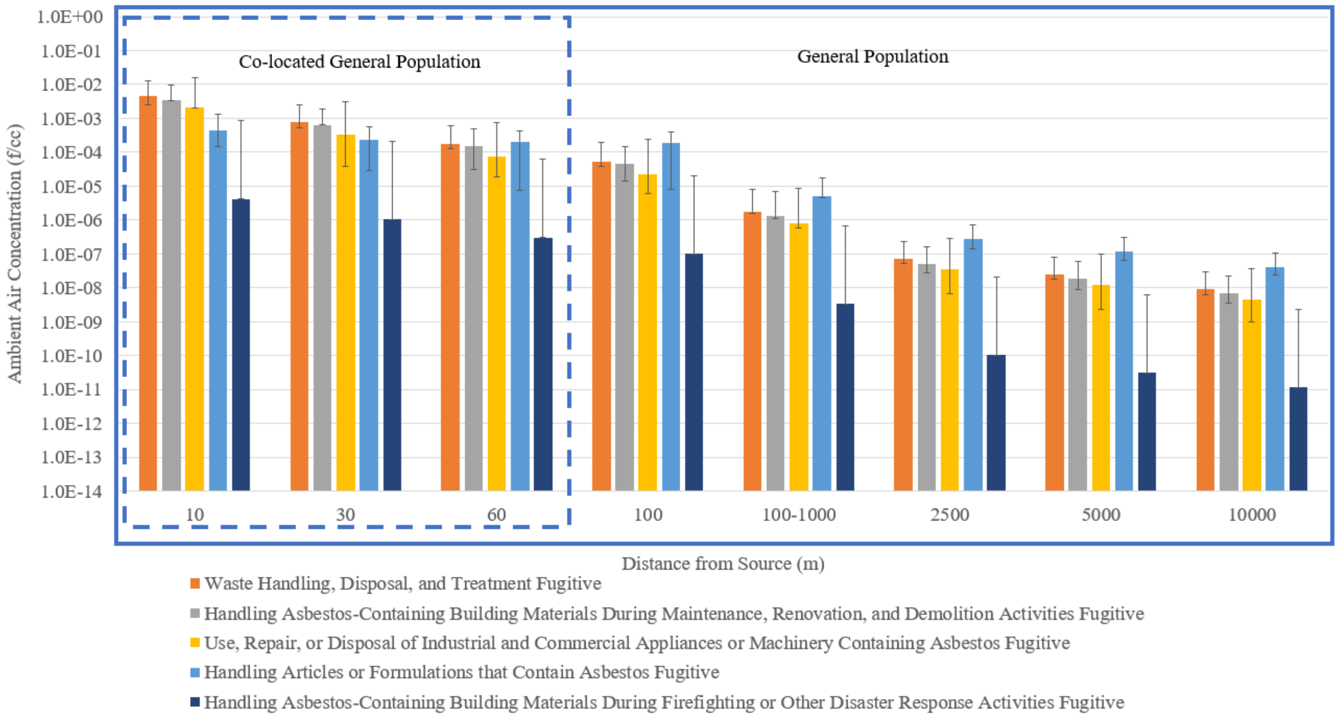


Figure 3-7. Ambient Air Concentration Summary

Table 3-11. Ambient Air Concentration Summary[a]

OES	COU	Distance from the Source (m)							
		10	30	60	100	1,000	2,500	5,000	10,000
Low-end tendency ambient air concentrations									
Waste handling, disposal, and treatment fugitive	COU: Disposal, including distribution for disposal	1.9E−03	2.5E−04	5.1E−05	1.4E−05	1.6E−07	2.2E−08	7.8E−09	2.7E−09
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	4.5E−03	6.4E−04	1.2E−04	3.0E−05	2.5E−007	2.3E−08	9.3E−09	3.5E−09
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos fugitive	COU: Construction, paint, electrical, and metal products	2.6E−03	3.0E−04	5.6E−05	1.6E−05	2.0E−007	2.9E−08	1.0E−08	3.4E−09
Handling articles or formulations that contain asbestos fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products COU: Packaging, paper, plastic, toys, hobby products	3.1E−04	2.1E−04	2.0E−04	1.9E−04	4.4E−007	1.3E−07	5.0E−08	1.6E−08
Central tendency ambient air concentrations									
Waste handling, disposal, and treatment fugitive	COU: Disposal, including distribution for disposal	4.5E−03	7.7E−04	1.8E−04	5.3E−05	1.8E−06	7.4E−08	2.6E−08	9.1E−09
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	3.3E−03	6.3E−04	1.5E−04	4.4E−05	1.3E−06	5.1E−08	1.8E−08	7.0E−09
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos fugitive	COU: Construction, paint, electrical, and metal products	2.1E−03	3.3E−04	7.5E−05	2.2E−05	7.9E−07	3.5E−08	1.3E−08	4.4E−09
Handling articles or formulations that contain asbestos fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products COU: Packaging, paper, plastic, toys, hobby products	4.6E−04	2.4E−04	2.0E−04	1.9E−04	5.0E−06	2.8E−07	1.1E−07	4.0E−08

OES	COU	Distance from the Source (m)							
		10	30	60	100	1,000	2,500	5,000	10,000
Handling asbestos-containing building materials during firefighting or other disaster response activities fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	4.2E−06	1.1E−06	3.1E−07	1.0E−07	3.3E−09	1.0E−10	3.1E−11	1.1E−11
High-end tendency ambient air concentrations									
Waste handling, disposal, and treatment fugitive	COU: Disposal, including distribution for disposal	8.7E−03	1.8E−03	4.5E−04	1.4E−04	6.0E−06	1.6E−07	5.5E−08	2.0E−08
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	6.3E−03	1.3E−03	3.3E−04	9.9E−05	5.8E−06	1.2E−07	4.0E−08	1.5E−08
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos fugitive	COU: Construction, paint, electrical, and metal products	1.4E−02	2.7E−03	6.9E−04	2.1E−04	7.7E−06	2.6E−07	9.0E−08	3.3E−08
Handling articles or formulations that contain asbestos fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products COU: Packaging, paper, plastic, toys, hobby products	8.3E−04	3.2E−04	2.3E−04	2.1E−04	1.2E−05	4.5E−07	1.9E−07	6.9E−08
Handling asbestos-containing building materials during firefighting or other disaster response activities fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	8.4E−04	2.1E−04	6.1E−05	2.0E−05	6.6E−07	2.1E−08	6.2E−09	2.3E−09

[a] Modeled generic and specific asbestos air concentrations from activity-based scenarios are grouped and averaged by OES and mapped to COUs in this table. A detailed summary of the specific and generic facility results is in Appendix H.3.
Low-end tendency concentrations were calculated from the average of all 10th percentile modeled concentrations for specific and generic facilities.
Central tendency concentrations were calculated from the average of all 50th percentile modeled concentrations for specific and generic facilities.
High-end tendency concentrations were calculated from the average of all 95th percentile modeled concentrations for specific and generic facilities.

3.3.1.4 Ambient Air Concentration Data Uncertainty and Variability

Sources of uncertainty in measured asbestos ambient air concentration data are related to the sample collection and analysis in the studies EPA considered. These studies reported using TEM, PCM, and other asbestos concentration analysis method. A detailed description of reported data sources and statistics is available in Appendix H.1. TEM can distinguish between asbestos and non-asbestos fibers in addition to asbestos fiber type identification capabilities. The use of TEM decreases uncertainties in the identification of asbestos fibers and quantification. Of the studies considered, 2 out of 6 used PCM or PCME to quantify asbestos concentrations and hence it is expected that these studies have greater uncertainties. In addition, one study did not report particle size and one reported providing concentrations for particles less than 5 µm. Inclusion of particles less than 5µm will increase uncertainty and variability as concentrations and concentration ranges will likely be larger.

Sources of uncertainty in modeled asbestos ambient air concentration data are related to the environmental release estimates discussed in Section 3.2.1.2, and modeling approaches approximations, assumptions, and parameters. A detailed description of modeling inputs, assumptions, and approximations are described in Appendix H.2.

Table 3-12. Qualitative Assessment of the Uncertainty and Variability Associated with Concentration Data Used for Ambient Air

Variable Name	Effect	Data Source(s)	Uncertainty (L, M, H)	Variability (L, M, H)
Measured ambient air concentration sample analysis methods	Majority (2 of 6) of studies used TEM that decreases uncertainty	Systematic Review identified studies measurements, Appendix H.1	M	L
Asbestos fiber sizes in measured ambient air concentrations	Concentration data used may include smaller particle sizes and hence overestimate risk	Systematic Review identified studies measurements, Appendix H.1	H	H
Overall measured ambient air concentration	**Overall uncertainty in concentration data used**	**Systematic Review identified studies**	**H**	**H**
AERMOD defaults for air modeling: meteorological data specific facilities	Meteorological data determines fate and transport patterns away from source; used locally reported data for specific locations for current conditions.	AERMOD model, Section 3.3.1.2, Appendix H.2	L	H
AERMOD defaults for air modeling: meteorological data generic facilities	Meteorological data determines fate and transport patterns away from source; generic facility estimates used two data sets to generalize and central and high-end tendency	AERMOD model, Section 3.3.1.2, Appendix H.2	M	H
AERMOD defaults for air modeling: source specification parameters for fugitive emission parameters	Height of emission for point and area source emissions can determine air mass mixing and transport tendencies.	AERMOD model, Section 3.3.1.2, Appendix H.2	M	H
AERMOD defaults for air modeling:	Number of emissions per year	AERMOD model, Section 3.3.1.2, Appendix H.2	M	H

Temporal emission parameters				
Overall modeled ambient air concentration	**Overall uncertainty in concentration data used**	AERMOD model	**M**	**H**
L = low; M = moderate; H = high Low- to high-end concentration ranges were within the same to 1 order of magnitude difference for all scenarios concentrations.				

3.3.2 Water Pathway

3.3.2.1 Measured Concentrations in Surface and Drinking Water

Measured surface water concentrations were obtained from EPA's Water Quality Exchange (WQX) using the Water Quality Portal (WQP) tool, which is the nation's largest source of water quality monitoring data and includes results from EPA's STORage and RETrieval (STORET) Data Warehouse, the U.S. Geological Service (USGS) National Water Information System (NWIS), and other federal, state, and tribal sources, summarize in Table 3-13 with the label STORET (U.S. EPA et al., 2023) in the scenario description.

Through systematic review, other sources of asbestos concentrations in water were also identified. The data selected for surface and drinking water in this section is summarized in Table 3-13 and Appendix H.4 has details of selected and unused data. The published literature yielded information of surface water monitoring data for asbestos. EPA identified surface water monitoring studies from various countries ranging from 1971 to 2016. The data can be classified in three groups: surface water, well water, and drinking water. EPA opted to only use surface and drinking water in this discussion as other water types (groundwater, wastewater, and sediments) did not meet the integration criteria (see Appendix H.4). EPA used data from 2008 forward and only U.S.-based studies to obtain a current representation of asbestos concentrations in water from legacy uses, associated disposal, and possibly from natural sources. The data presented in this section will not be used to further assess risk because it cannot be apportioned to specific COUs under this risk evaluation. EPA used the data to qualitatively discuss observations of asbestos fibers releases and transportation within water.

- ATSDR (2015) – Measured asbestos in surface water on-site and off-site at BoRit. The site was historically used to dispose of asbestos-containing materials, starting in the 1800s and ending in 1970. Remediation efforts are currently ongoing.
- ATSDR (2012a) – Measured asbestos in groundwater on-site and off-site at BoRit.
- CDM Federal Programs Corporation (2014) – Libby asbestos superfund site ecological risk assessment. Measured asbestos in various environmental media including freshwater from various locations around the site.
- U.S. EPA (2016a) – The Six-Year Review 3 of drinking water database is the latest publicly available set. This review is part of EPA's obligation to review each national primary drinking water regulation. EPA evaluates any newly available data, information, and technologies to determine if any regulatory revisions are needed. This database contains asbestos measurements from 2006 to 2011 from all U.S. states, territories, including tribal lands. The database contains approximately 12,084 data points of asbestos concentrations measured in drinking water facilities, of the 12,084 data points, 330 measured asbestos above detection limit, and 15 samples were above EPA's Maximum Contaminant Level (MCL).
- (ATSDR, 2016) – Samples were collected between 2009 and 2012. The purpose of the evaluation was to determine whether the concentrations of naturally occurring asbestos and metals found in groundwater are at levels of health concern. The study reported asbestos concentrations in drinking

water from wells for various fiber sizes (≥0.5 µm, ≥0.5–10 µm, and >10 µm). Only the greater than 10 µm size has a MCL value to assess risk to asbestos fibers in drinking water. The reported values are summarized in Table 3-13.

The National Primary Drinking Water Regulations (NPDWR) establish the MCL[4] for asbestos among many other chemicals. These standards, based on potential health effects from long-term exposures apply to public water systems and limit the levels of certain contaminants in drinking water. Asbestos MCL is 7×10^6 f/L (7×10^3 f/cc) with a potential risk of developing benign polyps from decay of asbestos cement in water mains and erosion of natural deposits. Table 3-13 summarized the comparison of water concentrations to the MCL. Starting with the surface water rows from Libby, Montana, and the BoRit site in Pennsylvania, it is notable that samples close to the asbestos source will have larger concentrations and exceed the MCL. In addition, efforts to clean and remediate Libby and BoRit sites started in 2012 and finished 2022, and the expectation was to observe fewer asbestos fibers as these efforts successfully remove asbestos fibers. The reported BoRit and Libby sites 2009 and 2014 samples with asbestos concentrations above the MCL are from pre-remediation efforts from surface water that are not used as a source of drinking water directly, however it may be that some of the creeks, streams, rivers, and lakes surface water from the Libby, Montana, site and the BoRit site will end up in bodies of water that source drinking water. The BoRit site remediation efforts are reported for the years 2018, 2020, and 2021, for two surface water sources within the site and show asbestos concentrations two orders of magnitude below the pre-remediation efforts.

Table 3-13. Summary of Measured Surface and Groundwater Concentrations*[a]*

Source	Data Quality	Date Sampled	Sample Description	Concentration (f/cc)		Comparison to MCL (Drinking Water) 7E3 f/cc	
				CT	HE	CT	HE
(CDM Federal Programs Corporation, 2014)	Medium	2014	Surface freshwater from creek stream (Rainy, Carney, and Fleetwood Creeks) close to source, Libby mine	7.3E03	5.2E05	Above	Above
(CDM Federal Programs Corporation, 2014)	Medium	2014	Surface freshwater from Kootenai River close to source, Libby mine	1.0E02	1.3E03	Under	Under
(CDM Federal Programs Corporation, 2014)	Medium	2014	Surface freshwater from tailing, mill, and reference ponds close to source, Libby mine	1.5E04	1.0E06	Above	Above
(U.S. EPA, 2022c)		2009	Surface water from on-site reservoir close to source, BoRit asbestos disposal site	1.7E08	5.4E08	Above	Above
(U.S. EPA, 2022c)		2018	Surface water from on-site reservoir close to source, BoRit asbestos disposal site	4.9E06	1.4E07	Above	Above
(U.S. EPA, 2022c)		2020	Surface water from on-site reservoir close to source, BoRit asbestos disposal site	2.4E06	3.3E06	Above	Above

[4] https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations.

Source	Data Quality	Date Sampled	Sample Description	Concentration (f/cc)		Comparison to MCL (Drinking Water) 7E3 f/cc	
				CT	HE	CT	HE
(U.S. EPA, 2022c)		2021	Surface water from on-site reservoir close to source, BoRit asbestos disposal site	7.5E06	1.0E07	Above	Above
(U.S. EPA, 2022c)		2009	Surface freshwater from creek stream (Wissahickon Creek, Rose Valley Creek, Tannery Run) close to source, BoRit asbestos disposal site	1.4E07	2.9E07	Above	Above
(U.S. EPA, 2022c)		2018	Surface freshwater from creek stream (Wissahickon Creek, Rose Valley Creek, Tannery Run) close to source, BoRit asbestos disposal site	1.5E05	3.0E05	Above	Above
(U.S. EPA, 2022c)		2020	Surface freshwater from creek stream (Wissahickon Creek, Rose Valley Creek, Tannery Run) close to source, BoRit asbestos disposal site	9.8E04	3.9E05	Above	Above
(U.S. EPA, 2022c)		2021	Surface freshwater from creek stream (Wissahickon Creek, Rose Valley Creek, Tannery Run) close to source, BoRit asbestos disposal site	5.4E05	1.5E06	Above	Above
(ATSDR, 2012a)	Medium	2011	Treated drinking groundwater from BoRit asbestos disposal site county	8.20E01	NR	Under	N/A
(ATSDR, 2012a)	Medium	2009–2010	Drinking groundwater from monitoring well at BoRit asbestos disposal site	2.0E02	5.1E02	Under	Under
(U.S. EPA et al., 2023)	High	2011–2013	STORET City of Honolulu, Honouliuli WWTP Plant	0	0	Under	Under
(U.S. EPA et al., 2023)	High	2012	STORET Random Private Potable Ground Water Florida	7.90E−04	3.70E−04	Under	Under
(U.S. EPA et al., 2023)	High	2019–2022	STORET Yavapai Prescott Indian Tribe, Arizona (Tribal)	8.65E02	4.40E02	Under	Under
(U.S. EPA, 2016a)	Medium	2006–2011	Drinking water throughout United States	0	0	N/A	N/A
(ATSDR, 2016)		2009–2012	Drinking water from wells and groundwater	0	–	Under	Under

MCL = maximum contaminant level; WWTP = wastewater treatment plant
[a] The majority of the data was non-detect, zeros, and the values in the table were calculated with all zeros to represent and generalize to all of the United States. Without zeros the values would be 1.06E5 f/cc.

Asbestos contaminated waters, for example, from former asbestos mines, naturally occuring asbestos, asbestos waste handling sites, or other sources end up in drinking water, it is likely that the fibers are either diluted or removed by deposition or other processes in the transport and mixing of cleaning drinking water sources process. This pattern is evidenced from drinking water samples around the BoRit site that are under the MCL and drinking water from the 6-year drinking water database, U.S. EPA (2016a), which show all sites to be under the MCL or show no asbestos detected.

3.3.3 Land Pathway

Asbestos fibers in soils can lead to inhalation exposures as the settled particles are stirred up and suspended to become available for inhalation. Asbestos in soils can either be naturally occuring or released from asbestos containing products during construction/demolition, firefighting activities, and waste and disposal of asbestos containing materials.

Emission of asbestos fibers in soil depend on disturbances. Soil disturbances resulting in soil erosion depend on the size, weight, and wetness of the soil particles. Each individual soil particle needs to be less than 1 mm (1,000 µm) to be moved by wind. Furthermore, suspension of soil particles tends to happen for fine particles less than 0.1 mm (100 µm), and these can go long-range transport and reach higher levels of the atmosphere beyond the troposphere. Saltation processes in which particles bounce along the surface tend to happen for particles ranging from 0.05 to 0.5 mm (50–500 µm) and remain within 30 cm of the surface. Soil creep is like saltation for larger particles, 0.5 to 2 mm (500–2,000 µm) in diameter (Queensland DERM, 2011). Bouncing particles, subject to saltation and soil creep, can further breakdown into smaller sizes and can undergo suspension. The particle sizes for suspension are well within the range of the asbestos particle size targeted within this assessment (>5 µm, with a 3:1 ratio) and hence soils can be a source of asbestos for inhalation exposures.

The data presented in this section will not be used to further assess risk because it cannot be apportioned to specific COUs under this risk evaluation. EPA used the data to qualitatively discuss observations of asbestos fibers releases within soil. A literature search was conducted to identify peer-reviewed references of measured asbestos concentrations in United States soils. The preferred search was narrowed to target studies that had sampled U.S. soils after the year 2000 and without mining influences to obtain representative concentrations for current conditions (Qualitative discussion Table 3-14). EPA identified studies that reported on mining related activities or in areas that are likely to be affected by their proximity to mines like Libby, Montana, or activity-based exposures to naturally occurring asbestos. Table 3-14 summarizes the identified references, descriptions, and rationale for using or not utilizing these studies in the inhalation exposure assessment. A detailed description of the studies is available in Appendix H.5.

Table 3-14. Soil Concentration Data Sources Description

Source, SR Rating[a]	Description	Use in Assessment
(CDM Federal Programs Corporation, 2015), High	Soil samples from town of Troy, Montana, from various outside residential buildings such as driveways, yards, gardens. Sampling was conducted the summer of 2011 and 2012 and reported Libby Amphibole concentrations.	Mining activity related, not using
(Jones et al., 2010), Medium	Soil sample from town of Libby, Montana, reporting Libby vermiculite relationship to mine activity. Study is from 2010.	Mining activity related, not using
(ATSDR, 2007)	Study designed to assess naturally occurring asbestos exposures to all-terrain-vehicle (ATV) ridders on a gravel pit in Ambler, AK. Personal air sampling, four suspended reference level measurements in the community and soil samples along the ATV riding route. Sampling was performed only to determine the presence or absence of asbestos and airborne particle size distributions. Background samples reported asbestos fibers using PCME. Concerns about	Qualitative discussion

Source, SR Rating[a]	Description	Use in Assessment
	overloaded filters add uncertainty to this measurement.	
(ATSDR, 2011)	Potential community activity-based exposures to naturally occurring asbestos in El Dorado Hills, CA. Sampling was performed in Fall 2004 during activities that aimed at stirring soil and becoming airborne for inhalation. No soil asbestos fiber concentrations reported.	Qualitative discussion
(ATSDR, 2012b)	Exposures to naturally occurring asbestos in an old quarry that is now a youth camp. Activity-based assessment sampled in 2011, 22 surface soil, 6 surface water, and 7 sediment samples in several areas, including camp use areas. Soil samples from various areas showed trace levels (<0.25%) of asbestos.	Qualitative discussion
(ATSDR, 2014a)	The AK location was a processing and shipping plant of vermiculite ore from Libby, MT. Assessed outdoor activity-based exposures to asbestos at the processing and shipping plant.	Mining activity related, not using
(MDH, 2003)	The MN location was a processing and shipping plant of vermiculite ore from Libby, MT. Assessed outdoor activity-based exposures to asbestos at the processing and shipping plant.	Mining activity related, not using
[a] SR rating is the overall systematic review rating for the study.		

While the studies in Table 3-14 are used in this discussion have measurements of naturally occurring asbestos, none of these can be matched to a specific COU. The data reported in the completed assessments studies were used to assess asbestos exposure from activity-based scenarios and report on asbestos soil concentrations and at times on suspended (air) concentrations as background or related to some activity and specific location. Although EPA cannot continue a COU specific assessment from the identified data it is noteworthy that these assessments provide a location specific exposure and risk evaluation of naturally occurring asbestos that is of relevance to the communities in the vicinity and people recreating in these areas. While the data reported in these studies can potentially be used as a U.S. representative surrogate for naturally occurring asbestos releases and exposures, there are significant uncertainties due to the large variability in the asbestos fiber distribution across the U.S. (Gunter, 2018).

EPA modeled releases to ambient air from activities that are likely to result in subsequent deposition to soil, refer to Section 3.3.4 for a discussion of asbestos concentrations onto soils from suspended asbestos fibers. Specific and generic facilities ambient air modeling outputs and simulations results from Section 3.3.1.2 can be used to estimate release concentrations after deposition and re-suspension of asbestos in soil particles from activities that can be traced to demolition/renovation, firefighting, and asbestos waste handling activities, and use, repair, removal of asbestos containing machinery.

3.3.4 Modeled Deposition Rates from Environmental Releases

EPA used AERMOD to estimate air deposition from facility releases to calculate deposition concentrations near specific and generic facilities. Asbestos particles may deposit on surface water, soil surfaces, and structure surfaces. The air deposition modeling was conducted using AERMOD. A description of the modeling and the deposition results is provided in Appendix H.2. Briefly, EPA used the AERMOD module that assumes at least 10 percent of particles (by mass) are 10 µm or larger.

Asbestos fibers are not spheres and AERMOD assumes spheres in the deposition calculations which affects settling velocity. EPA calculated the potential sphericity of asbestos particles using the average diameter, aspect ratio, and percent by size bin provided by Wilson et al. (2008). The settings for particle deposition modeling are summarized in Appendix H.2.6. Figure 3-8 and Figure 3-9 shows the overall deposition pattern of asbestos fibers for specific and generic facilities by distance from source for each OES. Each bar in Figure 3-8 and Figure 3-9 represents various facility types within each OES, see Appendix H.3 for further details.

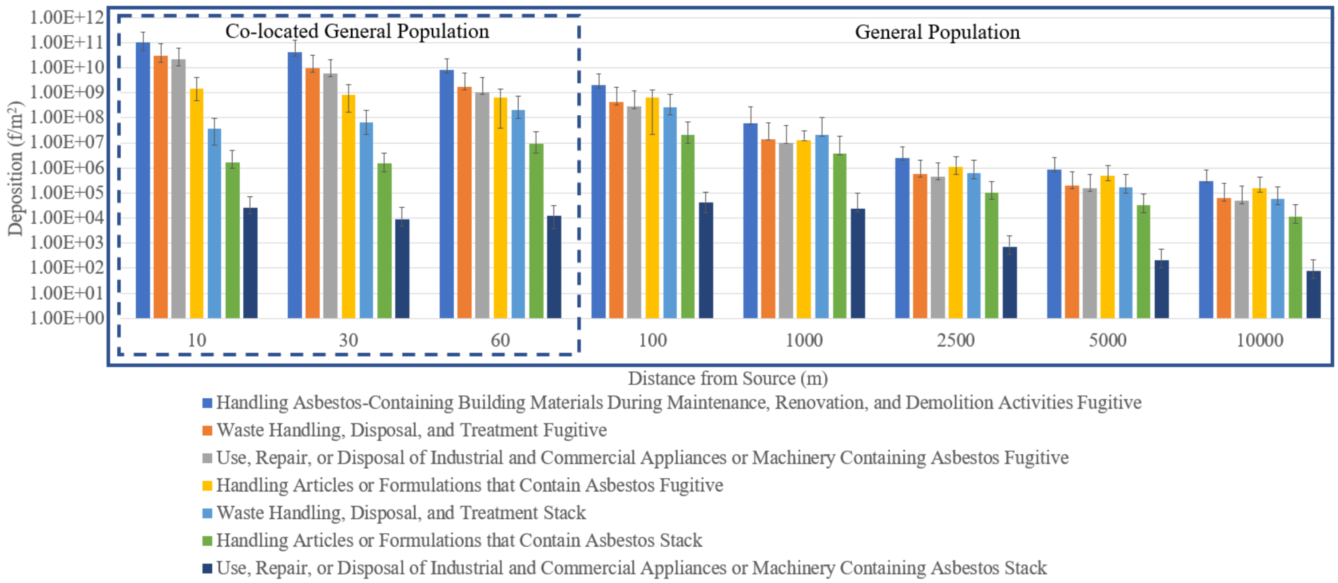


Figure 3-8. Deposition of Asbestos Fibers from Specific Facilities by Distance for Each OES

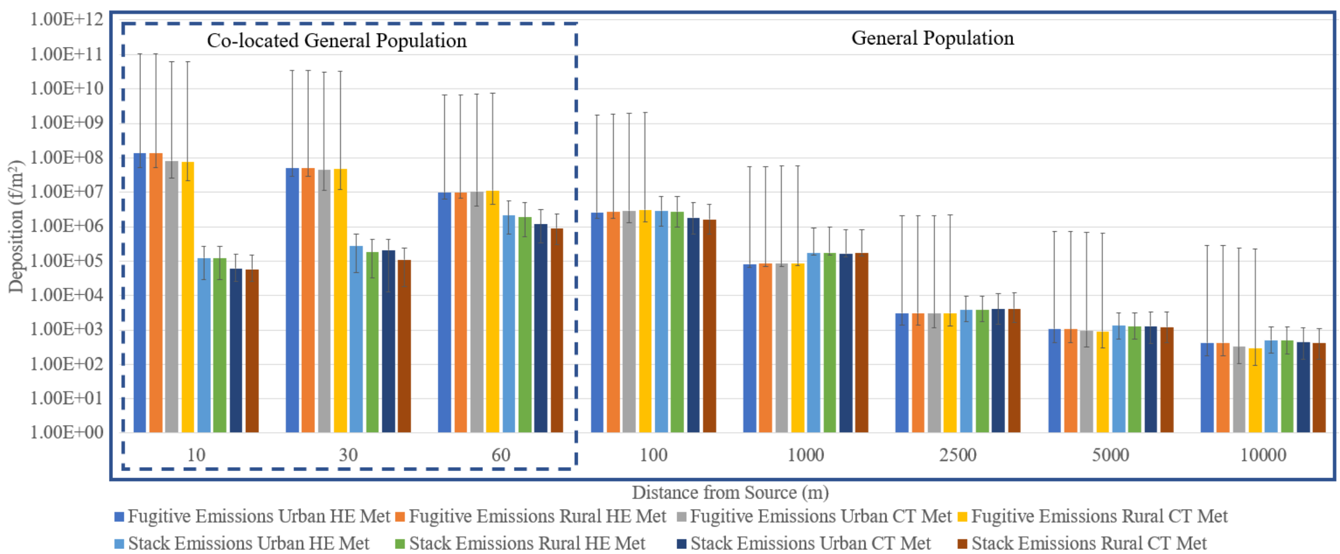


Figure 3-9. Deposition of Asbestos Fibers from Generic Facilities by Distance for Each OES

Deposition rates of asbestos fibers are larger closer to the source and decrease farther away from the source. This decreasing pattern is expected as asbestos fibers concentrations are higher closer to the source (see Section 3.3.1.2). Based on the deposition pattern the concentrations of asbestos on surfaces (soil, water, and structures) are also expected to be larger closer to the source. For asbestos to be a health concern the fibers must be resuspended (re-released) from the surfaces it deposited onto via a disturbance caused by meteorological events, human activities, or other events. The disturbance and subsequent resuspension of asbestos fibers from surfaces act as a source of asbestos and similar patterns of dispersion described in Section 3.3.1.2 and this modeled deposition rates section are expected.

4 ENVIRONMENTAL RISK ASSESSMENT

4.1 Environmental Exposures

Asbestos – Environmental Exposures (Section 4.1):
Key Points

EPA evaluated the reasonably available information for environmental exposures to asbestos following asbestos exposures. The following bullets summarize the key points of this section of the Part 2 Risk Evaluation:

- Ingestion by aquatic and terrestrial organisms is the primary asbestos exposure route for environmental hazard.
  - Asbestos ingestion can occur via surface water or soil ingestion.
- U.S.-based and recent (<15 years) soil asbestos concentrations were not identified.

4.1.1 Approach and Methodology

The major environmental compartments for asbestos are ambient air, water, and soil. Environmental asbestos concentrations of suspended particulates in ambient air in proximity to emitting sources are summarized in Section 3.3.1 and 3.3.4. Surface water and soil concentrations are summarized in Sections 3.3.2 and 3.3.3, respectively. Details about identification of information through systematic review are included in Appendix H.3, Appendix H.4, and Appendix H.5.

Exposure to asbestos via ingestion is the most relevant exposure route for ecological organisms. In particular, ingestion of asbestos in water is of concern for aquatic organisms. As described in Section 3.3.2.1, surface water monitoring data was available to estimate environmental concentrations of asbestos. Asbestos exposure via soil is of concern for terrestrial organisms. The use of these data in consideration of exposures to aquatic and terrestrial species is presented in Section 4.1.2 and 4.1.3, respectively.

Inhalation and dermal exposures of asbestos to ecological organisms are not the primary exposure routes of concern. As described in Section 4.2, environmental hazard data for ecological organisms does not demonstrate effects from these exposure routes and thus risk is not expected.

4.1.2 Exposures to Ecological Species

The environmental concentrations of asbestos presented in Section 3.3 are relevant to the consideration of exposure to aquatic and terrestrial species. Asbestos concentrations in water, soil, and air are highest in close proximity to an asbestos source and asbestos concentrations decrease as you move away from the source. Exposures to terrestrial species were not specifically considered as the hazard data do not demonstrate relevant ecological apical assessment endpoints resulting from asbestos exposures (Section 4.2.2).

Aquatic organisms may be exposed to asbestos via untreated water sources that are not subject to regulation for asbestos. EPA develops recommended aquatic exposure values for frequency and duration of chemical exposures, such as asbestos, that are protective of human and aquatic life under section 304(a) of the CWA, although as of this time there are no nationally recommended exposure values (aquatic life criteria) for aquatic organisms and asbestos under the CWA.

Aquatic organisms may be exposed to asbestos in waterbodies though asbestos settles into sediments and biosolids close to the source, as discussed in Section 2.2.2. Organisms close to the source of asbestos have the potential to be exposed to higher concentrations of asbestos compared to those further downstream from the source. Acute and chronic toxicity is possible for aquatic organisms exposed to asbestos (Section 4.2).

4.1.3 Weight of Scientific Evidence Conclusions for Environmental Exposures

Limited monitoring data are available for aquatic and terrestrial species in the U.S. Monitoring data (<15 years old) is available within proximity of Superfund sites, though this would not be an appropriate representation of asbestos concentrations in surface waters across the United States to be used in an environmental hazard analysis. When considering older monitoring data or monitoring data from international sources, there are uncertainties associated with using these data because it is unknown whether those sampling sites are representative of current sites within the United States. EPA was also unable to find recent (<15 years) asbestos soil concentrations within the United States to account for naturally occurring asbestos and deposition from dispersion of human activity.

4.2 Environmental Hazards

Asbestos – Environmental Hazards (Section 4.2):
Key Points

EPA considered all reasonably available information identified by the Agency through its systematic review process under TSCA to characterize environmental hazard endpoints for asbestos. The following bullets summarize the key points of this section of the Part 2 Risk Evaluation for Asbestos:

- Aquatic species:
  - The acute concentration of concern (COC) was calculated using the available 96-hour lowest-observed-effect-concentration (LOEC) for an aquatic invertebrate (*Corbicula* sp.).
  - Two chronic COCs were calculated using the available LOECs for an aquatic vertebrates (*Oryzias latipes*) and aquatic invertebrates (*Corbicula* sp.).
  - No aquatic plant hazard data with an overall quality determination of medium or high were identified for asbestos.
- Terrestrial species:
  - No terrestrial vascular or non-vascular plant or soil invertebrate studies with an overall quality determination of medium or high were identified for asbestos.
  - Terrestrial vertebrate studies were sorted by exposure route (*e.g.*, dermal, oral, inhalation); oral exposure studies were considered for hazard endpoints following asbestos exposure.
  - EPA determined that the hazard endpoints identified for terrestrial vertebrates following oral exposure to asbestos were not ecologically relevant.

4.2.1 Approach and Methodology

During scoping, EPA reviewed potential environmental health hazards associated with asbestos. EPA identified sources of environmental hazard data shown in Figure 2-10 of the Final Scope (U.S. EPA, 2022b).

EPA completed the review of environmental hazard data/information sources during risk evaluation using the data quality review evaluation metrics and the rating criteria described in the Draft Systematic Review Protocol (U.S. EPA, 2021a). Studies were assigned overall quality determination (OQD) of high, medium, low, or uninformative. EPA assigned metric ratings of high, medium, or low to 7 aquatic and 21 terrestrial toxicity studies; however, only high and medium quality studies were used for hazard identification.

Environmental hazard was characterized in the *Risk Evaluation for Asbestos Part 1: Chrysotile Asbestos* (U.S. EPA, 2020c). In the Problem Formulation stage of Part 1, terrestrial pathways, including biosolids, were eliminated as it was determined that EPA expects little to no risk to terrestrial organisms exposed to [chrysotile] asbestos and the exclusion of ambient air and land (disposal) pathways. Terrestrial pathways were included in the Part 2 Final Scope. The four aquatic toxicity studies of asbestos identified in Part 1 were also reviewed as acceptable studies for Part 2, along with additional toxicity studies found during the review of literature and inclusion of terrestrial exposure pathways.

The Asbestos Part 1 Risk Evaluation only considered a single fiber type (chrysotile asbestos), while Part 2 expands upon the fiber types of consideration for hazard evaluation including amosite, tremolite, crocidolite, anthophyllite, actinolite, and LAA. Terrestrial vertebrate studies were also evaluated for hazard and were filtered by exposure route; dermal and inhalation studies were excluded from evaluation for environmental hazard while oral exposure studies were considered relevant as on-topic studies for review.

4.2.2 Aquatic Species Hazard

Toxicity to Aquatic Organisms

EPA assigned an overall quality determination of high or medium to six aquatic toxicity studies; low quality studies were not considered for hazard identification in aquatic species. The high and medium studies contained relevant aquatic toxicity data for Japanese medaka (*Oryzias latipes*), coho salmon (*Oncorhynchus kisutch*), green sunfish (*Lepomis cyanellus*), fathead minnows (*Pimephales promelas*), and Asiatic clams (*Corbicula fluminea*, *Corbicula* sp.). EPA identified and summarized these six aquatic toxicity studies, displayed in Table 4-1, as the most relevant for quantitative assessment in Part 2 of the Risk Evaluation. There were no studies with a high or medium overall quality determination identified examining asbestos exposure to aquatic plants.

Aquatic Vertebrates

Three relevant fish studies were identified as acceptable with a quality rating of high or medium; the species represented in these studies include Japanese medaka (*Oryzias latipes*), coho salmon (*Oncorhynchus kisutch*), green sunfish (*Lepomis cyanellus*), and fathead minnows (*Pimephales promelas*). *The Risk Evaluation for Asbestos Part 1: Chrysotile Asbestos* identified the Japanese medaka, coho salmon, and green sunfish studies as acceptable and included them in the risk evaluation (U.S. EPA, 2020c). In addition to the previous studies that were included in Part 1, an additional study examining juvenile fathead minnows was identified for Part 2. The apical assessment endpoints included mortality, growth, fiber uptake, histology, and behavior. All relevant studies evaluated were chronic endpoints with chrysotile asbestos exposure; acute aquatic vertebrate studies were not identified for asbestos.

Japanese medaka (*Oryzias latipes*) were exposed to chrysotile asbestos for 5 months; the no-observed-effect-concentration (NOEC)/LOEC (no observed effect concentration/lowest observed effect concentration) for growth was reported as the most sensitive outcome at 1.0×10^4 and 1.0×10^6 fibers/L, respectively (Belanger et al., 1990). Coho salmon (*Oncorhynchus kisutch*) and green sunfish (*Lepomis* *cyanellus*) were exposed to chrysotile asbestos for 86 and 67 days, respectively; behavioral and histopathological analyses were reported. Behavioral stress was observed for coho salmon at 3.0×10^6 fibers/L and 1.5×10^6 fibers/L for green sunfish (Belanger et al., 1986c). Juvenile fathead minnows (*Pimephales promelas*) were exposed to chrysotile asbestos for 30 days; the NOEC/LOEC for growth was reported as the most sensitive endpoint at 1.0×10^8 fibers/L (Belanger, 1985). EPA calculated the geometric mean of the NOEC and LOEC in both Japanese medaka and fathead minnows, resulting in chronic values (ChV) for both species (Table 4-1). There were no aquatic vertebrates studies examining exposures to amphibole asbestos fibers or LAA.

Aquatic Invertebrates

EPA identified four relevant studies exposing aquatic invertebrates to chrysotile asbestos and assigned overall quality levels of medium or high. Siphoning activity, shell and tissue growth, fiber uptake/accumulation, gill ultrastructure, larval release, and mortality of Asiatic clams (*Corbicula* sp.) were monitored across the four studies. Exposure to asbestos ranges from 0 to10^8 fibers/L. In Part 1: Chrysotile Asbestos, EPA reported on two of the four studies in Part 2 where *Corbicula* sp. were exposed to chrysotile asbestos resulting in the reduced siphoning activity (U.S. EPA, 2020c). A decrease in siphoning behavior to clams exposed to asbestos for 96 hours without food at 10^2 fibers/L; lower siphoning in clams with food was suspected to be a result of satiation. Similar behaviors were observed in chronic 30-day studies as observed in the acute 96-hour study for siphoning behavior. A decrease in siphoning behavior to clams exposed to asbestos across all four reported studies as well as decreased growth in clams exposed to asbestos at 10^6 fibers/L (LOEC) (Belanger et al., 1987; Belanger et al., 1986a, b; Belanger, 1985).

Table 4-1. Aquatic Organisms Environmental Hazard Studies Used for Asbestos

Duration	Test Organism (Scientific Name)	Endpoint	Hazard Values (fibers/L)	Geometric Mean (fibers/L)[a]	Effect	Fiber Type	Citation (Overall Quality Determination)
Aquatic Invertebrates							
Chronic	Asiatic clam (*Corbicula* sp./*Corbicula fluminea*)	30 days LOEC	10^2 [b] 10^4 [c]	–	Reduced siphoning [b]; Growth[c]	Chrysotile	(Belanger et al., 1986a) (High); (Belanger et al., 1986b) (High); (Belanger et al., 1987) (High);
Acute	Asiatic clam (*Corbicula sp.*)	96-hour LOEC	10^2	–	Reduced Siphoning	Chrysotile	(Belanger et al., 1986b) (High)
	Aquatic Vertebrates						
Chronic	Japanese Medaka (*Oryzias latipes*)	13 days to 5 months LOEC	10^4 10^6 [d]	10^5	Hatchability; mortality (eggs, larvae); growth [d]; reproduction	Chrysotile	(Belanger et al., 1990) (High)
	Coho salmon (*Oncorhynchus kisutch*)	40 to 86 days	3.0E06	–	Behavioral	Chrysotile	(Belanger et al., 1986c) (High)
	Green Sunfish (*Lepomis cyanellus*)	52 to 67 days	1.5E06	–	Behavioral	Chrysotile	
	Fathead minnows (*Pimephales promales*)	30 days LOEC	10E08	10E07	Growth/developmental	Chrysotile	(Belanger, 1985) (High)

[a] Geometric mean of definitive values only
[b] Hazard value for effects on reduced siphoning to Asiatic clam
[c] Hazard value for effects on growth to Asiatic clam
[d] Hazard value for effect on growth to Japanese Medaka

4.2.3 Terrestrial Species Hazard

EPA assigned an overall quality determination of high or medium to 15 terrestrial acceptable studies. These studies contained relevant terrestrial toxicity data for three rat (*Rattus norvegicus*) strains (F344, Sprague-Dawley, and Wistar Han), mice (*Mus musculus*), golden Syrian hamsters (*Mesocricetus auratus*), guinea pigs (*Cavia porcellus*), and white leghorn fowls (*Gallus gallus domesticus*). No terrestrial invertebrate or plant studies with an overall quality determination of high or medium were identified.

Terrestrial Vertebrates

Hazard to terrestrial vertebrates was not assessed in *The Risk Evaluation for Asbestos Part 1: Chrysotile Asbestos* (U.S. EPA, 2020c). At the time Part 1 was developed, pathways were excluded if covered by existing EPA statutes, so the ambient air and land (disposal) pathways were excluded from analysis. Pathways are no longer excluded based on existing EPA statutes. 40 CFR 702.39(d)(9).

In Asbestos Part 2, non-human animal studies were included for consideration with exposure to asbestos via the oral exposure route. Authors reported ecologically relevant hazard endpoints including mortality, reproductive effects, and impacts on growth/development, as well as ADME. Cancer endpoints were evaluated and reported across studies however, cancer is not an ecologically relevant endpoint, thus not considered further for ecological hazard. Study organisms were exposed to chrysotile, amosite, tremolite, crocidolite, and anthophyllite fibers across the 15 studies.

There is not a relevant connection to a COU and exposures to environmental species with population effects. Asbestos did not significantly affect mortality across the high and medium studies for rats, mice, hamsters, guinea pigs, and fowls exposed to asbestos fibers. Growth was monitored across studies; no significant impact on growth was observed across the studies. Two studies reported smaller growth of offspring but it was not reported as significant after statistical analysis of the results (NTP, 1988; McConnell et al., 1983). Fertility and litter size were reported across two studies as reproductive endpoints; this did not yield significant differences between organisms exposed to asbestos and controls (NTP, 1985; McConnell et al., 1983). Therefore, no ecologically relevant effects were reported for terrestrial organisms and hazard could not be evaluated due to a lack of applicable data.

4.2.4 Environmental Hazard Thresholds

EPA calculated hazard thresholds to identify potential concerns to aquatic species based on weighing the scientific evidence and selection of the appropriate toxicity value from the integrated data to use for hazard thresholds. 6.4Appendix I provides more details about how EPA weighed the scientific evidence.

For aquatic species, hazard was estimated by calculating a concentration of concern (COC) for a hazard threshold. COCs can be calculated using a deterministic method by dividing a hazard value by an assessment factor (AF) according to EPA methods (U.S. EPA, 2016b, 2013, 2012) and Equation 4-1.

Equation 4-1.

$$COC = \text{toxicity value} \div AF$$

Concentration of Concern (COC) for Aquatic Toxicity

Acute COC: For the acute COC, EPA used the 96-hour LOEC for *Corbicula sp.* where decreased siphoning activity was observed for adult clams that were not fed; decreased siphoning was observed at concentrations of asbestos ranging 10^2 to 10^8 fibers/L from Table 4-1. EPA applied an assessment factor

(AF) of 5 to the lowest observed effect concentration of 10^2 fibers/L chrysotile asbestos (Belanger et al., 1986a).

$$COC = 10^2 \text{ fibers/L} \div 5$$
$$COC = 20 \text{ fibers/L chrysotile asbestos}$$

Chronic COC: EPA calculated two chronic aquatic COCs, using the most sensitive vertebrate and invertebrate available data. Decreased siphoning was reported for clams (*Corbicula sp.*) at 10^2 fibers/L chrysotile asbestos. An AF of 10 was applied to the LOEC (Belanger et al., 1986a).

$$COC = 10^2 \text{ fibers/L} \div 10$$
$$COC = 10 \text{ fibers/L chrysotile asbestos}$$

EPA calculated a second chronic COC and used the Japanese medaka (*Oryzias latipes*) geometric mean of 10^5 fibers/L chrysotile asbestos from Table 4-1, with the application of an AF of 10. Japanese medaka were reported to have decreased growth and increased mortality at the LOEC of 10^6 fibers/L (NOEC of 10^4 fibers/L) (Belanger et al., 1990).

$$COC = 10^5 \text{ fibers/L} \div 10$$
$$COC = 10{,}000 \text{ fibers/L chrysotile asbestos}$$

A COC was calculated for both aquatic vertebrates and invertebrates to be protective of the physiological differences between mollusks and fish (*e.g.*, cephalopod mollusks use their siphuncle to move water throughout their chambers which differs from the potential exposure fish may have in their mouths or gills). This approach acknowledges the increased uncertainty, detailed in Section 4.2.6.1, associated with the limited data landscape for asbestos environmental hazard.

For terrestrial species, EPA estimates hazard by using a hazard value for soil invertebrates, a deterministic approach, or calculating a toxicity reference value (TRV) for mammals. There were no reasonably available mammalian toxicity studies with apical assessment endpoints and EPA was unable to model mammalian hazard values for asbestos, therefore a TRV was not calculated.

4.2.5 Summary of Environmental Hazard Assessment

For acute aquatic exposures to chrysotile asbestos, the 96-hour LOEC value was 10^2 fibers/L for *Corbicula sp.*, from one high quality study (Belanger et al., 1986a). For chronic aquatic exposures to chrysotile asbestos, EPA calculated two COCs; the invertebrate COC and vertebrate COC. EPA calculated both an invertebrate and vertebrate chronic COC due to the physiological differences between clams and fish. The chronic invertebrate COC was calculated using the LOEC for *Corbicula sp.* exhibiting decreased siphoning at 10^2 fibers/L for *Corbicula sp.*, from one high quality study (Belanger et al., 1986a). Three studies reported environmental hazards on clams, cited in Table 4-1. EPA calculated the chronic aquatic vertebrate COC by applying an AF to the geometric mean of the NOEC and LOEC reported for Japanese medaka (Belanger et al., 1990). Available aquatic studies did not include asbestos fiber types outside of chrysotile. No studies were available for aquatic or terrestrial plants, and there were no high or medium quality studies available for terrestrial invertebrates. Relevant ecological endpoints with reported hazard values were not available for terrestrial vertebrates.

Clams were the principal organism for aquatic invertebrates in the available studies. According to ATSDR, clams that are located in asbestos-contaminated areas (*e.g.*, areas with shore-line erosion) may accumulate asbestos fibers. If asbestos fibers are found in the sediments and/or water, clams may become contaminated by uptaking the fibers with their siphuncle and this is likely where the fibers would concentrate while siphoning (ATSDR, 2014b). In the *Corbicula sp.* studies discussed in Section 4.2, authors observed decreased siphoning behavior in clams exposed to asbestos fibers at concentrations as low as 10^2 fibers/L; EPA utilized this hazard value to calculate an acute COC of 20 fibers/L and a chronic COC of 10 fibers/L (Table 4-2).

Table 4-2. Environmental Hazard Thresholds for Aquatic Environmental Toxicity

Environmental Aquatic Toxicity	Hazard Value (fibers/L)	Assessment Factor (AF)	COC (fibers/L)
Acute aquatic exposure: LOEC	10^2	5	20
Chronic aquatic exposure: invertebrate (mollusk)	10^2	10	10
Chronic aquatic exposure: vertebrate (fish)	10^6	10	10^5

When asbestos enters water, it will settle into sediments and biosolids (see Section 2.2.2). Due to sediment settling, it is unlikely that asbestos will accumulate (or bioaccumulate) in terrestrial or aquatic organisms. Limited data are available to support accumulation within organisms. Environmental hazard data suggests that at concentrations of asbestos >10^2 fibers/L, hazard effects are reported for organisms. As explained in Section 3.3.4, concentrations and deposition of asbestos fibers will be higher closer to the source of asbestos; therefore, organisms closer to an asbestos source may experience a greater risk than organisms further away from the source due to decreasing concentrations the further away from the source. The concentration of suspended asbestos fibers in water is reported to decrease by more than 99 percent in water reservoirs (Section 2.2.2), supporting the evidence from Asbestos Part 1 describing how asbestos will settle into sediments.

4.2.6 Weight of Scientific Evidence Conclusions for Environmental Hazards

EPA/OPPT uses several considerations when weighing and weighting the scientific evidence to determine confidence in the environmental hazard data. These considerations include the quality of the database, consistency, strength, and precision, biological gradient/dose response, and relevance (Table_Apx I-1). This approach is consistent with the *Draft Systematic Review Protocol Supporting TSCA Risk Evaluations for Chemical Substances* (U.S. EPA, 2021a). Table 4-3 summarizes how these considerations were ranked for each environmental hazard threshold. Overall, EPA considers the evidence for aquatic hazard thresholds moderate and terrestrial vertebrate hazard thresholds indeterminate. A more detailed explanation of the weight of scientific evidence, uncertainties, and overall confidence is presented in Appendix I.2.1.

4.2.6.1 Strengths, Limitations, Assumptions, and Key Sources of Uncertainty for the Environmental Hazard Assessment

Quality of the Database; and Strength (Effect Magnitude) and Precision

All the studies used to calculate COCs (aquatic fish and invertebrates) received a high data quality level from the systematic review data quality evaluation. Effect size was reported for aquatic studies using LOECs.

Consistency

For aquatic invertebrate species, the behavior effect of reduced siphoning was reported across three studies with LOECs for both acute and chronic durations, therefore EPA assigned robust confidence in the consistency consideration for the acute and chronic aquatic assessments. The acute clam study utilized two groups of fed (n = 7) and two groups of unfed clams (n = 5). Behavior was monitored and reduced siphoning was observed for clams in the unfed groups. One exposure group (n = 5) of clams was used in the chronic study. Behavioral effects were consistent between acute and chronic clam studies. Juvenile Japanese medaka used in calculating the chronic vertebrate COC were separated into five exposure groups in triplicate (n = 15). Growth effects between chronic vertebrate and invertebrates differed, which supports the decision to calculate two COCs due to the physiological differences among the species tested.

Biological Gradient/Dose-Response
LOECs were reported for clam and medaka studies; effects were reported across doses.

Biological Relevance
Behavioral effects were consistent across acute and chronic clam studies. Japanese medaka and fathead minnow studies both reported growth impacts due to asbestos exposure. Behavioral effects were also consistent across green sunfish and coho salmon.

Physical and Chemical Relevance
Asbestos is a solid/fiber that does not degrade and lacks solubility. Therefore, asbestos can accumulate in sediment where sediment-dwelling organisms may be exposed to the fibers or exposure may occur in the water column when the fibers are disturbed. Fibers will settle and concentrations decrease the further away from the source the organisms reside.

Environmental Relevance
Additional uncertainty is associated with the concentrations of asbestos used in the environmental hazard assessments. The lowest concentration utilized in the hazard studies was 10^2 fibers/L asbestos, while concentrations in the environment can vary with distance from the source of asbestos.

Apical assessment endpoints (*i.e.*, growth and mortality) were not reported for terrestrial studies and therefore the overall confidence threshold was indeterminate.

Table 4-3. Evidence Table Summarizing the Overall Confidence Derived from Hazard Thresholds

Types of Evidence	Quality of the Database	Consistency	Strength and Precision	Biological Gradient/Dose-Response	Relevance[a]	Hazard Confidence
Aquatic						
Acute Aquatic Assessment	+++	++	++	+	+	Moderate
Chronic Aquatic Assessment	+++	++	++	+	+	Moderate
Terrestrial						
Mammalian Assessment	+	++	+	N/A	N/A	Indeterminate

[a] Relevance includes biological, physical and chemical, and environmental relevance.
+ + + Robust confidence suggests thorough understanding of the scientific evidence and uncertainties. The supporting weight of scientific evidence outweighs the uncertainties to the point where it is unlikely that the uncertainties could have a significant effect on the hazard estimate.
+ + Moderate confidence suggests some understanding of the scientific evidence and uncertainties. The supporting scientific evidence weighed against the uncertainties is reasonably adequate to characterize hazard estimates.
+ Slight confidence is assigned when the weight of scientific evidence may not be adequate to characterize the scenario, and when the assessor is making the best scientific assessment possible in the absence of complete information. There are additional uncertainties that may need to be considered.
Indeterminate is assigned when there is no available data for which to evaluate potential hazard.

4.3 Environmental Risk Characterization

Asbestos – Environmental Risk Characterization (Section 4.3):
Key Points

EPA evaluated the reasonably available information to support environmental risk characterization. The following bullets summarize the key points of this section of the draft Part 2 risk evaluation:

- RQs (risk quotients) are unable to be calculated for asbestos
  - Limited aquatic exposure data did not yield numbers for monitoring data outside of Superfund sites; therefore, a representative exposure was unavailable.
  - Environmental hazard to terrestrial species was not quantified due to a lack of data with apical assessment endpoints.

EPA considered fate, exposure, and environmental hazard to consider the environmental risk of multiple asbestos fiber types. EPA identified hazards to aquatic species via water and sediment and calculated a COC based on the available studies. However, EPA did not estimate risks to aquatic species due to a lack of relevant environmental exposure concentrations. EPA did not estimate risk to terrestrial species from asbestos due to the lack of apical assessment endpoints available to assess hazard and risk.

The physical and chemical properties of asbestos limit the potential for exposure to aquatic species. Asbestos is classified as naturally occurring mineral silicate fibers, see Section 2.1. Therefore, according to the physical and chemical properties, asbestos fibers are not expected to degrade in the environment. As described in Section 2.2.2, once asbestos enters water it will settle into sediments and biosolids. Concentrations of asbestos will be higher in water and sediment closer to the source of asbestos. Aquatic organisms located close to the source of asbestos may be at risk for asbestos exposure, although this does not account for hazard and risk at a population level as organisms further downstream from the source of asbestos will not be exposed to the same concentrations of asbestos.

4.3.1 Risk Characterization Approach and Summary

EPA characterizes the environmental risk of chemicals using risk quotients (RQs) (U.S. EPA, 1998; Barnthouse et al., 1982). The RQ is defined in Equation 4-2:

Equation 4-2.

RQ = Predicted Environmental Concentration / Hazard Threshold

EPA was unable to quantitatively calculate an RQ for asbestos due to a lack of relevant aquatic exposure data. As shown in Table 3-13, recent monitoring data for asbestos in water (2000 to present) exists for Superfund sites (*e.g.*, Libby Asbestos Site, Libby, Montana or BoRit Asbestos Site, Ambler, Pennsylvania). Using Superfund data to calculate an RQ would not be representative to populations of organisms that may be exposed to asbestos at lower levels relevant to this assessment. Additionally, exposure is not expected under the COUs for asbestos for terrestrial and aquatic organisms. A TRV was not calculated for terrestrial hazard due to limited terrestrial toxicity data and no apical endpoints in available studies. Without predicted environmental concentrations, EPA was unable to calculate an RQ using the above equation.

Aquatic environmental hazard studies were characterized in Section 4.2, with sublethal acute effects observed at 10^2 fibers/L chrysotile asbestos and sublethal chronic effects observed at 10^6 fibers/L chrysotile asbestos. Hazard endpoints included reproductive and behavioral effects for aquatic exposures (Table 4-2). Aquatic hazard data was not available for other fiber types, outside of chrysotile asbestos.

EPA concludes that there is very limited potential for asbestos exposures to aquatic or sediment-dwelling organisms and risk is not observed from exposure to asbestos fibers (U.S. EPA, 2020c).

5 HUMAN HEALTH RISK ASSESSMENT

5.1 Human Exposures

Asbestos – Human Exposures (Section 5.1):
Key Points

EPA evaluated all reasonably available information for the following exposure categories: occupational, consumer, and general population. The following bullets summarize the key points of this section of the Part 2 Risk Evaluation:

- Inhalation is the primary route for all human exposures considered under this Part 2 of the risk evaluation. Oral exposure was not assessed in depth, because ingestion of low concentrations of respirable fibers in mucus shows inconclusive associations with health effects. Dermal exposure was not assessed due to lack of systemic dermal penetration.
- Systematic review was conducted to identify the reasonably available information relevant for consideration in the quantitative human health approach; however, no cancer or non-cancer epidemiologic studies from oral or dermal exposures that support dose-response analysis were identified.
- Occupational exposures through inhalation were estimated using inhalation monitoring data to calculate high-end and central tendency exposure values for each relevant occupational exposure scenario. Occupational exposure to asbestos varied by several orders of magnitude based on the activity, with the highest number of exposed workers involved in maintenance, renovation, and demolition, and firefighting and other disaster response activities.
- Take-home exposures to asbestos through inhalation of fibers loaded onto clothing/garment during some occupational/DIY activity and subsequent garment handling at home were calculated for each COU. Exposures varied by orders of magnitude for high-end and central tendency estimates due to large differences between occupational activities exposure concentrations for those scenarios.
- The consumer DIY activity-base scenarios from inhalation exposure concentrations related to removal of asbestos containing products are generally larger than activities related to maintaining, cutting, or moving asbestos containing materials.
- The general population inhalation exposure to asbestos fibers released to ambient air from occupational activities such as demolitions, firefighting, and removal of asbestos containing materials show exposure concentrations are higher closer to the source and decrease by a few orders of magnitude beyond the co-located general population distances (100 m).
- EPA explored aggregation of risks across populations and COUs and found that people engaged in various asbestos releasing activities, may those be occupational, DIY, take-home, or from releases to the environment and subsequent indoor infiltration have higher exposures and potential risks.

Evaluated Exposure Routes

Inhalation is the primary route of occupational and non-occupational exposure to released friable asbestos fibers evaluated in this Part 2 of the risk evaluation. Although ingestion of respirable fibers can occur via mucus in the respiratory tract, studies aiming to assess the adverse health effects from asbestos ingestion have found low correlations or undecisive results (ATSDR, 2012a; Polissar et al., 1983).

Asbestos fibers ingested via the oral pathway will pass the digestive system and be excreted within a few days, while small fibers may migrate to blood or other tissues before urinary elimination. Therefore, EPA does not consider the ingestion of asbestos fibers as a relevant exposure pathway for establishing risks related to asbestos exposure. Similarly, dermal exposures are not assessed for workers or ONUs in Part 2 Risk Evaluation for Asbestos. Asbestos exists in a solid/fiber physical form only, and the size and lack of solubility of an asbestos fiber prevents systemic dermal penetration, thus this route was not considered further. While asbestos may deposit on open/unprotected skin, it will not absorb into the body through the protective outer skin layers. Therefore, a dermal dose resulting from dermal exposure is not expected.

Human Exposure Concentrations

For each exposure pathway, low-end (LE), central tendency (CT), and high-end (HE) risk from inhalation exposure concentrations were estimated. EPA's Human Exposure Guidelines defined central tendency exposures as "an estimate of individuals in the middle of the distribution." It is anticipated that these estimates apply to most individuals in the United States. HE exposure estimates are defined as the "plausible estimate of individual exposure for those individuals at the upper end of an exposure distribution, the intent of which is to convey an estimate of exposure in the upper range of the distribution while avoiding estimates that are beyond the true distribution." It is anticipated that these estimates apply to some individuals, particularly those who may live, work, and recreate near facilities with elevated concentrations.

Sentinel and Aggregate Considerations

Section 2605(b)(4)(F)(ii) of TSCA requires EPA, as a part of the risk evaluation, to describe whether aggregate or sentinel exposures under the conditions of use were considered and the basis for their consideration. EPA defines sentinel exposure as "the exposure from a chemical substance that represents the plausible upper bound of exposure relative to all other exposures within a broad category of similar or related exposures" (40 CFR 702.33). In terms of this risk evaluation, EPA considered sentinel exposures by considering risks to populations who may have upper bound exposures; for example, workers and ONUs who perform activities with higher exposure potential, or consumers who have higher exposure potential (*e.g.*, those involved with do-it-yourself projects) or certain physical factors like body weight or skin surface area exposed. EPA characterized high-end exposures in evaluating exposure using both monitoring data and modeling approaches. Where statistical data are available, EPA typically uses the 95th percentile value of the available data set to characterize high-end exposure for a given condition of use. For consumer and bystander exposures, EPA characterized sentinel exposure through a "high-intensity use" category based on both product and user-specific factors. The aggregate analysis considers the aggregation of scenarios for high intensity users when the individual scenarios do not exceed risk benchmarks, Section 6.1.1.

5.1.1 Occupational Exposures

The following subsections briefly describe EPA's approach to assessing occupational exposures and results for each condition of use assessed. For additional details on development of approaches and results refer to Appendix G.

5.1.1.1 Approach and Methodology

As described in the *Scope of the Risk Evaluation for Asbestos Part 2* (U.S. EPA, 2022b), for each condition of use, EPA endeavors to distinguish exposures among potentially exposed employees for workers and occupational non-users (ONUs). Normally, a primary difference between workers and ONUs is that workers may handle asbestos and have direct contact with the substance, while ONUs are working in the general vicinity of workers but do not handle asbestos and do not have direct contact with asbestos being handled by the workers. As discussed in Section 3.1.1, EPA established OESs to assess the exposure scenarios more specifically within each COU. Table 3-1 provides a crosswalk between COUs and OESs. Also, EPA identified job types and categories for workers and ONUs and developed Similar Exposure Groups (SEGs) for a few of the OESs where more detailed information was available to split between higher exposure-potential workers and lower exposure-potential workers.

For the OESs that were split into SEGs, higher exposure-potential workers are defined as workers whose activities may directly generate friable asbestos through actions such as cutting, grinding, welding, or tearing asbestos-containing materials; lower exposure-potential workers are workers who are not expected to generate friable asbestos but may come into direct contact with friable asbestos while performing their required work activities. ONUs do not directly handle asbestos or asbestos-containing products but are present during their work time in an area where asbestos or an asbestos-containing product is or may be present. Examples of ONUs include supervisors/managers, building inspectors, ship captains and other marine personnel, and truck drivers who might access the work area or transport materials but do not perform tasks directly with asbestos or asbestos containing products.

EPA identified relevant inhalation exposure monitoring data for all of the given OESs. The quality of this monitoring data was evaluated using the data quality review evaluation metrics and the rating criteria described in the Draft Systematic Review Protocol (U.S. EPA, 2021a). Relevant data were assigned an overall quality level of high, medium, or low. In addition, EPA established an overall confidence for the data when integrated into the occupational exposure assessment. EPA considered the assessment approach, the quality of the data and models, and uncertainties in assessment results to assign an overall confidence level of robust, moderate, slight, or indeterminant.

In the *Risk Evaluation for Asbestos Part I: Chrysotile Asbestos* (U.S. EPA, 2020c), EPA only evaluated inhalation exposures to workers and ONUs in association with chrysotile asbestos manufacturing (import), processing, distribution and use in industrial applications and products. Part 2 of the risk evaluation covers exposure to industrial and commercial legacy uses and associated disposals of all forms of asbestos, as well as consideration of talc and vermiculite products that may contain asbestos. The physical condition of asbestos is an important factor when considering the potential human pathways of exposure. Several of the asbestos-containing products identified as COUs of asbestos are not friable as intact products; however, the products can be made friable due to physical and chemical wear over time. Exposures to asbestos can potentially occur via all routes; however, EPA anticipates that the most likely exposure route is inhalation for workers and ONUs.

Where monitoring data were reasonably available, EPA used these data to characterize central tendency and high-end inhalation exposures. In cases where no ONU sampling data were available, the Agency typically assumed that ONU inhalation exposure is either comparable to area monitoring results or assumed that ONU exposure is likely lower than workers. EPA identified monitoring data for ONUs for three of the four OESs where ONU exposure was assessed. For the Waste handling and disposal OES, EPA did not have monitoring data to estimate inhalation exposure for ONUs. In this case, exposure for ONUs was addressed using the central tendency for estimates of worker inhalation exposure. As noted in Section 5.1, dermal exposures were not assessed for workers or ONUs because the expected physical form of asbestos is only the solid/fiber phase. While asbestos may deposit on open/unprotected skin, it will not absorb into the body through the protective outer skin layers.

EPA considered two issues unique to asbestos, when compared to other chemicals for which the Agency developed TSCA risk evaluations. One issue is the possibility of asbestos fibers settling to surfaces and subsequently becoming resuspended into the workplace air. The extent to which this process occurs is assumed to be reflected in the sampling data that EPA considered for each COU. The second unique issue for asbestos is that it can be found in friable and non-friable materials; and the friability of the materials has direct bearing on asbestos released to the air. This issue is also presumably reflected in the sampling data (*i.e.,* asbestos in friable materials has a greater likelihood of being detected in the air samples, as compared to asbestos in non-friable materials).

The occupational exposure assessment of each OES comprises the following components:

- **Process Description:** A description of the OES, including the role of asbestos in the use; process vessels, equipment, and tools used during the OES; and descriptions of the worker activities, including an assessment for potential points of worker exposure.
- **Worker Activities:** Activities in which workers may be potentially exposed to asbestos.
- **Number of Establishments:** Estimated number of establishments with workers and ONUs that use asbestos for the given OES. Workers and ONUs from one establishment may perform work activities at various sites for the following OESs: Handling asbestos-containing building materials during maintenance, renovation, and demolition activities; Handling of asbestos-containing building materials during firefighting or other disaster response activities.
- **Number of Potentially Exposed Workers:** Estimated number of workers, including ONUs, who could potentially be exposed to asbestos for the given OES.
- **Occupational Inhalation Exposure Results:** EPA used exposure monitoring data provided by industry and/or available in the peer-reviewed literature, when it was available, to assess occupational inhalation exposures. In all cases, EPA synthesized the reasonably available information and considered limitations associated with each data set. In Section 5.1.1.2, EPA reports central tendency and high-end estimates for exposure distribution derived for workers and for ONUs for each OES and Section 5.1.4.1 presents the strengths, limitations, assumptions, and uncertainties associated with these exposure estimates. Figure 5-1 displays the general approaches used to develop occupational exposure estimates for each OES. Inhalation exposure estimates were generated by analyzing monitoring data that was found in NIOSH Health Hazard Evaluations (HHEs), OSHA CEHD, or were provided by industry. Estimates for the number of workers and ONUs potentially exposed were generally estimated by analyzing Occupational Employment Statistics data from BLS and data from the U.S. Census' Statistics of U.S. Businesses for relevant NAICS codes. Further discussion on the approaches used for each occupational exposure assessment is provided in Appendix G.

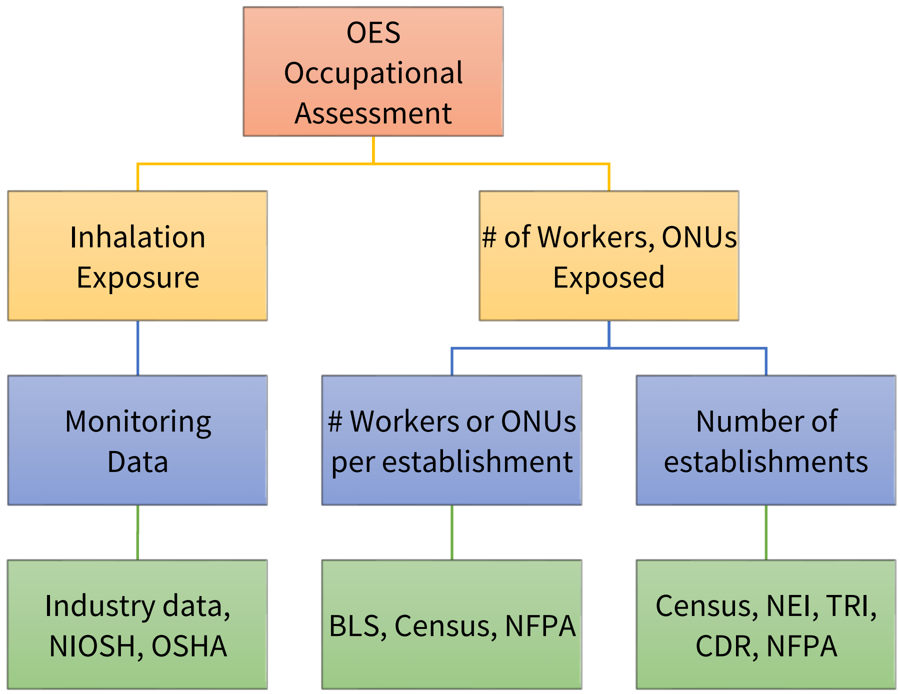


Figure 5-1. Approaches Used for Each Component of the Occupational Assessment for Each OES
TRI = Toxics Release Inventory; NEI = National Emissions Inventory; CDR = Chemical Data Reporting; BLS = Bureau of Labor Statistics; NIOSH = National Institute of Occupational Safety and Health; OSHA = Occupational Safety and Health Administration; NFPA = National Fire Protection Association

Appendix G provides a summary of EPA's estimates for the total exposed workers and ONUs for each OES. To prepare these estimates, the Agency first attempted to identify North American Industrial Classification (NAICS) codes associated with each OES. For these NAICS codes, EPA then reviewed Standard Occupational Classification (SOC) codes from BLS and classified relevant SOC codes as workers or ONUs. All other SOC codes were assumed to represent occupations where exposure is unlikely. EPA also estimated the total number establishments associated with the NAICS codes previously identified based on data from the U.S. Census Bureau.

EPA then estimated the average number of workers and ONUs potentially exposed per establishment by dividing the total number of workers and ONUs by the total number of establishments. For the OES for Firefighting and Other Disaster Response Activities, EPA used data provided by the National Fire Protection Association (NFPA) in order to estimate the number of firefighters (both career and volunteer), the number of fire departments, and the number of responders per structure fire (NFPA, 2022b, 2012). Because all workers in firefighting and disaster response may be highly exposed, EPA assumed that there are only workers and that there are no ONUs for the OES. Additional details on EPA's approach and methodology for estimating the number of establishments using asbestos and the number of workers and ONUs potentially exposed to asbestos can be found in Appendix G.

5.1.1.1.1 Consideration of Engineering Controls and Personal Protective Equipment

OSHA requires employers to utilize the hierarchy of controls to address hazardous exposures in the workplace. The hierarchy of controls prioritizes the most effective measures to address exposure; the first of which is to eliminate or substitute the harmful chemical (*e.g.*, use a different process, substitute with a less hazardous material), thereby preventing or reducing exposure potential. Following elimination and substitution, the hierarchy prioritizes engineering controls to isolate employees from the hazard (*e.g.,* source enclosure, local exhaust ventilation systems), followed by administrative controls, or changes in work practices to reduce exposure potential. Administrative controls are policies and procedures instituted and overseen by the employer to prevent worker exposures. As the last means of control, the use of PPE (*e.g.,* respirators, gloves) is required, when the other feasible control measures cannot reduce workplace exposure to an acceptable level.

OSHA Respiratory Protection and Asbestos Standards

OSHA has standards that are applicable to occupational exposure to asbestos including the Respiratory Protection Standard (29 CFR 1910.134); and the Asbestos Standard for general industry (29 CFR 1910.1001) construction (29 CFR 1926.1101), and shipyards (29 CFR 1915.1001). These standards have multiple provisions that are highlighted below.

OSHA's Respiratory Protection Standard (29 CFR 1910.134) requires employers to provide respiratory protection whenever it is necessary to protect the health of the employee from contaminated or oxygen deficient air. This includes situations where respirators are necessary to protect employees in an emergency. Employers must follow the hierarchy of controls that requires the use of engineering and work practice controls, where feasible. Only if such controls are not feasible or while they are being implemented may an employer rely on a respirator to protect employees. Respirator selection provisions are provided in CFR 1910.134(d) and require that appropriate respirators be selected based on the respiratory hazard(s) to which the worker will be exposed and workplace and user factors that affect respirator performance and reliability. Assigned protection factors (APFs) are provided in Table 1 under CFR 1910.134(d)(3)(i)(A) (see also Table 5-1). APFs refer to the level of respiratory protection that a respirator or class of respirators is expected to provide to employees when the employer implements a continuing, effective respiratory protection program.

Table 5-1. Assigned Protection Factors for Respirators in OSHA Standard 29 CFR 1910.134[e g]

Type of Respirator[a b]	Quarter Mask	Half Mask	Full Facepiece	Helmet/Hood	Loose-Fitting Facepiece
1. Air-Purifying Respirator	5	**10**[c]	**50**		
2. Powered Air-Purifying Respirator (PAPR)		**50**	**1,000**	25/1,000[d]	25
3. Supplied-Air Respirator (SAR) or Airline Respirator					
• Demand mode		**10**[f]	**50**		
• Continuous flow mode		**50**[f]	**1,000**	25/1,000[d]	25
• Pressure-demand or other positive-pressure mode		**50**[f]	**1,000**		
4. Self-Contained Breathing Apparatus (SCBA)					
• Demand mode		**10**[f]	**50**	50	
• Pressure-demand or other positive-pressure mode			**10,000**	10,000	

[a] Employers may select respirators assigned for use in higher workplace concentrations of a hazardous substance for use at lower concentrations of that substance, or when required respirator use is independent of concentration.
[b] The assigned protection factors are only effective when the employer implements a continuing, effective respirator program as required by 29 CFR 1910.134, including training, fit testing, maintenance, and use requirements.
[c] This APF category includes filtering facepieces and half masks with elastomeric facepieces.
[d] The employer must have evidence provided by the respirator manufacturer that testing of these respirators demonstrates performance at a level of protection of 1,000 or greater to receive an APF of 1,000. This level of performance can best be demonstrated by performing a workplace protection factor (WPF) or simulated workplace protection factor (SWPF) study or equivalent testing. Absent such testing, all other PAPRs and SARs with helmets/hoods are to be treated as loose-fitting facepiece respirators and receive an APF of 25.
[e] These APFs do not apply to respirators used solely for escape. For escape respirators used in association with specific substances covered by 29 CFR 1910 subpart Z, employers must refer to the appropriate substance-specific standards in that subpart. Escape respirators for other IDLH atmospheres are specified by 29 CFR 1910.134(d)(2)(ii).
[f] These respirators are not common.
[g] Respirators with bolded APFs satisfy the OSHA requirements for asbestos and an appropriate respirator should be selected based on the air concentration. Filtering facepiece respirators do not satisfy OSHA requirements for protection against asbestos fiber.

OSHA's asbestos standards also include respiratory protection provisions found at 29 CFR 1910.1001(g) for general industry, 29 CFR 1926.1101(h) for construction, and 29 CFR 1915.1001(g) for shipyards. The respiratory protection provisions in these standards require employers to provide each employee with an appropriate respirator that complies with the requirements outlined in the provision. In the general industry standard, 29 CFR 1910.1001(g)(2)(ii) requires employers to provide an employee with a tightfitting, powered air-purifying respirator (PAPR) instead of a negative pressure respirator selected according to 29 CFR 1910.1001(g)(3) when the employee chooses to use a PAPR and it provides adequate protection to the employee. In addition, 29 CFR 1910.1001(g)(3) states that employers must not select or use filtering facepiece respirators for protection against asbestos fibers. Therefore, filtering facepiece respirators were not included in Table 5-1. Based on the general industry standards for handling asbestos, the following PPE should not be used as protection against asbestos fibers: filtering facepieces (N95), quarter masks, helmets, hoods, and loose fitting facepieces. 29 CFR 1910.1001(g)(3)(ii) also indicates that high-efficiency particulate air (HEPA) filters for PAPR and non-powered air-purifying respirators must be provided.

APFs are intended to guide the selection of an appropriate class of respirators to protect workers after a substance is determined to be hazardous, after an occupational exposure limit is established, and only when the occupational exposure limit is exceeded after feasible engineering, work practice, and administrative controls have been put in place. For asbestos, the employee permissible exposure limit

(PEL) is 0.1 fibers per cubic centimeter (f/cc) as an 8-hour, TWA and/or the excursion limit of 1.0 f/cc averaged over a sampling period of 30 minutes.

Using the OSHA PEL for asbestos of 0.1 f/cc, a half-mask negative pressure HEPA filtered facepiece (when fitted properly) can provide protection in atmospheres with up to 1.0 f/cc [0.1 f/cc multiplied by the APF of 10].

Only the respirator types and corresponding APFs bolded in Table 5-1 meet the OSHA requirements for asbestos. The specific respiratory protection required in any situation is selected based on air monitoring data. OSHA specifies that the Maximum Use Concentration (MUC) be calculated to assess respirator selection. The MUC is the maximum amount of asbestos that a respirator can handle from which an employee can be expected to be protected when wearing a respirator. The APF of the respirator or class of respirators is the amount of protection that it provides the worker compared to not wearing a respirator. The permissible exposure limit for asbestos (0.1 f/cc) sets the threshold for respirator requirements. The MUC can be determined by multiplying the APF specified for a respirator by the OSHA PEL, short-term exposure limit, or ceiling limit.

The APFs are not assumed to be interchangeable for any COU, any workplace, or any worker. The use of a respirator would not necessarily resolve inhalation exposures if the industrial hygiene program in place is poorly maintained. An inadequate respiratory protection program could lead to inadequate respirator fit tests and poor maintenance of respirators which could affect APF. Based on the APFs specifically identified for asbestos and presented in Table 5-1, inhalation exposures may be reduced by a factor of 10 to 10,000 assuming employers institute a comprehensive respiratory protection program.

5.1.1.2 Summary of Inhalation Exposure Assessment

Table 5-2 summarizes the number of establishments and total number of exposed workers for all occupational exposure scenarios (see Appendix G for additional information).

Table 5-2. Summary of Total Number of Workers and ONUs Potentially Exposed to Asbestos for Each OES*[a]*

OES	Total Exposed Workers	Total Exposed ONUs	Total Exposed Workers and ONUs	Number of Establishments[a]
Maintenance, renovation, and demolition	3.7E06	1.2E06	4.8E006	6.8E05
Firefighting and other disaster response activities (career)	3.6E05	N/A	3.6E5	5.2E03
Firefighting and other disaster response activities (volunteer)	6.8E05	N/A	6.8E05	2.4E04
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	6.4E04	5.5E04	1.2E05	2.9E04
Handling articles or formulations that contain asbestos (battery insulators, burner mats, plastics, cured coatings/adhesives/sealants)	3.1E05	1.6E05	4.7E05	1.6E04
Waste handling, disposal, and treatment	3.1E04	4.7E04	7.7E04	5.4E03

OES	Total Exposed Workers	Total Exposed ONUs	Total Exposed Workers and ONUs	Number of Establishments[a]
[a] EPA's approach and methodology for estimating the number of establishments using asbestos and the number of workers and ONUs potentially exposed to asbestos can be found in Appendix G.				

A summary of inhalation exposure results based on monitoring data and exposure modeling for each OES is presented for higher-exposure potential workers in Table 5-3, lower-exposure potential workers in Table 5-4, and ONUs in Table 5-5. These tables provide a summary of 8-hour time-weighted average (8-hour TWA) and short-term (30-minute) inhalation exposure estimates, as well as average daily concentration (ADC) estimates based on the 8-hour TWA monitoring data. Additional details regarding occupational ADC calculations can be found in Appendix G.5.4. Also, it is important to note that EPA provides qualitative assessments of potential exposures for the Handling of vermiculite-containing products OES (Appendix G.14.2) and the Mining of non-asbestos commodities OES (Appendix G.15.2); therefore, exposures and number of workers are not quantified for the two aforementioned OESs.

Table 5-3. Summary of Inhalation Exposure Results for Higher-Exposure Potential Workers Based on Monitoring Data and Exposure Modeling for Each OES

OES	Inhalation Monitoring (Worker, f/cc)[a]					
	Short-Term (30-minute)		8-Hour TWA		Average Daily Concentrations (ADC)[b]	
	HE	CT	HE	CT	HE	CT
Maintenance, renovation, and demolition	0.16	2.5E−02	0.43	1.1E−03	2.0E−02	5.1E−05
Firefighting and other disaster response activities (career)	–	–	0.39	2.0E−02	1.1E−03	5.5E−05
Firefighting and other disaster response activities (volunteer)	–	–	0.39	2.0E−02	3.5E−04	1.8E−05
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	0.17	1.9E−02	0.16	8.4E−03	3.6E−02	1.9E−03
Handling articles or formulations that contain asbestos (battery insulators, burner mats, plastics, cured coatings/adhesives/sealants)	8.8E−02	7.3E−02	3.3	0.14	0.75	3.2E−02
Waste handling, disposal, and treatment	–	–	3.2E−02	1.5E−03	7.2E−03	3.4E−04

[a] Where there is no split between higher and lower-exposure potential workers, workers are grouped with higher-exposure potential workers and lower-exposure potential workers are not assessed.
[b] ADC presented here is based on 8-hour TWA monitoring data. Short-term ADC estimates are calculated using the 30-minute exposure concentrations presented here, averaged with 7.5 hours at the full shift (*i.e.*, 8-hour TWA) exposure concentrations. See Table_Apx G-47 for ADC estimates associated with short-term exposures.

Table 5-4. Summary of Inhalation Exposure Results for Lower-Exposure Potential Workers Based on Monitoring Data and Exposure Modeling for Each OES

OES	Inhalation Monitoring (Worker, f/cc)[a]					
	Short-Term (30-minute)		8-hour TWA		Average Daily Concentrations (ADC)[b]	
	HE	CT	HE	CT	HE	CT
Maintenance, renovation, and demolition	2.5E−02	2.5E−02	0.22	1.1E−03	1.0E−02	5.1E−05
Firefighting and other disaster response activities (career)	–	–	–	–	–	–
Firefighting and other disaster response activities (volunteer)	–	–	–	–	–	–
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	–	–	–	–	–	–
Handling articles or formulations that contain asbestos (battery insulators, burner mats, plastics, cured coatings/adhesives/sealants)	4.2E−02	2.1E−02	1.1E−02	8.3E−03	2.5E−03	1.9E−03
Waste handling, disposal, and treatment	–	–	–	–	–	–

[a] Where there is no split between higher and lower-exposure potential workers, workers are grouped with higher-exposure potential workers and lower-exposure potential workers are not assessed.
[b] ADC presented here is based on 8-hour TWA monitoring data. Short-term ADC estimates are calculated using the 30-minute exposure concentrations presented here, averaged with 7.5 hours at the full shift (*i.e.*, 8-hour TWA) exposure concentrations. See Table_Apx G-47 for ADC estimates associated with short-term exposures.

Table 5-5. Summary of Inhalation Exposure Results for ONUs Based on Monitoring Data and Exposure Modeling for Each OES

OES	Inhalation Monitoring (Worker, f/cc)					
	Short-Term (30-minute)		8-Hour TWA		Average Daily Concentrations (ADC)[a]	
	HE	CT	HE	CT	HE	CT
Maintenance, renovation, and demolition	5.3E−02	2.7E−02	4.6E−02	1.2E−02	2.1E−03	5.6E−04
Firefighting and other disaster response activities (career)	–	–	–	–	–	–
Firefighting and other disaster response activities (volunteer)	–	–	–	–	–	–
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	–	–	4.9E−02	2.8E−02	1.1E−02	6.4E−03
Handling articles or formulations that contain asbestos (battery insulators, burner mats, plastics, cured coatings/adhesives/sealants)	1.5E−03	7.7E−04	0.84	1.1E−03	0.19	2.5E−04
Waste handling, disposal, and treatment	–	–	–	–	–	–

[a] ADC presented here is based on 8-hour TWA monitoring data. Short-term ADC estimates are calculated using the 30-minute exposure concentrations presented here, averaged with 7.5 hours at the full shift (*i.e.*, 8-hour TWA) exposure concentrations. See Table_Apx G-47 for ADC estimates associated with short-term exposures.

5.1.1.3 Summary of Dermal and Oral Exposure Assessment

As described in Section 5.1, dermal and oral exposures are not assessed for workers and ONUs in Part 2 of the risk evaluation for asbestos.

5.1.1.4 Weight of Scientific Evidence Conclusions for Occupational Exposure

In Table 5-6, EPA provides a summary of the weight of scientific evidence for each of the OESs indicating whether monitoring data was reasonably available, the number of data points identified, the quality of the data, EPA's overall confidence in the data, and whether the data was used to estimate inhalation exposures for workers and ONUs. Appendix G provides further details of EPA's overall confidence for inhalation exposure estimates for each OES assessed.

Table 5-6. Summary of the Weight of Scientific Evidence for Occupational Exposure Estimates by OES[a]

OES	Inhalation Exposure								
	Monitoring							Weight of Scientific Evidence Conclusion	
	High Exposure-Potential Worker	# Data Points	Low Exposure-Potential Worker	# Data Points	ONU	# Data Points	Data Quality Ratings	Worker	ONU
Maintenance, renovation, and demolition	✓	992	✓	36	✓	104	H	Moderate	Moderate
Firefighting and other disaster response activities	✓	62	×	N/A	×	N/A	H	Moderate to Robust	N/A
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	✓	253	×	N/A	✓	20	H	Moderate to Robust	Moderate to Robust
Handling articles or formulations that contain asbestos (battery insulators, burner mats, plastics, cured coatings/ adhesives/ sealants)	✓	62	✓	15	✓	8	H	Moderate	Moderate
Waste handling, disposal, and treatment	✓	95	×	N/A	×	N/A	H	Moderate	N/A

[a] The number of data points is the combined count of TWA and short-term samples. Where EPA was not able to estimate ONU inhalation exposure from monitoring data or models, this was assumed equivalent to the central tendency experienced by workers for the corresponding OES; dermal exposure for workers and ONUs was not evaluated because asbestos is not expected to absorb into the body through the skin.

5.1.1.4.1 Strengths, Limitations, Assumptions, and Key Sources of Uncertainty for the Occupational Exposure Assessment

Number of Workers

There are several uncertainties surrounding the estimated number of workers potentially exposed to asbestos, as outlined below. Most are unlikely to result in a systematic underestimate or overestimate but could result in an inaccurate estimate.

There are also uncertainties with BLS data, which are used to estimate the number of workers for most OESs within the risk evaluation. First, BLS employment data for each industry/occupation combination are only available at the 3-, 4-, or 5-digit NAICS level, rather than the full 6-digit NAICS level. This lack of granularity could result in an overestimate of the number of exposed workers if some 6-digit NAICS are included in the less granular BLS estimates but are not, in reality, likely to use asbestos for the assessed applications. EPA addressed this issue by refining the OES estimates using total employment data from the U.S. Census Statistics of U.S. Businesses (SUSB). However, this approach assumes that the distribution of occupation types (SOC codes) in each 6-digit NAICS is equal to the distribution of occupation types at the parent 5-digit NAICS level. If the distribution of workers in occupations with asbestos exposure differs from the overall distribution of workers in each NAICS, then this approach will result in inaccuracy.

Second, EPA's judgments about which industries (represented by NAICS codes) and occupations (represented by SOC codes) are associated with the uses assessed in this report are based on EPA's understanding of how asbestos is used in each industry. Designations of which industries and occupations have potential exposures is nevertheless subjective, and some industries/occupations with few exposures might erroneously be included, or some industries/occupations with exposures might erroneously be excluded. This would result in inaccuracy but would be unlikely to systematically either overestimate or underestimate the number of exposed workers.

Due to limited information found in the BLS data, the number of workers and establishments for firefighting and other disaster response activities were estimated using data from the National Fire Protection Association (NFPA) (NFPA, 2022b). These data are based on two surveys conducted by the NFPA and may result in some inaccuracy in the number of exposed workers estimates for this OES.

Analysis of Exposure Monitoring Data

This report uses existing worker exposure monitoring data to assess exposure to asbestos from several conditions of use. To analyze the exposure data, EPA categorized each data point as either "worker" or "occupational non-user," with additional designations of "higher exposure-potential" or "lower exposure-potential" for workers. The categorizations are based on descriptions of worker job activity as provided in literature and EPA's judgment. In general, samples for employees that are expected to have the highest exposure from direct handling of asbestos are categorized as "worker" and samples for employees that are expected to have the lower exposure and do not directly handle asbestos are categorized as "occupational non-user." The occupational exposure scenario for firefighting and disaster response also categorizes career and volunteer firefighters separately due to an expected difference in exposure frequency.

Exposures for occupational non-users can vary substantially. Most data sources do not sufficiently describe the proximity of these employees to the asbestos exposure source. As such, exposure levels for the "occupational non-user" category will have high variability depending on the specific work activity performed. It is possible that some employees categorized as "occupational non-user" have exposures similar to those in the "worker" category depending on their specific work activity pattern. There were two OESs (*i.e.,* Maintenance, renovation, and demolition; and Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos) where ONU central tendency exposure values were estimated at higher levels than worker central tendency exposure values. The resulting high central tendency values for ONUs are a result of the lack of data, specifically a lack of ONU samples that contain low measured amounts of asbestos. For the same OESs, there were more comprehensive data available to characterize a wider range of potential worker exposure values which led to lower central tendency exposure estimations for workers in these cases.

Also, some data sources may be inherently biased. For example, bias may be present if exposure monitoring was conducted to address concerns regarding adverse human health effects reported following exposures during use or if exposure monitoring results were only provided from industry. Another source of bias among data occurs due to changes in behavior of the individual being monitored. Specifically, workers that are aware that they are being monitored may exhibit more hygienic practices if they wish to show that there is lesser exposure in their occupation, or they may exhibit less hygienic practices if they wish to show that there is greater exposure in their occupation.

One limitation of the monitoring data is the uncertainty in the representativeness of the data. Differences in work practices and engineering controls across sites can introduce variability and limit the representativeness of monitoring data. The age of the monitoring data can also introduce uncertainty due to differences in workplace practices and equipment used at the time the monitoring data were collected compared to those currently in use. Therefore, older data may overestimate or underestimate exposures, depending on these differences. The effects of these uncertainties on the occupational exposure assessment are unknown, as the uncertainties may result in either overestimation or underestimation of exposures depending on the actual distribution of asbestos air concentrations and the variability of work practices among different sites.

Where sufficient data were reasonably available, the 95th and 50th percentile exposure concentrations were calculated using reasonably available data. The 95th percentile exposure concentration is intended to represent a high-end exposure level, while the 50th percentile exposure concentration represents a central tendency exposure level. The underlying distribution of the data, and the representativeness of the reasonably available data, are not known. Where discrete data was not reasonably available, EPA used reported statistics (*i.e.,* median, mean, 90th percentile, etc.). Because the Agency could not verify these values, there is an added level of uncertainty.

EPA calculated ADC values assuming workers and ONUs are regularly exposed during their entire working lifetime, which likely results in an overestimate for some but not all. Individuals may change jobs during the course of their career such that they are no longer exposed to asbestos, and that actual ADC values become lower than the estimates presented.

5.1.2 Take-Home Exposures

Monitoring data to obtain take-home exposure concentrations was described in Section 3.1.2 and in Section 5.1.1. Briefly, the 8-hour TWA occupational exposure concentrations in Table 5-3 were used to estimate take-home exposure concentrations from people that bring asbestos contaminated clothing from occupational activities into their households and come to be exposed to asbestos from handling the contaminated garments. Each of the occupational exposure scenarios discussed in Section 5.1.1 result in distinct occupational 8-hour TWA concentrations for distinct numbers of days per year (see Table_Apx G-47), amounting to different numbers of exposure for the associated take-home scenarios from worn occupational garments. The take-home exposure scenarios include both handlers and bystanders for each of the OESs in Section 5.1.1:

- Maintenance, renovation, and demolition;
- Firefighting and other disaster response activities (career);
- Firefighting and other disaster response activities (volunteer);
- Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos;
- Handling articles or formulations that contain asbestos (battery insulators, burner mats, plastics, cured coatings/adhesives/sealants); and
- Waste handling, disposal, and treatment.

The data needed to estimate the yearly average concentration for each scenario using the unit exposure approach is summarized in Table 5-7 and are explained in Equation_Apx L-1.

The one-unit approach described in Section 3.1.4 greatly simplifies the estimation of exposure for each take-home scenario. For example, for the wear/wash patterns discussed in Section 3.1.4 and assuming an occupational TWA concentration of 1 f/cc: (1) a worker wearing one garment set for three consecutive days and then laundering, and (2) a worker wearing a different garment set each day and laundering all three together both correspond to three exposure units and, when averaged over a year, give the same yearly average concentrations. Implicit in this assumption is that all the asbestos fibers that load onto one garment set worn over multiple workdays between washing events are retained until the laundry preparation activity; in actuality, as a garment set is worn multiple days, some fibers will slough off the garment, resulting in less than three full units of exposure. In the developed approach, the key assumption used in this analysis tends to overestimate the take-home exposures for wear/wash patterns where a single garment is worn multiple days before washing.

Table 5-7. Data Needs to Obtain Take-Home Yearly Average Concentrations

Variable	Value/Calculation	Source
8-hour TWA Occupational Exposure Concentration	[**X**] f/cc	Occupational exposure analysis, Table_Apx G-47
24-hour TWA Take-Home Exposure Concentration	**Take-home slope factor**[a] × [X] f/cc	Calculated using regression based on available data sources, Section 3.1.4
Frequency	[**Y**] days a year	Occupational exposure analysis, Table_Apx G-47

[a] The [**X**] 8-hour TWA occupational exposure concentration and the [**Y**] frequency in days per year are taken directly from the occupational exposure analysis in Table_Apx G-47.

5.1.2.1 Concentrations of Asbestos in Take-Home Scenarios

The 24-hour TWA take-home concentrations are estimated using the 8-hour TWA loading concentrations, CT for central tendency and HE for high-end tendency and the take-home slope factors (CT and HE). CT and HE were obtained from the reported average and maximum for each study, four studies and six data points were used to obtain CT and three studies were used for HE (see Section 3.1.2). In this calculation, the CT slope factor is multiplied by the CT loading concentration to estimate the CT take-home concentration, and similarly for the HE estimates. The take-home concentrations are estimated using the "higher-exposure potential worker" from Table 5-3. Then the yearly average concentration for lifetime cancer risk is calculated using Equation 5-1.

Equation 5-1. Yearly Average Take-Home Concentration Example Calculation Using Equation_Apx L-1

$$Yearly\ Ave\ Concen = [X\ f/cc] \times take\text{-}home\ slope\ factor \times \left[\frac{[Y\ days]}{365\ days}\right]$$

$$Yearly\ Ave\ Concen = 1.10 \times 10^{-3} f/cc\ \times 0.0011 \times \left[\frac{[50\ days]}{365\ days}\right]$$

$$Yearly\ Ave\ Concen\ Handler\ CT = 1.67 \times 10^{-7} f/cc$$

Calculations and slope factor approaches to obtain take-home exposure concentrations and the lifetime and non-cancer chronic risk values estimates are available in *Asbestos Part 2 RE - Risk Calculator for Take Home - November 2024* (see Appendix C).

Table 5-8. Estimated CT and HE Yearly Average Concentrations Using Take-Home Slope Factors

OES, Higher-Exposed Worker [a] or Low-Exposed Worker [b]	8-Hour TWA Loading Concentration (f/cc)		Yearly Average Take Home Concentration (f/cc)			
			Handler		Bystander	
	CT	HE	CT	HE	CT	HE
Maintenance, renovation, and demolition[a]	1.10E−03	4.30E−01	1.66E−07	5.77E−04	1.06E−07	3.79E−04
Firefighting and other disaster response activities (career) [a]	2.00E−02	3.90E−01	1.81E−07	3.14E−05	1.15E−07	2.06E−05
Firefighting and other disaster response activities (volunteer) [a]	2.00E−02	3.90E−01	6.03E−08	1.05E−05	3.84E−08	6.87E−06
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos [a]	8.40E−03	1.60E−01	6.33E−06	1.07E−03	4.03E−06	7.05E−04
Handling articles or formulations that contain asbestos (battery insulators, burner mats, plastics, cured coatings/adhesives/sealants) [b]	8.25E−03	1.11E−02	6.22E−06	7.44E−05	3.96E−06	4.89E−05
Waste handling, disposal, and treatment[a]	1.50E−03	3.20E−02	1.13E−06	2.15E−04	7.20E−07	1.41E−04

[a] Calculated using higher-exposed worker data.
[b] Calculated using low-exposed worker data.
Notes:
CT Slope Factor for Handler is 0.0011 and for Bystander is 0.00070.
CT Slope Factor was obtained using regression 3 using Madl et al. (2008), Jiang et al. (2008), Sahmel et al. (2014), and Sahmel et al. (2016).
HE Slope Factor for Handler is 0.0098 and for Bystander is 0.0064.
HE Slope Factor was obtained using regression 2 using Abelmann et al. (2017), Madl et al. (2014), and Madl et al. (2009).

5.1.2.2 Weight of Scientific Evidence Conclusions for Take-Home

Overall confidence in each take-home scenario is robust (+++) for maintenance and renovation, and moderate to robust (++ to +++) for all other OESs. The slight confidence in the data used for four of the OESs is because EPA used the regression of the two OESs with data to calculate concentration of asbestos fibers in one garment and extrapolated the use of these data to the other four OESs. The regression approach and the use of occupational setting concentrations is of robust and moderate confidence for the scenarios in which the regression was built and the scenarios for which the regression was extrapolated.

Table 5-9. Weight of Scientific Evidence Conclusions for Take-Home Exposure Scenarios

Take-Home Scenario/OES	Confidence in Data Used	Confidence in User-Selected Varied Inputs				Weight of Scientific Evidence Conclusion
		Regression Slope Approach	8-hour TWA Occ. Loading	24-hour TWA Take-Home Loading	Frequency (Y)	
Maintenance, renovation, and demolition handler and bystander	++	+++	++	+++	+++	++
Firefighting and other disaster response activities (career) handler and bystander	+	++	++	++	+++	++
Firefighting and other disaster response activities (volunteer) handler and bystander	+	++	++	++	+++	++
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos handler and bystander	+	++	++	++	+++	++
Handling articles or formulations that contain asbestos (battery insulators, burner mats, plastics, cured coatings/adhesives/sealants) handler and bystander	++	++	++	++	+++	++
Waste handling, disposal, and treatment handler and bystander	+	++	++	++	+++	++
+ = Slight; ++ = moderate; +++ = robust						

5.1.2.2.1 Strengths, Limitations, Assumptions, and Key Sources of Uncertainty for the Take-Home Exposure Assessment

Variability and uncertainty in the take-home exposure approaches, calculations, assumptions, and concentrations calculated are both addressed in this section. Variability refers to the inherent heterogeneity or diversity of data in an assessment. It is a description of the range or spread of a set of values. Uncertainty refers to a lack of data or an incomplete understanding of the context of the risk evaluation decision.

Variability cannot be reduced, but it can be better characterized. Uncertainty can be reduced by collecting more or better data. Uncertainty is addressed qualitatively by including a discussion of factors such as data gaps and subjective decisions or instances where professional judgment was used. Uncertainties associated with approaches and data used in the evaluation of take-home exposures are described below.

Table 5-10. Qualitative Assessment of the Uncertainty and Variability Associated with Concentrations Data Used in Take-Home Exposure Analysis

Variable Name	Effect	Data Source	Uncertainty (Low, Medium, High)	Variability (Low, Medium, High)
Overall take-home 24-hour concentration data	Take-home regression approach includes a number of activity-based asbestos releases, more studies would help keep the uncertainty at low.	Section 3.1.2	Low, number of studies and overall rating	High, data ranges 3 to 4 orders of magnitude
Overall take-home yearly concentration calculation	More studies are expected to decrease the uncertainty.	Section 5.1.2	Medium, CT, and HE approaches for specific activities not available extrapolated for COUs that did not have specific activity data.	High, data ranges 3 to 4 orders of magnitude
Occupational parameters used in yearly concentrations		Section 5.1.2	Low, occupational parameters are well understood and characterized	NA
Overall take-home concentration data	**Concentrations used in risk calculation estimates**	**Sections 3.1.2 and 5.1.2**	**Low, number of studies, representative of take-home scenarios with well understood use parameters**	High, data ranges 3 to 4 orders of magnitude
Variability refers to the inherent heterogeneity or diversity of data in an assessment, while uncertainty refers to a lack of data or an incomplete understanding of the context of the risk evaluation decision.				

5.1.3 Consumer Exposures

5.1.3.1 Approach and Methodology

Part 2 of the risk evaluation covers exposure to consumer legacy uses and associated disposals of all forms of asbestos, as well as consideration of talc and vermiculite products that may contain asbestos.

5.1.3.1.1 Consumer COUs and Activity-Based Exposure

Table 3-5 and Table 3-6 summarize the consumer COUs, activity-based scenarios that are quantitatively evaluated. Direct inhalation of particulate/dust containing asbestos fibers from activity-based scenarios is expected to be the most significant route of exposure to released friable asbestos fibers for DIY consumers and bystanders, see Section 5.1 for a detailed discussion of evaluated exposure routes.

5.1.3.1.2 Consumer Exposure and Risk Estimation Approach

Consumer and bystander activity-based exposure concentrations and risks were calculated using Equation_Apx J-1, which is the general equation for estimating cancer risks for lifetime and less than lifetime exposure from inhalation of asbestos, from the *Office of Land and Emergency Management Framework for Investigating Asbestos-contaminated Superfund Sites* (U.S. EPA, 2008).

All of the activity-based scenarios considered people 16 years of age and older of all genders for DIY users and, and all ages and genders for bystanders. The exposure duration is 62 years for DIY users and 78 years for bystanders, and the averaging time is 78 years. The TWFs accounting for lifetime cancer exposure time and frequency are summarized in Table 5-11. The non-cancer chronic TWF are calculated using Equation_Apx J-3 and the values are summarized in Table 5-13, while all basis for assumptions and descriptions remain the same for lifetime and chronic. The values are based on assumptions related to the activity type (*e.g.*, disturbance/repair or removal) rather than the specific product.

For repair activities, it was assumed that a DIY user may perform one repair or renovation task where they may disturb ACM per year, and the length of time spent on the task varies for low-end, high-end, and central tendency exposure estimates. These time estimates are based on reasonably available information, including EPA guidance documents (*Exposure Factors Handbook* (U.S. EPA, 2011)) and professional judgement of EPA staff. For removal activities, EPA reviewed the frequency of replacement for various home materials such as tiles and roofing, but also considered the likelihood of consumers encountering legacy use ACM. For example, while industry experts might recommend replacing floor tile every 20 years, only the first replacement job is likely to involve removing asbestos-containing floor tile. It is unlikely that newly installed floor tile that might be replaced again after 20 years would contain asbestos. Therefore, it was assumed for low-end and central tendency estimates, a DIY user perform removal jobs with asbestos-containing products once in their lifetime, and for high-end estimates, a DIY user might remove asbestos-containing products three times over their lifetime. It was assumed that each removal job takes 10 days for central tendency and high-end and estimates and 5 days for low-end estimates. In contrast to repair activities, it was assumed that removal work takes a longer time (*i.e.*, 8 hours per day). Lifetime cancer and non-cancer chronic risk estimates are available in *Asbestos Part 2 RE - Risk Calculator for Consumer - November 2024* (see Appendix C).

Table 5-11. Lifetime Cancer Time-Weighting Factors Assumptions for All COUs

Activity-Based Scenario	Low- End TWF	Low-End TWF Basis	High-End TWF	High-End TWF Basis	Central Tendency TWF	Central-Tendency TWF Basis
Construction, paint, electrical, and metal products COU: construction and building materials covering large surface areas subcategory						
Outdoor, disturbance/repair (sanding or scraping) of **roofing materials**	0.00006	Assumed 1 repair/year, taking 1 day, lasting 30 min/day	0.00034	Assumed 1 repair/year, taking 1 day, lasting 3 hr/day	0.00011	Assumed 1 repair/year, taking 1 day, lasting 1 hr/day
Outdoor, removal of **roofing materials**	0.00457	Assumed 1 removal job in lifetime taking 5 days lasting 8 hr/day	0.02740	Assumed 3 removal jobs in lifetime taking 10 days lasting 8 hr/day	0.00913	Assumed 1 removal job in lifetime taking 10 days lasting 8 hr/day
Indoor, removal of **plaster**	0.00457	Assumed 1 removal job in lifetime taking 5 days lasting 8 hr/day	0.02740	Assumed 3 removal jobs in lifetime taking 10 days lasting 8 hr/day	0.00913	Assumed 1 removal job in lifetime taking 10 days lasting 8 hr/day
Indoor, disturbance (sliding) of **ceiling tiles**	0.00006	Assumed 1 repair/year, taking 1 day, lasting 30 min/day	0.00034	Assumed 1 repair/year, taking 1 day, lasting 3 hr/day	0.00011	Assumed 1 repair/year, taking 1 day, lasting 1 hr/day
Indoor, removal of **ceiling tiles**	0.00457	Assumed 1 removal job in lifetime taking 5 days lasting 8 hr/day	0.02740	Assumed 3 removal jobs in lifetime taking 10 days lasting 8 hr/day	0.00913	Assumed 1 removal job in lifetime taking 10 days lasting 8 hr/day
Indoor, maintenance (chemical stripping, polishing, or buffing) of **vinyl floor tiles**	0.00006	Assumed 1 repair/year, taking 1 day, lasting 30 min/day	0.00034	Assumed 1 repair/year, taking 1 day, lasting 3 hr/day	0.00011	Assumed 1 repair/year, taking 1 day, lasting 1 hr/day
Indoor, removal of **vinyl floor tiles**	0.00457	Assumed 1 removal job in lifetime taking 5 days lasting 8 hr/day	0.02740	Assumed 3 removal jobs in lifetime taking 10 days lasting 8 hr/day	0.00913	Assumed 1 removal job in lifetime taking 10 days lasting 8 hr/day
Indoor, disturbance/repair (cutting) of **attic insulation**.	0.00006	Assumed 1 repair/year, taking 1 day, lasting 30 min/day	0.00034	Assumed 1 repair/year, taking 1 day, lasting 3 hr/day	0.00011	Assumed 1 repair/year, taking 1 day, lasting 1 hr/day
Construction, paint, electrical, and metal products COU: fillers and putties subcategory						
Indoor, disturbance (pole or hand sanding and cleaning) of **spackle**	0.00006	Assumed 1 repair/year, taking 1 day, lasting 30 min/day	0.00034	Assumed 1 repair/year, taking 1 day, lasting 3 hr/day	0.00011	Assumed 1 repair/year, taking 1 day, lasting 1 hr/day
Indoor, disturbance (sanding and cleaning) of **coatings, mastics, and adhesives**	0.00006	Assumed 1 repair/year, taking 1 day, lasting 30 min/day	0.00034	Assumed 1 repair/year, taking 1 day, lasting 3 hr/day	0.00011	Assumed 1 repair/year, taking 1 day, lasting 1 hr/day
Indoor, removal of **floor tile/mastic**	0.00457	Assumed 1 removal job in lifetime taking 5 days lasting 8 hr/day	0.02740	Assumed 3 removal jobs in lifetime taking 10 days lasting 8 hr/day	0.00913	Assumed 1 removal job in lifetime taking 10 days lasting 8 hr/day
Indoor, removal of **window caulking**	0.00457	Assumed 1 removal job in lifetime taking 5 days lasting 8 hr/day	0.02740	Assumed 3 removal jobs in lifetime taking 10 days lasting 8 hr/day	0.00913	Assumed 1 removal job in lifetime taking 10 days lasting 8 hr/day
Furnishing, cleaning, treatment care products COU: construction and building materials covering large surface areas, including fabrics, textiles, and apparel subcategory						

Activity-Based Scenario	Low- End TWF	Low-End TWF Basis	High-End TWF	High-End TWF Basis	Central Tendency TWF	Central-Tendency TWF Basis
Use of mittens for glass manufacturing, (proxy for **oven mittens and potholders**)	0.00019	Assumed BBQ[a] mittens used more than other hobbies. People grill on average 1 hr/day, 1 day per week (52 days per year), using an ACM mitt for 2 years over their lifetime	0.00096	Assumed BBQ mittens used more than other hobbies. People grill on average 1 hr/day, 1 day per week (52 days per year), using an ACM mitt for 10 years over their lifetime	0.00048	Assumed BBQ mittens used more than other hobbies. People grill on average 1 hr/day, 1 day per week (52 days per year), using an ACM mitt for 5 years over their lifetime
[a] Note, EPA assumed a cooking or grilling activity-based scenario, which is likely performed in higher frequencies and durations than other hobbies requiring the need for protective clothing such as mittens and potholders under this COU.						

5.1.3.2 Summary of Consumer Activity-Based Scenarios Exposure Concentrations

Using Equation_Apx J-1 in Appendix J.2 the exposure point concentrations summarized in Table 3-6 and TWFs summarized in Table 5-11, exposure concentrations were calculated for each activity-based scenario and are presented in Table 5-12 and Table 5-13 for lifetime cancer and non-cancer chronic.

Table 5-12. Lifetime Cancer Human Exposure Concentrations for Consumer Exposure Activity-Based Scenarios by COU and Subcategory

Activity-Based Scenario	Lifetime Cancer Human Exposure Concentration (f/cc)					
	DIY User (62-year exposure)			Bystander (lifetime exposure)		
	Low-End	Central Tendency	High-End	Low-End	Central Tendency	High-End
Construction, paint, electrical, and metal products COU: construction and building materials covering large surface areas subcategory						
Outdoor, disturbance/repair (sanding or scraping) of **roofing materials**	2.5E−07	7.9E−07	3.3E−06	4.2E−08	1.3E−07	5.5E−07
Outdoor, removal of **roofing materials**	2.3E−05	4.6E−05	2.7E−04	2.3E−05	4.6E−05	2.7E−04
Indoor, removal of **plaster**	4.6E−05	1.8E−04	1.4E−03	2.3E−05	4.6E−05	2.7E−04
Indoor, disturbance (sliding) of **ceiling tiles**	1.3E−06	2.6E−06	1.5E−05	1.3E−06	2.6E−06	1.5E−05
Indoor, removal of **ceiling tiles**	2.3E−05	8.2E−05	5.2E−04	3.8E−06	1.4E−05	8.7E−05
Indoor, maintenance (chemical stripping, polishing, or buffing) of **vinyl floor tiles**	Below LOD	Below LOD	Below LOD	Below LOD	Below LOD	Below LOD
Indoor, removal of **vinyl floor tiles**	2.6E−05	5.1E−05	1.5E−04	1.8E−06	3.7E−06	1.1E−05
Indoor, disturbance/repair (cutting) of attic **insulation**	6.6E−05	1.3E−04	4.0E−04	2.8E−05	5.6E−05	1.7E−04
Indoor, moving and removal with vacuum of **attic insulation**	4.4E−03	4.7E−02	2.5E−01	2.1E−03	9.1E−03	4.2E−02
Paper articles	Qualitative, J.1.1, see Section 3.1.3.1					
Metal articles	Qualitative, J.1.1, see Section 3.1.3.1					
Stone, plaster, cement, glass, and ceramic articles	See Indoor, removal of **plaster**					
Construction, paint, electrical, and metal products COU: Machinery, mechanical appliances, electrical/ electronic articles						
Plastics: Reinforced plastics for appliances	Qualitative, J.1.1, see Section 3.1.3.1					
Electro-mechanical parts: Miscellaneous electro-mechanical parts for appliances	Qualitative, J.1.1, see Section 3.1.3.1					
Construction, paint, electrical, and metal products COU: fillers and putties subcategory						
Indoor, disturbance (pole or hand sanding and cleaning) of **spackle**	7.1E−05	1.6E−03	8.9E−03	1.1E−04	5.7E−04	3.3E−03
Indoor, disturbance (sanding and cleaning) of **coatings, mastics, and adhesives**	1.3E−06	2.6E−06	1.4E−05	1.7E−07	3.4E−07	2.7E−06
Indoor, removal of **floor tile/mastic**	2.3E−05	4.6E−05	2.7E−04	2.3E−05	4.6E−05	2.7E−04
Indoor, removal of **window caulking**	2.3E−05	4.6E−05	2.7E−04	2.3E−05	4.6E−05	2.7E−04
Adhesives: Glues and epoxies	See Indoor, disturbance (sanding and cleaning) of coatings, mastics, and adhesives and indoor, removal of floor tile/mastic					

Activity-Based Scenario	Lifetime Cancer Human Exposure Concentration (f/cc)					
	DIY User (62-year exposure)			Bystander (lifetime exposure)		
	Low-End	Central Tendency	High-End	Low-End	Central Tendency	High-End
Sealants: liquid sealants used for waterproofing and sound deadening interior walls	See Indoor, disturbance (sanding and cleaning) of **coatings, mastics, and adhesives** and indoor, removal of **floor tile/mastic**					
Sealants: Extruded sealant tape used as a gasket for sealing building windows, automotive windshields, and mobile home windows	See Indoor, disturbance (pole or hand sanding and cleaning) of **spackle** and indoor, removal of **window caulking**					
Coatings: Vehicle undercoating to prevent corrosion	See Indoor, disturbance (sanding and cleaning) of **coatings, mastics, and adhesives** and indoor, removal of **floor tile/mastic**					
Construction, paint, electrical, and metal products COU: Solvent-based/water-based paint						
Coatings; textured paints: Coatings; textured paints	See Indoor, disturbance (sanding and cleaning) of **coatings, mastics, and adhesives** and indoor, removal of **floor tile/mastic**					
Furnishing, cleaning, treatment care products COU: Construction and building materials covering large surface areas, including fabrics, textiles, and apparel						
Asbestos textiles including yarn, thread, wick, cord, rope, tubing (sleeving), cloth, tape: Wicks for oil burning	Qualitative J.1.2 and see Textiles and cloth (including gloves and mittens)					
Furnishing, cleaning, treatment care products COU: Construction and building materials covering large surface areas, including fabrics, textiles, and apparel Subcategory						
Use of mittens for glass manufacturing, (**oven mittens and potholders**)	2.3E−05	1.4E−04	5.1E−04	3.8E−06	2.3E−05	8.5E−05
Fabrics, textiles, and apparel: burner mats	Qualitative J.1.2 and see Textiles and cloth (including gloves and mittens)					

Table 5-13. Non-cancer Chronic Human Exposure Concentrations for Consumer Exposure Activity-Based Scenarios by COU and Subcategory

Activity-Based Scenario	Lifetime Cancer Human Exposure Concentration (f/cc)					
	DIY User (62-year exposure)			Bystander (lifetime exposure)		
	Low-End	Central Tendency	High-End	Low-End	Central Tendency	High-End
Construction, paint, electrical, and metal products COU: construction and building materials covering large surface areas subcategory						
Outdoor, disturbance/repair (sanding or scraping) of **roofing materials**	2.0E−07	6.3E−07	2.6E−06	3.4E−08	1.0E−07	4.4E−07
Outdoor, removal of **roofing materials**	1.8E−05	3.6E−05	2.2E−04	1.8E−05	3.6E−05	2.2E−04
Indoor, removal of **plaster**	3.6E−05	1.5E−04	1.1E−03	1.8E−05	3.6E−05	2.2E−04
Indoor, disturbance (sliding) of **ceiling tiles**	1.0E−06	2.0E−06	1.2E−05	1.0E−06	2.0E−06	1.2E−05
Indoor, removal of **ceiling tiles**	1.8E−05	6.5E−05	4.1E−04	3.0E−06	1.1E−05	6.9E−05
Indoor, maintenance (chemical stripping, polishing, or buffing) of **vinyl floor tiles**	Below LOD	Below LOD	Below LOD	Below LOD	Below LOD	Below LOD
Indoor, removal of **vinyl floor tiles**	2.0E−05	4.1E−05	1.2E−04	1.5E−06	2.9E−06	8.7E−06
Indoor, disturbance/repair (cutting) of attic **insulation**	5.3E−05	1.1E−04	3.2E−04	2.2E−05	4.5E−05	1.3E−04
Indoor, moving and removal with vacuum of **attic insulation**	3.5E−03	3.7E−02	2.0E−01	1.7E−03	7.3E−03	3.4E−02
Paper articles	Qualitative, J.1.1, see Section 3.1.3.1					
Metal articles	Qualitative, J.1.1, see Section 3.1.3.1					
Stone, plaster, cement, glass, and ceramic articles	See Indoor, removal of **plaster**					
Construction, paint, electrical, and metal products COU: Machinery, mechanical appliances, electrical/ electronic articles						
Plastics: Reinforced plastics for appliances	Qualitative, J.1.1, see Section 3.1.3.1					
Electro-mechanical parts: Miscellaneous electro-mechanical parts for appliances	Qualitative, J.1.1, see Section 3.1.3.1					
Construction, paint, electrical, and metal products COU: fillers and putties subcategory						
Indoor, disturbance (pole or hand sanding and cleaning) of **spackle**	5.7E−05	1.3E−03	7.0E−03	8.8E−05	4.5E−04	2.6E−03
Indoor, disturbance (sanding and cleaning) of **coatings, mastics, and adhesives**	1.0E−06	2.1E−06	1.1E−05	1.4E−07	2.7E−07	2.2E−06
Indoor, removal of **floor tile/mastic**	1.8E−05	3.6E−05	2.2E−04	1.8E−05	3.6E−05	2.2E−04
Indoor, removal of **window caulking**	1.8E−05	3.6E−05	2.2E−04	1.8E−05	3.6E−05	2.2E−04
Adhesives: Glues and epoxies	See Indoor, disturbance (sanding and cleaning) of coatings, mastics, and adhesives and indoor, removal of floor tile/mastic					
Sealants: liquid sealants used for waterproofing and sound deadening interior walls	See Indoor, disturbance (sanding and cleaning) of **coatings, mastics, and adhesives** and indoor, removal of **floor tile/mastic**					
Sealants: Extruded sealant tape used as a gasket for sealing building windows,	See Indoor, disturbance (pole or hand sanding and cleaning) of **spackle** and indoor, removal of **window caulking**					

Activity-Based Scenario	Lifetime Cancer Human Exposure Concentration (f/cc)					
	DIY User (62-year exposure)			Bystander (lifetime exposure)		
	Low-End	Central Tendency	High-End	Low-End	Central Tendency	High-End
automotive windshields, and mobile home windows						
Coatings: Vehicle undercoating to prevent corrosion	See Indoor, disturbance (sanding and cleaning) of **coatings, mastics, and adhesives** and indoor, removal of **floor tile/mastic**					
Construction, paint, electrical, and metal products COU: Solvent-based/water-based paint						
Coatings; textured paints: Coatings; textured paints	See Indoor, disturbance (sanding and cleaning) of **coatings, mastics, and adhesives** and indoor, removal of **floor tile/mastic**					
Chemical substances in furnishing, cleaning, treatment care products COU: Construction and building materials covering large surface areas, including fabrics, textiles, and apparel						
Asbestos textiles including yarn, thread, wick, cord, rope, tubing (sleeving), cloth, tape: Wicks for oil burning	Qualitative J.1.2 and see Textiles and cloth (including gloves and mittens)					
Furnishing, cleaning, treatment care products COU: Construction and building materials covering large surface areas, including fabrics, textiles, and apparel Subcategory						
Use of mittens for glass manufacturing, (**oven mittens and potholders**)	1.8E−05	1.1E−04	4.0E−04	3.0E−06	1.8E−05	6.7E−05
Fabrics, textiles, and apparel: burner mats	Qualitative J.1.2 and see Textiles and cloth (including gloves and mittens)					

5.1.3.3 Weight of Scientific Evidence Conclusions for Consumer Exposure

There is uncertainty associated with the activity-based scenarios' TWF assumptions summarized in Section 5.1.3.1.2. EPA considered using the *Exposure Factors Handbook* suggestions for general activities when it seemed relevant. However, many of the activity scenarios built in this evaluation are specific and unique to the hazards and COUs of asbestos, and the *Exposure Factors Handbook* did not contain appropriate time or frequency information. Table 16-100 "Annual Average Time Use by the U.S. Civilian Population, Ages 15 Years and Older" provides an annual average time estimate of 1.79 hours spent on household activities, which includes home maintenance, repair, and renovation. This seemed to underestimate time spent performing specific DIY user activities, so EPA used professional judgement to develop exposure time and frequency estimates for repair/disturbance and removal activities, see Table 5-11.

As noted in the prior section, EPA used occupational studies as proxies for DIY consumer scenarios. There is uncertainty related to differences in exposure patterns between professionals and DIY users. For example, DIY work is expected to be on a smaller scale than professional work, but due to lack of experience or proper tools DIY users may take longer to perform certain tasks.

For bystanders, it is a conservative assumption that bystanders are present during every instance a DIY user performs work disturbing asbestos-containing products, and that bystanders remain within the work area of the DIY user throughout the entire time the DIY user is performing the work. Bystander exposures therefore may be overestimated, but the magnitude is uncertain.

Finally, EPA has made assumptions regarding both age at start of exposure and duration of exposure for DIY users and bystanders that may overestimate exposures.

Table 5-14. Weight of Scientific Evidence Conclusions for Consumer Exposure Activity-Based Scenarios

Activity-Based DIY Scenario	DIYer/ Bystander	Confidence in Data Used	Confidence in User-Selected Varied Inputs				Weight of Scientific Evidence Conclusion
			EPC	TWF	ED	AT	
Outdoor, disturbance/repair (sanding or scraping) of roofing materials	DIYer	++	++	++	+++	+++	++
	Bystander	+	+	++	+++	+++	+ t
Outdoor, removal of roofing materials	DIYer	++	++ to +	++	+++	+++	++
	Bystander	+	+	++	+++	+++	+
Indoor, removal of plaster	DIYer	++	++ to +	++	+++	+++	++
	Bystander	+	+	++	+++	+++	+
Indoor, disturbance (sliding) of ceiling tiles	DIYer	++	++ to +	++	+++	+++	++
	Bystander	+	+	++	+++	+++	+
Indoor, removal of ceiling tiles	DIYer	++	++ to +	++	+++	+++	++
	Bystander	+	+	++	+++	+++	+
Indoor, maintenance (chemical stripping, polishing, or buffing) of vinyl floor tiles	DIYer	++	++ to +	++	+++	+++	++
	Bystander	+	+	++	+++	+++	+
Indoor, removal of vinyl floor tiles	DIYer	++	++ to +	++	+++	+++	++
	Bystander	+	+	++	+++	+++	+
Indoor, disturbance / repair (cutting) of attic insulation	DIYer	++	++ to +	++	+++	+++	++
	Bystander	+	+	++	+++	+++	+
Indoor, moving and removal (with vacuum) of attic insulation	DIYer	++	++ to +	++	+++	+++	++
	Bystander	+	+	++	+++	+++	+
Indoor, disturbance (pole or hand sanding and cleaning) of spackle	DIYer	++	++ to +	++	+++	+++	++
	Bystander	+	+	++	+++	+++	+
Indoor, disturbance (sanding and cleaning) of coatings, mastics, and adhesives	DIYer	++	++ to +	++	+++	+++	++
	Bystander	+	+	++	+++	+++	+
Indoor, removal of floor tile/mastic	DIYer	++	++ to +	++	+++	+++	++
	Bystander	+	+	++	+++	+++	+

Activity-Based DIY Scenario	DIYer/ Bystander	Confidence in Data Used	Confidence in User-Selected Varied Inputs				Weight of Scientific Evidence Conclusion
			EPC	TWF	ED	AT	
Indoor, removal of window caulking	DIYer	++	++ to +	++	+++	+++	++
	Bystander	+	+	++	+++	+++	+
Use of mittens for glass manufacturing, (proxy for oven mittens and potholders)	DIYer	++	+	+	+++	+++	+
	Bystander	+	+	+	+++	+++	+

5.1.3.3.1 Strengths, Limitations, Assumptions, and Key Sources of Uncertainty for the Consumer Exposure Assessment

Variability and uncertainty in the consumer DIY activity-based exposure approaches, assumptions and concentrations calculated are both addressed in this section. Variability refers to the inherent heterogeneity or diversity of data in an assessment. It is a description of the range or spread of a set of values and cannot be reduced, but it can be better characterized. Uncertainty refers to a lack of data or an incomplete understanding of the context of the risk evaluation decision. Uncertainty is addressed qualitatively by including a discussion of factors such as data gaps and subjective decisions or instances where professional judgment was used.

Table 5-15. Qualitative Assessment of the Uncertainty and Variability Associated with Consumer Risk Assessment

Variable Name	Effect	Data Source	Uncertainty (+, ++, +++) [a]	Variability (+, ++, +++) [a]
Overall consumer DIY concentration data	Concentrations used in risk calculation estimates (EPC).	Systematic review identified studies measurements	++	++ [b]
Exposure time (activity time in hours during a day) within a TWF [d] calculation	Assumption used in all scenarios that only one activity is performed. This assumption may underestimate risk [d]	Assumption	+[c]	+++
Exposure duration (years of exposure) within TWF calculation	Assumption for each activity type used in the calculation of LE, CT, and HE exposure concentrations	Assumption	+++	+++
Exposure duration	Assumption for all consumer DIY scenarios to start at 16 years of age covers most practical and usual exposures in a lifetime	Assumption	+++	+++
Overall consumer DIY concentration data	**Overall calculation of human exposure concentration**	**Systematic review identified studies measurements, assumptions, and other parameters**	**++**	**++ [b]**

[a] + = slight; ++ = moderate; +++ = robust.
[b] Low-end to high-end concentration ranges were within the same or one order of magnitude difference for all scenarios concentrations.
[c] It is possible that similar activities can be performed more than once in a lifetime.
[d] Time-weighting factors (TWF) values are based on assumptions, where similar job types (*e.g.*, "repair") were given consistent TWF. The assumptions take into account not only the frequency of a job type (*e.g.*, "roof replacement") but also the number of times per lifetime that a given job will include asbestos materials. For example, a roof may be replaced every 10 years, but only the first replacement job is likely to include legacy use asbestos; in contrast, repeat repair jobs are more likely to contain legacy asbestos each time.

5.1.4 General Population Exposures

General population exposures occur when asbestos fibers are released into the environment from occupational activities and people that live or recreate at certain distances (10, 30, 60, 100, 1,000, 2,500, 5,000, and 10,000 m) from the release source are exposed from inhaling suspended fibers. Section 3.3 provides a summary of the monitoring, database, and modeled data concentrations of asbestos fibers released into the environment from occupational activities.

5.1.4.1 Approach and Methodology

Asbestos fibers have been detected in the outdoor environment indicating that some amount of exposure is occurring and vary across the general population depending on proximity to sources and the activities releasing asbestos fibers. See Section 3.3.3 for a summary of environmental studies where asbestos has been measured and detected in various environmental media.

Emission of asbestos fibers is expected to occur through the following mechanisms: releases from activities in which asbestos materials are modified, and abrasion of materials to form small particulates through routine use. Releases of asbestos fibers to the outdoor environment may occur through direct releases to air as well as indirect releases from the indoor environment activities. In this analysis, EPA does not aggregate the activities that modified asbestos containing materials in indoor environments, like those from occupational exposures, in Section 5.1.1, and DIY consumer exposures in Section 5.1.3 to the environmental releases concentrations infiltrating the indoor environment. In this analysis, EPA only estimates risks from exposures to releases to the environment that then infiltrate the indoor environment.

Exposure to the general population was estimated for the industrial and commercial releases per OES and matched to each COU. Table 5-16 summarizes industrial and commercial releases to the environmental media by OES and COU.

Table 5-16. Summary of Environmental Releases from Industrial and Commercial Activities for Inhalation Exposures by OES and Media

OES	COU(s)	Specific Facility Fugitive Air	Generic Facility Fugitive Air	Measured
Handling articles or formulations that contain asbestos	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products COU: Packaging, paper, plastic, toys, hobby products	✓		
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	✓	✓	✓
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos	COU: Construction, paint, electrical, and metal products	✓	✓	

OES	COU(s)	Specific Facility Fugitive Air	Generic Facility Fugitive Air	Measured
Waste handling, disposal, and treatment fugitive annual ambient air risk	COU: Disposal, including distribution for disposal	✓		✓
Handling asbestos-containing building materials during firefighting or other disaster response activities	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products		✓	✓
N/A[a]	COU: Chemical substances in automotive, fuel, agriculture, outdoor use products			✓

[a] N/A is because measured data cannot be easily apportioned to one specific COU.

Figure 5-2 depicts the methods EPA used to estimate general population inhalation exposures. The assessment used environmental release estimates that were related to the industrial and commercial OES (Section 3.2.1). Release estimates were used to model ambient air concentrations (Section 3.3.1.3). EPA modeled estimates for ambient air concentrations from environmental releases from industrial and commercial activities were used to obtain estimated inhalation exposure for the general population.

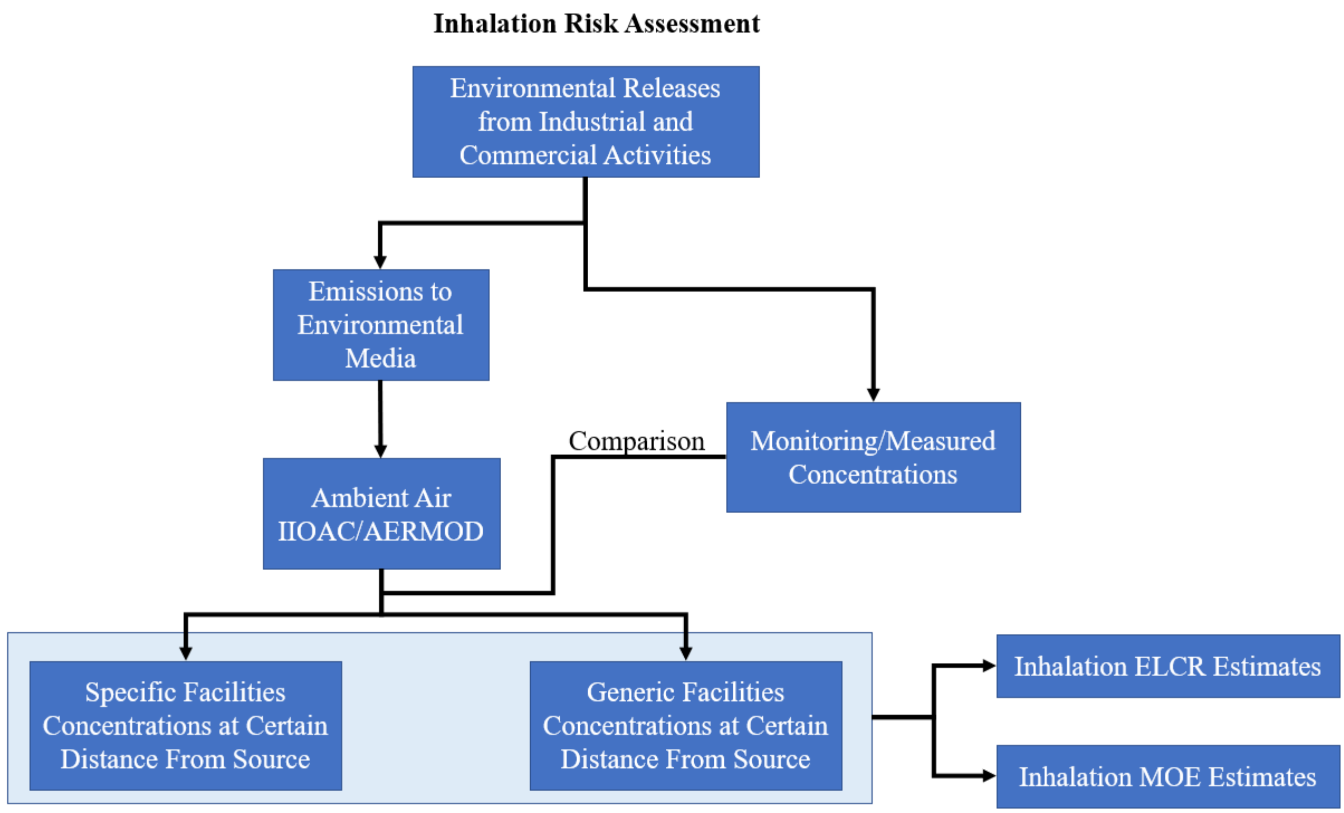


Figure 5-2. Exposure Assessment Approaches Used to Estimate General Population Exposure to Asbestos

Modeled air concentrations were utilized to estimate general population risk associated to inhalation exposures at various distances from a facility performing specific activities that release asbestos fibers, see Section 3.3.1.3 for Specific and Generic Facilities emission concentrations grouped and summarized by OES. Measured air concentrations in Table 3-9 are the environmental media monitoring data that was available in the United States. For a description of statistical methods, methodology of data integration and treatment of non-detects and outliers used to generate these estimates please reference Section 3.3.1.1 and Appendix G.17. The measured concentrations scenarios are commonly used to ground truth portions of the results from the ambient air modeled scenarios for specific and generic facilities when describing similar distances from the source. However, because of the differences in activity-based scenarios asbestos fibers releases within each COU and its matching OES measured and modeled results comparisons in this RE are to be used as a guidance rather than ground truth. See Section 3.3.1.3 for a comparison discussion between modeled and measured concentrations for various COUs.

Concentrations in Table 3-11 are used to calculate the associated lifetime cancer and non-cancer chronic risk to asbestos fibers inhalation. The general population exposure concentrations and inhalation lifetime cancer risk are calculated using Equation_Apx N-1 and Equation_Apx N-2. Lifetime cancer and non-cancer chronic risk estimates are available in *Asbestos Part 2 RE - Risk for Calculator Consumer - November 2024* (see Appendix N and Appendix C).

Various exposure duration (ED) and LTL IUR values were considered per COU for both non-cancer chronic and lifetime cancer risk estimates. One (1) year is used for OES that are not stationary activities such as demolitions, firefighting, and modification of machinery. Appendix N summarizes the references, assumptions, and sources of information used for the 1 year ED for non-stationary occupational activities related to firefighting and cleanup and extended to renovation and demolitions, recognizing this is likely to overestimate ED. Twenty years were used as the number of years children are assumed to reside in a single residential location for OESs that are stationary, such as waste handling (landfills) and formulation of asbestos products. The 20-year assumption is based on expected number of years children will remain in a household from birth to adulthood. This assumption considers exposures at early stages and following no exposure to the end of their entire lifetime, 78-year. Additional ED considerations are available in Appendix N (Table_Apx N-1 and Table_Apx N-2) for exposures starting at 20 years of age and lasting for 30 years, representing young and mature adults that move away from their childhood residence and remain in the same residence for 30 years and following no exposure to the end of their entire lifetime, 78 years. Also considered in the appendix analysis is an estimate for people that remain in the same residence their entire lifetime, 78 years. Table 5-17 summarizes main general population exposure duration assumptions and parameters used in estimating risk.

Table 5-17. General Population Exposure Duration Parameters

Parameter	Description	Values and Notation
Exposure duration (ED) for stationary OES OES examples: Waste handling at landfills and Formulation of asbestos products at specific locations/facilities	Exposures starting at birth and lasting 20 years of residing at same household. Assumption of number of years children reside in a single residential location. Most protective short duration assumption as the exposure will be carried out through the exposed population's lifetime.	ED = 20 years Less-than-lifetime (LTL) IUR = IUR(0,20) = 0.13 per f/cc
Exposure duration for non-stationary short duration OES OES examples: Demolition, renovation, maintenance of asbestos containing structures, Removal/maintenance of machinery/appliances, and Firefighting activities outside firehouse	Exposures starting at birth and lasting 1 year of residing at same household. Assumption is that the activity sporadically occurs for 1 year. Most protective assumption as the exposure will take place through the exposed population's lifetime.	ED = 1 LTL IUR = IUR(0,1) = 0.01 per f/cc

The Ambient Air Methodology utilizing AERMOD evaluated exposures to exposure points at eight finite distances 10, 30, 60, 100, 2,500, 5,000, and 10,000 m) and one area distance (100 to 1,000 m) from a hypothetical releasing source for each OES. Exposure points for each of the eight finite distances were placed in a polar grid every 22.5 degrees around the respective distance ring. This results in a total of 16 exposure points around each finite distance ring for which exposures are modeled. Figure 5-3 provides a visual depiction of the placement of exposure points around a finite distance ring. Although the visual depiction only shows exposure points locations around a single finite distance ring, the same placement of exposure points occurred for all eight finite distance rings.

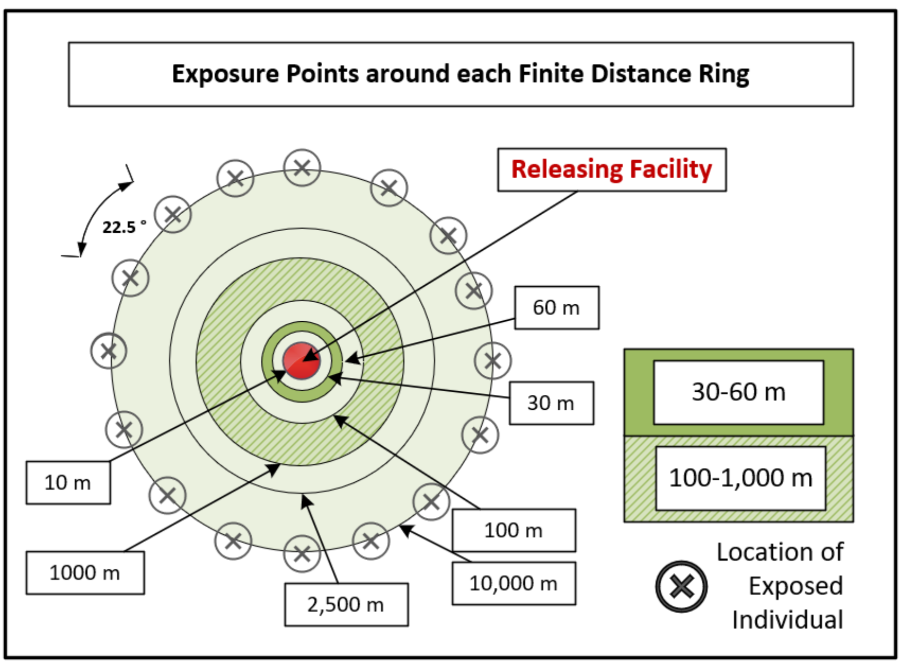


Figure 5-3. Modeled Exposure Point Locations for Finite Distance Rings for Ambient Air Modeling (AERMOD)

Exposure points for the area distance evaluated were placed in a cartesian grid at equal distances between 200 and 900 m around each releasing facility (or generic facility for alternative release estimates). Exposure points were placed at 100-meter increments. This results in a total of 456 exposure points for which exposures are modeled.

5.1.4.2 Summary of General Population Ambient Air Exposure Concentrations

Releases of asbestos fibers to ambient air from various industrial or commercial activities, described by occupational exposure scenarios (OES), were used to estimate environmental concentrations. Modeled air concentration releases from industrial and commercial OESs emissions summarized in Section 3.3.1 were used to calculate risk to the general population using Equation_Apx N-1 and Equation_Apx N-2 and the assumptions and parameters described in Section 5.1.4.1. The generic and specific facilities modeled air concentrations were grouped and averaged (when appropriate) per OES, see Figure 5-4 and Appendix H.3 for groupings and pivot tables.

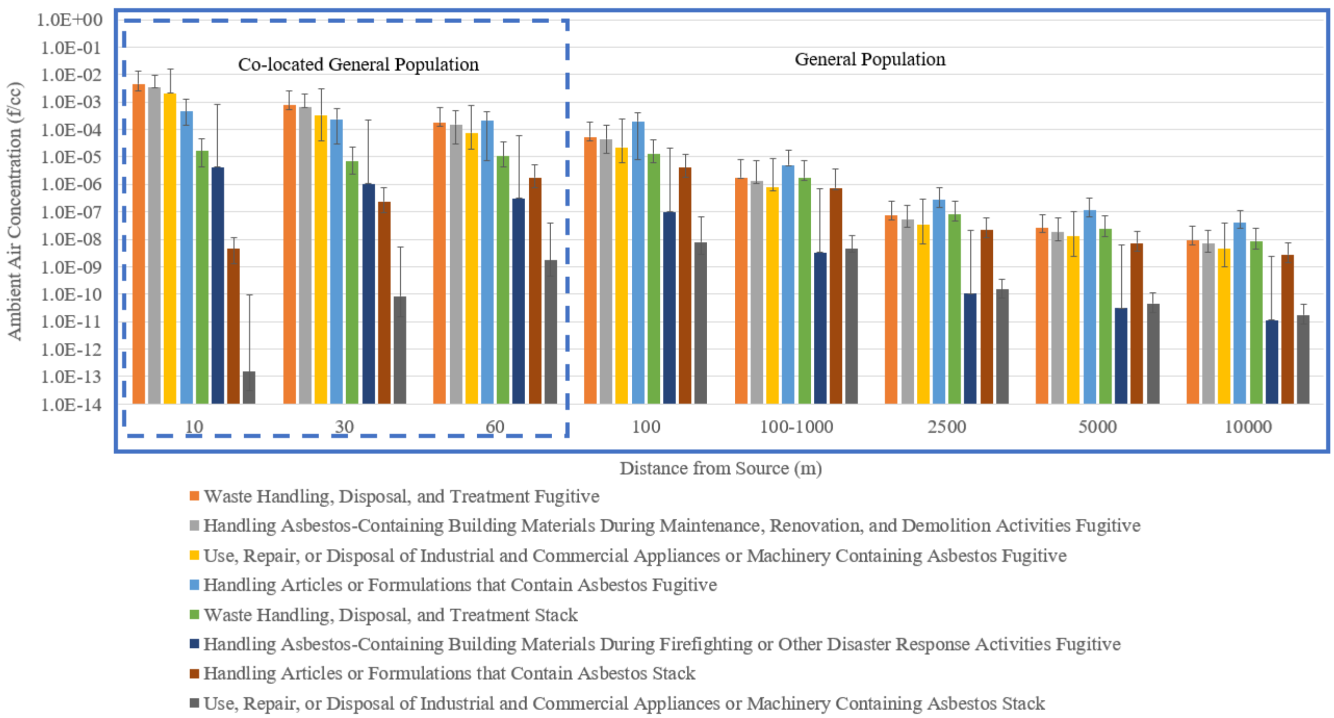


Figure 5-4. Modeled Ambient Air Concentrations by OES

Bar lines are the low- and high-end concentrations.

5.1.4.3 Weight of Scientific Evidence Conclusions for General Population Exposure

EPA modeled inhalation to asbestos fibers in ambient air. EPA considered multiple low-end, central tendency and high-end inputs for ambient air modeled scenarios. Further, each scenario was split into many sub-scenarios to fully explore potential variability. Modeled estimates were compared with monitoring data to ensure overlap and evaluate the overall magnitude and trends. For example, firefighting and fireproofing asbestos containing building material in Section 3.3.1.3. A qualitative assessment of the uncertainty and variability associated with this approach is presented in Section 5.1.4.3.1 below and the overall confidence in the general population exposure scenarios inhalation risk calculation is summarized in Table 5-18. All monitoring data used to estimate releases to ambient air had data quality ratings of medium/high. For releases modeled with TRI/NEI/NRC data, the weight of scientific evidence conclusion was moderate to robust.

Table 5-18. Overall Confidence for General Population Exposure Scenarios

General Population Exposure Scenario	Environmental Releases[a]	Overall Dispersion Model Concentrations
Waste Handling, Disposal, and Treatment Fugitive	++ to +++	++
Handling Asbestos-Containing Building Materials During Maintenance, Renovation, and Demolition Activities Fugitive	++ to +++	++
Use, Repair, or Disposal of Industrial and Commercial Appliances or Machinery Containing Asbestos Fugitive	++ to +++	++
Handling Articles or Formulations that Contain Asbestos Fugitive	++ to +++	++
Handling Asbestos-Containing Building Materials During Firefighting or Other Disaster Response Activities Fugitive	++	++
[a] See Section 3.2.1.2 and Appendix G.8.		

5.1.4.3.1 Strengths, Limitations, Assumptions, and Key Sources of Uncertainty for the General Population Exposure Assessment

Table 5-19. Qualitative Assessment of the Uncertainty and Variability Associated with General Population Assessment

Variable Name	Relevant Section(s) in Risk Evaluation	Data Source	Uncertainty (L, M, H)	Variability (L, M, H)
General population exposure assessment				
Environmental release estimates	3.2	EPA modeled	M to L	H
Environmental monitoring data	3.3	Extracted and evaluated data (all) plus key studies	M	H
Exposure factors and activity patterns	5.1.4.1	EPA *Exposure Factors Handbook*	L	M
Key parameters for modeling environmental concentrations				
Air modeling defaults: meteorological data, indoor/outdoor transfer	3.3.1, Appendix J	IIOAC/AERMOD defaults	L	H
Particle deposition	3.3.4, Appendix J (Air Section)	AERMOD	M	H
L = low; M = moderate; H = high				

EPA considered water, soil and land, and air pathways, and only the releases to air were moved on to risk characterization, see Section 3.3. This may result in a potential underestimation of exposure in some cases. Examples of exposure pathways that were not considered include incidental inhalation of suspended soil during recreational activities. However, EPA expects these exposures to be less than those that were included in the aggregate assessment. As such, their impact will likely be minimal and would be unlikely to influence the overall magnitude of the results.

5.1.1 Aggregate Exposure Scenarios

EPA defines aggregate exposure as "the combined exposures from a chemical substance across multiple routes and across multiple pathways (40 CFR 702.33)." Aggregate exposure can be done across several pathways and routes in the non-occupational and occupational risk assessments. However, the principal route of exposure considered in asbestos risk assessment to legacy uses is inhalation; hence, EPA only considered aggregation across inhalation exposure scenarios and COUs (Figure 5-5). If the individual estimates in the aggregation result in risk for a particular COU or exposure scenario, this value is omitted from aggregation calculations, but the possibility of that specific COU/activity occurring is described. When considering scenario specific estimates and aggregate exposures, there is uncertainty associated with which scenarios co-occur in a given population group. Further, there is variability within a given exposure scenario. For the same exposure scenarios, central tendency estimates are more likely to co-occur than high-end estimates. To address this, EPA used different combinations of exposures sampling from the entire distribution for all estimated exposures that were not above the risk benchmark.

This approach offers more clarity than static sensitivity analyses based on combining assorted high-end and/or central tendency estimates of the component distributions. For instance, combining the 95th percentile estimate of all component variables in an exposure equation in a static sensitivity analysis may produce a conservative high-end estimate of exposure that cannot be related to a specific percentile on the exposure distribution. Instead, EPA selected the risk estimates when those were not above the risk benchmark and aggregated across exposure scenarios and COUs/OES. While EPA identified studies (see Table 3-14) with measurements of naturally occurring asbestos, the data was not used to further assess risk because it cannot be apportioned to specific COUs under this risk evaluation. EPA used the data to qualitatively discuss observations of asbestos fibers releases within soil. The expected high variability of naturally occurring asbestos concentrations from one location to another and high uncertainty in using these data as background in the aggregation would further compound uncertainties that are not characterized.

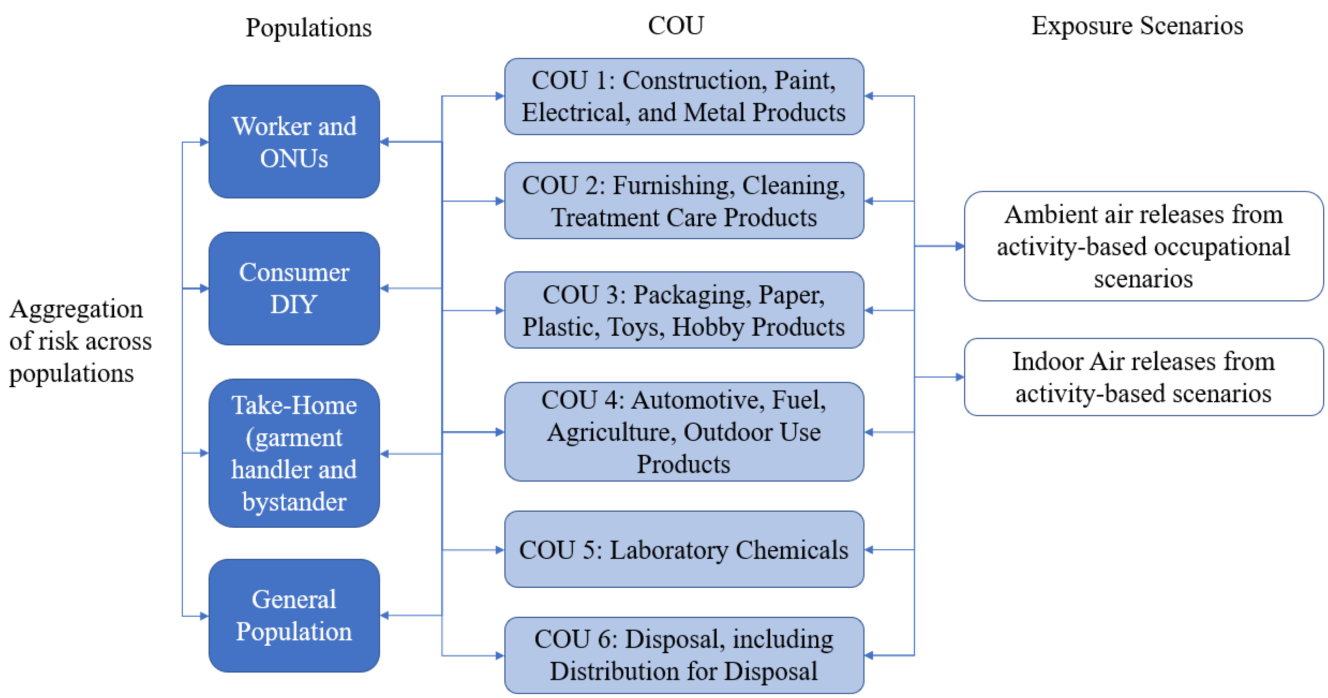


Figure 5-5. Asbestos Aggregate Analysis Approach

5.2 Human Health Hazard

As described in Part 1 of the Risk Evaluation, the risk related to asbestos exposures are well established and have been reviewed by several authorities. Data collected since the early 1970s from extensive population studies with lengthy follow-up have increased our understanding of diseases linked to asbestos exposure and reinforced the case for a causal relationship between asbestos exposure and particular adverse health outcomes.

After a thorough and comprehensive investigation into the reasonably available evidence on the hazards and health risks associated with asbestos, from data sources like the IRIS 1988 Assessment on Asbestos (U.S. EPA, 1986a), IRIS 2014 Assessment on Libby Amphibole Asbestos (U.S. EPA, 2014c), National Toxicology Program (NPT) 2016 Report on Carcinogens, Fourteenth Edition (NTP, 2016), NIOSH 2011 Asbestos Fibers and Other Elongated Mineral Particles: State of the Science and Roadmap for Research (NIOSH, 2011b), ATSDR 2001 Toxicological Profile for Asbestos (ATSDR, 2001), International Agency for Research of Cancer (IARC) 2012 Monographs on the Evaluation of Carcinogenic Risks to Humans. Arsenic, Metals, Fibres, and Dust. Asbestos (Chrysotile, Amosite, Crocidolite, Tremolite, Actinolite, and Anthophyllite (IARC, 2012b), and World Health Organization (WHO) 2014 Chrysotile Asbestos (WHO, 2014), the EPA determined that the human health hazards identified in the previous reports are still relevant and valid. These studies continue to show that asbestos exposure is associated with lung cancer, mesothelioma, laryngeal cancer and ovarian cancer (U.S. EPA, 2020c).

Cancer of Larynx and Ovaries

While lung cancer and mesothelioma have historically been the major focus of health studies and were the focus in Part 1, it is recognized that laryngeal and ovarian cancers have more recently been causally linked to asbestos exposure and were included in the cancer IUR derivation of Part 1. Notably IARC monograph on epidemiological data showed that there is a high incidence of lung cancer among workers who were exposed to chrysotile, amosite, anthophyllite, and mixed fibers containing crocidolite and tremolite. Within the IARC monograph, exposure to all asbestos fiber types was considered together as "cumulative exposure," so the conclusions are summarized using that term here. There was also strong evidence for a positive exposure-response relationship between cumulative asbestos exposure and cancer of the larynx and ovaries as reported in several of the well-conducted cohort studies. This relationship was based on the fairly consistent findings of both occupational cohort studies and case-control studies, as well as the evidence for positive exposure-response relationships between cumulative asbestos exposure and laryngeal cancer and/or ovarian cancer (IARC, 2012a). In the most recent IARC Monograph on asbestos (IARC, 2012a), five highly positive cohort mortality studies of women with heavy occupational exposure to asbestos were reviewed and it was concluded that the evidence clearly demonstrated a causal association between exposure to asbestos and cancer of the ovary. Studies demonstrating that women and girls with environmental exposure to asbestos, but not occupational exposure, showed positive associations in both ovarian cancer incidence and death, providing additional support for the relationship between asbestos exposure and ovarian cancer. The occupational workforce exposed to asbestos has been predominately male, especially in occupations like mining, milling, shipyard work, construction, and asbestos insulation. Thus, the published literature examining the association between asbestos exposure and cancer of the ovaries has been more limited.

Colorectal Cancer

When considering cohort and case-control studies examining asbestos exposure and colorectal cancer, several studies demonstrated a position relationship. However, evidence for a dose-response relationship was not established across the various cohorts studies (IARC, 2012a). Studies of populations with prolonged and heavy exposure to asbestos that included high quality exposure assessment and had long-term follow-up show positive exposure-response associations between asbestos exposure and colorectal cancer, but several studies present conflicting results. Overall, the range of epidemiologic evidence is not sufficient to establish causality in the association between asbestos and colorectal cancer (IARC, 2012a).

Overall, there was no new information for cancers such as mesothelioma, lung cancer, laryngeal, ovarian, and colorectal cancers that substantively changed conclusions from prior assessments on the causal relationship with asbestos exposure.

Besides cancer effects, it is well established that asbestos exposure can have adverse effects on the lungs as well as other non-cancer health outcomes. There is ample evidence that asbestos exposure can have negative effects on the respiratory system, including asbestosis, non-malignant respiratory disease (NMRD), pulmonary function impairments, diffuse pleural thickening (DPT), and pleural plaques. There are a number of immunological and lymphoreticular effects that have been hypothesized but not substantiated. Numerous asbestos-exposed cohorts have shown evidence of asbestosis and NMRD as a cause of death. Pulmonary function is decreased by DPT and pleural plaques. Because a change in the distribution of pulmonary function in an exposed population causes a significant increase in the proportion of people with a significant level of pulmonary impairment below a clinically adverse level, pulmonary deficits are considered to be harmful for an asbestos-exposed populations (U.S. EPA, 2020c).

As described in the IRIS LAA Assessment (U.S. EPA, 2014c) the LAA epidemiologic database contains research conducted in workplace settings as well as community-based investigations of workers, their families, and other members of the general public. Occupational cohorts have included employees exposed to LAA at the vermiculite mine and mill at the Zonolite Mountain facilities in Libby, Montana, and at the manufacturing facility using the vermiculite ore in Marysville, Ohio. Additionally, community-based studies have been carried out among residents in Libby, Montana as well as in the vicinity of a Minneapolis, Minnesota industrial facility that produced vermiculite insulation. These studies have looked at mortality due to cancer and non-cancer, effects on the lungs seen by x-ray exams, pulmonary function testing, or respiratory symptoms, autoimmune illnesses, and the prevalence of autoantibodies (U.S. EPA, 2014c).

Respiratory Effects

Several studies discussed mortality data for non-cancer respiratory diseases that had previously been reported. Nonmalignant respiratory disease is a broad classification (International Classification of Diseases [ICD]-9 codes 460–519) that encompasses asbestosis (ICD-9 code 501), several types of pneumoconiosis, chronic obstructive pulmonary disease, asthma, pneumonia, and respiratory infections. Comparing asbestosis to nonmalignant respiratory disease, the narrower the category, one would anticipate more effect specificity of asbestos-related symptoms. Libby, Montana vermiculite mining and milling worker cohorts' first research were based on a relatively modest number of nonmalignant respiratory-related deaths (25); later studies saw more than 50 deaths in this category. However, a pattern of increasing risk with increasing cumulative exposure is evident, with more than a 10-fold increased risk of death from asbestosis and a 1.5- to 3-fold increased risk of nonmalignant respiratory disease in the analyses using an internal referent group (Larson et al., 2010; Sullivan, 2007; McDonald et al., 2004). The analytic strategy (*e.g.*, use of a lag period to exclude exposures that occurred after the onset of disease or use of a latency period to exclude cases that occurred before the effect of exposure would be expected to manifest) and the cut-points for exposure categories varied among the studies (U.S. EPA, 2014c).

According to the geographic-based research conducted by the ATSDR, the risk of developing asbestosis increased as well, with SMRs of about 40 based on Montana rates and 65 based on U.S. comparator rates (ATSDR, 2000). Since there was only one asbestosis-related death in the Marysville, Ohio, worker cohort, it is difficult to estimate the risk (Dunning et al., 2012). Asbestosis is the interstitial pneumonitis (inflammation of lung tissue) and fibrosis caused by inhalation of asbestos fibers. It is characterized by a diffuse increase in collagen in the alveolar walls (fibrosis) and the presence of asbestos fibers, either free or coated with a proteinaceous material and iron (asbestos bodies), which are the main symptoms of asbestosis. Following lung damage, a series of processes that include inflammatory cell migration, edema, cellular proliferation, and collagen accumulation lead to fibrosis. Asbestosis is linked to dyspnea (shortness of breath), bibasilar rales, and alterations in pulmonary function, including a restrictive pattern, a mixed restrictive-obstructive pattern, and/or a reduced diffusing capacity. In clinical practice, tiny lung opacities on radiographic examination are the most typical signs of fibrotic scarring of lung tissue consistent with mineral dust and mineral fiber toxicity. Scarring of the lung's parenchymal tissue causes changes in pulmonary function, such as restrictive pulmonary deficits brought on by the lung's increased stiffness (reduced elasticity), impaired gas exchange brought on in part by thickening of the alveolar wall, and occasionally mild obstructive deficits brought on by asbestos-induced airways disease (U.S. EPA, 2014c).

The two main biological abnormalities that make up pleural thickening brought on by mineral fiber exposure are localized pleural plaques in the parietal (outer) pleura and widespread pleural thickening of the visceral (inner) pleura. Pleural and parenchymal abnormalities (pathological, structural modifications) which can be found by radiography or other methods of imaging, can serve as evidence of the risk of respiratory disease. The International Labour Organization (ILO) of the United Nations developed these criteria to standardize descriptions of effects and to increase inter-rater agreement and accuracy for interpreting chest radiographs in pneumoconiosis. Standard radiographs can detect both of these types of pleural thickening; however, smaller/thinner plaques and thinner diffuse thickening could not be seen, especially if they are not calcified or hidden by other typical chest structures. High resolution computed tomography is a radiographic technique that is more sensitive and specific than conventional chest x-rays; for example, it can detect pleural abnormalities that are not visible on conventional x-rays and more reliably exclude fat tissue that can occasionally be mistaken for pleural thickening on conventional x-rays (U.S. EPA, 2014c).

Cardiovascular and Immunologic Effects

Research on non-cancer health impacts happening beyond the pleura and respiratory system is more limited. Studies examining effects in workers from the Libby, Montana, considered cardiovascular disease and related mortality. As described in Section 4.1.3.1 of the IRIS LAA Assessment, weak associations were identified; however, the observed associations may be influenced by smoking patterns and/or underlying respiratory disease that may have preceded cardiovascular effects. Other research looked at the relationship between asbestos exposure and immunological indicators including autoantibodies and autoimmune diseases. Evidence is more thoroughly described in Section 4.1.3.2 of the IRIS LAA Assessment, which includes discussion of three community-based cohort studies. Across these studies, the data indicates some perturbation in immune function, but it is challenging to draw conclusions about the role of asbestos in autoimmune illness due to limitations in the quantity, breadth, and design methodology of these studies. Studies on chronic inflammation after asbestos inhalation exposure have been conducted for many years in both people and animals. As is the case with cardiovascular diseases that may be associated with asbestos exposure, it is likely that the respiratory effects observed precede altered immunologic activity (U.S. EPA, 2014c).

For Part 2, EPA employed a systematic review approach to identify the relevant epidemiologic evidence and to determine if new information is available that would extend or substantively alter the well-established existing conclusions on asbestos exposure and human health. The systematic review approach is described in the Draft Systematic Review Protocol (U.S. EPA, 2021a). EPA reviewed the epidemiologic data examining human health hazards and determined the most informative hazard studies to be those that included data and employed methodologies informing a dose-response relationship. Studies that are useful for dose response are generally based on historical occupational cohorts with the longest follow-up for each cohort or the most pertinent exposure-response data when a cohort has been the subject of more than one publication. Consideration of studies that could inform a dose-response relationship were not limited by exposure route. Inhalation and ingestion are the main exposure pathways of concern. Dermal contact is not regarded as a primary exposure route because fibers are inert and therefore do not penetrate through the skin. Dermal exposures were recognized as a potential exposure route in the SR process, but no dermal studies were identified in the process. Although studies of oral exposure were identified and considered, these studies were not considered informative for dose-response analysis in the context of existing assessments and the robust data available for inhalation exposures.

Exposure via the oral route was evaluated in the *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Asbestos (Chrysotile, Amosite, Crocidolite, Tremolite, Actinolite, and Anthophyllite)* (IARC, 2012a). This report acknowledges that several individual studies show a positive association between ingestion of asbestos via drinking water and stomach and colorectal cancer across several different communities; however, there are studies that did not find an association. The monograph describes two systematic reviews that reached an overall conclusion that information was insufficient to assess the risk of cancer (stomach and colorectal) from asbestos in drinking water or there was no clear pattern of association between asbestos in drinking water and stomach cancer (stomach and colorectal).

Through the systematic review process, EPA identified nine oral studies. Three of these studies were considered in the IARC Monograph. Two studies conducted by Polissar et al. (Polissar et al., 1984, 1983) were not included in the IARC Monograph, but they were similar to the 1982 study by Polissar et.al, which was included in the IARC report and identified in our systematic review. These epidemiologic studies conducted in western Washington state found inconclusive evidence or evidence due to chance for the association between asbestos in drinking water and gastrointestinal tract, esophagus, stomach, and pancreatic cancers as well as esophagus, stomach, digestive-related organs, and pancreatic malignancies (Polissar et al., 1984, 1983; Polissar et al., 1982). Three other studies by Haque et al., (Haque et al., 1998; Haque et al., 1996; Haque and Kanz, 1988) investigated the effects of asbestos fibers on several maternal and fetal medical, demographic, and environmental factors, as well as the asbestos loads in stillborn infants from transplacental transfer or ingestion or inhalation of contaminated amniotic fluid following premature rupture of membranes. Ultimately, these studies found detectable amounts of fibers in placenta and fetal tissues of stillborn babies compared to controls (live-born placenta). However, the presence of asbestos fibers was not linked to premature membrane rupture. Asbestos fibers were found throughout the whole gestation period and did not correlate with gestational age. The lack of a maternal history of work involving asbestos raises the possibility that the fibers were ingested from ambient exposure (Haque et al., 1998; Haque et al., 1996).

Inhalation is the critical route of exposure as the respiratory tract is the most sensitive to asbestos fibers when compared to dermal and oral exposures, and an IUR value and a POD based on epidemiologic studies are available. Quantitative dose-response analysis was not conducted for oral and dermal routes of exposure based on the limited information available for these exposures. In addition, respiratory effects are the most sensitive and early effects observed across the database of information.

5.2.1 Dose-Response Considerations: Cancer

In keeping with the various occupational epidemiological study designs which were discussed in previous risk assessments, EPA is using dose-response and exposure-response relationship interchangeably because it describes the amount of exposure/dose a person is exposed to. Through the systematic review process and fit-for-purpose filtering that was employed (U.S. EPA, 2021a), 16 cohorts were identified for consideration in assessing dose response of cancer outcome related to asbestos inhalation exposures. Most of these cohorts were identified and considered in previous assessments, including the 1988 IRIS Asbestos Assessment, the 2014 IRIS LAA Assessment, and the 2020 Part 1 of the Risk Evaluation for Asbestos. Only one cohort was identified that was not previously considered in a prior EPA assessment—and as a community-based cohort (Wittenoom, Australia, Residents Cohort), rather than an occupational cohort—this study was unique. In the consideration of these cohorts in the previous assessments, with the exception of the Wittenoom Cohort, IURs were developed for use in risk assessment. Each of these IURs is described in the White Paper (U.S. EPA, 2023g) and summarized here.

1988 IRIS Asbestos Assessment

The IRIS Asbestos Assessment, released in 1988 (U.S. EPA, 1986a), utilizes the Airborne Asbestos Health Assessment Update from 1986 (U.S. EPA, 1986a). The latter was developed as the scientific foundation to support EPA's review and revision of the designation of asbestos as a hazardous air pollutant under the 1973 National Emission Standards for Hazardous Air Pollutants (NESHAP) under the 1977 Clean Air Act Amendments (U.S. EPA, 1986a). The original designation of asbestos was based upon a qualitative review of the evidence prior to 1972 establishing associations between exposure and carcinogenicity. The objectives of the Airborne Asbestos Health Assessment Update (U.S. EPA, 1986a) were to identify any new asbestos-related health effects from studies published after 1972, examine the dose-response relationship, and establish unit risk values for asbestos, if warranted.

The assessment included occupational studies with exposures to any of the principal commercial varieties of asbestos fibers (*i.e.*, amosite, anthophyllite, crocidolite, and chrysotile). A total of 14 occupational studies provided data for a dose-response assessment, however only 6 of those studies were considered because of the robustness of the data and the OQD rating of medium or high (Appendix I). The data for a best estimate of increased risk of lung cancer per unit exposure are provided across a range of occupational activities. Studies of mining and milling were excluded due to a substantial difference in risk observed and the notion that exposure assessment in these operations is significantly more challenging due to a wide array of fibers being present. Factories have a more limited set of sources of dust and fibers, making fiber counts more straightforward and less likely to be impacted by the presence of other fibers. In deriving the overall slope factor for lung cancer (K_L), the geometric mean was calculated from the 14 epidemiologic studies, representing exposures to a mix of fibers from chrysotile, amosite, and crocidolite.

A cancer slope factor for mesothelioma (K_M) was derived using information from the same 14 studies. Four of these studies examined mortality resulting from mesothelioma. Estimates of mesothelioma in the other ten studies were developed by determining the ratio of lung cancer to mesothelioma in the four studies examining both, and then applying an adjustment to lung cancer rates in the ten studies that did not examine mesothelioma. In addition, there was consideration of uncertainty resulting from exposure to crocidolite which was postulated to be more potent; however, examination of potency revealed that the impact of this uncertainty was minimal. Overall, there were no outliers in slope factors dervied for each study, so the geometric mean was used to calculate the slope factor for mesothelioma(U.S. EPA, 1986a).

The cancer slope factors for lung cancer and mesothelioma were separately derived and then statistically combined. Subsequently, a life table analysis was conducted using the K_L and K_M to represent the epidemiologic data, a relative risk model for lung cancer, and an absolute risk model for mesothelioma with linear low dose extrapolation to arrive at an IUR of 0.23 per fiber/cc. An important observation from this assessment is that risk from lung cancer is proportional to cumulative exposure and death from mesothelioma increased sharply with the time since onset of exposure. Limitations of the analysis in this assessment include (1) variability in the exposure-response relationship at high exposure; (2) uncertainty in extrapolating to much lower exposures (*i.e.*, background exposures that can be 1/100th the levels seen in occupational settings); and (3) uncertainties in converting between detection methods (*e.g.*, optical fiber counts, mass determination) (U.S. EPA, 1986a).

2014 IRIS Libby Amphibole Asbestos Assessment

The IRIS LAA Assessment, released in 2014, included a detailed toxicological review that provides the scientific foundation to support the risk and dose-response assessment of chronic inhalation exposure specific to LAA in the Rainy Creek complex and from the vermiculite mine near Libby, Montana (U.S. EPA, 2014c). The LAA Assessment evaluated the possible risks associated with exposure to LAA, including those related to cancer and non-cancer health effects, and presents risk values for use in risk assessments, including an RfC for non-cancer health effects (summarized below in Section 5.2.2 and an IUR to address cancer risk. The LAA Assessment considered several occupational and community-based cohorts for dose-response assessment (see Figure 4-1 in the LAA Assessment); however, for cancer dose-response, the Libby, Montana, Vermiculite Milling and Mining Cohort examining workers participating in mining and milling activities at the mine in Libby, Montana, and a plant in Marysville, Ohio, as being most relevant for dose-response consideration.

This cohort was determined to have the most robust data for dose-response assessment for numerous reasons, including the use of individual level exposure data based on impinger and PCM measurements, complete demographic data, and vital status with extended follow-up through 2006 (approximately 30 years of follow-up). For mesothelioma mortality in this data set, Poisson modeling was conducted to fit mortality data and exposure data with a range of exposure metrics. The best model was based upon a subcohort with employment beginning in 1959 and a cumulative exposure metric with a 5-year half-life and a 10-year lag time. The central estimate for K_M was 3.11×10^{-4} per fibers/cc. Following selection of the K_M, a lifetable procedure was applied to the U.S. general population using age-specific mortality statistics to estimate the exposure levels that would be expected to result in a 1 percent increase in absolute risk of mesothelioma over a lifetime of continuous exposure. Linear low-dose extrapolation was used to find an effective concentration corresponding to the central tendency, which was estimated to be 0.032 per fiber/cc and 0.074 per fiber/cc when adjusted to account for under-ascertainment of mesothelioma and the upper bound unit risk was 0.122 per fiber/cc (highest adjusted unit risk value).

Lung cancer unit risk values were also calculated separately and based on a subcohort of the Libby, Montana, workers hired after 1959. Multivariate extended Cox models were run with a range of exposure metrics, and the best fit was based on cumulative exposure with a 10-year half-life and a 10-year lag. The resulting KL from this model was 0.0126 per fiber/cc-yr. As was done for the mesothelioma cancer slope factor, a life-table analysis was applied to the KL to determine an exposure level of asbestos expected to result in a 1 percent increase in relative cancer risks when taking into account age-specific background risk. The corresponding effective concentration relating to the central tendency was 0.0399 per fiber/cc for a lifetime continuous exposure with an upper bound unit risk of 0.0679 per fiber/cc.

The statistical derivation of a combined upper bound unit risk value accounted for overprediction resulting from combining individual upper bound estimates. The upper bound combined risk from the best fitting models applied to individual-level data from the Libby, Montana, workers was 0.17 per fiber/cc. The 2014 IRIS LAA Assessment notes some limitations, including the difficulty in controlling for smoking as a confounder, the potential for under-ascertainment of mesothelioma, and uncertainties in the exposure measurements in the facility.

Part 1 Risk Evaluation for Asbestos

The most recent asbestos IUR was developed as part of the Risk Evaluation for Asbestos Part 1: Chrysotile Asbestos (U.S. EPA, 2020c). An IUR of 0.16 per fiber/cc was derived based upon thorough consideration and analysis of data from epidemiological studies on mesothelioma and lung cancer in cohorts of workers using chrysotile asbestos. Data from several cohorts was available for dose-response modeling following a systematic approach to literature identification and evaluation. Ultimately, data from cohorts of workers in textile plants in North and South Carolina were selected for IUR derivation.

For the NC cohort, individual-level exposure-response data was available for lung cancer in Loomis et al. (2009) and Elliott et al. (2012) as well as mesothelioma in Loomis et al. (2019). For these studies, the Part 1 Risk Evaluation presents cancer potency values based on Poisson regressions of the individual-level data using both logistical and additive relative rate model forms with adjustment for age, sex, race, calendar period, and birth cohort (see Table 3-4 in (U.S. EPA, 2020c)). For the SC cohort, individual-level data was available for lung cancer in Hein et al. (2007) and (Elliott et al., 2012) as well as for mesothelioma from Berman and Crump (2008). Lung cancer potency values for these studies were based on Poisson regression models using a linear relative rate model form with adjustment for sex, race, and age. Mesothelioma cancer potency values were reported in Berman and Crump (2008) based on analyses of the original cohort data using the Peto model (see Table 3-3 in (U.S. EPA, 2020c)).

The 2014 LAA Assessment and Part 1 describes uncertainty related to under-ascertainment of mesothelioma as an International Classification of Diseases (ICD) code specific to mesothelioma that was not available prior to 1999. An adjustment factor was applied in the derivation of the IUR to account for this under-ascertainment in the same way the Libby IUR was adjusted. Additionally, the IUR was adjusted to account for cancer risk from other cancer endpoints beyond lung cancer and mesothelioma. As explained in Section 3.2.3.8.1 of Part 1 (U.S. EPA, 2020c), IARC concluded that exposure to asbestos is causally related to lung cancer and mesothelioma as well as laryngeal and ovarian cancer (U.S. EPA, 2020c; Straif et al., 2009). Data was not available to derive potency factors for laryngeal and ovarian cancer, so an adjustment factor was developed to account for potential underestimation of cancer risk when only considering data for lung cancer and mesothelioma.

For each modeling result from the NC and SC data sets (U.S. EPA, 2020c), the unit risks were calculated separately for lung cancer and mesothelioma. Lung cancer unit risks were adjusted to account for other cancers and mesothelioma unit risks were adjusted to account for under-ascertainment. The unit risks were then statistically combined for central unit risk and upper bound risk. Of the available IURs from modeling results, the median IUR was ultimately selected because there was low model uncertainty (see Table 3-12 in (U.S. EPA, 2020c)). The median lifetime cancer incidence IUR was 0.16 per fiber/cc based upon a linear model of the data from the NC textile workers cohort (Elliott et al., 2012).

Part 1 notes a few important uncertainties in the 0.16 per fiber/cc IUR (see Section 4.3.5 in (U.S. EPA, 2020c)). First, PCM measurements were used despite TEM being a more precise analytical technique. However, it was determined that when TEM and PCM were available in the same data set, TEM and PCM model results were similar. Thus, this uncertainty was considered to be low for the NC textile worker cohort. Another source of uncertainty in exposure measurements is the use of impinger sampling data for early asbestos exposures. Prior to 1965, the majority of the data on asbestos workers' exposures came from total dust concentrations determined with a midget impinger, which were frequently employed as area samplers in place of personal samplers. In general, there were weak associations between fiber concentrations and midget impinger particle counts determined with bright field microscopy (U.S. EPA, 1986a). The most robust approach to account for this is to use paired and concurrent sampling data to derive a conversation factor, and this was performed in the analysis of the NC and SC textile cohorts resulting in low uncertainty. When considering uncertainties related to outcome data, use of mortality data rather than incidence, which was not available, was of concern. To account for this, background rates of lung cancer incidence were used in lifetable analyses. However, this was not possible for mesothelioma. While this remains a bias, it is noteworthy that median survival for mesothelioma is less than 1 year. Finally, confounding must be considered with regard to uncertainties. Smoking is considered a strong confounder for lung cancer related to asbestos exposure, but in the NC and SC cohorts, confounding was deemed to be low because regression models accounted for birth cohort that would reflect changes in smoking rates over time. Additionally, it is likely that smoking rates among workers were similar across facilities and occupations. Smoking is not a confounder for mesothelioma.

5.2.1.1 Inhalation Unit Risk for Part 2

All three of the EPA's currently available IURs (0.23 per fiber/cc, 0.17 per fiber/cc and 0.16 per fiber/cc) are numerically very similar, despite decades of epidemiologic research conducted in a variety of occupational settings, using a variety of exposure measurement techniques and exposure assignment approaches, and based on a wide range of dose response modeling with the application of adjustment factors. Sensitivity analyses were conducted on IURs of 0.23 per fiber/cc and 0.2 per fiber/cc, and unreasonable risk determination decisions were not different regardless of values used (Appendix M).

The IUR of 0.16 per fiber/cc presented in Part 1 of the Risk Evaluation for Asbestos (U.S. EPA, 2020c) benefits from the most recent data available and generally, the longest follow-up periods. Advanced exposure measurement methods are reflected in the underlying data resulting in exposure estimates that are of high confidence. Furthermore, longer follow-up times increase the statistical power of the study as more mortality is observed. Other notable strengths include accounting for laryngeal and ovarian cancers, which are causally associated with asbestos exposure, and accounting for under-ascertainment of mesothelioma.

The IUR of 0.17 per fiber/cc presented in the IRIS LAA Assessment (U.S. EPA, 2014c) has similar strengths and limitations as the chrysotile IUR. Robust analyses were conducted based on very detailed individual-level exposure measurements and outcome data for lung cancer and mesothelioma as the cohort was established from one operation, the mine in Libby, Montana. There was insufficient data on laryngeal or ovarian cancers in this cohort for quantitative consideration, but under-ascertainment of mesothelioma was accounted for. The data used in the analysis was comprehensive and yielded quantitative analyses of high confidence.

The earliest IUR of 0.23 per fiber/cc presented in the IRIS Asbestos Assessment (U.S. EPA, 1986a) was developed to describe risks related to all asbestos fiber types. Development of this IUR was based on historically robust data at a time when standard fiber measurement methods had not yet been established and reporting and publication standards were highly variable. A major strength of this IUR is that it represents exposures to a range of fiber types and is most appropriately applied to describe risks related to mixed-fiber exposures, which is pertinent to exposure scenarios in Part 2 of the Risk Evaluation for Asbestos. The authors of the report acknowledged this objective when they described the use of data from all cohorts and not isolating data from the cohort with the most detailed exposure assessment that may have been specific to only a single fiber.

An IUR of 0.2 per fiber/cc is a representative value that reflects the strength and uncertainties of each individual IUR. Selecting an IUR of 0.2 is well-supported and takes into account a broad range of applicable information. This value reflects exposures in a variety of settings and levels, an array of asbestos fibers, and relevant cancer outcomes. Exposure scenarios described herein do not pertain to specific fiber types (*e.g.*, chrysotile and LAA). Specifically, for asbestos-containing building materials, exposure to mixed fiber types is expected.

The use of an IUR of 0.2 per fiber/cc takes into account the existing IUR's developed by the EPA since 1988 as well as the newer body of evidence, that produce a numerically similar IUR 0.17 per fiber/cc and 0.16 per fiber/cc. Exposure sensitivity analysis did not show any change in unreasonable risk determination decisions from using an IUR of 0.2 per fiber/cc vs. 0.23 per fiber/cc, 0.17 per fiber/cc and 0.16 per fiber/cc (Appendix M).

5.2.1.2 Uncertainties

Inherent strengths and uncertainties pertain to each IUR, and all were developed for a distinct purpose and application. The IUR of 0.16 per fiber/cc (U.S. EPA, 2020c) was strictly limited to exposures to chrysotile asbestos and is therefore most appropriately applied in cases where exposures are chrysotile-specific.

As described in Section 5.1.1, the comprehensiveness of the data for the IRIS LAA Assessment IUR of 0.17 per fiber/cc (U.S. EPA, 2014c) yielded quantitative analyses of high confidence. However, this IUR is based on data specific to scenarios of exposure to only LAA, and therefore, is most appropriately applied in risk estimates based on Libby-specific exposures.

Although development of the IUR of 0.23 per fiber/cc (U.S. EPA, 1986a) was robust, additional uncertainty exists in the exposure measurement provided in the published studies. It is important to note that EPA technical experts were diligent in advancing their understanding and use of data beyond what was available in original publications to reduce uncertainties, as reflected in the 1988 Asbestos Assessment, and related publications.

The Part 1 Risk Evaluation notes a few important uncertainties in the IUR (see Section 4.3.5 in (U.S. EPA, 2020c)). First, PCM measurements were used despite TEM being a more precise analytical technique. However, it was determined that when TEM and PCM were available in the same data set, TEM and PCM model results were similar. Thus, this uncertainty was considered to be low for the NC textile worker cohort. Another source of uncertainty in exposure measurements is the use of impinger sampling data for early asbestos exposures. The most robust approach to account for this is to use paired and concurrent sampling data to derive a conversation factor, and this was performed in the analysis of the NC and SC textile cohorts resulting in low uncertainty. When considering uncertainties related to outcome data, use of mortality data rather than incidence, which was not available, was of concern. To account for this, background rates of lung cancer incidence were used in lifetable analyses. However, this was not possible for mesothelioma. While this remains a bias, it is noteworthy that median survival for mesothelioma is less than 1 year. Finally, confounding must be considered with regard to uncertainties. Smoking is considered a strong confounder for lung cancer related to asbestos exposure, but in the NC and SC cohorts, confounding was deemed to be low because regression models accounted for birth cohort that would reflect changes in smoking rates over time. Additionally, it is likely that smoking rates among workers were similar across facilities and occupations. Smoking is not a confounder for mesothelioma.

In Part 1 of the risk evaluation, this IUR was applied for all chrysotile asbestos exposure scenarios, with less-than-lifetime adjustments applied where appropriate for less-than-lifetime exposures. Risk determinations were based, in part, on quantitative risk characterization computed with this IUR. Risk management rulemaking that has been finalized addressed the unreasonable risk identified in Part 1 of the Risk Evaluation for Asbestos (U.S. EPA, 2020).

5.2.2 Dose-Response Considerations: Non-cancer

Application of the systematic review approach described in *White Paper: Quantitative Human Health Approach to be Applied in the Risk Evaluation for Asbestos Part 2 – Supplemental Evaluation including Legacy Uses and Associated Disposals of Asbestos* (U.S. EPA, 2023g) and Draft Systematic Review Protocol (U.S. EPA, 2021a) resulted in the identification of seven cohorts for consideration in assessing dose response of non-cancer outcomes related to asbestos exposures. EPA is using dose-response and exposure-response relationship interchangeable because it describes the amount of exposure/dose a person is exposed to. All of the cohorts identified examined inhalation exposures. Epidemiologic studies examining oral or dermal exposures with dose-response information were not identified by the systematic review approach. The outcomes assessed in the identified cohorts included non-cancer mortality (including asbestosis and pneumoconiosis), pleural changes/thickening, and lung function changes. Some of these cohorts were identified and considered in the IRIS LAA Assessment (U.S. EPA, 2014a), which is the only EPA assessment that has quantitatively considered non-cancer effects to date.

In evaluating all of the cohorts with dose-response information to determine which provides the most robust and relevant data for dose-response analysis (see Appendix C of the White Paper) an occupational cohort from the O.M. Scott plant in Marysville, OH described by Lockey et al. (1984) and followed up by Rohs et al. (2008) was selected. This cohort was selected for multiple reasons: (1) absence of confounding from community and residential exposure; (2) availability of data on significant covariates (*e.g.*, BMI); (3) exposure-response relationship defined for lower cumulative exposure levels (especially for workers hired in 1972 or later and evaluated in 2002-2005); (4) over 50 years of follow-up; (5) use of more recent criteria for evaluating radiographs (ILO, 2002); (6) availability of high quality exposure estimates based on numerous industrial hygiene samples and work records; and (7) availability of data on time since first exposure (TSFE) matched to the exposure data (U.S. EPA, 2014a). This cohort also has reliable individual-level measurements of asbestos exposures and detection of pleural thickening, an early adverse effect. The other six cohorts OPPT identified, which were not within the scope of the IRIS LAA Assessment, were less suitable for non-cancer dose-response assessment because the outcomes examined were less sensitive (*i.e.*, mortality-related outcomes) and/or because there was greater uncertainty in the exposure data (*e.g.*, community-based measurements rather than personal sampling). Generally, for dose-response assessment, preference is given to studies examining the most sensitive outcome(s), so although mortality can be used in the assessment, it is less sensitive than a well-described outcome preceding mortality from a disease state. Appendix C in the White Paper (U.S. EPA, 2023g) provides more details on the dose-response considerations for each cohort.

The O.M. Scott Marysville, Ohio, Plant Cohort included a total of 512 workers in the 1980 investigation of pulmonary effects in Ohio plant workers (Lockey et al., 1984). Workers were drawn from a variety of departments/facilities, including production and packaging of commercial products, maintenance, research, the front office, and the polyform plant. The initial study of this cohort utilized air sample measurements collected in 1972 to assign cumulative worker exposures based on individual job histories. Outcomes were assessed by radiologist readings of chest x-ray films and spirometry for lung function measures. A follow-up of this cohort was conducted nearly 25 years later, providing more robust exposure-response analyses (Rohs et al., 2008).

In this follow-up analysis (Rohs et al., 2008), the cohort was limited to men hired after 1972 as there was more certainty in the exposure estimates; post-1972 measurements were taken by industrial hygienists who followed employees during the course of their work with sampling devices. Sampling data were also collected within personal breathing zones beginning in 1977. Detailed employee records were used to construct exposure histories and estimate cumulative asbestos exposures for each individual. Health outcomes were assessed in 1980 and between 2002 and 2005; however, the use of different protocols was considered an uncertainty and the later film readings were deemed more reliable. In addition, the later radiographic films extended the follow-up time by roughly 25 years, which is important given the latency of effects. These considerations resulted in a sub-cohort of 119 men for which robust exposure and outcome data were available for dose-response modeling. With the data from the sub-cohort, a range of dose-response model forms were evaluated, but the most suitable model fitting results were obtained using the Dichotomous Hill model using the mean exposure and pleural thickening. Time since first exposure (TSFE) has been demonstrated to be an important predictor of effect, data from the broader cohort (including those hired prior to 1972) was used to develop a fixed regression coefficient that was included in the model. In the modeling, a benchmark response (BMR) of 10 percent was used based on considerations of adversity for LPT. The benchmark concentration is the level of exposure expected to result in the excess risk defined by the BMR. More specific details and results of model-fitting are presented in Section 5.2.2.6.1 in the IRIS LAA Assessment (U.S. EPA, 2014c). A POD based on a 10 percent BMR for LPT was calculated to be 2.6×10^{-2} fiber/cc.

The IRIS program noted important uncertainties related to the underlying evidence base for this POD and applied UFs to account for intraspecies variability (UF_H of 10), database uncertainty (UF_D of 3), and data-informed subchronic-to-chronic uncertainty (UF_S of 10) in the 2014 LAA Assessment (U.S. EPA, 2014c).

- Regarding the UF_H, the occupational cohort included individuals healthy enough to work, and when taking into account human variability, it is plausible that there are more sensitive individuals in the population. This uncertainty remains at this time; thus, UF_H of 10 continues to be applied.
- Regarding the UF_D of 3, applied in the IRIS LAA Assessment because of the limited number of cohort studies evaluating the most sensitive non-cancer effects of chronic asbestos exposure, the Agency has reevaluated the appropriateness of UF_D of 3 in light of the systematic review. As described in Section 4, no new cohort studies have been published that would inform the dose response relationship for hazards beyond pleural effects and asbestosis for the non-cancer POD. Therefore, the Agency will continue to apply a UF_D of 3.
- Regarding the UF_S, it was anticipated that if the cohort had been followed for longer, even more cases of LPT would have been identified. The cohort used to derive the 2014 IRIS RfC, O.M. Scott Marysville, Ohio, was followed for approximately 30 years. The IRIS LAA Assessment determined that it was appropriate to apply a UF_S because even 30 years of observation is insufficient to describe lifetime risk of LPT, which continues to increase over a person's lifetime (see page 5-42 of the IRIS LAA Assessment for further rationale for applying the UF_S (U.S. EPA, 2014a)). The IRIS LAA Assessment, therefore, derived a data informed UF_S of 10 based on the fact that "the central estimate of the risk at TSFE = 70 years is ~10-fold greater than the central estimate of the risk at TSFE = 28 years (from 6 to 61%)" (see page 5-43 of the IRIS LAA Assessment for further details (U.S. EPA, 2014a). TSFE in the model was set at 28 years due to limitations in the statistical uncertainty.

5.2.2.1 Point of Departure for Part 2

In thoroughly reviewing the reasonably available information and the LAA POD from the IRIS assessment, using the POD in Part 2 of the Risk Evaluation is a reliable approach to quantitatively consider non-cancer risks from asbestos exposures. While there is some uncertainty in application of a Libby-specific POD for exposures to a broader range of asbestos fibers, the uncertainty of using other studies for quantitative assessment would be even greater given the limited exposure characterization for those cohorts (see Appendix M in this document and Appendix C of the White Paper). For example, for the SC Vermiculite Miners Cohort, non-cancer outcomes were only categorically analyzed as exposed and unexposed. In addition, details of the exposure assessment are insufficient for dose-response assessment, and there is a lack of information on TSFE. The Anatolia, Turkey, Villagers Cohort constructed individual-level exposure estimates, but these were based on broad assumptions of time spent indoors, outdoors, and sleeping. The other cohorts available for dose-response assessment similarly had exposures to a single fiber type and examined mortality as the outcome, which would not be representative of the more sensitive effects known to result from asbestos exposures.

Based on the comprehensive approach to identify and evaluate the relevant epidemiologic literature for dose-response assessment of non-cancer effects resulting from asbestos exposures, use of the POD presented in the IRIS LAA Assessment is appropriate. In the IRIS LAA Assessment, LPT was selected as the critical non-cancer effect for POD selection with a BMR of 10 percent extra risk. LPT, as indicated by the presence of pleural plaques is the most effective endpoint to select because it is the outcome that generally appears at lower doses after asbestos inhalation exposure. Reduced lung function is typically linked to LPT, which is an irreversible structural and pathological modification of the pleura. Using a non-lethal POD, like LPT, instead of asbestosis or mortality means that if the EPA could prevent people from developing LPT, this would mitigate them getting asbestosis and avoid mortality. In summary, non-cancer risks will be calculated using the IRIS LAA POD of 2.6×10^{-2}. The uncertainty factors presented in the IRIS LAA Assessment will be considered in establishing the benchmark MOE, described in Section 5.3.

5.2.3 Mode of Action Considerations

EPA assessed potential modes of action (MOA) for asbestos based on existing literature, including previous EPA IRIS Assessment (U.S. EPA, 2014c), EPA Asbestos Part 1 Risk Evaluation (U.S. EPA, 2020c), and proposed mechanisms by IARC (2012a). It has been hypothesized that asbestos, may act through multiple MOAs with adverse health effects resulting from the collective interaction of various toxicity determinants. Additionally, physical, and chemical characteristics of fibers such as dimensions, chemical composition, surface characteristics, and biopersistence appear to influence their pathogenic potential. Although the precise MOA of asbestos induced malignant and non-malignant respiratory diseases remains unclear, numerous studies have proposed several direct and indirect mechanisms to explain the biological activity of asbestos fibers (U.S. EPA, 2014c; IARC, 2012a; ATSDR, 2001). Furthermore, both *in vitro* and *in vivo* studies have indicated that asbestos fiber exposure could lead to sustained oxidative stress due to the generation of reactive oxygen species through interactions with macrophages and the production of hydroxyl radicals from surface-bound iron (U.S. EPA, 2020c, 2014c; IARC, 2012a). Persistent oxidative stress and chronic inflammation induced by asbestos fibers have been linked to the aberrant activation of intracellular signaling pathways, which may lead to increased cellular proliferation, impaired DNA damage repair, and oncogene activation (U.S. EPA, 2014c; IARC, 2012a). Asbestos fibers have also been shown to induce direct genotoxicity through interference with mitotic spindle leading to chromosome aberrations (IARC, 2012a). Overall, existing evidence suggests that oxidative stress, chronic inflammation, and associated cell injury may play pivotal roles in both cancerous and non-cancerous health effects following asbestos exposure. However, the extent to which these and other biological alterations serve as key events in asbestos-related pathogenicity has not yet been fully elucidated.

Overall MOA Conclusions

Although the evidence largely indicates an MOA involving long-term interplay between chronic oxidative stress and persistent inflammation, the available data are insufficient to establish an MOA for non-cancer or cancer health effects following asbestos exposure. Hence, the cancer unit risk for inhalation exposure is calculated using a linear approach in accordance with the default recommendation of the 2005 Guidelines for Carcinogen Risk Assessment (U.S. EPA, 2005).

5.3 Human Health Risk Characterization

Asbestos – Human Health Risk Characterization (Section 5.3):
Key Points

EPA evaluated all reasonably available information to support human health risk characterization. The following bullets summarize the key points of this section of the Part 2 risk evaluation:

- Inhalation exposures drive risks to workers in occupational settings, and both lifetime cancer Excess Lifetime Cancer Risks (ELCRs) and non-cancer chronic MOEs are in the range of 1.8×10^{-7} to 1.5×10^{-3} and, 0.16 to 1,424, respectively.
- The take-home exposure risk assessment lifetime cancer and non-cancer risk values, ELCR and MOEs, are in the range of 4.8×10^{-9} to 3.7×10^{-4}, and 11 to 840,437, respectively for most high-end exposure activities, such as demolition/renovation, career firefighting, repair/removal of machinery, handling of articles or formulations, and handling waste.
- DIY activity-base exposures result in lifetime cancer and non-cancer risk values, ELCR and MOEs, range of 8.4×10^{-9} to 2.3×10^{-2}, and 0.1 to 774,424, respectively.
- The general population exposure assessment considers people living at certain distances from an occupational asbestos release activity. Lifetime cancer risk values, ELCR, are in the range of 2.2×10^{-11} to 8.6×10^{-4}. Non-cancer chronic, MOE, risk estimates range from 12 to 2.7×10^{11}.

5.3.1 Risk Characterization Approach

The use scenarios, populations of interest and toxicological endpoints used for lifetime and chronic exposures are presented in Table 5-1.

Table 5-20. Use Scenarios, Populations of Interest and Toxicological Endpoints Used for Acute and Chronic Exposures

Population of Interest and Exposure Scenario	**Workers** Chronic and Lifetime – Adolescent (≥16 years old) and adult workers exposed to asbestos for the entire 8-hr workday for up to 250 days per year for 40 working years
	Occupational non-users Chronic and Lifetime – Adolescent (≥16 years old) and adult workers exposed to asbestos for the entire 8-hr workday for up to 250 days per year for 40 working years
	Take-Home Garment Handlers Chronic and Lifetime – Adolescent (≥16 years old) and adults exposed to asbestos during handling of clothing contaminated with asbestos from occupational activities, for 40 working years
	Consumers Lifetime and Chronic – Adolescent (≥16 years old) and adult DIYers exposed to asbestos fibers for a long period of time during an activity
	General Population Lifetime and Chronic – All genders and age groups in indoor environments exposed to asbestos fibers infiltrating from outside from occupational exposure activities and disposal releases
	Bystanders Lifetime and Chronic – Individuals of all ages exposed to asbestos fibers through DIYers and take-home activities.
Health Effects, Concentration and Time Duration	**Non-cancer Hazard Value** **POD:** The POD derived from epidemiologic data represents a chronic, lifetime value for continuous exposure and exposure concentrations have been adjusted to match the time duration for inhalation exposure. 2.6E−02 fiber/cc **Most sensitive and robust non-cancer health effects**[a] Chronic – Localized pleural thickening of pleura in humans based on epidemiologic data from an occupational cohort (see Section 5.2.1)

Uncertainty Factors (UF) and Risk Estimate Calculations	*Benchmark MOE* = 300 for the most sensitive and robust endpoint ***Benchmark MOE*** = $(UF_S) \times (UF_H) \times (UF_D)$ [b] = 10 × 10 × 3 -- **Equation 5-2. Equation to Calculate Non-cancer Risks** $$MOE_{chronic} = \frac{Non - cancer\ Hazard\ value\ (POD)}{Human\ Exposure}$$ Where: *MOE* = margin of exposure (unitless) *Hazard value (POD)* = *POD* (f/cc) *Human Exposure* = Exposure estimate (f/cc) from occupational (see Appendix G), take-home (see Section 5.1.2), consumer (see Section 5.1.3), and general population (see Section 5.1.40) **---** **Cancer Hazard Value** **IUR:** The inhalation unit risk value derived from epidemiologic data represents the upper-bound excess lifetime cancer risk estimated to result from continuous exposure (per fiber/cc). For asbestos, the underlying epidemiologic data accounts for exposure to a range of fibers and for cancers including mesothelioma, lung, laryngeal, and ovarian. **---** **Equation 5-3. Equation to Calculate Lifetime Cancer Risk** $$ELCR = EPC \times TWF \times IUR_{LTL\ or\ Lifetime}$$ Where: *ELCR* = Excess Lifetime Cancer Risk, the risk of developing cancer as a consequence of the site-related exposure *EPC* = Exposure Point Concentration, the concentration of asbestos fibers in air (f/cc) for the specific activity being assessed $IUR_{LTL\ or\ Lifetime}$ = Inhalation Unit Risk per (f/cc) Less than Lifetime or Lifetime *TWF* = Time Weighting Factor, this factor accounts for less-than-continuous exposure during a 1-year exposure

[a] Exposures earlier in life result in greater risk, as time since first exposure is a strong predictor of effect.
[b] UF_S = subchronic to chronic UF; UF_H = intraspecies UF; UF_D = database

EPA considered exposures to asbestos for the entire 8-hour workday for up to 250 days per year for 40 working years. Non-cancer risks from exposure in occupational settings are assessed by first calculating the MOE using Equation 5-2, where human exposure is defined by the average daily concentration (ADC). The calculated MOE is then compared to the benchmark MOE of 300. **If the numerical value of the MOE is less than the benchmark MOE, this is a starting point to determine if there are unreasonable non-cancer risks.** Chronic cancer risks from exposure in occupational settings are assessed by calculating the Excess Lifetime Cancer Risk (ELCR) using Equation 5-3, where the exposure point concentration is equal to the 8-hour TWA concentration for the occupational use. The calculated ELCR is then compared to the benchmark ELCR. **If the calculated ELCR is greater than the benchmark ELCR, this is a starting point to determine if there are unreasonable cancer risks.** For information on how the ADC and 8-hour TWA concentrations are calculated, see Appendix G.

Inhalation non-cancer and lifetime-cancer risk estimates from take-home exposures are calculated using yearly average concentrations summarize in Section 5.1.2 with the specific considerations of POD (MOE) and IUR (ELCR) values. Consumer DIY inhalation non-cancer and lifetime-cancer risk estimates are calculated using the scenario specific exposure point concentration and exposure duration parameters described in Section 5.1.3.1 and using Equation 5-2 and Equation 5-3. Similarly, general population inhalation non-cancer and lifetime-cancer risk estimates are calculated using releases of asbestos to ambient air and unique scenario exposure durations summarized in Section 5.1.40 and using Equation 5-2 and Equation 5-3 to obtain MOE and ELCR estimates.

EPA considers a range of extra cancer risk from 1×10^{-4} to 1×10^{-6} to be relevant benchmarks for risk assessment. Consistent with NIOSH guidance, under TSCA, EPA typically applies a 1×10^{-4} benchmark for occupational scenarios in industrial and commercial work environments subject to OSHA requirements; and EPA typically applies a 1×10^{-6} benchmark for consumer uses. In addition, the Agency typically considers the general population benchmark for cancer risk to be within the range of 1×10^{-6} and 1×10^{-4}. Again, it is important to note that these benchmarks are not bright lines and EPA has discretion to find unreasonable risks based on other risk-related considerations based on analysis. Exposure-related considerations (*e.g.*, duration, magnitude, population exposed) can affect EPA's estimates of the excess lifetime cancer risk.

5.3.2 Summary of Human Health Risk Characterization

5.3.2.1 Summary of Risk Estimates for Workers

This section presents a summary of occupational risk characterization for each occupational exposure scenario (OES), and Table 5-21 summarizes the risk estimates for inhalation exposures for all OESs. The crosswalk between OESs and COUs can be found in Table 3-1, and EPA expects that the data within an OES are representative of all COU subcategories mapped to the OES. The occupational exposure assessment is presented in Section 5.1.1, and all uncertainties and assumptions associated with the occupational exposure assessment are described in Section 5.1.1.4.1. It is important to note that all occupational inhalation exposures are based on monitoring data. With the exception of two OESs (*i.e.*, handling of vermiculite-containing products and mining of non-asbestos commodities), all occupational exposure estimations are quantitative analyses. The basis in the development of occupational exposure scenarios for this risk evaluation is that friable asbestos is modified (*e.g.*, removed, sanded, cut, disturbed) to release fibers. An asbestos containing product that stays in place without any modification done to it is not expected to result in releases, and hence no human exposures and risks are expected. Monitoring data were collected from OSHA's Chemical Exposure Health Data (CEHD) database. These data were mapped using SIC codes without specific information on worker activities. As a result, there is some uncertainty in the mapping of OSHA CEHD data to similar exposure groups under each OES.

Current federal regulations mitigate asbestos exposure through actions such as exposure limits for workers (OSHA), bans of certain asbestos materials or garments (CPSA and FHSA), and protections for schools (AHERA). The mitigations utilized during area and personal sampling underlying the exposure estimates for this assessment varied and were not always reported. Additionally, EPA recognizes that guidelines may not always be followed due to lack of knowledge regarding asbestos identification, removal, handling, and disposal, as well as personal choice. To account for these uncertainties, the exposure scenarios in this risk evaluation did not assume compliance with existing federal regulations.

Handling Asbestos-Containing Building Materials During Maintenance, Renovation, and Demolition Activities

For chronic non-cancer inhalation exposures, high-end MOE values ranged from 1.3 to 12 and central tendency MOE values ranged from 43 to 514. For chronic cancer inhalation exposures, high-end ELCR values ranged from 2.0×10^{-5} to 1.9×10^{-4} and central tendency ELCR values ranged from 4.9×10^{-7} to 5.8×10^{-6}.

There were two orders of magnitude variation in the values of the central tendency and high-end risk estimates for two of the three Similar Exposure Groups (SEGs) assessed in this OES. These differences are explained below for each SEG:

- *Higher Exposure-Potential Workers:* There was a large amount of data for workers in this SEG (847 monitoring data points). The central tendency exposure value for this group was 0.001 f/cc, while the high-end value was 0.429 f/cc. Workers in this SEG included asbestos removal workers, insulation workers, demolition workers, and maintenance personnel. A total of 467 data points for this SEG were found in OSHA's CEHD database, and 317 of these data points were non-detects. For these samples, EPA estimated potential asbestos concentrations using the LOD of 2,117.5 fibers/sample based on NIOSH Method 7400. The samples evaluated with this method averaged concentrations around 0.001 f/cc for 8-hour TWAs. This large group of non-detects and zero asbestos concentration samples resulted in a large deviation between the central tendency and high-end results for this SEG.
- *Lower Exposure-Potential Workers:* There were only 31 monitoring datapoints included for the workers in this SEG. The central tendency exposure value for this group was 0.001 f/cc, while the high-end value was 0.219 f/cc. Similar to the SEG for Higher Exposure-Potential Workers, a majority of the samples came from OSHA's CEHD database. All 17 samples were non-detects. For these samples, EPA again estimated potential asbestos concentrations using the LOD of 2,117.5 fibers/sample based on NIOSH Method 7400. The samples evaluated with this method averaged concentrations around 0.001 f/cc for 8-hour TWAs. This large group of non-detects and zero asbestos concentration samples resulted in a large deviation between the central tendency and high-end results for this SEG.
- *Occupational Non-users:* There was a smaller variation in the exposure data for this SEG; the central tendency exposure value for this group was 0.012 f/cc, while the high-end (maximum) value was 0.05 f/cc. There was a total of 103 datapoints for this group, 100 of which came from one source that only provided the arithmetic mean of the data. This lack of data resulted in a small range between the central tendency and high-end exposure estimates.

It is important to note that worker responsibilities may vary on a daily basis, and a worker may be involved with either higher exposure potential or lower exposure potential activities as needed by the specific project. It is also pertinent to note that the large number of non-detect exposure values for higher and lower exposure potential workers may have led to artificially reduced inhalation exposure values of central tendency for workers. Because workers may shift responsibilities as needed, and because of the large number of non-detect exposure values that may have led to reduced central tendency estimates for workers, EPA assumes that risk to workers involved with demolition, maintenance, and renovation of structures containing asbestos is most reflected by the high-end of the higher exposure potential worker group.

Regarding ONU risk characterization, ONUs assessed for this OES had higher central tendency chronic (non-cancer) inhalation exposures and ELCR values than worker estimates. This is due to a lack of data sources for ONU inhalation monitoring data. Exposure estimates for ONUs were based on a total of 103 data points, 100 of which came from a single source (Bailey et al., 1988) while another source provided the remaining 3 (Boelter et al., 2016). The first source did not provide the raw data, but gave the mean for the data of 0.04 f/cc. Boelter et al. provided samples of 0.0008, 0.017, and 0.046 f/cc. Because Bailey *et al.* (1988) only provided the mean value of exposure data, it was not possible to determine an accurate value of central tendency (*i.e.,* 50th percentile) from the overall pool of data for the OES. However, based on the available data for the OES described above, it can be confidently stated that the highest measured concentration of asbestos was 0.046 f/cc from Boetler *et al.*(2016). The high-end data point was captured using reliable monitoring methods and is also consistent with the data collected by Bailey *et al.* (1988). Therefore, EPA assumes that risk to ONUs involved with demolition, maintenance, and renovation of structures containing asbestos is most reflected by the high-end of the ONU exposure data.

Based on the strengths and limitations of the data described above, the confidence rating for the inhalation data used to characterize the inhalation exposures from maintenance, renovation, and demolition activities was assigned as moderate.

Handling Asbestos-Containing Building Materials During Firefighting or Other Disaster Response Activities

For chronic non-cancer inhalation exposures, high-end MOE values ranged from 25 to 74 and central tendency MOE values ranged from 475 to 1,424. For chronic cancer inhalation exposures, high-end ELCR values ranged from 3.4×10^{-6} to 1.0×10^{-5} and central tendency ELCR values ranged from 1.8×10^{-7} to 5.3×10^{-7}.

There was an order of magnitude difference in the values for the central tendency and high-end exposure estimates for the workers assessed in this OES. There were 62 monitoring data points for the workers in this OES. The central tendency exposure value for this group was 0.02 f/cc, while the high-end value was 0.39 f/cc. Activities for the workers in this OES included truck and heavy equipment operation, general labor, and cleanup after fires, earthquakes, and other disasters (including 9/11 cleanup). The monitoring data collected for these activities varied, with datapoints for 9/11 debris and fire cleanup having the highest asbestos concentrations of 0.54 and 0.4 f/cc respectively. The low value for the central tendency exposure estimate was primarily a result of 24 non-detect datapoints, 22 of which were taken from a study where workers were assisting in the cleanup effort from a fire (Lewis and Curtis, 1990). The asbestos concentrations in the samples were conservatively estimated as half of the author provided LOD for the sampling method in the study. The samples evaluated with this method had calculated concentrations between 0.003 to 0.005 f/cc for 8-hour TWAs. This group of non-detects and zero asbestos concentration samples resulted in a large deviation between the central tendency and high-end results for this OES. Because of the large number of non-detect exposure values that may have led to reduced central tendency estimates for workers, EPA assumes that risk to workers involved with firefighting and disaster response activities is most reflected by the high-end of the worker group. Based on the strengths and limitations of the data described above, the confidence rating for the inhalation data used to characterize the inhalation exposures from firefighting and disaster response activities was assigned as moderate to robust.

Use, Repair, or Removal of Industrial and Commercial Appliances or Machinery Containing Asbestos

For chronic non-cancer inhalation exposures, high-end MOE values ranged from 0.72 to 2.3 and central tendency MOE values ranged from 4.1 to 14. For chronic cancer inhalation exposures, high-end ELCR values ranged from 1.1×10^{-4} to 3.5×10^{-4} and central tendency ELCR values ranged from 1.9×10^{-5} to 6.1×10^{-5}.

There were two orders of magnitude difference in the values of the central tendency and high-end risk estimates for the two SEGs assessed in this OES. These differences are explained below for each SEG:

- *Workers:* There was a total of 216 monitoring data points for workers in this SEG. The central tendency exposure value for this group was 0.008 f/cc, while the high-end value was 0.157 f/cc. Workers in this SEG included heavy machinery workers, mechanics, and engine workers, while worker activities ranged from engine repair to working with asbestos insulation on furnaces. These activities varied in their potential for worker exposure to asbestos, and likely contributed to the difference between the central tendency and high-end exposure estimates. Another contributor may have been the considerable number of samples that were sourced from a study conducted by Mlynarek and Van Orden at one site where workers we reperforming maintenance on an airplane engine (Mlynarek and Van Orden, 2012). This study provided 114 monitoring datapoints for workers in this OES that averaged asbestos concentrations of 0.006 f/cc, which lowered the central tendency estimate for this SEG.
- *Occupational Non-users:* There was a smaller variation in the exposure data for this SEG; the central tendency exposure value for this group was 0.028 f/cc, while the high-end (maximum) value was 0.049 f/cc. There were a total of 20 datapoints for this group, all of which came from the study conducted by Mlynarek & Orden (Mlynarek and Van Orden, 2012). This lack of data resulted in a small range between the central tendency and high-end exposure estimates.

PBZ monitoring data used to estimate worker exposure showed high-end and central tendency exposure levels that exceeded the benchmark MOE for the chronic (non-cancer) endpoint, as well as high-end chronic (cancer) exposure levels that exceeded the benchmark ELCR. Because the analysis contained 114 monitoring datapoints for workers in this OES that averaged asbestos concentrations of 0.006 f/cc, artificially lowering the central tendency estimate for this SEG, EPA assumes that risk to workers involved with use, repair, and removal of machinery or appliances containing asbestos is most reflected by the high-end of the worker group.

ONUs assessed for this OES had higher central tendency chronic (non-cancer) inhalation exposures and ELCR values than worker estimates (ELCR values were 7.6×10^{-4} for ONUs and 2.3×10^{-4} for workers). This is due to a lack of data sources for ONU inhalation monitoring data. Exposure estimates for ONUs were all collected from the study conducted by Mlynarek & Orden (2012). The source did not provide the raw data but gave two mean values taken from two groups of ten samples that were taken from bystanders in the workshop while workers were performing a high-risk activity (disassembling/ reassembling an aircraft engine). Due to the lack of information regarding the full distribution of exposure data, it was not possible to determine an accurate value of central tendency (*i.e.*, 50th percentile) from the overall pool of data for the OES. Because the true distribution of data is not certain from the available data, EPA assumes that the risk to ONUs involved with use, repair, and removal of machinery is most reflected by the larger of the two mean values from Mlynarek & Orden (2012) which is associated with high-end ONU exposure for the OES.

During use, repair, or removal of appliances or machinery, workers may be exposed to asbestos from legacy gaskets. However, EPA estimated occupational exposure to asbestos from gasket removal and handling in the *Risk Evaluation for Asbestos Part 1: Chrysotile Asbestos* (U.S. EPA, 2020c), and this estimate extends to the removal and handling of legacy gaskets. For occupational exposure estimates associated with legacy gasket removal and handling, please see the *Risk Evaluation for Asbestos Part 1: Chrysotile Asbestos* (U.S. EPA, 2020c).

Based on the strengths and limitations of the data described above, the confidence rating for the inhalation data used to characterize the inhalation exposures from use, repair, or removal of machinery or appliances was assigned as moderate to robust.

Handling Articles or Formulations that Contain Asbestos

For chronic non-cancer inhalation exposures, high-end MOE values ranged from 3.5×10^{-2} to 10 and central tendency MOE values ranged from 0.81 to 106. For chronic cancer inhalation exposures, high-end ELCR values ranged from 2.4×10^{-5} to 7.2×10^{-3} and central tendency ELCR values ranged from 2.4×10^{-6} to 3.1×10^{-4}.

There was an order of magnitude variation in the values of the central tendency and high-end risk estimates for two of the three SEGs assessed in this OES. These differences are explained below for each SEG:

- *Higher Exposure-Potential Workers:* There were a total of 69 monitoring data points for workers in this SEG. The central tendency exposure value for this group was 0.14 f/cc, while the high-end value was 3.3 f/cc. Worker activities for this SEG included working with asbestos-containing plastics, sanding asbestos-containing joint compounds, and processing/using asbestos-containing coatings, adhesives, and sealants. A total of 6 data points for this SEG were found in OSHA's CEHD database, all of which were zero values or non-detects. For these samples, EPA estimated potential asbestos concentrations using the LOD of 2,117.5 fibers/sample based on NIOSH Method 7400. The samples evaluated with this method averaged concentrations around 0.001 f/cc for 8-hour TWAs. There was also a group of 13 datapoints for workers handling asbestos-containing window caulking that had a maximum 8-hour TWA value of 0.05 f/cc; further lowering the central tendency value. In addition, two studies for pole sanding of asbestos-containing joint compound provided samples with high levels of asbestos concentrations. The first study provided two groups of samples that averaged 8-hour TWAs of 0.99 f/cc (6 samples) and 0.62 f/cc (5 samples) (Brorby et al., 2013); originally from Rhodes and Ingalls (1976). The second study provided sampling data for workers during pole sanding, hand sanding, and sweeping that had average 8-hour TWAs of 1.3 f/cc (10 samples), 0.66 f/cc (11 samples), and 4.2 f/cc respectively (Rohl et al., 1975). Data collected during these asbestos-generating activities had the effect of raising the estimate for high-end exposure for this SEG. These groups of non-detects and low asbestos concentration samples combined with the groups of high concentration samples resulted in a deviation between the central tendency and high-end results for this SEG.
- *Lower Exposure-Potential Workers:* There were only seven monitoring datapoints included for the workers in this SEG. The central tendency exposure value for this group was 0.008 f/cc, while the high-end value was 0.011 f/cc. One non-detect sample came from OSHA's CEHD database. EPA again estimated potential asbestos concentrations using the LOD of 2,117.5 fibers/sample based on NIOSH Method 7400. The sample evaluated with this method had a concentration around 0.001 f/cc for an 8-hour TWA. The remaining samples were taken from one study that sampled laboratory workers (8-hour TWAs were between 0.009-0.012 f/cc). The

following COUs are best represented by the Lower Exposure-Potential Workers SEG of the Handling Articles or Formulations that Contain Asbestos OES since these COUs are expected to contain asbestos at levels similar to other articles assessed but are expected to have minimal handling: artifacts, electrical batteries, accumulators; packaging (excluding food packaging), plastics (hard and soft), and rubber articles.

- *Occupational Non-users:* There was a larger variation in the exposure data for this SEG; the central tendency exposure value for this group was 0.0011 f/cc, while the high-end value was 0.84 f/cc. There were 16 datapoints in total for this group, 7 of which were non-detect samples taken from OSHA's CEHD database. The remaining 9 data points were area background samples taken from the study conducted by Rohl et al. (1975) while workers performed sanding activities on asbestos-containing joint compound. These groups of non-detects combined with the group of high concentration samples resulted in a deviation between the central tendency and high-end results for this SEG.

Based on the strengths and limitations of the data described above, the confidence rating for the inhalation data used to characterize the inhalation exposures from articles or formulations that contain asbestos was assigned as moderate.

Waste Handling, Disposal, and Treatment

For chronic non-cancer inhalation exposures, the high-end MOE value for workers was 3.6 and the central tendency MOE value for workers was 77. For chronic cancer inhalation exposures, the high-end ELCR value for workers was 6.9×10^{-5} and the central tendency ELCR value for workers was 3.2×10^{-6}. There were no ONU data available for this OES, therefore, central tendency worker estimates were applied as an approximation of likely ONU exposures.

There was a significant difference in the values for the central tendency and high-end exposure estimates for the workers assessed in this OES. There were 95 monitoring data points for the workers in this OES. The central tendency exposure value for this group was 0.001 f/cc, while the high-end value was 0.032 f/cc. A total of 36 data points for this SEG were found in OSHA's CEHD database, and 35 of these data points were non-detects. For these samples, EPA estimated potential asbestos concentrations using the LOD of 2,117.5 fibers/sample based on NIOSH Method 7400. The samples evaluated with this method averaged concentrations around 0.001 f/cc for 8-hour TWAs. This large group of non-detects and zero asbestos concentration samples resulted in a large deviation between the central tendency and high-end results for this SEG. Because of the large number of non-detect exposure values that may have led to reduced central tendency estimates for workers, EPA assumes that risk to workers involved with disposal of asbestos-containing materials is most reflected by the high-end of the worker group.

Based on the strengths and limitations of the data described above, the confidence rating for the inhalation data used to characterize the inhalation exposures from waste handling, disposal, and treatment was assigned as moderate.

Handling of Vermiculite-Containing Products for Agricultural and Laboratory Purposes

Qualitative assessment of vermiculite-containing products for agricultural and laboratory use indicates that risk of asbestos exposure is not expected during occupational use. See Appendix G.14 for more details.

Mining of Non-asbestos Commodities

Qualitative assessment of asbestos exposure during the mining of non-asbestos commodities indicates that risk of asbestos exposure is not expected. See Appendix G.15 for more details.

Table 5-21. Occupational Risk Estimates Summary

Life Cycle Stage/ Category	Subcategory	OES	Endpoint	Benchmark MOE or ELCR[a]	Population[b]	Exposure Route and Duration[c]	Exposure Level	Inhalation Monitoring: No PPE Worker MOE or ELCR[a]	Inhalation Monitoring: APF = 10 Worker MOE or ELCR[a]	Inhalation Monitoring: APF = 50 Worker MOE or ELCR[a]
Industrial/ Commercial Uses	Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities	Chronic non-cancer	300	Higher Exposure-Potential Worker	Inhalation 8-hr TWA	High-End	1.3	13	66
							Central Tendency	514	5,137	2.6E04
					Lower Exposure-Potential Worker		High-End	2.6	26	130
							Central Tendency	509	5,092	2.5E04
					ONU		High-End	12	–	–
							Central Tendency	46	–	–
	Construction and building materials covering large surface areas, including fabrics, textiles, and apparel	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities	Cancer	1E−04	Higher Exposure-Potential Worker	Inhalation 8-hr TWA	High-End	1.9E−04	1.9E−05	3.8E−06
							Central Tendency	4.9E−07	4.9E−08	9.7E−09
					Lower Exposure-Potential Worker	Inhalation 8-hr TWA	High-End	9.6E−05	9.6E−06	1.9E−06
							Central Tendency	4.9E−07	4.9E−08	9.8E−09
					ONU	Inhalation 8-hr TWA	High-End	2.0E−05	–	–
							Central Tendency	5.4E−06	–	–
Industrial/ Commercial Uses	Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles;	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities	Chronic non-cancer	300	Higher Exposure-Potential Worker	Inhalation Short-Term	High-End	1.4	14	69
							Central Tendency	219	2,191	1.1E04
					Lower Exposure-Potential Worker	Inhalation Short-Term	High-End	2.7	27	137
							Central Tendency	218	2,183	1.1E04
					ONU	Inhalation Short-Term	High-End	12	–	–
							Central Tendency	43	–	–

Life Cycle Stage/ Category	Subcategory	OES	Endpoint	Benchmark MOE or ELCR[a]	Population[b]	Exposure Route and Duration [c]	Exposure Level	Inhalation Monitoring: No PPE Worker MOE or ELCR[a]	Inhalation Monitoring: APF = 10 Worker MOE or ELCR[a]	Inhalation Monitoring: APF = 50 Worker MOE or ELCR[a]
Industrial/ Commercial Uses	Construction and building materials covering large surface areas, including fabrics, textiles, and apparel	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities	Cancer	1E−04	Higher Exposure-Potential Worker	Inhalation Short-Term	High-End	1.8E−04	1.8E−05	3.6E−06
							Central Tendency	1.1E−06	1.1E−07	2.3E−08
					Lower Exposure-Potential Worker	Inhalation Short-Term	High-End	9.1E−05	9.1E−06	1.8E−06
							Central Tendency	1.1E−06	1.1E−07	2.3E−08
					ONU	Inhalation Short-Term	High-End	2.0E−05	–	–
							Central Tendency	5.8E−06	–	–
Industrial/ Commercial Uses	Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles; Construction and building materials covering large surface areas, including fabrics, textiles, and apparel	Handling asbestos-containing building materials during firefighting or other disaster response activities	Chronic non-cancer	300	Firefighters (Career)	Inhalation 8-hr TWA	High-End	25	246	1,231
							Central Tendency	475	4,745	2.4E04
					Firefighters (Volunteer)	Inhalation 8-hr TWA	High-End	74	739	3,693
							Central Tendency	1,424	1.4E04	7.1E04
		Handling asbestos-containing building materials during firefighting or other disaster response activities	Cancer	1E−04	Firefighters (Career)	Inhalation 8-hr TWA	High-End	1.0E−5	1.0E−6	2.0E−7
							Central Tendency	5.3E−7	5.3E−8	1.1E−8
					Firefighters (Volunteer)	Inhalation 8-hr TWA	High-End	3.4E−6	3.4E−7	6.8E−8
							Central Tendency	1.8E−7	1.8E−8	3.5E−9
	Machinery, mechanical	Use, repair, or removal of	Chronic non-cancer	300	Worker	Inhalation 8-hr TWA	High-End	0.73	7.3	36

Life Cycle Stage/ Category	Subcategory	OES	Endpoint	Benchmark MOE or ELCR[a]	Population[b]	Exposure Route and Duration [c]	Exposure Level	Inhalation Monitoring: No PPE Worker MOE or ELCR[a]	Inhalation Monitoring: APF = 10 Worker MOE or ELCR[a]	Inhalation Monitoring: APF = 50 Worker MOE or ELCR[a]
Industrial/ Commercial Uses	appliances, electrical/electronic articles Other machinery, mechanical appliances, electronic/electronic articles	industrial and commercial appliances or machinery containing asbestos					Central Tendency	14	135	674
					ONU	Inhalation 8-hr TWA	High-End	2.3	–	–
							Central Tendency	4.1	–	–
		Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	Cancer	1E−04	Worker	Inhalation 8-hr TWA	High-End	3.4E−4	3.4E−5	6.9E−6
							Central Tendency	1.9E−5	1.9E−6	3.7E−7
					ONU	Inhalation 8-hr TWA	High-End	1.1E−4	–	–
							Central Tendency	6.1E−5	–	–
Industrial/ Commercial Uses	Machinery, mechanical appliances, electrical/electronic articles Other machinery, mechanical appliances, electronic/electronic articles	Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	Chronic non-cancer	300	Worker	Inhalation Short-Term	High-End	0.72	7.2	36
							Central Tendency	13	125	625
					ONU	Inhalation Short-Term	High-End	No Data	No Data	No Data
							Central Tendency	No Data	No Data	No Data
		Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	Cancer	1E−04	Worker	Inhalation Short-Term	High-End	3.5E−4	3.5E−5	6.9E−6
							Central Tendency	2.0E−5	2.0E−6	4.0E−7
					ONU	Inhalation Short-Term	High-End	No Data	No Data	No Data
							Central Tendency	No Data	No Data	No Data
Industrial/ Commercial Uses	Electrical batteries and accumulators Solvent-based/water-based paint	Handling articles or formulations that contain asbestos	Chronic non-cancer	300	Higher Exposure-Potential Worker	Inhalation 8-hr TWA	High-End	3.5E-2	0.35	1.7
							Central Tendency	0.81	8.1	41
					Lower Exposure-	Inhalation 8-hr TWA	High-End	10	103	513

Life Cycle Stage/ Category	Subcategory	OES	Endpoint	Benchmark MOE or ELCR[a]	Population[b]	Exposure Route and Duration [c]	Exposure Level	Inhalation Monitoring: No PPE Worker MOE or ELCR[a]	Inhalation Monitoring: APF = 10 Worker MOE or ELCR[a]	Inhalation Monitoring: APF = 50 Worker MOE or ELCR[a]
Industrial/ Commercial Uses	Fillers and putties Furniture & furnishings including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles Packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft) Other (artifacts) Other (aerospace applications)				Potential Worker		Central Tendency	14	138	690
					ONU	Inhalation 8-hr TWA	High-End	0.14	–	–
							Central Tendency	104	–	–
		Handling articles or formulations that contain asbestos	Cancer	1E−04	Higher Exposure-Potential Worker	Inhalation 8-hr TWA	High-End	7.2E−03	7.2E−04	1.4E−04
							Central Tendency	3.1E−04	3.1E−05	6.1E−06
					Lower Exposure-Potential Worker	Inhalation 8-hr TWA	High-End	2.4E−05	2.4E−06	4.9E−07
							Central Tendency	1.8E−05	1.8E−06	3.6E−07
					ONU	Inhalation 8-hr TWA	High-End	1.8E−03	–	–
							Central Tendency	2.4E−06	–	–
Industrial/ Commercial Uses	Electrical batteries and accumulators Solvent-based/water-based paint Fillers and putties Furniture & furnishings including stone, plaster,	Handling articles or formulations that contain asbestos	Chronic Non-cancer	300	Higher Exposure-Potential Worker	Inhalation Short-Term	High-End	3.7E−02	0.37	1.8
							Central Tendency	0.84	8.4	42
					Lower Exposure-Potential Worker	Inhalation Short-Term	High-End	8.7	87	436
							Central Tendency	13	126	632
					ONU	Inhalation Short-Term	High-End	0.14	–	–
							Central Tendency	106	–	–

Life Cycle Stage/ Category	Subcategory	OES	Endpoint	Benchmark MOE or ELCR[a]	Population[b]	Exposure Route and Duration[c]	Exposure Level	Inhalation Monitoring: No PPE Worker MOE or ELCR[a]	Inhalation Monitoring: APF = 10 Worker MOE or ELCR[a]	Inhalation Monitoring: APF = 50 Worker MOE or ELCR[a]
Industrial/ Commercial Uses	cement, glass, and ceramic articles; metal articles; or rubber articles Packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft) Other (artifacts) Other (aerospace applications)	Handling articles or formulations that contain asbestos	Cancer	1E−04	Higher Exposure-Potential Worker	Inhalation Short-Term	High-End	6.8E−03	6.8E−04	1.4E−04
							Central Tendency	3.0E−04	3.0E−05	6.0E−06
					Lower Exposure-Potential Worker	Inhalation Short-Term	High-End	2.9E−05	2.9E−06	5.7E−07
							Central Tendency	2.0E−05	2.0E−06	4.0E−07
					ONU	Inhalation Short-Term	High-End	1.7E−03	–	–
							Central Tendency	2.4E−06	–	–
Disposal, including Distribution for Disposal	Disposal, including distribution for disposal	Waste handling, disposal, and treatment	Chronic Non-cancer	300	Worker	Inhalation 8-hr TWA	High-End	3.6	36	180
							Central Tendency	77	774	3,872
		Waste handling, disposal, and treatment	Cancer	1E−04	Worker	Inhalation 8-hr TWA	High-End	6.9E−05	6.9E−06	1.4E−06
							Central Tendency	3.2E−06	3.2E−07	6.4E−08

[a] For chronic non-cancer endpoints, the benchmark MOE is compared to the estimated MOE values calculated from inhalation monitoring data. For chronic cancer endpoints, the benchmark ELCR is compared to the estimated ELCR values calculated from inhalation monitoring data.
[b] EPA is unable to estimate ONU exposures separately from workers; central tendency worker estimates were applied as an approximation of likely ONU exposures.
[c] Short-term risk estimates use 30 minute exposure concentrations averaged with 7.5 hours at the full shift exposure concentration.

5.3.2.2 Summary of Risk Estimates for Take-Home Exposures

Table 5-22 summarizes the risk estimates for take-home exposures for lifetime cancer and non-cancer chronic inhalation exposures. The take-home exposure assessment approaches and calculations are presented in Sections 3.1.2 and 5.1.2. The take-home exposure assessment considers handlers and bystanders, that are exposed to asbestos contaminated clothing during garment handling (*e.i.,* laundry, shaking of garment, undressing and dressing, folding). The source of the asbestos contamination are activities related to occupational scenarios, hence the link to the occupational exposure COUs and scenarios. In addition, this take-home exposure assessment considers people, *i.e.*, bystanders, in proximity or within the same room as the person handling the contaminated garment. All of the take-home exposure scenarios considered people 16 years of age and older for all genders for garment handler for less-than-lifetime exposure scenarios and 78 years for lifetime cancer risk estimates. Bystanders were considered in three lifestages, 0 to 20 years to represent children living at home (where the take-home exposure occurs) and then moving away at 20 years of age, shown in Table 5-22. Other bystander populations considered are people living in the same household as the take-home exposure occurs for the duration of the exposure, 40 years, risk estimates shown in Appendix L.3. Additional bystander scenarios considered all ages and genders, lifetime exposure for bystanders, representing people starting the exposure at birth and throughout their entire life, whether they live in the same households or other in which take-home exposures occur and they are bystanders to the handling of asbestos contaminated clothing, shown in Appendix L.3. This lifetime exposure duration is 78 years total, which is equal to the life expectancy.

Of note, the risk summary below is based on the most sensitive non-cancer endpoint for all relevant duration scenarios, as well as cancer. For the majority of exposure scenarios, risks were identified for multiple endpoints in lifetime cancer exposure scenarios. The approach used in this take-home assessment is described in Section 3.1.2. Briefly, take-home asbestos fiber loading concentrations onto worker clothes regression approach was developed because EPA did not identify studies that measured take-home exposures for all COUs and asbestos containing products. Although EPA has moderate confidence in the regression approach, see Table 5-9, there are sources of uncertainty in the assumptions and approximations used. For example, there is high variability (3 to 4 orders of magnitude difference) in the data used and the estimated risk values, which can be representative of a wide number of use patterns and product fiber emissions. The uncertainty increases due the small number of studies and the lack of product and activity specific data. Additionally, all studies used PCM and PCME for asbestos concentration and identification which decreases uncertainty from mixing in non-asbestos fibers in the reported measurements. However, none of the studies reported fiber size which increases uncertainty in the reported concentrations as smaller particles could have been included and could result in increased concentrations and subsequently overestimate risk.

For chronic non-cancer inhalation exposures, the risk values for garment handlers and bystanders for high-intensity exposure levels for all COUs except firefighting related activities range from 11 to 236. While central tendency risk values range from 672 to 8.4×10^{5} (840,437) for handler and bystander. The wide range between HE and CT risk values is due to, (1) one order of magnitude difference between the slope in the regression analysis used to calculate HE and CT exposure concentrations, and (2) the occupational exposure concentration (see Section 5.3.2.1) used to estimate garment asbestos contamination concentrations.

For lifetime cancer inhalation exposures the risk values for both garment handlers and bystanders for high-intensity exposure levels for all COUs except for volunteer firefighting and other disaster response activities range from 2.5×10^{-6} to 3.7×10^{-4}. Central-tendency inhalation lifetime cancer risk values for handler and bystander range from 3.1×10^{-9} to 6.0×10^{-6}. The wide range between HE and CT risk values is due to, (1) one order of magnitude difference between the slope in the regression analysis used to calculate HE and CT exposure concentrations, and (2) the occupational exposure concentration (see Section 5.3.2.1) used to estimate garment asbestos contamination concentrations.

Table 5-22. Take-Home Inhalation Risk Estimates Summary

COUs	OES	Population	Age Group	Chronic Non-cancer (Benchmark MOE = 300)		Cancer Lifetime (Benchmark = 1E−6)	
				CT	HE	CT	HE
Construction, paint, electrical, and metal products and, Furnishing, cleaning, treatment care products	Maintenance, renovation, and demolition	Handler	>16 to 40[a]	305,613	88	1.3E−08	4.6E−05
		Bystander	0 to 20[b]	960,756	268	1.3E−08	4.5E−05
Construction, paint, electrical, and metal products and, Furnishing, cleaning, treatment care products	Firefighting and other disaster response activities (career)	Handler	>16 to 40[a]	280,146	1,615	1.4E−08	2.5E−06
		Bystander	0 to 20[b]	880,693	4,919	9.2E−09	2.5E−06
Construction, paint, electrical, and metal products and, Furnishing, cleaning, treatment care products	Firefighting and other disaster response activities (volunteer)	Handler	>16 to 40[a]	840,437	4,846	4.8E−09	8.4E−07
		Bystander	0 to 20[b]	2,642,080	14,757	3.1E−09	8.2E−07
Construction, paint, electrical, and metal products	Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	Handler	>16 to 40[a]	8,004	47	5.1E−07	8.6E−05
		Bystander	0 to 20[b]	25,163	144	3.2E−07	8.5E−05
Construction, paint, electrical, and metal products, Furnishing, cleaning, treatment care products, and Packaging, paper, plastic, toys, hobby products	Handling articles or formulations that contain asbestos (battery insulators, burner mats, plastics, cured coatings/adhesives/ sealants)	Handler	>16 to 40[a]	8,150	681	5.0E−07	6.0E−06
		Bystander	0 to 20[b]	25,620	2,074	3.0E−07	5.9E−06
Disposal, including distribution for disposal	Waste handling, disposal, and treatment	Handler	>16 to 40[a]	44,823	236	9.1E−08	1.7E−05
		Bystander	0 to 20[b]	140,911	719	5.8E−08	1.7E−05

[a] Handler – Scenario representative of garment handler patterns similar to those from occupational durations which is the source of asbestos fibers into clothing.
[b] Bystander – Scenario representative of children living at home while contaminated clothing is handled during their living at home status, 20 years.
Other bystander scenarios are available in Appendix L.3.

5.3.2.3 Summary of Risk Estimates for Consumers

Table 5-23 summarizes the risk estimates for DIY activity-based scenarios for lifetime cancer and non-cancer chronic inhalation exposures. The consumer exposure assessment is presented in 5.1.3 and data used for the assessment is presented in Section 3.1.3. The basis in the development of consumer DIY exposure scenarios for this risk evaluation is that friable asbestos products have to be modified (*e.g.,* removed, sanded, cut, disturbed) to release fibers. An asbestos containing product that stays in place without any modification done to it is not expected to result in asbestos fiber releases, and hence no human exposures and risks are expected. The overall confidence in DIY estimates is moderate due to uncertainties within the data used and the exposures durations and frequencies for each activity-based DIY scenario. Due to the lack of specific information on DIY consumer exposures, occupational studies measuring exposure to professionals were often used as proxies. There is uncertainty in using occupational data for consumers due to differences in building volumes, air exchange rates, available engineering controls, and potential use of PPE. If available, EPA used data under certain environmental conditions expected to be more representative of a DIY user (*i.e.,* no engineering controls and no PPE use). There is uncertainty associated with studies that did not report asbestos size. Although EPA targeted studies that reported asbestos concentrations for fibers >5 µm and 3:1 ratio (the "respirable" size range), several of the identified studies did not report fiber size which are related to the following COUs:

- Construction, paint, electrical, and metal products; construction and building materials covering large surface areas subcategory;
- Furnishing, cleaning, treatment care products; construction and building materials covering large surface areas, including fabrics, textiles, and apparel subcategory; and
- Construction, paint, electrical, and metal products; fillers and putties subcategory.

Generally, 50 to 98 percent of asbestos fibers are less than 5 µm, therefore by including asbestos concentrations less than 5 µm would result in the use of larger concentrations values, this means that the reported concentrations of asbestos may overestimate risk.

For bystanders, the overall confidence in the estimates is slight. In addition to less available data than the one used for the DIY scenario, the estimates use the conservative assumption that bystanders are present during every instance a DIY user performs work disturbing asbestos-containing products, and that bystanders remain within the work area of the DIY user throughout the entire time the DIY user is performing the work. Bystander exposures therefore may be overestimated, but the magnitude is uncertain.

Finally, EPA has made assumptions regarding both age at start of exposure and duration of exposure for DIY users and bystanders that may overestimate exposures. Frequencies and durations of use values are based on assumptions, where similar job types (*e.g.,* "repair") were given consistent frequencies and durations of use. The assumptions consider not only the frequency of a job type (*e.g.,* "roof replacement") but also the number of times per lifetime that a given job will include asbestos materials. For example, a roof may be replaced every 10 years, but only the first replacement job is likely to include legacy use asbestos; in contrast, repeat repair jobs are more likely to contain legacy asbestos each time.

Of note, the risk summary below is based on the most sensitive non-cancer endpoint for all relevant duration scenarios, as well as cancer. For the majority of consumer DIY exposure scenarios, risks were identified for multiple endpoints in lifetime cancer exposure scenarios. All DIY activities except indoor disturbance of coatings, mastic and adhesives, and outdoor disturbance of roofing materials resulted in high-end tendency risks. Generally, activities that involve removing asbestos containing materials resulted in risks at the low-end, central, and high-end tendencies, while disturbing the materials resulted in risks at the high-level tendencies. Activities related to disturbance or removal of insulation, and sanding spackle showed risk at low and high tendencies. Removal activities resulted in larger risk estimates than disturbance activities.

For chronic non-cancer inhalation exposures there are risks for consumer DIYers and bystanders for some exposure scenarios for all COUs at low, medium, and high-intensity user exposure levels. As expected, there are more DIYer and bystander scenarios with risk at the high-intensity level than at the low-intensity level. Generally, activities that involve removing asbestos containing materials resulted in risks at high-end tendencies, while disturbing the materials resulted in risks at the high-level tendencies.

For lifetime cancer inhalation exposures there are risks for consumer DIYers and bystanders for most scenarios and all COUs at low, central, and high-intensity user exposure levels. Risk values range from 5.1×10^{-8} to 5.1×10^{-2} for various DIY scenarios, however the LE, CT, and HE risk values for specific DIY scenarios are an order of magnitude between LE to CT, and CT to HE. The difference in risk values is due to the asbestos concentrations measured during DIY activities and exposure time and frequency values used for LE, CT, and HE calculations, see Table 5-11.

Table 5-23. Consumer Activity-Based Do-It-Yourself Inhalation Risk Estimates Summary

Life Cycle COU/Subcategory	DIY Activity-Based Scenario	Population	Age Group	Chronic Non-cancer (Benchmark MOE = 300)			Cancer Lifetime (Benchmark = 1E−06)		
				LE	CT	HE	LE	CT	HE
Construction, paint, electrical, and metal products / construction and building materials covering large surface areas: paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles	Outdoor, disturbance/repair (sanding or scraping) of roofing materials	User	16 to 78	129,071	41,288	9,836	2.3E−08	7.1E−08	3.0E−07
		Bystander	0 to 78	774,424	247,726	59,019	8.4E−09	2.6E−08	1.1E−07
	Outdoor, removal of roofing materials	User	16 to 78	1,433	716	119	2.1E−06	4.1E−06	2.5E−05
		Bystander	0 to 78	1,433	716	119	4.6E−06	9.1E−06	5.5E−05
	Indoor, removal of plaster	User	16 to 78	716	179	24	4.1E−06	1.6E−05	1.2E−04
		Bystander	0 to 78	1,433	716	119	4.6E−06	9.1E−06	5.5E−05
	Indoor, disturbance (sliding) of ceiling tiles	User	16 to 78	25,470	12,735	2,122	1.2E−07	2.3E−07	1.4E−06
		Bystander	0 to 78	25,470	12,735	2,122	2.6E−07	5.1E−07	3.1E−06
	Indoor, removal of ceiling tiles	User	16 to 78	1,433	398	63	2.1E−06	7.4E−06	4.7E−05
		Bystander	0 to 78	8,596	2,388	377	7.6E−07	2.7E−06	1.7E−05
	Indoor, removal of vinyl floor tiles	User	16 to 78	Below LOD	Below LOD	Below LOD	Below LOD	Below LOD	Below LOD
		Bystander	0 to 78	Below LOD	Below LOD	Below LOD	Below LOD	Below LOD	Below LOD
	Indoor, disturbance/repair (cutting) of attic insulation.	User	16 to 78	1,279	640	213	2.3E−06	4.6E−06	1.4E−05
		Bystander	0 to 78	17,909	8,954	2,985	3.7E−07	7.3E−07	2.2E−06
	Indoor, moving and removal (with vacuum) of attic insulation	User	16 to 78	494	247	82	6.0E−06	1.2E−05	3.6E−05
		Bystander	0 to 78	1162	581	194	5.6E−06	1.1E−05	3.4E−05
	Paper articles	Qualitative, J.1.1, see Section 3.1.3.1							
	Metal articles	Qualitative, J.1.1, see Section 3.1.3.1							
	Stone, plaster, cement, glass, and ceramic articles	See Indoor, removal of **plaster**							

Life Cycle COU/Subcategory	DIY Activity-Based Scenario	Population	Age Group	Chronic Non-cancer (Benchmark MOE = 300)			Cancer Lifetime (Benchmark = 1E−06)		
				LE	CT	HE	LE	CT	HE
Construction, paint, electrical, and metal products COU: Machinery, mechanical appliances, electrical/ electronic articles	Plastics: Reinforced plastics for appliances	Qualitative, J.1.1, see Section 3.1.3.1							
Construction, paint, electrical, and metal products / fillers and putties	Electro-mechanical parts: Miscellaneous electro-mechanical parts for appliances	Qualitative, J.1.1, see Section 3.1.3.1							
	Indoor, disturbance (pole or hand sanding and cleaning) of spackle	User	16 to 78	7	1	0.1	4.0E−04	4.2E−03	2.3E−02
		Bystander	0 to 78	16	4	1	4.2E−04	1.8E−03	8.5E−03
	Indoor, disturbance (sanding and cleaning) of coatings, mastics, and adhesives	User	16 to 78	458	21	4	6.4E−06	1.4E−04	8.0E−04
		Bystander	0 to 78	294	57	10	2.2E−05	1.1E−04	6.5E−04
	Indoor, removal of floor tile/mastic	User	16 to 78	24,916	12,458	2,388	1.2E−07	2.4E−07	1.2E−06
		Bystander	0 to 78	191,025	95,512	11,939	3.4E−08	6.8E−08	5.5E−07
	Indoor, removal of window caulking	User	16 to 78	1,433	716	119	2.1E−06	4.1E−06	2.5E−05
		Bystander	0 to 78	1,433	716	119	4.6E−06	9.1E−06	5.5E−05
	Adhesives: Glues and epoxies	See Indoor, disturbance (sanding and cleaning) of **coatings, mastics, and adhesives** and indoor, removal of **floor tile/mastic**							
	Sealants: liquid sealants used for waterproofing and sound deadening interior walls	See Indoor, disturbance (sanding and cleaning) of **coatings, mastics, and adhesives** and indoor, removal of **floor tile/mastic**							
	Sealants: Extruded sealant tape used as a gasket for sealing building windows, automotive windshields, and mobile home windows	See Indoor, disturbance (pole or hand sanding and cleaning) of **spackle** and indoor, removal of **window caulking**							
	Coatings: Vehicle undercoating to prevent corrosion	See Indoor, disturbance (sanding and cleaning) of **coatings, mastics, and adhesives** and indoor, removal of **floor tile/mastic**							
Construction, paint, electrical, and metal products COU: Solvent-based/water-based paint	Coatings; textured paints: Coatings; textured paints	See Indoor, disturbance (sanding and cleaning) of **coatings, mastics, and adhesives** and indoor, removal of **floor tile/mastic**							

Life Cycle COU/Subcategory	DIY Activity-Based Scenario	Population	Age Group	Chronic Non-cancer (Benchmark MOE = 300)			Cancer Lifetime (Benchmark = 1E−06)		
				LE	CT	HE	LE	CT	HE
Chemical substances in furnishing, cleaning, treatment care products COU: Construction and building materials covering large surface areas, including fabrics, textiles, and apparel	Asbestos textiles including yarn, thread, wick, cord, rope, tubing (sleeving), cloth, tape: Wicks for oil burning	Qualitative J.1.2 and see Textiles and cloth (including gloves and mittens)							
Furnishing, cleaning, treatment care products / Furniture and furnishings, including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles	Use of mittens for glass manufacturing, (proxy for oven mittens and potholders)	User	16 to 78	1,433	716	119	2.1E−06	4.1E−06	2.5E−05
		Bystander	0 to 78	1,433	716	119	4.6E−06	9.1E−06	5.5E−05
	Fabrics, textiles, and apparel: burner mats	Qualitative J.1.2 and see Textiles and cloth (including gloves and mittens)							

5.3.2.4 Summary of Risk Estimates for General Population

Table 5-24 and Table 5-25 summarize the lifetime cancer and non-cancer chronic risk estimates for inhalation exposures for general population exposure to ambient air releases from occupational activities. The general population exposure assessment is described in Section 5.1.40. and the data used for the dispersion model estimates is described in Section 3.3.1.2. The general population exposure assessment considers indoor exposures for people living at certain distance from the asbestos releases. The distances explored in this assessment all assess exposures to the general population at the following distances: 10, 30, 60, 100, 2,500, 5,000, and 10,000 m and the area between 100 to 1,000 m. Distances 10 to 100 m are called co-located because they are exposures in proximity to the activity which is the source of the asbestos releases. The populations assessed in the co-located distances are different for each of the occupational activities releasing asbestos. For example, landfills tend to have fences to keep people outside, and hence it is not expected to have general population living, recreating, or routinely passing by within the perimeter. However, the distance from the landfill release point to the general population outside the perimeter can vary depending on the size of the landfill. Other activities, such as firefighting and demolitions can have people living next to the activity without a perimeter. The co-located distances distinction is an approach to identify people with increased exposures due to their proximity to emission sources. In addition, the asbestos releases are summarized by COU/OES fugitive emissions. Fugitive emissions refer to area source emissions.

The overall confidence in the modeling estimates is moderate. The overall confidence in the general population risk estimates originates from a multiple inputs and assumptions in the calculation of environmental releases, the subsequent use of these data to model dispersion from the emission source, and the air modeling inputs, and exposure durations and frequencies used for the general population risk assessment.

The specific modeling inputs and scenario parameters that drive risk are the distance from the source, release days, and assumptions about the non-stationary or stationary status of the activity source. In terms of distance from the source, higher concentrations are expected closer to the source, and that is evident in the decrease in ELCR and MOE values with increasing distance. The release frequency for demolition, renovation, and maintenance was 12 days per year; for firefighting and disaster response the release was 3 hours for 1 day per year; and for the other three OESs, repair, removal of appliances, handling articles and formulations, and waste handling releases were 250 days a year. The release frequency can provide a measure of relative contribution and impact on the risk estimates when considering the number of times an asbestos fiber releasing activity occurs in a year with respect to proximity to the release and whether is a stationary or non-stationary activity. Stationary activities result in longer exposures over the extent of residency. Stationary scenarios used $IUR_{(0,20)}$, and since these scenarios use a larger IUR value for exposures from birth to 20 years of age than non-stationary activity scenarios ($IUR_{(0,1)}$), it is expected that non-stationary scenarios would have lower risk estimates.

OESs with the highest risk estimates are those related to stationary activities like waste handling and disposal, and handling of articles and formulations which also use 250 days per year releases. OESs with the lowest risk estimates correspond to firefighting and disaster response which consider non-stationary risks ($IUR_{(0,1)}$) and 1-day releases per year. The repair and removal of appliances and machinery OES used 250 days per year releases and non-stationary activity IUR resulting in slightly higher risk estimates than firefighting and demolition OES. The demolition and renovation OES was the second lowest risk estimate because it was simulated for 12 days per year releases and non-stationary activity. For chronic non-cancer inhalation exposures, the risk values for each COU across all distances range from 12 to 2.7×10^{11} for LE, CT, and HE tendencies. The wide range of risk values for a single COU is due the differences among concentrations and the expected deposition/fall off as distances from the source increase.

For lifetime cancer inhalation exposures, the risk values for the general population for people at various distances from the source for high-intensity exposure levels are summarized in Table 5-24. The risk values for each COU across all distances range from 2.2×10^{-11} to 8.6×10^{-4} for LE, CT, and HE tendencies. The wide range of risk values for a single COU is due to the differences among concentrations and the expected deposition/fall off as distances from the source increase.

Table 5-24. General Population Inhalation of Outside Ambient Air Lifetime Cancer Risk Estimate Summary

OES	COU(s)	Distance from the Source (m)							
		10	30	60	100	100–1,000	2,500	5,000	10,000
Low-end tendency lifetime cancer ELCR (f/cc) (benchmark = 1E−06 to 1E−04)									
Waste handling, disposal, and treatment fugitive [a]	COU: Disposal, including distribution for disposal	1.3E−04	1.7E−05	3.4E−06	9.4E−07	1.1E−08	1.5E−09	5.1E−10	1.7E−10
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities fugitive [b]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	3.0E−05	4.2E−06	7.9E−07	2.0E−07	1.6E−09	1.5E−10	6.1E−11	2.3E−11
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos fugitive [b]	COU: Construction, paint, electrical, and metal products	1.7E−05	1.9E−06	3.7E−07	1.1E−07	1.3E−09	1.9E−10	6.8E−11	2.2E−11
Handling articles or formulations that contain asbestos fugitive [a]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products COU: Packaging, paper, plastic, toys, hobby products	2.0E−05	1.4E−05	1.3E−05	1.2E−05	2.9E−08	8.6E−09	3.3E−09	1.0E−09
Central tendency lifetime cancer ELCR (benchmark = 1E−06 to 1E−04)									
Waste handling, disposal, and treatment fugitive [a]	COU: Disposal, including distribution for disposal	3.0E−04	5.1E−05	1.2E−05	3.5E−06	1.2E−07	4.9E−09	1.7E−09	6.0E−10
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities fugitive [b]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	2.2E−05	4.2E−06	9.9E−07	2.9E−07	8.7E−09	3.4E−10	1.2E−10	4.6E−11
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos fugitive [b]	COU: Construction, paint, electrical, and metal products	1.4E−05	2.2E−06	4.9E−07	1.5E−07	5.2E−09	2.3E−10	8.3E−11	2.9E−11
Handling articles or formulations that contain asbestos fugitive [a]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	3.0E−05	1.6E−05	1.3E−05	1.3E−05	3.3E−07	1.8E−08	7.6E−09	2.7E−09

OES	COU(s)	Distance from the Source (m)							
		10	30	60	100	100–1,000	2,500	5,000	10,000
	COU: Packaging, paper, plastic, toys, hobby products								
Handling asbestos-containing building materials during firefighting or other disaster response activities fugitive [b]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	2.8E−08	7.0E−09	2.0E−09	6.6E−10	2.2E−11	6.8E−13	2.0E−13	7.5E−14
High-end tendency lifetime cancer ELCR (f/cc) (benchmark = 1E−06 to 1E−04)									
Waste handling, disposal, and treatment fugitive [a]	COU: Disposal, including distribution for disposal	8.6E−04	1.8E−04	4.4E−05	1.4E−05	6.0E−07	1.6E−08	5.5E−09	2.0E−09
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities fugitive [b]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	6.3E−05	1.3E−05	3.2E−06	9.8E−07	5.8E−08	1.2E−09	4.0E−10	1.5E−10
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos fugitive [b]	COU: Construction, paint, electrical, and metal products	1.3E−04	2.7E−05	6.8E−06	2.1E−06	7.7E−08	2.6E−09	8.9E−10	3.3E−10
Handling articles or formulations that contain asbestos fugitive [a]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products COU: Packaging, paper, plastic, toys, hobby products	8.2E−05	3.2E−05	2.2E−05	2.1E−05	1.2E−06	4.5E−08	1.9E−08	6.8E−09
Handling asbestos-containing building materials during firefighting or other disaster response activities fugitive [b]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	8.3E−06	2.1E−06	6.1E−07	2.0E−07	6.6E−09	2.1E−10	6.1E−11	2.3E−11

[a] The lifetime cancer risk exposure duration is 20 years which is the number of years residents are assumed to reside in a single residential location for stationary OES. The exposure starting age is zero (birth) to consider highly exposed and sensitive population. The Averaging time for exposure years is 78 years representing the number of years an individual is assumed to live (*Exposure Factors Handbook* (U.S. EPA, 2011)).
[b] The lifetime cancer risk exposure duration is 1 year for non-stationary OES, $IUR_{(0,1)}$.

Table 5-25. General Population Inhalation of Outside Ambient Air Non-cancer Chronic Risk Estimate Summary

OES	COU(s)	Distance from the Source (m)							
		10	30	60	100	100–1,000	2,500	5,000	10,000
Low-end tendency non-cancer chronic MOE (benchmark = 300)									
Waste handling, disposal, and treatment fugitive [a]	COU: Disposal, including distribution for disposal	7.9E01	6.0E02	3.0E03	1.1E04	9.3E05	6.9E06	2.0E07	5.8E07
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities fugitive [b]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	6.8E02	4.8E03	2.6E04	1.0E05	1.2E07	1.3E08	3.3E08	8.8E08
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos fugitive [b]	COU: Construction, paint, electrical, and metal products	1.2E03	1.0E04	5.5E04	1.9E05	1.5E07	1.1E08	3.0E08	9.0E08
Handling articles or formulations that contain asbestos fugitive [a]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products COU: Packaging, paper, plastic, toys, hobby products	5.0E02	7.4E02	7.8E02	8.3E02	3.5E05	1.2E06	3.1E06	9.7E06
Central tendency non-cancer chronic MOE (benchmark = 300)									
Waste handling, disposal, and treatment fugitive [a]	COU: Disposal, including distribution for disposal	3.4E01	2.0E02	8.6E02	2.9E03	8.7E04	2.1E06	6.0E06	1.7E07
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities fugitive [b]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	9.3E02	4.9E03	2.0E04	6.9E04	2.3E06	6.0E07	1.7E08	4.4E08
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos fugitive [b]	COU: Construction, paint, electrical, and metal products	1.5E03	9.3E03	4.1E04	1.4E05	3.9E06	8.8E07	2.4E08	7.0E08
Handling articles or formulations that contain asbestos fugitive [a]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products COU: Packaging, paper, plastic, toys, hobby products	3.4E02	6.5E02	7.6E02	7.9E02	3.1E04	5.6E05	1.3E06	3.8E06

OES	COU(s)	Distance from the Source (m)							
		10	30	60	100	100–1,000	2,500	5,000	10,000
Handling asbestos-containing building materials during firefighting or other disaster response activities fugitive [b]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	7.4E05	2.9E06	1.0E07	3.1E07	9.3E08	3.0E010	1.0E011	2.7E011
High-end tendency non-cancer chronic MOE (benchmark = 300)									
Waste handling, disposal, and treatment fugitive [a]	COU: Disposal, including distribution for disposal	1.2E01	5.7E01	2.3E02	7.5E02	1.7E04	6.3E05	1.9E06	5.0E06
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities fugitive [b]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	3.2E02	1.6E03	6.3E03	2.1E04	3.5E05	1.8E07	5.1E07	1.4E08
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos fugitive [b]	COU: Construction, paint, electrical, and metal products	1.5E02	7.6E02	3.0E03	9.6E03	2.6E05	7.8E06	2.3E07	6.1E07
Handling articles or formulations that contain asbestos fugitive [a]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products COU: Packaging, paper, plastic, toys, hobby products	1.2E02	3.2E02	4.5E02	4.9E02	8.4E03	2.3E05	5.4E05	1.5E06
Handling asbestos-containing building materials during firefighting or other disaster response activities fugitive [b]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	2.4E03	9.7E03	3.3E04	1.0E05	3.1E06	9.9E07	3.3E08	8.9E08

[a] The chronic non-cancer risk exposure duration is 20 years which is the number of years residents are assumed to reside in a single residential location for stationary OES. The exposure starting age is zero (birth) to consider highly exposed and sensitive population. The Averaging time for exposure years is 78 years representing the number of years an individual is assumed to live (*Exposure Factors Handbook* (U.S. EPA, 2011)).
[b] The chronic non-cancer risk exposure duration is 1 year for non-stationary OES, $IUR_{(0,1)}$. The exposure starting age is zero (birth) to consider highly exposed and sensitive population. The Averaging time for exposure years is 78 years representing the number of years an individual is assumed to live (*Exposure Factors Handbook* (U.S. EPA, 2011)).

5.3.2.5 Summary of Risk Estimates for Asbestos Unintentionally Present in Other Mined Materials and in Manufactured/Processed Articles from Such Materials

In addition to risk from legacy asbestos characterized above, the EPA considered information on ongoing use of asbestos in manufacturing (including import and mining), processing, distribution, use, and disposal received since the Part 1 Risk Evaluation. As described in Section 1.1.2.2, asbestos in trace amounts has been identified in mined non-asbestos commodities and manufactured/processed articles. Air monitoring data from mining sites collected by MSHA (MSHA, 2022a) from 2008 to 2022 under the current personal exposure limit (PEL) were largely non-detects Appendix G.15. Data received under TSCA section 8(a), 15 U.S.C. 2607(a), indicates that ongoing manufacturing, importation, and processing of asbestos containing products is limited to materials with trace amounts of asbestos that are not intentionally added and less than 0.1 percent weight fraction (Section 1.1.2.2).

An exposure study evaluating the use of crayons with trace amounts of asbestos showed no release of asbestos fibers during vigorous use (Section 3.1.3 and Appendix J.1.3). No exposure data were available to evaluate trace asbestos in mineral kits (Section 3.1.3 and Appendix J.1.3). Therefore, EPA's confidence in these exposures is indeterminant and EPA cannot quantify risk from these uses. However, EPA acknowledges that while some releases and exposures could occur during these uses, particularly in the wide variety of items that asbestos may unintentionally find its way into, these are expected to be minimal and dispersed, and exposures are expected to be negligible. Thus, EPA finds that the evidence suggests that exposure to trace asbestos unintentionally present in mined commodities and manufactured/processed articles that are subject to TSCA occurs infrequently and at low levels as described in Section 1.1.2.2. Therefore, the Agency did not conduct any further analysis of trace amounts of asbestos in this risk evaluation. It is also important to note that EPA has not considered information related to asbestos-containing products that are not subject to TSCA, such as cosmetics.

5.3.3 Risk Characterization for Potentially Exposed or Susceptible Subpopulations

The PESS groups that are of concern with regard to risks related to asbestos exposure include primarily those with occupational exposures, children, individuals who are exposed through DIY activity, and those who smoke.

Occupational exposures were described in Section 5.1.1 and include a broad range of occupations. Individuals who are involved in demolition and removal of asbestos-containing material are more likely to be exposed than individuals in other occupations. This includes firefighters, who may be exposed during residential and commercial building firefighting activities. Higher-exposure workers high-end (95th percentile) scenarios represent worker populations that have increased exposures from activities that release asbestos like sanding, cutting, and others.

Children are also a particularly susceptible subpopulation, as time since first exposure is known to be an important predictor of asbestos-related disease, see Section 5.2.2.1. As described in Section 5.1.1, the earlier an individual is exposed, the greater the risk due to the latency of asbestos-related disease. For example, onset of cancer can take up to 40 years from exposure. For this reason, individuals who are first exposed during childhood are more likely to experience asbestos-related disease than those first exposed during adulthood.

As described in Part 1 and the prior assessments, smoking has long been recognized as a potential effect modifier for asbestos-related disease, with individuals who smoke being more susceptible to the respiratory effects associated with asbestos.

Table 5-26 summarizes the available information in the risk evaluation to inform considerations of PESS factors, including increased exposures and/or increased biological susceptibility. The table also summarizes whether EPA believes the risk evaluation adequately addressed those factors in the risk characterization or otherwise.

Table 5-26. Summary of PESS Considerations in the Risk Evaluation

PESS Categories	Potential Increased Exposures Incorporated into Exposure Assessment	Potential Sources of Biological Susceptibility Incorporated into Hazard Assessment
Lifestage (Age)	• Considered age at which activity-based do-it-yourself scenarios start, like exposures starting at age zero with various durations of exposures as well as other starting ages and durations	• Epidemiologic evidence has demonstrated that time since first exposure is a key predictor in asbestos-related disease (Section 5.2.2). Thus, exposures during childhood are associated with greater risk.
Pre-existing Disease	• EPA did not identify pre-existing disease factors influencing exposure	• EPA did not identify pre-existing disease factors that are associated with increased susceptibility.
Lifestyle Activities	• EPA evaluated exposures resulting from activity-based do-it-yourself scenarios that may apply to certain hobbies	• Some epidemiologic evidence demonstrates a differential response based on smoking, but evidence is not sufficient to quantitatively estimate risk for smokers separate from the general population (see Section 3.2.4 in Part 1 of the Risk Evaluation for Asbestos). • EPA did not identify other lifestyle factors associated with susceptibility.
Occupational and consumer	• EPA evaluated a range of occupational exposure scenarios for workers and higher-exposure workers high-end scenario. This consideration expands to children 16 and older because these occupational scenarios consider exposure starting at 16 years of age.	• EPA did not identify occupational and consumer exposures that are associated with susceptibility.
Sociodemographic	• EPA did not identify specific sociodemographic factors that influence exposure to asbestos. This is a remaining source of uncertainty.	• EPA did not identify specific sociodemographic factors that are associated with susceptibility.
Nutrition	• EPA did not identify nutrition factors influencing exposure	• EPA did not identify nutritional factors that are associated with susceptibility.
Genetics	• EPA did not identify genetic factors influencing exposure	• EPA did not identify any genetic factors that are associated with susceptibility.
Unique Activities	• EPA did not identify unique activity factors influencing exposure apart from the activity-based DIY scenarios	• EPA did not identify unique activities that are associated with susceptibility.
Aggregate Exposures	• Occupational and non-occupational inhalation exposures aggregated • Use of non-TSCA products/articles, such as cosmetic talc powder can increase susceptibility	• EPA did not identify unique activities that are associated with susceptibility.
Other Chemical and Nonchemical Stressors	• EPA did not identify factors influencing exposure	• EPA did not identify other chemical or specific nonchemical stressors that are associated with susceptibility.

5.3.4 Risk Characterization for Aggregate and Sentinel Exposures

Exposures were considered in aggregate only for COUs that do not individually exceed benchmarks. As discussed in Section 5.3.2, a significant number of occupational and non-occupational COUs exceed benchmarks alone at central tendency and/or high-end exposure scenarios, especially those related to high-end exposures for workers. The COUs that do not individually exceed benchmarks are indicated in Table 5-27. The aggregate analysis across exposure scenarios and COUs figures and summaries are available in *Asbestos Part 2 RE - Aggregate Analysis - November 2024* (see Appendix C). EPA did not identify statistics, probabilities, and frequencies for the populations engaging in activity patterns represented in the aggregate analysis scenarios, but the analysis identified possible activity patterns that exceed benchmarks.

Table 5-27. Exposure Scenarios Included in Aggregate Analysis

Exposure Scenario	Affected Population(s) – HE						Affected Population(s) – CT							
	Take-Home		DIYer		General Population		Worker		Take-Home		DIYer		General Population	
	MOE	ELCR	MOE	ELCR	MOE	ELCR	MOE	ELCR	MOE	ELCR	MOE	ELCR	MOE	ELCR
Demolition, renovation, maintenance	×	×	× / ✓	×	✓	✓ / × (≤30 m)	✓	✓	✓	✓	✓ / ×	✓ / ×	✓	✓ / × (≤10 m)
Firefighting/ disaster – career	✓	×	–	–	✓	✓ / × (≤10 m)	✓	✓	✓	✓	–	–	✓	✓
Firefighting/ disaster – volunteer	✓	✓	–	–	✓	✓ / × (≤10 m)	✓	✓	✓	✓	–	–	✓	✓
Removal/ repair of machinery	×	×	–	–	✓	✓ / × (≤60 m)	×	×	✓	✓	–	–	✓	✓ / × (≤10 m)
Handling articles or formulations	×	×	–	–	✓	✓ / × (≤100 m)	×	×	✓	×	–	–	✓	✓ / × (≤100 m)
Waste handling	×	×	–	–	✓ / × (≤30 m)	✓ / × (≤100 m)	×	×	✓	✓	–	–	✓ / × (≤10 m)	✓ / × (≤100 m)

× / ✓ Some activities for the DIYer (modifications, such as removal, disturbance of asbestos containing materials) and distances for the general population exceeded benchmarks and were not used in the aggregation, each of these populations have activities and distances from the source that were not above the benchmarks and were included in the aggregation.
(≤10, or 30, or 100 m) Less than this distance was not included in the aggregation, further distances were included in the aggregation.
✓ Exposure scenarios were used in the aggregation.
× Exposure scenarios were not used in the aggregation because already exceeded benchmark.

The aggregate exposure scenarios that exceed benchmarks include the following:

- Lifetime cancer risk
    - Take-home, DIYers, and general population for repair/removal of commercial and industrial appliances or machinery COU at all distances
    - Take-home, DIYers, and general population for demolition COU at ≤30 m distance
    - Occupational exposures for firefighting (career) or demolition COUs combined with take-home, DIY, and general population exposures
- Non-cancer chronic risk
    - DIYers LE disturbance of construction and furnishing products COUs

- DIYers LE construction materials and furnishing products and CT construction materials products COUs

Many CT and HE exposure scenarios exceeded risk benchmarks alone, and thus were not included in the aggregate analysis.

Additional details on the aggregate analysis are available in Appendix O.

5.3.5 Overall Confidence and Remaining Uncertainties in Human Health Risk Characterization

Human health risk characterization evaluated confidence from occupational, take-home, consumer DIYer, and general population exposures and human health hazards. Hazard confidence and uncertainty is represented by health outcome and exposure duration as reported in Section 5.1.1, which presents the confidence, uncertainties, and limitations of the human health hazards for asbestos. Confidence in the exposure assessment has been synthesized in the respective weight of scientific evidence conclusion sections for occupational exposures (Section 5.1.1.4), take-home exposures (Section 5.1.2.2), consumer DIYer exposures (Section 5.1.3.3), and general population exposures (Section 5.1.4.3). Table 5-28 provides a summary of confidence for exposures and hazards for lifetime cancer and non-cancer chronic endpoints for the COUs that resulted in any cancer and non-cancer risks.

Uncertainties associated with the occupational exposure assessment as describe in Section 5.1.1.4, include a lack of reported data from databases such as TRI, and NEI. Site-specific data were only available for a small number of current occupational activities, and it is not clear if these data are representative of current workplace practices.

Uncertainties associated with the general population exposures assessment included the lack of site-specific information, the incongruence between the modeled concentrations and measured concentrations in the monitoring data, and the complexity of the assessed exposure scenarios.

The quantitative values are robust because they are based on historical occupational epidemiology cohorts with use of the longest follow-up for each cohort or the most pertinent exposure-response when a cohort had been the subject of more than one publication. Additionally advanced exposure measurement methods are reflected in the underlying data resulting in exposure estimates that are of high confidence. Furthermore, longer follow-up times increase the statistical power of the study as more mortality is observed. Other notable strengths include accounting for laryngeal and ovarian cancers, which are causally associated with asbestos exposure, and accounting for under-ascertainment of mesothelioma.

When deriving hazard values for risk assessment there are always uncertainties. These uncertainties are described in the white paper (U.S. EPA, 2023g) and in Section 5.1.1. Uncertainties are related to the following: use of PCM over TEM in available exposure measurement data; use of impinger sampling data for early asbestos exposure; use of mortality data rather than incidence data; under ascertainment of mesothelioma; inter individual variability and confounding due to smoking. However, these uncertainties were accounted for to the extent possible in modeling and the data were robust when considering the strengths and uncertainties.

Table 5-28. Asbestos Evidence Table Summarizing Overall Confidence for Human Health Lifetime Cancer and Non-cancer Chronic Risk Characterization for COUs Resulting in Risks

COU	Subcategory	OES or DIY Scenario	Exposure Confidence	Hazard Confidence	Risk Characterization Confidence
Occupational					
COU: Construction, paint, electrical, and metal products subcategory: Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles COU: Furnishing, cleaning, treatment care products subcategory: Construction and building materials covering large surface areas, including fabrics, textiles, and apparel		Handling asbestos-containing building materials during maintenance, renovation, and demolition activities (workers and ONUs)	++	+++	++
COU: Construction, paint, electrical, and metal products subcategory: Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles COU: Furnishing, cleaning, treatment care products subcategory: Construction and building materials covering large surface areas, including fabrics, textiles, and apparel		Handling of asbestos-containing building materials during firefighting or other disaster response activities (career workers) Handling of asbestos-containing building materials during firefighting or other disaster response activities (volunteer workers)	++ /+++	+++	+++
COU: Construction, paint, electrical, and metal products subcategory: Machinery, mechanical appliances, electrical/electronic articles and other machinery, mechanical appliances, electronic/electronic articles		Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos (workers and ONUs)	++/+++	+++	+++
COU: Construction, paint, electrical, and metal products subcategory: Fillers and putties, electrical batteries and accumulators, and solvent-based/water-based paint COU: Furnishing, cleaning, treatment care products subcategory: Furniture & furnishings including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles COU: Packaging, paper, plastic, toys, hobby products subcategory: Packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft) and Toys intended for children's use (and child dedicated articles), including fabrics, textiles, and apparel; or plastic articles (hard)		Handling articles or formulations that contain asbestos (workers and ONUs)	++	+++	++
COU and subcategory: Disposal, including distribution for disposal		Waste handling, disposal, and treatment (workers and ONUs)	++	+++	++
Take-home					
COU: Construction, paint, electrical, and metal products		Maintenance, renovation, and demolition handler and bystander	++	+++	++

COU	Subcategory	OES or DIY Scenario	Exposure Confidence	Hazard Confidence	Risk Characterization Confidence
subcategory: Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles COU: Furnishing, cleaning, treatment care products subcategory: Construction and building materials covering large surface areas, including fabrics, textiles, and apparel					
COU: Construction, paint, electrical, and metal products Subcategory: Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles COU: Furnishing, cleaning, treatment care products subcategory: Construction and building materials covering large surface areas, including fabrics, textiles, and apparel		Firefighting and other disaster response activities (career) handler and bystander	++	+++	++
		Firefighting and other disaster response activities (volunteer) handler and bystander	++	+++	++
COU: Construction, paint, electrical, and metal products subcategory: Machinery, mechanical appliances, electrical/electronic articles and other machinery, mechanical appliances, electronic/electronic articles		Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos handler and bystander	++	+++	++
COU: Construction, paint, electrical, and metal products subcategory: Solvent-based/water-based paint, fillers, and putties COU: Furnishing, cleaning, treatment care products subcategory: Furniture & furnishings including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles COU: Packaging, paper, plastic, toys, hobby products subcategory: Packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft) and Toys intended for children's use (and child dedicated articles), including fabrics, textiles, and apparel; or plastic articles (hard)		Handling articles or formulations that contain asbestos (battery insulators, burner mats, plastics, cured coatings/adhesives/sealants) handler and bystander	++	+++	++
COU and subcategory: Disposal, including Distribution for Disposal		Waste handling, disposal, and treatment handler and bystander	++	+++	++
Consumer DIYer / bystander					
Chemical substances in construction, paint, electrical, and metal products	Construction and building materials covering large surface areas: paper articles; metal articles; stone, plaster, cement, glass and ceramic articles	Outdoor, disturbance/repair (sanding or scraping) of roofing materials DIYer	++	+++	++
		Outdoor, disturbance/repair (sanding or scraping) of roofing materials bystander	+	+++	+
		Outdoor, removal of roofing materials DIYer	++	+++	++

COU	Subcategory	OES or DIY Scenario	Exposure Confidence	Hazard Confidence	Risk Characterization Confidence
Chemical substances in construction, paint, electrical, and metal products	Construction and building materials covering large surface areas: paper articles; metal articles; stone, plaster, cement, glass and ceramic articles	Outdoor, removal of roofing materials bystander	+	+++	+
		Indoor, removal of plaster DIYer	++	+++	++
		Indoor, removal of plaster bystander	+	+++	+
		Indoor, disturbance (sliding) of ceiling tiles DIYer	++	+++	++
		Indoor, disturbance (sliding) of ceiling tiles bystander	+	+++	+
		Indoor, removal of ceiling tiles DIYer	++	+++	++
		Indoor, removal of ceiling tiles bystander	+	+++	+
		Indoor, maintenance (chemical stripping, polishing, or buffing) of vinyl floor tiles DIYer	++	+++	++
		Indoor, maintenance (chemical stripping, polishing, or buffing) of vinyl floor tiles bystander	+	+++	+
		Indoor, removal of vinyl floor tiles DIYer	++	+++	++
		Indoor, removal of vinyl floor tiles bystander	+	+++	+
		Indoor, disturbance/repair (cutting) of attic insulation DIYer	++	+++	++
		Indoor, disturbance/repair (cutting) of attic insulation bystander	+	+++	+
		Indoor, moving and removal (with vacuum) of attic insulation DIYer	++	+++	++
		Indoor, moving and removal (with vacuum) of attic insulation bystander	+	+++	+
	Fillers and putties	Indoor, disturbance (pole or hand sanding and cleaning) of spackle DIYer	++	+++	++
		Indoor, disturbance (pole or hand sanding and cleaning) of spackle bystander	+	+++	+
		Indoor, disturbance (sanding and cleaning) of coatings, mastics, and adhesives DIYer	++	+++	++
		Indoor, disturbance (sanding and cleaning) of coatings, mastics, and adhesives bystander	+	+++	+
		Indoor, removal of floor tile/mastic DIYer	++	+++	++

COU	Subcategory	OES or DIY Scenario	Exposure Confidence	Hazard Confidence	Risk Characterization Confidence
		Indoor, removal of floor tile/mastic bystander	+	+++	+
		Indoor, removal of window caulking DIYer	++	+++	++
		Indoor, removal of window caulking bystander	+	+++	+
Chemical substances in furnishing, cleaning, treatment care products	Construction and building materials covering large surface areas, including fabrics, textiles, and apparel	Use of mittens for glass manufacturing, (proxy for oven mittens and potholders) DIYer	+	+++	+
		Use of mittens for glass manufacturing, (proxy for oven mittens and potholders) bystander	+	+++	+
General population					
COU: Construction, paint, electrical, and metal products subcategory: Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles COU: Furnishing, cleaning, treatment care products subcategory: Construction and building materials covering large surface areas, including fabrics, textiles, and apparel		Maintenance, renovation, and demolition handler and bystander	++	+++	++
COU: Construction, paint, electrical, and metal products subcategory: Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles COU: Furnishing, cleaning, treatment care products subcategory: Construction and building materials covering large surface areas, including fabrics, textiles, and apparel		Firefighting and other disaster response activities (career) handler and bystander	++	+++	++
		Firefighting and other disaster response activities (volunteer) handler and bystander	++	+++	++
COU: Construction, paint, electrical, and metal products subcategory: Machinery, mechanical appliances, electrical/electronic articles and other machinery, mechanical appliances, electronic/electronic articles		Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos handler and bystander	++	+++	++
COU: Construction, paint, electrical, and metal products subcategory: Solvent-based/water-based paint, fillers, and putties COU: Furnishing, cleaning, treatment care products subcategory: Furniture & furnishings including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles COU: Packaging, paper, plastic, toys, hobby products		Handling articles or formulations that contain asbestos (battery insulators, burner mats, plastics, cured coatings/adhesives/sealants) handler and bystander	++	+++	++

COU	Subcategory	OES or DIY Scenario	Exposure Confidence	Hazard Confidence	Risk Characterization Confidence
subcategory: Packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft) and Toys intended for children's use (and child dedicated articles), including fabrics, textiles, and apparel; or plastic articles (hard)					
COU and subcategory: Disposal, including distribution for disposal		Waste handling, disposal, and treatment handler and bystander	++	+++	++

5.3.5.1 Occupational Risk Estimates

Table 5-6 provides a summary of the weight of scientific evidence for each occupational exposure scenario (OES), indicating whether monitoring data were reasonably available, the number of data points identified, the quality of the data, overall confidence in the data, and whether the data were used to estimate inhalation exposures for workers and ONUs. For all OES and worker populations, occupational exposure estimates were assigned Moderate or Moderate to Robust confidence according to the weight of scientific evidence of the monitoring data available. Appendix G provides further details of the overall confidence for inhalation exposure estimates for each OES assessed. Uncertainties in occupational exposure estimation include representativeness of data, data that may be inherently biased, number of working years, and lack of sufficient metadata. Also, there are uncertainties with respect to the approach for estimating the number of workers using NAICS codes and BLS data. The strengths, limitations, assumptions, and key sources of uncertainty for the occupational exposure assessment are detailed in Section 5.1.1.4.1.

5.3.5.2 Take-Home Risk Estimates

Sections 3.1.2.3 and 5.1.2.2 summarize the data used in this analysis and the approaches developed to evaluate asbestos risk from take-home exposures. The studies used in the take-home exposure analysis contained data that were specific to two types of activities that are related to building/construction materials and machinery. The other studies used simulated asbestos fiber concentrations ranges to generalize the applicability of the data to more than one type of product and activity. In addition, the studies also measured exposure concentrations to bystanders as part of their objectives, which means the bystander concentrations used in this evaluation were measured similar to what was done with the garment handler and the risk estimates for the bystander have the same uncertainties as the handler. EPA used all the data in a regression approach to identify central- and high-end tendencies for all OESs/COUs. The use of specific activity product release data and generated range of concentrations data facilitated the generalization to all COUs. The regression approach used one garment (unit) to a loading event and subsequent laundry activity minimizes uncertainties and variability while decreasing complexity of the overall approach.

5.3.5.3 Consumer DIY Risk Estimates

Asbestos Releases from Products Data

Sections 3.1.3.5 and 5.1.3.3 summarize the available information on the consumer DIY COUs and relevant exposure scenarios. EPA only assessed activity-based scenarios in which asbestos containing products are modified in a way that releases fibers and are subsequently inhaled by the DIYer and bystander. Due to the lack of specific information on DIY consumer exposures, occupational studies measuring exposure to professionals were often used as proxies. There is uncertainty in using occupational data for consumers due to differences in building volumes, air exchange rates, available engineering controls, and potential use of PPE.

Applicability and Generalization of Activity-Base DIY Scenarios

The activity-base DIY scenarios in this asbestos part 2 risk evaluation were built based on the information identified via the systematic review process. EPA was able to identify information for most COUs and product examples within Table 3-5, however not all possible activities, or activity durations, or activity locations were sampled and reported, hence there is some extrapolation and generalization to apply the information to DIY scenarios. EPA aims to cover possible scenarios with the low-, central, and high-end use pattern assumptions used to estimate exposure durations and frequencies summarized in Table 5-11.

5.3.5.4 General Population Risk Estimates

The releases into ambient air from occupational activities and subsequent general population inhalation exposure are described in Sections 3.2, 3.3, and 5.1.4. The average daily release calculated from sites reporting to TRI, NEI or NRC was applied to the total number of sites, however it is uncertain how accurate this average release is to actual releases at these sites; therefore, releases may be higher or lower than the calculated amount. For releases modeled with TRI/NEI/NRC, the weight of scientific evidence conclusion was moderate to robust since information on the conditions of use of asbestos at sites in TRI and NEI is limited, and NRC does not provide the condition of use of asbestos at sites. For the Handling Asbestos-Containing Building Materials During Firefighting or Other Disaster Response Activities OES, the weight of scientific evidence conclusion was moderate since surrogate data from a different OESs were utilized. The combined estimates of releases to ambient air and the use of these data to estimate general population exposure concentrations and risk at various distances from the activity were given a moderate confidence level. See Sections 3.3.1.4 and 5.1.4.3 for a summary of the weight of scientific evidence for general population exposures to releases from occupational activities.

6 UNREASONABLE RISK DETERMINATION

TSCA section 6(b)(4) requires EPA to conduct a risk evaluation to determine whether a chemical substance presents an unreasonable risk of injury to health or the environment, without consideration of costs or other non-risk factors—including an unreasonable risk to a potentially exposed or susceptible subpopulation (PESS) identified by the Agency as relevant to the risk evaluation under the TSCA COUs.

EPA has determined that asbestos presents an unreasonable risk due to injury to health under the COUs. Risk of injury to the environment does not contribute to EPA's determination of unreasonable risk. This unreasonable risk determination is based on the information in the 2020 *Risk Evaluation for Asbestos Part 1: Chrysotile Asbestos* (U.S. EPA, 2020c) and the appendices and supporting documents, as well as on the previous sections of this *Risk Evaluation for Asbestos Part 2: Supplemental Evaluation Including Legacy Uses and Associated Disposals* and the appendices and supporting documents—in accordance with TSCA section 6(b), as well as (1) the best available science (TSCA section 26(h)), and (2) weight of scientific evidence standards (TSCA section 26(i)), and (3) relevant implementing regulations in 40 CFR 702, including, to the extent practicable, the amendments to the procedures for chemical risk evaluation under TSCA finalized in May of 2024.

EPA will initiate risk management rulemaking to mitigate identified unreasonable risk associated with asbestos under the COUs in Part 2 by applying one or more of the requirements under TSCA section 6(a) to the extent necessary so that asbestos no longer presents such risk. Following issuance of the Part 1 Risk Evaluation for Asbestos, EPA proposed (87 FR 21706) and, after considering public comment, finalized regulation of certain conditions of use of chrysotile asbestos to address the unreasonable risk identified in the Part 1 Risk Evaluation relating to ongoing uses of chrysotile asbestos (89 FR 21970). EPA will issue a proposed rule following completion of this Part 2 Risk Evaluation for Asbestos in accordance with section 6(a). The Agency would also consider whether such risk may be prevented or reduced to a sufficient extent by action taken under another federal law, such that referral to another agency under TSCA section 9(a) or use of another EPA-administered authority to protect against such risk pursuant to TSCA section 9(b) may be appropriate.

The risk identified for asbestos under the COUs evaluated in this *Risk Evaluation for Asbestos, Part 2: Supplementary Evaluation Including Legacy Uses and Associated Disposals* supplements the risk of asbestos determined in the 2020 *Risk Evaluation for Asbestos, Part 1: Chrysotile Asbestos* (U.S. EPA, 2020c) (see also Section 1.1. Scope of the Risk Evaluation). The Agency is now making a single unreasonable risk determination for asbestos as a chemical substance. The majority of the COUs in this Part 2 Risk Evaluation that EPA determines contribute to the unreasonable risk posed by asbestos relate to handling or disturbing articles into which asbestos was incorporated in the past, but for which the manufacture (including import), processing, and distribution of these articles no longer occurs. The rough handling or disturbance of these articles can cause asbestos to be released as respirable (friable) asbestos fibers. As noted in Section 6.1.1, and further discussed in Sections 6.2.1.2 and 6.2.1.3, in this risk determination, EPA believes it is appropriate to evaluate the levels of risk present in baseline scenarios where personal protective equipment (PPE) is not assumed to be used by workers.

The COUs evaluated for asbestos are listed in Table 1-1. The following COUs significantly contribute to the unreasonable risk:

- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – construction and building materials covering large surface areas, including paper articles; metal articles; stone plaster, cement, glass, and ceramic articles;

- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – machinery, mechanical appliances, electrical/electronic articles;
- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – other machinery, mechanical appliances, electronic/electronic articles;
- Industrial/commercial use – chemical substances in furnishing, cleaning, treatment care products – construction and building materials covering large surface areas, including fabrics, textiles, and apparel;
- Industrial/commercial use – chemical substances in furnishing, cleaning, treatment care products – furniture and furnishings, including stone, plaster, cement, glass, ceramic articles, metal articles, and rubber articles;
- Consumer use – chemical substances in construction, paint, electrical, and metal products – construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles; and
- Disposal.

The following COUs do not significantly contribute to the unreasonable risk:

- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – fillers and putties*;
- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – solvent based/water-based paint*;
- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – electrical batteries and accumulators;
- Industrial/commercial use – chemical substances in packaging, paper, plastic – packaging (excluding food packaging) – rubber articles; plastic articles (hard); plastic articles (soft):
- Industrial/commercial use – chemical substances in automotive, fuel, agriculture, outdoor use products – lawn and garden care products;
- Industrial/commercial use – mining of non-asbestos commodities – mining of non-asbestos commodities;
- Industrial/commercial use – laboratory chemicals – laboratory chemicals;
- Industrial/commercial use – chemical substances in products not described by other codes – other (artifacts);
- Industrial/commercial use – chemical substances in products not described by other codes – other (aerospace applications);
- Consumer use – chemical substances in construction, paint, electrical, and metal products – machinery, mechanical appliances, electrical/ electronic articles;
- Consumer use – chemical substances in construction, paint, electrical, and metal products – fillers and putties*;
- Consumer use – construction, paint, electrical, and metal products – solvent-based/water-based paint*;
- Consumer use – chemical substances in furnishing, cleaning, treatment care products – construction and building materials covering large surface areas, including fabrics, textiles, and apparel;
- Consumer use – chemical substances in furnishing, cleaning, treatment care products – furniture and furnishings, including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles;
- Consumer use – chemical substances in packaging paper, plastic, toys, hobby products – packaging (excluding food packaging) – rubber articles; plastic articles (hard); plastic articles (soft);

- Consumer use – chemical substances in packaging paper, plastic, toys, hobby products – toys intended for children's use (and child dedicated articles) – fabrics, textiles, and apparel; or plastic articles (hard):
- Consumer use – chemical substances in products not described by other codes – other (artifacts); and
- Consumer use – chemical substances in automotive, fuel, agriculture, outdoor use products – lawn and garden care products.

Note that EPA considered the specific circumstances related to four of the COUs that do not significantly contribute to the unreasonable risk of asbestos, marked with an asterisk (*) above. Asbestos-containing fillers and putties and solvent and water-based paints already applied to articles are unlikely to release asbestos fibers unless disturbed though rough handling, which EPA does not expect for these COUs. However, it is possible that asbestos fiber releases may occur during the rough handling of building materials, machinery or furnishings containing putties and paints during construction, renovation, demolition, repairs, and other similar activities that make the asbestos-containing material friable. These releases are already represented by COUs that significantly contribute to the unreasonable risk of asbestos. In addition, EPA finds that the evidence suggests that exposure to asbestos unintentionally present in trace amounts in other mined commodities and manufactured/processed products/articles from such materials that are subject to TSCA occurs infrequently and at low levels (see Section 5.3.2.5), and therefore their manufacture (including mining and import), processing, distribution in commerce, use, and disposal does not significantly contribute to the unreasonable risk of asbestos. Note that EPA did not assess exposures from asbestos unintentionally present in trace amounts in products that are not subject to TSCA such as cosmetics; thus, EPA's finding on trace amounts should not be extrapolated to conclusions about uses of asbestos that are not subject to TSCA.

This risk determination for asbestos as a chemical substance reflects policy changes announced by EPA in June 2021 (and further discussed in Section 6.1.1) and is based on the risk estimates and risk-related factors in the Part 1 Risk Evaluation for Asbestos. The policy changes announced by the Agency in June 2021 do not change the conditions of use that significantly contribute to the unreasonable risk of asbestos evaluated in Part 1. In addition, this risk determination is based on the risk estimates and risk-related factors presented in this Part 2 Risk Evaluation for Asbestos.

EPA had limited data available to evaluate certain COUs. In determining whether COUs that the Agency had limited information significantly contributed to the unreasonable risk of asbestos, EPA integrated reasonably available information in a qualitative risk characterization using professional judgement of read-across evidence to other COUs with similar expected exposure scenarios. The qualitative analyses are a best estimate of what EPA expects given the weight of scientific evidence without overstating the science. Environmental and human health risk characterizations for those COUs with limited data are in Sections 4.3.1and 5.3.2 of this risk evaluation. Additional explanation regarding the qualitative risk characterizations and EPA's conclusion about whether the COU significantly contributes to unreasonable risk are included in Sections 6.2.1.4, 6.2.1.5, 6.2.1.6, and 6.2.1.7.

Whether EPA makes a determination of unreasonable risk for a particular chemical substance under amended TSCA depends upon risk-related factors beyond exceedance of benchmarks, such as the endpoint under consideration, the reversibility of effect, exposure-related considerations (*e.g.*, duration, magnitude, or frequency of exposure, or population exposed), and the confidence in the information used to inform the hazard and exposure values. For COUs evaluated quantitatively, to determine if a COU contributed significantly to unreasonable risk, EPA compared the risk estimates of the scenario used to evaluate the COUs and considered whether the risk from the COU was best represented by the central tendency or high-end risk estimates. Additionally, in the risk evaluation, the Agency describes the strength of the scientific evidence supporting the human health and environmental assessments as robust, moderate, or slight. Robust confidence suggests thorough understanding of the scientific evidence and uncertainties, and the supporting weight of scientific evidence outweighs the uncertainties to the point where it is unlikely that the uncertainties could have a significant effect on the exposure or hazard estimate or the overall risk characterization. Moderate confidence suggests some understanding of the scientific evidence and uncertainties, and the supporting scientific evidence weighed against the uncertainties is reasonably adequate to characterize exposure or hazard estimates or the overall risk characterization. Slight confidence is assigned when the weight of scientific evidence may not be adequate to characterize the scenario, and when the Agency is making the best scientific assessment possible in the absence of complete information. This risk evaluation discusses important assumptions and key sources of uncertainty in the risk characterization. These are described in more detail in the respective weight of scientific evidence conclusions sections for fate and transport, environmental release, environmental exposures, environmental hazards, and human health hazards. It also includes overall confidence and remaining uncertainties sections for human health and environmental risk characterizations.

In making the asbestos unreasonable risk determination, EPA considered risk estimates with an overall confidence rating of slight, moderate, robust, and the Agency considered COUs with limited reasonably available information. In general, EPA makes an unreasonable risk determination based on risk estimates that have an overall confidence rating of moderate or robust, because those confidence ratings indicate the scientific evidence is adequate to characterize risk estimates despite uncertainties or is such that it is unlikely the uncertainties could have a significant effect on the risk estimates (Section 5.3.5).

6.1 Background

6.1.1 Policy Changes Relating to a Single Risk Determination on the Chemical Substance and Assumption of PPE Use by Workers

From June 2020 to January 2021, EPA published risk evaluations on the first 10 chemical substances, including the 2020 *Risk Evaluation for Asbestos, Part 1: Chrysotile Asbestos* (U.S. EPA, 2020c). The risk evaluations included individual unreasonable risk determinations for each COU evaluated. The determinations that particular conditions of use did not present an unreasonable risk were issued by order under TSCA section 6(i)(1).

In accordance with Executive Order 13990 ("Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis") (EOP, 2021a) and other Administration priorities (EOP, 2021b, c, d; EPA Press Office, 2021), EPA reviewed the risk evaluations for the first 10 chemical substances to ensure that they met the requirements of TSCA, including conducting decision-making in a manner that is consistent with the best available science and weight of scientific evidence.

As a result of this review, EPA announced plans to revise specific aspects of certain of the first 10 risk evaluations in order to ensure that the risk evaluations appropriately identify unreasonable risks and thereby can help ensure the protection of health and the environment (EPA Press Office, 2021). The changes to no longer assume the use of PPE in making the unreasonable risk determination does not change what conditions of use evaluated under Part 1 would contribute to a single unreasonable risk determination for asbestos as a chemical substance. Further discussion of the decision to not rely on assumptions regarding the use of PPE in this *Risk Evaluation for Asbestos Part 2: Supplemental Evaluation Including Legacy Uses and Associated Disposals* is provided in Sections 6.2.1.2 and 6.2.1.3 below. With the issuance of the Part 2 Risk Evaluation for Asbestos, the Agency is determining that this approach will apply to this risk evaluation. In addition, as discussed below in Sections 6.2.1.2 and 6.2.1.3, in this risk determination, EPA believes it is appropriate to evaluate the levels of risk present in baseline scenarios where PPE is not assumed to be used by workers; although the Agency does not question the information received regarding the occupational safety practices often followed by many industry respondents.

Making unreasonable risk determinations based on the baseline scenario without assuming PPE should not be viewed as an indication that EPA believes there are no occupational safety protections in place at any location or that there is widespread noncompliance with applicable OSHA standards. EPA understands that there could be occupational safety protections in place at workplace locations. Nevertheless, not assuming use of PPE reflects the Agency's recognition that unreasonable risk may exist for subpopulations of workers that may be highly exposed because they are (1) not covered by OSHA standards; (2) their employers are out of compliance with OSHA standards; (3) many of OSHA's chemical-specific permissible exposure limits largely adopted in the 1970s are described by OSHA as being "outdated and inadequate for ensuring protection of worker health"[5]; or (4) EPA finds unreasonable risk for purposes of TSCA notwithstanding OSHA requirements.

With regard to the specific circumstances of asbestos, as further explained below, EPA has determined that a single risk determination on the chemical substance asbestos is appropriate in order to protect health and the environment. The single risk determination on the chemical is appropriate for asbestos because there are benchmark exceedances for multiple COUs (spanning across most aspects of the chemical life cycle—from manufacturing [including import], processing, industrial, commercial and consumer use, and disposal) for human health. Furthermore, the risk of severe health effects—specifically mesothelioma and lung, ovarian, and laryngeal cancers, along with non-cancer effects—is associated with chronic inhalation exposures of asbestos. Because these chemical-specific properties cut across the COUs within the scope of the risk evaluation and a substantial amount of the COUs contribute to the unreasonable risk, it is therefore appropriate for the Agency to determine that the chemical substance presents an unreasonable risk. For those COUs assessed in the *Risk Evaluation for Asbestos, Part 1: Chrysotile Asbestos* (U.S. EPA, 2020c), EPA does not intend to amend, nor does a single risk determination on the chemical substance require, amending the underlying scientific analysis and the risk characterization.

The discussion of these issues in this risk determination supersede any conflicting statements in the 2020 *Risk Evaluation for Asbestos, Part 1: Chrysotile Asbestos* (U.S. EPA, 2020c) and the response to comments document (*Summary of External Peer Review and Public Comments for Asbestos and Disposition for Asbestos, Part 1: Chrysotile Asbestos* (U.S. EPA, 2020c). EPA also views the peer-reviewed hazard and exposure assessments and associated risk characterization of Part 1 as robust and upholding the standards of best available science and weight of scientific evidence per TSCA sections 26(h) and (i).

The December 2020 Part 1 Risk Evaluation for Asbestos included individual risk determinations for each condition of use evaluated. The determinations that certain conditions of use did not present unreasonable risk were issued by order under TSCA section 6(i)(1). Section 5.3.1 of the December 2020 Risk Evaluation stated: "This subsection of the Part 1 of the risk evaluation for asbestos…constitutes the order required under TSCA section 6(i)(1), and the 'no unreasonable risk' determinations in this

---

[5] As noted on OSHA's Annotated Table of Permissible Exposure Limits: "OSHA recognizes that many of its permissible exposure limits (PELs) are outdated and inadequate for ensuring protection of worker health. Most of OSHA's PELs were issued shortly after adoption of the Occupational Safety and Health (OSH) Act in 1970 and have not been updated since that time" (OSHA, 2016).

subsection are considered to be final agency action effective on the date of issuance of this order." In this final risk determination in the Part 2 Risk Evaluation for Asbestos, EPA has determined that asbestos presents an unreasonable risk of injury to health under the conditions of use. This risk determination supersedes the no unreasonable risk determinations in the December 2020 Risk Evaluation that were premised on a condition of use-specific approach to determining unreasonable risk. This subsection of the risk determination also constitutes an order withdrawing the TSCA section 6(i)(1) order in the December 2020 Risk Evaluation. EPA has inherent authority to reconsider previous decisions and to revise, replace, or repeal a decision to the to the extent permitted by law and supported by reasoned explanation. *FCC v. Fox Television Stations, Inc*., 556 U.S. 502, 515 (2009); *see also Motor Vehicle Mfrs. Ass'n v. State Farm Mutual Auto. Ins. Co*., 463 U.S. 29, 42 (1983).

6.2 Human Health

Calculated risk estimates (MOEs or cancer risk estimates) can provide a risk profile of asbestos by presenting a range of estimates for different health effects for different COUs. In addition, the risk estimates are based on exposure scenarios with monitoring data that may reflect existing requirements, such as those established by EPA (*i.e.,* NESHAP under the Clean Air Act and the Asbestos Hazard Emergency Response Act under TSCA Title II), OSHA (*i.e.,* asbestos standard), or industry or sector best practices. A calculated MOE that is less than the benchmark MOE is a starting point for informing a determination of unreasonable risk of injury to health, based on non-cancer effects. Similarly, a calculated cancer risk estimate that is greater than the cancer benchmark is a starting point for informing a determination of unreasonable risk of injury to health from cancer. It is important to emphasize that these calculated risk estimates alone are not "bright-line" indicators of unreasonable risk.

6.2.1 Human Health Asbestos Part 2

6.2.1.1 Populations and Exposures EPA Assessed for Human Health

EPA evaluated risk to workers—including ONUs (male and female, adults and adolescents ≥16 years old, and firefighters). In addition, EPA evaluated risk to handlers (16 to 40 years old), and bystanders (0 to 78 years old)—with take-home exposures from the workplace (*e.g.,* people exposed to asbestos fibers adhering to garments taken home by workers/ONUs). Also, EPA evaluated risk to consumers (male and female, adolescents and adults (16–78 years old)); bystanders (male and female, 0–20 years old); and the general population. The risk to all of these populations were evaluated using reasonably available monitoring and modeling data for chronic inhalation exposures. The Agency evaluated cancer and non-cancer chronic risk estimates from such inhalation exposures and considered the distance of the general population from the source of the exposures. Descriptions of the data used for human health exposure and human health hazards are provided in Section 5.1 and Section 5.1.1. Uncertainties for overall exposures and hazards are presented in Section 5.3.5 and summarized in Table 5-28 and are considered in the unreasonable risk determination.

6.2.1.2 Summary of Human Health Effects

EPA has determined that the unreasonable risks presented to workers (including ONUs and firefighters), handlers of asbestos contaminated clothing from occupational activities, consumers, bystanders, and general population by exposure to asbestos, are due to

- cancer and non-cancer effects in workers, including ONUs and firefighters, from inhalation exposures;
- cancer and non-cancer effects in handlers and bystanders from inhalation exposures associated with handling of garments taken home from occupational exposure;
- cancer and non-cancer effects in consumers and bystanders from inhalation exposures; and

- cancer and non-cancer effects in the general population from inhalation exposures.

An IUR of 0.2 per f/cc was used for this assessment. Risk estimates from previous EPA assessments of varied fiber types used IURs from 0.16-0.23 per f/cc. A sensitivity analysis showed no change in risk indication across these values; therefore, EPA selected 0.2 per f/cc as the most appropriate IUR for this Part 2 assessment. The human health hazard studies show that asbestos exposure is associated with lung cancer, mesothelioma, laryngeal cancer, and ovarian cancer. When available, EPA used monitoring data to characterize central tendency (median) and high-end (95th percentile) inhalation exposures. In cases where no ONU sampling data were available, EPA typically assumed that ONU inhalation exposure is either comparable to area monitoring results or assumed that ONU exposure is likely lower than workers.

For the Disposal COU, EPA did not have monitoring data to estimate inhalation exposure for ONUs; exposure for ONUs were addressed using the central tendency for estimates of worker inhalation exposure. In addition, for some COUs, EPA classified workers in two categories: "higher exposure-potential workers" are workers whose activities may directly generate friable asbestos through actions such as cutting, grinding, welding, or tearing asbestos-containing materials; and "lower exposure-potential workers" are workers who were not expected to generate friable asbestos but may come into direct contact with friable asbestos while performing their required work activities. More information on EPA's confidence in these risk estimates for inhalation and the uncertainties associated with them can be found in Section 5.1.1.4.

For workers, including ONUs, EPA estimated risks using several occupational exposure scenarios related to the central tendency (median) and high-end (95th percentile) estimates of exposure. For workers and ONUs, cancer risks in excess of the benchmark (1×10^{-4}) were indicated for virtually all quantitatively assessed COUs when PPE was not used. For handler and bystanders of take-home occupational use, consumers (DIYers), and bystanders of consumer use, EPA estimated cancer risks resulting from inhalation exposures. For handlers and bystanders, cancer risks in excess of the benchmark (1×10^{-6}) were indicated for five COUs. For consumers and bystanders, cancer risks in excess of the benchmark (1×10^{-6}) were indicated for four COUs. For the general population, cancer risk estimates for each COU across all distances range from 2.2×10^{-11} to 8.6×10^{-4} for low exposure, central tendency, and high exposure, and in excess of the benchmark (1×10^{-6}) for five COUs (see Table 5-24).

EPA considers 1×10^{-6} as the appropriate benchmark for increased cancer risk for the general population, including people who live in fenceline communities near the sources of asbestos. Again, these benchmarks are not bright lines and the Agency has discretion to consider other risk-related factors when determining if a condition of use significantly contributes to the unreasonable risk determination of the chemical substance. The confidence in the modeling estimates and explanation of the assumptions for the exposure scenarios used to calculate risk estimates for inhalation exposures for general population from the conditions of use are explained in Section 5.3.2.1. The sections below provide further detail of how the risk estimates for workers (6.2.1.4.), take-home exposures (6.2.1.5), consumers (6.2.1.6), and the general population (6.2.1.7) were considered in the unreasonable risk determination.

With respect to non-cancer health endpoints upon which EPA is basing this unreasonable risk determination, the Agency has moderate overall confidence in the (1) non-cancer hazard value POD, which is derived from epidemiologic data and chronic, lifetime value for continuous exposure and exposure concentrations have been adjusted to match the time duration for inhalation exposure; and (2) most sensitive and robust non-cancer health effects from chronic exposure of localized pleural thickening of lung tissue in humans based on epidemiologic data from an occupational cohort (see

Section 5.3.1). EPA's exposure and overall risk characterization confidence levels varied and are summarized in Table 5-28.

The non-cancer risk estimates for workers, ONUs, take home exposures (handlers and bystanders), consumers, bystanders, and the general population are presented in Section 5.3.2, including a benchmark MOE of 300 for the most sensitive and robust non-cancer endpoint. A summary of health risk estimates is available for workers and ONUs (Section 5.3.2.1), take-home exposures (handlers and bystanders) (Section 5.3.2.2), consumers and bystanders (Section 5.3.2.3), and general population (Section 5.3.2.4).

6.2.1.3 Basis for Unreasonable Risk to Human Health

In developing the exposure and hazard assessments for asbestos, EPA analyzed reasonably available information to ascertain whether some human populations may have greater exposure and/or susceptibility than the general population to the hazard posed by asbestos. For the Part 2 Risk Evaluation, EPA identified as PESS groups that are of concern with regards to risks related to asbestos exposure—including those with occupational exposures, children, individuals who are exposed through DIY activity, and those who smoke (see Section 5.3.2.5 and Table 5-26). The PESS group represented by occupational exposures include a broad range of occupations, including individuals involved in demolition and disposal of asbestos-containing material as well as firefighters who may be exposed during residential and commercial building firefighting activity. Similarly, consumers who engage in DIY activities related to demolition and disposal of asbestos-containing materials have greater risk and are considered a PESS.

Risk estimates based on central tendency (median) exposure levels are generally estimates of average or typical exposure. High-end exposure levels (*e.g.,* 95th percentile or "high intensity use") are generally intended to cover individuals with sentinel exposure levels. For several COUs, EPA considered sentinel exposures by considering risks to populations who may have upper bound exposures; for example, workers and ONUs who perform activities with higher exposure potential or consumers who have higher exposure potential (*e.g.,* those involved with DIY projects). In cases where sentinel exposures result in MOEs or excess cancer risks (ELCRs) greater than the benchmark or cancer risk lower than the benchmark (*i.e.,* risks were not identified), EPA did no further analysis because sentinel exposures represent the highly exposed. A worker may be involved in multiple activities aside from their work requirements that exposes them to asbestos that have varying occupational exposure scenarios. DIYers may also perform multiple projects that exposes them to asbestos fibers. This would increase the overall risk posed to these workers and DIYers. However, EPA is unable to determine the likelihood of a worker or DIYer partaking in these multiple activities; therefore, the Agency did not carry forward the aggregate analysis into the risk determination. Additional information on how EPA characterized sentinel and aggregate risks is provided in Section 5.3.4.

The UF of 10 for human variability that EPA has applied to MOEs accounts for increased susceptibility of populations such as children and elderly populations. The Agency also generally relies on high-end exposure levels to make an unreasonable risk determination to capture vulnerable populations that are expected to have higher exposures. In the case of Part 2 Risk Evaluation for Asbestos, EPA calculated risk estimates to subpopulations with higher exposure, such as higher exposure-potential workers, firefighters, and DYIers.

EPA's estimates for workers and ONU risks for each occupational exposure scenario are presented in Table 5-21, risk estimates for take-home exposures are presented in Table 5-22, while risk estimates for the general population are presented in Table 5-24.

6.2.1.4 Workers

Based on the risk estimates and related risk factors, EPA has determined that worker risk (including ONUs) for all COUs with quantified risk estimates contribute to the unreasonable risk for asbestos due to cancer and non-cancer risks from inhalation exposures. The Agency has also determined that two of these occupational COUs associated with firefighters contribute to the unreasonable risk for asbestos due to non-cancer risks from inhalation exposures. For workers, including ONUs, EPA considered exposures to asbestos for the entire 8-hour workday for up to 250 days per year for 40 working years. Also, the Agency is using an 8-hour time weighted average (8-hour TWA) and short-term (30-minute) inhalation exposure estimates. The short-term average daily concentration (ADC) estimates are calculated using the 30-minute exposure concentrations, averaged with 7.5 hours at the full shift (*i.e.*, 8-hour TWA) exposure concentrations.

Although the exposure scenarios in the risk evaluation did not assume compliance with existing federal regulation, the monitoring data used may reflect the existing federal, state, and local regulations requiring proper management of asbestos-containing materials. Under the Asbestos Hazard Emergency Response Act (AHERA) under Title II of TSCA, EPA regulations require local education agencies (*i.e.*, public school districts and non-profit private schools, including charter schools and schools affiliated with religious institutions) to inspect their school buildings for asbestos, prepare asbestos management plans and perform asbestos response actions. AHERA also required EPA to develop a model plan for states for training and accrediting persons conducting asbestos inspections and corrective-action activities at schools and public and commercial buildings.

Under the Clean Air Act, the asbestos National Emission Standards for Hazardous Air Pollutants (NESHAPs) regulations specify work practices for asbestos to be followed during renovations and prior to demolitions of all structures, installations, and buildings (excluding residential buildings that have four or fewer dwelling units). And OSHA regulates asbestos through standards for the construction industry, general industry, and shipyard employment sectors. These standards require exposure monitoring and awareness training. When asbestos exposure is identified, employers are required to establish regulated areas, control certain work practices, institute engineering controls, use administrative controls and, if needed, provide for the wearing of personal protective equipment. OSHA standards also require proper handling of work clothing to prevent "take home" contaminated work clothing. MOEs and cancer risk estimates at the central tendency that show risks below the benchmark may include situations where existing federal, state, and local asbestos regulatory requirements required work practices that reduced the release of asbestos fibers. EPA focused on the high-end risk estimates to represent situations where workers, including persons hired to perform home renovation work, may not be subject to existing asbestos regulatory requirements or follow work practices to reduce asbestos exposure. There are situations where workers, including self-employed persons hired to perform home renovation work, may not be subject to existing asbestos regulatory requirements, or do not follow work practices to reduce asbestos exposure, or may not be aware that asbestos is present at the worksite.

For workers, cancer risks were indicated for most quantitatively assessed COUs, for workers with high-end exposures when PPE was not used. In general, the chronic non-cancer MOE at the high-end and central tendency exposure level indicated risk for all quantitatively assessed COUs across all populations (high exposure potential worker, low exposure potential worker, ONU, worker, and those COUs where firefighters [both career and volunteer] where assessed). EPA identified non-cancer risk for firefighters due to exposures from two occupational COUs: (1) Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – construction and building materials covering large surface areas – paper articles; metal articles; stone plaster, cement, glass, and ceramic articles; and (2) Industrial/commercial use – chemical substances in furnishing, cleaning, treatment care products – construction and building materials covering large surface areas – fabrics, textiles, and apparel.

The following COUs were evaluated using an OES; however, the activities described in those scenarios are not expected to accurately represent the risk presented by the COUs. Some COUs evaluated quantitatively are best represented by the lower exposure-potential workers of the Handling articles or formulations that contain asbestos OES, since articles covered by these COUs are expected to contain asbestos at levels similar to other articles assessed but are not expected to be manipulated (*e.g.*, sanded). Other COUs evaluated quantitatively by OESs that include activities where the product/article is disturbed or replaced (or both), but the COU does not encompass disturbing or replacing the article. And there are other COUs evaluated quantitatively for which the OES use indicates that the specific activity encompassed by the COU will not contribute to the unreasonable risk of asbestos. For the specific COUs below, EPA explains how the risk estimates of the exposure scenario described in Appendix G are interpreted and why EPA has determined that the COUs listed below do not significantly contribute to the unreasonable risk of asbestos:

- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – fillers and putties: because the asbestos-containing fillers and putties are unlikely to release asbestos fibers unless disturbed through rough handling (*i.e.*, handling the fillers and putties in a way that would create friable asbestos);
- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – solvent based/water based paint: because the asbestos-containing solvent and water-based paints are unlikely to release asbestos fibers unless disturbed through rough handling;
- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – electrical batteries and accumulators: because the batteries and accumulators are not expected to be manipulated in a way that release asbestos fibers;
- Industrial/commercial use – chemical substances in packaging, paper, plastic – packaging (excluding food packaging) – rubber articles; plastic articles (hard); plastic articles (soft): because these articles are not expected to be manipulated in a way that release asbestos fibers;
- Industrial/commercial use – chemical substances in automotive, fuel, agriculture, outdoor use products – lawn and garden care products: based on EPA analysis of vermiculite products, EPA does not expect any significant asbestos releases or occupational exposures;
- Industrial/ commercial use – mining of non-asbestos commodities – mining of non-asbestos commodities: based on data and information from MSHA and stakeholders, EPA has determined that exposure to asbestos is unlikely (Appendix E.11 and Appendix G);
- Industrial/ commercial use – laboratory chemicals – laboratory chemicals: based on EPA analysis of vermiculite products, EPA does not expect any significant asbestos releases or occupational exposures (Appendix E.12);
- Industrial/commercial use – chemical substances in products not described by other codes – other (artifacts): because these artifacts are not expected to be manipulated in a way that release asbestos fibers;
- Industrial/commercial use – chemical substances in products not described by other codes – other (aerospace applications): based on the exposure scenario of activities related to aerospace applications (Appendix G.13).

6.2.1.5 Take-Home Exposures

Based on the risk estimates and related risk factors, EPA has determined that take-home exposure risks contribute to the unreasonable risk for asbestos due to cancer and non-cancer risks from inhalation exposures.

To determine the unreasonable risk presented by asbestos, EPA considered the non-cancer MOEs and cancer risk estimates for central tendency and high end based on chronic inhalation exposures for both garment handlers who may handle asbestos containing garments and bystanders. The Agency estimates the yearly average concentration for each exposure scenario for cancer and non-cancer risk estimates, taking into consideration the exposure concentration (asbestos fibers in the air), the exposure time (hours/day) over a 24-hour period, and the exposure frequency (days/year) over 365 days. Section 5.1.2 provides a detailed description on how the Agency developed the yearly average concentration for in take-home scenarios.

EPA identified cancer and non-cancer risks for garment handlers who may handle asbestos-containing garments and bystanders near those handling the asbestos-containing garments for most quantitatively assessed COUs with the exception of firefighting (career and volunteer) and those handling solvent-based/water-based paint, fillers and putties, furniture & furnishings including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles, packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft), other (artifacts), and other (aerospace applications) and bystanders of disposal. No cancer risk was identified below the benchmark for take-home exposures from firefighting (volunteer) and those handling solvent-based/water-based paint, fillers and putties, furniture & furnishings including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles, packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft), other (artifacts), and other (aerospace applications).

EPA has moderate confidence in the regression approach used to calculate the risk estimates (see Table 5-9), although, there are sources of uncertainty in the assumptions and approximations used. For example, there is high variability (3–4 orders of magnitude difference) in the data used and the estimated risk values, which can be representative of a wide number of use patterns and product fiber emissions. The uncertainty increases due the small number of studies and the lack of product and activity specific data. However, for purpose of the unreasonable risk determination, EPA is considering the risk estimates based on high-end exposure because such high-end exposures are based on representative occupational exposure concentrations and the data indicates that the risk to those handing garments with that high occupational contamination concentration (and the bystanders) significantly contribute to the unreasonable risk to asbestos.

6.2.1.6 Consumers

Based on the risk estimates and related risk factors, EPA has determined the consumer COUs quantitatively evaluated contribute to the unreasonable risk for asbestos due to cancer and non-cancer risks from consumer DIYer and bystander inhalation exposures.

EPA estimated both consumer and bystander activity-based exposures. The exposure can start at 16 years of age and because asbestos remains in the body (*e.g.*, lungs) until the estimated life expectancy age of 78 years, the total exposure duration is 62 years of asbestos presence in the body after exposure for DIY users. The exposure duration is 78 years for bystanders, since exposures can occur for younger than 16 years of age. For repair activities, it was assumed that a DIY user may perform one repair or renovation task where they may disturb asbestos containing material per year, as well as the length of time spent on the task varies for low-end, high-end, and central tendency exposure estimates. For removal activities, EPA reviewed the frequency of replacement for various home materials such as tiles and roofing, but also considered the likelihood of consumers encountering legacy use ACM. Section 5.1.3.2 has a detailed description on how the Agency considered activity-based exposures.

For consumers (DIYers) and bystanders of consumer use cancer risks and non-cancer risk were indicated for the quantitatively assessed COUs from inhalation exposures. EPA's estimates for consumer and bystander risks for each consumer use exposure scenario are presented in Table 5-23. Confidence levels on the risk estimates are presented in Table 5-28. One COU (Consumer use – chemical substances in furnishing, cleaning, treatment care products – furniture and furnishings, including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles) and risk to bystanders from another COU (Consumer use – chemical substances in construction, paint, electrical, and metal products – construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles) were found to not significantly contribute to the unreasonable risk of asbestos because of the Agency's slight confidence in their risk estimates.

For products where quantitative information was not available in the literature, exposure and risk potential were done qualitatively in Appendix J, by integrating limited amounts of reasonably available information using professional judgement of read-across evidence. The qualitative analyses are a best estimate of what EPA expects given the weight of scientific evidence without overstating the science and describe the environmental releases and occupational exposure assessment. Therefore, for the COUs below, EPA has determined the COUs do not significantly contribute to the unreasonable risk of asbestos:

- Consumer use – chemical substances in construction, paint, electrical, and metal products – machinery, mechanical appliances, electrical/ electronic articles: these articles are not friable and are unlikely to be modified by consumers, EPA concludes asbestos fibers are not to be released and hence no exposure is expected;
- Consumer use – chemical substances in construction, paint, electrical, and metal products – fillers and putties: because the asbestos-containing fillers and putties are unlikely to release asbestos fibers unless disturbed through rough handling;
- Consumer use – construction, paint, electrical, and metal products – Solvent-based/water-based paint: because the asbestos-containing solvent and water-based paints are unlikely to release asbestos fibers unless disturbed through rough handling Consumer use – chemical substances in furnishing, cleaning, treatment care products – construction and building materials covering large surface areas, including fabrics, textiles, and apparel: because these articles are not friable and are unlikely to be modified by consumers via sanding or cutting, EPA concludes asbestos fibers are not to be released from an undisturbed item and hence no exposure is expected;
- Consumer use – chemical substances in packaging paper, plastic, toys, hobby products – packaging (excluding food packaging) – rubber articles; plastic articles (hard); plastic articles (soft): because these articles are not friable and are unlikely to be modified by consumers via sanding or cutting, EPA concludes asbestos fibers are not to be released from an undisturbed item and hence no exposure is expected;
- Consumer use – chemical substances in packaging paper, plastic, toys, hobby products – toys intended for children's use (and child dedicated articles) – fabrics, textiles, and apparel; or plastic articles (hard): while some exposure might occur with the use of mineral kits, studies with crayons indicated that no asbestos fibers were measured during the typical crayon use patterns;
- Consumer use – chemical substances in products not described by other codes – other (artifacts): because these products are not friable and are unlikely to be modified by consumers via sanding or cutting, EPA concludes asbestos fibers are not to be released from an undisturbed item and hence no exposure is expected; and

- Consumer use – chemical substances in automotive, fuel, agriculture, outdoor use products – lawn and garden care products: based on EPA analysis of vermiculite products, EPA does not expect any significant asbestos exposures to consumers.

More information on EPA's confidence in these risk estimates for inhalation and the uncertainties associated with them can be found in Section 5.1.3.3.1.

6.2.1.7 General Population

Based on the risk estimates and related risk factors, EPA has determined general population risks contribute to the unreasonable risk for asbestos due to cancer and non-cancer risks from inhalation exposures. For cancer inhalation exposures there are risks for the general population relative to the benchmark for people within 10 to 60 m from the source, also known as the co-located distances, and 100 m from the source, defined as the general population distances, at low, central, and high-intensity exposure levels for several COUs. For purposes of the risk determination, EPA is considering the 100 to 1,000 m risk estimates to determine cancer and non-cancer risk from inhalation exposures from the disposal COU.

Exposure to the general population was estimated for the industrial and commercial releases per OES and matched to each COU (see Section 5.1.4.1). These release estimates were then used to model ambient air concentrations (see Section 5.1.4.2). Then the EPA modeled estimates for ambient air were used to obtain inhalation exposures for general population. More information on the Agency's approach and methodology for modeling and estimating general population exposures can be found in Section 5.1.4.1.

EPA identified cancer risk for general population in the following five COUs:

- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – construction and building materials covering large surface areas, including paper articles; metal articles; stone plaster, cement, glass, and ceramic articles;
- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – machinery, mechanical appliances, electrical/electronic articles;
- Industrial/commercial use – chemical substances in construction, paint, electrical, and metal products – other machinery, mechanical appliances, electronic/electronic articles;
- Industrial/commercial use – chemical substances in furnishing, cleaning, treatment care products – construction and building materials covering large surface areas – fabrics, textiles, and apparel; and
- Industrial/commercial use – chemical substances in furnishing, cleaning, treatment care products – Furniture & furnishings including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles.

6.3 Environment

6.3.1 Environment Asbestos Part 2

Calculated risk quotients (RQs) can provide a risk profile by presenting a range of estimates for different environmental hazard effects for different COUs. EPA was unable to calculate RQs for asbestos due to limited exposure data. Based on the risk evaluation for asbestos—including the risk estimates, the environmental effects of asbestos, the exposures, physical and chemical properties of asbestos, and consideration of uncertainties—EPA did not identify risk of injury to the environment that would significantly contribute to the unreasonable risk determination for asbestos. Similar to the Part 1 Risk Evaluation, EPA concluded that there is very limited potential for asbestos exposures for aquatic- or sediment-dwelling organisms. EPA finds that asbestos does not present an unreasonable risk to aquatic or terrestrial species. See Section 4.2 for more information on environmental hazards and the methodology for assessment of aquatic and terrestrial species.

6.4 Additional Information Regarding the Basis for the Risk Determination

Table 6-1 through Table 6-4 summarize the basis for this unreasonable risk determination of injury to human health and the environment presented in this asbestos risk evaluation. In these tables, a checkmark (✓) indicates how the COU significantly contributes both to the unreasonable risk by identifying the type of effect (*e.g.*, human health, the environment) and the exposure route to the population that results in such contribution. Please note that not all COUs, exposure routes, or populations evaluated are included in these tables. The tables only include the relevant exposure route, or the population that supports the conclusion that the COU significantly contributes to the asbestos unreasonable risk determination. As explained in Section 6.2, for this unreasonable risk determination, EPA considered the effects of asbestos to human health at the central tendency and high-end, as well as effects of asbestos to human health and the environment from the exposures associated from the COU, risk estimates, and uncertainties in the analysis. See Sections 5.3.2.1, 5.3.2.2, 5.3.2.3, and 5.3.2.4 of this Part 2 Risk Evaluation for Asbestos for a summary of risk estimates.

Table 6-1. Supporting Basis for the Unreasonable Risk Determination for Human Health (Part 1 Occupational COUs)

Life Cycle Stage	Category	Population	Human Health Effects (Chronic Cancer)			
			Central Tendency		High-End[a]	
			8-Hour TWA	Short-Term	8-Hour TWA	Short-Term
Processing	Diaphragms in chlor-alkali industry	Workers		✓	✓	✓
		ONUs		N/A	✓	N/A
	Sheet gaskets in chemical production	Workers	✓	✓	✓	✓
		ONUs			✓	✓
Industrial Use	Sheet gaskets in chemical production	Workers	✓	✓	✓	✓
		ONUs	✓	✓	✓	✓
	Diaphragms in chlor-alkali industry	Workers		✓	✓	✓
		ONUs		N/A	✓	N/A
	Brake blocks in oil industry	Workers	✓	N/A	N/A	N/A
		ONUs	✓	N/A	N/A	N/A
Industrial/ Commercial use	Aftermarket automotive brakes/linings	Workers	✓	✓	✓	✓
		ONUs				
	Other vehicle friction products (excludes NASA aircraft use)	Workers	✓	✓	✓	✓
		ONUs				
	Other gaskets	Workers	✓	N/A	✓	N/A
		ONUs	✓	N/A	✓	N/A
Disposal	Brake blocks in oil industry	Workers	✓	N/A	N/A	N/A
		ONUs	✓	N/A	N/A	N/A
	Aftermarket automotive brakes/linings	Workers	✓	✓	✓	✓
		ONUs				
	Other vehicle friction products (excludes NASA aircraft use)	Workers	✓	✓	✓	✓
		ONUs				
	Other gaskets	Workers	✓	N/A	✓	N/A
		ONUs	✓	N/A	✓	N/A

[a] See Sections 6.2.1.2 and 6.2.1.3 for discussion of central tendency vs. high-end.
N/A = not assessed

Table 6-2. Supporting Basis for the Unreasonable Risk Determination for Human Health (Part 1 Consumer COUs)

Life Cycle Stage	Category	Population	Human Health Effects (Chronic Cancer)	
			Central Tendency	High-End[a]
Consumer Use	Aftermarket automotive brakes/linings	Consumers	✓	✓
		Bystander	✓	✓
	Other gaskets	Consumers	✓	✓
		Bystander	✓	✓
Disposal	Aftermarket automotive brakes/linings	Consumers	✓	✓
		Bystander	✓	✓
	Other gaskets	Consumers	✓	✓
		Bystander	✓	✓

[a] See Sections 6.2.1.2 and 6.2.1.3 for discussion of central tendency vs. high-end.

Table 6-3. Supporting Basis for the Unreasonable Risk Determination for Human Health (Part 2 Occupational COUs)

Life Cycle Stage	Category	Subcategory	Population	Chronic Non-cancer (8-hour TWA)	Cancer (8-hour TWA)
Industrial/ Commercial Uses	Chemical substances in construction, paint, electrical, and metal products	Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles	High Exposure Potential Worker	✓	✓
			Low Exposure Potential Worker	✓	
			ONU	✓	
			Firefighters (Career)	✓	
			Firefighters (Volunteer)	✓	
			Take Home – Handler	✓	✓
			Take Home – Bystander	✓	✓
			Take Home – Handler (Firefighting Career)		✓
			Take Home – Bystander (Firefighting Career)		✓
			General Population		✓
			General Population from Firefighting or Other Disaster Response		✓
		Machinery, mechanical appliances, electrical/electronic articles	Worker	✓	✓
			Take Home – Handler	✓	✓
			Take Home – Bystander	✓	✓
			General Population	✓	✓
		Other machinery, mechanical appliances,	Worker	✓	✓
			Take Home –Handler	✓	✓

Life Cycle Stage	Category	Subcategory	Population	Chronic Non-cancer (8-hour TWA)	Cancer (8-hour TWA)
		electronic/electronic articles	Take Home – Bystander	✓	✓
			General Population	✓	✓
Industrial/ Commercial Uses	Chemical substances in furnishing, cleaning, treatment care products	Construction and building materials covering large surface areas, including fabrics, textiles, and apparel	High Exposure Potential Worker	✓	✓
			Low Exposure Potential Worker	✓	
			ONU	✓	
			Firefighters (Career)	✓	
			Firefighters (Volunteer)	✓	
			Take Home – Handler	✓	✓
			Take Home – Bystander	✓	✓
			Take Home –Handler (Firefighting Career)		✓
			Take Home – Bystander (Firefighting Career)		✓
			General Population		✓
			General Population from Firefighting or Other Disaster Response		✓
		Furniture & furnishings including stone, plaster, cement, glass, and ceramic articles; metal articles; or rubber articles	High Exposure Potential Worker	✓	✓
			Low Exposure Potential Worker	✓	
			ONU	✓	
			Take Home – Handler		
			Take Home – Bystander		
			General Population	✓	✓
Disposal	Disposal	Disposal	Worker	✓	
			Take Home – Handler	✓	✓
			Take Home – Bystander		✓

Table 6-4. Supporting Basis for the Unreasonable Risk Determination for Human Health (Part 2 Consumer DIY COUs)

Life Cycle Stage	Category	Subcategory	Population	Chronic Non-cancer	Cancer
Consumer Use	Chemical substances in construction, paint, electrical, and metal products	Construction and building materials covering large surface areas: paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles	User (Consumer DIYer [a])	✓	✓

[a] DIY = do-it-yourself

REFERENCES

Abelmann, A; Maskrey, JR; Lotter, JT; Chapman, AM; Nembhard, MD; Pierce, JS; Wilmoth, JM; Lee, RJ; Paustenbach, DJ. (2017). Evaluation of take-home exposure to asbestos from handling asbestos-contaminated worker clothing following the abrasive sawing of cement pipe. Inhal Toxicol 29: 555-566. http://dx.doi.org/10.1080/08958378.2017.1418940

ACC. (2017). Use of non-friable asbestos containing gaskets in titanium dioxide manufacturing. October 30, 2017 [Information submitted by email to EPA].

Addison, WE; Neal, GH; Sharp, JH; White, AD. (1966). Amphiboles. Part IV. Surface properties of amosite and crocidolite. J Chem Soc Sect A Inorg Phys Theor Chem 1966: 79-81. http://dx.doi.org/10.1039/J19660000079

Ahrenholz, SH. (1988). Health hazard evaluation report no. HETA 86-422-1891, City of Ames Municipal Power Plant, Ames, Iowa. (HETA 86-422-1891). Cincinnati, OH: National Institute for Occupational Safety and Health.

Amer Mine Serv. (2023). Different types of mining [Website]. https://americanmineservices.com/different-types-of-mining/

Amer Tech Lab. (1979a). Atmosphere filtering monitoring report [878210782] [TSCA Submission]. (OTS0206152. 878210782. TSCATS/18201). Manville Service Corporation.

Amer Tech Lab. (1979b). Atmosphere filtering monitoring report [878210783] [TSCA Submission]. (OTS0206152. 878210783. TSCATS/18202). Manville Service Corporation.

Amer Tech Lab. (1979c). Atmosphere filtering monitoring report [878210785] [TSCA Submission]. (OTS0206152. 878210785. TSCATS/18204). Manville Service Corporation.

Anania, TL; Price, JH; Evans, WA. (1978). Health hazard evaluation report no. HHE 77-34-417, Midwest Steel Division, National Steel Corporation, Portage, Indiana. (HHE 77-34-417). Cincinnati, OH: National Institute for Occupational Safety and Health.

ANL. (1979). Asbestos in cooling-tower waters: Final report. (NUREG/CR-0770). Washington, DC: U.S. Nuclear Regulatory Commission. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/NUREGCR0770.xhtml

Archer, SR; Blackwood, TR. (1979). Status assessment of toxic chemicals : Asbestos (pp. 34). (EPA-600/2-79-210 c). Cincinnati, OH: Environmental Protection Agency. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100F2HZ.PDF?Dockey=P100F2HZ.PDF

ATSDR. (2000). Health consultation: Mortality from asbestosis in Libby, Montana. Atlanta, GA: U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. http://www.atsdr.cdc.gov/hac/pha/pha.asp?docid=1225&pg=0

ATSDR. (2001). Toxicological profile for asbestos (Update, September 2001) [ATSDR Tox Profile]. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. http://www.atsdr.cdc.gov/ToxProfiles/tp61.pdf

ATSDR. (2002). Public health assessment for Sunflower Army Ammunition Plant, Desoto, Johnson County, Kansas (EPA Facility ID: KS3213820878). Atlanta, GA. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB2002104687.xhtml

ATSDR. (2006). Health consultation: Asbestos exposures at Oak Ridge High School: 1120 Harvard Way: EL Dorado Hills, California: EPA facility ID: CAN000906055. Atlanta, GA.

ATSDR. (2007). Health consultation: Exposure investigation: Final report: Ambler Gravel Pit: Ambler, Alaska. Atlanta, GA.

ATSDR. (2011). Health consultation: Evaluation of community-wide asbestos exposures: El Dorado Hills naturally occurring asbestos site: El Dorado Hills Boulevard, El Dorado Hills, California: EPA facility ID: CAN000906083. Atlanta, GA.

ATSDR. (2012a). Health consultation: Public comment release: Groundwater monitoring data review: BoRit asbestos site: Ambler, Montgomery County, Pennsylvania. Atlanta, GA: U.S. Department Of Health And Human Services.

ATSDR. (2012b). Letter health consultation: Bald Friar Quarry NOA site: Conowingo, Maryland. Atlanta, GA: U.S. Department Of Health And Human Services.
ATSDR. (2014a). Health consultation: Review of activity based sampling: Former W. R. Grace facility (a/k/a North Little Rock Auto Salvage): 600 Dixie Lane North Little Rock, Pulaski County, AR 72114: EPA identification number: ARN000607042: AFIN number: 60-02502. Atlanta, GA: U.S. Department of Health and Human Services.
ATSDR. (2014b). Public health consultation: Potential exposure to asbestos in clams, Port Heiden, Alaska. Atlanta, GA: U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/HAC/pha/PotentialExposuretoAsbestos/Revisons2_20_2014PublicHealthConsultationPortHeidenClamsFN3-5_201-508.pdf
ATSDR. (2015). Final release: Public health assessment: BoRit asbestos national priorities list site: Ambler, Montgomery County, Pennsylvania. Atlanta, GA: U.S. Department Of Health And Human Services.
ATSDR. (2016). Health consultation: Asbestos and metals in groundwater and leachate: Swift Creek, Whatcom County, Washington. Atlanta, GA: U.S. Department of Health and Human Services.
Axten, CW; Foster, D. (2008). Analysis of airborne and waterborne particles around a taconite ore processing facility. Regul Toxicol Pharmacol 52: S66-S72. http://dx.doi.org/10.1016/j.yrtph.2007.11.010
Bacon, DW; Coomes, OT; Marsan, AA; Rowlands, N. (1986). Assessing potential sources of asbestos fibers in water supplies of S.E. Quebec. Water Resour Bull 22: 29-38. http://dx.doi.org/10.1111/j.1752-1688.1986.tb01856.x
Badollet, MS. (1951). Asbestos, a mineral of unparalleled properties. Trans Can Inst Min Metall 54: 151-160.
Bailey, S; Conchie, A; Hiett, DM; Thomas, C. (1988). Personal exposure to asbestos dust during clearance certification. Ann Occup Hyg 32: 423-426. http://dx.doi.org/10.1093/annhyg/32.3.423
Bales, RC; Morgan, JJ. (1985). Surface-charge and adsorption properties of chrysotile asbestos in natural waters. Environ Sci Technol 19: 1213-1219.
Bales, RC; Newkirk, DD; Hayward, SB. (1984). Chrysotile asbestos in California surface waters: From upstream rivers through water treatment. J Am Water Works Assoc 76: 66-74.
Banks, AJ. (1991). Asbestos Removal in the Construction Industry (pp. 76). Springfield, VA: NTIS. https://apps.dtic.mil/sti/citations/ADA240652
Barnthouse, LW; DeAngelis, DL; Gardner, RH; O'Neill, RV; Suter, GW; Vaughan, DS. (1982). Methodology for Environmental Risk Analysis. (ORNL/TM-8167). Oak Ridge, TN: Oak Ridge National Laboratory.
Baxter, D; Ziskind, R; Shokes, R. (1983). Ambient asbestos concentrations in California, volume 1. (ARB/R 83-218). Sacramento. CA: Air Resources Board. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB84138122.xhtml
Beaucham, C; Eisenberg, J. (2019). Evaluation of fire debris cleanup employees' exposure to silica, asbestos, metals, and polyaromatic hydrocarbons. (NIOSHTIC No. 20057066). Cincinnati, OH: National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/hhe/reports/pdfs/2018-0094-3355.pdf
Belanger, SE. (1985) Functional and pathological responses of selected aquatic organisms to chrysotile asbestos. (Doctoral Dissertation). Virginia Polytechnic Institute and State University, Blacksburg, VA. Retrieved from https://vtechworks.lib.vt.edu/handle/10919/37860
Belanger, SE; Cherry, DS; Cairns, J. (1990). Functional and pathological impairment of japanese medaka (Oryzias latipes) by long-term asbestos exposure. Aquat Toxicol 17: 133-154. http://dx.doi.org/10.1016/0166-445X(90)90027-M

Belanger, SE; Cherry, DS; Cairns J, JR. (1986a). Seasonal behavioral and growth changes of juvenile Corbicula-fluminea exposed to chrysotile asbestos. Water Res 20: 1243-1250.
Belanger, SE; Cherry, DS; Cairns J, JR. (1986b). Uptake of chrysotile asbestos fibers alters growth and reproduction of Asiatic clams. Can J Fish Aquat Sci 43: 43-52. http://dx.doi.org/10.1139/f86-006
Belanger, SE; Cherry, DS; Cairns, J; McGuire, MJ. (1987). Using Asiatic clams as a biomonitor for chrysotile asbestos in public water supplies. J Am Water Works Assoc 79: 69-74. http://dx.doi.org/10.1002/j.1551-8833.1987.tb02817.x
Belanger, SE; Schurr, K; Allen, DJ; Gohara, AF. (1986c). Effects of chrysotile asbestos on coho salmon and green sunfish: evidence of behavioral and pathological stress. Environ Res 39: 74-85.
Berman, DW; Crump, KS. (2008). Update of potency factors for asbestos-related lung cancer and mesothelioma. Crit Rev Toxicol 38: 1-47. http://dx.doi.org/10.1080/10408440802276167
Blake, CL; Harbison, SC; Johnson, GT; Harbison, RD. (2011). Airborne asbestos exposures associated with work on asbestos fire sleeve materials. Regul Toxicol Pharmacol 61: 236-242. http://dx.doi.org/10.1016/j.yrtph.2011.08.003
Boelter, FW; Xia, Y; Persky, JD. (2016). A Bayesian model and stochastic exposure (dose) estimation for relative exposure risk comparison involving asbestos-containing dropped ceiling panel installation and maintenance tasks. Risk Anal1729-1741. http://dx.doi.org/10.1111/risa.12733
Breysse, PN; Williams, DL; Herbstman, JB; Symons, JM; Chillrud, SN; Ross, J; Henshaw, S; Rees, K; Watson, M; Geyh, AS. (2005). Asbestos exposures to truck drivers during World Trade Center cleanup operations. J Occup Environ Hyg 2: 400-405. http://dx.doi.org/10.1080/15459620500194286
Brorby, GP; Sheehan, PJ; Berman, DW; Bogen, KT; Holm, SE. (2013). Exposures from chrysotile-containing joint compound: evaluation of new model relating respirable dust to fiber concentrations. Risk Anal 33: 161-176. http://dx.doi.org/10.1111/j.1539-6924.2012.01847.x
Brown, SK. (1988). Asbestos exposure to workers demolishing asbestos cement clad buildings. In Y Kasai (Ed.), (pp. 344-350). London, United Kingdom: Chapman and Hall.
Buczaj, A; Brzana, W; Tarasińska, J; Buczaj, M; Choina, P. (2014). Study on the concentration of airbone respirable asbestos fibres in rural areas of the Lublin region in south-east Poland. Ann Agric Environ Med 21: 639-643. http://dx.doi.org/10.5604/12321966.1120617
Buelow, RW; Millette, JR; McFarren, EF; Symons, JM. (1980). The behavior of asbestos-cement pipe under various water quality conditions: A progress report. J Am Water Works Assoc 72: 91-102. http://dx.doi.org/10.1002/j.1551-8833.1980.tb04474.x
Burkhart, JE; Short, S. (1995). Health Hazard Evaluation Report No. HETA-91-0354-2532, South Dade Disposal Site, Goulds, Florida (pp. 91-0354). (NIOSH/00230302). Burkhart, JE; Short, S.
CalEPA. (2003). Public health goal for Asbestos in drinking water. Sacramento, CA: Office of Environmental Health Hazard Assessment, California Environmental Protection Agency. https://oehha.ca.gov/media/downloads/water/chemicals/phg/ph4asbestos92603_0.pdf
Capella, S; Bellis, D; Fioretti, E; Marinelli, R; Belluso, E. (2020). Respirable inorganic fibers dispersed in air and settled in human lung samples: Assessment of their nature, source, and concentration in a NW Italy large city [Review]. Environ Pollut 263 Pt. B: 114384. http://dx.doi.org/10.1016/j.envpol.2020.114384
Carex Canada. (2017). Fibers and dusts: Asbestos. http://www.carexcanada.ca/en/asbestos/environmental_estimate/#data
Cargo Handbook. (2023). Cargo Handbook: Asbestos [Website]. https://www.cargohandbook.com/Asbestos
Carneiro, GO; Santos, TA; Simonelli, G; Ribeiro, DV; Cilla, MS; Dias, CMR. (2021). Thermal treatment optimization of asbestos cement waste (ACW) potentializing its use as alternative binder. J Clean Prod 320: 28801. http://dx.doi.org/10.1016/j.jclepro.2021.128801

Cattaneo, A; Somigliana, A; Gemmi, M; Bernabeo, F; Savoca, D; Cavallo, DM; Bertazzi, PA. (2012). Airborne concentrations of chrysotile asbestos in serpentine quarries and stone processing facilities in Valmalenco, Italy. Ann Occup Hyg 56: 671-683. http://dx.doi.org/10.1093/annhyg/mer119

CDM Federal Programs Corporation. (2014). Site-wide baseline ecological risk assessment. Libby, MT: Libby Asbestos Superfund Site. https://cumulis.epa.gov/supercpad/cursites/cscdocument.cfm?id=0801744&doc=Y&colid=32329

CDM Federal Programs Corporation. (2015). Site-wide human health risk assessment. Libby, MT: Libby Asbestos Superfund Site. https://cumulis.epa.gov/supercpad/cursites/cscdocument.cfm?id=0801744&doc=Y&colid=32329

Cely-García, MF; Torres-Duque, CA; Durán, M; Parada, P; Sarmiento, OL; Breysse, PN; Ramos-Bonilla, JP. (2015). Personal exposure to asbestos and respiratory health of heavy vehicle brake mechanics. J Expo Sci Environ Epidemiol 25: 26-36. http://dx.doi.org/10.1038/jes.2014.8

Cherrie, JW; Tindall, M; Cowie, H. (2005). Exposure and risks from wearing asbestos mitts. Part Fibre Toxicol 2: 5. http://dx.doi.org/10.1186/1743-8977-2-5

Chesson, J; Hatfield, J; Schultz, B; Dutrow, E; Blake, J. (1990). Airborne asbestos in public buildings. Environ Res 51: 100-107.

Choi, I; Smith, RW. (1972). Kinetic study of dissolution of asbestos fibers in water. J Colloid Interface Sci 40: 253-262. http://dx.doi.org/10.1016/0021-9797(72)90014-8

Clark, SG; Holt, PF. (1961). Studies on the chemical properties of chrysotile in relation to asbestosis. Ann Occup Hyg 3: 22-29. http://dx.doi.org/10.1093/annhyg/3.1.22

Coelho, A; de Brito, J. (2011). Economic analysis of conventional versus selective demolition - A case study. Resour Conservat Recycl 55: 382-392. http://dx.doi.org/10.1016/j.resconrec.2010.11.003

Confidential. (1986). Submission of health and safety data on acetonitrile [TSCA Submission]. (OTS0513240. 86870000055. TSCATS/302862).

Conway, DM; Lacey, RF. (1984). Asbestos in drinking water: Results of a survey. In Technical report (Water Research Centre (Great Britain)), TR 202. (TR 202). Marlow, United Kingdom: Water Research Centre.

Cooper, RC; Murchio, JC. (1974). Preliminary studies of asbestiform fibers in domestic water supplies (pp. 61-73). (AMRL-TR-74-125-Paper-5). Wright-Patterson Air Force Base, OH: Aerospace Medical Research Lab. https://apps.dtic.mil/sti/pdfs/ADA011563.pdf#page=67

Corn, M; Crump, K; Farrar, DB; Lee, RJ; McFee, DR. (1991). Airborne concentrations of asbestos in 71 school buildings. Regul Toxicol Pharmacol 13: 99-114. http://dx.doi.org/10.1016/0273-2300(91)90044-v

Costello, R. (1984). Health Hazard Evaluation Report No. HETA-82-305-1541, Fountain Avenue Landfill, Brooklyn, New York (pp. 82-305). (NIOSH/00148231). Costello, R.

CPSC. (1977). Review of asbestos use in consumer products (final report). Washington, DC.

Cunningham, HM; Pontefract, R. (1971). Asbestos fibres in beverages and drinking water. Nature 232: 332-333. http://dx.doi.org/10.1038/232332a0

Dantata, N; Touran, A; Wang, J. (2005). An analysis of cost and duration for deconstruction and demolition of residential buildings in Massachusetts. Resour Conservat Recycl 44: 1-15. http://dx.doi.org/10.1016/j.resconrec.2004.09.001

Dement, JM; Kuempel, ED; Zumwalde, RD; Smith, RJ; Stayner, LT; Loomis, D. (2008). Development of a fibre size-specific job-exposure matrix for airborne asbestos fibres. Occup Environ Med 65: 605-612. http://dx.doi.org/10.1136/oem.2007.033712

Desaulniers, G; P'An, A; Trudeau, M; Lecomte, R; Landsberger, S; Paradis, P; Monaro, S. (1981). On the use of PIXE as methodology for measuring asbestos pollution in river-water. Appl Radiat Isot 32: 122-125. http://dx.doi.org/10.1016/0020-708X(81)90148-4

Dodic-Fikfak, M. (2007). An experiment to develop conversion factors to standardise measurements of airborne asbestos. Arh Hig Rada Toksikol 58: 179-185. http://dx.doi.org/10.2478/v10004-007-0003-9
Dong, H; Saint-Etienne, L; Renier, A; Billon Galland, MA; Brochard, P; Jaurand, MC. (1994). Air samples from a building with asbestos-containing material: asbestos content and in vitro toxicity on rat pleural mesothelial cells. Fundam Appl Toxicol 22: 178-185. http://dx.doi.org/10.1006/faat.1994.1022
DTSC. (2005). Study of airborne asbestos from a serpentine road in Garden Valley, California. Sacramento, CA. https://www.dtsc.ca.gov/SiteCleanup/Projects/upload/Garden-Valley_REP_Slodusty.pdf
Dunning, KK; Adjei, S; Levin, L; Rohs, AM; Hilbert, T; Borton, E; Kapil, V; Rice, C; Lemasters, GK; Lockey, JE. (2012). Mesothelioma associated with commercial use of vermiculite containing Libby amphibole. J Occup Environ Med 54: 1359-1363. http://dx.doi.org/10.1097/JOM.0b013e318250b5f5
Durham, RW; Pang, T. (1976). Asbestiform fibre levels in Lakes Superior and Huron. In Canada, Inland Waters Directorate, Scientific Series, no 67. Burlington, ON: Inland Waters Directorate, Canada Centre for Inland Waters. https://publications.gc.ca/collections/collection_2017/eccc/En36-502-67-eng.pdf
Dusek, CJ; Yetman, JM. (1993). Control and prevention of asbestos exposure from construction in naturally occurring asbestos. Trans Res Rec 1424: 34-41.
Dynamac. (1984). Draft final report industrial hygiene assessment of petroleum refinery turnaround activities: Survey #2 with cover letter dated 092084 [TSCA Submission]. (OTS0000349-0. FYI-AX-0984-0349. TSCATS/200083). American Petroleum Institute. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/OTS00003490.xhtml
EC/HC. (2019). Information on the prohibition of asbestos and products containing asbestos regulations [Fact Sheet]. (En14-359/2019E-PDF). Gatineau, Quebec: Chemicals Management Division, Environment and Climate Change Canada. https://www.canada.ca/content/dam/eccc/documents/pdf/pollution-waste/asbestos-amiante/general%20factsheet%20_EN.pdf
ECCC. (2024). Trace amounts of asbestos in consumer products: Guidance. Available online at https://www.canada.ca/en/environment-climate-change/services/management-toxic-substances/list-canadian-environmental-protection-act/asbestos/trace-asbestos-consumer-products-guidance.html (accessed November 12, 2024).https://hero.epa.gov/hero/index.cfm?action=search.view&reference_id=11138828EIA. (2022). Table B10: Number of floors, number of buildings and floorspace, 2018. Available online at https://www.eia.gov/consumption/commercial/data/2018/
Elliott, L; Loomis, D; Dement, J; Hein, MJ; Richardson, D; Stayner, L. (2012). Lung cancer mortality in North Carolina and South Carolina chrysotile asbestos textile workers. Occup Environ Med 69: 385-390. http://dx.doi.org/10.1136/oemed-2011-100229
Elsevier. (2021a). Reaxys: physical-chemical property data for Actinolite [Website].
Elsevier. (2021b). Reaxys: physical-chemical property data for Anthophyllite [Website].
Elsevier. (2021c). Reaxys: physical-chemical property data for Chrysotile [Website].
Emmanouil, K; Kalliopi, A; Dimitrios, K; Evangelos, G. (2009). Asbestos pollution in an inactive mine: Determination of asbestos fibers in the deposit tailings and water. J Hazard Mater 167: 1080-1088. http://dx.doi.org/10.1016/j.jhazmat.2009.01.102
EOP. (2021a). 86 FR 7009: Advancing racial equity and support for underserved communities through the federal government (pp. 7009-7013). Fed. Reg. https://www.federalregister.gov/documents/2021/01/25/2021-01753/advancing-racial-equity-and-support-for-underserved-communities-through-the-federal-government

EOP. (2021b). 86 FR 7037: Protecting public health and the environment and restoring science to tackle the climate crisis. https://www.federalregister.gov/documents/2021/01/25/2021-01765/protecting-public-health-and-the-environment-and-restoring-science-to-tackle-the-climate-crisis
EOP. (2021c). 86 FR 7619: Tackling the climate crisis at home and abroad (pp. 7619-7633). Fed. Reg. https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad
EOP. (2021d). 86 FR 8845: Restoring trust in government through scientific integrity and evidence-based policymaking. https://www.govinfo.gov/app/details/FR-2021-02-10/2021-02839
EPA Press Office. (2021). EPA Press Release: EPA announces path forward for TSCA Chemical Risk Evaluations. Available online at https://www.epa.gov/newsreleases/epa-announces-path-forward-tsca-chemical-risk-evaluations
Esswein, EJ; Tubbs, RL. (1994). Health Hazard Evaluation Report HETA 93-0696-2395, Hardy Road Landfill, Akron, Ohio. 27.
EuroParl. (2019). Parliamentary question: Answer given by Ms Bieńkowska on behalf of the European Commission (P-006206/2018(ASW)). Available online at https://www.europarl.europa.eu/doceo/document/P-8-2018-006206-ASW_EN.html#ref3 (accessed November 12, 2024).
Ewing, WM; Hays, SM; Hatfield, R; Longo, WE; Millette, JR. (2010). Zonolite attic insulation exposure studies. Int J Occup Environ Health 16: 279-290. http://dx.doi.org/10.1179/oeh.2010.16.3.279
Favero-Longo, SE; Turci, F; Tomatis, M; Castelli, D; Bonfante, P; Hochella, MF; Piervittori, R; Fubini, B. (2005). Chrysotile asbestos is progressively converted into a non-fibrous amorphous material by the chelating action of lichen metabolites. J Environ Monit 7: 764-766. http://dx.doi.org/10.1039/b507569f
Fent, KW; Horn, GP; DeCrane, S. (2015). Firefighters' perspective on flame retardants [Website]. https://www.sfpe.org/publications/fpemagazine/fpearchives/2015q4/fpe2015q44
Ganor, E; Fischbein, A; Brenner, S; Froom, P. (1992). Extreme airborne asbestos concentrations in a public building. Br J Ind Med 49: 486-488. http://dx.doi.org/10.1136/oem.49.7.486
Garcia, E; Newfang, D; Coyle, JP; Blake, CL; Spencer, JW; Burrelli, LG; Johnson, GT; Harbison, RD. (2018). Evaluation of airborne asbestos exposure from routine handling of asbestos-containing wire gauze pads in the research laboratory. Regul Toxicol Pharmacol 96: 135-141. http://dx.doi.org/10.1016/j.yrtph.2018.04.020
Gaze, R. (1965). The physical and molecular structure of asbestos. Ann N Y Acad Sci 132: 23-30. http://dx.doi.org/10.1111/j.1749-6632.1965.tb41087.x
Gronow, JR. (1987). The dissolution of asbestos fibres in water. Clay Miner 22: 21-35. http://dx.doi.org/10.1180/claymin.1987.022.1.03
Gunter, BJ. (1981). Health hazard evaluation report no. HETA-81-038-801, Hensel Phelps Construction Company, Greeley, Colorado. (HETA-81-038-801). Cincinnati, OH: National Institute for Occupational Safety and Health.
Gunter, ME. (2018). Elongate mineral particles in the natural environment [Review]. Toxicol Appl Pharmacol 361: 157-164. http://dx.doi.org/10.1016/j.taap.2018.09.024
Haque, AK; Kanz, ME. (1988). Asbestos bodies in children's lungs: An association with sudden infant death syndrome and bronchopulmonary dysplasia. Arch Pathol Lab Med 112: 514-518.
Haque, AK; Vrazel, DM; Burau, KD; Cooper, SP; Downs, T. (1996). Is there transplacental transfer of asbestos? A study of 40 stillborn infants. Pediatr Pathol Lab Med 16: 877-892.
Haque, AK; Vrazel, DM; Uchida, T. (1998). Assessment of asbestos burden in the placenta and tissue digests of stillborn infants in South Texas. Arch Environ Contam Toxicol 35: 532-538. http://dx.doi.org/10.1007/s002449900413

Hatfield, J; Stockrahm, J; Todt, F; Ogden, J; Leczynski, B; Price, B; Chesson, J; Russell, J; Ford, P; Thomas, J; Fitzgerald, J; Roat, R; Lee, R; Van Orden, D; Dunmyre, G; Constant, P; McHugh, J; Mayer, D; Spain, W; Ewing, B; Hays, S; Hatfield, R; Claveria, A. (1988). Assessing asbestos exposure in public buildings. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB88230909.xhtml

Hawkins, JW; Haynes, DC; Istone, WK; Schmidt, AF. (1988). Asbestos. 2. Abatement removal programs. TAPPI J 71: 199-200.

Hayward, SB. (1984). Field monitoring of chrysotile asbestos in California waters. J Am Water Works Assoc 76: 66-73. http://dx.doi.org/10.1002/j.1551-8833.1984.tb05301.x

Hein, MJ; Stayner, LT; Lehman, E; Dement, JM. (2007). Follow-up study of chrysotile textile workers: Cohort mortality and exposure-response. Occup Environ Med 64: 616-625. http://dx.doi.org/10.1136/oem.2006.031005

Hervin, RL. (1977). Health hazard evaluation report no. HETA-77-102-434, Terminal B, Trans World Airlines, Inc., Kansas City, Missouri. (HETA-77-102-434). Cincinnati, OH: National Institute for Occupational Safety and Health.

Hoang, NH; Ishigaki, T; Kubota, R; Tong, TK; Nguyen, TT; Nguyen, HG; Yamada, M; Kawamoto, K. (2020). Waste generation, composition, and handling in building-related construction and demolition in Hanoi, Vietnam. Waste Manag 117: 32-41. http://dx.doi.org/10.1016/j.wasman.2020.08.006

Hollins, D; Burns, A; Unice, K; Paustenbach, DJ. (2019). An analysis of workplace exposures to asbestos at three steel mills located in the United States (1972-1982). Toxicol Ind Health 35: 726-737. http://dx.doi.org/10.1177/0748233719893905

Hoppe, KA; Metwali, N; Perry, SS; Hart, T; Kostle, PA; Thorne, PS. (2012). Assessment of airborne exposures and health in flooded homes undergoing renovation. Indoor Air 22: 446-456. http://dx.doi.org/10.1111/j.1600-0668.2012.00785.x

Huang, JQ. (1990). A study on the dose-response relationship between asbestos exposure level and asbestosis among workers in a Chinese chrysotile product factory. Biomed Environ Sci 3: 90-98.

Hwang, CY. (1983). Size and shape of airborne asbestos fibres in mines and mills. Br J Ind Med 40: 273-279. http://dx.doi.org/10.1136/oem.40.3.273

Hwang, SH; Park, WM. (2016). Evaluation of asbestos-containing products and released fibers in home appliances. J Air Waste Manag Assoc 66: 922-929. http://dx.doi.org/10.1080/10962247.2016.1180329

IARC. (1977). IARC monographs on the evaluation of carcinogenic risk of chemicals to man: Asbestos. Lyon, France: World Health Organization. http://monographs.iarc.fr/ENG/Monographs/vol1-42/mono14.pdf

IARC. (2010). Painting, firefighting, and shiftwork [IARC Monograph] (pp. 804-804 pages). Lyon, France. http://monographs.iarc.fr/ENG/Monographs/vol98/mono98.pdf

IARC. (2012a). ARC Monographs on the evaluation of carcinogenic risks to humans: Asbestos (Chrysotile, amosite, crocidolite, tremolite, actinolite, and anthophyllite). Geneva, Switzerland: World Health Organization, International Agency for Research on Cancer. http://monographs.iarc.fr/ENG/Monographs/PDFs/index.php

IARC. (2012b). Arsenic, metals, fibres and dusts. IARC monographs on the evaluation of carcinogenic risks to humans, vol. 100C: A review of human carcinogens [IARC Monograph]. In IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, vol 100C. Lyon, France: World Health Organization. http://monographs.iarc.fr/ENG/Monographs/vol100C/mono100C.pdf

IARC. (2012c). Asbestos (chrysotile, amosite, crocidolite, tremolite, actinolite and anthophyllite) [IARC Monograph]. In IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, vol

100C (pp. 219-309). Lyon, France. https://publications.iarc.fr/Book-And-Report-Series/Iarc-Monographs-On-The-Identification-Of-Carcinogenic-Hazards-To-Humans/Arsenic-Metals-Fibres-And-Dusts-2012
ICFI. (1988). Asbestos exposure assessment (Revised report). Washington, DC: U.S. Environmental Protection Agency.
IHC World. (2023). ABC of safety in the biological sciences: General guidelines for the disposal of laboratory chemicals via waste disposal authorities/companies [Website]. https://www.ihcworld.com/royellis/ABCSafe/glossary/chemical-disposal.htm
IPCS. (1986). Asbestos and other natural mineral fibres. In Environmental Health Criteria (pp. 194). (Environmental Health Criteria 53). Geneva, Switzerland: World Health Organization. http://www.inchem.org/documents/ehc/ehc/ehc53.htm
IT Corporation. (1993). Asbestos release during building demolition activities. Cincinnati, OH: U.S. Environmental Protection Agency. https://nepis.epa.gov/Exe/ZyPDF.cgi/930013TJ.PDF?Dockey=930013TJ.PDF
Jaffrey, S. (1990). Environmental asbestos fiber release from brake and clutch linings of vehicular traffic. Ann Occup Hyg 34: 529-534.
Jeon, SJ; Jin, BM; Kim, YJ. (2012). Assessment of the fire resistance of a nuclear power plant subjected to a large commercial aircraft crash. Nucl Eng Des 247: 11-22. http://dx.doi.org/10.1016/j.nucengdes.2012.02.003
Jiang, GC; Madl, AK; Ingmundson, KJ; Murbach, DM; Fehling, KA; Paustenbach, DJ; Finley, BL. (2008). A study of airborne chrysotile concentrations associated with handling, unpacking, and repacking boxes of automobile clutch discs. Regul Toxicol Pharmacol 51: 87-97. http://dx.doi.org/10.1016/j.yrtph.2008.02.009
John, AVNTSC. (2004). Sampling and analysis summary report: Roadside airborne asbestos monitoring along an El Dorado Country serpentine roadway (pp. 261). Sacramento, CA: California Department of Toxic Substances Control. https://www.dtsc.ca.gov/SiteCleanup/Projects/upload/Garden-Valley_REP_Volpe-Slodusty-Sampling.pdf
Jolicoeur, C; Duchesne, D. (1981). Infrared and thermogravimetric studies of the thermal-degradation of chrysotile asbestos fibers - evidence for matrix effects. Can J Chem 59: 1521-1526. http://dx.doi.org/10.1139/v81-223
Jones, AD; Apsley, A; Clark, S; Addison, J; Van Orden, DR; Lee, RJ. (2010). Laboratory Tests to Compare Airborne Respirable Mass and Fibre Concentrations from Soil Samples from Libby, Montana. Indoor Built Environ 19: 286-297. http://dx.doi.org/10.1177/1420326X09349908
Jung, HS; Jang, J; Cho, Y; Lee, JC; Kim, H. (2021). Asbestos in the ambient air from rural, urban, residential, baseball and mining areas in South Korea. Environ Chem Lett 19: 3487-3495. http://dx.doi.org/10.1007/s10311-021-01226-7
Kakooei, H; Normohammadi, M. (2014). Asbestos exposure among construction workers during demolition of old houses in Tehran, Iran. Ind Health 52: 71-77. http://dx.doi.org/10.2486/indhealth.2012-0118
Kanarek, MS; Conforti, PM; Jackson, LA. (1981). Chrysotile asbestos fibers in drinking water from asbestos-cement pipe. Environ Sci Technol 15: 923-925. http://dx.doi.org/10.1021/es00090a006
Kay, GH. (1974). Asbestos in drinking water. J Am Water Works Assoc 66: 513-514. http://dx.doi.org/10.1002/j.1551-8833.1974.tb02090.x
Kebler, DG; Bales, RC; Amy, GL. (1989). Coagulation of submicron colloids by supramicron silica particles. Water Sci Technol 21: 519-528. http://dx.doi.org/10.2166/wst.1989.0254
Kohyama, N. (1989). Airborne asbestos levels in non-occupational environments in Japan. In J Bignon; J Peto; R Saracci (Eds.), IARC Scientific Publications, no 90 (pp. 262-276). Lyon, France: International Agency for Research on Cancer.

Kominsky, JR; Freyberg, RW; Powers, TJ; Wilmoth, RC. (1989). Statistical evaluation of airborne asbestos measured before, during and after abatement. (EPA/600/D-89/054). Cincinnati, OH: U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB89221253.xhtml

Koppers. (1981). Status report of industrial hygiene monitoring at the Follansbee, West Virginia plant with cover letter [TSCA Submission]. (OTS0215074. 878220551. TSCATS/019621). Koppers Co Inc. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/OTS0215074.xhtml

Krakowiak, E; Górny, RL; Cembrzyńska, J; Sakol, G; Boissier-Draghi, M; Anczyk, E. (2009). Environmental exposure to airborne asbestos fibres in a highly urbanized city. Ann Agric Environ Med 16: 121-128.

Kwon, J. (2022). Impact of Naturally Occurring Asbestos on Asbestos Ban: Regulations and Experience of the Republic of Korea [Review]. International journal of environmental research and public health 19. http://dx.doi.org/10.3390/ijerph19020742

Lamontagne, AD; Van Dyke, MV; Martyny, JW; Ruttenber, AJ. (2001). Cleanup worker exposures to hazardous chemicals at a former nuclear weapons plant: piloting of an exposure surveillance system. Appl Occup Environ Hyg 16: 284-290. http://dx.doi.org/10.1080/10473220119685

Landrigan, PJ; Lioy, PJ; Thurston, G; Berkowitz, G; Chen, LC; Chillrud, SN; Gavett, SH; Georgopoulos, PG; Geyh, AS; Levin, S; Perera, F; Rappaport, SM; Small, C. (2004). Health and environmental consequences of the world trade center disaster [Review]. Environ Health Perspect 112: 731-739. http://dx.doi.org/10.1289/ehp.6702

Lange, JH. (1999). A statistical evaluation of asbestos air concentrations [Review]. Indoor Built Environ 8: 293-303. http://dx.doi.org/10.1159/000024657

Lange, JH. (2002). Impact of asbestos concentrations in floor tiles on exposure during removal. Int J Environ Health Res 12: 293-300. http://dx.doi.org/10.1080/0960312021000056401

Lange, JH; Grad, JW; Lange, PA; Thomulka, KW; Dunmyre, GR; Lee, RJ; Richardson, CF; Blumershine, RVH. (1993). Asbestos abatement of ceiling panels and mold growth in a public school building after water damage: A case study of contaminant levels. Fresen Environ Bull 2: 13-18.

Lange, JH; Sites, SL; Mastrangelo, G; Thomulka, KW. (2006). Exposure to airborne asbestos during abatement of ceiling material, window caulking, floor tile, and roofing material. Bull Environ Contam Toxicol 77: 718-722. http://dx.doi.org/10.1007/s00128-006-1122-8

Lange, JH; Sites, SL; Mastrangelo, G; Thomulka, KW. (2008). Exposure to airborne asbestos during abatement of ceiling material, window caulking, floor tile and roofing material. Bull Environ Contam Toxicol 80: 10-13. http://dx.doi.org/10.1007/s00128-007-9280-x

Lange, JH; Thomulka, KW. (2000a). Air sampling during asbestos abatement of floor tile and mastic. Bull Environ Contam Toxicol 64: 497-501. http://dx.doi.org/10.1007/s001280000031

Lange, JH; Thomulka, KW. (2000b). Area and personal airborne exposure during abatement of asbestos-containing roofing material. Bull Environ Contam Toxicol 64: 673-678.

Lange, JH; Thomulka, KW. (2000c). Occupational exposure to airborne asbestos during abatement of asbestos-containing pipe and boiler insulation. Fresen Environ Bull 9: 477-482.

Lange, JH; Thomulka, KW. (2001). Personal exposure to asbestos during removal of asbestos-containing window caulking and floor tile/pipe insulation. Fresen Environ Bull 10: 688-691.

Lange, JH; Thomulka, KW. (2002). Airborne exposure concentrations during asbestos abatement of ceiling and wall plaster. Bull Environ Contam Toxicol 69: 712-718. http://dx.doi.org/10.1007/s00128-002-0119-1

Larrañaga, MD; Lewis, RJ; Lewis, RA. (2016). Hawley's condensed chemical dictionary (16th ed.). Hoboken, NJ: John Wiley & Sons. http://dx.doi.org/10.1002/9781119312468

Larson, TC; Antao, VC; Bove, FJ. (2010). Vermiculite worker mortality: Estimated effects of occupational exposure to Libby amphibole. J Occup Environ Med 52: 555-560. http://dx.doi.org/10.1097/JOM.0b013e3181dc6d45
Lauer, WC; Convery, JJ. (1988). Proceedings of the Eleventh United States/Japan Conference on Sewage Treatment Technology: Status of the Potable Water Reuse Demonstration Project at Denver. Cincinnati, OH: Water Engineering Research Laboratory. https://nepis.epa.gov/Exe/ZyNET.exe/20009I2L.txt?ZyActionD=ZyDocument&Client=EPA&Index=1986%20Thru%201990&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5CZYFILES%5CINDEX%20DATA%5C86THRU90%5CTXT%5C00000002%5C20009I2L.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=447
Lawrence, J; Zimmermann, HW. (1976). Potable water treatment for some asbestiform minerals: optimization and turbidity data. Water Res 10: 195-198. http://dx.doi.org/10.1016/0043-1354(76)90127-5
Lawrence, J; Zimmermann, HW. (1977). Asbestos in water - mining and processing effluent treatment. J Water Pollut Control Fed 49: 156-160.
Le Bouffant, L. (1980). Physics and chemistry of asbestos dust. In JC Wagner (Ed.), IARC Scientific Publication No 30 (pp. 15-33). Lyon, France: International Agency for Research on Cancer.
Lee, RJ; Van Orden, DR. (2008). Airborne asbestos in buildings. Regul Toxicol Pharmacol 50: 218-225. http://dx.doi.org/10.1016/j.yrtph.2007.10.005
Lee, RJ; Van Orden, DR; Allison, KA; Bunker, KL; Huntington, C. (2009). Characterization of Airborne Amphibole Particles in Libby, MT. Indoor Built Environ 18: 524-530. http://dx.doi.org/10.1177/1420326X09341518
Lee, RJ; Van Orden, DR; Stewart, IM. (1999). Dust and airborne concentrations - Is there a correlation? In ASTM Special Technical Publication (STP), no 1342 (pp. 313-322). (STP42347S). West Conshohocken, PA: ASTM International. https://www.astm.org/stp42347s.html
Lewis, NJ; Curtis, MF. (1990). Occupational health and hygiene following a fire in a warehouse with an asbestos cement roof. J Soc Occup Med 40: 53-54. http://dx.doi.org/10.1093/occmed/40.2.53
Lim, HS; Kim, JY; Sakai, K; Hisanaga, N. (2004). Airborne asbestos and non-asbestos fiber concentrations in non-occupational environments in Korea. Ind Health 42: 171-178.
Lin, RT; Chien, LC; Jimba, M; Furuya, S; Takahashi, K. (2019). Implementation of national policies for a total asbestos ban: a global comparison. The Lancet Planetary Health 3: e341-e348. http://dx.doi.org/10.1016/S2542-5196(19)30109-3
Litzistorf, G; Guillemin, M; Buffat, P; Iselin, F. (1985). A brief survey of outdoor concentrations - Ambient air-pollution by mineral fibers in Switzerland [Review]. Staub Reinhalt Luft 45: 302-307.
Liukonen, LR; Weir, FW. (2005). Asbestos exposure from gaskets during disassembly of a medium duty diesel engine. Regul Toxicol Pharmacol 41: 113-121. http://dx.doi.org/10.1016/j.yrtph.2004.10.003
Lockey, JE; Brooks, SM; Jarabek, AM; Khoury, PR; McKay, RT; Carson, A; Morrison, JA; Wiot, JF; Spitz, HB. (1984). Pulmonary changes after exposure to vermiculite contaminated with fibrous tremolite. Am Rev Respir Dis 129: 952-958. http://dx.doi.org/10.1164/arrd.1984.129.6.952
Loomis, D; Dement, JM; Wolf, SH; Richardson, DB. (2009). Lung cancer mortality and fibre exposures among North Carolina asbestos textile workers. Occup Environ Med 66: 535-542. http://dx.doi.org/10.1136/oem.2008.044362

Loomis, D; Richardson, DB; Elliott, L. (2019). Quantitative relationships of exposure to chrysotile asbestos and mesothelioma mortality. Am J Ind Med 62: 471-477. http://dx.doi.org/10.1002/ajim.22985

Lott, PF. (1989). Correlating dispersion staining colors to the numerical value of the refractive-index for asbestos fibers. Microchem J 39: 145-148. http://dx.doi.org/10.1016/0026-265X(89)90022-2

Lowers, HA; Bern, AM. (2009). Particle size characterization of water-elutriated Libby amphibole 2000 and RTI international amosite (pp. 3). Reston, VA: U.S. Geological Survey. http://pubs.usgs.gov/of/2009/1242/

Lucarelli, J. (2002). Asbestos ban. Lucarelli, J.

Lundgren, DA; Vanderpool, RW; Liu, BYH. (1991). Asbestos fiber concentrations resulting from the installation, maintenance and removal of vinyl-asbestos floor tile. Particle & Particle Systems Characterization 8: 233-236. http://dx.doi.org/10.1002/ppsc.19910080142

Ma, C; Kang, G. (2017). Actual situation of asbestos in tract drinking-water in Korean and Japanese local cities. Water Air Soil Pollut 228: 50-p. 50. http://dx.doi.org/10.1007/s11270-016-3225-0

Madl, AK; Gaffney, SH; Balzer, JL; Paustenbach, DJ. (2009). Airborne asbestos concentrations associated with heavy equipment brake removal. Ann Occup Hyg 53: 839-857. http://dx.doi.org/10.1093/annhyg/mep056

Madl, AK; Hollins, DM; Devlin, KD; Donovan, EP; Dopart, PJ; Scott, PK; Perez, AL. (2014). Airborne asbestos exposures associated with gasket and packing replacement: a simulation study and meta-analysis. Regul Toxicol Pharmacol 69: 304-319. http://dx.doi.org/10.1016/j.yrtph.2014.04.007

Madl, AK; Scott, LL; Murbach, DM; Fehling, KA; Finley, BL; Paustenbach, DJ. (2008). Exposure to chrysotile asbestos associated with unpacking and repacking boxes of automobile brake pads and shoes. Ann Occup Hyg 52: 463-479. http://dx.doi.org/10.1093/annhyg/men028

Maisey; et al. (2020). The sleep of shift workers in a remote mining operation: methodology for a randomized control trial to determine evidence-based interventions. Maisey et al.

Mancuso, TF. (1991). Mesotheliomas among railroad workers in the United States. Ann N Y Acad Sci 643: 333-346.

Mangold, C; Clark, K; Madl, A; Paustenbach, D. (2006). An exposure study of bystanders and workers during the installation and removal of asbestos gaskets and packing. J Occup Environ Hyg 3: 87-98. http://dx.doi.org/10.1080/15459620500498067

Manville Serv Corp. (1980a). Monitoring the atmospheric filtering [878211010] [TSCA Submission]. (OTS0206152. 878211010. TSCATS/018167).

Manville Serv Corp. (1980b). Monitoring the atmospheric filtering [878211011] [TSCA Submission]. (OTS0206152. 878211011. TSCATS/018168).

Maresca, GP; Puffer, JH; Germine, M. (1984). Asbestos in lake and reservoir waters of Staten-Island, New York - source, concentration, mineralogy, and size distribution. Environ Geol Water Sci 6: 201-210. http://dx.doi.org/10.1007/BF02509928

Maulida, PT; Kim, JW; Jung, MC. (2022). Environmental assessment of friable asbestos from soil to air using the releasable asbestos sampler (RAS). Toxics 10: 748. http://dx.doi.org/10.3390/toxics10120748

McConnell, EE; Rutter, HA; Ulland, BM; Moore, JA. (1983). Chronic effects of dietary exposure to amosite asbestos and tremolite in F344 rats. Environ Health Perspect 53: 27-44. http://dx.doi.org/10.1289/ehp.835327

McDonald, JC; Harris, J; Armstrong, B. (2004). Mortality in a cohort of vermiculite miners exposed to fibrous amphibole in Libby, Montana. Occup Environ Med 61: 363-366. http://dx.doi.org/10.1136/oem.2003.008649

McGuire, MJ; Bowers, AE; Bowers, DA. (1983). Optimizing large-scale water-treatment plants for asbestos-fiber removal. J Am Water Works Assoc 75: 364-370.

McMillan, LM; Stout, RG; Willey, BF. (1977). Asbestos in raw and treated water: An electron microscopy study. Environ Sci Technol 11: 390-394. http://dx.doi.org/10.1021/es60127a008
MDH. (2003). Final release: Health consultation exposure assessment: Western Mineral Products site: City of Minneapolis, Hennepin County, Minnesota: EPA facility ID: MNN000508056. St. Paul, MN. https://www.health.state.mn.us/communities/environment/hazardous/docs/sites/hennepin/wstrnhc1003.pdf
Metintas, M; Metintas, S; Hillerdal, G; Ucgun, I; Erginel, S; Alatas, F; Yildirim, H. (2005). Nonmalignant pleural lesions due to environmental exposure to asbestos: a field-based, cross-sectional study. Eur Respir J 26: 875-880. http://dx.doi.org/10.1183/09031936.05.00136404
Milošević, M; Petrović, LJ. (1988). Environmental exposure to chrysotile asbestos and cancer epidemiology. Arh Hig Rada Toksikol 39: 489-498.
Mimides, TM; Aggelides, SM; Kaplanides, AC. (1997). Refuse disposal of asbestos and other mineral fibres and environmental health hazards. In PG Marinos; GC Koukis; GC Tsiambaos; GC Stournaras (Eds.), (pp. 2011-2015). Rotterdam, Netherlands: A.A. Balkema.
Mlynarek, SP; Van Orden, DR. (2012). Asbestos exposure from the overhaul of a Pratt & Whitney R2800 engine. Regul Toxicol Pharmacol 64: 189-194. http://dx.doi.org/10.1016/j.yrtph.2012.07.004
Mohanty, SK; Salamatipour, A; Willenbring, JK. (2021). Mobility of asbestos fibers below ground is enhanced by dissolved organic matter from soil amendments. JHM Letters 2: 100015. http://dx.doi.org/10.1016/j.hazl.2021.100015
Monaro, S; Lecomte, R; Paradis, P; Landsberger, S; Desaulniers, G. (1981). Asbestos pollution assessment in river water by PIXE methods. Nuclear Instruments and Methods 181: 239-241. http://dx.doi.org/10.1016/0029-554X(81)90613-3
Mowat, F; Weidling, R; Sheehan, P. (2007). Simulation tests to assess occupational exposure to airborne asbestos from asphalt-based roofing products. Ann Occup Hyg 51: 451-462. http://dx.doi.org/10.1093/annhyg/mem020
MSHA. (2000). Asbestos hazards in the mining industry. https://hero.epa.gov/hero/index.cfm?action=search.view&reference_id=10259534Neitzel, RL; Sayler, SK; Demond, AH; D'Arcy, H; Garabrant, DH; Franzblau, A. (2020). Measurement of asbestos emissions associated with demolition of abandoned residential dwellings. Sci Total Environ 722: 37891-37891. http://dx.doi.org/10.1016/j.scitotenv.2020.137891
NFPA. (2012). Understanding & implementing standards: NFPA 1500, 1720, and 1851. Washington, DC: National Volunteer Fire Council (NVFC). https://hero.epa.gov/hero/index.cfm?action=search.view&reference_id=11138825NFPA. (2022b). US Fire Department Profile 2020. Washington, DC.
NICNAS. (1999). Chrysotile asbestos: Priority existing chemical no. 9. Sydney, Australia. https://www.industrialchemicals.gov.au/sites/default/files/PEC9-Chrysotile-asbestos.pdf
NIH. (2016). Report on carcinogens: Asbestos. Washington, DC: National Toxicology Program. https://ntp.niehs.nih.gov/pubhealth/roc/index-1.html#C
NIOSH. (1980). Occupational exposure to talc containing asbestos.
NIOSH. (1983). Health hazard evaluation report: HETA-82-96-1259. Kaiser Aluminum and Chemical Corporation, Ravenswood, West Virginia (pp. 19831983). (NIOSH/00127796). Washington, DC: Center for Disease Control. https://www.cdc.gov/niosh/hhe/reports/pdfs/82-96-1259.pdf
NIOSH. (2003). Respirator Usage in Private Sector Firms. Washington D.C.: United States Department of Labor, Bureau of Labor Statistics and National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/docs/respsurv/
NIOSH. (2011a). Asbestos fibers and other elongate mineral particles: State of the science and roadmap for research. In Current Intelligence Bulletin no 62 (Rev. ed.). (DHHS (NIOSH) Publication No.

2011-159). Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. http://www.cdc.gov/niosh/docs/2011-159/

NIOSH. (2011b). Current intelligence bulletin 62: Asbestos fibers and other elongate mineral particles: State of the science and roadmap for research [Revised April 2011]. In Current Intelligence (Revised ed.). (DHHS (NIOSH) Publication No. 2011–159). Atlanta, GA: National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. https://www.cdc.gov/niosh/docs/2011-159/pdfs/2011-159.pdf

NLM. (2021). PubChem: Hazardous Substance Data Bank: Chrysotile, 12001-29-5 [Website]. https://pubchem.ncbi.nlm.nih.gov/compound/25477

Nolan, RP; Langer, AM. (2001). Concentration and type of asbestos fibers in air inside buildings. In RP Nolan; AM Langer; M Ross; FJ Wicks; RF Martin (Eds.), Canadian Mineralogist, special issue 5 (pp. 39-51). Ottawa, ON: Mineralogical Association of Canada. https://hero.epa.gov/hero/index.cfm?action=search.view&reference_id=11138813NTP. (1985). NTP toxicology and carcinogenesis studies of chrysotile asbestos (CAS no. 12001-29-5) in F344/N rats (feed studies) (pp. 1-390). (ISSN 0888-8051). Research Triangle Park, NC: U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health. http://ntp.niehs.nih.gov/ntp/htdocs/LT_rpts/tr279.pdf#search=Toxicology%20and%20carcinogenesis%20studies%20of%20chrysotile%20asbestos

NTP. (1988). Toxicology and carcinogenesis studies of crocidolite asbestos (CAS No. 12001-28-4) in F344/N rats (feed studies) [NTP]. (TR-280). Research Triangle Park, NC: U.S. Department of Health and Human Services, National Toxicology Program. https://ntp.niehs.nih.gov/ntp/htdocs/lt_rpts/tr280.pdf?utm_source=direct&utm_medium=prod&utm_campaign=ntpgolinks&utm_term=tr280

NTP. (2016). 14th Report on carcinogens. In Report on Carcinogens. Research Triangle Park, NC. https://ntp.niehs.nih.gov/pubhealth/roc/index-1.html

Obmiński, A. (2021). Asbestos waste recycling using the microwave technique - Benefits and risks. Environ Nanotechnol Monit Manag 16: 100577. http://dx.doi.org/10.1016/j.enmm.2021.100577

Osada, M; Takamiya, Ke; Manako, K; Noguchi, M; Sakai, SI. (2013). Demonstration study of high temperature melting for asbestos-containing waste (ACW). Journal of Material Cycles and Waste Management 15: 25-36. http://dx.doi.org/10.1007/s10163-012-0088-3

OSHA. (2016). Permissible exposure limits – Annotated tables. https://www.osha.gov/dsg/annotated-pels/

OSHA. (2019). 29 CFR § 1910.1001: Asbestos. (Code of Federal Regulations Title 29 Part 1910.1001). https://www.govinfo.gov/app/details/CFR-2019-title29-vol6/CFR-2019-title29-vol6-sec1910-1001

Paustenbach, DJ; Sage, A; Bono, M; Mowat, F. (2004). Occupational exposure to airborne asbestos from coatings, mastics, and adhesives. J Expo Anal Environ Epidemiol 14: 234-244. http://dx.doi.org/10.1038/sj.jea.7500320

Perez, AL; Nelson, ML; Cheng, TJ; Comerford, CE; Scott, PK. (2018). A meta-analysis of airborne asbestos fiber concentrations from work with or around asbestos-containing floor tile. Int J Occup Environ Health 24: 134-148. http://dx.doi.org/10.1080/10773525.2018.1533671

Perkins, RA; Hargesheimer, J; Fourie, W. (2007). Asbestos release from whole-building demolition of buildings with asbestos-containing material. J Occup Environ Hyg 4: 889-894. http://dx.doi.org/10.1080/15459620701691023

Pitt, R. (1988). Asbestos as an urban area pollutant. J Water Pollut Control Fed 60: 1993-2001.

Polissar, L; Severson, RK; Boatman, ES. (1983). Cancer risk from asbestos in drinking water: summary of a case-control study in western Washington. Environ Health Perspect 53: 57-60.

Polissar, L; Severson, RK; Boatman, ES. (1984). A case-control study of asbestos in drinking water and cancer risk. Am J Epidemiol 119: 456-471. http://dx.doi.org/10.1093/oxfordjournals.aje.a113763
Polissar, L; Severson, RK; Boatman, ES; Thomas, DB. (1982). Cancer incidence in relation to asbestos in drinking water in the Puget Sound region. Am J Epidemiol 116: 314-328. http://dx.doi.org/10.1093/oxfordjournals.aje.a113415
Pollastri, S; Gualtieri, AF; Gualtieri, ML; Hanuskova, M; Cavallo, A; Gaudino, G. (2014). The zeta potential of mineral fibres. J Hazard Mater 276: 469-479. http://dx.doi.org/10.1016/j.jhazmat.2014.05.060
Porcu, M; Orru, R; Cincotti, A; Cao, GC. (2005). Self-propagating reactions for environmental protection: Treatment of wastes containing asbestos. Ind Eng Chem Res 44: 85-91. http://dx.doi.org/10.1021/ie040058c
Price, B; Crump, KS; Baird, EC, III. (1992). Airborne asbestos levels in buildings - Maintenance worker and occupant exposures. J Expo Anal Environ Epidemiol 2: 357-374.
Puffer, JH; Germine, M; Maresca, GP. (1987). Rutile fibers in surface waters of northern New Jersey. Arch Environ Contam Toxicol 16: 103-110. http://dx.doi.org/10.1007/BF01055365
Puffer, JH; Maresca, GP; Germine, M. (1983). Asbestos in water supplies of the northern New Jersey area: Source, concentration, mineralogy, and size distribution. New Brunswick, NJ: Center for Coastal and Environmental Studies, Rutgers University. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB84136811.xhtml
QDOE. (2023). Safety Alert: Asbestos samples in mineral kits [Website]. https://www.asbestos.qld.gov.au/resources/safety-alerts/safety-alert-asbestos-mineral-kits
Queensland DERM. (2011). Wind erosion. Queensland, Australia: Queensland Environment Department. https://www.qld.gov.au/__data/assets/pdf_file/0021/65217/wind-erosion.pdf
Racine, WP. (2010). Emissions concerns during renovation in the healthcare setting: asbestos abatement of floor tile and mastic in medical facilities. J Environ Manage 91: 1429-1436. http://dx.doi.org/10.1016/j.jenvman.2010.02.027
Raghuwanshi, R. (2017). A comparative analysis between demolition and deconstruction (pp. 16-24). East Lansing, MI: Michigan State University Center for Community and Economic Development and the School of Planning, Design & Construction's Urban and Regional Planning Program. https://domicology.msu.edu/upload/domicology-primer_2017.pdf#page=16
Reynolds, SJ; Kreiger, RA; Bohn, JA; Fish, D; Marxhausen, T; McJilton, C. (1994). Factors affecting airborne concentrations of asbestos in a commercial building. Am Ind Hyg Assoc J 55: 823-828. http://dx.doi.org/10.1080/15428119491018547
Rhodes, HB; Ingalls, BL. (1976). Asbestos and silica dust in the drywall industry. Business-health-life part 2 [Magazine]. GDCI Drywall Magazine, January/February.
Riala, RE; Riipinen, HM. (1998). Respirator and High Efficiency Particulate Air Filtration Unit Performance in Asbestos Abatement. Appl Occup Environ Hyg 13: 32-40. http://dx.doi.org/10.1080/1047322X.1998.10389544
Rohl, AN; Langer, AM; Selikoff, IJ; Nicholson, WJ. (1975). Exposure to asbestos in the use of consumer spackling, patching, and taping compounds. Science 189: 551-553. http://dx.doi.org/10.1126/science.1145211
Rohs, A; Lockey, J; Dunning, K; Shukla, R; Fan, H; Hilbert, T; Borton, E; Wiot, J; Meyer, C; Shipley, R; Lemasters, G; Kapil, V. (2008). Low-level fiber-induced radiographic changes caused by Libby vermiculite: a 25-year follow-up study. Am J Respir Crit Care Med 177: 630-637. http://dx.doi.org/10.1164/rccm.200706-841OC
Ryan, PH; LeMasters, GK; Burkle, J; Lockey, JE; Black, B; Rice, C. (2015). Childhood exposure to Libby amphibole during outdoor activities. J Expo Sci Environ Epidemiol 25: 4-11. http://dx.doi.org/10.1038/jes.2013.26

SafeStart. (2017). 3 mining industry safety issues. https://safestart.com/news/3-mining-industry-safety-issues/
Sahmel, J; Barlow, CA; Gaffney, S; Avens, HJ; Madl, A; Henshaw, J; Unice, Ke; Galbraith, D; Derose, G; Lee, RJ; Van Orden, D; Sanchez, M; Zock, M; Paustenbach, DJ. (2016). Airborne asbestos take-home exposures during handling of chrysotile-contaminated clothing following simulated full shift workplace exposures. J Expo Sci Environ Epidemiol 26: 48-62. http://dx.doi.org/10.1038/jes.2015.15
Sahmel, J; Barlow, CA; Simmons, B; Gaffney, SH; Avens, HJ; Madl, AK; Henshaw, J; Lee, RJ; Van Orden, D; Sanchez, M; Zock, M; Paustenbach, DJ. (2014). Evaluation of take-home exposure and risk associated with the handling of clothing contaminated with chrysotile asbestos. Risk Anal 34: 1448-1468. http://dx.doi.org/10.1111/risa.12174
Sakai, K; Hisanaga, N; Kohyama, N; Shibata, E; Takeuchi, Y. (2001). Airborne fiber concentration and size distribution of mineral fibers in area with serpentinite outcrops in Aichi prefecture, Japan. Ind Health 39: 132-140.
Saltzman, LE; Hatlelid, KM. (2000). CPSC staff report on asbestos fibers in children's crayons. Washington, DC: U.S. Consumer Product Safety Commission. https://www.cpsc.gov/PageFiles/108033/crayons.pdf
Sawyer, RN. (1977). Asbestos exposure in a Yale building: Analysis and resolution. Environ Res 13: 146-169. http://dx.doi.org/10.1016/0013-9351(77)90013-5
Scansetti, G; Pira, E; Botta, GC; Turbiglio, M; Piolatto, G. (1993). Asbestos exposure in a steam-electric generating plant. Ann Occup Hyg 37: 645-653. http://dx.doi.org/10.1093/annhyg/37.6.645
Scarlett, HP; Delzell, E; Sathiakumar, N; Oestenstad, RK; Postlethwait, E. (2010). Exposure to airborne asbestos in Jamaican hospitals. West Indian Med J 59: 668-673.
Scarlett, HP; Postlethwait, E; Delzell, E; Sathiakumar, N; Oestenstad, RK. (2012). Asbestos in public hospitals: Are employees at risk? J Environ Health 74: 22-26.
Schiller, JE; Payne, SL. (1980). Surface charge measurements of amphibole cleavage fragments and fibers. (Report of Investigations 8483). Minneapolis, MN: U.S. Department of the Interior, Bureau of Mines.
Schmitt, RP; Lindsten, DC; Shannon, TF. (1977). Decontaminating Lake Superior of asbestos fibers. Environ Sci Technol 11: 462-465.
Schreier, H; Lavkulich, L. (2015). Cumulative effects of the transport of asbestos-rich serpentine sediments in the trans-boundary Sumas Watershed in Washington State and British Columbia. Can Water Resour J 40: 262-271. http://dx.doi.org/10.1080/07011784.2015.1051495
Schreier, H; Omueti, JA; Lavkulich, LM. (1987). Weathering processes of asbestos-rich serpentinitic sediments. Soil Sci Soc Am J 51: 993-999. http://dx.doi.org/10.2136/sssaj1987.03615995005100040032x
Schreier, H; Taylor, J. (1981). Variations and Mechanisms of Asbestos Fibre Distribution in Stream Water. Schreier, H; Taylor, J.
Siegrist, HG; Wylie, AG. (1980). Characterizing and discriminating the shape of asbestos particles. Environ Res 23: 348-361. http://dx.doi.org/10.1016/0013-9351(80)90070-5
SLIC. (2006). A practical guide on best practices to prevent or minimise asbestos risks in work that involves (or may involve) asbestos: for the employer, the workers, and the labour inspector. Brussels, Belgium.
Snyder, JG; Virta, RL; Segreti, JM. (1987). Evaluation of the phase contrast microscopy method for the detection of fibrous and other elongated mineral particulates by comparison with a STEM technique. Am Ind Hyg Assoc J 48: 471-477. http://dx.doi.org/10.1080/15298668791385066
Spear, TM; Hart, JF; Spear, TE; Loushin, MM; Shaw, NN; Elashhab, MI. (2012). The presence of asbestos-contaminated vermiculite attic insulation or other asbestos-containing materials in homes and the potential for living space contamination. J Environ Health 75: 24-29.

Spence, SK; Rocchi, PSJ. (1996). Exposure to asbestos fibres during gasket removal. Ann Occup Hyg 40: 583-588. http://dx.doi.org/10.1016/0003-4878(95)00098-4
Standard Oil. (1981). Occupational health survey El Segundo Refinery [TSCA Submission]. (OTS0205993. 878211945. TSCATS/16899). Standard Oil Co.
Stefani, D; Wardman, D; Lambert, T. (2005). The implosion of the Calgary General Hospital: Ambient air quality issues. J Air Waste Manag Assoc 55: 52-59. http://dx.doi.org/10.1080/10473289.2005.10464605
Stewart, IM; Putscher, RE; Humecki, HJ; Shimps, RJ. (1977). Asbestos Fibers in Discharges from Selected Mining and Milling Activities. Final Report Part III. (EPA/560-6-77-001). Washington, DC: Office of Toxic Substances. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=91012GVN.PDF
Straif, K; Benbrahim-Tallaa, L; Baan, R; Grosse, Y; Secretan, B; El Ghissassi, F; Bouvard, V; Guha, N; Freeman, C; Galichet, L; Cogliano, V. (2009). A review of human carcinogens: Part C: Metals, arsenic, dusts, and fibres. Lancet Oncol 10: 453-454. http://dx.doi.org/10.1016/S1470-2045(09)70134-2
Sullivan, PA. (2007). Vermiculite, respiratory disease, and asbestos exposure in Libby, Montana: update of a cohort mortality study. Environ Health Perspect 115: 579-585. http://dx.doi.org/10.1289/ehp.9481
Suter, G. (2016). Weight of evidence in ecological assessment. (EPA100R16001). Washington, DC: U.S. Environmental Protection Agency. https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=335523
Szeinuk, J; Padilla, M; de la Hoz, RE. (2008). Potential for diffuse parenchymal lung disease after exposures at World Trade Center Disaster site [Review]. Mt Sinai J Med 75: 101-107. http://dx.doi.org/10.1002/msj.20025
Szeszenia-Dąbrowska, N; Sobala, W; Swiątkowska, B; Stroszejn-Mrowca, G; Wilczyńska, U. (2012). Environmental asbestos pollution -- situation in Poland. Int J Occup Med Environ Health 25: 3-13. http://dx.doi.org/10.2478/s13382-012-0003-0
Tang, KM; Nace, CG, Jr.; Lynes, CL; Maddaloni, MA; Laposta, D; Callahan, KC. (2004). Characterization of background concentrations in upper Manhattan, New York apartments for select contaminants identified in World Trade Center dust. Environ Sci Technol 38: 6482-6490. http://dx.doi.org/10.1021/es035468r
Tannahill, SN; Willey, RJ; Jackson, MH. (1990). Workplace protection factors of HSE approved negative pressure full-facepiece dust respirators during asbestos stripping: preliminary findings. Ann Occup Hyg 34: 547-552. http://dx.doi.org/10.1093/annhyg/34.6.547
Tech Servs Inc. (1979). Atmosphere filtering monitoring report [878210781] [TSCA Submission]. (OTS0206152. 878210781. TSCATS/18205). Manville Service Corporation.
Teschke, K; Ahrens, W; Andersen, A; Boffetta, P; Fincham, S; Finkelstein, M; Henneberger, P; Kauppinen, T; Kogevinas, M; Korhonen, K; Liss, G; Liukkonnen, T; Osvoll, P; Savela, A; Szadkowska-Stanczyk, I; Westbergh, H; Widerkiewicz, K. (1999). Occupational exposure to chemical and biological agents in the nonproduction departments of pulp, paper, and paper product mills: An International Study. Am Ind Hyg Assoc J 60: 73-83. http://dx.doi.org/10.1080/00028899908984424
Thorne, PS; Lightfoot, EN; Albrecht, RM. (1985). Physicochemical characterization of cryogenically ground, size separated, fibrogenic particles. Environ Res 36: 89-110. http://dx.doi.org/10.1016/0013-9351(85)90010-6
Tiseo, I. (2022). U.S. C&D debris generation by source 2018: Weight of waste generated during construction and demolition in the United States in 2018, by source (in million metric tons). Available online at https://www.statista.com/statistics/726455/construction-demolition-waste-generation-in-us-by-source/

TOMA. (1979). Cross-sectional health study of workers at the Follansbee, West Virginia plant of Koppers Company, Inc [TSCA Submission]. (OTS0206278. 878210954. TSCATS/018655). Koppers Company. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/OTS0206278.xhtml

Turci, F; Favero-Longo, SE; Gazzano, C; Tomatis, M; Gentile-Garofalo, L; Bergamini, M. (2016). Assessment of asbestos exposure during a simulated agricultural activity in the proximity of the former asbestos mine of Balangero, Italy. J Hazard Mater 308: 321-327. http://dx.doi.org/10.1016/j.jhazmat.2016.01.056

U.S. BLS. (2014). Employee Tenure News Release. http://www.bls.gov/news.release/archives/tenure_09182014.htm

U.S. BLS. (2016). May 2016 Occupational Employment and Wage Estimates: National Industry-Specific Estimates [Website]. http://www.bls.gov/oes/tables.htm

U.S. Census Bureau. (2012). Statistics of U.S. businesses: Historical data available for downloading - 2012 [Website]. https://www.census.gov/data/datasets/2012/econ/susb/2012-susb.html

U.S. Census Bureau. (2015). Statistics of U.S. Businesses (SUSB). https://www.census.gov/data/tables/2015/econ/susb/2015-susb-annual.html

U.S. Census Bureau. (2019a). Survey of Income and Program Participation data [Website]. https://www.census.gov/programs-surveys/sipp/data/datasets/2008-panel/wave-1.html

U.S. Census Bureau. (2019b). Survey of Income and Program Participation: SIPP introduction and history. Washington, DC. https://www.census.gov/programs-surveys/sipp/about/sipp-introduction-history.html

U.S. EPA. (1976). Asbestos in the water supplies of the ten regional cities. Final report, part I [EPA Report]. (EPA-560/6-76-017). Washington, DC. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB252620.xhtml

U.S. EPA. (1980). Ambient water quality criteria for asbestos [EPA Report]. (EPA/440/5-80/022). Washington, DC. http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=00001LP6.txt

U.S. EPA. (1985). Drinking water criteria document for asbestos. (600/X-84/199-1). Cincinnati, OH: Environmental Criteria and Assessment Office, U.S. Environmental Protection Agency.

U.S. EPA. (1986a). Airborne asbestos health assessment update. (EPA/600/8-84/003F). Washington DC: U.S. Environmental Protection Agency, Environmental Criteria and Assessment.

U.S. EPA. (1986b). Assessment of assay methods for evaluating asbestos abatement technology at the Corvallis Environmental Research Laboratory [EPA Report]. (EPA/600/2-86/070). Washington, DC. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=91024UUD.txt

U.S. EPA. (1988). EPA Study of asbestos-containing materials in public buildings - A report to Congress. (CIS/89/01314). ANON.

U.S. EPA. (1989). Regulatory impact analysis of controls on asbestos and asbestos products: Final report: Volume III. (5601989ICF001). Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency.

U.S. EPA. (1990a). Guidelines for asbestos: NESHAP demolition and renovation inspection procedures [EPA Report]. (EPA-340/1-90-007). Washington, DC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. http://nepis.epa.gov/exe/ZyPURL.cgi?Dockey=50000LP9.txt

U.S. EPA. (1990b). National emission standards for hazardous air pollutants; Asbestos NESHAP revision. Washington, DC. https://www.epa.gov/stationary-sources-air-pollution/national-emission-standards-hazardous-air-pollutants-neshap-7

U.S. EPA. (1991). Assessment of asbestos removal carried our using EPA Purple Book guidance. (EPA/600/2-91/003). Cincinnati, OH: U.S. Environmental Protection Agency. https://nepis.epa.gov/Exe/ZyPDF.cgi/9100R1T1.PDF?Dockey=9100R1T1.PDF

U.S. EPA. (1992). Guidelines for exposure assessment. Federal Register 57(104):22888-22938 [EPA Report]. (EPA/600/Z-92/001). Washington, DC. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=15263

U.S. EPA. (1993). Airborne asbestos concentrations three years after abatement in seventeen schools. (EPA/600/SR-93/152). Cincinnati, OH: U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory. https://nepis.epa.gov/Exe/ZyPDF.cgi/30003WJW.PDF?Dockey=30003WJW.PDF

U.S. EPA. (1994). Guidelines for Statistical Analysis of Occupational Exposure Data: Final. United States Environmental Protection Agency :: U.S. EPA.

U.S. EPA. (1995a). Talc processing.

U.S. EPA. (1995b). Vermiculite processing.

U.S. EPA. (1998). Guidelines for ecological risk assessment [EPA Report]. (EPA/630/R-95/002F). Washington, DC: U.S. Environmental Protection Agency, Risk Assessment Forum. https://www.epa.gov/risk/guidelines-ecological-risk-assessment

U.S. EPA. (2000a). Sampling and analysis of consumer garden products that contain vermiculite. Washington, DC: U.S. Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances.

U.S. EPA. (2000b). Supplementary guidance for conducting health risk assessment of chemical mixtures (pp. 1-209). (EPA/630/R-00/002). Washington, DC: U.S. Environmental Protection Agency, Risk Assessment Forum. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=20533

U.S. EPA. (2002). Guidance on cumulative risk assessment of pesticide chemicals that have a common mechanism of toxicity [EPA Report]. Washington, D.C.

U.S. EPA. (2003a). Estimating 2003 building-related construction and demolition materials amounts. https://www.epa.gov/smm/estimating-2003-building-related-construction-and-demolition-materials-amounts

U.S. EPA. (2003b). Methodology for deriving ambient water quality criteria for the protection of human health (2000), technical support document. Volume 2: Development of national bioaccumulation factors [EPA Report]. (EPA/822/R-03/030). Washington, DC. http://www.epa.gov/waterscience/criteria/humanhealth/method/tsdvol2.pdf

U.S. EPA. (2005). Guidelines for carcinogen risk assessment [EPA Report]. (EPA630P03001F). Washington, DC. https://www.epa.gov/sites/production/files/2013-09/documents/cancer_guidelines_final_3-25-05.pdf

U.S. EPA. (2008). Framework for investigating asbestos-contaminated superfund sites (pp. 71). (OSWER Directive #9200.0-68). Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. http://www.epa.gov/superfund/health/contaminants/asbestos/pdfs/framework_asbestos_guidance.pdf

U.S. EPA. (2009). Risk assessment guidance for superfund volume I: Human health evaluation manual (Part F, supplemental guidance for inhalation risk assessment): Final [EPA Report]. (EPA/540/-R-070/002). Washington, DC. https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part-f

U.S. EPA. (2011). Exposure factors handbook: 2011 edition [EPA Report]. (EPA/600/R-090/052F). Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100F2OS.txt

U.S. EPA. (2012). Sustainable Futures / P2 Framework Manual, Section 12: Estimating general population and aquatic exposure using E-FAST. (EPA-748-B12-001). Washington, DC: U.S. Environmental Protection Agency, OCSPP. https://www.epa.gov/sustainable-futures/sustainable-futures-p2-framework-manual

U.S. EPA. (2013). Benchmark Dose (BMD) methodology assessment [Website]. https://web.archive.org/web/20170118115236/https://www.epa.gov/bmds
U.S. EPA. (2014a). Integrated Risk Information System (IRIS) chemical assessment summary: Libby amphibole asbestos; CASRN not applicable. https://www.epa.gov/iris/supporting-documents-libby-amphibole-asbestos
U.S. EPA. (2014b). Site-wide baseline ecological risk assessment Libby Asbestos Superfund Site.
U.S. EPA. (2014c). Toxicological review of libby amphibole asbestos: In support of summary information on the Integrated Risk Information System (IRIS) [EPA Report]. (EPA/635/R-11/002F). Washington, DC: Integrated Risk Information System, National Center for Environmental Assessment, Office of Research and Development. https://cfpub.epa.gov/ncea/iris/iris_documents/documents/toxreviews/1026tr.pdf
U.S. EPA. (2016b). Weight of evidence in ecological assessment [EPA Report]. (EPA/100/R-16/001). Washington, DC: Office of the Science Advisor. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100SFXR.txt
U.S. EPA. (2017). Scope of the risk evaluation for asbestos [EPA Report]. (EPA-740-R1-7008). Washington, DC: Office of Chemical Safety and Pollution Prevention. https://www.epa.gov/sites/production/files/2017-06/documents/asbestos_scope_06-22-17.pdf
U.S. EPA. (2018a). Application of systematic review in TSCA risk evaluations. (740-P1-8001). Washington, DC: U.S. Environmental Protection Agency, Office of Chemical Safety and Pollution Prevention. https://www.epa.gov/sites/production/files/2018-06/documents/final_application_of_sr_in_tsca_05-31-18.pdf
U.S. EPA. (2018b). Hazardous Waste Management Facilities and Units. https://www.epa.gov/hwpermitting/hazardous-waste-management-facilities-and-units
U.S. EPA. (2018c). User's Guide for the AMS/EPA Regulatory Model (AERMOD). (EPA Document Number: EPA-454/B-18-001). U.S. EPA. https://hero.epa.gov/hero/index.cfm?action=search.view&reference_id=6127841U.S. EPA. (2019b). National emission standards for hazardous air pollutants for asbestos: Notice of final approval for an alternative work practice standard for asbestos cement pipe replacement (pp. 26852-26866). (EPA–HQ–OAR–2017–0427). Washington, DC: Federal Information & News Dispatch, LLC. https://www.federalregister.gov/documents/2019/06/10/2019-12085/national-emission-standards-for-hazardous-air-pollutants-for-asbestos-notice-of-final-approval-for
U.S. EPA. (2020a). Final risk evaluation for asbestos part 1: Chrysotile asbestos, systematic review supplemental file: Data quality evaluation for epidemiological studies of ovarian and laryngeal cancers [EPA Report].
U.S. EPA. (2020b). Instructions for reporting 2020 TSCA Chemical Data Reporting. Washington, DC: Office of Pollution Prevention and Toxics. https://www.epa.gov/sites/default/files/2020-12/documents/instructions_for_reporting_2020_tsca_cdr_2020-11-25.pdf
U.S. EPA. (2020c). Risk evaluation for asbestos, Part I: Chrysotile asbestos [EPA Report]. (EPA-740-R1-8012). Washington, DC: Office of Chemical Safety and Pollution Prevention. https://www.regulations.gov/document/EPA-HQ-OPPT-2019-0501-0117
U.S. EPA. (2021a). Draft systematic review protocol supporting TSCA risk evaluations for chemical substances, Version 1.0: A generic TSCA systematic review protocol with chemical-specific methodologies. (EPA Document #EPA-D-20-031). Washington, DC: Office of Chemical Safety and Pollution Prevention. https://www.regulations.gov/document/EPA-HQ-OPPT-2021-0414-0005
U.S. EPA. (2021b). Final scope of the risk evaluation for di-isodecyl phthalate (DIDP) (1,2-benzenedicarboxylic acid, 1,2-diisodecyl ester and 1,2-benzenedicarboxylic acid, di-C9-11-branched alkyl esters, C10-rich); CASRN 26761-40-0 and 68515-49-1 [EPA Report]. (EPA-740-R-21-001). Washington, DC: Office of Chemical Safety and Pollution Prevention.

https://www.epa.gov/system/files/documents/2021-08/casrn-26761-40-0-di-isodecyl-phthalate-final-scope.pdf

U.S. EPA. (2022b). Final scope of the risk evaluation for asbestos. Part 2: Supplemental evaluation including legacy uses and associated disposals of asbestos [EPA Report]. (EPA Document# EPA-740-R-21-002). n.p.: U.S. Environmental Protection Agency, Office of Chemical Pollution and Safety Prevention. https://www.epa.gov/system/files/documents/2022-06/Asbestos%20Part%202_FinalScope.pdf

U.S. EPA. (2022c). First five-year review report for BoRit Asbestos Superfund Site, Montgomery County, Pennsylvania [EPA Report]. Philadelphia, PA: U.S. Environmental Protection Agency, Region 3. https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0301842

U.S. EPA. (2023a). Draft Risk Evaluation for Asbestos Part 2 – Systematic Review Supplemental File: Aggregate Analysis. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics.

U.S. EPA. (2023b). Draft Risk Evaluation for Asbestos Part 2 – Systematic Review Supplemental File: Environmental Release and Occupational Exposure Data Tables. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics.

U.S. EPA. (2023c). Draft Risk Evaluation for Asbestos Part 2 – Systematic Review Supplemental File: Risk Calculator for Consumer. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics.

U.S. EPA. (2023d). Draft Risk Evaluation for Asbestos Part 2 – Systematic Review Supplemental File: Risk calculator for occupational exposure. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics.

U.S. EPA. (2023e). Draft Risk Evaluation for Asbestos Part 2 – Systematic Review Supplemental File: Risk calculator for take home. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics.

U.S. EPA. (2023f). Draft Risk Evaluation for Asbestos Part 2: Supplemental Evaluation Including Legacy Uses and Associated Disposals of Asbestos – Systematic Review Protocol. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics.

U.S. EPA. (2023g). White Paper: Quantitative Human Health Approach to be Applied in the Risk Evaluation for Asbestos Part 2 – Supplemental Evaluation including Legacy Uses and Associated Disposals of Asbestos. (EPA-740-S-23-001). Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics.

U.S. EPA. (2024a). Risk Evaluation for Asbestos Part 2 – Systematic Review Supplemental File: Data Extraction Information for Environmental Hazard and Human Health Hazard Animal Toxicology and Epidemiology. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics.

U.S. EPA. (2024b). Risk Evaluation for Asbestos Part 2 – Systematic Review Supplemental File: Data Extraction Information for General Population, Consumer, and Environmental Exposure. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics.

U.S. EPA. (2024c). Risk Evaluation for Asbestos Part 2 – Systematic Review Supplemental File: Data Quality Evaluation and Data Extraction Information for Environmental Fate and Transport. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics.

U.S. EPA. (2024d). Risk Evaluation for Asbestos Part 2 – Systematic Review Supplemental File: Data Quality Evaluation and Data Extraction Information for Environmental Release and Occupational Exposure. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics.

U.S. EPA. (2024e). Risk Evaluation for Asbestos Part 2 – Systematic Review Supplemental File: Data Quality Evaluation and Data Extraction Information for Physical and Chemical Properties. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics.
U.S. EPA. (2024f). Risk Evaluation for Asbestos Part 2 – Systematic Review Supplemental File: Data Quality Evaluation Information for Environmental Hazard. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics.
U.S. EPA. (2024g). Risk Evaluation for Asbestos Part 2 – Systematic Review Supplemental File: Data Quality Evaluation Information for General Population, Consumer, and Environmental Exposure. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics.
U.S. EPA. (2024h). Risk Evaluation for Asbestos Part 2 – Systematic Review Supplemental File: Data Quality Evaluation Information for Human Health Hazard Epidemiology. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics. https://hero.epa.gov/hero/index.cfm?action=search.view&reference_id=10692769UK Parliament. (2012). The Control of Asbestos Regulations 2012. Available online at https://www.legislation.gov.uk/uksi/2012/632/contents/made (accessed November 12, 2024).
USGS. (2021). Vermiculite.
USGS. (2022). Talc and pyrophyllite.
van Orden, DR; Lee, RJ; Bishop, KM; Kahane, D; Morse, R. (1995). Evaluation of ambient asbestos concentrations in buildings following the Loma Prieta earthquake. Regul Toxicol Pharmacol 21: 117-122. http://dx.doi.org/10.1006/rtph.1995.1016
Versar. (1987). Nonoccupational asbestos exposure: Revised draft report. Washington, DC: U.S. Environmental Protection Agency.
Versar. (1988). Final report: Asbestos Modeling Study [EPA Report]. (EPA 560/3-88/091). Washington, D.C.: US Environmental Protection Agency.
Virta, RL. (2004). Kirk-Othmer Encyclopedia of Chemical Technology: Asbestos.
Virta, RL; Shedd, KB; Wylie, AG; Snyder, JG. (1983). Size and shape characteristics of amphibole asbestos (amosite) and amphibole cleavage fragments (actinolite, cummingtonite) collected on occupational air monitoring filters. In VA Marple; BY Liu (Eds.), Ann Arbor Science Publications, no 2 (pp. 633-643). Ann Arbor, MI: Ann Arbor Science.
Vitello, C. (2001). Asbestos exposure & health impacts in New York City. Hazardous Materials Management 13: 15-16.
W. R. Grace & Co. (1988). Health of vermiculite miners exposed to trace amounts of fibrous tremolite with cover letter dated 022988 [TSCA Submission]. (OTS0514047. 86880000158. TSCATS/305260).
Wallingford, KM; Snyder, EM. (2001). Occupational exposures during the World Trade Center disaster response. Toxicol Ind Health 17: 247-253. http://dx.doi.org/10.1191/0748233701th112oa
Webber, JS; Jackson, KW; Parekh, PP; Bopp, RF. (2004). Reconstruction of a century of airborne asbestos concentrations. Environ Sci Technol 38: 707-714. http://dx.doi.org/10.1021/es034479h
Webber, JS; Syrotynski, S; King, MV. (1988). Asbestos-contaminated drinking-water - its impact on household air. Environ Res 46: 153-167. http://dx.doi.org/10.1016/S0013-9351(88)80029-X
Weir, FW; Tolar, G; Meraz, LB. (2001). Characterization of vehicular brake service personnel exposure to airborne asbestos and particulate. Appl Occup Environ Hyg 16: 1139-1146. http://dx.doi.org/10.1080/10473220127402
WHO. (2014). Chrysotile asbestos. Geneva, Switzerland. http://www.who.int/ipcs/assessment/public_health/chrysotile_asbestos_summary.pdf

Wilson, R; McConnell, EE; Ross, M; Axten, CW; Nolan, RP. (2008). Risk assessment due to environmental exposures to fibrous particulates associated with taconite ore. Regul Toxicol Pharmacol 52: S232-S245. http://dx.doi.org/10.1016/j.yrtph.2007.11.005

Witek, J; Psiuk, B; Naziemiec, Z; Kusiorowski, R. (2019). Obtaining an artificial aggregate from cement-asbestos waste by the melting technique in an arc-resistance furnace. Fibers 7. http://dx.doi.org/10.3390/FIB7020010

WST. (2019). Asbestos in mineral kits [Website]. https://worksafe.tas.gov.au/topics/Health-and-Safety/safety-alerts/asbestos-in-mineral-kits

Yoon, S; Yeom, K; Kim, Y; Park, B; Park, J; Kim, H; Jeong, H; Roh, Y. (2020). Management of naturally occurring asbestos area in Republic of Korea. Environmental and Engineering Geoscience 26: 79-87. http://dx.doi.org/10.2113/EEG-2287

Zhang, YL; Byeon, HS; Hong, WH; Cha, GW; Lee, YH; Kim, YC. (2021). Risk assessment of asbestos containing materials in a deteriorated dwelling area using four different methods. J Hazard Mater 410: 124645. http://dx.doi.org/10.1016/j.jhazmat.2020.124645

Zhong, Q; Liao, ZT; Qi, LJ; Zhou, ZY. (2019). Black Nephrite Jade from Guangxi, Southern China. Gems & Gemology 55: 198-215. http://dx.doi.org/10.5741/GEMS.55.2.198

Zielina, M; Dabrowski, W; Lang, T. (2007). Assessing the risk of corrosion of asbestos-cement pipes in Krakow's water supply network. Environ Protect Eng 33: 17-26.

APPENDICES

Appendix A ABBREVIATIONS, ACRONYMS, AND SELECT GLOSSARY

A.1 Key Abbreviations and Acronyms

A/C	Asbestos Cement
ACGIH	American Conference of Governmental Industrial Hygienists
ACM	Asbestos-containing material(s)
ACH	Air changes per hour
ADC	Average daily concentration
AERMOD	American Meteorological Society/EPA Regulatory Model
AF	Assessment factor
AHERA	Asbestos Hazard Emergency Response Act
ATSDR	Agency for Toxic Substances and Disease Registry
BCF	Bioconcentration factor
BLS	Bureau of Labor Statistics
BMR	Benchmark response
CAS	Chemical Abstracts Service
CASRN	Chemical Abstracts Service Registry Number
CDR	Chemical Data Reporting
CEHD	Chemical Exposure Health Data
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
ChV	Chronic value
COC	Concentration(s) of concern
CPSA	Consumer Product Safety Act
CPSC	Consumer Product Safety Commission
CWA	Clean Water Act
DIY	Do-it-yourself
DMR	Discharge Monitoring Report
ECEL	Existing chemical exposure limit
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ESD	Emission Scenario Document
EU	European Union
FDA	Food and Drug Administration
FFDCA	Federal Food, Drug, and Cosmetic Act
GWB	Gypsum wallboard
HAP	Hazardous Air Pollutant
HERO	Health and Environmental Research Online (Database)
HHE	Health hazard evaluation
HMTA	Hazardous Materials Transportation Act
IARC	International Agency for Research on Cancer
IIOAC	Integrated Indoor-Outdoor Air Calculator
IDLH	Immediately Dangerous to Life and Health
IRIS	Integrated Risk Information System

IUR	Inhalation unit risk
LAA	Libby Amphibole Asbestos
LOD	Limit of detection
LOEC	Lowest-observed-effect-concentration
LTL	Less-than-lifetime
MCL	Maximum Contaminant Level
MOA	Mode of action
MSHA	Mine Safety and Health Administration
MUC	Maximum Use Concentration (OSHA)
NAICS	North American Industry Classification System
ND	Non-detect
NEI	National Emissions Inventory
NESHAP	National Emission Standards for Hazardous Air Pollutants
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NIOSH	National Institute for Occupational Safety and Health
NITE	National Institute of Technology and Evaluation
NOEC	No-observed-effect-concentration
NPDES	National Pollutant Discharge Elimination System
NPDWR	National Primary Drinking Water Regulation
NRC	National Response Center
NTP	National Toxicology Program
NWIS	National Water Information System
OCSPP	Office of Chemical Safety and Pollution Prevention
OECD	Organisation for Economic Co-operation and Development
OEL	Occupational exposure limit
OES	Occupational exposure scenario
ONU	Occupational non-user
OPPT	Office of Pollution Prevention and Toxics
OSHA	Occupational Safety and Health Administration
PBZ	Personal breathing zone
PCM	Phase contrast microscopy
PCME	PCM-equivalent
PECO	Population, exposure, comparator, and outcome
PEL	Permissible exposure limit (OSHA)
PESS	Potentially exposed or susceptible subpopulations
PLM	Polarized light microscopy
POD	Point of departure
POTW	Publicly owned treatment works
PPE	Personal protective equipment
RACM	Regulated asbestos-containing materials
RCRA	Resource Conservation and Recovery Act
REL	Recommended Exposure Limit
RF	Reduction factor
RQ	Risk quotient
RTR	Risk and technology review (EPA program)
SCC	Source classification code
SDWA	Safe Drinking Water Act
SEM	Scanning electron microscopy
SIPP	Survey of Income and Program Participation (U.S. Census)

SEG	Similar exposure group
SOC	Standard Occupational Classification
STORET	STOrage and RETrieval and Water Quality (data warehouse)
SUSB	Statistics of U.S. Businesses (U.S. Census)
TEM	Transmission electron microscopy
TLV	Threshold Limit Value
TRI	Toxics Release Inventory
TRV	Toxicity reference value
TSCA	Toxic Substances Control Act
TWA	Time-weighted average
TWF	Time-weighted factor
U.S.	United States
USGS	United States Geological Survey
WHO	World Health Organization
WTC	World Trade Center

A.2 Glossary of Select Terms

Condition of use (COU) (15 U.S.C. 2602(4)): "means the circumstances, as determined by the Administrator, under which a chemical substance is intended, known, or reasonably foreseen to be manufactured, processed, distributed in commerce, used, or disposed of."

Margin of exposure (MOE) (U.S. EPA, 2002): "a numerical value that characterizes the amount of safety to a toxic chemical–a ratio of a toxicological endpoint (usually a NOAEL [no observed adverse effect level]) to exposure. The MOE is a measure of how closely the exposure comes to the NOAEL."

Mode of action (MOA) (U.S. EPA, 2000b): "a series of key events and processes starting with interaction of an agent with a cell, and proceeding through operational and anatomical changes causing disease formation."

Point of departure (POD) (U.S. EPA, 2002): "dose that can be considered to be in the range of observed responses, without significant extrapolation. A POD can be a data point or an estimated point that is derived from observed dose-response data. A POD is used to mark the beginning of extrapolation to determine risk associated with lower environmentally relevant human exposures."

Potentially exposed or susceptible subpopulations (PESS) (40 CFR 702.33): "means a group of individuals within the general population identified by the Agency who, due to either greater susceptibility or greater exposure, may be at greater risk than the general population of adverse health effects from exposure to a chemical substance or mixture, such as infants, children, pregnant women, workers, the elderly, or overburdened communities."

Reasonably available information (40 CFR 702.33): "means information that EPA possesses or can reasonably generate, obtain, and synthesize for use in risk evaluations, considering the deadlines specified in TSCA section 6(b)(4)(G) for completing such evaluation. Information that meets the terms of the preceding sentence is reasonably available information whether or not the information is confidential business information, that is protected from public disclosure under TSCA section 14."

Routes (40 CFR 702.33): "means the ways a chemical substance enters an organism after contact, *e.g.*, by ingestion, inhalation, or dermal absorption."

Sentinel exposure (40 CFR 702.33): "means the exposure from a chemical substance that represents the plausible upper bound of exposure relative to all other exposures within a broad category of similar or related exposures."

Appendix B REGULATORY AND ASSESSMENT HISTORY

B.1 Federal Laws and Regulations

The chemical substance, asbestos, is subject to federal and state laws and regulations in the United States (Table_Apx B-1 and Table_Apx B-2). Regulatory actions by other governments, tribes, and international agreements applicable to asbestos are listed in Table_Apx B-3. A history of asbestos assessments by EPA and other organizations is provided in Table_Apx B-4. Assessment History of Asbestos.

Regulatory actions by other federal agencies, both domestic and abroad, have established threshold values for asbestos in trace amounts of 0.1 to 1 percent (weight fraction). Within the United States, Asbestos Hazard Emergency Response Act (AHERA), National Emission Standards for Hazardous Air Pollutants (NESHAP), and Occupational Safety and Health Administration (OSHA) regulate asbestos-containing materials above 1 percent (OSHA, 2016; U.S. EPA, 1990b). Regulatory agencies in Canada, Korea, and Japan regulate asbestos levels exceeding 0.1 percent, while the European Commission and United Kingdom do not regulate asbestos that is not intentionally added to products (ECCC, 2024; Kwon, 2022; EuroParl, 2019; UK Parliament, 2012). EPA acknowledges that these regulations likely encouraged companies to maintain an awareness of asbestos in trace amounts in mined products, thus leading to the reports provided under TSCA section 8(a).

Table_Apx B-1. Federal Laws and Regulations

Statutes/Regulations	Description of Authority/Regulation	Description of Regulation
EPA statues/regulations		
TSCA – section 5(a)	Directs EPA to determine that a use of a chemical substance is a "significant new use." EPA must make this determination by rule after considering all relevant factors, including those listed in TSCA section 5(a)(2). Once EPA determines that a use of a chemical substance is a significant new use, TSCA section 5(a)(1) requires persons to submit a significant new use notice (SNUN) to EPA at least 90 days before they manufacture (including import) or process the chemical substance for that use. TSCA prohibits the manufacturing (including importing) or processing from commencing until EPA has conducted a review of the notice, made an appropriate determination on the notice, and taken such actions as are required in association with that determination.	A significant new use rule for asbestos was issued to ensure that any discontinued uses of asbestos cannot re-enter the marketplace without EPA review, closing a loophole in the regulatory regime for asbestos (84 FR 17345, April 25, 2019)
TSCA – section 6(b)	Directs EPA to promulgate regulations to establish processes for prioritizing chemical substances and conducting risk evaluations on priority chemicals substances. In the meantime, EPA was required to identify and begin risk	Asbestos is one of the 10 chemical substances on the initial list to be evaluated for unreasonable risk of injury to health or the environment (81 FR 91927, December 19, 2016).

Statutes/Regulations	Description of Authority/Regulation	Description of Regulation
	evaluations on 10 chemical substances drawn from the 2014 update of the TSCA Work Plan for Chemical Assessments.	
TSCA – section 8(a)	The TSCA section 8(a) CDR Rule requires manufacturers (including importers) to give EPA basic exposure-related information on the types, quantities and uses of chemical substances produced domestically and imported into the United States. TSCA section 8(a) generally authorizes EPA to promulgate rules that require entities, other than small manufacturers (including importers) or processors, who manufacture (including import) or process, chemical substance to maintain certain records and submit such reports as the EPA Administrator may reasonably require.	Asbestos manufacturing (including importing), processing, and use information is reported under the CDR rule (76 FR 50816, August 16, 2011). A rule under TSCA section 8(a)(1) requiring certain persons who manufactured (including imported) or processed asbestos and asbestos-containing articles (including as an impurity) in the last four years to report certain exposure-related information, including quantities of asbestos manufactured or processed, types of use, and employee data (88 FR 47782, July 25, 2023)
TSCA – section 8(b)	EPA must compile, keep current and publish a list (the TSCA Inventory) of each chemical substance manufactured, processed, or imported in the United States.	Asbestos was on the initial TSCA Inventory.
TSCA – section 8(d)	Provides EPA with authority to issue rules requiring producers, importers, and (if specified) processors of a chemical substance or mixture to submit lists and/or copies of ongoing and completed, unpublished health and safety studies.	One submission received in 2001 (U.S. EPA, Chemical Data Access Tool. Accessed April 24, 2017).
TSCA – section 8(e)	Manufacturers (including importers), processors, and distributors must immediately notify EPA if they obtain information that supports the conclusion that a chemical substance or mixture presents a substantial risk of injury to health or the environment.	Four submissions received 1992, 1993, 1994, and 1996 (U.S. EPA, ChemView. Accessed May 8, 2023).
Asbestos Hazard Emergency Response Act (AHERA), 1986 TSCA Subchapter II: Asbestos Hazard Emergency Response 15 U.S.C. 2641–2656	Defines asbestos as the asbestiform varieties of chrysotile (serpentine), crocidolite (riebeckite), amosite (cummingtonite-grunerite), anthophyllite, tremolite or actinolite. Requires local education agencies (*i.e.*, school districts) to inspect school buildings for asbestos and submit asbestos management plans to appropriate state; management plans must be publicly	Asbestos-Containing Materials in Schools Rule (per AHERA), 1987 40 CFR Part 763, subpart E Requires local education agencies to use trained and accredited asbestos professionals to identify and manage asbestos-containing building material and perform asbestos response actions (abatements) in school buildings.

Statutes/Regulations	Description of Authority/Regulation	Description of Regulation
	available, and inspectors must be trained and accredited. Tasked EPA to develop an asbestos Model Accreditation Plan (MAP) for states to establish training requirements for asbestos professionals who do work in school buildings and also public and commercial buildings.	
TSCA section 6(a) – Asbestos: Manufacture, Importation, Processing, and Distribution in Commerce Prohibitions; Final Rule (1989) 40 CFR part 763, subpart I		EPA issued a final rule under section 6 of TSCA banning most asbestos-containing products. In 1991, this rule was vacated and remanded by the Fifth Circuit Court of Appeals. As a result, most of the original ban on the manufacture, importation, processing, or distribution in commerce for the majority of the asbestos-containing products originally covered in the 1989 final rule was overturned. The following products remain banned by rule under TSCA: • Corrugated paper • Rollboard • Commercial paper • Specialty paper • Flooring felt In addition, the regulation continues to ban the use of asbestos in products that have not historically contained asbestos, otherwise referred to as "new uses" of asbestos (Defined by 40 CFR 763.163 as "commercial uses of asbestos not identified in §763.165 the manufacture, importation or processing of which would be initiated for the first time after August 25, 1989."). EPA has also prohibited ongoing uses of chrysotile asbestos. 40 CFR 751 subpart F.
Asbestos Worker Protection Rule, 2000 40 CFR part 763, subpart G		Extends OSHA standards to public employees in states that do not have an OSHA approved worker protection plan.
Asbestos Information Act, 1988 15 U.S.C. 2607(f)		Helped to provide transparency and identify the companies making certain types of asbestos-containing products by requiring manufacturers to report production to the EPA.
Asbestos School Hazard Abatement Act		Provided funding for and established an asbestos abatement loan and grant program

Statutes/Regulations	Description of Authority/Regulation	Description of Regulation
(ASHAA), 1984 and Asbestos School Hazard Abatement Reauthorization Act (ASHARA), 1990 20 U.S.C. 4011 et seq.		for school districts and ASHARA further tasked EPA to update the MAP asbestos worker training requirements.
Emergency Planning and Community Right-to-Know Act (EPCRA) – section 313	Requires annual reporting from facilities in specific industry sectors that employ 10 or more full-time equivalent employees and that manufacture, process or otherwise use a TRI-listed chemical in quantities above threshold levels. A facility that meets reporting requirements must submit a reporting form for each chemical for which it triggered reporting, providing data across a variety of categories, including activities and uses of the chemical, releases and other waste management (*e.g.*, quantities recycled, treated, combusted) and pollution prevention activities (under section 6607 of the Pollution Prevention Act). These data include on- and off-site data as well as multimedia data (*i.e.*, air, land, and water).	Under section 313, Toxics Release Inventory (TRI), requires reporting of environmental releases of friable asbestos at a concentration level of 0.1%. Friable asbestos is designated as a hazardous substance subject to an Emergency Release Notification at 40 CFR 355.40 with a reportable quantity of 1 lb.
Clean Air Act, 1970 42 U.S.C. 7401 et seq. Asbestos National Emission Standard for Hazardous Air Pollutants (NESHAP), 1973	40 CFR part 61, subpart M	Specifies demolition and renovation work practices involving asbestos in buildings and other facilities (but excluding residences with 4 or fewer dwelling units single family homes). Requires building owner/operator notify appropriate state agency of potential asbestos hazard prior to demolition/renovation. Banned spray-applied surfacing asbestos-containing material for fireproofing/insulating purposes in certain applications. Requires that asbestos-containing waste material from regulated activities be sealed in a leak-tight container while wet, labeled, and disposed of properly in a landfill qualified to receive asbestos waste.
Clean Water Act (CWA), 1972 33 U.S.C. 1251 et seq.		Toxic pollutant subject to effluent limitations per section 1317. Asbestos is a Priority Pollutant.

Statutes/Regulations	Description of Authority/Regulation	Description of Regulation
Safe Drinking Water Act (SDWA), 1974 42 U.S.C. 300f et seq.		Asbestos Maximum Contaminant Level (MCL) 7 million fibers/L (longer than 10 μm).
Resource Conservation and Recovery Act (RCRA), 1976 42 U.S.C. 6901 et seq.	40 CFR 239–282	Asbestos is subject to solid waste regulation when discarded; NOT considered a hazardous waste.
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 1980 42 U.S.C. 9601 et seq.	40 CFR part 302.4 – Designation of Hazardous Substances and Reportable Quantities	13 Superfund sites containing asbestos, 9 of which are on the National Priorities List (NPL) Reportable quantity of friable asbestos is 1 lb.
Other federal statutes/regulations		
Occupational Safety and Health Administration (OSHA): Public Law 91-596 Occupational Safety and Health Act, 1970	Asbestos General Standard 29 CFR 1910 Asbestos Shipyard Standard 29 CFR 1915 Asbestos Construction Standard 29 CFR 1926	Employee permissible exposure limit (PEL) is 0.1 fibers per cubic centimeter (f/cc) as an 8-hour, time- weighted average (TWA) and/or the excursion limit (1.0 f/cc as a 30-minute TWA).
Consumer Product Safety Act Federal Hazardous Substances Act (FHSA) 16 CFR 1500	The CPSA provides the Consumer Product Safety Commission with authority to recall and ban products under certain circumstances. The FHSA requires certain hazardous household products to have warning labels. It also gives CPSC the authority to regulate or ban a hazardous substance, and toys or other articles intended for use by children, under certain circumstances.	Consumer patching compounds and artificial ash and embers containing respirable freeform asbestos are banned as hazardous products under the CPSA. (16 CFR 1304 & 1305) General-use garments containing asbestos are banned as a hazardous substance under the FHSA (16 CFR 1500.17(a))
Federal Food and Cosmetics Act (FFDCA)	Provides the FDA with authority to oversee the safety of food, drugs and cosmetics.	Prohibits the use of asbestos-containing filters in pharmaceutical manufacturing, processing and packing. 21 CFR 211.72
Mine Safety and Health Administration (MSHA)		Surface Mines 30 CFR part 56, subpart D Underground Mines 30 CFR part 57, subpart D

Statutes/Regulations	Description of Authority/Regulation	Description of Regulation
Federal Hazardous Materials Transportation Act (HMTA)	Section 5103 of the Act directs the Secretary of Transportation to: • Designate material (including an explosive, radioactive material, infectious substance, flammable or combustible liquid, solid or gas, toxic, oxidizing or corrosive material, and compressed gas) as hazardous when the Secretary determines that transporting the material in commerce may pose an unreasonable risk to health and safety or property. • Issue regulations for the safe transportation, including security, of hazardous material in intrastate, interstate. and foreign commerce.	Asbestos is listed as a hazardous material with regard to transportation and is subject to regulations prescribing requirements applicable to the shipment and transportation of listed hazardous materials. 49 CFR part 172.101Appendix A.

B.2 State Laws and Regulations

Pursuant to AHERA, states have adopted through state regulation the EPA's Model Accreditation Plan (MAP) for asbestos abatement professionals who do work in schools and public and commercial buildings. Thirty-nine states have EPA-approved MAP programs and 12 states have also applied to and received a waiver from EPA to oversee implementation of the Asbestos-Containing Materials in Schools Rule pursuant to AHERA. States also implement regulations pursuant to the Asbestos NESHAP regulations or further delegate those oversight responsibilities to local municipal governments. While federal regulations set national asbestos safety standards, states have the authority to impose stricter regulations. As an example, many states extend asbestos federal regulations—such as asbestos remediation by trained and accredited professionals, demolition notification, and asbestos disposal—to ensure safety in single-family homes. Thirty states require firms hired to abate asbestos in single family homes to be licensed by the state. Nine states mandate a combination of notifications to the state, asbestos inspections, or proper removal of asbestos in single family homes. Some states have regulations completely independent of the federal regulations. For example, California and Washington regulate products containing asbestos. Both prohibit use of more than 0.1 percent of asbestos in brake pads and require laboratory testing and labeling.

Table_Apx B-2 includes a non-exhaustive list of state regulations that are independent of the federal AHERA and NESHAP requirements that states implement.

Table_Apx B-2. State Laws and Regulations

State Actions	Description of Action
California	Asbestos is listed on California's Candidate Chemical List as a carcinogen. Under California's Propositions 65, businesses are required to warn Californians of the presence and danger of asbestos in products, home, workplace and environment.
California Brake Friction Material Requirements (Effective 2017)	*Division 4.5, California Code of Regulations, Title 22 Chapter 30* Sale of any motor vehicle brake friction materials containing more than 0.1% asbestiform fibers by weight is prohibited. All brake pads for sale in the state of California must be laboratory tested, certified, and labeled by the manufacturer.
Massachusetts	*Massachusetts Toxics Use Reduction Act (TURA)*

State Actions	Description of Action
	Requires companies in Massachusetts to provide annual pollution reports and to evaluate and implement pollution prevention plans. Asbestos is included on the Complete List of TURA Chemicals – March 2016.
Minnesota	*Toxic Free Kids Act* *Minn. Stat. 2010 116.9401 – 116.9407* Asbestos is included on the 2016 Minnesota Chemicals of High Concern List as a known carcinogen.
New Jersey	New Jersey *Right to Know Hazardous Substances* The state of New Jersey identifies hazardous chemicals and products. Asbestos is listed as a known carcinogen and talc containing asbestos is identified on the Right to Know Hazardous Substances list.
Rhode Island	*Rhode Island Air Resources – Air Toxics Air Pollution Control Regulation No. 22* Establishes acceptable ambient air levels for asbestos.
Washington	*Better Brakes Law (Effective 2015) Chapter 70.285 RCW Brake Friction Material* Prohibits the sale of brake pads containing more than 0.1% asbestiform fibers (by weight) in the state of Washington and requires manufacturer certification and package/product labeling. *Requirement to Label Building Materials that Contain Asbestos Chapter 70.310 RCW* Building materials that contain asbestos must be clearly labeled as such by manufacturers, wholesalers, and distributors.

B.3 International Laws and Regulations

Table_Apx B-3. Regulatory Actions by Other Governments, Tribes, and International Agreements

Country/ Organization	Requirements and Restrictions
European Union	The European Union (EU) will prohibit the use of asbestos in the chlor-alkali industry by 2025 (Regulation(EC) No 1907/2006 of the European Parliament and of the Council, 18 December 2006). Otherwise, under EU regulations, the placing on the market and use of chrysotile fibers and products containing these fibers added intentionally are already prohibited pursuant to Directive 1999/77/ E.C. of 26.7.1999. The use of products containing asbestos fibers that were already installed and/or in service before the implementation date of Directive 1999/77/ EC continues to be authorized until such products are disposed of or reach the end of their service life. However, Member States may prohibit the use of such products before they are disposed of or reach the end of their service life (Regulatory Status of chrysotile asbestos in the EU). The emissions and release of asbestos is regulated, and construction materials containing asbestos are classified as hazardous waste. Concerning the safety of workers, EU regulations stipulate that employers shall ensure that no worker is

Country/ Organization	Requirements and Restrictions
	exposed to an airborne concentration of asbestos (including chrysotile) in excess of 0.1 fibers per cm^3 as an 8-hour TWA (Regulatory Status of chrysotile asbestos in the EU).
Canada	Canada banned asbestos in 2018. *Prohibition of Asbestos and Products Containing Asbestos Regulations: SOR/2018-196* (Canada Gazette, Part II, Volume 152, Number 21).
UNEP Rotterdam Convention	The Conference of Parties is considering a recommendation from the Chemical Review Committee to list chrysotile asbestos in Annex III to the Rotterdam Convention. Annex III chemicals require prior informed consent for importation.
UNEP Basel Convention	Under the Basel Convention, Asbestos (dust and fibres) is designated a hazardous waste. Listed codes Y36 (Annex 1) and A2050 (Annex VIII). Among its provisions, the Convention restricts the import and export of hazardous waste and requires parties to the convention to appropriate measures to ensure the environmentally sound management of hazardous waste.
World Health Organization (WHO)	The World Health Assembly resolution 60.26 requests WHO to carry out a global campaign for the elimination of asbestos-related diseases "…bearing in mind a differentiated approach to regulating its various forms - in line with the relevant international legal instruments and the latest evidence for effective interventions…."
Algeria, Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Chile, Croatia, Cyprus, Czech Republic, Denmark, Egypt, Estonia, Finland, France, Germany, Greece, Honduras, Hungary, Iceland, Ireland, Israel, Italy, Japan, Kuwait, Latvia, Lithuania, Luxembourg, Mozambique, Netherlands, New Zealand, North Macedonia, Norway, Oman, Poland, Portugal, Romania, Saudi Arabia, Serbia, Slovakia, Slovenia, South Afrika, South Korea, Spain, Sweden, Taiwan, Turkey, United Kingdom, Uruguay	National bans of asbestos are reported in these countries (Lin et al., 2019; IARC, 2012a).

B.4 Assessment History

Table_Apx B-4. Assessment History of Asbestos

Authoring Organization	Publication
EPA assessments	
EPA, Integrated Risk Information System (IRIS)	IRIS Assessment on Asbestos (U.S. EPA, 1986a)
EPA, IRIS	IRIS Assessment on Libby Amphibole Asbestos (U.S. EPA, 2014c)
EPA, Region 8	Site-Wide Baseline Ecological Risk Assessment, Libby Asbestos Superfund Site, Libby Montana (U.S. EPA, 2014b)
EPA, Drinking Water Criteria Document	Drinking Water Criteria Document for Asbestos (U.S. EPA, 1985)
EPA, Ambient Water Quality Criteria for Asbestos	Asbestos: Ambient Water Quality Criteria (U.S. EPA, 1980)
EPA, Final Rule (40 CFR part 763)	Asbestos; Manufacture, Importation, Processing and Distribution in Commerce Prohibitions (1989)
EPA, Asbestos Modeling Study	Final Report; Asbestos Modeling Study (Versar, 1988)
EPA, Asbestos Exposure Assessment	Revised Report to Support ABPO rule (ICFI, 1988)
EPA, Nonoccupational Exposure Report	Revised Draft Report, Nonoccupational Asbestos Exposure (Versar, 1987)
EPA, Airborne Asbestos Health Assessment Update	Support document for NESHAP review (U.S. EPA, 1986a)
Other U.S.-based organizations	
National Institute for Occupational Safety and Health (NIOSH)	Asbestos Fibers and Other Elongate Mineral Particles: State of the Science and Roadmap for Research (NIOSH, 2011a)
Agency for Toxic Substances and Disease Registry (ATSDR)	Toxicological Profile for Asbestos (ATSDR, 2001)
National Toxicology Program (NTP)	Report on Carcinogens, Fourteenth Edition (NIH, 2016)
CA Office of Environmental Health Hazard Assessment (OEHHA), Pesticide and Environmental Toxicology Section	Public Health Goal for Asbestos in Drinking Water (CalEPA, 2003)
International	
International Agency for Research on Cancer (IARC)	IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Arsenic, Metals, Fibres, and Dusts. Asbestos (Chrysotile, Amosite, Crocidolite, Tremolite, Actinolite, and Anthophyllite) (IARC, 2012c)
World Health Organization (WHO)	World Health Organization (WHO) Chrysotile Asbestos (WHO, 2014)
Environment and Climate Change Canada	Prohibition of Asbestos and Products Containing Asbestos Regulations (EC/HC, 2019)

Appendix C LIST OF SUPPLEMENTAL DOCUMENTS

Appendix C incudes a list and citations for all supplemental documents included in the Part 2 of the Risk Evaluation for Asbestos. See Docket EPA-HQ-OPPT-2021-0254 for all publicly released files associated with this risk evaluation package.

Associated **Systematic Review Data Quality Evaluation and Data Extraction** Documents – Provide additional detail and information on individual study evaluations and data extractions including criteria and data quality results.

Systematic Review Protocol (U.S. EPA, 2023f) – In lieu of an update to the *Draft Systematic Review Protocol Supporting TSCA Risk Evaluations for Chemical Substances*, also referred to as the "2021 Draft Systematic Review Protocol" (U.S. EPA, 2021a), this systematic review protocol for the Draft Risk Evaluation for Asbestos Part 2 describes some clarifications and different approaches that were implemented than those described in the 2021 Draft Systematic Review Protocol in response to (1) SACC comments, (2) public comments, or (3) to reflect chemical-specific risk evaluation needs. This supplemental file may also be referred to as the "Asbestos Part 2 Systematic Review Protocol." *[Supplemental File 2]*

Systematic Review Supplemental File: Data Quality Evaluation and Data Extraction Information for Physical and Chemical Properties (U.S. EPA, 2024e) – Provides a compilation of tables for the data extraction and data quality evaluation information for Asbestos Part 2. Each table shows the data point, set, or information element that was extracted and evaluated from a data source that has information relevant for the evaluation of physical and chemical properties. This supplemental file may also be referred to as the "Asbestos Part 2 Data Quality Evaluation and Data Extraction Information for Physical and Chemical Properties." *[Supplemental File 3]*

Systematic Review Supplemental File: Data Quality Evaluation and Data Extraction Information for Environmental Fate and Transport (U.S. EPA, 2024c) – Provides a compilation of tables for the data extraction and data quality evaluation information for Asbestos Part 2. Each table shows the data point, set, or information element that was extracted and evaluated from a data source that has information relevant for the evaluation for Environmental Fate and Transport. This supplemental file may also be referred to as the "Asbestos Part 2 Data Quality Evaluation and Data Extraction Information for Environmental Fate and Transport." *[Supplemental File 4]*

Systematic Review Supplemental File: Data Quality Evaluation and Data Extraction Information for Environmental Release and Occupational Exposure (U.S. EPA, 2024d) – Provides a compilation of tables for the data extraction and data quality evaluation information for Asbestos Part 2. Each table shows the data point, set, or information element that was extracted and evaluated from a data source that has information relevant for the evaluation of environmental release and occupational exposure. This supplemental file may also be referred to as the "Asbestos Part 2 Data Quality Evaluation and Data Extraction Information for Environmental Release and Occupational Exposure." *[Supplemental File 5]*

Systematic Review Supplemental File: Data Quality Evaluation Information for General Population, Consumer, and Environmental Exposure (U.S. EPA, 2024g) – Provides a compilation of tables for the data quality evaluation information for Asbestos Part 2. Each table shows the data point, set, or information element that was evaluated from a data source that has information relevant for the evaluation of general population, consumer, and environmental exposure. This supplemental file may also be referred to as the "Asbestos Part 2 Data Quality Evaluation Information for General Population, Consumer, and Environmental Exposure." *[Supplemental File 6]*

Systematic Review Supplemental File: Data Extraction Information for General Population, Consumer, and Environmental Exposure (U.S. EPA, 2024b) – Provides a compilation of tables for the data extraction for Asbestos Part 2. Each table shows the data point, set, or information element that was extracted from a data source that has information relevant for the evaluation of general population, consumer, and environmental exposure. This supplemental file may also be referred to as the "Asbestos Part 2 Data Extraction Information for General Population, Consumer, and Environmental Exposure." *[Supplemental File 7]*

Systematic Review Supplemental File: Data Quality Evaluation Information for Human Health Hazard Epidemiology (U.S. EPA, 2024h) – Provides a compilation of tables for the data quality evaluation information for Asbestos Part 2. Each table shows the data point, set, or information element that was evaluated from a data source that has information relevant for the evaluation of epidemiological information. This supplemental file may also be referred to as the "Asbestos Part 2 Data Quality Evaluation Information for Human Health Hazard Epidemiology." *[Supplemental File 8]*

Systematic Review Supplemental File: Data Quality Evaluation Information for Environmental Hazard (U.S. EPA, 2024f) – Provides a compilation of tables for the data quality evaluation information for Asbestos Part 2. Each table shows the data point, set, or information element that was evaluated from a data source that has information relevant for the evaluation of environmental hazard toxicity information. This supplemental file may also be referred to as the "Asbestos Part 2 Data Quality Evaluation Information for Environmental Hazard." *[Supplemental File 9]*

Systematic Review Supplemental File: Data Extraction Information for Environmental Hazard and Human Health Hazard Animal Toxicology and Epidemiology (U.S. EPA, 2024a) – Provides a compilation of tables for the data extraction for Asbestos Part 2. Each table shows the data point, set, or information element that was extracted from a data source that has information relevant for the evaluation of environmental hazard and human health hazard animal toxicology and epidemiology information. This supplemental file may also be referred to as the "Asbestos Part 2 Data Extraction Information for Environmental Hazard and Human Health Hazard Animal Toxicology and Epidemiology." *[Supplemental File 10]*

Associated **Supplemental Information Documents** – Provides additional details and information on exposure, hazard, and risk assessments.

Risk Calculator for Take Home – November 2024. Spreadsheet provides details and information on the take-home exposure assessment and analyses including modeling inputs and outputs. *[Supplemental File 11]*

Ambient Air Specific Facilities Released Concentrations – November 2024. Spreadsheet provides details and information on the approaches to combined AERMOD TRI and NEI ambient air concentrations for specific facilities *[Supplemental File 12]*.

Ambient Air Generic Facilities and Depo Concentrations – November 2024. Spreadsheet provides details and information on the approaches to combined AERMOD TRI and NEI ambient air concentrations for generic facilities *[Supplemental File 13]*.

Risk for Calculator Consumer – November 2024. [Supplemental File 14]

Risk for Calculator General Population – November 2024. [Supplemental File 15]

Aggregate Analysis – November 2024. [Supplemental File 16]

Environmental Release and Occupational Exposure Data Tables – November 2024. [Supplemental File 17]

Risk Calculator for Occupational Exposure – November 2024. [Supplemental File 18]

Asbestos Part 2. Memo - Asbestos Part 2 Gen Pop Modeling Files [Supplemental File 19]

Appendix D UPDATES TO THE CONDITIONS OF USE TABLE

After the final scope (U.S. EPA, 2021b), EPA updated Table 2-2 "Categories and Subcategories of Conditions of Use Included in the Scope of Part 2 of the Risk Evaluation" to better reflect the Agency's understanding of the conditions of use of asbestos following the scoping process based on EPA continuing research, public comment, and stakeholder engagement. Table_Apx D-1 summarizes the changes to the COUs based on the new information the Agency has received since the publication of the final scope and issuance of the Part 2 draft risk evaluation.

Table_Apx D-1. Additions and Name Changes to Categories and Subcategories of Conditions of Use between Final Scope and Risk Evaluation

Life Cycle Stage and Category	Original Subcategory in the Final Scope Document	Occurred Change	Revised Subcategory in the 2024 Draft Risk Evaluation
Industrial/Commercial Uses; Chemical Substances in Packaging, Paper, Plastic, Toys, Hobby Products	"*Toys intended for children's use (and child dedicated articles), including fabrics, textiles, and apparel; or plastic articles (hard)*"	Subcategory removed. After additional Agency review of this COU it was determined that the "mineral kits" that were being considered for this "industrial/commercial" use were strictly consumer grade and therefore there was no practical use in either industrial or commercial settings.	N/A
Industrial/Commercial Uses; Chemical Substances in Automotive, Fuel, Agriculture, Outdoor Use Products	N/A	Subcategory added	"*Lawn and garden care products*"
Industrial/Commercial Uses; Mining of Non-Asbestos Commodities	N/A	Subcategory added	"*Mining of non-asbestos commodities*"
Industrial/Commercial Uses: Laboratory Chemicals	N/A	Subcategory added	"*Laboratory chemicals*"

As indicated in Table_Apx D-1, the revisions/edits are based on additional research on the conditions of use, additional comments from stakeholders, and overall review of the use information. EPA expects that the edits will provide additional clarity to the conditions of use evaluated under TSCA. The Agency believes that the conditions of use presented in this final Part 2 of the Risk Evaluation for Asbestos are best reflective of the industrial, commercial, and consumer uses of asbestos and legacy asbestos.

Appendix E CONDITIONS OF USE DESCRIPTIONS

The following descriptions are intended to include examples of uses, so as not to exclude other activities that may also be included in the COUs of the chemical substance. EPA notes that there has been no reporting for asbestos in the 2016 or 2020 CDR reporting cycles. Examples of articles, products, or activities are included in the following descriptions to help describe the COU but are not exhaustive. EPA uses the terms "articles" and "products" or product mixtures in the following descriptions and is generally referring to articles and products as defined by 40 CFR Part 751. There may be instances where the terms are used interchangeably by a company or commenters, or by EPA in reference to a code from CDR reports that are referenced (*e.g.*, "plastic products manufacturing," or "fabric, textile, and leather products"). The Agency will clarify as needed when these references are included throughout the COU descriptions below.

E.1 Industrial/Commercial Uses – Construction and Building Materials Covering Large Surface Areas, Including Paper Articles; Metal Articles; Stone, Plaster, Cement, Glass, and Ceramic Articles

This COU is referring to the industrial and commercial use of various construction and building materials containing asbestos. EPA expects that the majority of this use would be commercial in nature; however, these materials could also be expected in industrial settings as well.

Some examples of articles that the Agency would expect to see associated with this COU include siding, corrugated paper (for use in pipe wrap insulation and appliances), commercial papers, millboard, rollboard, specialty paper, roofing felt, cement, shingles, corrugated cement, ceiling tiles, loose-fill insulation (asbestos-containing vermiculite), asbestos cement pipes and ducts (water, sewer and air), Galbestos (wallboard and joint compound), wall protectors, air duct insulation, soldering and welding blocks and sheets, stove gaskets and rings, asbestos-coated steel pipelines, flooring felt, and vinyl floor tiles.

E.2 Industrial/Commercial Uses – Machinery, Mechanical Appliances, Electrical/Electronic Articles

This COU is referring to the industrial and commercial use of various mechanical appliances and electrical/electronic articles containing asbestos. EPA expects that the majority of this use would be commercial in nature.

Some examples of articles that the Agency would expect to see associated with this COU include corrugated commercial and specialty papers; reinforced plastics for appliances such as ovens, dishwashers, boilers, and toasters. In addition, miscellaneous electro-mechanical parts for appliances including deep fryers, frying pans and grills, mixers, popcorn poppers, slow cookers, washers and dryers, refrigerators, curling irons, electric blankets, portable heaters, safes, safety boxes, filing cabinets, and kilns and incinerators are examples of this COU.

E.3 Industrial/Commercial Uses – Other Machinery, Mechanical Appliances, Electrical/Electronic Articles

This COU is referring to the industrial and commercial use of mechanical appliances and electrical/electronic articles containing asbestos, that would not be covered by another COU. EPA expects that the majority of these uses would be industrial in nature.

Some examples of articles that the Agency would expect to see associated with this COU include braking and gear-changing (clutch) components in a variety of industrial and commercial machinery including combines, mining equipment, construction equipment such as cranes and hoists, heavy equipment used in various manufacturing industries (*e.g.*, machine tools and presses), military equipment, marine engine transmissions, and elevators; packings/seals in rotary, centrifugal, and reciprocating pumps, valves, expansion joints, soot blowers, and other types of mechanical equipment; electro-mechanical parts including commutators, switches, casings, and thermoplugs; arc chutes; electrical panels; transformers (high-grade electrical paper).

E.4 Industrial/Commercial Uses – Fillers and Putties

This COU is referring to the industrial and commercial use of various older fillers, putties, caulks, and building material applications containing asbestos. EPA expects that the majority of these uses would be commercial in nature; however, these materials could also be expected in industrial settings as well.

Some examples of products and/or articles that the Agency would expect to see associated with this COU include adhesives and sealants, extruded sealant tape, rubber sealants, vinyl sealants, and epoxy adhesives.

E.5 Industrial/Commercial Uses – Solvent-Based/Water-Based Paint

This COU is referring to the industrial and commercial use of various older solvent- and water-based textured paints containing asbestos. EPA expects that the majority of these uses would be commercial in nature; however, these materials could also be expected in industrial settings as well.

Some examples of products that the Agency would expect to see associated with this COU include coatings, corrugated coatings, textured paints, and vehicle undercoating.

E.6 Industrial/Commercial Uses – Electrical Batteries and Accumulators

This COU is referring to the industrial and commercial use of various electrical batteries and electricity storage devices (*i.e.*, accumulators) containing asbestos. EPA expects that the majority of this use would be industrial in nature.

An example of articles that the Agency would expect to see associated with this COU include insulators for terminals.

E.7 Industrial/Commercial Uses – Construction and Building Materials Covering Large Surface Areas, Including Fabrics, Textiles, and Apparel

This COU is referring to the industrial and commercial use of various industrial/commercial-grade construction and building materials containing asbestos. EPA expects that the majority of this use would be commercial in nature.

Some examples of articles that the Agency would expect to see associated with this COU include asbestos textiles including yarn, thread, wick, cord, rope, tubing (sleeving), cloth, and tape.

E.8 Industrial/Commercial Uses – Furniture and Furnishings Including Stone, Plaster, Cement, Glass, and Ceramic Articles; Metal Articles; or Rubber Articles

This COU is referring to the industrial and commercial use of various articles containing asbestos that would be found in an industrial/commercial setting. EPA expects that the majority of this use would be commercial in nature.

Some examples of articles that the Agency would expect to see associated with this COU include iron rests, burner mats, barbecue mitts, and potholders.

E.9 Industrial/Commercial Use – Packaging (Excluding Food Packaging), Including Rubber Articles; Plastic Articles (Hard); Plastic Articles (Soft)

This COU is referring to the industrial and commercial use of asbestos in packaging products that are not associated with food packaging. EPA expects that the majority of this use would be commercial in nature.

An example of articles that the Agency would expect to see associated with this COU include asbestos reinforced plastics.

E.10 Industrial/Commercial Use – Lawn and Garden Care Products

This COU is referring to the industrial and commercial use of asbestos present in lawn and garden care products. This COU includes the use of lawn and garden products containing asbestos in a commercial setting or during application of asbestos-containing lawn and garden care products in commercial settings or contact with these products by commercial workers when in a commercial environment. EPA expects that the majority of this use would be commercial in nature.

An example of products that the Agency would expect to see associated with this COU include asbestos-containing vermiculite soil treatment.

E.11 Mining of Non-asbestos Commodities

This COU is referring to the presence of asbestos in other mined materials/non-asbestos commodities. EPA expects that the majority of this use would be in industrial settings and was listed as such in the COU table.

Some examples of settings that the Agency would expect to see associated with this COU include metal and nonmetal mines, surface coal mines, and surface areas of underground coal mines.

E.12 Industrial/Commercial Use – Laboratory Chemicals

This COU is referring to the presence of asbestos in laboratory chemicals in industrial and commercial settings. EPA expects that the majority of this use would be commercial in nature; however, there could be some industrial use in certain laboratory settings.

An example of products that the Agency would expect to see associated with this COU include vermiculite packaging products in laboratories. This could be material used in a laboratory to absorb or otherwise render laboratory material in a controlled state for disposal.

E.13 Industrial/Commercial Use – Other (Artifacts)

This COU is referring to the use of asbestos in vintage artifacts containing asbestos in industrial/commercial collections for viewing in commercial settings. EPA expects that the majority of this use would be commercial in nature.

An example of articles that the Agency would expect to see associated with this COU include artifacts in museums and private collections.

E.14 Industrial/Commercial Use – Other (Aerospace Applications)

This COU is referring to the industrial and commercial use of asbestos in specific aerospace application. EPA expects that the majority of this use would be industrial in nature.

Some examples of articles that the Agency would expect to see associated with this COU include RS-25 engine thermal isolator blocks, high-performance plastics for aerospace including heat shields, rocket motor casings, and rocket motor liners.

E.15 Consumer Use – Construction and Building Materials Covering Large Surface Areas, Including Paper Articles; Metal Articles; Stone, Plaster, Cement, Glass, and Ceramic Articles

This COU is referring to the consumer use of asbestos in various residential-grade construction and building materials.

Some examples of products found in older buildings that the Agency would expect to see associated with this COU include asbestos-containing siding, corrugated paper (for use in pipe wrap insulation and appliances), commercial papers, millboard, rollboard, specialty paper, roofing felt, cement, shingles, corrugated cement, ceiling tiles, loose-fill insulation (asbestos-containing vermiculite), asbestos cement pipes and ducts (water, sewer and air), Galbestos, fireplace embers, stove gaskets and rings, flooring felt, and vinyl floor tiles.

E.16 Consumer Use – Machinery, Mechanical Appliances, Electrical/Electronic Articles

This COU is referring to the consumer use of various consumer-grade machinery, appliances, and electrical/electronic articles containing asbestos.

Some examples of products that the Agency would expect to see associated with this COU include corrugated commercial and specialty papers, reinforced plastics for older appliances such as ovens, dishwashers, boilers and toasters, miscellaneous electro-mechanical parts for appliances including deep fryers, frying pans and grills, mixers, popcorn poppers, slow cookers, washers and dryers, refrigerators, curling irons, electric blankets, portable heaters, safes, safety boxes, filing cabinets, and kilns and incinerators.

E.17 Consumer Use – Fillers and Putties

This COU is referring to the consumer use of older filler, putties, adhesives, sealants, and tapes containing asbestos.

Some examples of products that the Agency would expect to see associated with this COU include adhesives and sealants as well as extruded sealant tape.

E.18 Consumer Use – Solvent-Based/Water-Based Paint

This COU is referring to the consumer use of older solvent-based and water-based coatings containing asbestos.

Some examples of products that the Agency would expect to see associated with this COU include coatings, textured paints, and vehicle undercoating.

E.19 Consumer Use – Construction and Building Materials Covering Large Surface Areas, Including Fabrics, Textiles, and Apparel

This COU is referring to the consumer use of asbestos in various asbestos-containing textiles.

Some examples of products that the Agency would expect to see associated with this COU include asbestos textiles including yarn, thread, wick, cord, rope, tubing (sleeving), cloth, and tape.

E.20 Consumer Use – Furniture and Furnishings, Including Stone, Plaster, Cement, Glass, and Ceramic Articles; Metal Articles; or Rubber Articles

This COU is referring to the consumer use of various home products containing asbestos.

Some examples of products that the Agency would expect to see associated with this COU include older iron rests, burner mats, barbecue mitts, potholders, and similar items.

E.21 Consumer Use – Packaging (Excluding Food Packaging), Including Rubber Articles; Plastic Articles (Hard); Plastic Articles (Soft)

This COU is referring to the consumer use of asbestos in packaging products that are not associated with food packaging.

An example of products that the Agency would expect to see associated with this COU include asbestos reinforced plastics.

E.22 Consumer Use – Toys Intended for Children's Use (and Child Dedicated Articles), Including Fabrics, Textiles, and Apparel; or Plastic Articles (Hard)

This COU is referring to the consumer use of toys containing asbestos, intended for childrens use.

This COU includes the use of mineral kits containing asbestos in a consumer use setting.

E.23 Consumer Use – Lawn and Garden Care Products

This COU is referring to the consumer use of asbestos present in lawn and garden care products. This COU includes the use of lawn and garden products containing asbestos in a consumer DIY setting or during contact with asbestos-containing lawn and garden care products present on their properties.

An example of products that the Agency would expect to see associated with this COU include asbestos-containing vermiculite soil treatment.

E.24 Consumer Use – Other (Artifacts)

This COU is referring to the consumer use of asbestos in vintage artifacts containing asbestos in private, consumer-level collections for personal use.

Some examples of products that the Agency would expect to see associated with this COU include vintage artifacts in private collections, vintage cars, articles, and curios.

E.25 Disposal

Each of the COUs of asbestos may generate waste streams of the chemical. For purposes of the risk evaluation, this COU refers to the asbestos in a waste stream that is collected and transported to third-party sites for disposal or treatment. EPA expects that these waste streams containing asbestos are transported in a way that does not result in contact with the outdoor air (*i.e.*, contained) and disposed of in a facility licensed for the purposes of disposing asbestos and asbestos contaminated waste.

Appendix F PHYSICAL AND CHEMICAL PROPERTIES AND FATE AND TRANSPORT DETAILS

F.1 Physical and Chemical Properties Evidence Integration

EPA gathered and evaluated physical and chemical property data and information according to the process described in the *Draft Systematic Review Protocol Supporting TSCA Risk Evaluations for Chemical Substances* (U.S. EPA, 2021a). During this evaluation of Asbestos, EPA considered both measured and estimated property data/information set forth in Table 2-1. Most values were taken from the *Final Scope of the Risk Evaluation for Asbestos Part 2: Supplemental Evaluation Including Legacy Uses and Associated Disposals of Asbestos* (U.S. EPA, 2022b) except for the surface area (anthophyllite and tremolite), individual fiber diameter (anthophyllite), particle dimensions (crocidolite, amosite, actinolite, and LAA), density (anthophyllite, tremolite, and actinolite), refractive index (actinolite), tensile strength (crocidolite, amosite and tremolite), and zeta potential (anthophyllite and tremolite).

Essential Composition

EPA extracted and evaluated twelve sources containing asbestos fibers essential composition. Six of the sources were identified and evaluated as high quality data sources and the remaining six as medium quality data sources. EPA selected four of the high quality essential composition data sources for the risk evaluation of asbestos part 2. The essential composition provides a description of the chemical compounds and/or elements for the identification of different asbestos fiber types. As described in Table 2-1, the general essential composition of asbestos fibers consists of hydrated silicates with a layer of brucite, sodium (Na), iron (Fe), magnesium (Mg), and/or calcium (Ca) (NLM, 2021; Larrañaga et al., 2016; U.S. EPA, 2014c; Badollet, 1951).

Color and Luster

EPA evaluated and extracted twenty sources containing information on the color of asbestos fibers and thirteen data sources containing asbestos fibers luster information. The luster provides a general description of asbestos fibers' overall surface sheen or brightness. From the color data sources, sixteen were extracted and evaluated as high quality sources and four as medium quality sources. All the luster data sources were evaluated and extracted as high quality sources. EPA selected four high quality sources describing the color and luster of chrysotile, crocidolite, amosite, anthophyllite, tremolite, and actinolite, as illustrated in Table 2-1 (NLM, 2021; Zhong et al., 2019; Larrañaga et al., 2016; Badollet, 1951). No color and luster data were identified in the systematic review process for Libby Amphibole Asbestos.

Surface Area

EPA evaluated and extracted fourteen sources containing surface area information of asbestos fibers. Nine of the data sources were determined to be of high quality and five were of medium quality. EPA selected two high quality sources and one medium quality data source to represent the range of the identified surface areas at ambient temperature for chrysotile, crocidolite, amosite, anthophyllite, tremolite, and Libby Amphibole as illustrated in Table 2-1 (Pollastri et al., 2014; U.S. EPA, 2014c; Addison et al., 1966). No surface area data were identified in the systematic review process for actinolite.

Fiber Diameter

EPA evaluated and extracted fifteen sources containing asbestos fiber diameters. From these data sources, 11 were high quality and 4 were medium quality. The fiber diameter describes the cross-sectional distance across the individual asbestos fiber types. Gaze (1965) and Le Bouffant (1980) reported amosite fiber diameters ranging from greater or equal to 0.1 to 1.2 µm. Le Bouffant (1980) also reported differing anthophyllite fiber diameters (≥0.1 to 1.4 µm). Gaze (1965), Le Bouffant (1980), and NLM (2021) reported chrysotile fiber diameters ranging from greater or equal to 0.1 to 0.8 µm. Gaze (1965), Le Bouffant (1980), and Hwang (1983) reported crocidolite fiber diameters ranging from 0.08 to 1.0 microns. U.S. EPA (2014c) reported Libby amphibole fiber diameter of 0.61 µm. For the purpose of this risk evaluation, EPA selected two high quality sources and one medium quality data source describing the fiber diameters of chrysotile, crocidolite, amosite, anthophyllite, tremolite, and Libby Amphibole, as illustrated in Table 2-1 (NLM, 2021; U.S. EPA, 2014c; Hwang, 1983; Le Bouffant, 1980). No fiber diameter data were identified in the systematic review process for actinolite.

Fiber Dimensions

EPA evaluated and extracted 24 sources containing data on asbestos fiber dimensions. From these data sources, 19 were evaluated as high and medium quality. The fiber dimensions describe the typical length and diameter of the individual asbestos fiber types. EPA selected the fiber dimension information from five high quality sources to represent the range of the identified fiber dimensions. These sources reported fiber lengths ranging 0.8 to 36 µm and widths from 0.02 to 12 µm for chrysotile, crocidolite, amosite, actinolite, and Libby amphibole, as described in Table 2-1 (Lowers and Bern, 2009; Snyder et al., 1987; Thorne et al., 1985; Virta et al., 1983; Siegrist and Wylie, 1980). No fiber dimension data were identified in the systematic review process for anthophyllite and tremolite.

Hardness

EPA evaluated and extracted 12 sources containing hardness data for asbestos fibers. From these data sources, six were evaluated as high quality and six as medium quality. The hardness describes the asbestos fibers' resistance to deformation when an external force is applied. EPA four high quality sources to represent the range of the identified hardness data for asbestos fibers. These sources reported fiber hardness ranging from 5.5 to 6 Mohs for actinolite, amosite, and tremolite, and 2.5 to 4 Mohs for chrysotile and crocidolite, as summarized in Table 2-1 (NLM, 2021; Larrañaga et al., 2016; Virta, 2004; Badollet, 1951). No fiber hardness data were identified in the systematic review process for Libby amphiboles.

Density

EPA evaluated and extracted twelve sources containing asbestos fiber density. From these data sources, 13 were evaluated as high quality and 13 as medium quality. EPA selected four high quality sources to represent the range of the identified asbestos fiber density data. These sources reported fiber densities ranging 2.19 to 3.3 for chrysotile, crocidolite, amosite, anthophyllite, tremolite, and actinolite as described in Table 2-1 (Elsevier, 2021a, b, c; Virta, 2004). No density data were identified in the systematic review process for Libby amphiboles.

Refractive Index

EPA evaluated and extracted 12 sources containing asbestos refractive index information. From these data sources, nine were evaluated as high quality and three as medium quality. Refractive index refers to the ability of a substance to bend light and can be used to identify asbestos fiber types. EPA selected two high quality sources to represent the range of the identified asbestos refractive index data. These sources reported refractive index ranging from 1.53 to 1.701 for chrysotile, crocidolite, amosite, anthophyllite, tremolite, and actinolite as described in Table 2-1 (NLM, 2021; Lott, 1989). No refractive index data were identified in the systematic review process for Libby amphiboles.

Flexibility and Spinnability

The flexibility and spinnability describes the ability of asbestos fibers to be bent, stretched, spun, and twisted without being deformed. EPA evaluated and extracted two high quality data sources containing asbestos flexibility and spinnability data. These sources reported good to high flexibility for chrysotile, crocidolite, and amosite, but poor flexibility for anthophyllite, tremolite, and actinolite. Likewise, fair to good spinnability was reported for chrysotile, crocidolite, and amosite, with poor spinnability for anthophyllite, tremolite, and actinolite, as described in Table 2-1 (NLM, 2021; Badollet, 1951). No flexibility and spinnability data were identified in the systematic review process for Libby amphiboles.

Zeta Potential

The zeta potential is a physical property that describes the colloidal stability of suspended fiber types based on their net surface charge. EPA evaluated and extracted eight data sources containing asbestos zeta potential data. From these data sources, six were evaluated as high quality and two as medium quality. These sources reported zeta potentials ranging from 13.6 to 54 mV for chrysotile, anthophyllite, and tremolite and −20 to −40 mV for crocidolite and amosite as described in Table 2-1 (Virta, 2004; Schiller and Payne, 1980). No zeta potential data were identified in the systematic review process for actinolite and Libby amphiboles.

Decomposition Temperature

The decomposition temperature describes the temperature at which asbestos fiber types are decomposed and recrystallized into non-asbestiform fiber types. EPA evaluated and extracted 23 data sources containing asbestos decomposition temperature data. From these data sources, 19 were evaluated as high quality and four as medium quality. EPA selected three sources to represent the range of the identified asbestos decomposition temperatures. Identified decomposition temperatures ranged from 400 to 900 °C for chrysotile, crocidolite, and amosite and 950 to 1,296 °C for anthophyllite, tremolite, and actinolite as described in Table 2-1 (Elsevier, 2021a, b; Virta, 2004). No decomposition temperature data were identified in the systematic review process for Libby amphiboles.

F.2 Fate and Transport

F.2.1 Approach and Methodology

EPA conducted a Tier I assessment to identify the environmental compartments (*i.e.*, water, sediment, biosolids, soil, groundwater, air) of major and minor relevance to the fate and transport of asbestos. EPA then conducted a Tier II assessment to identify the fate pathways and media most likely to cause exposure from environmental releases. Media-specific fate analyses were performed as described in Sections F.2.2, F.2.3, and F.2.4. Fate and transport approaches typically used for discrete organic chemicals, such as the use of EPI Suite™ models or the LRTP screening tool were not used, as they are not applicable for asbestos fibers. However, EPA used AERMOD to estimate air deposition of asbestos fibers as described in Section 3.3.4.

F.2.2 Air and Atmosphere

EPA obtained limited information about the air transport of asbestos fibers during the systematic review process. Asbestos is a category of persistent mineral fibers that can be found in soils, sediments, and lofted in air and windblow dust (ATSDR, 2001). Small spherical fibers (<1 μm) can remain suspended in air and water for extended periods of time and be transported over long distances (ATSDR, 2001).

EPA calculated the potential sphericity of asbestos particles and used AERMOD to estimate air deposition, as described in Section 3.3.4. Because air suspended asbestos fibers will eventually settle to soils, water bodies, and sediments, movement therein may occur via erosion, runoff, or mechanical resuspension (*e.g.*, wind-blown dust, vehicle traffic) (ATSDR, 2001).

F.2.3 Aquatic Environments

F.2.3.1 Surface Water

Asbestos fibers are not expected to undergo abiotic degradation processes such as hydrolysis and photolysis in aquatic environments under environmentally relevant conditions. Asbestos forms stable suspensions in water; under acidic conditions (pH = 1–3) surface minerals may leach into solution (Clark and Holt, 1961), with reported rates of dissolution being dependent on the mineral surface area and temperature conditions. Choi (1972) reported the removal of the brucite layer which resulted in release of Mg^{2+} leaving a silica skeleton. Higher release of Mg^{2+} was reported in smaller asbestos particles. Under neutral pH conditions, the underlying silicate structure remains unchanged (Schreier and Lavkulich, 2015; Favero-Longo et al., 2005; Gronow, 1987; Bales and Morgan, 1985; Choi and Smith, 1972). Asbestos fibers have been reported to absorb natural organic matter by replacing positively charged $Mg\text{-}OH^{2+}$ sites and acquiring a negative surface charge, which might increase the transport and resuspension of asbestos fibers from aquatic soils and sediments (Bales and Morgan, 1985).

The reported half-life in water is greater than 200 days (NICNAS, 1999). In surface water, the concentration of suspended asbestos fibers tends to naturally decrease with greater than 99 percent observed in water reservoirs with hydraulic detention times greater than 1 year (Bales et al., 1984). Storm events may increase the deposition and resuspension of asbestos fibers (Schreier and Lavkulich, 2015).

F.2.3.2 Sediments

Asbestos can be transported to sediment from overlying surface water by settling of suspended asbestos fibers. In surface water suspended asbestos fibers tend to naturally decrease by settling into aquatic sediments. Greater than 99 percent reduction of fiber concentrations have been documented for water bodies with hydraulic detention times greater than 1 year (Bales et al., 1984). In general, asbestos fibers in surface water will eventually settle into sediments, but environmental stress such as storm events, may increase the resuspension of asbestos fibers (Schreier and Lavkulich, 2015). Other sources of asbestos fibers in soils and sediments are biosolids from water treatment systems. The use of coagulation and flocculation treatment processes have been reported to remove 80 to 99 percent of asbestos fibers in sludge, with higher removals during the use of filtration treatment units (Kebler et al., 1989; Lauer and Convery, 1988; Bales et al., 1984; McGuire et al., 1983; Lawrence and Zimmermann, 1977; Schmitt et al., 1977; Lawrence and Zimmermann, 1976). Overall, asbestos in water will eventually settle into sediments and biosolids from wastewater treatment plants.

F.2.4 Terrestrial Environments

Asbestos is released to terrestrial environments via land application of biosolids, disposal of solid waste to landfills, windblown resuspension, and atmospheric deposition.

F.2.4.1 Soil

In general, asbestos fibers will eventually settle from surface water and the atmosphere to sediments and soil, and movement therein may occur via erosion, runoff, or mechanical resuspension (wind-blown dust, vehicle traffic, etc.) (ATSDR, 2001). Asbestos release from soil to air will most likely occur under high wind velocities and lower water content conditions (Maulida et al., 2022). Weathering of asbestos fibers might result in leaching of Mg and trace metals into the lower soil horizons (Schreier et al., 1987). Leaching of asbestos fibers into ground water is unlikely, however the presence of natural organic matter could increase fiber mobility (Mohanty et al., 2021).

F.2.4.2 Groundwater

Sources of asbestos in ground water include the occurrence and weathering of asbestos minerals, mechanical disturbance of contaminated sites, erosion, and runoff. Leachate from landfill sites is unlikely but has been documented in the presence of natural organic matter (Mohanty et al., 2021; Schreier et al., 1987).

F.2.4.3 Landfills

As stated in the *Final Scope of the Risk Evaluation for Asbestos Part 2: Supplemental Evaluation Including Legacy Uses and Associated Disposals of Asbestos* (U.S. EPA, 2022b), most of the total on-site and off-site disposal or other releases of friable asbestos are released to land (by means of RCRA Subtitle C landfills and other disposal landfills). Of the total releases, 77 lb were released to air (stack and fugitive air emissions), and 0 lb were released to water (surface water discharges) (U.S. EPA, 2022b). In general, asbestos fibers (all six types) are not likely to be leached out of a landfill. However, the presence of natural organic matter could increase fiber mobility (Mohanty et al., 2021).

F.2.4.4 Biosolids

Sludge is defined as the solid, semi-solid, or liquid residue generated by wastewater treatment processes. The term "biosolids" refers to treated sludge that meet the EPA pollutant and pathogen requirements for land application and surface disposal (40 CFR part 503).

In general, asbestos fibers are resistant to biodegradation in water treatment and are expected to settle into biosolids from wastewater treatment plants, as described in Section F.2.5.2.

F.2.5 Persistence Potential of Asbestos

Persistence, in terms of environmental protection, refers to the length of time a contaminant remains in the environment. Asbestos is considered a persistent and naturally occurring mineral fiber and are largely chemically inert in the environment (ATSDR, 2001). Under extreme environmental conditions asbestos fibers have been reported to undergo morphological changes and loss of trace metals from the first layer of the silicate structure, but the underlying silicate structure remains unchanged at neutral pH. In general, asbestos fibers do not react or dissolve in most environmental conditions (Favero-Longo et al., 2005; Gronow, 1987; Schreier et al., 1987; Bales and Morgan, 1985; Choi and Smith, 1972).

F.2.5.1 Destruction and Removal Efficiency

Destruction and removal efficiency (DRE) is a percentage that represents the mass of a pollutant removed or destroyed in a thermal incinerator relative to the mass that entered the system. EPA requires that hazardous waste incineration systems destroy and remove at least 99.99 percent of each harmful chemical in the waste, including treated hazardous waste (46 FR 7684).

EPA extracted and evaluated six high quality data sources containing asbestos incineration and thermal treatment information. One study reported the incineration of ACM with up to 7.3 percent chrysotile, 2.7 percent amosite, and trace levels of crocidolite in a combustion chamber operating between 850 to 900 °C. After incineration, asbestos fibers were not detected within the solid products or exhaust gas (Osada et al., 2013). A second study evaluated the fate of chrysotile asbestos between 100 to 1,000 °C, resulting on morphological changes rendering non asbestos fibers between 810 to 1,000 °C and loss of water between 100 to 600 °C (Jolicoeur and Duchesne, 1981). Other thermal treatment approaches have reported to complete loss of asbestos with thermochemical treatment and partial loss of asbestos with microwave thermal treatment of ACMs (Obmiński, 2021; Porcu et al., 2005).

F.2.5.2 Removal in Wastewater Treatment

Wastewater treatment is performed to remove contaminants from wastewater using physical, biological, and chemical processes. Generally, municipal wastewater treatment facilities apply primary and secondary treatments. During the primary treatment, screens, grit chambers, and settling tanks are used to remove solids from wastewater. After undergoing primary treatment, the wastewater undergoes a secondary treatment. Secondary treatment processes can remove up to 90 percent of the organic matter in wastewater using biological treatment processes such as trickling filters or activated sludge. Sometimes an additional stage of treatment such as tertiary treatment is utilized to further clean water for additional protection using advanced treatment techniques (*e.g.*, ozonation, chlorination, disinfection). A negative removal efficiency can be reported if the pollutant concentration is higher in the effluents than the pollutant concentration in the influents.

In general, asbestos fibers are resistant to biodegradation in water treatment and are expected to settle into biosolids from drinking water and wastewater treatment plants. EPA selected four medium quality and two high quality sources reporting the removal of asbestos fibers from drinking water treatment processes. The reported removal of asbestos fibers ranged 80 to 99 percent for systems employing coagulation, flocculation treatment processes, and filtration treatment units (Kebler et al., 1989; Bales et al., 1984; McGuire et al., 1983; Lawrence and Zimmermann, 1977; Schmitt et al., 1977; Lawrence and Zimmermann, 1976). In addition, the EPA selected one high quality data source reporting concentrations of asbestos fibers below detection limits in the effluent of a wastewater treatment plant receiving raw wastewater with 12.2 M fibers/L (Lauer and Convery, 1988). Overall, asbestos fibers are expected to settle into biosolids from wastewater treatment plants and eventually disposed in land application of biosolids and/or landfills.

F.2.6 Bioaccumulation Potential of Asbestos

Bioaccumulation is the absorption of chemical from both its environment and its diet. Bioconcentration in aquatic organisms occurs when a substance is absorbed by an organism from its environment only through respiratory and external uptake and does not include food ingestion. For some chemicals (particularly those that are persistent and hydrophobic), the magnitude of bioaccumulation can be substantially greater than the magnitude of bioconcentration (U.S. EPA, 2003b).

EPA evaluated and extracted five high quality data sources containing asbestos body burden and bioconcentration information on fish and clams. Three of the studies reported asbestos body burden and bioconcentration information for clams. The asbestos body burden for clams was reported to be 132.1 to 147.3 fibers/mg dry weight gill tissue and 903.7 to 1,127.4 fibers/mg dry weight visceral tissue after a 30-day exposure to 10^8 fibers/L chrysotile asbestos (Belanger et al., 1986a, b). A clam 30-day asbestos exposure to 10^8 fibers/L asbestos fibers resulted in BCF values of 0.308 in gill tissue, 1.89 in viscera tissue, and 1.91 in whole clam homogenates (Belanger et al., 1987). One study evaluated the body burden in Japanese Medaka after a 28-day exposure to chrysotile asbestos at 10^{10} fibers/L concentrations, fish total body burden was 375.7 fibers/mg (Belanger et al., 1990). In addition, Sunfish exposure to 10^6 fibers/L chrysotile asbestos resulted in lost scales and epidermal tissue erosion (Belanger et al., 1986c). Based on the reported low BCF values for asbestos, asbestos fibers are not expected to bioaccumulate (ATSDR, 2001).

Appendix G ENVIRONMENTAL RELEASES AND OCCUPATIONAL EXPOSURE ASSESSMENT

G.1 Components of an Occupational Exposure and Release Assessment

EPA describes the assessed COUs for asbestos in Section 1.1.2; however, some COUs differ from the specific asbestos processes and associated exposure/release scenarios. Therefore, Table 3-1 provides a crosswalk that maps the asbestos COUs to the more specific OESs. The environmental release and occupational exposure assessments of each OES comprised the following components:

- **Process Description:** A description of the OES, which includes the chemical function, products containing asbestos, process equipment, batch parameters, and process flow diagram.
- **Facility Estimates:** A characterization of the potential number of employment establishments and work sites where asbestos or asbestos-containing products are present for an OES. Workers and ONUs from one establishment may operate at several sites annually for some COUs, whereas employees within other COUs may operate at only one site or establishment permanently.
- **Environmental Release Assessment**
    - *Environmental Release Sources:* A description of the potential sources of environmental releases in the process and their expected media of release for the OES.
    - *Environmental Release Assessment Results:* Estimates of asbestos released into each environmental media (surface water, POTW, non POTW-WWT, fugitive air, stack air, and each type of land disposal) for the given OES.
- **Occupational Exposure Assessment**
    - *Worker Activities:* A description of the worker activities, including an assessment of potential points of worker and ONU exposure.
    - *Number of Workers and Occupational Non-users:* An estimate of the number of workers and occupational non-users potentially exposed to the chemical for the given OES.
    - *Occupational Inhalation Exposure Results:* Central tendency and high-end estimates of inhalation exposure to workers and ONUs.

G.2 Approach and Methodology for Process Descriptions

EPA performed a literature search to find descriptions of processes involved in each OES. EPA used a systematic review approach as discussed in Section 1.2 to complete the literature search. Where chemical-specific process descriptions were unclear or not reasonably available, EPA referenced relevant Emission Scenario Documents (ESDs) or Generic Scenarios (GSs). EPA developed the process descriptions to include facility throughputs or hypothetical scenarios assessed, key process steps, and where asbestos is present (*e.g.,* physical state, concentration) throughout the process. Appendices G.10 through G.16 provide process descriptions for each OES.

G.3 Approach and Methodology for Number of Sites and Establishments

CDR data were not available for the COUs included in this occupational exposure assessment. Therefore, EPA used data from BLS and SUSB, NFPA data, and literature search data to estimate the number of establishments and worksites for each OES.

For all OESs, except the Handling asbestos-containing building materials during firefighting or other disaster response activities, EPA used BLS and SUSB data to estimate the number of employment establishments as follows:

1. Identify the North American Industry Classification System (NAICS) codes for the industry sectors associated with the OES.
2. Estimate total number of establishments using SUSB data on total establishments by 6-digit NAICS.
3. Use market penetration data to estimate the percentage of establishments likely to be using asbestos or asbestos-containing products.
4. Combine the data generated in Steps 1 through 3 above to produce an estimate of the number of establishments using asbestos in each 6-digit NAICS code and sum across all applicable NAICS codes for the OES to arrive at a total estimate of the number of establishments within the OES.
5. If market penetration data required for Step 3 are not available, use generic industry data from GSs, ESDs, and other literature sources on typical throughputs/use rates, operating schedules, and the asbestos volume used within the OES to estimate the number of establishments.

For the Handling asbestos-containing building materials during firefighting or other disaster response activities OES, the number of establishments (*i.e.,* fire departments) were determined from NFPA data rather than BLS and SUSB data due to data limitations within BLS and SUSB for firefighting and disaster response occupations.

To estimate the number of work sites, EPA assumed that employees work at the establishment of employment only and workers do not operate at sites outside of the establishment of employment for the following three OES: Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos; Handling articles or formulations that contain asbestos; and Waste handling, disposal, and treatment. Therefore, the number of establishments is equal to the number of sites for these three OESs.

However, for the Handling asbestos-containing building materials during maintenance, renovation, and demolition activities as well as the Handling asbestos-containing building materials during firefighting or other disaster response activities OES, the number of establishments is not equal to the number sites since workers employed in one establishment may perform work activities at various sites annually. For these two OESs, EPA used literature search data to estimate the number of sites. See Appendix G.10.2 and Appendix G.11.2 for more information on these calculations.

A summary of the number of establishments and sites that EPA determined for each OES is shown in Table_Apx G-1. The number of establishments and sites may be different for each type of release within the same OES if sufficient data were available to make this differentiation.

Table_Apx G-1. Summary of EPA's Estimates for the Number of Establishments and Sites for Each OES

OES	Number of Establishments	Number of Sites	Notes
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities	683,066	46,789	The number of employment establishments is based on U.S. Census Bureau data (see Table_Apx G-20, whereas number of release/exposure sites is based on literature values for total demolition waste generated, percentage of residential vs commercial waste, area per building, waste generated per area of building, and percentage of buildings with friable asbestos (Tiseo, 2022; EIA, 2018; U.S. EPA, 2003a, 1988).
Handling asbestos-containing building materials during firefighting or other disaster response activities	29,452	97,920	The number of employment establishments is based on NFPA reported data for the number of fire departments (NFPA, 2022b), whereas number of release/exposure sites is based on NFPA report of fires per year, and percentage of buildings with friable asbestos (NFPA, 2022a; U.S. EPA, 1988).
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	29,211	29,211	The bounding estimate is based on U.S. Census Bureau data for NAICS codes 324110 (Petroleum Refineries), 325199 (All Other Basic Organic Chemical Manufacturing), and 423830 (Industrial Machinery and Equipment Merchant Wholesalers).
Handling articles or formulations that contain asbestos	15,592	15,592	The bounding estimate is based on U.S. Census Bureau data for NAICS codes 336411 (Aircraft Manufacturing), 541715 (Research and Development in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology)), and 611310 (Colleges, Universities, and Professional Schools).
Waste handling, disposal, and treatment	5,425	5,425	The bounding estimate is based on U.S. Census Bureau data for NAICS codes 221117 (Biomass Electric Power Generation), 562211 (Hazardous Waste Treatment and Disposal), 562212 (Solid Waste Landfill), 562920 (Materials Recovery Facilities), and 562998 (All Other Miscellaneous Waste Management Services).

G.4 Environmental Releases Approach and Methodology

Releases to the environment are a component of potential exposure and may be derived from reported data that are obtained through direct measurement via monitoring, calculations based on empirical data, and/or assumptions and models. For each OES, EPA attempted to provide annual releases, high-end, and central tendency daily releases, as well as the number of release days per year for each media of release (air, water, and land).

EPA used the following hierarchy in selecting data and approaches for assessing environmental releases:

1. Monitoring and measured data:
    a. Releases calculated from site-specific concentration in medium and flow rate data

b. Releases calculated from mass balances or emission factor methods using site-specific measured data

EPA's preference was to rely on site-specific release data reported in TRI, DMR, and NEI, where available. Where releases are expected for an OES—but TRI, DMR, and NEI data were not available or where EPA determined TRI, DMR, and/or NEI data did not capture the entirety of environmental releases for an OES—releases were estimated using data from the National Response Center (NRC). EPA's general approach to estimating releases from these sources is described in Appendix G.4.1 through Appendix G.4.3. Specific details related to the use of release data or models for each OES can be found in Appendix G.10 through Appendix G.16.

EPA used deterministic calculations to estimate the final release result. EPA used combinations of point estimates of each input parameter to estimate a central tendency and high-end for each final release result. EPA documented the method and rationale for selecting parametric combinations to be representative of central tendency and high-end in the relevant OES subsections in Appendix G.10 through Appendix G.16.

G.4.1 Approach for Estimating Wastewater Discharges

This section describes EPA's methodology for estimating daily wastewater discharges from industrial and commercial sites containing asbestos. No wastewater discharges of asbestos were reported in the 2016 to 2020 TRI. Therefore, EPA used 2015 to 2022 NRC data (NRC, 2022) to estimate daily wastewater discharges for the OES where available. Section 103 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requires the person in charge of a vessel or an onshore or offshore facility immediately notify the NRC when a CERCLA hazardous substance is released at or above the reportable quantity in any 24-hour period, unless the release is federally permitted. The NRC is an emergency call center maintained and operated by the U.S. Coast Guard that fields initial reports for pollution and railroad incidents. Information reported to the NRC is available on the NRC website. For OESs without NRC data, EPA used alternate assessment approaches to estimate wastewater discharges. Both approaches, that for OESs with NRC data and that for OESs without these data, are described below.

G.4.1.1 Approach for Estimating Wastewater Discharges from NRC

EPA identified 2012 to 2022 NRC data for incidents within the Handling asbestos-containing building materials during maintenance, renovation, and demolition activities OES.

The first step in estimating annual releases was to obtain the NRC data. EPA downloaded annual data sets from the past 10 years (2012–2022) from the NRC website. EPA then identified all of the data for spill reports pertaining to asbestos that reached a body of water and excluded reports of asbestos spills that were contained and did not reach water. This resulted in four reports of asbestos spills that reached water. EPA mapped each of the data points to an OES using the "Description of Incident" field from the NRC database to determine how the asbestos was being used prior to the spill.

The final step was to prepare a summary of the wastewater discharges. EPA estimated annual wastewater discharges by calculating the median and maximum of the reported NRC data. Then, EPA estimated daily wastewater discharges by dividing the annual releases by the number of operating days determined for the OES.

To accompany the summary table for each OES, EPA also provided any reasonably available information on the release duration and pattern, which are needed for the exposure modeling. Release duration is the expected time per day during which the wastewater discharge may occur. Release pattern is the temporal variation of the wastewater discharge, such as over consecutive days throughout the year, over cycles that occur intermittently throughout the year, or in an instantaneous discharge that occurs over a short duration. The NRC data set does not include release pattern or duration; therefore, EPA used information from models or literature, where available.

G.4.1.2 Approach for Estimating Wastewater Discharges from TRI

EPA used TRI data to estimate annual wastewater discharges, average daily wastewater discharges, and high-end daily wastewater discharges for the following OESs:

- Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos;
- Handling articles or formulations that contain asbestos; and
- Waste handling, disposal, and treatment.

Since there were no reported wastewater discharges in the 2016 to 2020 TRI data associated with the three OESs above, EPA does not expect wastewater discharges for these OESs. There may be incidental discharges of asbestos for these OESs; however, EPA expects those releases to be low and occur infrequently.

G.4.2 Approach for Estimating Air Emissions

This section describes EPA's methodology for estimating daily air emissions from industrial and commercial sites containing asbestos. EPA used 2016 to 2020 TRI data (U.S. EPA, 2022a) and 2014 to 2017 NEI data (U.S. EPA, 2022d) to estimate daily air emissions for the OES where available; however, EPA did not have these data for every OES. For OES without TRI or NEI data, EPA used alternate assessment approaches to estimate air emissions. Both approaches, that for OES with TRI and NEI data and that for OES without these data, are described below.

G.4.2.1 Assessment Using TRI and NEI

Where available, EPA used TRI and NEI data to estimate annual and average daily fugitive and stack air emissions. For air emissions, EPA attempted to estimate both release patterns (*i.e.*, days per year of release) and release durations (*i.e.*, hours per day the release occurs).

Annual Emissions

Facility-level annual emissions are available for TRI reporters and major sources in NEI. EPA used the reported annual emissions directly as reported in TRI and NEI for major sources. NEI also includes annual emissions for area sources that are aggregated at the county-level. However, for this analysis only point-source data were available in NEI.

Average Daily Emissions

To estimate average daily emissions for TRI reporters and major sources in NEI, EPA used the following steps:

1. Obtain total annual fugitive and stack emissions for each TRI reporter and major sources in NEI.
2. Divide the annual stack and fugitive emissions over the number of estimated operating days (note: NEI data includes operating schedules for many facilities that can be used to estimate facility-specific days per year).
3. Estimate a release duration using facility-specific data available in NEI, models, and/or literature sources. If no data is available, list as "unknown."

G.4.3 Approach for Estimating Land Disposals

This section describes EPA's methodology for estimating daily land disposals from industrial and commercial sites containing asbestos. EPA used 2016 to 2020 TRI data (U.S. EPA, 2022a) to estimate daily land emissions for the OES where available; however, EPA did not have these data for every OES. For OESs without TRI data, EPA used alternate assessment approaches to estimate land disposals. Both approaches, for OESs with TRI data and that for OESs without these data, are described below.

G.4.3.1 Assessment Using TRI

Where available, EPA used TRI data to estimate annual and average daily land disposal volumes. TRI includes reporting of disposal volumes for a variety of land disposal methods, including underground injection, RCRA Subtitle C landfills, land treatment, RCRA Subtitle C surface impoundments, other surface impoundments, and other land forms of disposal. EPA provided estimates for both a total aggregated land disposal volume and disposal volumes for each disposal method reported in TRI.

Annual Land Disposal

Facility-level annual disposal volumes are available directly for TRI reporters. EPA used the reported annual land disposal volumes directly as reported in TRI for each land disposal method. The Agency combined totals from all land disposal methods from each facility to estimate a total annual aggregate disposal volume to land.

Average Daily Land Disposal

To estimate average daily disposal volumes, EPA used the following steps:

1. Obtain total annual disposal volumes for each land disposal method for each TRI reporter.
2. Divide the annual disposal volumes for each land disposal method over the number of estimated operating days.
3. Combine totals from all land disposal methods from each facility to estimate a total aggregate disposal volume to land.

G.4.3.2 Assessment Using Literature Search Data

EPA used literature search data for sites within the Handling asbestos-containing building materials during maintenance, renovation, and demolition activities OES.

While EPA identified potential demolition sites in TRI data for this OES, EPA does not expect the TRI reports to include all demolition sites due to TRI reporting requirements/thresholds. Therefore, EPA supplemented TRI data using data obtained from literature.

Literature data may include directly measured release data or information useful for release modeling. Therefore, EPA's approach to literature data differs depending on the type of literature data available. For example, if site-specific release data is available, EPA may use that data directly to estimate releases for that site. If site-specific data is available for only a subset of the sites within an OES, EPA may also build a distribution of the available data and estimate releases from sites within the OES using central tendency and high-end values from the distribution. If site-specific data is not available, but industry- or chemical-specific emission factors are available, EPA may use those directly to calculate releases for an OES or incorporate the emission factors into release models to develop a distribution of potential releases for the OES. Detailed descriptions of how various literature data was incorporated into release estimates for each OES are described in Appendix G.11.

G.4.4 Approach for Estimating Number of Release Days

As a part of the assessment of industrial and commercial environmental releases, EPA also estimated the number of release days for each OES. The Agency used literature search data or made assumptions when estimating release days for each OES. Industry-specific data that is available in the form of trade publications or other relevant literature are preferrable when determining the number of release days. When such data exists, these industry-specific estimates should take precedent over other approaches or assumptions. If industry-specific data does not exist, EPA may assume 250 operating days per year as the default release schedule of a commercial or industrial facility based on 5 operating days per week, 50 weeks per year, and 2 weeks per year for shutdown activities. A summary along with a brief explanation is presented in Table_Apx G-2.

Table_Apx G-2. Summary of Estimates for Release Days Expected for Each OES

OES	Release Days	Notes
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities	12	EPA found information on release days per structure demolished in four industry-specific literature publications (Hoang et al., 2020; Raghuwanshi, 2017; Coelho and de Brito, 2011; Dantata et al., 2005). To estimate release days, EPA used the average of the four sources.
Handling asbestos-containing building materials during firefighting or other disaster response activities	1	Per one industry-specific literature publication, the average extinguish time of a structure fire is 3 hours (Jeon et al., 2012). EPA rounded this figure up to 1 day/yr.
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	250	Assumed 5 days per week and 50 weeks per year with 2 weeks per year for shutdown activities.
Handling articles or formulations that contain asbestos	250	Assumed 5 days per week and 50 weeks per year with 2 weeks per year for shutdown activities.
Waste handling, disposal, and treatment	250	Assumed 5 days per week and 50 weeks per year with 2 weeks per year for shutdown activities.

G.5 Occupational Exposure Approach and Methodology

EPA provided occupational exposure results representative of central tendency conditions and high-end conditions. A central tendency is assumed to be representative of occupational exposures in the center of the exposure distribution for a given condition of use. For risk evaluation, EPA used the 50th percentile (median), mean (arithmetic or geometric), mode, or midpoint values of a distribution as representative of the central tendency scenario. The Agency's preference is to provide the 50th percentile of the exposure distribution. However, if the full distribution is not known, EPA may assume that the mean, mode, or midpoint of the distribution represents the central tendency depending on the statistics available for the distribution.

A high-end is assumed to be representative of occupational exposures that occur at probabilities above the 90th percentile but below the exposure of the individual with the highest exposure (U.S. EPA, 1992). For purposes of this risk evaluation, EPA has provided high-end results at the 95th percentile. If the 95th percentile was not reasonably available, EPA used a different percentile greater than or equal to the 90th percentile but less than or equal to the 99.9th percentile, depending on the statistics available for the distribution. If the full distribution was not known and the preferred statistics were not reasonably available, EPA estimated a maximum or bounding estimate in lieu of the high-end.

For occupational exposures, EPA used measured or estimated air concentrations to calculate exposure concentration metrics required for risk assessment, such as average daily concentration (ADC), margin of exposure (MOE), and excess lifetime cancer risk (ELCR). These calculations require additional parameter inputs, such as years of exposure, exposure duration and frequency, and lifetime years. EPA estimated exposure concentrations from occupational monitoring data only because available data was sufficient to characterize exposure for all occupational exposure scenarios. For the final exposure result metrics, each of the input parameters (*e.g.,* air concentrations, working years, exposure frequency, lifetime years) may be a point estimate (*i.e.,* a single descriptor or statistic, such as central tendency or high-end) or a full distribution.

EPA follows the following hierarchy in selecting data and approaches for assessing inhalation exposures:

- Monitoring data
  - Personal and directly applicable
  - Area and directly applicable
  - Personal and potentially applicable or similar
  - Area and potentially applicable or similar
- Modeling approaches
  - Surrogate monitoring data
  - Fundamental modeling approaches
  - Statistical regression modeling approaches
- Occupational exposure limits (OELs)
  - Company-specific OELs for site-specific exposure assessments (*e.g.,* there is only one manufacturer who provided EPA their internal OEL but did not provide monitoring data)
  - OSHA PEL
  - Voluntary limits (ACGIH Threshold Limit Value [TLV], NIOSH Recommended Exposure Limit [REL], Occupational Alliance for Risk Science [OARS] workplace environmental exposure level [WEEL; formerly by the AIHA])

EPA assessed occupational exposure to asbestos for the following two population categories: male or female workers who are 16 years or older; and female workers of reproductive age (16 years or older to less than 50 years). Exposure metrics for inhalation exposures include ADCs, MOEs, and ELCRs. ADC values were used to calculate MOE, which were used to determine chronic non-cancer risk compared to a benchmark MOE of 300. Measured and calculated 8-hour TWA data were used to calculate ELCR (along with IUR), which was used for chronic cancer risk compared to a benchmark of 1×10^{-4}. The approach to estimating each exposure metric is described in Appendix G.5.4.

G.5.1 Worker Activities

EPA performed a literature search and reviewed data from systematic review to identify worker activities that could potentially result in occupational exposures. Where worker activities were unclear or not reasonably available, EPA performed targeted internet searches. Worker activities for each OES can be found in Appendices G.10 through G.16.

G.5.2 Number of Workers and Occupational Non-users

Because CDR data were not available for uses of asbestos covered within this risk evaluation, EPA utilized U.S. economic data to determine the number of workers, occupational non-users (ONUs), and establishments as follows:

1. Identify the NAICS codes for the industry sectors associated with each COU.

2. Estimate total employment by industry/occupation combination using BLS Occupational Employment Statistics (BLS OES) data (U.S. Census Bureau, 2015).
3. Refine the BLS OES estimates where they are not sufficiently granular by using the SUSB data on total employment by 6-digit NAICS.
4. Combine the data generated in Steps 1 through 3 above to produce an estimate of the number of employees exposed to asbestos in each industry/occupation combination, and sum these to arrive at a total estimate of the number of employees with exposure.

For the occupational exposure scenario on firefighting and other disaster response, EPA estimated the number of workers and ONUs using data from NFPA (NFPA, 2022b). The survey provides an estimate for the number of career firefighters at 364,300 and volunteer firefighters at 676,900 (see Appendix G.11.4.2). See Appendices G.10 through G.16 for more information on the estimation methods for number of workers and ONUs for each OES.

Table_Apx G-3 presents the confidence rating of data that EPA used to estimate number of workers.

Table_Apx G-3. Data Evaluation of Sources Containing Number of Worker Estimates

Source	Data Type	Data Quality Rating	OES(s)
(U.S. Census Bureau, 2015)	Number of Workers	High	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities; Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos; Handling articles or formulations that contain asbestos; Waste handling, disposal, and treatment
(NFPA, 2022b)	Number of Workers	High	Handling asbestos-containing building materials during firefighting or other disaster response activities

G.5.3 Inhalation Exposure Monitoring

To assess inhalation exposure, EPA reviewed reasonably available exposure monitoring data and mapped data to specific conditions of use. Monitoring data used in the occupational exposure assessment include data collected by government agencies such as OSHA and NIOSH, and data found in published literature. Studies were evaluated using the evaluation strategies laid out in the *Application of Systematic Review in TSCA Risk Evaluations* (U.S. EPA, 2018a).

For each exposure scenario and worker job category ("higher exposure-potential worker," "lower exposure-potential worker," "worker," or "occupational non-user"), where available, EPA provided results representative of central tendency and high-end exposure levels. For data sets with six or more data points, central tendency and high-end exposures were estimated using the 50th and 95th percentile value from the observed data set, respectively. For data sets with three to five data points, the central tendency and high-end exposures were estimated using the median and maximum values. For data sets with two data points, the midpoint and the maximum value were presented. Finally, data sets with only one data point were presented as-is. For data sets including exposure data that were reported as below the limit of detection (LOD), EPA estimated the exposure concentrations for these data, following guidance in EPA's *Guidelines for Statistical Analysis of Occupational Exposure Data* (U.S. EPA, 1994).[6] A data set comprises the combined exposure monitoring data from all studies applicable to that condition of use.

For short-term exposures, EPA grouped exposures into 30-minute TWA averaging periods in order to evaluate using existing toxicity values for this time period. For exposure assessments, PBZ monitoring data were used to determine the TWA exposure concentration, except in some cases where area monitoring data was used to evaluate inhalation exposure to ONUs. Table_Apx G-4 presents the data quality rating of monitoring data that EPA used to assess occupational exposures. The Agency evaluated monitoring data using the evaluation strategies described in the *Application of Systematic Review in TSCA Risk Evaluations* (U.S. EPA, 2018a). For more information on inhalation exposure monitoring data used to assess worker and ONU exposure for each OES, see Appendices G.10 through G.16.

Table_Apx G-4. Data Evaluation of Sources Containing Occupational Exposure Monitoring Data

Source	Data Type	Data Quality Rating	OES(s)
(Amer Tech Lab, 1979a)	PBZ Monitoring	Medium	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Amer Tech Lab, 1979b)	PBZ Monitoring	Medium	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Amer Tech Lab, 1979c)	PBZ Monitoring	Medium	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Boelter et al., 2016)	PBZ Monitoring	High	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Dynamac, 1984)	PBZ Monitoring	High	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Gunter, 1981)	PBZ Monitoring	High	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(TOMA, 1979)	PBZ Monitoring	High	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Koppers, 1981)	PBZ Monitoring	High	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Lange and Thomulka, 2000a)	PBZ Monitoring	High	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Lange and Thomulka, 2002)	PBZ Monitoring	High	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Lange, 2002)	PBZ Monitoring	High	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Manville Serv Corp, 1980b)	PBZ Monitoring	Medium	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Manville Serv Corp, 1980a)	PBZ Monitoring	Medium	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Hervin, 1977)	PBZ Monitoring	Medium	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Scarlett et al., 2010)	PBZ Monitoring	Medium	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities

[6] Using the $\frac{LOD}{\sqrt{2}}$ if the geometric standard deviation of the data is less than 3.0 and $\frac{LOD}{2}$ if the geometric standard deviation is 3.0 or greater.

Source	Data Type	Data Quality Rating	OES(s)
(Tannahill et al., 1990)	PBZ Monitoring	Medium	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Bailey et al., 1988)	PBZ Monitoring	Medium	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Lange, 1999)	PBZ Monitoring	High	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Price et al., 1992)	PBZ Monitoring	High	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Lundgren et al., 1991)	PBZ Monitoring	High	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Lange and Thomulka, 2001)	PBZ Monitoring	High	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities; handling articles or formulations that contain asbestos
(Lange and Thomulka, 2000c)	PBZ Monitoring	Medium	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(van Orden et al., 1995)	PBZ Monitoring	High	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities; Handling asbestos-containing building materials during firefighting or other disaster response activities
(Teschke et al., 1999)	PBZ Monitoring	Medium	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(OSHA, 2020)	PBZ and Area Monitoring	High	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities; Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos; Handling articles or formulations that contain asbestos; waste handling, disposal, and treatment
(Spence and Rocchi, 1996)	PBZ Monitoring	Medium	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Tech Servs Inc, 1979)	PBZ Monitoring	Medium	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Confidential, 1986)	PBZ Monitoring	Medium	Handling asbestos-containing building materials during maintenance, renovation, and demolition activities
(Wallingford and Snyder, 2001)	PBZ Monitoring	High	Handling asbestos-containing building materials during firefighting or other disaster response activities
(Lewis and Curtis, 1990)	PBZ Monitoring	Medium	Handling asbestos-containing building materials during firefighting or other disaster response activities
(Beaucham and Eisenberg, 2019)	PBZ Monitoring	High	Handling asbestos-containing building materials during firefighting or other disaster response activities
(Breysse et al., 2005)	PBZ Monitoring	High	Handling asbestos-containing building materials during firefighting or other disaster response activities
(Blake et al., 2011)	PBZ Monitoring	High	Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos
(Cely-García et al., 2015)	PBZ Monitoring	High	Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos
(Madl et al., 2014)	PBZ Monitoring	High	Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos

Source	Data Type	Data Quality Rating	OES(s)
(Mlynarek and Van Orden, 2012)	PBZ Monitoring	High	Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos
(NIOSH, 1983)	PBZ Monitoring	High	Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos
(Ahrenholz, 1988)	PBZ Monitoring	High	Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos
(Confidential, 1986)	PBZ Monitoring	High	Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos
(Brorby et al., 2013)	PBZ Monitoring	High	Handling articles or formulations that contain asbestos
(Rhodes and Ingalls, 1976)	PBZ Monitoring	Medium	Handling articles or formulations that contain asbestos
(Rohl et al., 1975)	PBZ and Area Monitoring	Medium	Handling articles or formulations that contain asbestos
(Garcia et al., 2018)	PBZ Monitoring	High	Handling articles or formulations that contain asbestos
(Lange et al., 2006)	PBZ Monitoring	Medium	Handling articles or formulations that contain asbestos
(Costello, 1984)	PBZ Monitoring	Medium	Waste handling, disposal, and treatment
(Lamontagne et al., 2001)	PBZ Monitoring	High	Waste handling, disposal, and treatment
(Anania et al., 1978)	PBZ Monitoring	High	Waste handling, disposal, and treatment

G.5.4 Average Daily Concentration and Risk Estimation Calculations

This risk evaluation assesses asbestos exposures to workers and ONUs in occupational settings, presented as an 8-hour TWA exposure. The 8-hour TWA exposures are then used to calculate ADCs for chronic, non-cancer risks as well as ELCR estimates for chronic, lifetime cancer risks. ADC estimates are used to calculate MOEs for chronic, non-cancer risks. For more detailed information regarding occupational risk estimation calculations, see *Asbestos Part 2 RE - Risk Calculator for Occupational Exposure - November 2024* (U.S. EPA, 2023d).

G.5.4.1 Average Daily Concentration Calculations

ADC is used to estimate workplace exposures for non-cancer risk. These exposures are estimated as follows:

Equation_Apx G-1.

$$ADC = \frac{C \times ED \times EF \times WY}{AT}$$

Equation_Apx G-2.

$$EF = AWD \times f$$

Equation_Apx G-3.

$$AT = WY \times 365\frac{day}{yr} \times 24\frac{hr}{day}$$

Where:

ADC	=	Average daily concentration (8-hour TWA) used for chronic, non-cancer risk calculations
C	=	Contaminant concentration in air (8-hour TWA)
ED	=	Exposure duration (hr/day)
EF	=	Exposure frequency (day/yr)
WY	=	Working years per lifetime (yr)
AT	=	Averaging time (hr) for chronic, non-cancer risk
AWD	=	Annual working days (day/yr)
f	=	Fractional working days with exposure (unitless)

The lifetime working years (WY) is defined as a triangular distribution with a minimum of 10.4 years, a mode of 36 years, and a maximum of 44 years (U.S. Census Bureau, 2019a, b; U.S. BLS, 2014). The corresponding 95th and 50th percentile values for this distribution are 40 years and 31 years, respectively (Table_Apx G-5).

Table_Apx G-5. Parameter Values for Calculating ADC

Parameter Name	Symbol	95th Percentile Value	50th Percentile Value	Unit
Exposure Duration	ED	8	8	hr/day
Annual Working Days	AWD	250	250	day/yr
Fractional Working Days with Exposure	f	1	1	unitless
Working Years per Lifetime	WY	40	31	yr
Averaging Time (chronic, non-cancer)	AT	350,400	271,560	hr

The subsections below (*i.e.,* "Exposure Frequency", "Working Years", and "Body Weight") describe the estimation of exposure frequency (EF) for each OES, as well as estimates for the number of working years (WY).

Exposure Frequency (EF)

Exposure frequency (EF) is the number of days per year a worker is exposed to the chemical being assessed. In some cases, it may be reasonable to assume a worker is exposed to the chemical on each working day. In other cases, it may be more appropriate to estimate a worker's exposure to the chemical occurs during a subset of the worker's annual working days. The relationship between exposure frequency and annual working days can be described as shown in Equation_Apx G-3.

For the Firefighting and other disaster response OES, the exposure frequency to ACM was estimated to be between 1 to 3 days per year depending on whether the worker is a career or volunteer firefighter (see Appendix G.11.4.2). For the Maintenance, renovation, and demolition OES, the exposure frequency to asbestos-containing material was estimated to be 50 days per year based annual working days and fraction of days exposed (see Appendix G.10.4.2). An exposure frequency of 250 days per year is assumed for all other OESs in this risk evaluation.

BLS provides data on the total number of hours worked and total number of employees by each industry NAICS code. These data are available from the 3- to 6-digit NAICS level (where 3-digit NAICS are less granular and 6-digit NAICS are the most granular). Dividing the total, annual hours worked by the number of employees yields the average number of hours worked per employee per year for each NAICS.

EPA has identified approximately 140 NAICS codes that are applicable to the various COUs commonly evaluated within occupational risk assessments. For each NAICS code of interest, EPA looked up the average hours worked per employee per year at the most granular NAICS level available (*i.e.*, 4-, 5-, or 6-digit). EPA converted the working hours per employee to working days per year per employee assuming employees work an average of 8 hours per day. The average number of days per year worked, or AWD, ranges from 169 to 282 days per year, with a 50th percentile value of 250 days per year. EPA repeated this analysis for all NAICS codes at the 4-digit level. The average AWD for all 4-digit NAICS codes ranges from 111 to 282 days per year, with a 50th percentile value of 228 days per year. 250 days per year is approximately the 75th percentile.

In the absence of industry- and asbestos-specific data, EPA assumes the fraction of days exposed while working is equal to one for all COUs.

Working Years (WY)
EPA has developed a triangular distribution for working years and defined the parameters of the triangular distribution as follows:

- *Minimum value:* BLS CPS tenure data with current employer as a low-end estimate of the number of lifetime working years (10.4 years);
- *Mode value:* The 50th percentile tenure data with all employers from the U.S. Census' (2016) Survey of Income and Program Participation (SIPP) as a mode value for the number of lifetime working years (36 years); and
- *Maximum value:* The maximum average tenure data with all employers from the SIPP as a high-end estimate on the number of lifetime working years (44 years).

This triangular distribution has a 50th percentile value of 31 years and a 95th percentile value of 40 years. EPA uses these values for central tendency and high-end ADC calculations, respectively.

The U.S. BLS (2014) provides information on employee tenure with *current employer* obtained from the Current Population Survey (CPS). CPS is a monthly sample survey of about 60,000 households that provides information on the labor force status of the civilian non-institutional population ages 16 and over; CPS data are released every 2 years. The data are available by demographics and by generic industry sectors but are not available by NAICS codes.

The U.S. Census Bureau (2019a) Survey of Income and Program Participation (SIPP) provides information on *lifetime tenure with all employers*. SIPP is a household survey that collects data on income, labor force participation, social program participation and eligibility, and general demographic characteristics through a continuous series of national panel surveys of between 14,000 and 52,000 households (U.S. Census Bureau, 2019a). EPA analyzed the 2008 SIPP Panel Wave 1, which began in 2008 and covers the interview months of September through December 2008 (U.S. Census Bureau, 2019a). For that panel, lifetime tenure data are available by Census Industry Codes, which can be crosswalked with NAICS codes.

SIPP data include fields for the industry in which each surveyed, employed individual works (TJBIND1), worker age (TAGE), and years of work experience *with all employers* over the surveyed individual's lifetime.[7] Census household surveys use different industry codes than the NAICS codes used in its firm surveys, so these were converted to NAICS using a published crosswalk (U.S. Census Bureau, 2012). EPA calculated the average tenure for the following age groups: (1) workers aged 50 and older; (2) workers aged 60 and older; and (3) workers of all ages employed at time of survey. EPA used tenure data for age group "50 and older" to determine the high-end lifetime working years, because the sample size in this age group is often substantially higher than the sample size for age group "60 and older." For some industries, the number of workers surveyed, or sample size, was too small to provide a reliable representation of the worker tenure in that industry. Therefore, EPA excluded data from the analysis where the sample size is less than five.

Table_Apx G-6 summarizes the average tenure for workers aged 50 and older from the SIPP data. Although the tenure may differ for any given industry sector, there is no significant variability between the 50th and 95th percentile values of average tenure across manufacturing and non-manufacturing sectors.

Table_Apx G-6. Overview of Average Worker Tenure from U.S. Census SIPP (Age Group 50+)

Industry Sectors	Working Years			
	Average	**50th Percentile**	**95th Percentile**	**Maximum**
All relevant industry sectors	35.9	36	39	44
Manufacturing sectors (NAICS 31–33)	35.7	36	39	40
Non-manufacturing sectors (NAICS 42–81)	36.1	36	39	44
Source: (U.S. BLS, 2016) Note: Industries where sample size is <5 are excluded from this analysis.				

BLS CPS data provides the median years of tenure that wage and salary workers had been with their current employer. Table_Apx G-7 presents CPS data for all demographics (men and women) by age group from 2008 to 2012. To estimate the low-end value on number of working years, EPA uses the most recent (2014) CPS data for workers aged 55 to 64 years, which indicates a median tenure of 10.4 years with their current employer. The use of this low-end value represents a scenario where workers are only exposed to the chemical of interest for a portion of their lifetime working years, as they may change jobs or move from one industry to another throughout their career.

Table_Apx G-7. Median Years of Tenure with Current Employer by Age Group

Age	January 2008	January 2010	January 2012	January 2014
16 years and over	4.1	4.4	4.6	4.6
16 to 17 years	0.7	0.7	0.7	0.7
18 to 19 years	0.8	1.0	0.8	0.8
20 to 24 years	1.3	1.5	1.3	1.3
25 years and over	5.1	5.2	5.4	5.5
25 to 34 years	2.7	3.1	3.2	3.0
35 to 44 years	4.9	5.1	5.3	5.2
45 to 54 years	7.6	7.8	7.8	7.9

[7] To calculate the number of years of work experience, EPA took the difference between the year first worked (TMAKMNYR) and the current data year (*i.e.*, 2008). The Agency then subtracted any intervening months when not working (ETIMEOFF).

Age	January 2008	January 2010	January 2012	January 2014
55 to 64 years	9.9	10.0	10.3	10.4
65 years and over	10.2	9.9	10.3	10.3
Source: (U.S. BLS, 2014)				

G.5.4.2 Margin of Exposure and Excess Lifetime Cancer Risk Calculations

Chronic, Non-cancer Risk Estimation Using MOE

EPA used the calculated ADC values to estimate chronic, non-cancer exposure using MOEs. The equation for calculating MOE is provided in Table_Apx G-4 below as well as Table 5-20.

Equation_Apx G-4.

$$MOE_{chronic} = \frac{Non - cancer\ Hazard\ value\ (POD)}{Human\ Exposure}$$

Where:

MOE	=	Margin of exposure (unitless)
Hazard value (POD)	=	0.026 (f/cc) (See Table 5-20)
Human exposure	=	ADC estimate for the relevant occupational exposure scenario from the exposure assessment (f/cc)

The calculated MOE value for an exposure scenario was compared to a benchmark MOE that was calculated using uncertainty factors (UF) that account for variation in sensitivity within human populations (see Table 5-20). The MOE estimate was interpreted as human health risk if the MOE estimate was less than the benchmark MOE (*i.e.*, the total UF) of 300. On the other hand, the MOE estimate indicated negligible concerns for adverse human health effects if the MOE estimate exceeded this benchmark MOE. Typically, the larger the MOE, the more unlikely it is that a non-cancer adverse effect would occur.

Chronic, Cancer Risk Estimation Using ELCR

EPA commonly estimates extra cancer risks for repeated exposures to a chemical using an equation format where Risk = Human Exposure (*e.g.*, 8-hour TWA concentration) × IUR. Estimates of extra cancer risks would be interpreted as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (*i.e.*, incremental or extra individual lifetime cancer risk).

However, as discussed in Section 3.2 of the Part 1 Risk Evaluation for Asbestos, assessment of asbestos is unique due to the relation of exposure timing to cancer outcome. The time since first exposure plays a dominant role in modeling risk. The most relevant exposures used in understanding mesothelioma risk were those that occurred decades prior to the onset of cancer and subsequent cancer progression. For this reason, EPA has used a less than lifetime exposure calculation (see Section 4.2.1 of the Part 1 Risk Evaluation for additional information).

The equations for ELCR are provided in Table 5-20. These equations can also be used for estimating cancer risks for less than lifetime exposure from inhalation of asbestos, as shown in the *Office of Land and Emergency Management Framework for Investigating Asbestos-contaminated Superfund Sites* (U.S. EPA, 2008).

To estimate risk, ELCR values were calculated for each similar exposure group and occupational exposure scenario and compared to a benchmark value of 1×10^{-4}. The ELCR value was determined a human health risk if the estimate was greater than this benchmark value. ELCR estimates under this benchmark indicated negligible human health concerns. Typically, the smaller the ELCR estimate, the more unlikely it is that a cancer-related adverse health effect would occur. The process for estimating ELCR values is explained in further detail in Equation_Apx G-5 below.

Equation_Apx G-5.

$$ELCR = EPC \times TWF \times IUR_{LTL}$$

Where:

ELCR	=	Excess Lifetime Cancer Risk, the risk of developing cancer as a consequence of the site-related exposure
EPC	=	Exposure Point Concentration, the concentration of asbestos fibers in air (f/cc) for the specific activity being assessed
IUR_{LTL}	=	Less than lifetime Inhalation Unit Risk per f/cc
TWF	=	Time-weighted factor that accounts for less-than-continuous exposure during a 1-year exposure.[8] This parameter is calculated using Equation_Apx G-6 below:

Equation_Apx G-6.

$$TWF = \left(\frac{Exposure\ time\ (hours\ per\ day)}{24\ hours}\right) \cdot \left(\frac{Exposure\ frequency\ (days\ per\ year)}{365\ days}\right)$$

Equation_Apx G-7.

$$EF = AWD \times f$$

Where:

EF	=	Exposure frequency (day/yr)
AWD	=	Annual working days (day/yr)
F	=	Fractional working days with exposure (unitless)

Equation_Apx G-7 above can be extended for more complex exposure scenarios by computing the TWA exposure of multiple exposures (*e.g.*, for 30-minute task samples within a full 8-hour shift). Similarly, when multiple exposures may each have different risks, those may be added together (*e.g.*, for episodic exposures during and between asbestos removal work). It is important to note that the short-term inhalation exposure estimates of ELCR are adjusted to account for a 30-minute exposure at the short-term concentration and a 7.5-hour exposure at the 8-hour TWA concentration. For example, if the short-term (30-minute) inhalation monitoring data leads to high end exposure of 0.1 f/cc, and the high end 8-hour TWA monitoring data for the same OES is 0.01 f/cc, then the 8-hour TWA adjustment for the high end short-term exposure point concentration would be calculated as EPC_{8hr,TWA_adj} = [(0.5 hr)(0.1 f/cc) + (7.5)(0.01 f/cc)] / 8 hr) = 0.016 f/cc.

When exposures of full-shift occupational workers are to be evaluated, the TWF should be adjusted to account for differences in inhalation volumes between workers and non-workers. EPA assumes workers breathe 10 m^3 air during an 8-hour shift and non-workers breathe 20 m^3 in 24 hours (U.S. EPA, 2009).

[8] See U.S. EPA (1994) and Part F update to RAGS Inhalation Guidance U.S. EPA (2009).

The hourly ratio of those breathing volumes is the volumetric adjustment factor for workers (V(worker)) [(10/8) / (20/24) = 1.5]. Thus, for workers, the formula, ELCR = EPC × TWF × IUR_{LTL}, is extended as ELCR = EPC × TWF × V × IUR_{LTL}, where TWF(worker) = (8 hr / 24 hr) × (EF / 365 days), and V(worker) = 1.5.

EPA assumes that a worker in the United States is at least 16 years of age, and the 95th percentile value for the number of working years is 40 years (see subsection titled "Working Years" below). Therefore, the Agency considers a less-than-lifetime IUR value corresponding to an individual that is first exposed at 16 years old and experiences regular exposure over 40 years (*i.e.*, IUR(16, 40)). As described in Appendix M of this risk evaluation, the IUR(16,40) = 0.08 per f/cc. Therefore, the excess lifetime cancer risk from occupational settings is computed as follows: ELCR = (EPC) × (8 hr / 24 hr) × (EF / 365 days) × (1.5) × (0.08 per f/cc).

The EPC is calculated as the 8-hour TWA inhalation monitoring concentration, which is adjusted for the short-term inhalation monitoring values as described above.

G.6 Consideration of Engineering Controls and Personal Protective Equipment

OSHA and NIOSH recommend employers utilize the hierarchy of controls to address hazardous exposures in the workplace. The hierarchy of controls strategy outlines, in descending order of priority, the use of elimination, substitution, engineering controls, administrative controls, and lastly personal protective equipment (PPE). The hierarchy of controls prioritizes the most effective measures first which is to eliminate or substitute the harmful chemical (*e.g.*, use a different process, substitute with a less hazardous material), thereby preventing or reducing exposure potential. Following elimination and substitution, the hierarchy recommends engineering controls to isolate employees from the hazard, followed by administrative controls, or changes in work practices to reduce exposure potential (*e.g.*, source enclosure, local exhaust ventilation systems). Administrative controls are policies and procedures instituted and overseen by the employer to protect worker exposures. As the last means of control, the use of personal protective equipment (*e.g.*, respirators, gloves) is recommended, when the other control measures cannot reduce workplace exposure to an acceptable level.

G.6.1 Respiratory Protection

Employers under the scope of OSHA's Asbestos standards for general industry or construction must ensure employees are provided respiratory protection in accordance with paragraphs 1910.1001(g) for general industry and 1926.1101(h) for construction. Respirator selection provisions are provided in section 1910.134(d) and require that appropriate respirators are selected based on the respiratory hazard(s) to which the worker will be exposed and workplace and user factors that affect respirator performance and reliability. Assigned protection factors (APFs) are provided in Table 1 under section 1910.134(d)(3)(i)(A) (see below in Table_Apx G-8) and refer to the level of respiratory protection that a respirator or class of respirators is expected to provide to employees when the employer implements a continuing, effective respiratory protection program according to the requirements of OSHA's Respiratory Protection Standard.

If respirators are necessary in atmospheres that are not immediately dangerous to life or health, workers must use NIOSH-certified air-purifying respirators or NIOSH-approved supplied-air respirators with the appropriate APF. Respirators that meet these criteria include air-purifying respirators with organic vapor cartridges. Respirators must meet or exceed the required level of protection listed in Table_Apx G-8.

Based on the APF, inhalation exposures may be reduced by a factor of 5 to 10,000, if respirators are properly worn and fitted.

However for asbestos, nominal APFs in Table_Apx G-8 may not be achieved for all PPE users (Riala and Riipinen, 1998) investigated performance of respirators and HEPA units in 21 different exposure abatement scenarios; most involved very high exposures not consistent with COUs identified in this RE. However, for three abatement scenarios, exposure concentrations were below 1 f/cc, which is relevant to the COUs in this risk evaluation. In the three scenarios with nominal APF 2,000, actual APFs were reported as 50, 5, and 4. The strength of this publication is the reporting of asbestos samples inside the mask, use of worker's own protective equipment, and measurement in different real work conditions. The results demonstrate that while some workers have protection above nominal APF, some workers have protection below nominal APF, so even with every worker wearing a respirator, some of these workers would not be protected.

Table_Apx G-8. Assigned Protection Factors for Respirators in OSHA Standard 29 CFR 1910.134

Type of Respirator	Quarter Mask	Half Mask	Full Facepiece	Helmet/ Hood	Loose-Fitting Facepiece
1. Air-Purifying Respirator	5	10	50		
2. Power Air-Purifying Respirator (PAPR)		50	1,000	25/1,000	25
3. Supplied-Air Respirator (SAR) or Airline Respirator					
• Demand mode		10	50		
• Continuous flow mode		50	1,000	25/1,000	25
• Pressure-demand or other positive-pressure mode		50	1,000		
4. Self-Contained Breathing Apparatus (SCBA)					
• Demand mode		10	50	50	
• Pressure-demand or other positive-pressure mode (*e.g.*, open/closed circuit)			10,000	10,000	
Source: 29 CFR 1910.134(d)(3)(i)(A)					

NIOSH and BLS conducted a voluntary survey of U.S. employers regarding the use of respiratory protective devices between August 2001 and January 2002 (NIOSH, 2003). The survey was sent to a sample of 40,002 establishments designed to represent all private sector establishments. The survey had a 75.5 percent response rate (NIOSH, 2003). A voluntary survey may not be representative of all private industry respirator use patterns as some establishments with low or no respirator use may choose to not respond to the survey. Therefore, results of the survey may potentially be biased towards higher respirator use.

NIOSH and BLS estimated about 619,400 establishments used respirators for voluntary or required purposes (including emergency and non-emergency uses). About 281,800 establishments (45%) were estimated to have had respirator use for required purposes in the 12 months prior to the survey. The 281,800 establishments estimated to have had respirator use for required purposes were estimated to be approximately 4.5 percent of all private industry establishments in the United States at that time (NIOSH, 2003).

The survey found that the establishments that required respirator use had the following respirator program characteristics (NIOSH, 2003):

- 59 percent provided training to workers on respirator use;

- 34 percent had a written respiratory protection program;
- 47 percent performed an assessment of the employees' medical fitness to wear respirators; and
- 24 percent included air sampling to determine respirator selection.

The survey report does not provide a result for respirator fit testing or identify if fit testing was included in one of the other program characteristics.

Of the establishments that had respirator use for a required purpose within the 12 months prior to the survey, NIOSH and BLS found (NIOSH, 2003):

- non-powered air purifying respirators are most common, 94 percent overall and varying from 89 to 100 percent across industry sectors;
- powered air-purifying respirators represent a minority of respirator use, 15 percent overall and varying from 7 to 22 percent across industry sectors; and
- supplied air respirators represent a minority of respirator use, 17 percent overall and varying from 4 to 37 percent across industry sectors.

Of the establishments that used non-powered air-purifying respirators for a required purpose within the 12 months prior to the survey, NIOSH and BLS found (NIOSH, 2003) that a

- high majority use dust masks, 76 percent overall and varying from 56 to 88 percent across industry sectors;
- varying fraction use half-mask respirators, 52 percent overall and varying from 26 to 66 percent across industry sectors; and
- varying fraction use full-facepiece respirators, 23 percent overall and varying from 4 to 33 percent across industry sectors.

Table_Apx G-9. summarizes the number and percent of all private industry establishments and employees that used respirators for a required purpose within the 12 months prior to the survey and includes a breakdown by industry sector (NIOSH, 2003).

Table_Apx G-9. Number and Percent of Establishments and Employees Using Respirators within 12 Months Prior to Survey

Industry	Establishments		Employees	
	Number	Percent of All Establishments	Number	Percent of All Employees
Total Private Industry	281,776	4.5	3,303,414	3.1
Agriculture, forestry, and fishing	13,186	9.4	101,778	5.8
Mining	3,493	11.7	53,984	9.9
Construction	64,172	9.6	590,987	8.9
Manufacturing	48,556	12.8	882,475	4.8
Transportation and public utilities	10,351	3.7	189,867	2.8
Wholesale Trade	31,238	5.2	182,922	2.6
Retail Trade	16,948	1.3	118,200	0.5
Finance, Insurance, and Real Estate	4,202	0.7	22,911	0.3
Services	89,629	4.0	1,160,289	3.2

G.7 Evidence Integration for Environmental Releases and Occupational Exposures

Evidence integration for the environmental release and occupational exposure assessment includes analysis, synthesis and integration of information, and data to produce estimates of environmental releases and occupational exposures. During evidence integration, EPA considered the likely location, duration, intensity, frequency, and quantity of releases and exposures while also considering factors that increase or decrease the strength of evidence when analyzing and integrating the data. Key factors EPA considered when integrating evidence includes the following:

1. **Data Quality:** EPA only integrated data or information rated as *high*, *medium*, *or low* obtained during the data evaluation phase. Data and information rated as *uninformative* are not used in exposure evidence integration. In general, higher rankings are given preference over lower rankings; however, lower ranked data may be used over higher ranked data when specific aspects of the data are carefully examined and compared. For example, a lower ranked data set that precisely matches the OES of interest may be used over a higher ranked study that does not as closely match the OES of interest.

2. **Data Hierarchy:** EPA used both measured and modeled data to obtain accurate and representative estimates (*e.g.,* central-tendency, high-end) of the environmental releases and occupational exposures resulting directly from a specific source, medium, or product. If available, measured release and exposure data are given preference over modeled data, with the highest preference given to data that are both chemical-specific and directly representative of the OES/exposure source.

EPA considered both data quality and data hierarchy when determining evidence integration strategies. For example, the Agency may have given preference to high quality modeled data directly applicable to the OES being assessed over low quality measured data that is not specific to the OES. The final integration of the environmental release and occupational exposure evidence combined decisions regarding the strength of the available information, including information on plausibility and coherence across each evidence stream.

EPA evaluated environmental releases based on reported release data from standard engineering sources such as TRI, NEI, and NRC. The Agency estimated COU-specific releases where supporting data existed and documented uncertainties where an absence of such data required a broader application of release estimates.

EPA evaluated occupational exposures based on monitoring data and worker activity information from standard engineering sources and systematic review. The Agency used COU-specific assessment approaches where supporting data existed and documented uncertainties where supporting data were only applicable for broader assessment approaches.

G.8 Weight of Scientific Evidence Ratings for Environmental Release Estimates by OES

For each OES, EPA considered the assessment approach, the quality of the data and models, and the strengths, limitations, assumptions, and key sources of uncertainties in the assessment results to determine a weight of scientific evidence rating. The Agency considered factors that increase or decrease the strength of the evidence supporting the release estimate—including quality of the data/information, applicability of the release or exposure data to the OES (including considerations of temporal relevance, locational relevance) and the representativeness of the estimate for the whole industry. The best professional judgment is summarized using the descriptors of robust, moderate, slight, or indeterminant, according to EPA's *Draft Systematic Review Protocol Supporting TSCA Risk Evaluations for Chemical Substances* (U.S. EPA, 2021a). For example, a conclusion of moderate is appropriate where there is measured release data from a limited number of sources such that there is a limited number of data points that may not cover most or all the sites within the OES. A conclusion of slight is appropriate where there is limited information that does not sufficiently cover all sites within the OES, and the assumptions and uncertainties are not fully known or documented. See EPA's *Application of Systematic Review in TSCA Risk Evaluations* (U.S. EPA, 2021a) for additional information on weight of scientific evidence conclusions.

Weight of scientific evidence ratings for the environmental release estimates for each OES are provided in Table 3-8. Weight of scientific evidence ratings for all OES are also summarized in Table_Apx G-10 below, as well as the rationale for each rating.

Table_Apx G-10. Summary of Assumptions, Uncertainty, and Overall Confidence in Release Estimates by OES

OES	Weight of Scientific Evidence Judgement	Rationale
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities	Moderate to Robust	EPA used TRI, NEI, NRC data, and literature data to assess environmental releases. TRI, NEI, NRC data have medium, high, and medium overall data quality determinations from the systematic review process, respectively. The literature data used in estimating releases have medium/high overall data quality determinations. The use of these sources falls under monitoring/measured data, which is most preferred based on the hierarchy of approaches. The primary strength of these estimates is that EPA used multiple years of data in the analysis. A strength of TRI data is that TRI compiles the best readily available release data for all reporting facilities. A strength of NEI data is that it includes comprehensive and detailed estimates of air emissions from point and area sources. A strength of NRC data is that it is the designated federal point of contact for reporting all spills of CERCLA hazardous chemicals, such as asbestos, so it is likely to be a comprehensive data set. A strength of literature search data is that all the underlying literature sources received data quality ratings of medium or higher. The primary limitation to this assessment is that information on the conditions of use of asbestos at facilities in TRI & NEI is limited, and NRC does not provide the condition of use of asbestos at facilities. Additional limitations to this assessment are that EPA made assumptions on the number of operating days to estimate daily releases and the uncertainty in the mapping of reporting facilities to this OES. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.
Handling asbestos-containing building materials during firefighting or other disaster response activities	Moderate	No OES-specific data was available to assess environmental releases. Therefore, EPA used surrogate data from the Handling Asbestos-Containing Building Materials During Maintenance, Renovation, and Demolition Activities OES. EPA assumed that the releases from an uncontrolled fire or clean up would be similar to releases from demolition of a structure. While the surrogate monitoring data had data quality ratings of medium/high, use of surrogate data may introduce uncertainties related to the extent to which the surrogate OES and the OES being assessed are similar. Even though surrogate data was used, the surrogate sources fall under monitoring/measured data, which is most preferred based on the hierarchy of approaches. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	Moderate to Robust	EPA used TRI and NEI data to assess environmental releases. These data sources have medium and high overall data quality determinations from the systematic review process, respectively. The use of TRI and NEI data falls under monitoring/measured data, which is most preferred based on the hierarchy of approaches. The primary strength of these estimates is that EPA used multiple years of data in the analysis. A strength of TRI data is that TRI compiles the best readily available release data for all reporting facilities. A strength of NEI data is that it includes comprehensive and detailed estimates of air emissions from point and area sources. The primary limitation to this assessment is that information on the conditions of use of asbestos at facilities in TRI & NEI is limited. Additional

OES	Weight of Scientific Evidence Judgement	Rationale
		limitations to this assessment are that EPA made assumptions on the number of operating days to estimate daily releases, assumption of no wastewater discharges where not reported in TRI, and the uncertainty in the mapping of reporting facilities to this OES. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.
Handling articles or formulations that contain asbestos	Moderate to Robust	EPA used TRI and NEI data to assess environmental releases. These data sources have medium and high overall data quality determinations from the systematic review process, respectively. The use of TRI and NEI data falls under monitoring/measured data, which is most preferred based on the hierarchy of approaches. The primary strength of these estimates is that EPA used multiple years of data in the analysis. A strength of TRI data is that TRI compiles the best readily available release data for all reporting facilities. A strength of NEI data is that it includes comprehensive and detailed estimates of air emissions from point and area sources. The primary limitation to this assessment is that information on the conditions of use of asbestos at facilities in TRI & NEI is limited. Additional limitations to this assessment are that EPA made assumptions on the number of operating days to estimate daily releases, assumption of no wastewater discharges where not reported in TRI, and the uncertainty in the mapping of reporting facilities sites to this OES. Based on this information, EPA has concluded that the weight of the scientific evidence for this assessment is moderate to robust and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.
Waste handling, disposal, and treatment	Moderate to Robust	EPA used TRI and NEI data to assess environmental releases. These data sources have medium and high overall data quality determinations from the systematic review process, respectively. The use of TRI and NEI data falls under monitoring/measured data, which is most preferred based on the hierarchy of approaches. The primary strength of these estimates is that EPA used multiple years of data in the analysis. A strength of TRI data is that TRI compiles the best readily available release data for all reporting facilities. A strength of NEI data is that it includes comprehensive and detailed estimates of air emissions from point and area sources. The primary limitation to this assessment is that information on the conditions of use of asbestos at facilities in TRI & NEI is limited. Additional limitations to this assessment are that EPA made assumptions on the number of operating days to estimate daily releases, assumption of no wastewater discharges where not reported in TRI, and the uncertainty in the mapping of reporting facilities to this OES. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.

G.9 Weight of Scientific Evidence Ratings for Inhalation Exposure Estimates by OES

For each OES, EPA considered the assessment approach, the quality of the data and models, and the strengths, limitations, assumptions, and key sources of uncertainties in the assessment results to determine a weight of scientific evidence rating. EPA considered factors that increase or decrease the strength of the evidence supporting the release estimate—including quality of the data/information, applicability of the release or exposure data to the OES (including considerations of temporal relevance, locational relevance) and the representativeness of the estimate for the whole industry. The best professional judgment is summarized using the descriptors of robust, moderate, slight, or indeterminant, according to EPA's *Application of Systematic Review in TSCA Risk Evaluations* (U.S. EPA, 2021a). For example, a conclusion of moderate is appropriate where there is measured release data from a limited number of sources such that there is a limited number of data points that may not cover most or all the sites within the OES. A conclusion of slight is appropriate where there is limited information that does not sufficiently cover all sites within the OES, and the assumptions and uncertainties are not fully known or documented. See EPA's *Application of Systematic Review in TSCA Risk Evaluations* (U.S. EPA, 2021a) for additional information on weight of scientific evidence conclusions. Table_Apx G-11 provides a summary of EPA's overall confidence in its inhalation exposure estimates for each of the OESs assessed.

Table_Apx G-11. Summary of Assumptions, Uncertainty, and Overall Confidence in Inhalation Exposure Estimates by OES

OES	Weight of Scientific Evidence Judgement	Rationale
Handling asbestos – containing building materials during maintenance, renovation, and demolition activities	Moderate	EPA considered the assessment approach, the quality of the data, and uncertainties in assessment results to determine a weight of scientific evidence conclusion for the 8-hour TWA inhalation exposure estimates. Monitoring data from published literature and OSHA's CEHD were used to estimate inhalation exposure for this OES. These monitoring data include 513 personal TWA samples and have an overall data quality determination of medium. The primary strength is the use of directly applicable monitoring data, which is preferrable to other assessment approaches such as modeling or the use of occupational exposure limits. The primary limitations of these data include uncertainty in mapping OSHA CEHD to this OES based on the SIC codes in the data set, lack of worker activity descriptions in the data set, uncertainty in the representativeness of the monitoring data for all sites in this OES, and number of non-detects (~40% of the TWA data were non-detect for asbestos). Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures in consideration of the strengths and limitations of reasonably available data.
Handling asbestos – containing building materials during firefighting or other disaster response activities	Moderate to Robust	EPA considered the assessment approach, the quality of the data, and uncertainties in assessment results to determine a weight of scientific evidence conclusion for the 8-hour TWA inhalation exposure estimates. Monitoring data from published literature were used to estimate inhalation exposure for this OES. These monitoring data include 60 personal breathing zone samples and have an overall data quality determination of medium/high. The primary strength is the use of directly applicable monitoring data, which is preferrable to other assessment approaches such as modeling or the use of occupational exposure limits. An additional strength is that the literature sources include information on worker activities. A primary limitation is that several of the literature sources do not provide discrete sampling values, with one only providing summary statistics for two groups of 636 and 114 samples. An additional limitation is the uncertainty in whether the activities performed in this study accurately reflect all firefighting scenarios or the disaster response scenario as a whole. Additionally, there is uncertainty in EPA's assumption of exposure frequency and exposure duration. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust and provides a plausible estimate of exposures in consideration of the strengths and limitations of reasonably available data.
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	Moderate to Robust	EPA considered the assessment approach, the quality of the data, and uncertainties in assessment results to determine a weight of scientific evidence conclusion for the 8-hour TWA inhalation exposure estimates. Monitoring data from published literature were primarily used to estimate inhalation exposure for this OES, along with five personal breathing zone data points from OSHA's CEHD. These monitoring data include 236 personal breathing zone TWA samples and have an overall data quality determination of high. The primary strength is the use of directly applicable monitoring data, which is preferrable to other assessment approaches such as modeling or the use of occupational exposure limits.

OES	Weight of Scientific Evidence Judgement	Rationale
		An additional strength is that the literature sources include information on worker activities. A primary limitation is that several of the literature sources do not provide discrete sampling values, with one only providing summary statistics for two groups of 59 and 47 samples. An additional limitation is the uncertainty in whether the activities performed in this study accurately reflect all use, repair, or removal of appliances or machinery scenario. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust and provides a plausible estimate of exposures in consideration of the strengths and limitations of reasonably available data.
Handling articles or formulations that contain asbestos	Moderate	EPA considered the assessment approach, the quality of the data, and uncertainties in assessment results to determine a weight of scientific evidence conclusion for the 8-hour TWA inhalation exposure estimates. Monitoring data from published literature were primarily used to estimate inhalation exposure for this OES, along with 13 personal breathing zone and area sampling data points from OSHA's CEHD. The monitoring data include a total of 69 personal breathing zone TWA samples and have an overall data quality determination of high. The primary strength is the use of directly applicable monitoring data, which is preferrable to other assessment approaches such as modeling or the use of occupational exposure limits. An additional strength is that the literature sources include information on worker activities. The primary limitations of these data include uncertainty in mapping OSHA CEHD to this OES based on the SIC codes in the data set, lack of worker activity descriptions in the OSHA CEHD data set, uncertainty in the representativeness of the monitoring data for all sites in this OES, and the number of non-detects (all of the TWA data from OSHA's CEHD were non-detect for asbestos). Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures in consideration of the strengths and limitations of reasonably available data.
Waste handling, disposal, and treatment	Moderate	EPA considered the assessment approach, the quality of the data, and uncertainties in assessment results to determine a weight of scientific evidence conclusion for the 8-hour TWA inhalation exposure estimates. Monitoring data from published literature and OSHA's CEHD were used to estimate inhalation exposure for this OES. This monitoring data includes 95 personal TWA samples and have an overall data quality determination of high. The primary strength is the use of directly applicable monitoring data, which is preferrable to other assessment approaches such as modeling or the use of occupational exposure limits. The primary limitations of these data include uncertainty in mapping OSHA CEHD to this OES based on the SIC codes in the data set, lack of worker activity descriptions in the data set, uncertainty in the representativeness of the monitoring data for all sites in this OES, number of non-detects (~40% of the TWA data were non-detect for asbestos), and age of the monitoring data. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures in consideration of the strengths and limitations of reasonably available data.

G.10 Handling Asbestos-Containing Building Materials During Maintenance, Renovation, and Demolition Activities

G.10.1 Process Description

Until the Asbestos Ban and Phaseout Rule of the late 1980s, various asbestos-containing construction materials were manufactured or imported into the U.S. and subsequently used in the construction of commercial and public buildings numbering in the hundreds of thousands. Older buildings in the United States may still house ACM, and workers may come into contact with dust-producing or "friable" asbestos when performing different activities involved in the renovation, maintenance, or demolition processes (Paustenbach et al., 2004). Workers with higher exposure potential to asbestos include carpenters, joiners, shopfitters, plumbers, gas service engineers, electricians, computer cabling installers, janitors, handymen, demolition workers, and repairers (SLIC, 2006). In a study conducted in 1984, EPA estimated that 20 percent of U.S. commercial and public buildings (>700,000) contain asbestos material in friable form; however, it is unknown how many of these buildings are still standing (U.S. EPA, 1988). The relevant conditions of use for this OES are the industrial/commercial uses of "Construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles" and "Construction and building materials covering large surface areas, including fabrics, textiles, and apparel." Specifically, articles covered under these COUs may be disturbed during maintenance, renovation, and demolition of existing structures, which may lead to occupational exposures to asbestos.

Worker exposures to and environmental releases of asbestos may occur when older buildings are being remodeled or renovated, or when they are being partially or completely demolished. Before remodeling, renovation, and demolition activities begin, the ACM must be removed from the structure. Exposure concerns arise from the disturbance of the ACM during the removal and disposal process. However, worker exposures to asbestos during the construction of new structures, or building additions onto existing structures, are possible but less likely than exposures to asbestos from refurbishing existing structures.

For the purposes of evaluating worker exposure risk in this assessment, workers that may be exposed to asbestos-containing legacy construction materials have been divided into three similar exposure groups (SEGs):

1. Higher Exposure-Potential Workers – workers who may directly generate friable asbestos through actions such as grinding, sanding, cutting, or abrading;
2. Lower Exposure-Potential Workers – workers who may come into direct contact with friable asbestos while performing their required work activities; and
3. ONUs – workers who may be in the vicinity of asbestos but are unlikely to have direct contact with ACM.

Renovation and demolition operations at all sites, with the exception of residential buildings with four or fewer units, are regulated under the Clean Air Act's National Emission Standards for Hazardous Air Pollutants (NESHAP) (U.S. EPA, 1990a). The NESHAP requires the owner or operator of the facility to perform an asbestos inspection of the area being worked on before performing any renovation or demolition to scope out any hazards or ACM. If asbestos is found, a risk assessment is performed and a management plan is created (SLIC, 2006).

When ACM is found in a commercial or public building, the asbestos NESHAP requires at least one person must be on-site that is trained in the work practices specified by the NESHAP, and a contractor specialized in asbestos removal is required to perform the removal. The regulation requires work practices that lower the emission potential for asbestos, such as removing all ACM, adequately wetting all regulated asbestos-containing materials, sealing the material in leak tight containers and disposing of the asbestos-containing waste material as efficiently as possible (U.S. EPA, 1990a).

The asbestos concentrations of common previously used (legacy) asbestos-containing materials that workers may come into contact with when working in older buildings are listed in Table_Apx G-12 below.

Table_Apx G-12. Asbestos Concentrations for Common Legacy Construction Materials

Product Category	Percent	Form of Asbestos	Source
Insulation Products (including spray)	12–100	C, A, Cr	(IPCS, 1986)
Vinyl Floor Tile	5–25	C	(Racine, 2010)
Asbestos-Cement Building Products	10–15	C, A, Cr	(IPCS, 1986)
Asbestos-Cement Pipes	12–15	C, A, Cr	(IPCS, 1986)
Asbestos Millboard	45–98	C	(Banks, 1991)
Insulation Boards	25–40	A and C	(IPCS, 1986)
Textile Products	65–100	C and Cr	(IPCS, 1986)
Roofing Materials	5–10	C	(Lange and Thomulka, 2000b)
C = chrysotile; A = amosite; Cr = crocidolite			

The general process for removing ACM during renovation operations first involves clearing any furniture and materials from the area being renovated. Plastic sheeting is used to cover the walls and create a barrier, and all means of air flow into the area are sealed to create a containment zone (Racine, 2010). The work environment is put under negative pressure and air filtration devices equipped with high-efficiency particulate air (HEPA) filters are positioned in or near the area so that any airborne fibers are captured before being discharged into the environment. ACM is treated with a water and/or wetting agent solution to minimize fiber release. If the material will not absorb the wetting agent, a dry removal using Type C respiratory protection is appropriate (Banks, 1991). After asbestos removal is complete, the ACM is appropriately disposed of and landfilled.

Encapsulation and enclosure are commonly used techniques to prevent friable asbestos from being released during removal or before demolition. Encapsulation involves spraying the ACM with a sealant that either penetrates and hardens the asbestos material or covers the surface of the material with a protective coating. Both types of sealants are applied using airless spray equipment at low pressure to reduce fiber release during application. Enclosure involves the construction of airtight walls and ceilings around the ACM to create a barrier between the ACM and the building environment (*i.e.*, corrugated metal or polyvinyl chloride installed around ACM insulated piping). A combination of encapsulation and enclosure are often required for maximum protection during removal (Banks, 1991). These work practices may have changed since they were reportedly used.

The specific processes for handling and removing different asbestos-containing materials are described below.

Asbestos Insulation

Although insulation manufactured and consumed in the United States presently does not contain asbestos, certain types of insulation used in the 1980s and before contained asbestos at concentrations between 12 and 100 percent (see Table_Apx G-12). General removal activities are described above. Friable ACM is disposed in leak tight containers, typically 6 mil (0.006 in thickness) polyethylene bags, which can be placed in 55-gallon drums for additional protection (Banks, 1991).

In a study for remediation of spray-on asbestos insulation from the ceiling of a large building in Yale, 92 tons of wet ACM was removed during a 20-day operation. A total of 40 workers were involved in the project (Sawyer, 1977). However, this is just one example and may not be representative of the entire industry.

Floor Tile

Vinyl floor tiling manufactured before 1980 may contain asbestos at concentrations from 5 to 25 percent (see Table_Apx G-12). Removal of floor tiles containing asbestos is generally performed using one of two different methodologies.

In the chemical stripping method, general preparation steps are taken to secure the area and the floor is then flooded or misted with water or a wetting agent to decrease the dust load. Tiles are removed using wide wood chisels and hammers or spud bars to pry up tiles without breakage (Perez et al., 2018). Floor tiles are then placed into disposal bags and loaded into a dumpster for delivery to an appropriately licensed landfill. Following floor tile removal, a chemical mastic removal liquid is spread onto the floor and subsequently agitated using a low-speed buffer. An absorbent is applied to the floor and mixed to form a semi-solid, which is then scooped into disposal bags. Lastly, the floor is mopped and allowed to air-dry (Racine, 2010).

The wet grinding methodology shares similar floor preparation steps with the chemical stripping method, but methods of mastic removal differ (Racine, 2010). At the start of the floor tile mastic removal activity, the floor is flooded with water and a small amount of fine sand. A floor tile buffer is fitted with a hard steel mesh disc and applied to the sand and water mixture. Areas not reachable by the buffer such as corners are hand scraped using a wire brush or scratch pad. This process also generates a sludge mixture of the water, sand, and the mastic compound. The sludge is collected and containerized similar to the chemical stripping methodology (Racine, 2010). Floor preparation, tile removal, and the cleanup process can take 2 to 3 days. For protection, workers may wear half-mask respirators and disposable suits (Perez et al., 2018); however, PPE practices may not be consistent throughout industrial and commercial workplaces.

Roofing

Asphalt shingles, plastics, and other roofing materials manufactured before 1980 may contain asbestos at concentrations from 5 to 10 percent (see Table_Apx G-12). Removal of roofing materials containing asbestos is generally performed with adherence to the following practices.

Workers wet the roofing material before and during removal activities. Sections of the roofing materials are cut out using a power saw and placed into a chute connected to a sealed dumpster (Mowat et al., 2007). Water is periodically dumped down the chute and into the dumpster to prevent the ACM from drying.

In one study, work trials were carried out at several sites where 30 to 40 year old ACM-clad buildings were re-roofed or demolished. In these trials, roof replacement was carried out by two to six men working on top of the roof who repetitively unfastened and removed small sections (20–40 m^2) of asbestos-containing roofing and replaced it with steel roofing (Brown, 1988). In these trials, work was conducted for 2 to 6 hours during which 50 to 100 m^2 of roofing was replaced (Brown, 1988). However, this is just one example and may not be representative of the entire industry.

Asbestos Cement (A/C) Pipes

Asbestos Cement (A/C) pipes manufactured before the 1980s may contain asbestos concentrations ranging from 12 to 15 percent (see Table_Apx G-12) and are conventionally remediated in one of three ways: cured-in place pipe (CIPP) lining, removal with open trenching, or the pipe is abandoned in place.

CIPP lining is used on pipes that are still in good condition and will be strong enough to withstand the daily pressures of their intended use. It is sprayed on the interior of unbroken, inline pipes, and is used to extend the useful life of the pipe. Open trenching is the practice under which the entire A/C pipe is excavated and open to the air. After excavation, the A/C pipe is wet-cut into 6- and 8-foot sections using a snap cutter or similar tool, wrapped for containment, and removed for disposal. Asbestos cement pipes may also simply be abandoned in place, with the new pipeline laid in a separate area (U.S. EPA, 2019b).

Demolition

Demolition of older buildings may release fibers from not only friable asbestos but also nonfriable ACM that becomes friable from rough handling. A 1995 study indicated approximately 44,000 commercial buildings are demolished in the United States each year (Perkins et al., 2007). The choice of demolition method depends on the project conditions, site construction, sensitivity of the neighborhood, and availability of equipment (Kakooei and Normohammadi, 2014). For smaller demolition projects, workers may use hand tools, simple electrically or pneumatically powered tools such as picks, hammers, wire cutting and welding cutters to break down the structure. For smaller jobs like this, typically 3 to 5 workers were involved and demolition and removal work took approximately 1 to 2 weeks per site (Kakooei and Normohammadi, 2014). A common and economical method for demolishing one- or two-story buildings is by using heavy equipment to push down the building and move the material inward. For taller buildings, a crane and wrecking ball generally are used to begin the process (Perkins et al., 2007). For some structures, explosives may be used to perform the initial demolition (U.S. EPA, 1990a).

The general demolition process involves workers operating backhoes or front-end loaders to remove the building in manageable pieces, then using the vehicles to break the building pieces down into smaller and more uniform chunks (Perkins et al., 2007). This waste is loaded onto trucks and transported to an approved landfill.

Demolition operations at all sites, with the exception of residential buildings with four or fewer units, are regulated under the asbestos NESHAP. The NESHAP also does not apply to demolition or renovation operations where the minimum amount of material to be disturbed is less than 260 linear feet, 160 square feet, or 35 cubic feet (U.S. EPA, 1990a). NESHAP regulations require that all regulated asbestos containing materials (RACM) be removed prior to demolition. RACM includes all friable ACM and certain types of nonfriable ACM. Nonfriable ACM has two categories under NESHAP. Category I: material such as roofing that is not likely to become friable under demolition (not considered RACM if it is non-friable). Category II nonfriable ACM covers ACM that is likely to become friable during the demolition process (considered to be RACM if there is a high probability of the asbestos becoming friable) (Perkins et al., 2007). ACM may be categorized differently based on the method of demolition used. For example, asbestos-cement may be considered a Category I material if the demolition method will not generate significant damage; however, if a wrecking ball or explosion/implosion techniques are used it can be considered to be a Category II and is subject to the provisions of the NESHAP (U.S. EPA, 1990a).

A 2007 study was conducted on a building demolition and a demolition of a city block that both occurred in Fairbanks, Alaska in the 1990s. Building A was three-stories high and contained asbestos in the form of joint compound in gypsum wallboard (GWB) (2,400 m^2 of wall, 2–3 percent chrysotile in the joint compound), vinyl sheet flooring (560 m^2, 2–3% chrysotile), and popcorn surfacing materials on the ceiling (1,400 m^2, 5% chrysotile). Building A's upper floors were demolished with a wrecking ball and a backhoe and front-end loader were used to demolish the remaining structure. Building A's upper floors totaled 1,120 m^2 of GWB and joint compound (5 to 8 percent chrysotile asbestos). Waste was loaded into dump trucks and set to a landfill; the whole process was completed over 8 days. Block B was primarily demolished using a bulldozer and a front end loader and was completed over 3 days (Perkins et al., 2007). However, this is just one example and is likely not representative of all building demolitions.

G.10.2 Facility Estimates

CDR data were not available for this OES. Therefore, EPA used BLS and SUSB data to estimate the number of establishments and workers. However, employees from one employment establishment may work at many different work sites throughout the year. Therefore, the number of establishments employing the workers is different than the number of sites where exposures and releases occur. EPA assumed that establishments and workers potentially involved in maintenance, renovation, and demolition activities are classified under the applicable NAICS codes listed in Table_Apx G-19.

For estimating the number of sites for the OES, EPA assumed that the highest potential for asbestos exposure to workers while performing demolitions. Literature search data was used to estimate the number of sites by calculating the number of demolitions per year. EPA first calculated the volume of demolition waste generated per year. An EPA report stated that 83,612,000 tons of construction and demolition (C&D) waste was generated in 2003 (U.S. EPA, 2003a). Out of this total, 64,612,000 tons (77%) was commercial waste, and 19,000,000 tons (23%) was residential waste. EPA assumed that this percentage was reflective of all asbestos demolition sites. A more recent report stated that 188,800,000 tons of C&D waste were generated in 2018 (Tiseo, 2022). EPA assumed that the percentage of the wastes from 2018 was the same as from the 2003 EPA report (*i.e.*, 77 percent × 188,800,000 tons of C&D wastes = 145,900,000 tons of commercial C&D wastes and 23 percent × 188,800,000 tons of C&D wastes = 42,900,000 tons of residential C&D wastes).

Next, EPA estimated the amount of waste generated per commercial building demolished. First, EPA compiled information on the surface area of commercial buildings. One literature source stated that there were roughly 5,900,000 commercial buildings in 2018, which had a total square footage of 96.4 billion ft^2, for an average area of 16,300 ft^2 per building (EIA, 2022). Another report found that 158 lb/ft^2 of debris are generated during commercial building demolition (U.S. EPA, 2003a). EPA multiplied the average area of commercial building space by the debris generation factor, resulting in an average of 1,149 tons of C&D waste generated per commercial building demolished. Finally, to obtain the number of commercial demolitions per year, EPA divided the estimated amount of commercial C&D waste, 145,900,000 tons, by the 1,149 tons of waste per commercial building. The same process was repeated for residential demolitions using the corresponding residential building values. This resulted in a total of 106,993 residential building demolitions per year and 126,950 commercial demolitions per year for a total of 233,943 demolition sites per year. To account for the number of buildings containing asbestos, these values were multiplied by 20 percent based on a 1984 U.S. EPA study that estimated 20 percent of buildings contain friable asbestos (U.S. EPA, 1988). The final estimate for the number of sites in this OES is 21,399 commercial demolition sites and 25,390 residential demolition sites, or 46,789 total sites.

G.10.3 Release Assessment

G.10.3.1 Environmental Release Points

EPA expects releases to occur during maintenance, renovation, and demolition activities. As stated in the process description, environmental releases of asbestos may occur when older buildings are being remodeled or renovated, or when they are being partially or completely demolished. Before remodeling, renovation, and demolition activities begin, any ACM must be removed from the structure. Release concerns arise from the disturbance of the ACM during the removal and disposal process.

G.10.3.2 Environmental Release Assessment Results

EPA estimated releases from this OES using TRI, NEI, and NRC data, and literature search data. Based on the data, EPA expects asbestos releases to fugitive air, surface water, and landfill. TRI data were available for water, air, and land disposals, NEI data were available for air emissions, and NRC data were available for wastewater discharges.

Within the NRC data, EPA mapped all four provided data points to the Handling asbestos-containing building materials during maintenance, renovation, and demolition activities OES based on the "Description of Incident" field including demolition, abatement, or piping issues. EPA only included estimates for asbestos releases that reached water sources. Finally, EPA estimated daily emissions for this OES by calculating the 50th and 95th percentile of all reported annual releases and dividing the results by 12 release days/yr determined in Appendix G.4.4.

To estimate land disposals, EPA used a number of other sources identified via literature search due to the large number of demolitions per year and the low number of TRI reporters for demolition. Three literature sources were used to estimate land disposals. One source included a table specifying the surface area of various materials used in building construction (m2), and the average concentration of asbestos in these materials (Zhang et al., 2021). This data is presented in Table_Apx G-13 and Table_Apx G-14.

Table_Apx G-13. Area of Asbestos Waste per Material

Material	Building Type	Area of Asbestos Waste (m^2)
Slate	Residential	9,911
	Commercial	0
Gypsum cement	Residential	1,939
	Commercial	197
Cement/wooden boards	Residential	116
	Commercial	0
Gaskets	Residential	8.58
	Commercial	0

Table_Apx G-14. Average Concentration of Asbestos in Building Materials

Material	Statistic	Concentration (%)
Slate	Average	12.3
	Maximum	16.0
Gypsum cement	Average	5.0
	Maximum	10.0
Cement/wooden boards	Average	10.0
	Maximum	14.0
Gaskets	Average	14.9
	Maximum	15.0

Another two sources provided information on the density (in kg/m2) of these materials (ARGCO, 2022; Ohio University, 2022). This data is presented in Table_Apx G-15.

Table_Apx G-15. Density of Asbestos-Containing Materials

Material	Density (kg/m^2)
Slate roofing (3/8")	73.2
Gypsum Cement	19.5
Wood Shingle	14.6
Gaskets	5.7

To calculate the amount of asbestos per building, the weight per unit area of each material was multiplied by the surface area used in building construction, and the concentration of asbestos in the material. This figure was then divided by the listed values for number of buildings (781) and the percentage of buildings with ACM (34.3%) listed in Zhang et al. (2021) to remain consistent with EPA's original estimates of buildings and percent of buildings containing ACM. Finally, all materials specified in the literature were summed to calculate a total mass of asbestos in building waste in both residential and commercial buildings.

Total annual asbestos land waste was calculated by multiplying the residential and commercial building totals by their respective number of demolitions per year and summing the resulting estimates.
A summary of daily environmental release estimates by media for this OES are provided in Table 3-8. In addition, Table_Apx G-16, Table_Apx G-17, and Table_Apx G-18 below present a summary of annual and daily releases estimates to water, air, and land, respectively. For the raw data set used in making these estimations, see *Asbestos Part 2 RE - Environmental Release and Occupational Exposure Data Tables – November 2024* (U.S. EPA, 2023b).

Table_Apx G-16. Wastewater Discharge Summary for Maintenance, Renovation, and Demolition Activities

Annual Wastewater Discharges (kg/site-year)		Number of Operating Days	Daily Wastewater Discharges (kg/site-day)	
Central Tendency	High-End		Central Tendency	High-End
1.4	45	12	0.11	4

Table_Apx G-17. Air Emission Summary for Maintenance, Renovation, and Demolition Activities

Annual Fugitive Emissions (kg/site-year)		Annual Stack Emissions (kg/site-year)		Number of Operating Days	Daily Fugitive Emissions (kg/site-day)		Daily Stack Emissions (kg/site-day)	
Central Tendency	High-End	Central Tendency	High-End		Central Tendency	High-End	Central Tendency	High-End
9.1E−03	1.8	N/A	N/A	12	7.6E−04	0.15	N/A	N/A

Table_Apx G-18. Land Release Summary for Maintenance, Renovation, and Demolition Activities

Annual Land Disposals (kg/site-year)		Number of Operating Days	Daily Land Disposals (kg/site-day)	
Central Tendency	High-End		Central Tendency	High-End
4,935	9,764	12	411	814

Strengths, Limitations, Assumptions, and Uncertainties

The primary strength of these estimates is that EPA used multiple years of data in the analysis. A strength of TRI data is that TRI compiles the best readily available release data for all reporting facilities. A strength of NEI data is that it includes comprehensive and detailed estimates of air emissions from point and area sources. A strength of NRC data is that it is the designated federal point of contact for reporting all spills of CERCLA hazardous chemicals, such as asbestos, so it is likely to be a comprehensive data set. A strength of literature search data is that all the underlying literature sources received data quality ratings of medium or higher. The primary limitation to this assessment is that information on the conditions of use of asbestos at facilities in TRI & NEI is limited, and NRC does not provide the condition of use of asbestos at facilities. Additional limitations include the uncertainty in the mapping of reporting sites to the OES, as well as uncertainty in assumptions about the number of operating days.

Some assumptions that were made in this release assessment include the assumption that the literature data sufficiently represent all maintenance, renovation, and demolition activities, and that all releases take place uniformly over time, as opposed to all at once or at varying intensities. Assessing environmental releases using TRI, NEI, and NRC data presents various sources of uncertainty. TRI data are self-reported and have reporting requirements that exclude certain facilities from reporting. Facilities are only required to report to TRI if the facility has 10 or more full-time employees, is included in an applicable NAICS code, and manufactures, processes, or uses the chemical in quantities greater than a certain threshold (25,000 lb for manufacturers and processors and 10,000 lb for users). NEI reporting of hazardous air pollutants, such as asbestos, is voluntary. Therefore, NEI may not include data from all emission sources. In NRC data, spill quantities are often estimated or unknown. It is also possible that not all spill incidents are reported to the NRC such that the available data likely does not encompass all spill related releases of asbestos. An overall uncertainty in this assessment is that information on the conditions of use of asbestos at facilities in TRI & NEI is limited, and NRC does not provide the condition of use of asbestos at facilities.

G.10.4 Occupational Exposure Assessment

G.10.4.1 Worker Activities

During maintenance, renovation, and demolition activities, workers are potentially exposed during various activities, including

- inspecting buildings for asbestos-containing materials (ACM),
- removing loose asbestos or ACM,
- working in the vicinity of friable asbestos, and
- handling demolition waste that may contain asbestos.

According to OSHA CFR 1910.1001, workers that handle asbestos are expected to wear proper chemical-specific PPE. Workers typically wear coveralls, face shields, and respirators. Local exhaust ventilation (LEV) and dust collection systems should be in place to control emissions, and LEV systems should be installed on any tools that have potential to release asbestos fibers, such as saws, scorers, or drills (OSHA, 2019). EPA did not find information that indicates the extent that engineering controls and worker PPE are used at sites that may contain ACM in the United States.

When ACM is found in a commercial or public building, a contractor specialized in asbestos removal is required to perform the removal. Regulation requires work practices that lower the emission potential for asbestos, such as removing all asbestos-containing materials, adequately wetting all regulated asbestos-containing materials, sealing the material in leak tight containers and disposing of the asbestos-containing waste material as efficiently as possible (U.S. EPA, 1990b).

As stated in the process descriptions above, workers for this OES were separated into three SEGs: Higher Exposure-Potential Workers, Lower Exposure-Potential Workers, and ONUs. Workers in these similar exposure groups have different job functions and are therefore expected to have different levels of potential exposure to friable asbestos. Because of this, their inhalation exposure risks are assessed separately.

Higher exposure-potential workers are those that may directly generate friable asbestos through actions such as grinding, sanding, cutting, or abrading ACM during maintenance or removal activities. Higher exposure-potential workers include asbestos abatement contractors, maintenance workers, carpenters, insulation workers, roofers, and floor/tile installers. Lower exposure-potential workers are not expected to generate friable asbestos but may come into direct contact with friable asbestos while performing their required work activities. Examples of lower exposure-potential workers are laborers, electricians, plumbers, and masonry workers.

ONUs include employees that may be in the vicinity of asbestos but are unlikely to have direct contact with ACM; ONUs are therefore expected to have lower inhalation exposures than other workers. ONUs for this scenario include supervisors, managers, and other bystanders that may be in the area but do not perform tasks that result in the same level of exposure as those workers that engage in tasks related to removal or handling of asbestos.

G.10.4.2 Number of Workers and Occupational Non-users

To estimate the number of workers potentially exposed per establishment, EPA analyzed information from BLS and 2019 data from the U.S. Census Bureau for the NAICS codes presented in Table_Apx G-19.

Table_Apx G-19. Number of Employees and Establishments for Relevant NAICS Codes for Maintenance, Renovation, and Demolition Activities

Industry	NAICS Description	Total Firms	Total Establishments	Total Employees	Avg. Employees per Est.
236118	Residential Remodelers	114,459	114,874	387,534	3
236115	New Single-Family Housing Construction (except For-Sale Builders)	54,532	54,735	198,946	4
236220	Commercial and Institutional Building Construction	38,130	39,368	623,672	16
237110	Water and Sewer Line and Related Structures Construction	10,578	10,773	155,472	14
237120	Oil and Gas Pipeline and Related Structures Construction	1,870	2,194	238,217	109
237130	Power and Communication Line and Related Structures Construction	5,329	6,371	246,711	39
238130	Framing Contractors	11,954	11,976	86,120	7
238140	Masonry Contractors	18,391	18,507	143,032	8
238160	Roofing Contractors	20,945	21,197	192,877	9
238210	Electrical Contractors and Other Wiring Installation Contractors	74,649	76,328	904,453	12
238220	Plumbing, Heating, and Air-Conditioning Contractors	101,408	103,359	1,099,138	11
238310	Drywall and Insulation Contractors	18,864	19,457	270,144	14
238330	Flooring Contractors	16,824	17,034	83,136	5
238350	Finish Carpentry Contractors	30,961	31,191	157,665	5
238910	Site Preparation Contractors (Demolition)	37,102	37,491	407,175	11
238990	All Other Specialty Trade Contractors	35,318	35,734	254,374	7
561720	Janitorial Services	58,011	62,592	1,096,144	18
561790	Other Services to Buildings and Dwellings	14,689	14,841	74,894	5
562910	Remediation Services	4,120	5,044	86,224	17

These data indicate that there are, on average, five workers and two ONUs per contractor establishment within these NAICS codes, see Appendix G.5.2 for more information on this estimation process (U.S. BLS, 2016). According to a 1984 survey conducted by EPA, about 20 percent of all buildings contain asbestos (U.S. EPA, 1988). Assuming 250 workdays per year and a fraction of exposure to asbestos-containing materials of 0.20, the exposure frequency for the OES is 50 days per year.

Table_Apx G-20. Estimated Number of Workers Potentially Exposed to Asbestos During Maintenance, Renovation, and Demolition Activities

Number of Establishments [a]	Exposed Workers per Establishment	Exposed ONUs per Establishment	Total Exposed Workers[a]	Total Exposed ONUs[a]	Total Exposed[a]
6.8E05	5	2	3.7E06	1.2E06	4.8E06
[a] Totals have been rounded to two significant figures; totals may not add exactly due to rounding.					

G.10.4.3 Occupational Exposure Results

When performing different activities involved in the maintenance, renovation, or demolition, workers may come into contact with asbestos-containing construction materials that were manufactured or imported into the U.S. and subsequently used in the construction of commercial and public buildings (Paustenbach et al., 2004). The information and data quality evaluation to assess occupational exposures during maintenance, renovation, or demolition activities is listed in Table_Apx G-4.

Occupational exposures to asbestos during maintenance, renovation, or demolition activities were estimated by evaluating PBZ samples from OSHA's CEHD (OSHA, 2020) along with various literature studies (see Table_Apx G-4). The samples included 981 measurements reported as 8-hour TWAs and 151 measurements reported as short-term samples, split amongst the three SEGs using information provided by NAICS and SIC codes associated with the data. A total of 200 of the 8-hour TWAs from the OSHA CEHD were measured as non-detects for asbestos and 8-hour TWAs were calculated using the asbestos LOD of 2,117.5 fibers/sample from NIOSH Method 7400. These data are shown in *Asbestos Part 2 RE - Environmental Release and Occupational Exposure Data Tables – November 2024* (U.S. EPA, 2023b).

EPA calculated the 95th percentile and 50th percentile of the available 981 TWA data points for inhalation exposure monitoring data to assess the high-end and central tendency exposures, respectively. Because the geometric standard deviation of the data set was greater than three for the worker inhalation exposure samples, EPA used half the detection limit for the non-detect values in the central tendency and high-end exposure calculations based on EPA's *Guidelines for Statistical Analysis of Occupational Exposure Data* (U.S. EPA, 1994). Using these 8-hour TWA exposure concentrations, EPA calculated the ADC for each SEG.

Only one sample was found to measure short-term inhalation exposure to ONUs. That sample was used to make a high-end estimate and the central tendency was estimated at half of the high-end estimate. These inhalation exposures are summarized for the three SEGs in Table_Apx G-21, Table_Apx G-22, and Table_Apx G-23 Additional information regarding the ADC calculation is provided in Appendix G.5.4.1.

Table_Apx G-21. Summary of Inhalation Monitoring Data for Maintenance, Renovation, and Demolition Activities for Higher-Exposure Potential Workers

Exposure Concentration Type	High-End (f/cc)	Central Tendency (f/cc)	Number of Samples	Data Quality Rating of Air Concentration Data	Weight of Scientific Evidence
8-hour TWA exposure concentration	0.43	1.1E−03	847	High	Moderate
Chronic, non-cancer ADC[a]	2.0E−02	5.1E−05			
30-minute short-term exposure concentration	0.16	2.5E−02	145	High	Moderate

[a] The Average Daily Concentration (ADC) presented here is based on 8-hour TWA monitoring data. Short-term ADC estimates are calculated using the 30-minute exposure concentrations presented here, averaged with 7.5 hours at the full shift (*i.e.*, 8-hour TWA) exposure concentrations.

Table_Apx G-22. Summary of Inhalation Monitoring Data for Maintenance, Renovation, and Demolition Activities for Lower-Exposure Potential Workers

Exposure Concentration Type	High-End (f/cc)	Central Tendency (f/cc)	Number of Samples	Data Quality Rating of Air Concentration Data	Weight of Scientific Evidence
8-hour TWA exposure concentration	0.22	1.1E−03	31	High	Moderate
Chronic, non-cancer ADC[a]	1.0E−02	5.1E−05			
30-minute short-term exposure concentration	2.5E−02	2.5E−02	5	High	Moderate

[a] The Average Daily Concentration (ADC) presented here is based on 8-hour TWA monitoring data. Short-term ADC estimates are calculated using the 30-minute exposure concentrations presented here, averaged with 7.5 hours at the full shift (*i.e.*, 8-hour TWA) exposure concentrations.

Table_Apx G-23. Summary of Inhalation Monitoring Data for Maintenance, Renovation, and Demolition Activities for ONUs

Exposure Concentration Type	High-End (f/cc)	Central Tendency (f/cc)	Number of Samples	Data Quality Rating of Air Concentration Data	Weight of Scientific Evidence
8-hour TWA exposure concentration	4.6E−02	1.2E−02	103	High	Moderate
Chronic, non-cancer ADC[a]	2.1E−03	5.6E−04			
30-minute short-term exposure concentration	5.3E−02	2.7E−02	1	High	Moderate

[a] The Average Daily Concentration (ADC) presented here is based on 8-hour TWA monitoring data. Short-term ADC estimates are calculated using the 30-minute exposure concentrations presented here, averaged with 7.5 hours at the full shift (*i.e.*, 8-hour TWA) exposure concentrations.

Strengths, Limitations, Assumptions, and Uncertainties
The primary strength of this assessment is the use of a large number of directly applicable monitoring data, which is preferrable to other assessment approaches such as modeling or the use of occupational exposure limits. However, the OSHA CEHD monitoring data does not include process information or worker activities; therefore, there is uncertainty as to which worker activities these data cover and whether all potential workers activities are represented in this data. Additionally, these data are from a wide variety of facility types, and it is unclear how representative the data are for all sites and all workers across the United States. Differences in work practices and engineering controls across sites can introduce variability and limit the representativeness of any one site relative to all sites. Also, as discussed above, EPA used half the detection limit for the non-detect values in the central tendency and high-end exposure calculations. This introduces uncertainty into the assessment because the true value of asbestos is unknown (though expected to be between zero and the level of detection).

G.11 Handling Asbestos-Containing Building Materials During Firefighting or Other Disaster Response Activities

G.11.1 Process Description

As discussed above, various construction materials found in older buildings may contain asbestos. The relevant conditions of use for this OES are the industrial/commercial uses of “construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass, and ceramic articles” and “construction and building materials covering large surface areas, including fabrics, textiles, and apparel.” Specifically, articles covered under these COUs may be damaged during a disaster and then subsequently disturbed during the firefighting or disaster response activities, which may lead to occupational exposures to asbestos.

Firefighting procedures depend on the type and severity of the fire. The general procedure for firefighting involves entry and ventilation of the burning structure, rescue of occupants, extinguishing of the fire and/or knockdown of the structure (IARC, 2010). Disaster cleanup entails removing damaged structures and/or debris from the aftermath of natural disasters (*e.g.,* earthquakes, fires, floods) or unforeseen manmade disasters (*e.g.,* explosions, bombings). The general disaster cleanup process involves workers operating backhoes or front-end loaders to remove debris and break it down into manageable chunks. This waste is loaded onto trucks and transported to an approved landfill (Perkins et al., 2007).

Building debris handled by disaster response crews may be a solid in the form of insulation, roofing, tiles, and any other structural component of the destroyed building. Often, a primary source of asbestos exposure comes from fibers in settled dust from the fire or disaster that is stirred up by disaster response activities (Landrigan et al., 2004). In one study, debris samples collected outside buildings and on cars downwind from “ground zero” of the September 11, 2001, World Trade Center (WTC) attacks contained 2.1 to 3.3 percent asbestos (Vitello, 2001). EPA did not find any chemical-specific throughputs for the quantity of asbestos handled during disaster response activities.

Firefighting and disaster response activities do not have a consistent operating schedule, as they are performed only as necessary. However, studies provide statistics on activity durations of firefighters. One study cites that firefighter exposure duration to contaminants during cleanup of debris from the WTC attacks lasted anywhere between 1 to 75 days per year (Szeinuk et al., 2008). However, it should be noted that the attack on the WTC is an unusual and extreme example of disaster-response activities. Another study reported that firefighters work 10- to 24-hour shifts for 188 days per year (IARC, 2010).

G.11.2 Facility Estimates

CDR data was not available for this OES. The number of employment establishments is based on NFPA reported data for the number of fire departments (NFPA, 2022b). The report shows 2,785 all-career; 2,459 mostly-career; 18,873 all-volunteer; and 5,335 mostly-volunteer fire/disaster response departments. However, workers from one department may work at several fire/disaster sites each year, and therefore the number of establishments for the OES is different than the number of sites where exposures and releases occur.

For determining the number of sites of exposures and releases, EPA used literature search data to estimate the number of structural fires per year that contain asbestos. A report from the NFPA found that 489,600 structure fires happen each year (NFPA, 2022a). Therefore, to estimate the number of sites, this figure was multiplied by 20 percent, per the ratio of buildings containing friable asbestos per a 1984 EPA survey (U.S. EPA, 1988). The final estimate is 97,920 sites containing asbestos that undergo fire or disaster each year.

G.11.3 Release Assessment

G.11.3.1 Environmental Release Points

EPA expects releases to occur during handling of asbestos-containing building materials during firefighting or other disaster response activities. Release concerns arise from the disturbance of ACM during disaster cleanup. Specific activities that may generate environmental releases include firefighting, operating backhoes to remove debris, and loading debris onto trucks (Perkins et al., 2007).

G.11.3.2 Environmental Release Assessment Results

For air, water, and land disposals, EPA assumed that the releases from an uncontrolled fire or other asbestos clean up would be similar to the releases from demolition. Therefore, EPA estimated annual releases using surrogate data from the literature search data, NRC, or TRI/NEI data for the maintenance, renovation, and demolition OES. Then, EPA estimated daily releases by dividing the annual releases by the number of operating days determined for this OES, which is different than that of the previous OES, resulting in different daily land disposal estimates.

A summary of daily environmental release estimates by media for this OES are provided in Table 3-8. In addition, Table_Apx G-24, Table_Apx G-25, and Table_Apx G-26 below present a summary of annual and daily releases estimates to water, air, and land, respectively. For the raw data set used in making these estimations, see *Asbestos Part 2 RE - Environmental Release and Occupational Exposure Data Tables – November 2024* (U.S. EPA, 2023b).

Table_Apx G-24. Wastewater Discharge Summary for Handling Asbestos-Containing Building Materials During Firefighting or Other Disaster Response Activities

Annual Wastewater Discharges (kg/site-year)		Number of Operating Days	Daily Wastewater Discharges (kg/site-day)	
Central Tendency	High-End		Central Tendency	High-End
1.4	45	1	1.4	45

Table_Apx G-25. Air Emission Summary for Handling Asbestos-Containing Building Materials During Firefighting or Other Disaster Response Activities

Annual Fugitive Emissions (kg/site-year)		Annual Stack Emissions (kg/site-year)		Number of Operating Days	Daily Fugitive Emissions (kg/site-day)		Daily Stack Emissions (kg/site-day)	
Central Tendency	High-End	Central Tendency	High-End		Central Tendency	High-End	Central Tendency	High-End
9.1E−03	1.8	N/A	N/A	1	9.1E−03	1.8	N/A	N/A

Table_Apx G-26. Land Release Summary for Handling Asbestos-Containing Building Materials During Firefighting or Other Disaster Response Activities

Annual Land Disposals (kg/site-year)		Number of Operating Days	Daily Land Disposals (kg/site-day)	
Central Tendency	High-End		Central Tendency	High-End
4,935	9,764	1	4,935	9,764

Strengths, Limitations, Assumptions, and Uncertainties

Even though surrogate data was used, a strength of this assessment is that the surrogate sources fall under monitoring/measured data, which is most preferred based on the hierarchy of approaches. A limitation of this assessment includes the lack of OES-specific data. EPA assumed that the releases from the surrogate OES are representative of this OES. In addition to having the same strengths, limitations, assumptions, and uncertainties as the surrogate OES, the use of surrogate data may introduce uncertainties related to the extent to which the surrogate OES and the OES being assessed are similar.

G.11.4 Occupational Exposure Assessment

G.11.4.1 Worker Activities

During firefighting or other disaster-response activities, workers are potentially exposed while performing the following activities:

- responding to fires in buildings for asbestos-containing materials (ACM),
- removing loose asbestos or ACM,
- working in the vicinity of friable asbestos, and
- handling building waste that may contain asbestos.

Worker activities for this occupational exposure scenario are based on firefighting activities, as disaster response activities are expected to be similar to those for firefighting. The general procedure for firefighting involves entry and ventilation of the burning structure, rescue of occupants, extinguishing of the fire and/or knockdown of the structure (IARC, 2010). Firefighters may be exposed to asbestos by performing any of these activities when responding to fires in buildings that contain asbestos.

There are two general phases in municipal structural firefighting: knockdown and overhaul. During knockdown, firefighters control and extinguish the fire. Municipal structural fires are either extinguished within 5 to 10 minutes or abandoned and fought from the outside. During overhaul, any remaining small fires are extinguished (IARC, 2010). When responding to an active fire, firefighters employ a personal protective ensemble that covers the entire body with a self-contained breathing apparatus (SCBA) system providing breathable air; however, they do not always wear SCBA during exterior operations (deploying hoses, forcible entry) or during overhaul operations (Fent et al., 2015).

G.11.4.2 Number of Workers and Occupational Non-users

Due to limited information found in the BLS data, the number of workers and establishments for firefighting and other disaster response activities were estimated using data from the National Fire Protection Association (NFPA) (NFPA, 2022b). The survey provides an estimate for the number of career firefighters at 364,300 and volunteer firefighters at 676,900.

The NFPA survey also indicates that departments with "All Volunteer" and "Mostly Volunteer" (24,208 departments total) handle firefighting for 30 percent of the population and that departments with "Mostly Career" and "All Career" (5,244 departments total) handle firefighting for 70 percent of the population. Based on this, EPA assumes that career firefighters handle 70 percent of structure fires and volunteer firefighters handle 30 percent of structure fires. This equates to an estimate of 69 career firefighters and 28 volunteer firefighters per department.

EPA generally assumes career and volunteer firefighters have relatively equal exposure potential. EPA also assumes that firefighters work 250 days/year; however, a firefighter would not be exposed to asbestos every workday. Instead, each firefighter responds to a certain number of structure fires each year, each with an estimated 20 percent chance of containing asbestos. NFPA estimates that there are 10 to 16 firefighters/structure fire for suburban and urban areas and 4 to 6 firefighters/structure fire for smaller areas (NFPA, 2012). EPA assumes that career firefighters are stationed in higher density areas and volunteer firefighters cover lower density areas; therefore, career firefighters respond in teams of 10 to 16 and volunteers may respond in teams of 4 to 6. EPA assumes that all workers engaged in firefighting and disaster response activities are potentially subject to high levels of exposure; therefore, ONUs are not considered as a worker category for this OES.

Table_Apx G-27. Estimated Number of Workers Potentially Exposed to Asbestos During Firefighting or Other Disaster Response Activities

Number of Departments[a]	Exposed Career Firefighters per Department	Exposed Volunteer Firefighters per Department	Total Exposed Career Firefighters[a]	Total Exposed Volunteer Firefighters[a]	Total Exposed[a]
2.4E04	N/A	28	N/A	6.8E05	1.0E06
5.2E03	69	N/A	3.6E05	N/A	

[a] Totals have been rounded to two significant figures. Totals may not add exactly due to rounding.

G.11.4.3 Occupational Exposure Result

Firefighters and other disaster responders may come into contact with asbestos-containing construction materials that were used in the construction of commercial and public buildings when responding to fires at these buildings. The information and data quality evaluation to assess occupational exposures during firefighting and other disaster response activities is listed in Table_Apx G-4.

Occupational exposures to asbestos during firefighting and other disaster response activities were estimated by evaluating PBZ samples from four literature studies (see Table_Apx G-4). One source gathered 636 phase contrast microscopy (PCM) and 114 transmission electron microscopy (TEM) air samples for disaster workers responding to the World Trade Center on September 11, 2001; however, the source only provided the minimum and maximum asbestos concentrations from the two groups of samples. EPA therefore assessed the minimum and maximum for the PCM samples and the maximum for the TEM samples; the minimum TEM sample was omitted because it was below the LOD but the source did not provide the LOD for the sampling method (Wallingford and Snyder, 2001).

Two sources collected a total of 62 PBZ inhalation exposure samples during debris cleanup after fires (Beaucham and Eisenberg, 2019; Lewis and Curtis, 1990). Another source provided two ranges of sampling data that covered 33 PCM data points and three ranges of sampling that covered 45 TEM data points, each of these ranges covered a 6- to 10-day sampling period (Breysse et al., 2005). Because the discrete samples were not provided in the study, EPA used the minimums and maximums from each range in the assessment. Of the 62 PBZ samples collected from these four sources, three were non-detect and an LOD was used to estimate the asbestos concentration of the sample. The authors of the data studies provided the LOD for two of the points, while the non-detect from Wallingford & Snyder was calculated by EPA assuming that NIOSH 7400 was used to analyze PCM samples (Wallingford and Snyder, 2001).

To calculate the number of fires responded to by each worker per year and therefore, the number of potential exposure days per year, EPA considers all career firefighters (364,300 career firefighters) in teams of 10 responding to 70 percent of all annual structure fires (342,720 fires), which equates to approximately 10 fires/team/year. Assuming teams of 16, that would be approximately 15 fires/team/year. EPA estimates that career firefighters experience 10 to 15 structure fires/worker/year. Only 20 percent of those occurrences would be expected to contain ACM, so 2 to 3 ACM structure fires/worker/year. Estimating all volunteer firefighters (676,900 volunteers) working in teams of 4 to 6 and responding to 30 percent of all annual structure fires (146,880 fires) equates to 1 to 2 structure fires/volunteer/year, with only 20 percent being ACM-related. Therefore, EPA assumes a high-end estimate of 1 ACM structure fire/volunteer/year.

EPA calculated the 95th percentile and 50th percentile of the available 62 data points for inhalation exposure monitoring data to assess the high-end and central tendency exposures, respectively. Using these 8-hour TWA exposure concentrations, EPA calculated the ADC. Inhalation exposure estimates are summarized in Table_Apx G-28 and Table_Apx G-29 Additional information regarding the ADC calculation is provided in Appendix G.5.4.

Table_Apx G-28. Summary of Inhalation Monitoring Data for Firefighting and Other Disaster Response Activities for Career Firefighters

Exposure Concentration Type	High-End (f/cc)	Central Tendency (f/cc)	Number of Samples	Data Quality Rating of Air Concentration Data	Weight of Scientific Evidence
8-hour TWA Exposure Concentration	0.39	2.0E−02	62	High	Moderate to Robust
Chronic, Non-cancer ADC[a]	1.1E−03	5.5E−05			
30-min Short-Term Exposure Concentration	–	–			

[a] The average daily concentration (ADC) presented here is based on 8-hour TWA monitoring data. Short-term exposure data were not available for this scenario.

Table_Apx G-29. Summary of Inhalation Monitoring Data for Firefighting and Other Disaster Response Activities for Volunteer Firefighters

Exposure Concentration Type	High-End (f/cc)	Central Tendency (f/cc)	Number of Samples	Data Quality Rating of Air Concentration Data	Weight of Scientific Evidence
8-hour TWA Exposure Concentration	0.39	2.0E−02	62	High	Moderate to Robust
Chronic, Non-cancer ADC[a]	3.5E−04	1.8E−05			
30-min Short-Term Exposure Concentration	–	–			

[a] The average daily concentration (ADC) presented here is based on 8-hour TWA monitoring data. Short-term exposure data were not available for this scenario.

Strengths, Limitations, Assumptions, and Uncertainties

The primary strength of the data used for this assessment is the use of directly applicable monitoring data, which is preferrable to other assessment approaches such as modeling or the use of occupational exposure limits. An additional strength is that the literature sources include information on worker activities. The data from these four studies only cover a narrow selection of building/structure fires, and it is unclear how representative the data are for all disaster response sites and all disaster response workers across the United States. Differences in work practices and engineering controls across sites can introduce variability and limit the representativeness of any one site relative to all sites. Two of the sources only provided ranges for their data sets, potentially reducing the usefulness of the data and the accuracy of the exposure estimates. There is also uncertainty in EPA's assumption of exposure frequency and exposure duration.

G.12 Use, Repair, or Removal of Industrial and Commercial Appliances or Machinery Containing Asbestos

G.12.1 Process Description

Various industrial and commercial appliances and machinery may contain asbestos. The asbestos may be present in reinforced plastics, industrial brake and gear clutches, and packing seals within machinery. Workers may come into contact with these materials in friable forms during use, repair, or removal of the appliances and machinery containing asbestos. In general, repair of appliances containing asbestos consists of disassembly of the machinery, replacement and/or repair of individual parts, and reassembly of the machinery. Often, asbestos-containing components of the machinery are replaced with components that do not contain asbestos, and the asbestos waste or debris is disposed of (Mlynarek and Van Orden, 2012). Friable ACM must be disposed of in leak tight containers (*e.g.*, 6 mil polyethylene bags). Bags can be placed in 55-gallon drums for additional protection (Banks, 1991).

Brake linings and gaskets are some of the most common machinery parts that contain asbestos. During brake repair and removal, the brakes are disassembled by removing the brake housing using a manual or power wrench to loosen bolts holding the housing in place. Then, the entire brake apparatus is removed from the machinery. Compressed air is used to clear the brake of any dusts and debris which may contain asbestos. Last, the brake linings are removed from the brakes (Madl et al., 2009). During gasket and valve repair and removal, mechanics remove gaskets with a scraper and use a brush to clean remaining residue from the surface (Liukonen and Weir, 2005). Installed gaskets typically remain in operation anywhere from a few weeks to 3 years; the timeframe before being replaced is largely dependent upon the temperature and pressure conditions (ACC, 2017), whether due to detected leaks or as part of a routine maintenance campaign. Used asbestos containing gaskets are handled as regulated non-hazardous material and are immediately bagged after removal from process equipment and then placed in containers designated for asbestos containing waste. There are legacy gaskets that may contain asbestos; however, occupational exposures to gaskets containing asbestos were covered in *Risk Evaluation for Asbestos Part 1: Chrysotile Asbestos* (U.S. EPA, 2020c) and no further analysis was necessary here for legacy gaskets.

Asbestos-containing materials in industrial or commercial appliances and machinery may be in solid form, sometimes in blocks or sheets (Scarlett et al., 2012; Mancuso, 1991). Table_Apx G-30 provides common asbestos-containing materials to which workers may be exposed, along with the associated asbestos concentrations of the ACM. EPA did not find any chemical-specific volumes for asbestos handled during the use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos.

Table_Apx G-30. Legacy Asbestos Concentrations for Common Appliance and Machinery Components

Product Category	Percentage	Form of Asbestos	Source
Friction Materials	15–70	C	(IPCS, 1986)
Molded Plastics and Battery Boxes	55–70	C and Cr	(IPCS, 1986)
Jointings and Packings	25–85	C and Cr	(IPCS, 1986)
Fillers	25–98	C and Cr	(IPCS, 1986)
Lagging	9–96	C and A	(Scansetti et al., 1993)
Machinery Insulation	15–60	C and A	(Standard Oil, 1981)
C = Chrysotile; A = Amosite; Cr = Crocidolite			

EPA did not identify data on site operating schedules; therefore, EPA assumes 250 days/yr of operation. However, sources report that the lifespan of furnace linings and other asbestos-containing machinery linings can range from approximately 400 to 600 heats. In addition, the length of time that a furnace operates once it is fully heated is typically 6 to 7 years, and up to 10 years, after which time the furnace is shut down and is relined (Hollins et al., 2019). It is assumed that industrial workers would be primarily exposed to the asbestos while replacing the lining once every 6 to 10 years. Exposure frequencies for workers may be higher for other types of appliances or machinery.

G.12.2 Facility Estimates

CDR data were not available for this OES. Therefore, EPA used BLS and SUSB data to estimate the number of establishments. Because it is assumed that employees work only at the employment establishment, the number of establishments is considered equal to the number of sites for this OES. EPA assumed that establishments involved in the use, repair, or removal of industrial or commercial appliances or machinery containing asbestos are classified under the applicable NAICS codes 324110 (Petroleum Refineries), 325199 (All Other Basic Organic Chemical Manufacturing), and 423830 (Industrial Machinery and Equipment Merchant Wholesalers). Based on the 2021 County Business Patterns data published by the U.S. Census Bureau, there are 29,211 establishments classified under these NAICS codes. This provides a high-end bounding estimate for the number of sites for this OES.

G.12.3 Release Assessment

G.12.3.1 Environmental Release Points

EPA expects releases to occur during the use, repair, or removal of industrial and commercial appliances or machinery containing asbestos. As stated in the process description, asbestos may be present in gaskets, reinforced plastics, industrial brake and gear clutches, and packing seals. Specific activities that may generate environmental releases include disassembly of machinery, replacement and/or repair of individual parts, and reassembly of machinery.

G.12.3.2 Environmental Release Assessment Results

EPA estimated releases from this OES using TRI and NEI data, as described in Appendix G.4. TRI data were available for water, air, and land disposals, NEI data were available for air emissions. EPA estimated daily emissions for this OES by calculating the 50th and 95th percentile of all reported annual releases and dividing the results by 250 release days/yr determined in Appendix G.4.4.
Based on the available data, EPA expects asbestos releases to air (fugitive and stack) and landfills. However, EPA does not expect wastewater discharges, as there were no reported wastewater discharges in the 2016 to 2020 TRI data associated with this OES. There may be incidental discharges of asbestos, however EPA expects those releases to be low and occur infrequently.

A summary of daily environmental release estimates by media for this OES are provided in Table 3-8. In addition, Table_Apx G-31 and Table_Apx G-32 below present a summary of annual and daily releases estimates to air and land, respectively. For the raw data set used in making these estimations, see *Asbestos Part 2 RE - Environmental Release and Occupational Exposure Data Tables – November 2024* (U.S. EPA, 2023b).

Table_Apx G-31. Air Emission Summary for Use, Repair, or Removal of Industrial and Commercial Appliances or Machinery

Annual Fugitive Emissions (kg/site-year)		Annual Stack Emissions (kg/site-year)		Number of Operating Days	Daily Fugitive Emissions (kg/site-day)		Daily Stack Emissions (kg/site-day)	
Central Tendency	High-End	Central Tendency	High-End		Central Tendency	High-End	Central Tendency	High-End
2.3E−02	23	0	1.6E−02	250	9.1E−05	9.0E−02	0	6.6E−05

Table_Apx G-32. Land Release Summary for Use, Repair, or Removal of Industrial and Commercial Appliances or Machinery

Annual Land Disposals (kg/site-year)		Number of Operating Days	Daily Land Disposals (kg/site-day)	
Central Tendency	High-End		Central Tendency	High-End
16,804	156,703	250	67	627
[a] Total land disposals include the following land disposal methods: RCRA Subtitle C Landfills, Other on-site landfills, Other off-site landfills, Other land disposal, and Other off-site management				

Strengths, Limitations, Assumptions, and Uncertainties

The primary strength of these estimates is that EPA used multiple years of data in the analysis. A strength of TRI data is that TRI compiles the best readily available release data for all reporting facilities. A strength of NEI data is that it includes comprehensive and detailed estimates of air emissions from point and area sources. The primary limitation to this assessment is that information on the conditions of use of asbestos at facilities in TRI and NEI is limited. Additional limitations to this assessment include the assumptions on the number of operating days to estimate daily releases, the assumption of no wastewater discharges (as reported in TRI), and the uncertainty in the mapping of reporting facilities to this OES.

For purposes of release assessment, it is assumed that the included data sufficiently represent all OES activities and that all releases take place uniformly over time, as opposed to all at once or at varying intensities. Another assumption is that the distribution created from the reporting sites is representative of all non-reporting sites. Assessing environmental releases using TRI and NEI data presents various sources of uncertainty. TRI data are self-reported and have reporting requirements that exclude certain facilities from reporting. Facilities are only required to report to TRI if the facility has 10 or more full-time employees, is included in an applicable NAICS code, and manufactures, processes, or uses the chemical in quantities greater than a certain threshold (25,000 lb for manufacturers and processors and 10,000 lb for users). NEI reporting of hazardous air pollutants, such as asbestos, is voluntary. Therefore, NEI may not include data from all emission sources. There is uncertainty in EPA's assumption of no wastewater discharges for this OES, as there could be more sites that dispose of/treat asbestos waste that are below the TRI reporting thresholds.

G.12.4 Occupational Exposure Assessment

G.12.4.1 Worker Activities

As stated above, various industrial and commercial appliances and machinery may contain asbestos. The asbestos may be present in gaskets, reinforced plastics, industrial brake and gear clutches, and packing seals within machinery. Workers may come into contact with these asbestos in friable forms during use, repair, or removal of the appliances and machinery that contain asbestos. In general, repair of appliances containing asbestos consists of disassembly of the machinery, replacement and/or repair of individual parts, and reassembly of the machinery. Often, asbestos-containing components of the machinery are replaced with components that do not contain asbestos, and the asbestos waste or debris is disposed of (Mlynarek and Van Orden, 2012). Friable ACM must be disposed of in leak tight containers (*e.g.*, 6 mil polyethylene bags). Bags can be placed in 55-gallon drums for additional protection (Banks, 1991).

EPA did not find information that indicates the extent that engineering controls and worker PPE are used at sites that work on industrial or commercial equipment or machinery that contain asbestos in the United States.

ONUs include employees that work at the site where industrial or commercial equipment or machinery that contain asbestos are repaired or removed, but they do not directly handle the chemical or work with the machinery and are therefore expected to have lower inhalation exposures than workers. ONUs include supervisors, managers, and other employees that may be in the work area but do not perform tasks that result in the same level of exposures as workers that engage in tasks related to the OES.

G.12.4.2 Number of Workers and Occupational Non-users

EPA used workers and ONU estimates determined from an analysis of BLS data for the NAICS codes 324110, Petroleum Refineries; 325199, All Other Basic Organic Chemical Manufacturing; and 423830, Industrial Machinery and Equipment Merchant Wholesalers. EPA assumes that all workers at these sites could potentially be exposed to ACM (U.S. BLS, 2016). Data from the 2019 U.S. Census Bureau estimated a total of 29,211 establishments that operated under these NAICS codes. Based on these data, EPA estimated that a total of two workers and two ONUs are potentially exposed per establishment in this exposure scenario.

Table_Apx G-33. Estimated Number of Workers Potentially Exposed to Asbestos During Use, Repair, or Removal of Industrial and Commercial Appliances or Machinery

Number of Establishments[a]	Exposed Workers per Establishment	Exposed ONUs per Establishment	Total Exposed Workers[a]	Total ONUs[a]	Total Exposed[a]
2.9E04	2	2	6.4E04	5.5E04	1.2E05
[a] Totals have been rounded to two significant figures. Totals may not add exactly due to rounding.					

G.12.4.3 Occupational Exposure Result

Asbestos may be present in gaskets, reinforced plastics, industrial brake and gear clutches, and packing seals within machinery used in industrial or commercial workplaces. Workers may come into contact with these materials in friable forms during use, repair, or removal of the appliances and machinery containing asbestos. The information and data quality evaluation to assess occupational exposures during use, repair, or removal of industrial or commercial appliances or machinery is listed in Table_Apx G-4.

Occupational exposures to asbestos during use, repair, or removal of the appliances and machinery were estimated by evaluating PBZ samples from OSHA's CEHD monitoring data (OSHA, 2020) along with two NIOSH Health Hazard Evaluations (HHE's) and other literature studies (see Table_Apx G-4). The samples used for this assessment include 236 data points, reported as 8-hour TWAs, and a total of 37 short-term samples that were each taken over 30 minutes. Nine of the TWA data points were non-detect for asbestos and 8-hour TWAs were calculated using the asbestos LOD of 2117.5 fibers/sample (https://www.cdc.gov/niosh/docs/2003-154/pdfs/7400.pdf). These data are shown in *Asbestos Part 2 RE - Environmental Release and Occupational Exposure Data Tables – November 2024* (U.S. EPA, 2023b).

EPA calculated the 95th percentile and 50th percentile of the available TWA and short-term data points for inhalation exposure monitoring data to assess the high-end and central tendency exposures, respectively. Because the geometric standard deviation of the data set was greater than three for the worker inhalation exposure samples, EPA used half the detection limit for the non-detect values in the central tendency and high-end exposure calculations based on EPA's *Guidelines for Statistical Analysis of Occupational Exposure Data* (U.S. EPA, 1994).

The exposure frequency for this exposure scenario is estimated at 250 days/year based on a worker schedule of 5 days per week and 50 weeks per year. EPA estimated worker exposure over the full working day, or 8 hours/day, as the data used to estimate inhalation exposures are 8-hour TWA data.

Short-term exposure data for ONUs were not available as all OSHA data were assumed to be applicable for workers. The ONU exposures are anticipated to be lower than worker exposures because ONUs do not typically directly handle the chemical. These inhalation exposures are summarized for workers and ONUs in Table_Apx G-34 and Table_Apx G-35. Additional information regarding the ADC calculation is provided in Appendix G.5.4.

Table_Apx G-34. Summary of Inhalation Monitoring Data for Use, Repair, or Removal of Appliances or Machinery for Workers

Exposure Concentration Type	High-End (f/cc)	Central Tendency (f/cc)	Number of Samples	Data Quality Rating of Air Concentration Data	Weight of Scientific Evidence
8-hour TWA Exposure Concentration	0.16	8.4E−03	216	High	Moderate to Robust
Chronic, non-cancer ADC[a]	3.6E−02	1.9E−03			
30-min Short-Term Exposure Concentration	0.17	1.9E−02	37	High	Moderate to Robust

[a] The ADC presented here is based on 8-hour TWA monitoring data. Short-term ADC estimates are calculated using the 30-minute exposure concentrations presented here, averaged with 7.5 hours at the full shift (*i.e.*, 8-hour TWA) exposure concentrations.

Table_Apx G-35. Summary of Inhalation Monitoring Data for Use, Repair, or Removal of Appliances or Machinery for ONUs

Exposure Concentration Type	High-End (f/cc)	Central Tendency (f/cc)	Number of Samples	Data Quality Rating of Air Concentration Data	Weight of Scientific Evidence
8-Hour TWA Exposure Concentration	4.9E−02	2.8E−02	20	High	Moderate to Robust
Chronic, Non-cancer ADC[a]	1.1E−02	6.4E−03			
30-Minute Short-Term Exposure Concentration	–	–			

[a] The ADC presented here is based on 8-hour TWA monitoring data. Short-term exposure data were not available for ONUs for this scenario.

Strengths, Limitations, Assumptions, and Uncertainties

The primary strength of the data used for this assessment is the use of directly applicable monitoring data, which is preferrable to other assessment approaches such as modeling or the use of occupational exposure limits. An additional strength is that the literature sources include information on worker activities. The OSHA CEHD monitoring data does not include process information or worker activities; therefore, there is uncertainty as to which worker activities these data cover and whether all potential workers activities are represented in this data. Additionally, these data are from a wide variety of facility types, and it is unclear how representative the data are for all sites and all workers across the United States. Differences in work practices and engineering controls across sites can introduce variability and limit the representativeness of any one site relative to all sites. As discussed above, EPA used half the detection limit for the non-detect values in the central tendency and high-end exposure calculations. This introduces uncertainty into the assessment because the true value of asbestos is unknown (though expected to be between zero and the level of detection).

G.13 Handling Articles or Formulations that Contain Asbestos

G.13.1 Process Description

Asbestos may be contained in articles or formulations such as plastics (hard and soft), joints and packings, and fillers (including talc containing asbestos fillers) that were manufactured before the 1980s. Other articles that contain asbestos and may be handled in an occupational setting include the following: furniture and furnishings including stone, plaster, cement, glass, and ceramic articles; metal articles; rubber articles; artifacts; electrical batteries; accumulators; and packaging (excluding food packaging). In general, asbestos contained in these objects is less likely to become friable since the asbestos is entrained in the articles and is not likely to be released; however, it is possible release may occur during rough handling of the objects (Perkins et al., 2007). See Table_Apx G-36 below for asbestos concentration forms and ranges for these articles and formulations.

Table_Apx G-36. Asbestos Concentrations for Common Articles and Formulations

Product Category	Percentage	Form of Asbestos	Source
Moulded Plastics and Battery Boxes	55–70	Chrysotile and crocidolite	(IPCS, 1986)
Joints and Packings	25–85	Chrysotile and crocidolite	(IPCS, 1986)
Fillers	25–98	Chrysotile and crocidolite	(IPCS, 1986)

There often are large quantities of GWB in buildings, and in buildings built before the 1980s, the joint compound may contain asbestos. Because the two materials are bonded together, the GWB and its associated ACM joint compound are considered one material by EPA. In contrast, because OSHA requires sampling of the GWB and joint compound separately, OSHA typically considers the joint compound to be ACM (Perkins et al., 2007). Before removal, the joint compound and GWB are thoroughly wetted to avoid dust formation (Perkins et al., 2007).

G.13.2 Facility Estimates

CDR data were not available for this OES. Therefore, EPA used BLS and SUSB data to estimate the number of establishments. Because it is assumed that employees work only at the employment location, the number of establishments is considered equal to the number of sites for this OES. EPA assumes that establishments involved in handling articles or formulations that contain asbestos are classified under the applicable NAICS codes 336411 (Aircraft Manufacturing), 541715 (Research and Development in the Physical, Engineering, and Life Sciences [except Nanotechnology and Biotechnology]), and 611310 (Colleges, Universities, and Professional Schools). Based on the 2021 County Business Patterns data published by the U.S. Census Bureau, there are 15,592 establishments classified under these NAICS codes. This provides a high-end bounding estimate for the number of sites for this OES.

G.13.3 Release Assessment

G.13.3.1 Environmental Release Points

EPA expects releases to occur during the handling of articles or formulations that contain asbestos. As stated in the process description, asbestos may be present in plastics, joints and packings, and fillers (including talc containing asbestos fillers) that were manufactured before the 1980s. Specific activities that may generate environmental releases include rough handling of these articles or during work or removal of gypsum wallboards.

G.13.3.2 Environmental Release Assessment Results

EPA estimated releases from this OES using TRI and NEI data, as described in Appendix G.4. TRI data were available for water, air, and land disposals, while NEI data were available for air emissions. In summary, EPA estimated daily emissions for this OES by calculating the 50th and 95th percentile of all reported annual releases and dividing the results by 250 release days/year as determined in Appendix G.4.4.

Based on the available data, EPA expects asbestos releases to air (fugitive and stack) and landfills. However, EPA does not expect wastewater discharges of asbestos during this OES, because the data gathered shows no discharges of asbestos to water. Each OES contained reporting sites from TRI from other medias of release, but not to water. Therefore, EPA assumed that there are no wastewater discharges of asbestos from this OES. Although there may be incidental discharges of asbestos, EPA expects those releases to be low.

EPA estimated air emissions using 10 reporting sites from TRI/NEI. EPA then built a distribution using central tendency and high-end results from the 10 data points to estimate releases from all potential sites under this OES. To estimate land releases, a similar approach was taken using a distribution built from the 4 reporting sites (11 data points) to estimate releases from all potential sites. The annual release values are the high end and central tendency values from each site's releases, separated by the type of land release and by waste-receiving facility.

A summary of daily environmental release estimates by media for this OES are provided in Table 3-8. In addition, Table_Apx G-37 and Table_Apx G-38 below present a summary of annual and daily releases estimates to air and land, respectively. For the raw data set used in making these estimations, see *Asbestos Part 2 RE - Environmental Release and Occupational Exposure Data Tables – November 2024* (U.S. EPA, 2023b).

Table_Apx G-37. Air Emission Summary for Handling Articles or Formulations that Contain Asbestos

Annual Fugitive Emissions (kg/site-year)		Annual Stack Emissions (kg/site-year)		Number of Operating Days	Daily Fugitive Emissions (kg/site-day)		Daily Stack Emissions (kg/site-day)	
Central Tendency	High-End	Central Tendency	High-End		Central Tendency	High-End	Central Tendency	High-End
6.8E−02	88	2.1	3.4	250	2.7E−04	0.35	8.5E−03	1.4E−02

Table_Apx G-38. Land Release Summary for Handling Articles or Formulations that Contain Asbestos

Annual Land Disposals[a] (kg/site-year)		Number of Operating Days	Daily Land Disposals (kg/site-day)	
Central Tendency	High-End		Central Tendency	High-End
14,057	58,323	250	56	233

[a] Total land disposals include the following land disposal methods: other landfills and transfer to waste broker.

Strengths, Limitations, Assumptions, and Uncertainties

The primary strength of these estimates is that EPA used multiple years of data in the analysis. A strength of TRI data is that it compiles the best readily available release data for all reporting facilities. A strength of NEI data is that it includes comprehensive and detailed estimates of air emissions from point and area sources. The primary limitation to this assessment is that information on the COUs of use of asbestos at facilities in TRI and NEI is limited. Additional limitations to this assessment include the assumptions on the number of operating days to estimate daily releases, the assumption of no wastewater discharges (as reported in TRI), and the uncertainty in the mapping of reporting facilities to this OES.

For purposes of release assessment, EPA assumed that (1) the included data sufficiently represent all OES activities; and (2) all releases take place uniformly over time, as opposed to all at once or at varying intensities. Assessing environmental releases using TRI and NEI data presents various sources of uncertainty. TRI data are self-reported and have reporting requirements that exclude certain facilities from reporting. Facilities are only required to report to TRI if the facility has 10 or more full-time employees, is included in an applicable NAICS code, and manufactures, processes, or uses the chemical in quantities greater than a certain threshold (25,000 lb for manufacturers and processors and 10,000 lb for users). NEI reporting of hazardous air pollutants, such as asbestos, is voluntary. Therefore, NEI may not include data from all emission sources. There is uncertainty in EPA's assumption of no wastewater discharges for this OES, as there could be more sites that dispose of/treat asbestos waste that are below the TRI reporting thresholds.

G.13.4 Occupational Exposure Assessment

G.13.4.1 Worker Activities

Asbestos may be contained in articles or formulations such as plastics, joints and packings, and fillers (including talc containing asbestos fillers) that were manufactured before the 1980s. Also, asbestos is used as a component in some specialty plastics used in missile research and development. In general, asbestos contained in these objects is less likely to become friable since the asbestos is entrained in the articles and is not likely to be released; however, it is possible that release can occur during rough handling of the objects (Perkins et al., 2007). Asbestos may also be present in GWB joint compounds in buildings that were constructed before the phase-out of ACM. Joint compound applied in the past may become friable when the wallboard is worked on or removed.

Two sites were identified that reported land releases of asbestos to TRI; one reported to NAICS code 927110, Space Research and Technology, while the other reported to NAICS code 541715, Research and Development in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology) (U.S. EPA, 2022a). Three sites reported asbestos air emissions to NEI under the NAICS code 611310, Colleges, Universities, and Professional Schools. EPA expects that asbestos is used for research at these sites under controlled conditions and exposure potential to friable asbestos is minimized.

Similar to the OES for maintenance, renovation, and demolition activities, workers for this OES were separated into three SEGs: high exposure-potential workers, low exposure-potential workers, and ONUs. Workers in these SEGs have different job functions and are therefore expected to have different levels of potential exposure to friable asbestos. For this reason, their inhalation exposure risks are assessed separately.

Higher exposure-potential workers are workers that may directly generate friable asbestos through actions such as grinding, sanding, cutting, or abrading ACM during maintenance or removal. Lower exposure-potential workers are not expected to generate friable asbestos but may come into direct contact with friable asbestos while performing their required work activities. ONUs include employees that may be in the vicinity of asbestos but are unlikely to have direct contact with ACM and are expected to have lower inhalation exposures than other workers. ONUs for this scenario include supervisors, managers, and other bystanders who may be in the area but do not perform tasks that result in the same level of exposure as those workers who engage in tasks related to ACM removal or handling of asbestos.

G.13.4.2 Number of Workers and Occupational Non-users

EPA used workers and ONU estimates determined from an analysis of BLS data for the NAICS codes 336411, Aircraft Manufacturing; 611310, Colleges, Universities, and Professional Schools; and 541715, Research and Development in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology). EPA assumes that all workers at these sites could potentially be exposed to ACM (U.S. BLS, 2016). Data from the 2019 U.S. Census Bureau estimated a total of 15,592 establishments that operated under these NAICS codes. Based on these data, EPA estimated that a total of 20 workers and 11 ONUs are potentially exposed per establishment in this exposure scenario.

Table_Apx G-39. Estimated Number of Workers Potentially Exposed During Handling Articles or Formulations that Contain Asbestos

Number of Establishments	Exposed Workers per Site Establishment	Exposed ONUs per Establishment	Total Exposed Workers[a]	Total ONUs[a]	Total Exposed[a]
1.6E04	20	11	3.1E05	1.6E05	4.7E05
[a] Totals have been rounded to two significant figures. Totals may not add exactly due to rounding.					

G.13.4.3 Occupational Exposure Result

Workers may come into contact with friable asbestos while handling articles or formulations such as plastics, joints and packings, and fillers (including talc containing asbestos fillers) that contain asbestos. The information and data quality evaluation to assess occupational exposures for workers while handling asbestos-containing articles or formulations is listed in Table_Apx G-4.

Occupational exposures to asbestos from handling articles or formulations were estimated by evaluating PBZ samples from OSHA's CEHD monitoring data (OSHA, 2020) along with three studies found during the data extraction and evaluation stage of the risk evaluation (see Table_Apx G-4). For the three SEGs assessed, the samples included 69 data points reported as 8-hour TWAs that are derived from the sum of same-day samples and a total of 25 short-term samples that were each taken over 30 minutes. All of the 8-hour TWAs from the OSHA CEHD were non-detect for asbestos and 8-hour TWAs were calculated using the asbestos LOD of 2,117.5 fibers/sample). These data are provided in *Asbestos Part 2 RE - Environmental Release and Occupational Exposure Data Tables – November 2024* (U.S. EPA, 2023b).

EPA calculated the 95th percentile and 50th percentile of the available 85 data points for inhalation exposure monitoring data to assess the high-end and central tendency exposures, respectively. Because the geometric standard deviation of the data set was greater than three for the higher exposure-potential worker inhalation exposure samples and less than three for lower exposure-potential workers and ONUs, EPA used (1) half the detection limit for higher exposure-potential worker non-detect samples and (2) the detection limit divided by the square root of two for both the lower exposure-potential worker non-detect samples in the central tendency and high-end exposure calculations based on EPA's *Guidelines for Statistical Analysis of Occupational Exposure Data* (U.S. EPA, 1994). Using these 8-hour TWA exposure concentrations, EPA calculated the ELCR. Only one sample was found to measure short-term inhalation exposure to ONUs. That sample was used to determine a high-end estimate while the central tendency was estimated at half of the high-end estimate.

EPA estimated ONU exposures using area sampling data provided by Rohl et al. (1975). These samples were taken in the background and in adjacent rooms as workers performed pole and hand sanding of joint compounds. Area sampling data from the OSHA OECD were also used to estimate exposure to ONUs, as EPA assumed these samples were placed to measure the general room concentrations, which are likely to be similar to ONU exposures. Brorby et al. (2013) gathered monitoring data from historical sources on workers sanding asbestos-containing joint compounds, including data from a 1976 study conducted by Rhodes and Ingalls (1976). The study by Rhodes and Ingalls conducted personal breathing zone sampling for workers and used the data to estimate 8-hour TWA exposures. Rohl et al. (1975) also provided personal breathing zone samples for workers as they sanded and cleaned asbestos-containing joint compounds. EPA used these data in the assessment for higher exposure-potential workers.

The exposure frequency for this exposure scenario is estimated at 250 days/year based on a worker schedule of 5 days per week and 50 weeks per year. EPA estimated worker exposure over the full working day, or 8 hours/day, as the data used to estimate inhalation exposures are 8-hour TWA data.

The inhalation exposures are summarized for the three SEGs are provided in Table_Apx G-40, Table_Apx G-41, and Table_Apx G-42. Additional information regarding the ADC calculation is provided in Appendix G.5.4.

Table_Apx G-40. Summary of Inhalation Monitoring Data for Handling Articles and Formulations for Higher-Exposure Potential Workers

Exposure Concentration Type	High-End (f/cc)	Central Tendency (f/cc)	Number of Samples	Data Quality Rating of Air Concentration Data	Weight of Scientific Evidence
8-Hour TWA Exposure Concentration	3.3	0.14	69	High	Moderate
Chronic, Non-cancer ADC[a]	0.75	3.2E−02			
30-Minute Short-Term Exposure Concentration	8.8E−02	7.3E−02	16	Medium	Moderate

[a] The ADC presented here is based on 8-hour TWA monitoring data. Short-term ADC estimates are calculated using the 30-minute exposure concentrations presented here, averaged with 7.5 hours at the full shift (*i.e.*, 8-hour TWA) exposure concentrations.

Table_Apx G-41. Summary of Inhalation Monitoring Data for Handling Articles and Formulations for Lower-Exposure Potential Workers

Exposure Concentration Type	High-End (f/cc)	Central Tendency (f/cc)	Number of Samples	Data Quality Rating of Air Concentration Data	Weight of Scientific Evidence
8-Hour TWA Exposure Concentration	1.1E−02	8.3E−03	7	High	Moderate
Chronic, Non-cancer ADC[a]	2.5E−03	1.9E−03			
30-Minute Short-Term Exposure Concentration	4.2E−02	2.1E−02	8	High	Moderate

[a] The ADC presented here is based on 8-hour TWA monitoring data. Short-term ADC estimates are calculated using the 30-minute exposure concentrations presented here, averaged with 7.5 hours at the full shift (*i.e.*, 8-hour TWA) exposure concentrations.

Table_Apx G-42. Summary of Inhalation Monitoring Data Handling Articles and Formulations for ONUs

Exposure Concentration Type	High-End (f/cc)	Central Tendency (f/cc)	Number of Samples	Data Quality Rating of Air Concentration Data	Weight of Scientific Evidence
8-Hour TWA Exposure Concentration	0.84	1.1E−03	16	High	Moderate
Chronic, Non-cancer ADC[a]	0.19	2.5E−04			
30-Minute Short-Term Exposure Concentration	1.5E−03	7.7E−04	1	High	Moderate

[a] The ADC presented here is based on 8-hour TWA monitoring data. Short-term ADC estimates are calculated using the 30-minute exposure concentrations presented here, averaged with 7.5 hours at the full shift (*i.e.*, 8-hour TWA) exposure concentrations.

Strengths, Limitations, Assumptions, and Uncertainties

The primary strength of the data used for this assessment is the use of directly applicable monitoring data, which is preferrable to other assessment approaches such as modeling or the use of occupational exposure limits. An additional strength is that the literature sources include information on worker activities. The OSHA CEHD monitoring data does not include process information or worker activities; therefore, there is uncertainty as to which worker activities these data cover and whether all potential workers activities are represented in this data Additionally, the OSHA CEHD data only include data from three sites. Therefore, EPA cannot determine the statistical representativeness of this data (*e.g.*, high-end, central tendency) towards potential exposures from this condition of use. Furthermore, it is unclear how representative the data are for all sites and all workers across the United States. Differences in work practices and engineering controls across sites can introduce variability and limit the representativeness of any one site relative to all sites. As discussed above, EPA used half the detection limit for the non-detect values or divided the non-detect values by the square root of two in the central tendency and high-end exposure calculations. This introduces uncertainty into the assessment because the true value of asbestos is unknown (though expected to be between zero and the LOD).

G.14 Handling of Vermiculite Products for Agriculture and Lab Chemicals

G.14.1 Process Description

Vermiculite is used in occupational settings as a soil treatment product for agricultural purposes and as a packaging/disposal material for laboratory purposes. Regarding agricultural uses of vermiculite in occupational settings (*e.g.,* landscaping), it is common for agricultural workers to mix a vermiculite product with soil and then spread the treated soil across some defined area. During the mixing and spreading of vermiculite containing materials, friable components within the mixture may become airborne which could lead to releases and worker exposure. Regarding laboratory uses, vermiculite is typically used by laboratory workers to absorb chemicals before incineration (IHC World, 2023). However, friable components of the vermiculite packaging material may become airborne during handling. The expected extent of asbestos releases and exposures are qualitatively assessed in Appendix G.14.2, which provides a qualitative assessment of exposure to asbestos from agricultural and laboratory uses of vermiculite products.

G.14.2 Qualitative Assessment

Based on information identified in EPA's "Sampling and Analysis of Consumer Garden Products That Contain Vermiculite" document (U.S. EPA, 2000a), asbestos has been identified in some lawn and gardening care products that contained vermiculite, as well as a vermiculite product used to package and dispose of laboratory chemicals. Specifically, the EPA study investigated 38 vermiculite products that were available nationwide, and asbestos was found in 5 of the vermiculite products. The sources of the vermiculite for the products investigated in the EPA study included one mine in Libby, Montana; one mine in South Africa; and various mines across the United States (U.S. EPA, 2000a). Asbestos measurements from products sourced from the Libby, Montana, mine showed slightly higher concentrations (up to 2.79%), whereas asbestos concentrations from other vermiculite products were below 1 percent as measured by transmission electron microscopy (TEM). The use of pesticides, including herbicides and fungicides, is regulated under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and is not assessed in this risk evaluation. However, the use of fertilizers and non-pesticidal lawncare products is under the purview of TSCA and is assessed in this risk evaluation.

The EPA study of vermiculite products simulated the preparation of potting soil by mixing 50 percent vermiculite and 50 percent peat moss. The researchers then simulated potting plants by emptying a container of soil into a plastic tub and manipulating the soil to break up clods. The soil was placed in plastic pots, which were emptied back into the plastic tub, and the work area was then cleaned by sweeping loose spilled soil back into the plastic tub. This simulation was run three times for each of the asbestos-containing vermiculite products (U.S. EPA, 2000a). Airborne asbestos fibers were detected during the simulated use of one product only (*i.e.,* Zonolite Chemical Packaging Vermiculite), which is used to pack laboratory chemicals for transport or disposal. The asbestos-containing product, Zonolite Chemical Packaging Vermiculite, was sourced from a mine in Libby, Montana, which closed in 1990. Because current uses of vermiculite products mined from Libby are not expected, the airborne asbestos measurements from simulated use of Zonolite Chemical Packaging Vermiculite are not representative of ongoing uses. None of the other asbestos-contaminated vermiculite products used in lawn care released measurable quantities of airborne asbestos fibers during simulated use (U.S. EPA, 2000a). Because currently available vermiculite products do not contain significant levels of asbestos, EPA does not expect any significant asbestos releases or occupational exposures from the commercial use of these products based on the data from the EPA analysis of vermiculite products. Therefore, the use of vermiculite for agricultural and laboratory purposes is not further assessed in this risk evaluation.

G.15 Mining of Non-asbestos Commodities

Asbestos mining ceased in the United States in 2002 (Lucarelli, 2002); therefore, asbestos mining is not considered in this risk evaluation. Instead, this risk evaluation considers only the mining of non-asbestos commodities (*e.g.*, talc and vermiculite). The expected extent of asbestos releases and exposures from mining of non-asbestos commodities are qualitatively assessed in Appendix G.15.2.

G.15.1 Process Description

Asbestos can be found in deposits in the ground and can be uncovered unintentionally during the mining of non-asbestos commodities. During industrial mining of non-asbestos commodities, friable components within the mined material may become airborne that could lead to releases and/or worker exposure. Vermiculite and talc mining operations, as well as general commodity mining operations, are described below.

Vermiculite and Talc Mining

Vermiculite ore is primarily mined using open-pit methods where rock and minerals are removed from the surface in order to reach and extract the ore—typically accomplished using conventional drilling and blasting methods (U.S. EPA, 1995a, b). Over 95 percent of the talc ore produced in the United States also comes from open-pit mines. Crude vermiculite and talc ore is typically transported from the mine by truck (U.S. EPA, 1995a, b).

Vermiculite and talc are minerals exist as shiny flakes in physical form. If vermiculite or talc are mined from ore that also contains asbestos fibers, it is possible that the resulting vermiculite or talc minerals are contaminated with asbestos fibers. One study found that raw talc ore contained 37 to 59 percent tremolite asbestos (NIOSH, 1980). In 2020, two companies with mining and processing facilities in South Carolina and Virginia produced approximately 100,000 tons of vermiculite (USGS, 2021). In 2021, domestic production of crude talc was estimated to be 490,000 tons, with the majority mined in Montana, Texas, and Vermont (USGS, 2022).

MSHA reported that there were 6,413 total active mines as of 2022 (MSHA, 2022b). Of these active mines, 14 are engaged in the mining talc or vermiculite (no asbestos mines are still active). Collectively, these 14 active mines employ an average of 30 mill operation workers and 9 strip/quarry/open pit workers per site (MSHA, 2022b). Control methods in vermiculite and talc mines include ventilation, wet drilling, and water sprays for dust suppression (NIOSH, 1980). MSHA recommends the use of NIOSH-approved respirators and disposable protective clothing during mining in the presence of asbestos. If disposable clothing is not available, work clothes should be vacuumed using a specially designed asbestos vacuum before being removed (MSHA, 2000). EPA did not find information on operating schedules during vermiculite and talc mining. Multiple sources suggest that commodity mines like iron ore and coal mines operate 365 days per year; therefore it can be assumed that talc and vermiculite mines would have similar operating schedules (Maisey and et al., 2020; SafeStart, 2017).

All Other Mining Commodities

Asbestos is found naturally in irregular veins scattered throughout rock masses in various parts of the world (Archer and Blackwood, 1979). These natural deposits of asbestos can be disturbed during traditional mining operations, leading to exposures and releases (CDM Federal Programs Corporation, 2015). The most common general mining practices include surface (open-pit) mining, where ore is extracted from the ground by digging with heavy machinery, and underground mining, where holes are drilled deep into the earth with explosives and drill rigs (Amer Mine Serv, 2023). Most recovered ores are transported from mines in trucks and rail cars, which may be subsequently transferred to ships

(Cargo Handbook, 2023). Due to the wide range of mined commodities, EPA was unable to find specific throughputs or asbestos contamination levels by commodity.

According to the MSHA's Mine Data Retrieval System, average annual employment at mines from 1983 to 2021 was 259,104 workers, not including office workers (MSHA, 2022b). This includes an average of 67,546 underground workers and 195,551 surface and facility workers per year. Out of these workers, it is estimated that 44,000 miners and mine workers may have been exposed where asbestos may have been a contaminant (IARC, 2012c). MSHA reported that there were 6,413 active mines in the United States as of 2022. As noted above, MSHA recommends the use of NIOSH-approved respirators and disposable protective clothing during mining in the presence of asbestos. If disposable clothing is not available, work clothes should be vacuumed using a specially-designed asbestos vacuum before being removed (MSHA, 2000). Because multiple sources suggest that commodity mines like iron ore and coal mines operate 365 days per year (Maisey and et al., 2020; SafeStart, 2017), talc and vermiculite mines are assumed to have similar, year-round operating schedules.

G.15.2 Qualitative Assessment

EPA considered MSHA asbestos air monitoring data from 2005 through 2022 from industrial mining of non-asbestos commodities, which showed a limited number of non-zero values post 2008 (MSHA, 2022a). This data builds on sampling that was conducted as part of the 2008 MSHA rulemaking to lower the 8-hour, TWA, full-shift personal exposure limit (PEL) for asbestos from 2 fibers per cubic centimeter of air (f/cc) to 0.1 f/cc at all metal and nonmetal mines, surface coal mines, and surface areas of underground coal mines (MSHA, 2022a). EPA consulted with its federal partners and outside stakeholders to determine the appropriate level of assessment for this COU.

The level of consideration or assessment afforded to a particular COU in a risk evaluation may vary. EPA is not required to conduct a quantitative assessment of every hazard, exposure, COU, or PESS that is within the scope of the risk evaluation. TSCA section 6(b)(4)(D) directs EPA to "publish the scope of the risk evaluation to be conducted, including the hazards, exposures, conditions of use, and the potentially exposed or susceptible subpopulations [EPA] *expects to consider*" (emphasis added). TSCA section 6(b)(4)(F) further instructs EPA, when conducting risk evaluations, to "*take into account, where relevant*, the likely duration, intensity, frequency, and number of exposures under the conditions of use of the chemical substance" (emphasis added). EPA has discretion in tailoring its level of analysis with respect to individual conditions of use within the scope of the risk evaluation and may choose to, for example, take a more qualitative approach to conditions of use that it determines are negligible contributors to exposures and risks based on the reasonable available information. EPA has incorporated such "fit-for-purpose" considerations into the Risk Evaluation Rule (40 CFR 702.37(a)(4)) ("a fit-for-purpose approach may result in varying types and levels of analysis and supporting information for certain conditions of use").

In determining the appropriate level of assessment of industrial mining of non-asbestos commodities in this risk evaluation, the Agency has considered the duration, intensity, frequency, and/or number of exposures to asbestos from this type of activity. Based on the data considered and the information from MSHA and outside stakeholders, EPA has determined that exposure to trace amounts of asbestos in other mined commodities occurs infrequently and at low levels. The information from MSHA shows that since the revised PEL was finalized in 2008 nearly all air monitoring samples were non-detects (MSHA, 2022a). The data received as part of the TSCA section 8(a) call in supports this finding. Additionally, EPA was provided with several sources of information that selective mining practices occur and are successful in generally avoiding deposits that are likely to contain asbestos minerals. Therefore, the Agency will not conduct any further analysis of this COU in this risk evaluation.

G.16 Waste Handling, Disposal, and Treatment

G.16.1 Process Description

Each of the COU of asbestos may generate waste streams of the chemical that are collected and transported to third-party sites for disposal or treatment. Industrial sites that treat or dispose on-site wastes that they themselves generate are assessed in each COU assessment. Wastes of asbestos that are generated during a COU and sent to a third-party site for treatment or disposal may include the following:

Wastewater

Asbestos may be contained in wastewater discharged to POTW or other, non-public treatment works for treatment. Industrial wastewater containing asbestos discharged to a POTW may be subject to EPA or authorized NPDES state pretreatment programs. The assessment of wastewater discharges to POTWs and non-public treatment works of asbestos is included in each of the condition of use assessments in Appendix G.10 through Appendix G.13.

Solid Wastes

Solid wastes are defined under RCRA as any material that is discarded by being (1) abandoned, (2) inherently waste-like, or (3) a discarded military munition. Solid wastes may subsequently meet RCRA's definition of hazardous waste by either being listed as a waste at 40 CFR 261.30 to 261.35 or by meeting waste-like characteristics as defined at 40 CFR 261.20 to 261.24. Solid wastes that are hazardous wastes are regulated under the more stringent requirements of Subtitle C of RCRA, whereas non-hazardous solid wastes are regulated under the less stringent requirements of Subtitle D of RCRA. Asbestos containing wastes are any wastes that contain one percent or more of asbestos by weight. Friable asbestos waste contains more than one-percent asbestos and can be crumbled, pulverized, or reduced to powder under hand pressure. Non-friable asbestos waste is treated as either construction and demolition or municipal solid waste and can be disposed of in a municipal landfill. Friable asbestos waste is considered a "non-RCRA" hazardous waste and is not subject to RCRA subtitle C regulation and can be disposed in a municipal landfill but special requirements for containerization, transportation, recordkeeping and disposal are needed.

2019 TRI data lists 15 off-site transfers of asbestos to land disposal, and none to wastewater treatment, incineration, or recycling facilities (U.S. EPA, 2019a).

Municipal Waste Landfill

Municipal solid waste landfills are discrete areas of land or excavated sites that receive household wastes and other types of non-hazardous wastes (*e.g.*, industrial and commercial solid wastes). Standards and requirements for municipal waste landfills include location restrictions, composite liner requirements, leachate collection and removal system, operating practices, groundwater monitoring requirements, closure-and post-closure care requirements, corrective action provisions, and financial assurance. Non-hazardous solid wastes are regulated under RCRA Subtitle D, but states may impose more stringent requirements.

Landfill activities include compacting refuse at the working face, moving soil for cover, and utilizing equipment to move wastes (Esswein and Tubbs, 1994). Municipal solid wastes may be first unloaded at waste transfer stations for temporary storage prior to being transported to the landfill or other treatment or disposal facilities.

Hazardous Waste Landfill
Hazardous waste landfills are excavated or engineered sites specifically designed for the final disposal of non-liquid hazardous wastes. Design standards for these landfills require double liner, double leachate collection and removal systems, leak detection system, run on, runoff and wind dispersal controls, and construction quality assurance program (U.S. EPA, 2018b). There are also requirements for closure and post-closure, such as the addition of a final cover over the landfill and continued monitoring and maintenance. These standards and requirements prevent potential contamination of groundwater and nearby surface water resources. Hazardous waste landfills are regulated under Part 264/265, Subpart N. Asbestos can be disposed of only at certified landfills registered to handle asbestos. When disposing of asbestos, arrangements are made prior to delivery to the landfill (Hawkins et al., 1988). All fibrous and dusty asbestos wastes are accepted at a landfill site only in robust plastic sacks or similar wrapping. On arrival, the delivery vehicle is directed to the designated drop-off area. The waste is then deposited in excavated trenches, and at least 5 meters of other wastes are immediately spread over the bagged asbestos (Mimides et al., 1997).

G.16.2 Facility Estimates

CDR data were not available for this OES. Therefore, EPA used BLS and SUSB data to estimate the number of establishments. Because it is assumed that employees work only at the employment establishment, the number of establishments is considered equal to the number of sites for this OES. EPA assumed that establishments involved in waste handling, disposal, and treatment of asbestos are classified under the applicable NAICS codes 221117 (Biomass Electric Power Generation), 562211 (Hazardous Waste Treatment and Disposal), 562112 (Hazardous Waste Collection), 562212 (Solid Waste Landfill), 562920 (Materials Recovery Facilities), and 562998 (All Other Miscellaneous Waste Management Services). Based on the 2021 County Business Patterns data published by the U.S. Census Bureau, there are 5,425 establishments classified under these NAICS codes. This provides a high-end bounding estimate for the number of sites for this OES.

G.16.3 Release Assessment

G.16.3.1 Environmental Release Points

EPA expects releases to occur during waste handling, disposal, and treatment. As stated in the process description, each of the conditions of use may generate waste streams of the asbestos that are collected and transported to third-party sites for disposal or treatment. Wastes of asbestos that are generated and sent to a third-party site for treatment or disposal may include wastewater and solid wastes.

G.16.3.2 Environmental Release Assessment Results

EPA estimated releases from this OES using TRI and NEI data, as described in Appendix G.4. TRI data were available for water, air, and land disposals, NEI data were available for air emissions. In summary, EPA estimated daily emissions for this OES by calculating the 50th and 95th percentile of all reported annual releases and dividing the results by 250 release days/yr determined in Appendix G.4.4.

Based on the available data, EPA expects asbestos releases to air (fugitive and stack) and landfills. However, EPA does not expect wastewater discharges of asbestos during this OES, since the data gathered shows no discharges of asbestos to water. Each OES contained reporting sites from TRI from other medias of release, but not to water. Therefore, EPA assumed that there are no wastewater discharges of asbestos from this OES. Although there may be incidental discharges of asbestos, EPA expects those releases to be low.

A summary of daily environmental release estimates by media for this OES are provided in Table 3-8. In addition, Table_Apx G-43 and Table_Apx G-44 below present a summary of annual and daily releases estimates to air and land, respectively. For the raw data set used in making these estimations, see *Asbestos Part 2 RE - Environmental Release and Occupational Exposure Data Tables – November 2024* (U.S. EPA, 2023b).

Table_Apx G-43. Air Emission Summary for Waste Handling, Disposal, and Treatment

Annual Fugitive Emissions (kg/site-year)		Annual Stack Emissions (kg/site-year)		Number of Operating Days	Daily Fugitive Emissions (kg/site-day)		Daily Stack Emissions (kg/site-day)	
Central Tendency	High-End	Central Tendency	High-End		Central Tendency	High-End	Central Tendency	High-End
1.6	18	0.23	24	250	6.3E−03	7.4E−02	9.1E−04	9.5E−02

Table_Apx G-44. Land Release Summary for Waste Handling, Disposal, and Treatment

Annual Land Disposals[a] (kg/site-year)		Number of Operating Days	Daily Land Disposals (kg/site-day)	
Central Tendency	High-End		Central Tendency	High-End
191,200	2,608,482	250	765	10,434

[a] Total land disposals include the following land disposal methods: RCRA Subtitle C Landfills, Other On-site Landfills, Other Off-site Landfills, Other Off-site Management, Solidification/Stabilization Treatment, and Unknown.

Strengths, Limitations, Assumptions, and Uncertainties

The primary strength of these estimates is that EPA used multiple years of data in the analysis. A strength of TRI data is that TRI compiles the best readily available release data for all reporting facilities. A strength of NEI data is that it includes comprehensive and detailed estimates of air emissions from point and area sources. The primary limitation to this assessment is that information on the COUs of asbestos at facilities in TRI and NEI is limited. Additional limitations to this assessment include the assumptions on the number of operating days to estimate daily releases, the assumption of no wastewater discharges where not reported in TRI, and the uncertainty in the mapping of reporting facilities to this OES.

For purposes of release assessment, it is assumed that the included data sufficiently represent all OES activities, and that all releases take place uniformly over time, as opposed to all at once or at varying intensities. Assessing environmental releases using TRI and NEI data presents various sources of uncertainty. TRI data are self-reported and have reporting requirements that exclude certain facilities from reporting. Facilities are only required to report to TRI if the facility has 10 or more full-time employees, is included in an applicable NAICS code, and manufactures, processes, or uses the chemical in quantities greater than a certain threshold (25,000 lb for manufacturers and processors and 10,000 lb for users). NEI reporting of hazardous air pollutants, such as asbestos, is voluntary. Therefore, NEI may not include data from all emission sources. There is uncertainty in EPA's assumption of no wastewater discharges for this OES, as there could be more sites that dispose of/treat asbestos waste that are below the TRI reporting thresholds.

G.16.4 Occupational Exposure Assessment

G.16.4.1 Worker Activities

The waste from demolition sites may be sent to construction and demolition landfills, incineration facilities, or recycled. Waste containing asbestos may be further broken down via shredders, or other equipment at landfill and incineration facilities. Workers and ONUs at these sites may be exposed to dust containing asbestos.

Solid waste may be first sent to waste transfer facilities, where waste is consolidated onto larger trucks. At many transfer stations, workers screen incoming waste located on conveyor systems, tipping floors, or in waste pits to identify recyclables and wastes inappropriate for disposal (*e.g.*, hazardous waste, whole tires). Workers at transfer stations operate heavy machinery such as conveyor belts, push blades, balers, and compactors, and may also clean the facility or perform equipment maintenance. Workers may be exposed to poor air quality due to dust and odor, particularly in tipping areas over waste pits (Esswein and Tubbs, 1994).

As reported for a municipal landfill facility, waste may be dumped onto tipping floors for storage, then fed to a conveyor system for sorting and eventual shredding of waste. The waste from these processes are either directly loaded on trucks to be sent into the landfill or deposited in storage pits (Burkhart and Short, 1995). Heavy machinery operators may be exposed to particulates and other contaminates while in the cabs of the machinery (Esswein and Tubbs, 1994). Mechanics servicing equipment may be exposed to residues on machinery. EPA expects similar processing of waste may occur at construction and demolition landfills. At municipal waste combustors, waste materials are not generally handled directly by workers. Trucks may dump the waste directly into a pit or be tipped to the floor and later pushed into the pit by a worker operating a front-end loader. A large grapple from an overhead crane is used to grab waste from the pit and drop it into a hopper where hydraulic rams feed the material continuously into the combustion unit at a controlled rate.

G.16.4.2 Number of Workers and Occupational Non-users

EPA used workers and ONU estimates determined from an analysis of BLS data for the NAICS codes 562112, Hazardous Waste Collection; 562211, Hazardous Waste Treatment and Disposal; 562998, All Other Misc. Waste Management Services; 562212, Solid Waste Landfill; 562920, Materials Recovery Facilities; and 221117, Biomass Electric Power Generation. EPA assumes that all workers at these sites could potentially be exposed to ACM (U.S. BLS, 2016). Data from the 2019 U.S. Census Bureau estimated a total of 5,425 establishments that operated under these NAICS codes. Based on these data, EPA estimated that a total of five workers and nine ONUs are potentially exposed per establishment in this exposure scenario Table_Apx G-45.

Table_Apx G-45. Estimated Number of Workers Potentially Exposed to Asbestos During Waste Disposal Activities

Number of Establishments	Exposed Workers per Establishment	Exposed ONUs per Establishment	Total Exposed Workers[a]	Total ONUs[a]	Total Exposed[a]
5.4E03	6	9	3.1E04	4.7E04	7.8E04
[a] Totals have been rounded to two significant figures. Totals may not add exactly due to rounding.					

G.16.4.3 Occupational Exposure Result

Workers may come into contact with friable asbestos while handling any asbestos-containing materials that are disposed, either in waste transfer facilities, landfills (municipal or construction and demolition), or at MWCs. The information and data quality evaluation to assess occupational exposures for workers while handling asbestos-containing waste is listed in Table_Apx G-4

Occupational exposures to asbestos during disposal activities were estimated by evaluating PBZ samples from OSHA's Chemical Exposure Health Data (CEHD) (OSHA, 2020) along with a NIOSH HHE and two other literature studies (see Table_Apx G-4). This inhalation exposure assessment includes 95 measurements, reported as 8-hour TWAs, that are derived from the sum of same-day samples. The majority of 8-hour TWAs from the OSHA CEHD were non-detect for asbestos, and 8-hour TWAs were calculated using the asbestos LOD of 2,117.5 fibers/sample (see https://www.cdc.gov/niosh/docs/2003-154/pdfs/7400.pdf). These data are shown in *Asbestos Part 2 RE - Environmental Release and Occupational Exposure Data Tables – November 2024* (U.S. EPA, 2023b).

EPA calculated the 95th percentile and 50th percentile of the available 95 data points for inhalation exposure monitoring data to assess the high-end and central tendency exposures for workers, respectively. Because the geometric standard deviation of the data set was greater than three for the exposure samples, EPA used half the detection limit to estimate the non-detect samples in the central tendency and high-end exposure calculations based on EPA's *Guidelines for Statistical Analysis of Occupational Exposure Data* (U.S. EPA, 1994). Using these 8-hour TWA exposure concentrations, EPA calculated corresponding ADC values as shown in Appendix G.5.4.

EPA did not identify any inhalation exposure data for ONUs or short-term exposure data for workers or ONUs. Therefore, the central tendency of worker inhalation exposure was used to approximate the high-end inhalation exposure for ONUs. In general, EPA assumes that ONU exposure is lower than worker exposure since ONUs are not expected to handle any ACM. These inhalation exposures are summarized for workers in Table_Apx G-46. Additional information regarding the ADC calculation is provided in Appendix G.5.4.

The exposure frequency for this exposure scenario is estimated at 250 days/year based on a worker schedule of five days per week and 50 weeks per year. EPA estimated worker exposure over the full working day, or eight hours/day, as the data used to estimate inhalation exposures are 8-hour TWA data.

Table_Apx G-46. Summary of Inhalation Monitoring Data for Workers Handling Asbestos-Containing Waste

Exposure Concentration Type	High-End (f/cc)	Central Tendency (f/cc)	Number of Samples	Data Quality Rating of Air Concentration Data	Weight of Scientific Evidence
8-hour TWA Exposure Concentration	3.2E−02	1.5E−03	95	High	Moderate
Chronic, Non-cancer ADC[a]	7.2E−03	3.4E−04			
30-min Short-Term Exposure Concentration	–	–			

[a] The ADC presented here is based on 8-hour TWA monitoring data. Short-term exposure data were not available for this scenario.

Strengths, Limitations, Assumptions, and Uncertainties

The primary strength of the data used for this assessment is the use of directly applicable monitoring data, which is preferrable to other assessment approaches such as modeling or the use of occupational exposure limits. An additional strength is that the literature sources include information on worker activities. The OSHA CEHD monitoring data does not include process information or worker activities; therefore, there is uncertainty as to which worker activities these data cover and whether all potential workers activities are represented in this data. Additionally, it is unclear how representative the data are for all sites and all workers across the United States. Differences in work practices and engineering controls across sites can introduce variability and limit the representativeness of any one site relative to all sites. There is uncertainty due to the non-detect values used in the assessment. As discussed above, EPA used half the detection limit for the non-detect values in the central tendency and high-end exposure calculations. This introduces uncertainty into the assessment because the true value of asbestos is unknown (though expected to be between zero and the LOD).

G.17 Summary of Occupational Inhalation Exposure Assessment

Table_Apx G-47. Summary of Occupational Inhalation Exposure Assessment for Asbestos

OES	Category	Exposure Scenario	Exposure Frequency	Short-Term Exposures $C_{30\text{-}min}$ (f/cc)		8-Hour TWA Exposures $C_{8\text{-}hr\ TWA}$ (f/cc) [a]		Chronic, Non-cancer Exposures $ADC_{asbestos}$ (f/cc)		8-Hour Data Points	Short-Term Data Points	Sources and Notes	Data Type
				High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency				
Maintenance, renovation, and demolition	Higher-Exposure Workers	8-hour	50	N/A	N/A	0.43	1.1E−03	2.0E−02	5.1E−05	847	N/A	See Table_Apx G-21	Monitoring data
Maintenance, renovation, and demolition	Lower-Exposure Workers	8-hour	50	N/A	N/A	0.22	1.1E−03	1.0E−02	5.1E−05	31	N/A	See Table_Apx G-22	Monitoring data
Maintenance, renovation, and demolition	ONU	8-hour	50	N/A	N/A	4.6E−02	1.2E−02	2.1E−03	5.6E−04	103	N/A	See Table_Apx G-23	Monitoring data
Maintenance, renovation, and demolition	Higher-Exposure Workers	30-min	50	0.16	2.5E−02	0.41	2.6E−03	1.9E−02	1.2E−04	N/A	145	See Table_Apx G-21	Monitoring data
Maintenance, renovation, and demolition	Lower-Exposure Workers	30-min	50	2.5E−02	2.5E−02	0.21	2.6E−03	9.5E−03	1.2E−04	N/A	5	See Table_Apx G-22	Monitoring data
Maintenance, renovation, and demolition	ONU	30-min	50	5.3E−02	2.7E−02	4.6E−02	1.3E−02	2.1E−03	6.0E−04	N/A	1	See Table_Apx G-23	Monitoring data
Firefighting and other disaster response activities	Firefighter (Career)	8-hour	3	No data available	No data available	0.39	2.0E−02	1.1E−03	5.5E−05	62	No data available	See Table_Apx G-28	Monitoring data
Firefighting and other disaster response activities	Firefighter (Volunteer)	8-hour	1	No data available	No data available	0.39	2.0E−02	3.5E−04	1.8E−05	62	No data available	See Table_Apx G-29	Monitoring data
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	Worker	8-hour	250	N/A	N/A	0.16	8.4E−03	3.6E−02	1.9E−03	216	N/A	See Table_Apx G-34	Monitoring data

OES	Category	Exposure Scenario	Exposure Frequency	Short-Term Exposures		8-Hour TWA Exposures		Chronic, Non-cancer Exposures		8-Hour Data Points	Short-Term Data Points	Sources and Notes	Data Type
				$C_{30\text{-min}}$ (f/cc)		$C_{8\text{-hr TWA}}$ (f/cc) [a]		$ADC_{asbestos}$ (f/cc)					
				High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency				
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	ONU	8-hour	250	No data available	No data available	4.9E−02	2.8E−02	1.1E−02	6.4E−03	20	No data available	See Table_Apx G-35	Monitoring data
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	Worker	30-min	250	0.17	1.9E−02	0.16	9.1E−03	3.6E−02	2.1E−03	N/A	37	See Table_Apx G-34	Monitoring data
Handling articles or formulations that contain asbestos	Higher-Exposure Workers	8-hour	250	N/A	N/A	3.3	0.14	0.75	3.2E−02	69	N/A	See Table_Apx G-40	Monitoring data
Handling articles or formulations that contain asbestos	Lower-Exposure Workers	8-hour	250	N/A	N/A	1.1E−02	8.3E−03	2.5E−03	1.9E−03	7	N/A	See Table_Apx G-41	Monitoring data
Handling articles or formulations that contain asbestos	ONU	8-hour	250	N/A	N/A	0.84	1.1E−03	0.19	2.5E−04	16	N/A	See Table_Apx G-42	Monitoring data
Handling articles or formulations that contain asbestos	Higher-Exposure Workers	30-min	250	8.8E−02	7.3E−02	3.1	0.14	0.71	3.1E−02	N/A	16	See Table_Apx G-40	Monitoring data
Handling articles or formulations that contain asbestos	Lower-Exposure Workers	30-min	250	4.2E−02	2.1E−02	1.3E−02	9.0E−03	3.0E−03	2.1E−03	N/A	8	See Table_Apx G-41	Monitoring data
Handling articles or formulations that contain asbestos	ONU	30-min	250	1.5E−03	7.7E−04	0.79	1.1E−03	0.18	2.5E−04	N/A	1	See Table_Apx G-42	Monitoring data
Waste handling, disposal, and treatment	Worker	8-hour	250	No data available	No data available	3.2E−02	1.5E−03	7.2E−03	3.4E−04	95	N/A	See Table_Apx G-46	Monitoring data
Waste handling, disposal, and treatment	ONU	8-hour	250	No data available	No data available	1.5E−03	–	N/A	N/A	No data available	No data available	ONU exposure assessed at central tendency of worker exposure	Surrogate monitoring data

[a] 8-hour TWA values for short-term (30-minute) exposures are adjusted using measured 8-hour TWA concentrations using the following equation: (0.5 × [Short-term concentration] + 7.5 × [Measured 8-hour TWA]) / 8.

G.18 Example of Estimating Number of Workers and Occupational Non-users

This appendix summarizes the methods that EPA/OPPT used to estimate the number of workers who are potentially exposed to asbestos in each of its occupational exposure scenarios. The method consists of the following steps:

1. identify NAICS codes for the industry sectors associated with each COU;
2. estimate total employment by industry/occupation combination using the BLS Occupational Employment Statistics (BLS OES) data (U.S. BLS, 2016);
3. refine the BLS OES estimates where they are not sufficiently granular by using SUSB data on total employment by 6-digit NAICS;
4. estimate the number of establishments and number of potentially exposed employees per establishment; and
5. estimate the number of potentially exposed employees within the COU.

Step 1: Identifying Affected NAICS Codes

As a first step, EPA/OPPT identified NAICS industry codes associated with each COU. EPA/OPPT generally identified NAICS industry codes for a COU by the following:

- Querying the U.S. Census Bureau's *NAICS Search* tool using keywords associated with each condition of use to identify NAICS codes with descriptions that match the COU.
- Referencing EPA/OPPT Generic Scenarios (GSs) and OECD ESDs for a COU to identify NAICS codes cited by the GS or ESD.
- Reviewing CDR data for the chemical, identifying the industrial sector codes reported for downstream industrial uses, and matching those industrial sector codes to NAICS codes using Table D-2 provided in the CDR reporting instructions.

Each COU in the main body of this report identifies the NAICS codes EPA/OPPT identified for the respective condition of use.

Step 2: Estimating Total Employment by Industry and Occupation

BLS' (2016) OES data provide employment data for workers in specific industries and occupations. The industries are classified by NAICS codes (identified previously), and occupations are classified by SOC codes.

Among the relevant NAICS codes (identified previously), EPA/OPPT reviewed the occupation description and identified those occupations (SOC codes) where workers are potentially exposed to asbestos Table_Apx G-48 shows the SOC codes EPA/OPPT classified as occupations potentially exposed to asbestos. These occupations are classified into workers (W) and occupational non-users (O). All other SOC codes are assumed to represent occupations where exposure is unlikely.

Table_Apx G-48. SOCs with Worker and ONU Designations for All Occupational Exposure Scenarios

SOC	Occupation	Designation
11-9020	Construction Managers	O
11-9040	Architectural and Engineering Managers	O
17-2010	Aerospace Engineers	O
17-2050	Civil Engineers	O
17-2070	Electrical and Electronics Engineers	O
17-2110	Industrial Engineers, Including Health and Safety	O
17-3022	Civil Engineering Technicians	W
25-4013	Museum Technicians and Conservators	W
33-1020	First-Line Supervisors of Fire Fighting and Prevention Workers	O
33-2000	Fire Fighting and Prevention Workers	W
33-3050	Police Officers	O
37-1010	First-Line Supervisors of Building and Grounds Cleaning and Maintenance Workers	O
37-1011	First-Line Supervisors of Housekeeping and Janitorial Workers	O
37-2010	Building Cleaning Workers	W
37-3000	Grounds Maintenance Workers	W
47-1000	Supervisors of Construction and Extraction Workers	O
47-2010	Boilermakers	W
47-2020	Brickmasons, Blockmasons, and Stonemasons	W
47-2030	Carpenters	W
47-2040	Carpet, Floor, and Tile Installers and Finishers	W
47-2050	Cement Masons, Concrete Finishers, and Terrazzo Workers	W
47-2060	Construction Laborers	W
47-2070	Construction Equipment Operators	W
47-2080	Drywall Installers, Ceiling Tile Installers, and Tapers	W
47-2110	Electricians	W
47-2130	Insulation Workers	W
47-2140	Painters and Paperhangers	O
47-2150	Pipelayers, Plumbers, Pipefitters, and Steamfitters	W
47-2160	Plasterers and Stucco Masons	W
47-2180	Roofers	W
47-2210	Sheet Metal Workers	O
47-3000	Helpers, Construction Trades	W
47-4010	Construction and Building Inspectors	O
47-4020	Elevator Installers and Repairers	O
47-4040	Hazardous Materials Removal Workers	W
47-4099	Construction and Related Workers, All Other	W
49-1000	Supervisors of Installation, Maintenance, and Repair Workers	O
49-2091	Avionics Technicians	W
49-2094	Electrical and Electronics Repairers, Commercial and Industrial Equipment	W
49-2095	Electrical and Electronics Repairers, Powerhouse, Substation, and Relay	W
49-3010	Aircraft Mechanics and Service Technicians	W
49-3042	Mobile Heavy Equipment Mechanics, Except Engines	W
49-9010	Control and Valve Installers and Repairers	W
49-9040	Industrial Machinery Installation, Repair, and Maintenance Workers	W
49-9070	Maintenance and Repair Workers, General	W
49-9098	Helpers–Installation, Maintenance, and Repair Workers	W
51-2010	Aircraft Structure, Surfaces, Rigging, and Systems Assemblers	W

SOC	Occupation	Designation
51-4050	Metal Furnace Operators, Tenders, Pourers, and Casters	W
51-4120	Welding, Soldering, and Brazing Workers	W
51-8020	Stationary Engineers and Boiler Operators	W
51-9050	Furnace, Kiln, Oven, Drier, and Kettle Operators and Tenders	W
53-3032	Heavy and Tractor-Trailer Truck Drivers	O
53-5010	Sailors and Marine Oilers	W
53-5020	Ship and Boat Captains and Operators	O
53-5030	Ship Engineers	W
53-7000	Material Moving Workers	O
W = worker designation; O = ONU designation		

After identifying relevant NAICS and SOC codes, EPA/OPPT used BLS data to determine total employment by industry and by occupation based on the NAICS and SOC combinations. For example, there are 66,772 employees associated with 6-digit NAICS 236118 (Residential Building Construction) and 47-2060 (Construction Laborers).

Using a combination of NAICS and SOC codes to estimate total employment provides more accurate estimates for the number of workers than using NAICS codes alone. Using only NAICS codes to estimate number of workers typically result in an overestimate because not all workers employed in that industry sector will be exposed. However, in some cases, BLS only provide employment data at the 4- or 5-digit NAICS level; therefore, further refinement of this approach may be needed (see next step).

Step 3: Refining Employment Estimates to Account for Lack of NAICS Granularity

The third step in EPA/OPPT's methodology was to further refine the employment estimates by using total employment data in the SUSB (U.S. Census Bureau, 2015). In some cases, BLS OES occupation-specific data are only available at the 4- or 5-digit NAICS level, whereas the SUSB data are available at the 6-digit level (but are not occupation-specific). Identifying specific 6-digit NAICS will ensure that only industries with potential asbestos exposure are included. As an example, OES data are available for the 4-digit NAICS 3251 Basic Chemical Manufacturing, which includes the following 6-digit NAICS:

- NAICS 325110 Petrochemical Manufacturing;
- NAICS 325120 Industrial Gas Manufacturing;
- NAICS 325130 Synthetic Dye and Pigment Manufacturing;
- NAICS 325180 Other Basic Inorganic Chemical Manufacturing;
- NAICS 325193 Ethyl Alcohol Manufacturing;
- NAICS 325194 Cyclic Crude, Intermediate, and Gum and Wood Chemical Manufacturing; and
- NAICS 325199 All Other Basic Organic Chemical Manufacturing.

In this example, only NAICS 325199 is of interest. The Census data allow EPA/OPPT to calculate employment in the specific 6-digit NAICS of interest as a percentage of employment in the BLS 4-digit NAICS.

The 6-digit NAICS 325199 comprises 43 percent of total employment under the 4-digit NAICS 3251. This percentage can be multiplied by the occupation-specific employment estimates given in the BLS OES data to further refine our estimates of the number of employees with potential exposure. Table_Apx G-49 illustrates this granularity adjustment for NAICS 325199.

Table_Apx G-49. Estimated Number of Potentially Exposed Workers and ONUs under NAICS 325199

NAICS	SOC CODE	SOC Description	Occupation Designation	Employment by SOC at 4-Digit NAICS Level	% of Total Employment	Estimated Employment by SOC at 6-Digit NAICS Level
3251	11-9020	Construction Managers	O	22	43	9
3251	11-9040	Architectural and Engineering Managers	O	332	43	143
3251	17-2050	Civil Engineers	O	69	43	30
3251	17-2070	Electrical and Electronics Engineers	O	190	43	82
3251	17-2110	Industrial Engineers, Including Health and Safety	O	1,169	43	503
3251	37-2010	Building Cleaning Workers	W	129	43	55
3251	37-3000	Grounds Maintenance Workers	W	22	43	9
3251	47-1000	Supervisors of Construction and Extraction Workers	O	17	43	7
3251	47-2010	Boilermakers	W	13	43	6
3251	47-2070	Construction Equipment Operators	W	142	43	61
3251	47-2110	Electricians	W	358	43	154
3251	47-2150	Pipelayers, Plumbers, Pipefitters, and Steamfitters	W	65	43	28
3251	49-1000	Supervisors of Installation, Maintenance, and Repair Workers	O	712	43	306
3251	49-2094	Electrical and Electronics Repairers, Commercial and Industrial Equipment	W	461	43	198
3251	49-9010	Control and Valve Installers and Repairers	W	121	43	52
3251	49-9040	Industrial Machinery Installation, Repair, and Maintenance Workers	W	2,488	43	1,070
3251	49-9070	Maintenance and Repair Workers, General	W	2,393	43	1,029
3251	49-9098	Helpers–Installation, Maintenance, and Repair Workers	W	39	43	17

NAICS	SOC CODE	SOC Description	Occupation Designation	Employment by SOC at 4-Digit NAICS Level	% of Total Employment	Estimated Employment by SOC at 6-Digit NAICS Level
3251	51-4120	Welding, Soldering, and Brazing Workers	W	112	43	48
3251	51-8020	Stationary Engineers and Boiler Operators	W	190	43	82
3251	51-9050	Furnace, Kiln, Oven, Drier, and Kettle Operators and Tenders	W	47	43	20
3251	53-3032	Heavy and Tractor-Trailer Truck Drivers	O	2,385	43	1,026
3251	53-7000	Material Moving Workers	O	2,243	43	964
Total Potentially Exposed Employees				**13,719**	**43**	**5,899**
Total Workers				**6,580**	**43**	**2,829**
Total Occupational Non-users				**7,139**	**43**	**3,070**
Source: (U.S. Census Bureau, 2015); (U.S. BLS, 2016) Note: numbers may not sum exactly due to rounding. W = worker; O = occupational non-user						

Step 4: Estimating the Number of Workers per Establishment

EPA/OPPT calculated the number of workers and ONUs in each industry/occupation combination using the formula below (granularity adjustment is only applicable where SOC data are not available at the 6-digit NAICS level): Number of Workers or ONUs in NAICS/SOC (Step 2) × Granularity Adjustment Percentage (Step 3) = Number of Workers or ONUs in the Industry/Occupation Combination

EPA/OPPT then estimated the total number of establishments by obtaining the number of establishments reported in the U.S. Census Bureau's SUSB (U.S. Census Bureau, 2015) data at the 6-digit NAICS level.

Next, EPA/OPPT summed the number of workers and ONUs across all occupations within a NAICS code and divided these sums by the number of establishments in the NAICS code to calculate the average number of workers and occupational non-users per establishment.

Step 5: Estimating the Number of Workers and Establishments for a COU

EPA/OPPT estimated the number of workers and ONUs potentially exposed to asbestos and the number of sites that use asbestos in a given COU through the following steps:

5.A Obtaining the number of establishments from SUSB (U.S. Census Bureau, 2015) at the 6-digit NAICS level (Step 3) for each NAICS code in the condition of use and summing these values; and

5.B Estimating the number of workers and occupational non-users potentially exposed to asbestos by taking the number of establishments calculated in Step 5.A and multiplying it by the average number of workers and occupational non-users per site from Step 4.

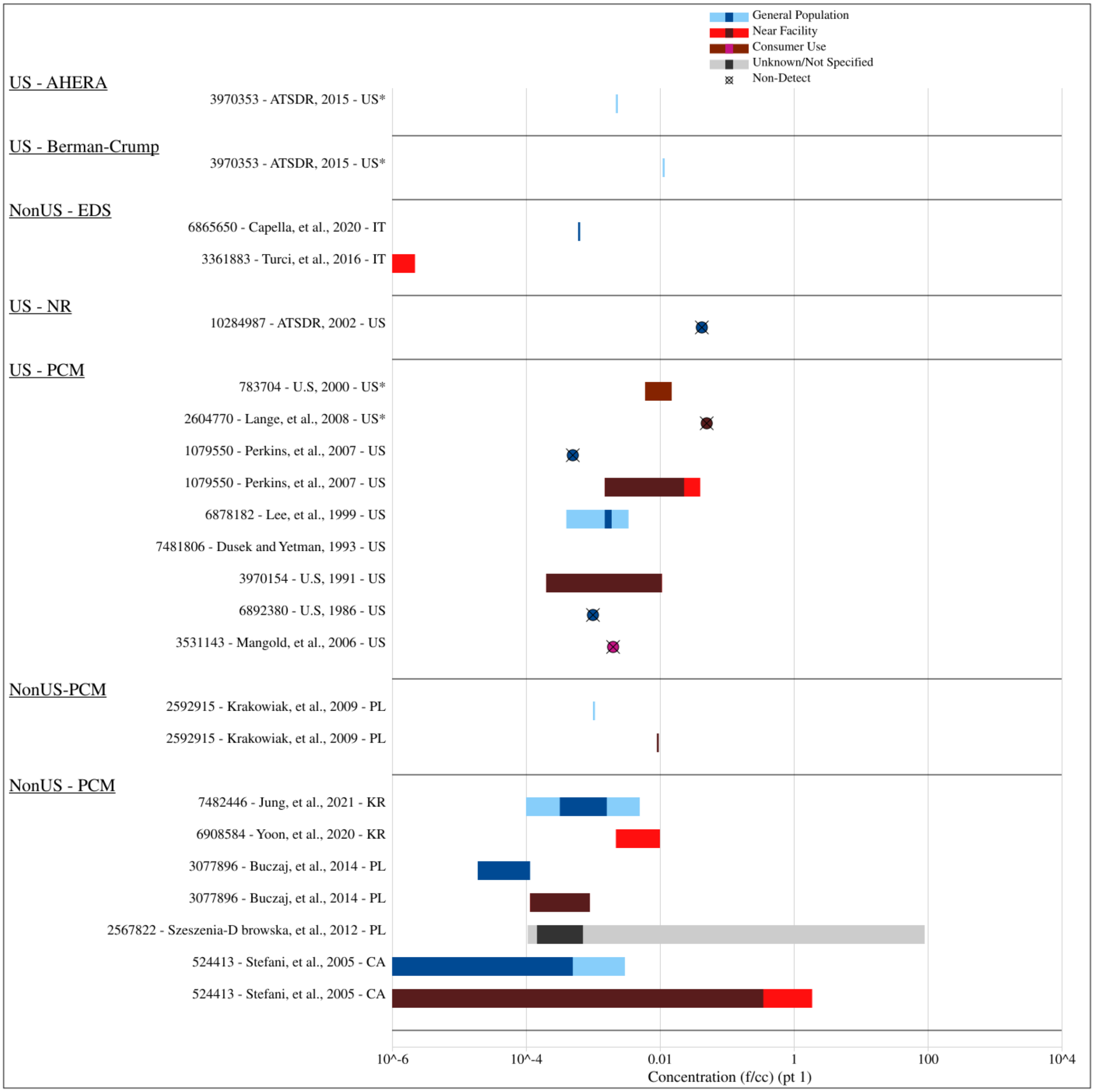
Appendix H ENVIRONMENTAL EXPOSURE DETAILS

H.1 Ambient Air Measured Concentrations

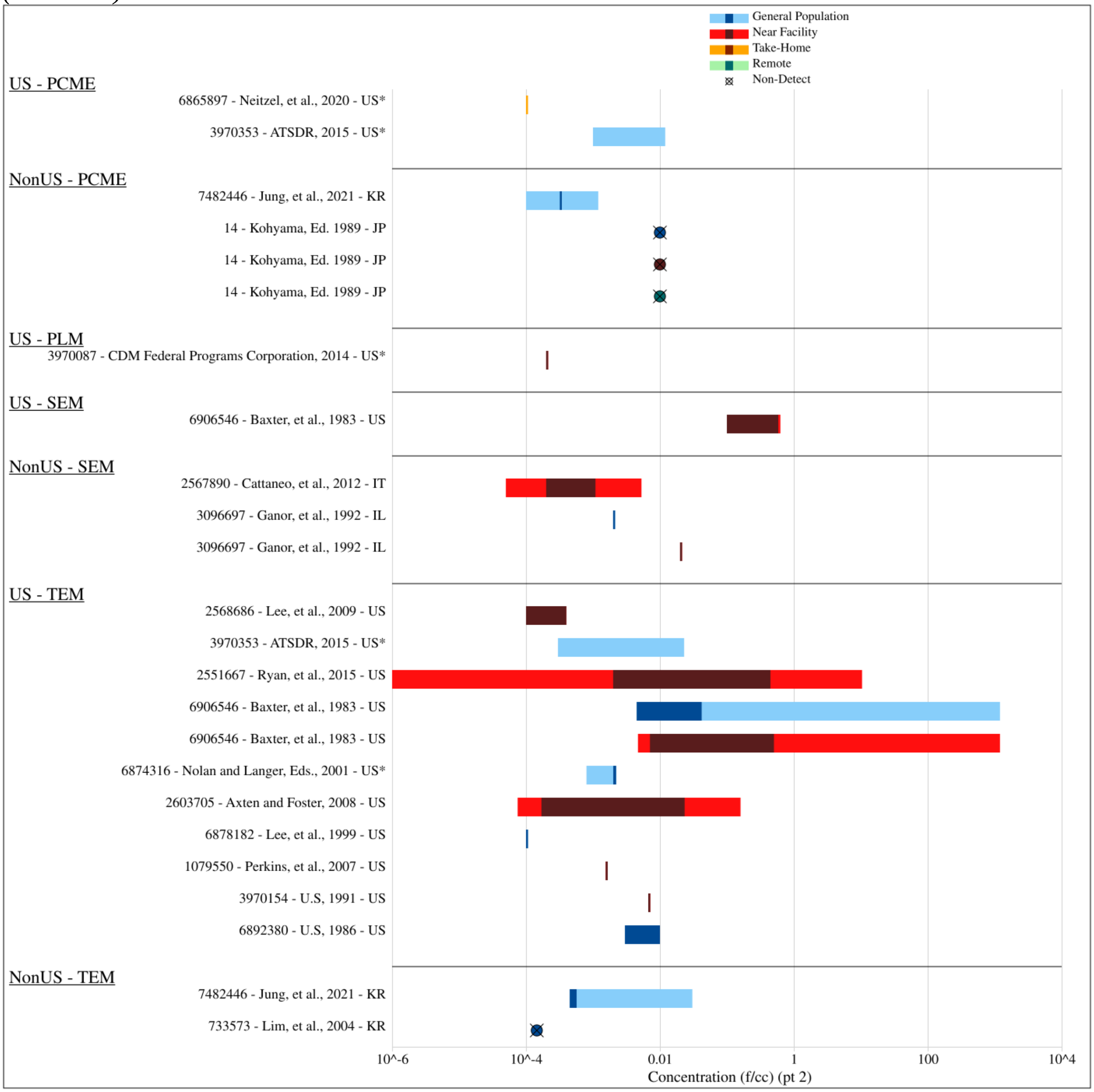
This section provides a summary of the data used to build the ambient air measured scenarios to be used to assess environmental concentrations and general population exposures to these releases. The systematic review process identified studies that measured asbestos fibers in ambient air, Figure_Apx H-1 presents the concentration data per country, per asbestos analysis method, and per year.

Overall measured concentrations of asbestos in ambient air with unit of f/cc, extracted from 34 sources, are summarized in the bullets that follow; Figure_Apx H-1 supplemental information is provided in Table_Apx H-1.

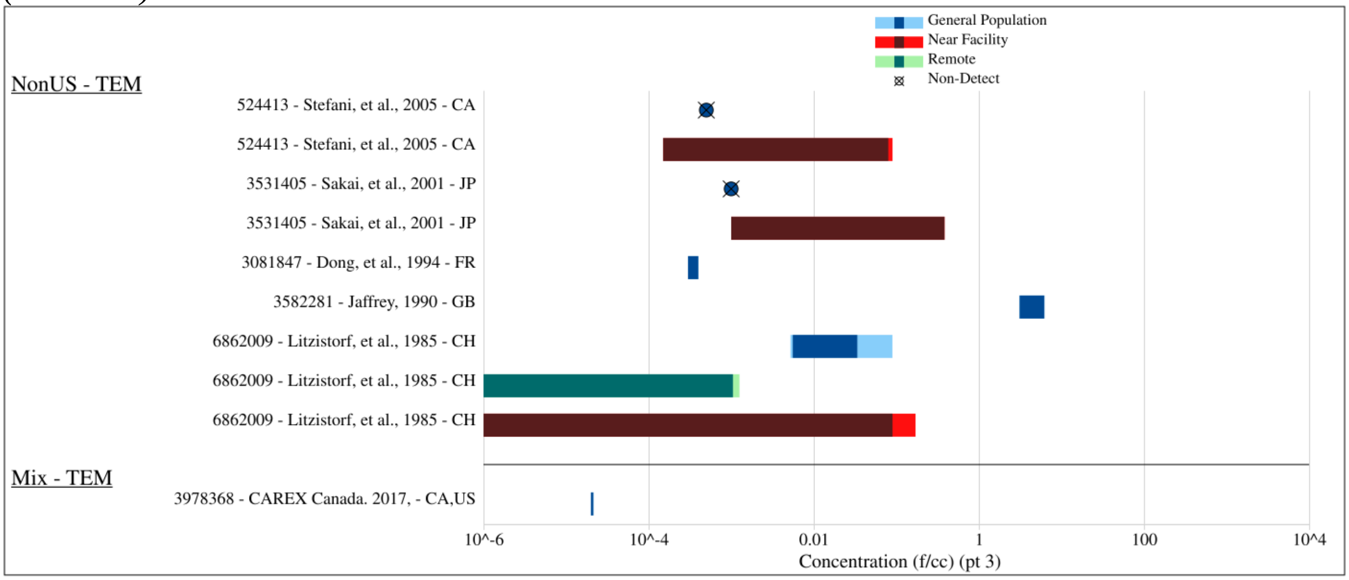
- AHERA concentrations ranged from not detected to 0.0022 f/cc from 98 samples collected between 2010 and 2011 in one country (United States). Location types were categorized as General Population. Reported detection frequency was 0.2.
- Berman-Crump ranged concentrations ranged from not detected to 0.011 f/cc from 98 samples collected between 2010 and 2011 in one country (United States). Location types were categorized as General Population. Reported detection frequency was 0.2.
- EDS concentrations ranged from not detected to 0.0006 f/cc from 50 samples collected between 2014 and 2016 in one country (Italy). Location types were categorized as General Population and Near Facility. Reported detection frequency ranged from 0.42 to 0.5.
- N/R concentrations were not detected f/cc from six samples collected in 1997 in one country, (United States). Location types were categorized as General Population. Reported detection frequency was 0.0.
- PCM concentrations ranged from not detected to 90.0 f/cc from 7,333 samples collected between 1982 and 2021 in 4 countries (Canada, Korea, Poland, and United States). Location types were categorized as General Population, Unknown/Not Specified, Consumer Use and Near Facility. Reported detection frequency ranged from 0.0 to 1.0.
- PCME concentrations ranged from not detected to 0.012 f/cc from 637 samples collected between 1989 and 2021 in 3 countries (Japan, Korea, and United States). Location types were categorized as Remote, General Population, Near Facility and Take-Home. Reported detection frequency was not reported.
- PLM concentrations were 0.0002 f/cc from 97 samples collected in 2014 in one country (United States). Location types were categorized as Near Facility. Reported detection frequency was 0.11.
- SEM concentrations ranged from not detected to 0.63 f/cc from 36 samples collected between 1991 and 2012 in 3 countries (Israel, Italy, and United States). Location types were categorized as General Population and Near Facility. Reported detection frequency was 1.0.
- TEM concentrations ranged from not detected to 1,200.0 f/cc from 3,843 samples collected between 1977 and 2021 in 7 countries (Canada, Switzerland, France, Great Britain, Japan, Korea, and United States). Location types were categorized as Remote, General Population and Near Facility. Reported detection frequency ranged from 0.0 to 1.0.


General Population
Near Facility
Consumer Use
Unknown/Not Specified
Non-Detect
US - AHERA
3970353 - ATSDR, 2015 - US*
US - Berman-Crump
3970353 - ATSDR, 2015 - US*
NonUS - EDS
6865650 - Capella, et al., 2020 - IT
3361883 - Turci, et al., 2016 - IT
US - NR
10284987 - ATSDR, 2002 - US
US - PCM
783704 - U.S, 2000 - US*
2604770 - Lange, et al., 2008 - US*
1079550 - Perkins, et al., 2007 - US
1079550 - Perkins, et al., 2007 - US
6878182 - Lee, et al., 1999 - US
7481806 - Dusek and Yetman, 1993 - US
3970154 - U.S, 1991 - US
6892380 - U.S, 1986 - US
3531143 - Mangold, et al., 2006 - US
NonUS-PCM
2592915 - Krakowiak, et al., 2009 - PL
2592915 - Krakowiak, et al., 2009 - PL
NonUS - PCM
7482446 - Jung, et al., 2021 - KR
6908584 - Yoon, et al., 2020 - KR
3077896 - Buczaj, et al., 2014 - PL
3077896 - Buczaj, et al., 2014 - PL
2567822 - Szeszenia-D browska, et al., 2012 - PL
524413 - Stefani, et al., 2005 - CA
524413 - Stefani, et al., 2005 - CA
10^-6
10^-4
0.01
1
100
10^4
Concentration (f/cc) (pt 1)

(continued)


General Population
Near Facility
Take-Home
Remote
Non-Detect
US - PCME
6865897 - Neitzel, et al., 2020 - US*
3970353 - ATSDR, 2015 - US*
NonUS - PCME
7482446 - Jung, et al., 2021 - KR
14 - Kohyama, Ed. 1989 - JP
14 - Kohyama, Ed. 1989 - JP
14 - Kohyama, Ed. 1989 - JP
US - PLM
3970087 - CDM Federal Programs Corporation, 2014 - US*
US - SEM
6906546 - Baxter, et al., 1983 - US
NonUS - SEM
2567890 - Cattaneo, et al., 2012 - IT
3096697 - Ganor, et al., 1992 - IL
3096697 - Ganor, et al., 1992 - IL
US - TEM
2568686 - Lee, et al., 2009 - US
3970353 - ATSDR, 2015 - US*
2551667 - Ryan, et al., 2015 - US
6906546 - Baxter, et al., 1983 - US
6906546 - Baxter, et al., 1983 - US
6874316 - Nolan and Langer, Eds., 2001 - US*
2603705 - Axten and Foster, 2008 - US
6878182 - Lee, et al., 1999 - US
1079550 - Perkins, et al., 2007 - US
3970154 - U.S, 1991 - US
6892380 - U.S, 1986 - US
NonUS - TEM
7482446 - Jung, et al., 2021 - KR
733573 - Lim, et al., 2004 - KR
10^-6
10^-4
0.01
1
100
10^4
Concentration (f/cc) (pt 2)

(continued)



Figure_Apx H-1. Concentrations of Asbestos (f/cc) in Ambient Air from 1977 to 2021
* = Reference used in risk evaluation

Table_Apx H-1. Summary of Peer-Reviewed Literature that Measured Asbestos (f/cc) Levels in Ambient Air

Citation	Fiber Type(s)	Fiber Size	Country	Location Type	Sampling Year(s)	Sample Size (Frequency of Detection)	Detection Limit (f/cc)	Overall Quality Level
AHERA								
(ATSDR, 2015) [a]	Chrysotile (asbestiform of mineral serpentine)	N/R	US	General Population	2010–2011	98 (0.20)	N/R	Medium
Berman-Crump								
(ATSDR, 2015) [a]	Chrysotile (asbestiform of mineral serpentine)	N/R	US	General Population	2010–2011	98 (0.20)	N/R	Medium
EDS								
(Capella et al., 2020)	Tremolite; actinolite	≥5 µm	IT	General Population	2014–2016	48 (0.42)	N/R	Medium
(Turci et al., 2016)	Chrysotile (asbestiform of mineral serpentine)	0.8 µm	IT	Near Facility	2016	2 (0.50)	N/R	Medium
N/R								
(ATSDR, 2002)	General	N/R	US	General Population	1997	6 (0.00)	0.0846	Medium
PCM								
(U.S. EPA, 2000a) [a]	General	>5µm	US	Consumer Use	2000	7 (1.00)	N/R	Medium
(Lange et al., 2008)	General	0.8 µm	US	Near Facility	2000	248 (N/R)	0.1	Medium
(Perkins et al., 2007)	General	N/R	US	General Population	1999	3 (0.00)	0.001	Medium
(Perkins et al., 2007)	General	N/R	US	Near Facility	1994–1999	24 (0.67)	0.003	Medium
(Lee et al., 1999)	General	≥5 µm	US	General Population	1998	590 (N/R)	N/R	Medium
(Dusek and Yetman, 1993)	General Tremolite Actinolite	N/R	US	General Population	1989–1990	12 (N/R)	N/R	Medium
(U.S. EPA, 1991)	Chrysotile (asbestiform of mineral serpentine)	≥5µm	US	Near Facility	1986–1987	8 (0.50)	N/R	Medium
(U.S. EPA, 1986b)	General	>0.8 µm	US	General Population	1984–1985	5 (0.00)	0.002	High
(Mangold et al., 2006)	Chrysotile (asbestiform of mineral serpentine)	> 5µm length	US	Consumer Use	1982	12 (N/R)	0.004	Medium
(Krakowiak et al., 2009)	Chrysotile	N/R	PL	General Population	2009	59 (N/R)	0.001	Medium
(Krakowiak et al., 2009)	Chrysotile	N/R	PL	Near Facility	2009	82 (N/R)	N/R	Medium

Citation	Fiber Type(s)	Fiber Size	Country	Location Type	Sampling Year(s)	Sample Size (Frequency of Detection)	Detection Limit (f/cc)	Overall Quality Level
(Jung et al., 2021)	Chrysotile (asbestiform of mineral serpentine) Tremolite Actinolite	5.24–35.5 µm 5.01–28.5 µm 6.07–40.2 µm	KR	General Population	2021	125 (N/R)	N/R	Medium
(Yoon et al., 2020)	General Chrysotile (asbestiform of mineral serpentine) Tremolite Actinolite	N/R	KR	Near Facility	2020	87 (0.31)	N/R	Low
(Buczaj et al., 2014)	General	0.8 µm	PL	General Population	2009–2011	21 (0.33)	N/R	Medium
(Buczaj et al., 2014)	General	0.8 µm	PL	Near Facility	2009–2011	66 (0.82)	N/R	Medium
(Szeszenia-Dąbrowska et al., 2012)	General	>5 µm	PL	Unknown/ Not Specified	2004–2010	5,962 (0.98)	180.0	Medium
(Stefani et al., 2005)	General	N/R	CA	General Population	1998	9 (0.22)	0.001	Low
(Stefani et al., 2005)	General	N/R	CA	Near Facility	1998	13 (0.77)	0.006	Low
PCME								
(Neitzel et al., 2020)*	Chrysotile (asbestiform of mineral serpentine)	10–20 µm	US	Take-Home	2017–2018	25 (N/R)	N/R	Medium
(ATSDR, 2015)*	General Chrysotile (asbestiform of mineral serpentine)	N/R	US	General Population	2008–2011	149 (N/R)	N/R	Medium
(Jung et al., 2021)	Chrysotile (asbestiform of mineral serpentine) Tremolite Actinolite	5.24–35.5 µm, 5.01–28.5 µm, 6.07–40.2 µm	KR	General Population	2021	227 (N/R)	N/R	Medium
(Kohyama, 1989)	Chrysotile (asbestiform of mineral serpentine)	>5 µm	JP	General Population	1989	96 (N/R)	0.02	Medium
(Kohyama, 1989)	Chrysotile (asbestiform of mineral serpentine) Amosite (asbestiform of mineral grunerite)	>5 µm	JP	Near Facility	1989	102 (N/R)	0.02	Medium
(Kohyama, 1989)	Chrysotile (asbestiform of mineral serpentine)	>5 µm	JP	Remote	1989	38 (N/R)	0.02	Medium
PLM								
(CDM Federal Programs Corporation, 2014)*	General Tremolite	N/R	US	Near Facility	2014	97 (0.11)	N/R	Medium

Citation	Fiber Type(s)	Fiber Size	Country	Location Type	Sampling Year(s)	Sample Size (Frequency of Detection)	Detection Limit (f/cc)	Overall Quality Level
SEM								
(Baxter et al., 1983)	Chrysotile (asbestiform of mineral serpentine)	>5µm	US	Near Facility	2001	6 (1.00)	2400.0	Medium
(Cattaneo et al., 2012)	Chrysotile (asbestiform of mineral serpentine)	8.1 µm	IT	Near Facility	2012	22 (N/R)	N/R	Medium
(Ganor et al., 1992)	Crocidolite (asbestiform of mineral riebeckite)	N/R	IL	General Population	1991	4 (N/R)	N/R	Medium
(Ganor et al., 1992)	Crocidolite (asbestiform of mineral riebeckite)	N/R	IL	Near Facility	1991	4 (N/R)	N/R	Medium
TEM								
(Lee et al., 2009)	General Crocidolite (asbestiform of mineral riebeckite) Amosite (asbestiform of mineral grunerite) Tremolite Actinolite	≥5 µm	US	Near Facility	2019	122 (N/R)	N/R	Medium
(ATSDR, 2015)*	General Chrysotile (asbestiform of mineral serpentine)	N/R	US	General Population	2008–2011	149 (N/R)	N/R	Medium
(Ryan et al., 2015)	General	>5µm	US	Near Facility	2007-2008	186 (N/R)	N/R	High
(Baxter et al., 1983)	Chrysotile (asbestiform of mineral serpentine)	>5µm	US	General Population	2001	38 (0.55)	2,400.0	Medium
(Baxter et al., 1983)	Chrysotile (asbestiform of mineral serpentine)	>5µm	US	Near Facility	2001	22 (0.73)	2,400.0	Medium
(Nolan and Langer, 2001)*	General Chrysotile (asbestiform of mineral serpentine) Amosite (asbestiform of mineral grunerite)	>5 µm	US	General Population	2001	40 (N/R)	N/R	Medium
(Axten and Foster, 2008)	Tremolite Actinolite	N/R	US	Near Facility	1990-1998	380 (N/R)	N/R	Medium
(Lee et al., 1999)	General	≥5 µm	US	General Population	1998	590 (N/R)	N/R	Medium
(Perkins et al., 2007)	General	N/R	US	Near Facility	1994	9 (0.22)	N/R	Medium
(U.S. EPA, 1991)	Chrysotile (asbestiform of mineral serpentine)	≥5 µm	US	Near Facility	1986	4 (0.75)	N/R	Medium
(U.S. EPA, 1986b)	General	>0.4 µm	US	General Population	1984–1985	2 (0.50)	0.006	High

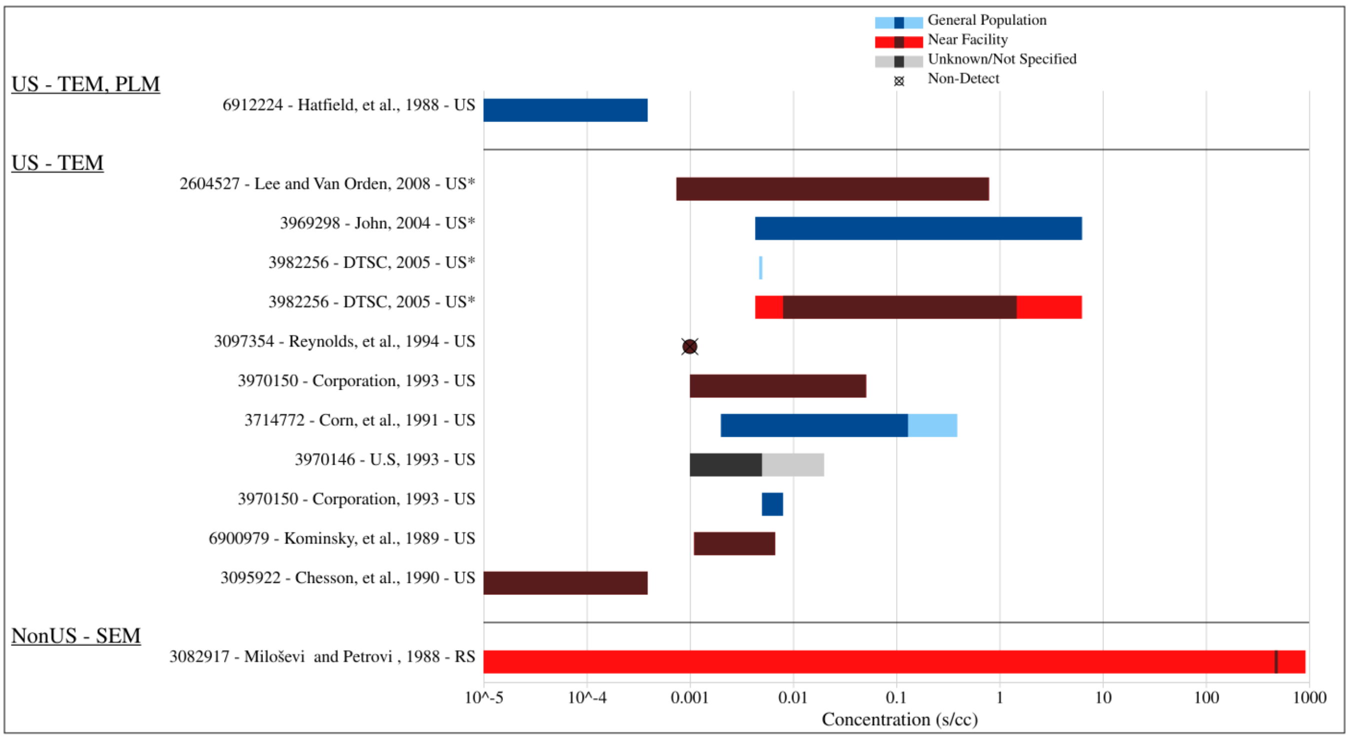
Citation	Fiber Type(s)	Fiber Size	Country	Location Type	Sampling Year(s)	Sample Size (Frequency of Detection)	Detection Limit (f/cc)	Overall Quality Level
(Jung et al., 2021)	Chrysotile (asbestiform of mineral serpentine) Tremolite Actinolite	5.24–35.5 µm, 5.01–28.5 µm, 6.07–40.2 µm	KR	General Population	2021	352 (N/R)	N/R	Medium
(Lim et al., 2004)	Chrysotile (asbestiform of mineral serpentine) Amosite (asbestiform of mineral grunerite) Tremolite Actinolite Chrysotile (asbestiform of mineral serpentine) Amosite (asbestiform of mineral grunerite) Actinolite Tremolite Crocidolite (asbestiform of mineral riebeckite) Anthophyllite	0.2 µm N/R	KR	General Population	2001	96 (N/R)	0.00029	Medium
(Stefani et al., 2005)	General	N/R	CA	General Population	1998	4 (0.00)	0.001	Low
(Stefani et al., 2005)	General	N/R	CA	Near Facility	1998	4 (0.75)	0.0003	Low
(Sakai et al., 2001)	General Chrysotile (asbestiform of mineral serpentine) Tremolite Actinolite Crocidolite (asbestiform of mineral riebeckite) Amosite (asbestiform of mineral grunerite) Anthophyllite	>2µm	JP	General Population	1996	2 (0.00)	0.002	Medium
(Sakai et al., 2001)	General Chrysotile (asbestiform of mineral serpentine) Tremolite Actinolite Crocidolite (asbestiform of mineral riebeckite)	>2µm	JP	Near Facility	1996	14 (0.79)	0.002	Medium

Citation	Fiber Type(s)	Fiber Size	Country	Location Type	Sampling Year(s)	Sample Size (Frequency of Detection)	Detection Limit (f/cc)	Overall Quality Level
	Amosite (asbestiform of mineral grunerite) Anthophyllite							
(Dong et al., 1994)	General Chrysotile (asbestiform of mineral serpentine)	>5µm >0.5µm	FR	General Population	1993	2 (0.50)	N/R	Medium
(Jaffrey, 1990)	General	N/R	GB	General Population	1990	50 (0.34)	N/R	Medium
(Litzistorf et al., 1985)	Chrysotile (asbestiform of mineral serpentine)	All sizes	CH	General Population	1977–1983	12 (1.00)	N/R	Medium
(Litzistorf et al., 1985)	Chrysotile (asbestiform of mineral serpentine)	All sizes	CH	Remote	1983	2 (1.00)	N/R	Medium
(Litzistorf et al., 1985)	Chrysotile (asbestiform of mineral serpentine)	All sizes	CH	Near Facility	1981–1982	4 (1.00)	N/R	Medium
(Carex Canada, 2017)	General	N/R	CA, US	General Population	2011	1,759 (N/R)	N/R	Medium

[a] Used in risk evaluation
N/R = not reported; CA = Canada; CH = Switzerland; FR = France; GB = Greece; IT = Italy; JP = Japan; KR = Korea; PL = Poland; US = United States

Overall measured concentrations of Asbestos in Ambient Air with unit of s/cc, extracted from 11 sources, are summarized in the bullets that follow and presented in Figure_Apx H-2. Additional information is provided in Table_Apx H-2.

- Concentrations for SEM ranged from not detected to 924.0 s/cc from 10 samples collected between 1975 and 1976 in 1 country, Russia. Location types were categorized as Near Facility. Reported detection frequency was 0.9.
- Concentrations for TEM ranged from not detected to 6.3 s/cc from 3,867 samples collected between 1987 and 2008 in 1 country (United States). Location types were categorized as General Population, Unknown/Not Specified and Near Facility. Reported detection frequency ranged from 0.0 to 1.0.
- Concentrations for TEM, PLM ranged from 1×10^{-5} to 0.00039 s/cc from 48 samples collected in 1988 in 1 country (United States). Location types were categorized as General Population. Reported detection frequency was not reported.



Figure_Apx H-2. Concentrations of Asbestos (s/cc) in Ambient Air from 1975 to 2008
* = Reference used in risk determination

Table_Apx H-2. Summary of Peer-Reviewed Literature that Measured Asbestos (s/cc) Levels in Ambient Air

Source	Fiber Type(s)	Fiber Size	Country	Location Type	Sampling Year(s)	Sample Size (Frequency of Detection)	Detection Limit (s/cc)	Overall Quality Level
SEM								
(Milošević and Petrović, 1988)	General	≤7 µm	RS	Near Facility	1975–1976	10 (0.90)	N/R	Low
TEM								
(Lee and Van Orden, 2008) [a]	General	N/R	US	Near Facility	2008	3356 (N/R)	N/R	Medium
(John, 2004) [a]	Chrysotile (asbestiform of mineral serpentine)	both <5 µm and ≥5 µm	US	General Population	2002–2003	68 (N/R)	N/R	Medium
(DTSC, 2005) [a]	General	>5µm	US	General Population	2002–2003	1 (1.00)	N/R	High
(DTSC, 2005) [a]	General	>5µm	US	Near Facility	2002–2003	29 (N/R)	N/R	High
(Reynolds et al., 1994)	General	>0.5 µm	US	Near Facility	1994	6 (0.00)	0.002	Medium
(IT Corporation, 1993)	General Chrysotile (asbestiform of mineral serpentine) Chrysotile (asbestiform of mineral serpentine) Amosite (asbestiform of mineral grunerite)	0.45 µm	US	Near Facility	1989–1993	156 (N/R)	N/R	Low
(Corn et al., 1991)	General	0.8–1.2 µm; 0.4 µm	US	General Population	1991	94 (N/R)	N/R	Medium
(U.S. EPA, 1993)	General	N/R	US	Unknown/ Not Specified	1991	75 (N/R)	N/R	High
(IT Corporation, 1993)	General Chrysotile (asbestiform of mineral serpentine)	0.45 µm	US	General Population	1989	33 (N/R)	N/R	Low
(Kominsky et al., 1989)	General	N/R	US	Near Facility	1989	12 (N/R)	N/R	Medium
(Chesson et al., 1990)	General	N/R	US	Near Facility	1987	37 (N/R)	N/R	Medium
TEM, PLM								
(Hatfield et al., 1988)	General	1 µm	US	General Population	1988	48 (N/R)	N/R	Medium

[a] Used in this risk evaluation.
N/R = not reported; RS = Russia; US = United States

Table 3-9 in Section 3.3.1 is an abbreviated version of Table_Apx H-3 below, which includes details on the source of the data, the statistics performed to obtain the low-, high-end, and central tendencies.

Table_Apx H-3. Summary of Published Literature for Measured Ambient Air Concentrations

Proposed Scenario	Source Description	Reported Concentration (f/cc)		Summary Stats Per Proposed Scenario (f/cc)		
		Value (f/cc)	Stat Type and Description	LE	HE	CT
Near Facility or Near Source gardening products	(U.S. EPA, 2000a) Location: Springfield, VA Sampling Date: 2000 (implied from publishing date) Rating: High	0.011	Min – source reported	0.011 Reported min	0.00957 Reported max	0.01029 Averaged LE and HE
		0.00957	Max – source reported			
Near Facility or Near Source public space urban	(Lange et al., 2008) Location: Eastern US Sampling Date: 2000 Rating: Medium	0.01 0.01 0.01 0.01 0.01	Min – source reported DL, multiple samples of 5 types of products removed. All BDL	0.00307 10th percentile all reported data	0.0202 95th percentile all reported data	0.01053 Averaged all reported data
		0.03 0.02 0.02 0.02 0.02	Max – source reported, multiple samples of 5 types of products removed.			
		0.01 0.01 0.01 0.01 0.01	Average – source reported DL, multiple samples of 5 types of products removed. All BDL			
	(Neitzel et al., 2020) Location: Detroit, MI Sampling Date: 2017 Rating: Medium	0.0001	90th percentile – source reported, only value above DL			
Near facility or near source public space urban	(Nolan and Langer, 2001) Location: Various U.S. Sampling Date: 2001 Rating: Medium	0.00201	Average – source reported from 9 samples at various schools	0.00104 10th percentile all reported data	0.0022 95th percentile all reported data	0.00168 Averaged all reported data
		0.0008	Data point – source reported from a school			
		0.00222	Average – source reported from 31 samples at various universities			
Perimeter industrial location	(ATSDR, 2015) Location: Ambler, Montgomery County, Pennsylvania, BoRit Site Sampling Date: 2008 and 2010 Rating Medium	0.0003	Min – source reported from 51 samples in 2008, all other samples were BDL	0.0015 10th percentile all reported data	0.009 95th percentile all reported data	0.0053 Averaged all reported data
		0.0006 0.012 0.001 0.0022 0.023 0.011	Max – source reported from 51 samples in 2008 and 98 in 2010			
LE = low-end, HE = high-end; CT = central tendency						

H.2 Ambient Air Modeled Concentrations

This section describes in detail the methodologies utilized to estimate ambient air concentrations and exposures for members of the general population that are in proximity (between 10 to 10,000 m) to emissions sources emitting asbestos fibers. All exposures were assessed for the inhalation route only.

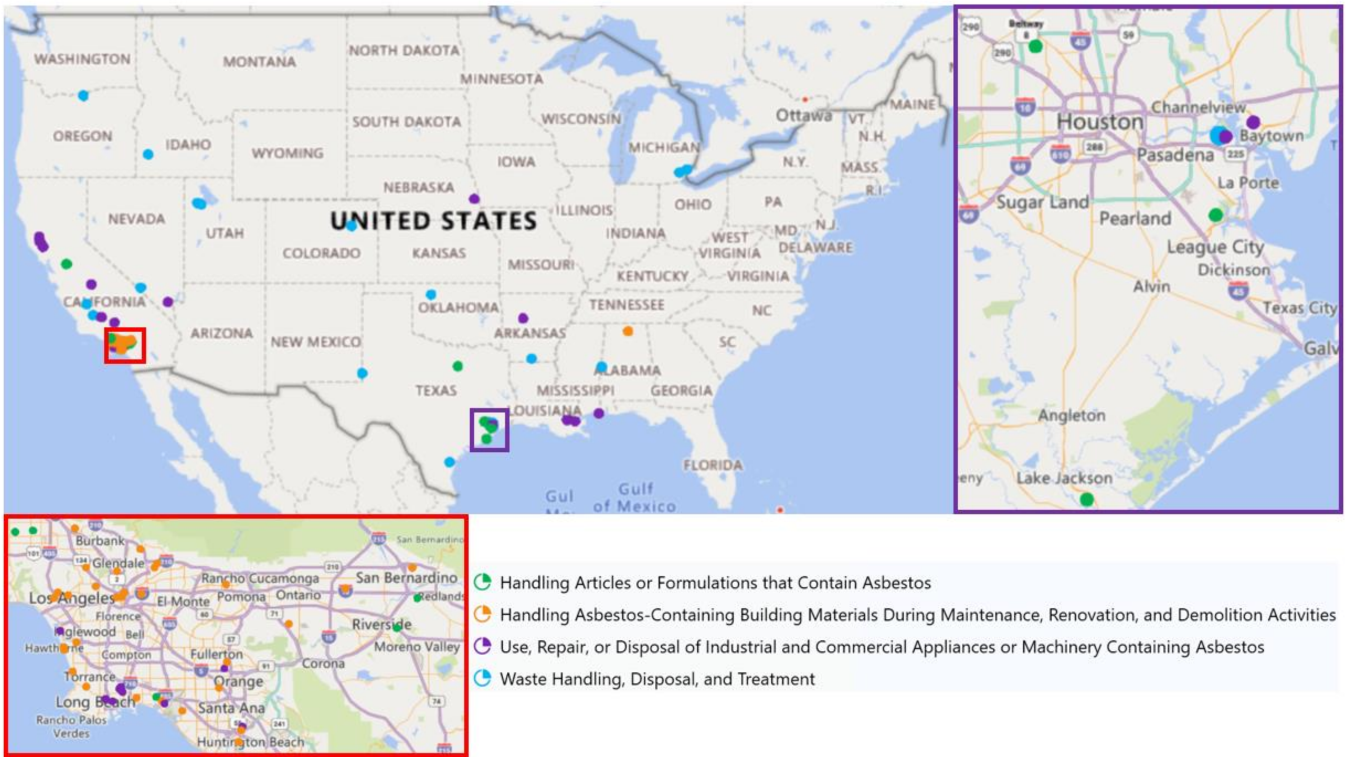
The overall steps to obtain ambient air exposure concentrations and risk calculations are provided below:

- Step 1: Obtain TRI and NEI data
- Step 2: Map TRI and NEI data to OESs
- Step 3: Estimate the number of releases days for each OES
- Step 4: Estimate air emissions for OES with no TRI or NEI data
- Step 5: Prepare air emission summary for ambient air exposure modeling, see *Air Release Assessment for Legacy Asbestos_3.27.2023.xlsx*
- Step 6: Specific facilities – EPA modeled exposure concentrations on a facility-by-facility basis, building out a series of facility specific exposure scenarios based on the release data provided by Steps 1 to 5. EPA modeled exposure concentrations at eight finite distances from a releasing facility (10, 30, 60, 100, 1,000 2,500, 5,000 and 10,000 m) in a series of concentric rings around the facility
- Step 7: Generic facilities – Represent additional unknown facilities, EPA developed generic TRI facilities with ranges of emission rates
- Step 8: Estimate air concentrations and deposition resulting from air releases of asbestos, modeled at general-population and co-located exposure points surrounding the release sources using AERMOD

TRI and NEI emission data are for specific facilities provided actual geographical coordinates and description of asbestos releases activities. Because activities that release asbestos can be transitory, for example demolition of structures and removal of asbestos containing materials, and firefighting activities the word facilities in this RE can apply to stationary and permanent locations as well as temporary. EPA developed scenarios for TRI facilities with ranges of emission rates for unknown and transitory activities and are referred to as “generic facilities.”

EPA modeled exposure concentrations on a facility-by-facility basis (specific and generic facilities), building out a series of facility-specific exposure scenarios based on the release data provided in Appendix G.16.3. EPA modeled exposure concentrations at eight points at finite distances from a releasing facility (10, 30, 60, 100, 1,000, 2,500, 5,000 and 10,000 m) in a series of concentric rings around the facility. All modeling scenarios utilized a region of gridded exposure points and several rings/radials of exposure points. The rings had exposure points placed every 22.5 degrees (starting due north of the facility) for distances 10, 30, and 60 m from the source for co-located exposure points and 100, 1,000, 2,500, 5,000, and 10,000 m from the source for general-population exposure points. Between 100 m and 1,000 m from the source—an area termed “community” in IIOAC. All exposure points were at 1.8 m above ground, as a proxy for breathing height for concentration estimates. A duplicate set of exposure points was at ground level (0 m) for deposition estimations.

Facility coordinates, in the form of latitude/longitude coordinates, were mapped (Figure_Apx H-3) to show locations by OES and used to match the facility to the closest available meteorological station. Latitude/longitude coordinates were extracted from TRI and provided as part of the release assessment for facilities reporting to the 2019 TRI. NEI facilities did not have coordinates.



Figure_Apx H-3. Map of Specific Facilities by OES

More parameters were required to run the higher tier model, AERMOD. EPA reviewed available literature to select input parameters for deposition, particle sizes, meteorological data, urban/rural designations, and physical source specifications. A full description of the input parameters selected for AERMOD and details regarding post-processing of the results are provided in Appendices H.2.1 to H.2.9 below.

H.2.1 Meteorological Data

Specific facilities meteorological data used in AERMOD the same meteorological data that EPA's Risk and Technology Review (RTR) program uses for risk modeling in review of National Emission Standards for Hazardous Air Pollutants (NESHAP). The RTR data cover hourly stations in the 50 states, District of Columbia, and Puerto Rico. The meteorological data set that the RTR program currently uses includes 838 stations with data mostly from the year 2019 for 47 stations (mainly in Alaska and West Virginia). EPA utilized data from 2016, 2017, or 2018 to fill notable spatial gaps. The RTR 2019 meteorological data set was used to model emission years 2018 and 2019. Meteorological data from 2016 was used for emission years 2014 to 2017, covering 824 stations, which the RTR program used prior to the updates to the 2019 data set.

Generic facilities meteorological data was modeled twice with two different meteorological stations. EPA's IIOAC utilized a meteorological station for each region of the country and from this data set it was determined that meteorological conditions from Sioux Falls, South Dakota, led to central tendency modeled concentrations and particle deposition, and those from Lake Charles, Louisiana, led to high-end modeled concentrations, relative to the other regional stations (see Sections 5.4 and 5.7.4 of the IIOAC User Guide for more information on the stations.

H.2.2 Urban and Rural Populations

Urban/rural designations of the area around a facility are relevant when considering possible boundary layer effects on concentrations. Air emissions taking place in an urbanized area are subject to the effects of urban heat islands, particularly at night. When sources are set as urban in AERMOD, the model will modify the boundary layer to enhance nighttime turbulence, often leading to higher nighttime air concentrations. AERMOD uses urban-area population as a proxy for the intensity of this effect. Facilities were not set as urban unless they met one of the EPA-recommended definitions of an urban area—specifically, the Agency considered a facility to be in an urban area if it had a population density greater than 750 people per square km within a 3 km radius. Generic facilities were modeled for both rural and urban populations for the applicable OES.

H.2.3 Source Specifications

The TRI facilities modeling assumed all emissions were centered on one location. EPA set the same default physical parameters as in IIOAC, stack emissions released from a point source at 10 m above ground from a 2-meter inside diameter, with an exit gas temperature of 300 °K and an exit gas velocity of 5 m/s (see Table 6 of the IIOAC User Guide), and fugitive emissions released at 3.05 m above ground from a square area source 10 m on a side (see Table 7 of the IIOAC User Guide).

The NEI modeling also assumed all emissions were centered on one location. When the site-specific parameter values were available, EPA utilized these in the modeling as done for TRI facilities. When parameters were not available or had values outside of normal bounds, EPA replaced the values based on the procedures used in AirToxScreen (see Section 2.1.3 of EPA, 2018 AirToxScreen Technical Support Document).

- There were 89 fugitive sources with quantifiable emissions.
  - Zero sources had release heights and 3 sources had values of length and width that were above zero.
  - A fugitive height of 3.048 m to all 89 fugitive sources was used; 3 sources provided length, width, and angle values, and a value of 10 m was used for the fugitive length and width (and 0 degrees for fugitive angle) for the other 86 sources.
- There were 15 stack sources with quantifiable emissions. Source classification codes (SCCs) were not provided.
  - One source had values of zero for all physical stack parameters. The values with global default values were replaced (height = 3 m, inside diameter = 0.2 m, exit gas temperature = 295.4 °K; exit gas velocity = 4 m/s).
  - One additional source had a value of zero for exit gas velocity with values above zero for inside diameter and exit gas flow rate. The velocity was calculated using the diameter and flow values (Table_Apx H-4). This source had in-bounds values for the other parameters.
  - All other sources had in-bounds values for all physical stack parameters and were used for modeling.

Table_Apx H-4. Procedures for Replacing Values of Physical Source Parameters from the National Emissions Inventory

Parameters	Bounds	Condition			
		Missing Value or Zero			Value Is Out of Normal Bounds
		First Pass	Second Pass (When First Pass Unsuccessful)	Third Pass (When First and Second Passes Unsuccessful)	
Stack height	1–1300 ft (0.3048–396 m)	Use default value by SCC (pstk file)	Use global default: 3 m	N/A	Use the minimum in-bound value
Stack inside diameter	0.001–300 ft (0.0003048–91.4 m)	Use default value by SCC (pstk file)	Use global default: 0.2 m	N/A	Use the minimum in-bound value
Stack exit gas temperature*a*	>0–4000 °F (>255.4–2477.6 °K)	Use default value by SCC (pstk file)	Use global default: 295.4 °K	N/A	Use the minimum in-bound value
Stack exit gas velocity	0.001–1000 ft/s (0.0003048–304.8 m/s)	Calculate from existing exit gas flow rate and inside diameter: (4 × flow) / (π × diameter^2)	Use default value by SCC (pstk file)	Use global default: 4 m/s	Use the minimum in-bound value
Fugitive height	N/A	0 m if length and width are not missing and are above 0; 3.048 m if length or width are missing or 0	N/A	N/A	N/A
Fugitive length	N/A	10 m	N/A	N/A	N/A
Fugitive width	N/A	10 m	N/A	N/A	N/A
Fugitive angle	N/A	0 deg	N/A	N/A	N/A

[a] For exit gas temperatures, EPA modified AirToxScreen's value bounds so that values must be above 0 °F.
pstk file = file of default stack parameters by source classification code (SCC) from EPA's SMOKE emissions kernel: pstk_13nov2018_v1.txt, retrieved on 28 September 2022 from https://cmascenter.org/smoke/.

H.2.4 Temporal Emission Patterns

The Air Release Assessment for Legacy Asbestos spreadsheet available in the occupational exposure assessment (*Asbestos Part 2 RE - Environmental Release and Occupational Exposure Data Tables – November 2024* (U.S. EPA, 2023b) (see Appendix C) contain information on temporal emission patterns such as release duration (across the hours of a day, or intraday) and release pattern (across the days of a year, or interday), by OES. The hours shown conform to AERMOD's notation scheme of using hours 1 to 24, where hour 1 is the hour ending at 1 a.m. and hour 24 is the final hour of the same day ending at midnight. EPA assumed that emissions took place every day of the year, and then turned emissions off for certain days of the year as needed to achieve the desired number of emission days, such as no emissions on Saturday and Sunday, and major holidays. Table_Apx H-5 summarizes assumptions used for intraday release duration and Table_Apx H-6 summaries assumptions used for interday release patterns.

Table_Apx H-5. Assumptions for Intraday Emission-Release Duration Used in AERMOD

Hours per Day of Emissions	Assumed Hours of the Day Emitting (Inclusive)
4	Hours 13–16 (hour ending at 1 p.m. through hour ending at 4 p.m.; *i.e.*, 12–4 p.m.)
8	Hours 9–16 (hour ending at 9 a.m. through hour ending at 4 p.m.; *i.e.*, 8 a.m. to 4 p.m.)

Table_Apx H-6. Assumptions for Interday Emission-Release Pattern Used in AERMOD

Provided Language for Release Pattern	Implemented Release Pattern: Days When Emissions Are On
Release pattern: **250 days/year** based on the assumption of operations over **5 days/week and 50 weeks/year**	All Mondays through Fridays, except 1/1−1/4 and 12/21−12/31 (and 1/5 for years 2012, 2016, and 2020)
Release pattern: **12 days/year** based on results of literature search	The first day of each month
Release pattern: **1 day/year** based on results of literature search	2/1
Note that some of the "Provided Language for Release Pattern" is specific to an OES.	

H.2.5 Emission Rates

The Air Release Assessment for Legacy Asbestos spreadsheet available in the occupational exposure assessment (*Asbestos Part 2 RE - Environmental Release and Occupational Exposure Data Tables – November 2024*) (U.S. EPA, 2023b) (see also Appendix C) contain emission rates (kg/yr) for each facility, total fugitive emissions, and total stack emissions. A central tendency value and a high-end value was provided for generic TRI facilities and was used to obtain total fugitive and stack emissions. EPA modeled lower- and higher-end emission scenarios separately. The rates were converted to grams per second (g/s) for stack sources and grams per second per m^2 for fugitive sources. The conversion from per-hour to per-second utilized the number of emitting hours per year based on the assumed temporal release patterns, and the conversion to per m^2 for fugitive sources utilized the final length and width values decided based on the procedures by the physical specifications.

H.2.6 Deposition Parameters

EPA used method_1 option in AERMOD, which is recommended when the particle-size distribution is well known or when at least 10 percent of particles (by mass) are 10 µm or larger. Asbestos fibers are not spheres and AERMOD assumes spheres in the deposition calculations that affect settling velocity. EPA calculated the potential sphericity of asbestos particles. The average diameter, aspect ratio, and percent by size bin in Table 3 of Wilson et al. (2008) provided a particle size distribution guideline and it was assumed fibers are cylindrical to calculate fiber length (Equation 1) and volume fraction (mass fraction). The settings for particle deposition modeling are summarized in Table_Apx H-7. Fiber length was calculated using Equation_Apx H-1:

Equation_Apx H-1.

$$Fiber\ Length\ = Diameter\ \times Aspect\ Ratio$$

The fiber size was calculated using Equation_Apx H-2:

Equation_Apx H-2.

$$Fiber\ Size = \left(\frac{Diameter^2}{Length \times Diameter}\right)^{1/3}$$

The equivalent spherical diameter of each size was calculated using Equation_Apx H-3:

Equation_Apx H-3.

$$Spherical\ Diameter = 2 \times \left(Sphericity \times \left(\frac{Length}{2}\right)^2\right)^{1/2}$$

Table_Apx H-7. Settings for Particle Deposition

Mass-Mean Aerodynamic Diameter (µm)	Mass Fraction	Density (g/cm^3)	Notes/Sources
2.6	0.02	3.3	Diameter and mass fraction: (Wilson et al., 2008) Table 3, Equations 1, 2 and 3. Density: conservative setting, the high value of specific gravity provided for crocidolite fibers from (Virta, 2004)
6.1	0.06	3.3	
10.8	0.07	3.3	
37.8	0.85	3.3	

Exposure points All modeling scenarios utilized a region of gridded exposure points and several rings/radials of exposure points. The rings had exposure points placed every 22.5 degrees (starting due north of the facility) for distances 10, 30, and 60 m from the source for co-located general population exposure points and 100, 1,000, 2,500, 5,000, and 10,000 m from the source for general-population exposure points. Between 100 and 1,000 m from the source—an area termed “community” in IIOAC. All exposure points were at 1.8 m above ground, as a proxy for breathing height for concentration estimates. A duplicate set of exposure points was at ground level (0 m) for deposition estimations.

H.2.7 Output

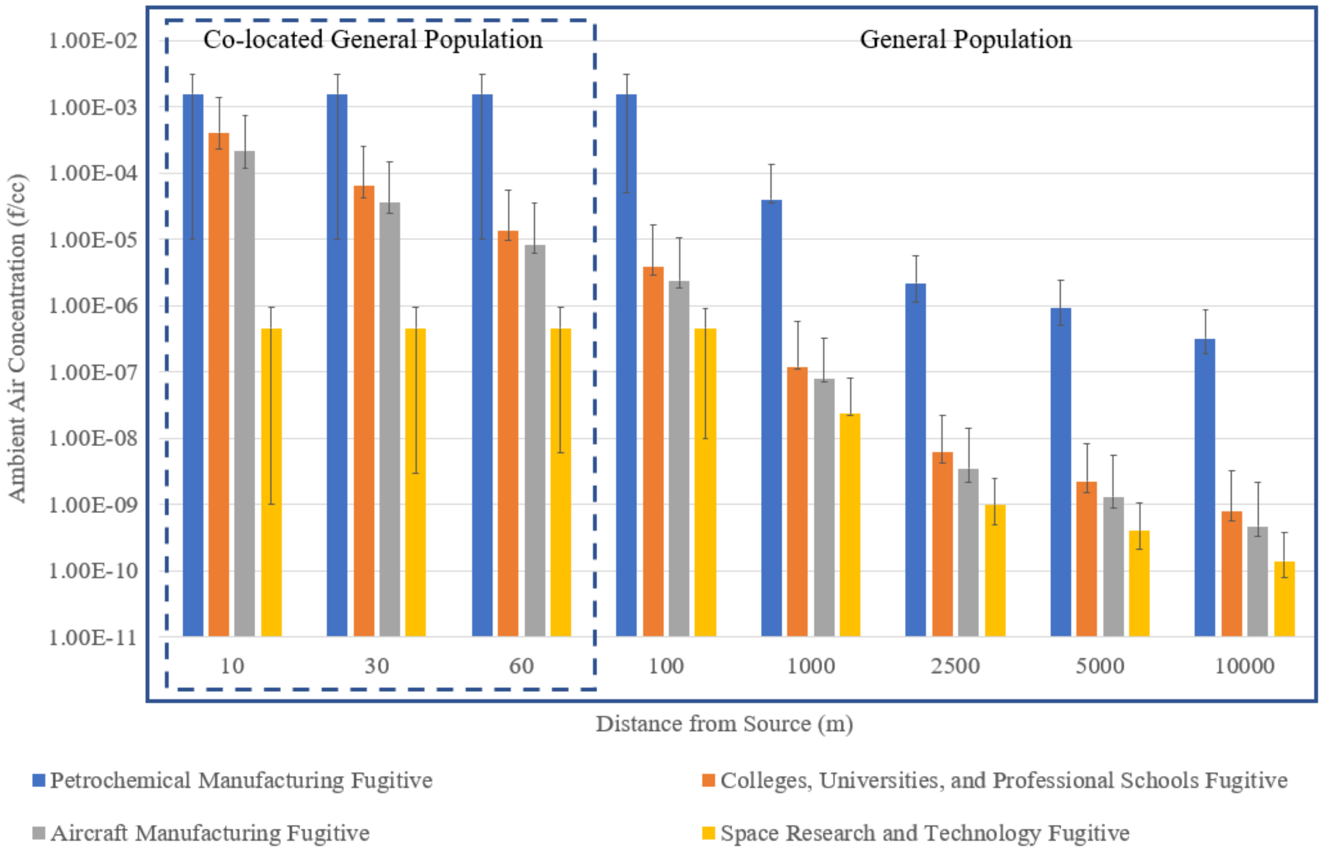
EPA converted AERMOD concentration output units of micrograms (µg) per m^3 to fibers per cubic centimeter (cm^3), using the “European Community Directive 72/217/EEC” conversion factor in (Dodic-Fikfak, 2007), specifically 0.1 mg/m^3 = 2 $fibers/cm^3$, or 1 $µg/m^3$ = 0.02 $fibers/cm^3$—one of the higher and more conservative values cited in that study, but not the highest. That same conversion factor was used to convert AERMOD deposition units of g/m^2 to $fibers/m^2$, specifically, 1 g per m^2 = 2×10^{10} fibers per m^2.

AERMOD daily and annual outputs assumed flat terrain for all modeling scenarios. Daily- and period-average outputs for every run, where the period was 1 year for real facilities and 5 years for generic TRI facilities.

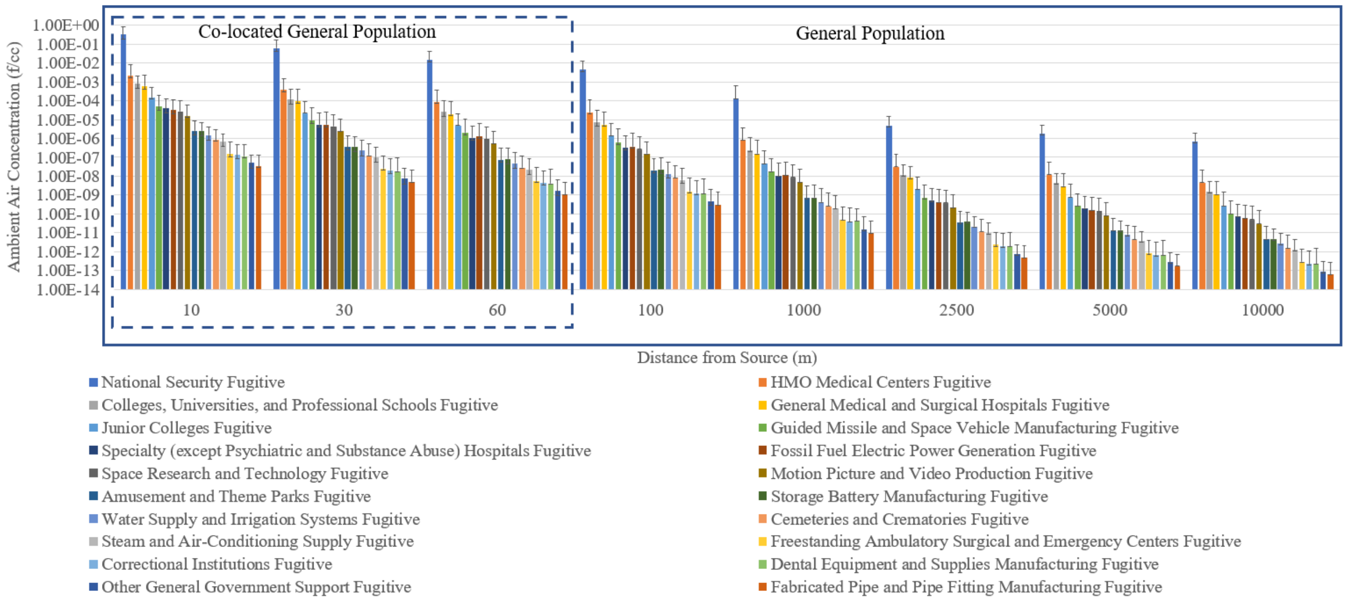
Percentile statistics for released concentrations for OESs Handling asbestos-containing building materials during maintenance, renovation, and demolition activities as well as Handling asbestos-containing building materials during firefighting or other disaster response activities both emit only a small number of days per year, so more than 95 percent of the days of the year are not emitting (no concentrations) and hence the 10th, 50th, and 95th percentile daily concentrations is zero (while the average is >0).

H.2.8 Specific Facilities Ambient Air Concentrations

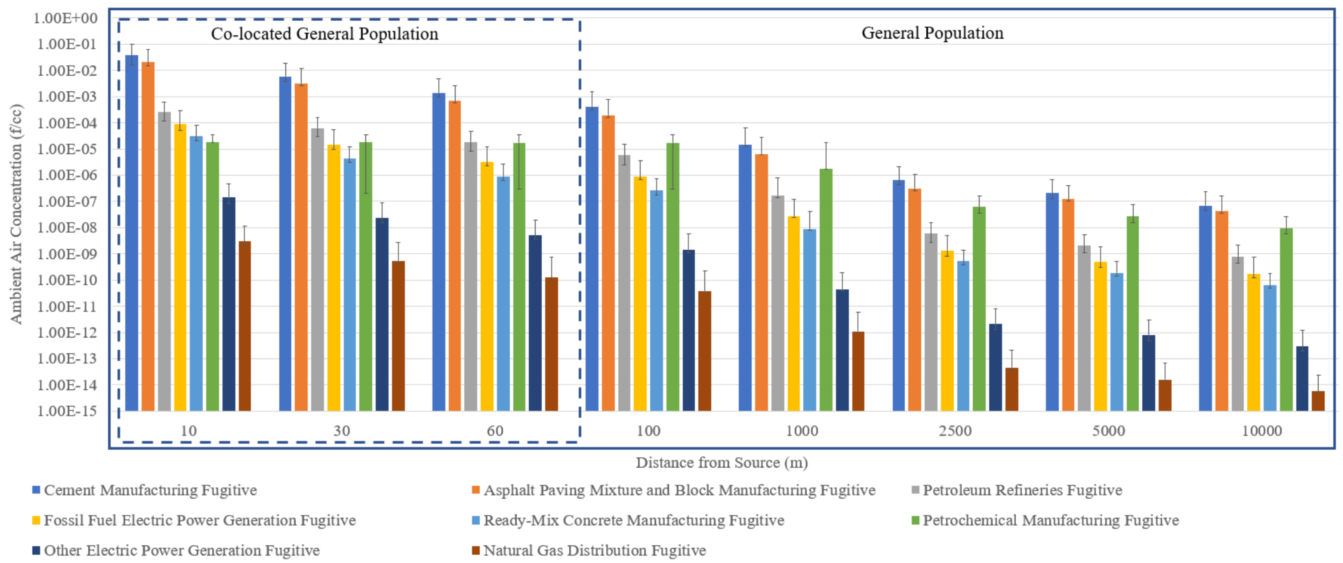
This section summarizes specific facilities ambient air concentrations data by facility description. The patterns presented in Figure_Apx H-4 through Figure_Apx H-7 further support Section 3.3.1.2 discussion points. These figures show a wide range of asbestos concentrations among facilities of similar descriptions at the same distance from the source ranging 2 to 3 orders of magnitude difference, which means that grouping and averaging by facility description will not show the differences among similar description facilities even under the same OES.



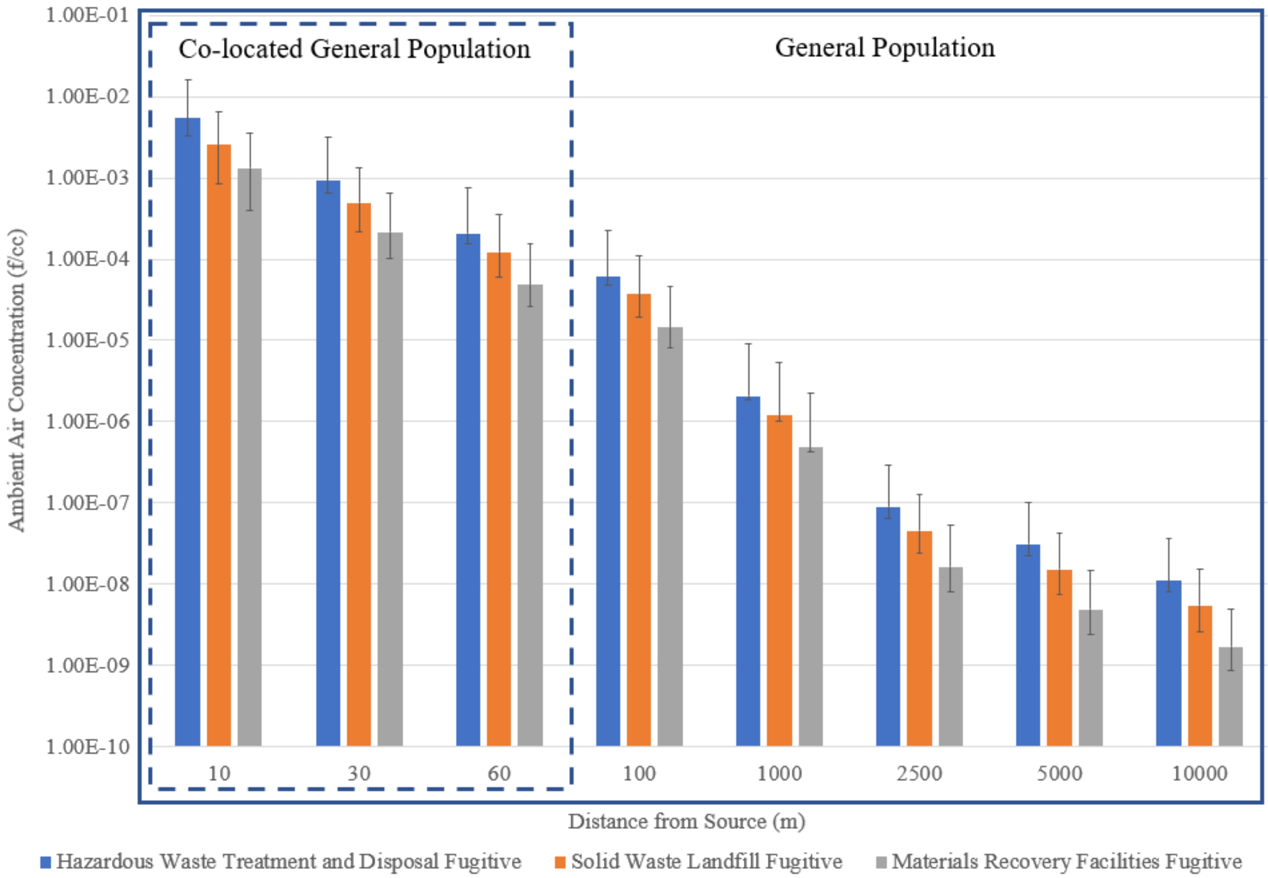
Figure_Apx H-4. Ambient Air Concentrations for Facilities under the Handling Articles or Formulations that Contain Asbestos OES



Figure_Apx H-5. Ambient Air Concentrations for Facilities under Handling Asbestos-Containing Building Materials During Maintenance, Renovation, and Demolition Activities OES



Figure_Apx H-6. Ambient Air Concentrations for Facilities under Use, Repair, or Disposal of Industrial and Commercial Appliances or Machinery Containing Asbestos OES

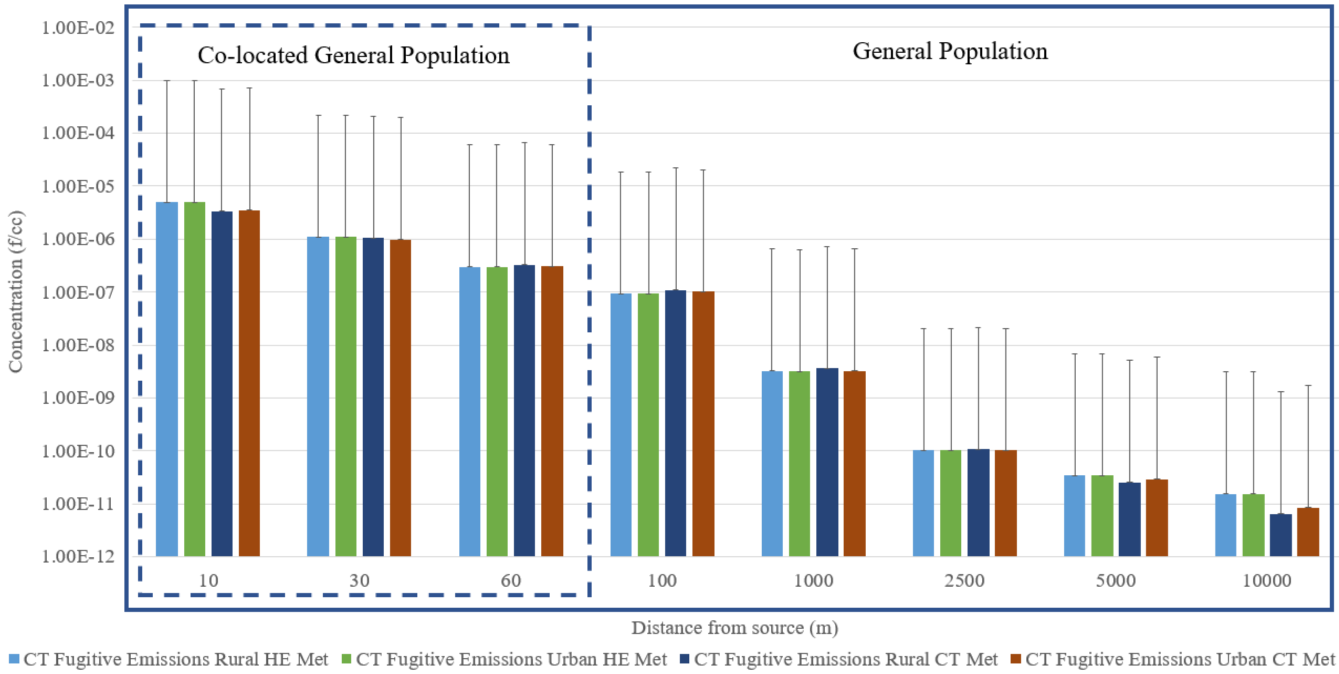


Figure_Apx H-7. Ambient Air Concentrations for Facilities under Waste Handling, Disposal, and Treatment OES

The specific facilities range of asbestos ambient air concentrations is orders of magnitude within OES and same distance from the source.

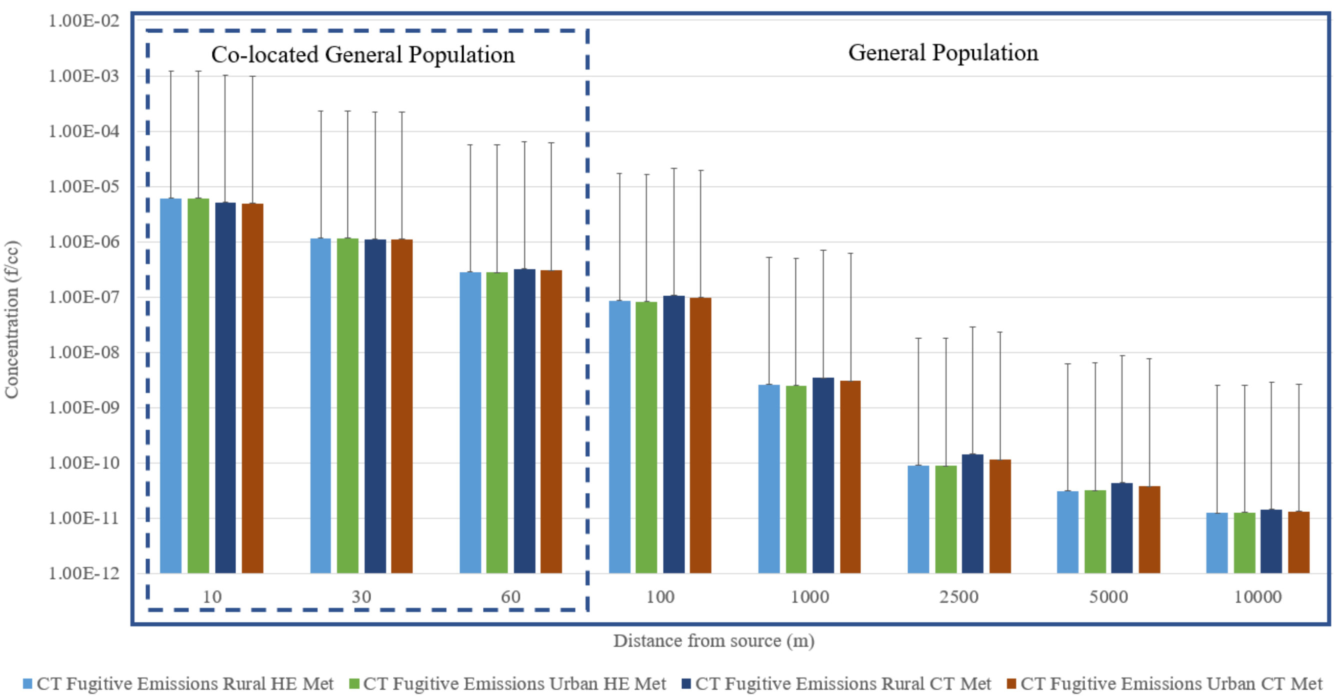
H.2.9 Generic Facilities Ambient Air Concentrations by OES

This section summarizes generic facilities ambient air concentrations data by OES by rural and urban fugitive emissions. The patterns in the figures further support Section 3.3.1.2 Generic Facilities discussion points. Figure_Apx H-8, Figure_Apx H-9, and Figure_Apx H-10 show a wide range of asbestos concentrations between fugitive emissions by distance from source ranging 5 to 6 orders of magnitude difference close to the source and increasing distance away from the source.

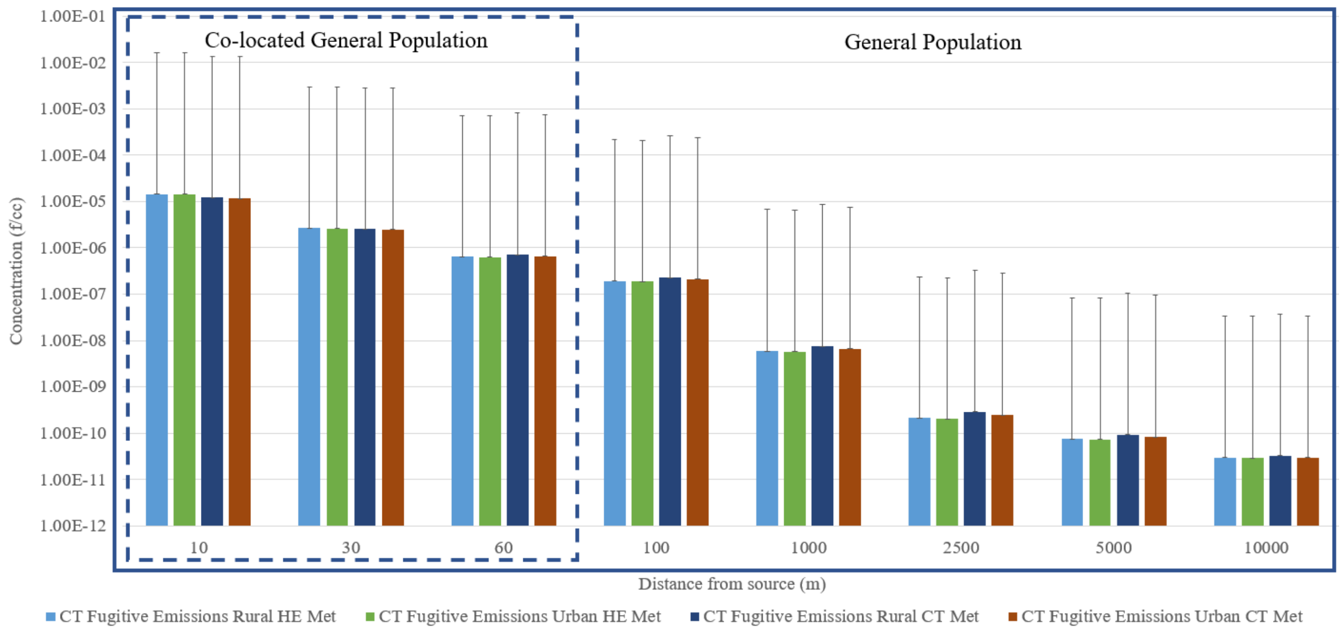


CT is Central Tendency.

Figure_Apx H-8. Generic Annual Ambient Air Asbestos Concentrations: Handling Asbestos-Containing Building Materials During Firefighting or Other Disaster Response Activities



Figure_Apx H-9. Generic Annual Ambient Air Asbestos Concentrations: Handling Asbestos-Containing Building Materials During Maintenance, Renovation, and Demolition Activities



Figure_Apx H-10. Generic Annual Ambient Air Concentrations Waste Handling, Disposal, and Treatment Fugitive Emissions

H.3 Ambient Air Concentrations Summary

This section summarizes how the measured and modeled asbestos air concentrations were grouped by OES to be used for human and environmental risk characterization. First the modeled ambient air concentrations per OES figures in Appendix H.2.8 and Appendix H.2.9 show the low-end, central tendency, and high-end summary tables per OES and grouping and averaging (when appropriate) in this section. Bolded text within the tables are the values used in the assessment, in some instances these were the only values available in others are the result of combining, not bolded text, specific and generic rural and urban emissions.

H.3.1 Low-End Tendency Ambient Air Concentration Groupings and Summary Tables

Table_Apx H-8. Low-End Tendency Ambient Air Concentrations Summary by OES

Analysis	OES Description	10 m	30 m	60 m	100 m	1,000 m	2,500 m	5,000 m	10,000 m
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos									
Grouping Specific Facilities Summary	**Fugitive**	**2.62E−03**	**2.95E−04**	**5.61E−05**	**1.63E−05**	**2.03E−07**	**2.86E−08**	**1.03E−08**	**3.41E−09**
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities									
Grouping Specific Facilities Summary	**Fugitive**	**4.51E−03**	**6.37E−04**	**1.21E−04**	**3.05E−05**	**2.49E−07**	**2.34E−08**	**9.33E−09**	**3.48E−09**
Waste handling, disposal, and treatment									
Grouping Specific	**Fugitive**	**1.95E−03**	**2.55E−04**	**5.15E−05**	**1.43E−05**	**1.65E−07**	**2.23E−08**	**7.81E−09**	**2.65E−09**

Analysis	OES Description	10 m	30 m	60 m	100 m	1,000 m	2,500 m	5,000 m	10,000 m
Facilities Summary									
Handling articles or formulations that contain asbestos									
Grouping Specific Facilities Summary	**Fugitive**	**3.09E−04**	**2.08E−04**	**1.96E−04**	**1.86E−04**	**4.43E−07**	**1.30E−07**	**5.01E−08**	**1.59E−08**

H.3.2 Central Tendency Ambient Air Concentration Summary Tables

Table_Apx H-9. Use, Repair, or Disposal of Industrial and Commercial Appliances or Machinery Containing Asbestos OES Central Tendency Ambient Air Concentrations Summary Table

Analysis	OES Description	10 m	30 m	60 m	100 m	10,00 m	2,500 m	5,000 m	10,000 m
Specific Facilities	Fugitive	6.22E−03	9.94E−04	2.23E−04	6.64E−05	2.35E−06	1.05E−07	3.78E−08	1.32E−08
Generic Facilities	Rural Fugitive	1.33E−05	2.60E−06	6.75E−07	2.10E−07	6.72E−09	2.52E−10	8.39E−11	3.11E−11
Generic Facilities	Urban Fugitive	1.30E−05	2.55E−06	6.45E−07	1.99E−07	6.20E−09	2.26E−10	7.86E−11	2.96E−11
Grouping Average Summary	**Fugitive**	**2.08E−03**	**3.33E−04**	**7.47E−05**	**2.23E−05**	**7.89E−07**	**3.52E−08**	**1.27E−08**	**4.43E−09**

Table_Apx H-10. Handling Asbestos-Containing Building Materials During Maintenance, Renovation, and Demolition Activities OES Central Tendency Ambient Air Concentrations Summary Table

Analysis	OES Description	10 m	30 m	60 m	100 m	1,000 m	2,500 m	5,000 m	10,000 m
Specific Facilities	Fugitive	9.97E−03	1.89E−03	4.52E−04	1.33E−04	3.97E−06	1.53E−07	5.51E−08	2.09E−08
Generic Facilities	Rural Fugitive	5.65E−06	1.14E−06	3.05E−07	9.64E−08	3.04E−09	1.18E−10	3.75E−11	1.36E−11
Generic Facilities	Urban Fugitive	5.53E−06	1.13E−06	2.90E−07	9.03E−08	2.79E−09	1.03E−10	3.50E−11	1.31E−11
Grouping Average Summary	**Fugitive**	**3.33E−03**	**6.31E−04**	**1.51E−04**	**4.44E−05**	**1.32E−06**	**5.10E−08**	**1.84E−08**	**6.98E−09**

Table_Apx H-11. Handling Asbestos-Containing Building Materials During Firefighting or Other Disaster Response Activities OES Central Tendency Ambient Air Concentrations Summary Table

Analysis	OES Description	10 m	30 m	60 m	100 m	1,000 m	2,500 m	5,000 m	10,000 m
Generic Facilities	Urban Fugitive	4.22E−06	1.04E−06	3.01E−07	9.78E−08	3.21E−09	1.02E−10	3.19E−11	1.20E−11
Generic Facilities	Rural Fugitive	4.14E−06	1.07E−06	3.13E−07	1.02E−07	3.42E−09	1.05E−10	2.99E−11	1.09E−11
Grouping Average Summary	**Fugitive**	**4.18E−06**	**1.06E−06**	**3.07E−07**	**1.00E−07**	**3.31E−09**	**1.04E−10**	**3.09E−11**	**1.15E−11**

Table_Apx H-12. Waste Handling, Disposal, and Treatment OES Central Tendency Ambient Air Concentrations Summary Table

Analysis	OES Description	10 m	30 m	60 m	100 m	10,00 m	2,500 m	5,000 m	10,000 m
Grouping Specific Facilities Summary	**Fugitive**	**4.53E−03**	**7.74E−04**	**1.78E−04**	**5.28E−05**	**1.76E−06**	**7.44E−08**	**2.57E−08**	**9.08E−09**

Table_Apx H-13. Handling Articles or Formulations that Contain Asbestos OES Central Tendency Ambient Air Concentrations Summary Table

Analysis	OES Description	10 m	30 m	60 m	100 m	1,000 m	2,500 m	5,000 m	10,000 m
Grouping Specific Facilities Summary	**Fugitive**	**4.57E−04**	**2.37E−04**	**2.04E−04**	**1.94E−04**	**5.03E−06**	**2.77E−07**	**1.15E−07**	**4.04E−08**

H.3.3 High-End Tendency Ambient Air Concentration Summary Tables

Table_Apx H-14. Use, Repair, or Disposal of Industrial and Commercial Appliances or Machinery Containing Asbestos OES High-End Tendency Ambient Air Concentrations Summary Table

Analysis	OES Description	10 m	30 m	60 m	100 m	1,000 m	2,500 m	5,000 m	10,000 m
Generic Facilities	Rural Fugitive	1.5E−02	2.9E−03	7.6E−04	2.4E−04	7.6E−06	2.8E−07	9.4E−08	3.5E−08
Generic Facilities	Urban Fugitive	1.5E−02	2.9E−03	7.3E−04	2.2E−04	7.0E−06	2.5E−07	8.9E−08	3.3E−08
Specific Facilities	Fugitive	1.1E−02	2.3E−03	5.9E−04	1.8E−04	8.7E−06	2.5E−07	8.7E−08	3.2E−08
Grouping Average Summary	**Fugitive**	**1.4E−02**	**2.7E−03**	**6.9E−04**	**2.1E−04**	**7.7E−06**	**2.6E−07**	**9.0E−08**	**3.3E−08**

Table_Apx H-15. Handling Asbestos-Containing Building Materials During Maintenance, Renovation, and Demolition Activities OES High-End Tendency Ambient Air Concentrations Summary Table

Analysis	OES Description	10 m	30 m	60 m	100 m	1000 m	2500 m	5000 m	10000 m
Specific Facilities	Fugitive	1.7E−02	3.4E−03	8.6E−04	2.6E−04	1.6E−05	3.1E−07	1.1E−07	3.9E−08
Generic Facilities	Rural Fugitive	1.1E−03	2.3E−04	6.1E−05	1.9E−05	6.1E−07	2.4E−08	7.5E−09	2.7E−09
Generic Facilities	Urban Fugitive	1.1E−03	2.2E−04	5.8E−05	1.8E−05	5.6E−07	2.1E−08	7.0E−09	2.6E−09
Grouping Average Summary	**Fugitive**	**6.3E−03**	**1.3E−03**	**3.3E−04**	**9.9E−05**	**5.8E−06**	**1.2E−07**	**4.0E−08**	**1.5E−08**
Measured Air		2.0E−02							

Table_Apx H-16. Handling Asbestos-Containing Building Materials During Firefighting or Other Disaster Response Activities OES High-End Tendency Ambient Air Concentrations Summary Table

Analysis	OES Description	10 m	30 m	60 m	100 m	1,000 m	2,500 m	5,000 m	10,000 m
Generic Facilities	Urban Fugitive	8.4E−04	2.1E−04	6.0E−05	2.0E−05	6.4E−07	2.0E−08	6.4E−09	2.4E−09
Generic Facilities	Rural Fugitive	8.3E−04	2.1E−04	6.3E−05	2.0E−05	6.8E−07	2.1E−08	6.0E−09	2.2E−09
Grouping Average Summary	**Fugitive**	**8.4E−04**	**2.1E−04**	**6.1E−05**	**2.0E−05**	**6.6E−07**	**2.1E−08**	**6.2E−09**	**2.3E−09**
Measured Air		2.2E−03							
Dash is for measured data that was not identified.									

Table_Apx H-17. Waste Handling, Disposal, and Treatment OES High-End Tendency Ambient Air Concentrations Summary Table

Analysis	OES Description	10 m	30 m	60 m	100 m	1,000 m	2,500 m	5,000 m	10,000 m
Grouping Specific Facilities Summary	**Fugitive**	**8.7E−03**	**1.8E−03**	**4.5E−04**	**1.4E−04**	**6.0E−06**	**1.6E−07**	**5.5E−08**	**2.0E−08**
Measured Air		6.3E−03							
Dash is for measured data that was not identified.									

Table_Apx H-18. Handling Articles or Formulations that Contain Asbestos OES High-End Tendency Ambient Air Concentrations Summary Table

Analysis	OES Description	10 m	30 m	60 m	100 m	1,000 m	2,500 m	5,000 m	10,000 m
Grouping Specific Facilities Summary	**Fugitive**	**8.3E−04**	**3.2E−04**	**2.3E−04**	**2.1E−04**	**1.2E−05**	**4.5E−07**	**1.9E−07**	**6.9E−08**

Table_Apx H-19. Ambient Air Concentration Summary by OES

OES	COU	Distance from Source (m)							
		10	**30**	**60**	**100**	**100–1,000**	**2,500**	**5,000**	**10,000**
Low-end tendency lifetime cancer ELCR									
Waste handling, disposal, and treatment fugitive	COU: Disposal, including distribution for disposal	1.9E−03	2.5E−04	5.1E−05	1.4E−05	1.6E−07	2.2E−08	7.8E−09	2.7E−09
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	4.5E−03	6.4E−04	1.2E−04	3.0E−05	2.5E−07	2.3E−08	9.3E−09	3.5E−09
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos fugitive	COU: Construction, paint, electrical, and metal products	2.6E−03	3.0E−04	5.6E−05	1.6E−05	2.0E−07	2.9E−08	1.0E−08	3.4E−09
Handling articles or formulations that contain asbestos fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products COU: Packaging, paper, plastic, toys, hobby products	3.1E−04	2.1E−04	2.0E−04	1.9E−04	4.4E−07	1.3E−07	5.0E−08	1.6E−08
Central tendency lifetime cancer ELCR									
Waste handling, disposal, and treatment fugitive	COU: Disposal, including distribution for disposal	4.5E−03	7.7E−04	1.8E−04	5.3E−05	1.8E−06	7.4E−08	2.6E−08	9.1E−09
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	3.3E−03	6.3E−04	1.5E−04	4.4E−05	1.3E−06	5.1E−08	1.8E−08	7.0E−09
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos fugitive	COU: Construction, paint, electrical, and metal products	2.1E−03	3.3E−04	7.5E−05	2.2E−05	7.9E−07	3.5E−08	1.3E−08	4.4E−09
Handling articles or formulations that contain asbestos fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products COU: Packaging, paper, plastic, toys, hobby products	4.6E−04	2.4E−04	2.0E−04	1.9E−04	5.0E−06	2.8E−07	1.1E−07	4.0E−08
Handling asbestos-containing building materials during firefighting or other disaster response activities fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	4.2E−06	1.1E−06	3.1E−07	1.0E−07	3.3E−09	1.0E−10	3.1E−11	1.1E−11

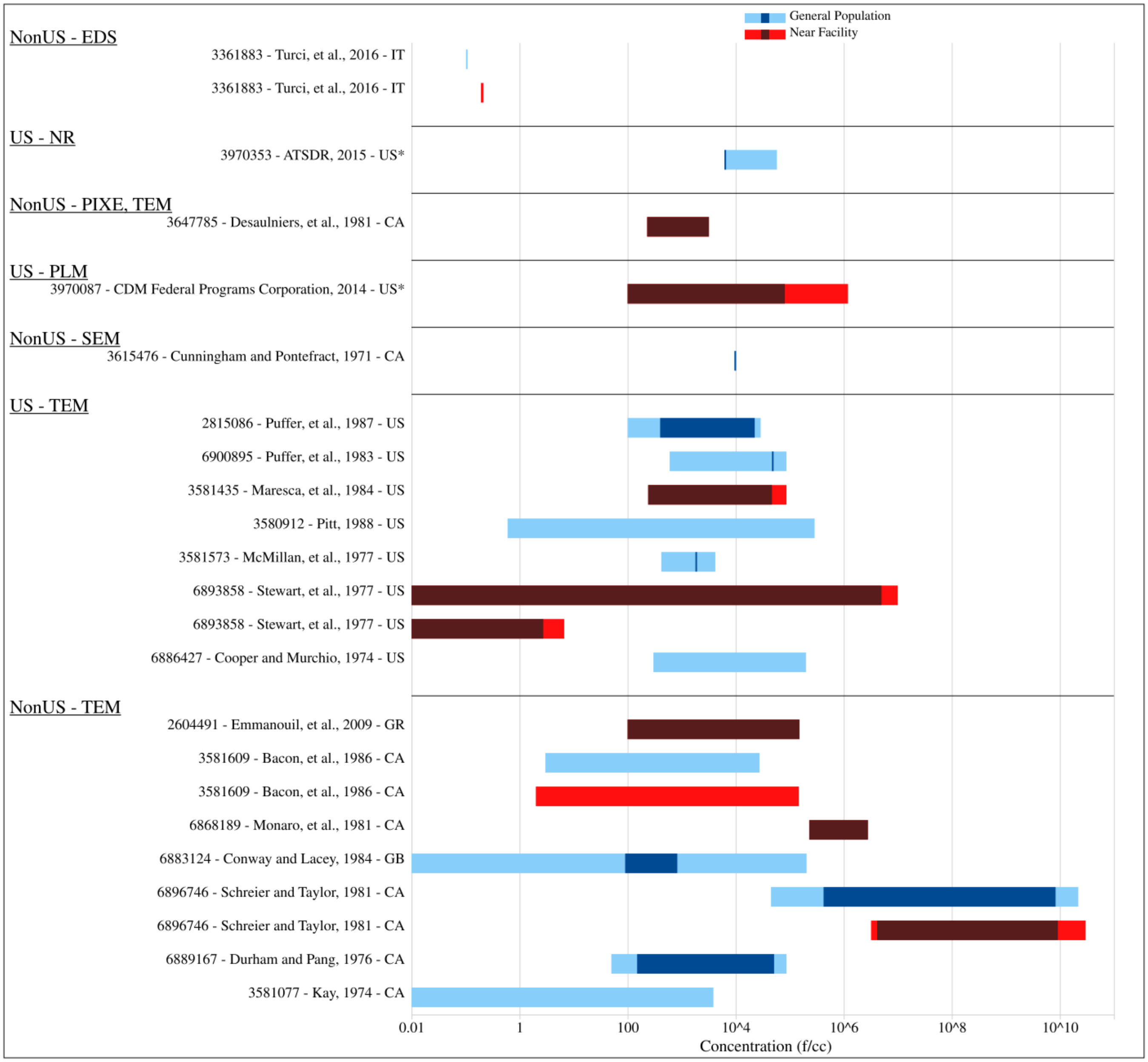
OES	COU	Distance from Source (m)							
		10	30	60	100	100–1,000	2,500	5,000	10,000
High-end tendency lifetime cancer ELCR									
Waste handling, disposal, and treatment fugitive	COU: Disposal, including distribution for disposal	8.7E−03	1.8E−03	4.5E−04	1.4E−04	6.0E−06	1.6E−07	5.5E−08	2.0E−08
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	6.3E−03	1.3E−03	3.3E−04	9.9E−05	5.8E−06	1.2E−07	4.0E−08	1.5E−08
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos fugitive	COU: Construction, paint, electrical, and metal products	1.4E−02	2.7E−03	6.9E−04	2.1E−04	7.7E−06	2.6E−07	9.0E−08	3.3E−08
Handling articles or formulations that contain asbestos fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products COU: Packaging, paper, plastic, toys, hobby products	8.3E−04	3.2E−04	2.3E−04	2.1E−04	1.2E−05	4.5E−07	1.9E−07	6.9E−08
Handling asbestos-containing building materials during firefighting or other disaster response activities fugitive	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	8.4E−04	2.1E−04	6.1E−05	2.0E−05	6.6E−07	2.1E−08	6.2E−09	2.3E−09

H.4 Water Pathway

H.4.1 Surface Water

Measured concentrations of Asbestos in Surface Water with unit of f/cc, extracted from 19 sources, are presented in Figure_Apx H-11 and supplemental information is summarized in Table_Apx H-20. More than one asbestos analysis method was reported, and overall concentrations provided in the bullets that follow:

- Concentrations for EDS ranged from not detected to 0.215373 f/cc from three samples collected in 2016 in one country (Italy). Location types were categorized as General Population and Near Facility. Reported detection frequency was 1.0.
- Concentrations for N/R ranged from 6,200.0 to 58,000.0 f/cc from 30 samples collected between 2009 and 2011 in 1 country (United States). Location types were categorized as General Population. Reported detection frequency was 0.3.
- Concentrations for PIXE, TEM ranged from 230.0 to 3,200.0 f/cc from two samples collected in 1981 in 1 country (Canada). Location types were categorized as Near Facility. Reported detection frequency was 1.0.
- Concentrations for PLM ranged from 100.0 to 1,200,000.0 f/cc from 502 samples collected in 2014 in 1 country (United States). Location types were categorized as Near Facility. Reported detection frequency was 0.77.
- Concentrations for SEM were 9,500.0 f/cc from one sample collected in 1971 in one country (Canada). Location types were categorized as General Population. Reported detection frequency was 1.0.
- Concentrations for TEM ranged from not detected to 30,000,000,000.0 f/cc from 2,355 samples collected between 1972 and 2009 in 4 countries (Canada, Great Britain, Greece, and United States). Location types were categorized as General Population and Near Facility. Reported detection frequency ranged from 0.6 to 1.0.



Figure_Apx H-11. Concentrations of Asbestos (f/cc) in Surface Water from 1971 to 2016

* = Reference used in risk determination

Table_Apx H-20. Summary of Peer-Reviewed Literature that Measured Asbestos (f/cc) Levels in Surface Water

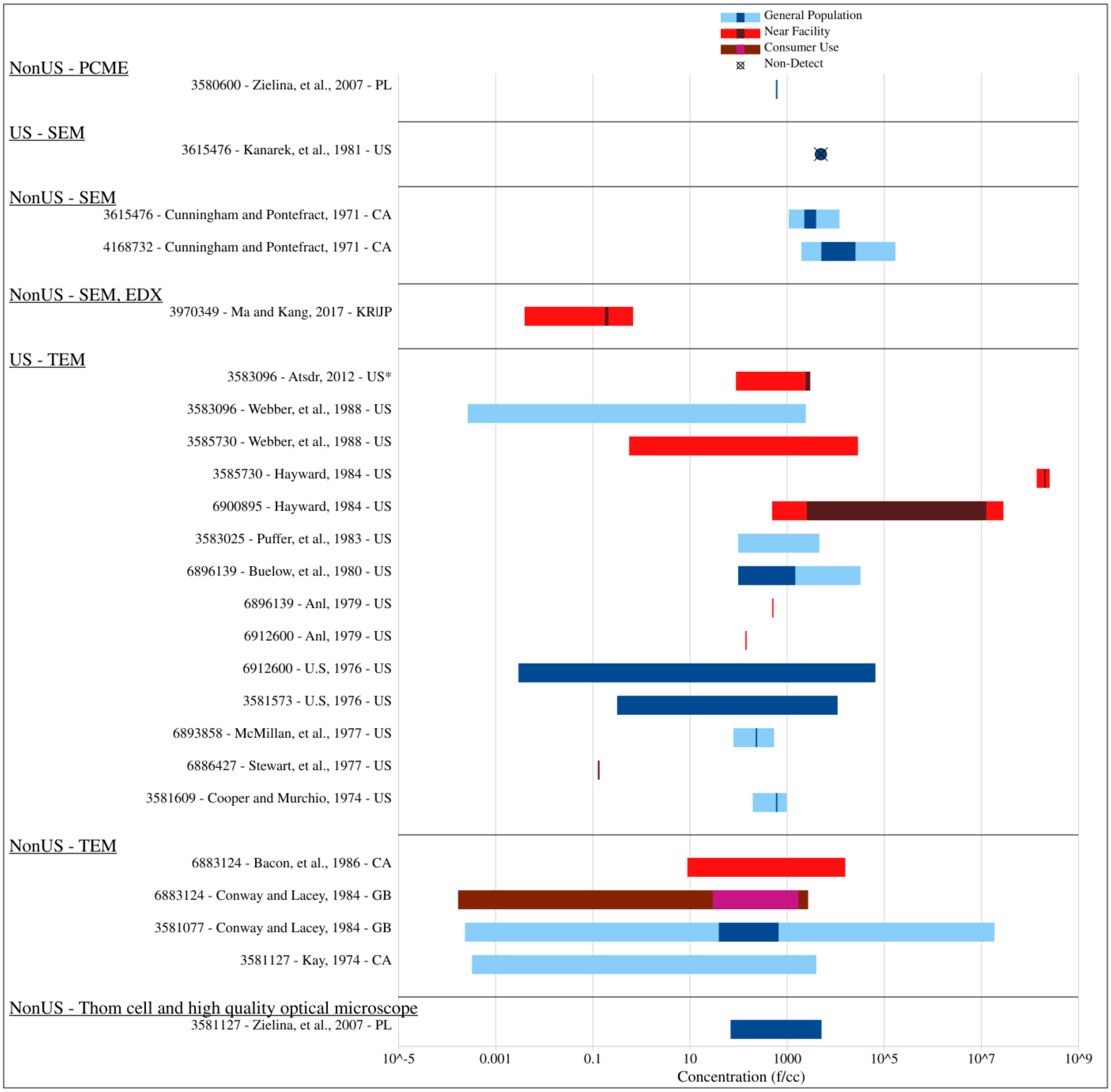
Citation	Fiber Type	Fiber Size	Country	Location Type	Sampling Year(s)	Sample Size (Frequency of Detection)	Detection Limit (f/cc)	Overall Quality Level
EDS								
(Turci et al., 2016)	Chrysotile (asbestiform of mineral serpentine)	0.8 µm	IT	General Population	2016	1 (1.00)	N/R	Medium
(Turci et al., 2016)	Chrysotile (asbestiform of mineral serpentine)	0.8 µm	IT	Near Facility	2016	2 (1.00)	N/R	Medium
N/R								
(ATSDR, 2015)	General	N/R	US	General Population	2009–2011	30 (0.30)	N/R	Medium
PIXE, TEM								
(Desaulniers et al., 1981)	General	N/R	CA	Near Facility	1981	2 (1.00)	N/R	Medium
PLM								
(CDM Federal Programs Corporation, 2014)	General Tremolite	N/R	US	Near Facility	2014	502 (0.77)	N/R	Medium
SEM								
(Cunningham and Pontefract, 1971)	General	N/R	CA	General Population	1971	1 (1.00)	N/R	Medium
TEM								
(Puffer et al., 1987)	General	0.1 µm	US	General Population	1987	8 (0.88)	N/R	Medium
(Puffer et al., 1983)	Chrysotile (asbestiform of mineral serpentine) Crocidolite (asbestiform of mineral riebeckite)	0.55–1.0 µm	US	General Population	1981–1982	8 (1.00)	N/R	Medium
(Maresca et al., 1984)	Chrysotile (asbestiform of mineral serpentine)	0.55–0.71 µm	US	Near Facility	1981	7 (N/R)	N/R	Medium
(Pitt, 1988)	Chrysotile (asbestiform of mineral serpentine) Crocidolite (asbestiform of	~1 µm	US	General Population	1979–1980	5 (1.00)	N/R	Medium

Citation	Fiber Type	Fiber Size	Country	Location Type	Sampling Year(s)	Sample Size (Frequency of Detection)	Detection Limit (f/cc)	Overall Quality Level
	mineral riebeckite) Anthophyllite Tremolite Actinolite General							
(McMillan et al., 1977)	General	N/R	US	General Population	1974–1975	2028 (1.00)	N/R	Medium
(Stewart et al., 1977)	Chrysotile (asbestiform of mineral serpentine) General	>5 µm	US	Near Facility	1975	43 (0.65)	N/R	Medium
(Stewart et al., 1977)	General	>5 µm	US	Near Facility	1975	36 (0.64)	N/R	Medium
(Cooper and Murchio, 1974)	Chrysotile (asbestiform of mineral serpentine)	2–10 µm long	US	General Population	1973	5 (0.60)	N/R	Medium
(Emmanouil et al., 2009)	Chrysotile (asbestiform of mineral serpentine) Anthophyllite Tremolite Actinolite	N/R	GR	Near Facility	2009	5 (N/R)	N/R	Medium
(Bacon et al., 1986)	General	N/R	CA	General Population	1981	6 (1.00)	N/R	Medium
(Bacon et al., 1986)	General	N/R	CA	Near Facility	1981	24 (1.00)	N/R	Medium
(Monaro et al., 1981)	General	N/R	CA	Near Facility	1981	10 (N/R)	N/R	Low
(Conway and Lacey, 1984)	Chrysotile (asbestiform of mineral serpentine) General	35 to <2 µm	GB	General Population	1980	2 (1.00)	410,830.0	Medium
(Schreier and Taylor, 1981)	General	N/R	CA	General Population	1979–1980	18 (1.00)	N/R	Medium
(Schreier and Taylor, 1981)	General	N/R	CA	Near Facility	1979–1980	8 (1.00)	N/R	Medium
(Durham and Pang, 1976)	General	<1 µm	CA	General Population	1973–1974	130 (0.94)	100.0	Medium
(Kay, 1974)	General	3 µm	CA	General Population	1972	12 (1.00)	N/R	Medium
CA = Canada; GB = Great Britain; IT = Italy; PL = Poland; US = United States								

H.4.2 Drinking Water

Overall measured concentrations of asbestos in drinking water with unit of f/cc, extracted from 17 sources, are summarized in Figure_Apx H-12 and supplemental information is provided in Table_Apx H-21. More than one asbestos analysis method was reported, and each summarized separately the bullets that follow:

- Concentrations for PCME were 600.0 f/cc from three samples collected in 2007 in one country (Poland). Location types were categorized as General Population. Reported detection frequency was not reported.
- Concentrations for SEM ranged from not detected to 172,700.0 f/cc from 100 samples collected between 1971 and 1978 in 2 countries (Canada and United States). Location types were categorized as General Population. Reported detection frequency was 1.0.
- Concentrations for SEM, EDX ranged from 0.004 to 0.688 f/cc from 15 samples collected in 2005 in 2 countries (Japan and South Korea). Location types were categorized as Near Facility. Reported detection frequency was 1.0.
- Concentrations for TEM ranged from not detected to 260,000,000.0 f/cc from 502 samples collected between 1972 and 2011 in 3 countries (Canada, Great Britain, and United States). Location types were categorized as General Population, Consumer Use and Near Facility. Reported detection frequency ranged from 0.2 to 1.0.
- Concentrations for Thom cell and optical microscope ranged from 70.0 to 5,200.0 f/cc from 39 samples collected in 2007 in 1 country (Poland). Location types were categorized as General Population. Reported detection frequency was not reported.



Figure_Apx H-12. Concentrations of Asbestos (f/cc) in Drinking Water from 1971 to 2011

* = Reference used in risk evaluation

Table_Apx H-21. Summary of Peer-Reviewed Literature that Measured Asbestos (f/cc) Levels in Drinking Water

Citation	Fiber Type	Fiber Size	Country	Location Type	Sampling Year(s)	Sample Size (Frequency of Detection)	Detection Limit (f/cc)	Overall Quality Level
PCME								
(Zielina et al., 2007)	General	<10 µm	PL	General Population	2007	3 (N/R)	N/R	Medium
SEM								
(Kanarek et al., 1981)	Chrysotile (asbestiform of mineral serpentine)	0.45 um	US	General Population	1974–1978	78 (N/R)	10,100.0	Medium
(Cunningham and Pontefract, 1971)	General	N/R	CA	General Population	1971	14 (1.00)	N/R	Medium
(Cunningham and Pontefract, 1971)	General	N/R	CA	General Population	1971	8 (1.00)	N/R	Medium
SEM, EDX								
(Ma and Kang, 2017)	Chrysotile (asbestiform of mineral serpentine) Crocidolite (asbestiform of mineral riebeckite) Amosite (asbestiform of mineral grunerite)	N/R	JP, KR	Near Facility	2005	15 (1.00)	N/R	Medium
TEM								
(ATSDR, 2012a)	Chrysotile (asbestiform of mineral serpentine)	>5 µm	US	Near Facility	2011	5 (0.20)	6,090.0	Medium
(Webber et al., 1988)	Chrysotile (asbestiform of mineral serpentine)	N/R	US	General Population	1985-1986	3 (1.00)	N/R	Medium
(Webber et al., 1988)	Chrysotile (asbestiform of mineral serpentine)	N/R	US	Near Facility	1985-1986	2 (1.00)	N/R	Medium
(Hayward, 1984)	Chrysotile (asbestiform of mineral serpentine)	N/R	US	Near Facility	1982	2 (1.00)	N/R	Medium

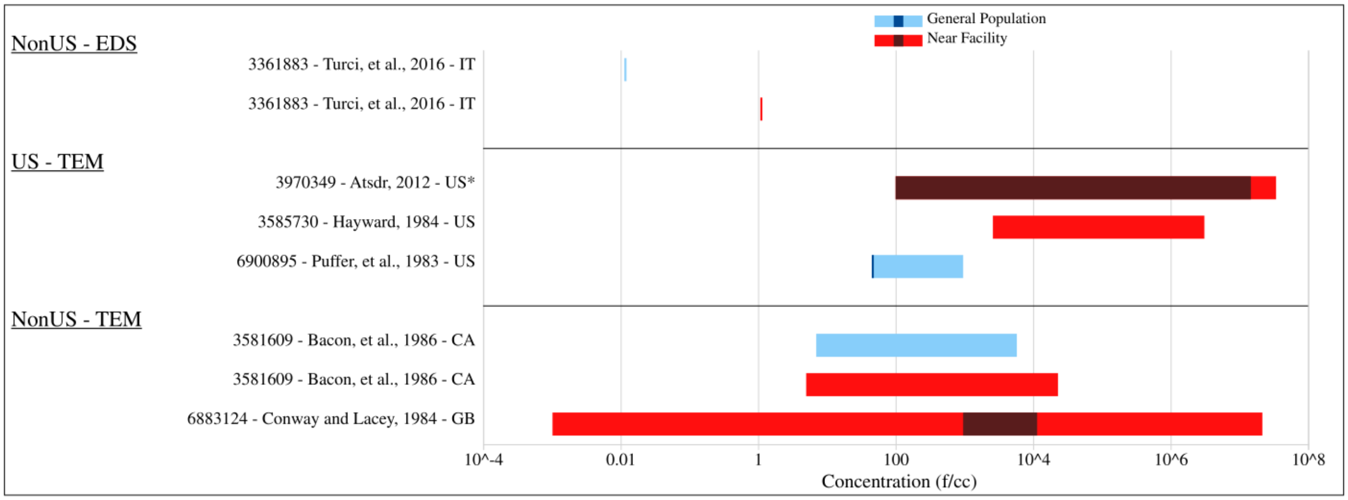
Citation	Fiber Type	Fiber Size	Country	Location Type	Sampling Year(s)	Sample Size (Frequency of Detection)	Detection Limit (f/cc)	Overall Quality Level
(Hayward, 1984)	Chrysotile (asbestiform of mineral serpentine)	N/R	US	Near Facility	1982	10 (1.00)	N/R	Medium
(Puffer et al., 1983)	Crocidolite (asbestiform of mineral riebeckite) Tremolite	1.0 µm 2.8 µm	US	General Population	1982	8 (1.00)	N/R	Medium
(Buelow et al., 1980)	General Chrysotile (asbestiform of mineral serpentine)	0.7–60 µm 0.3–40 µm	US	General Population	1975–1979	94 (0.41)	N/R	Medium
(ANL, 1979)	Chrysotile (asbestiform of mineral serpentine)	5 µm	US	Near Facility	1976	1 (1.00)	120.0	Medium
(ANL, 1979)	General	5 µm	US	Near Facility	1976	2 (1.00)	47.0	Medium
(U.S. EPA, 1976)	General Chrysotile (asbestiform of mineral serpentine)	N/R	US	General Population	1975–1976	104 (0.39)	3,300.0	Medium
(U.S. EPA, 1976)	Crocidolite (asbestiform of mineral riebeckite) Amosite (asbestiform of mineral grunerite) Chrysotile (asbestiform of mineral serpentine)	N/R	US	General Population	1975–1976	10 (1.00)	5,000.0	Medium
(McMillan et al., 1977)	General	N/R	US	General Population	1974–1975	234 (1.00)	N/R	Medium
(Stewart et al., 1977)	Chrysotile (asbestiform of mineral serpentine)	>5	US	Near Facility	1975	1 (1.00)	N/R	Medium
(Cooper and Murchio, 1974)	Chrysotile (asbestiform of mineral serpentine)	2–10 µm long	US	General Population	1973–1974	2 (1.00)	N/R	Medium
(Bacon et al., 1986)	General	N/R	CA	Near Facility	1981	2 (1.00)	N/R	Medium

Citation	Fiber Type	Fiber Size	Country	Location Type	Sampling Year(s)	Sample Size (Frequency of Detection)	Detection Limit (f/cc)	Overall Quality Level
(Conway and Lacey, 1984)	Chrysotile (asbestiform of mineral serpentine) General	35 to <2 µm	GB	Consumer Use	1980	8 (1.00)	8,601,460.0	Medium
(Conway and Lacey, 1984)	Chrysotile (asbestiform of mineral serpentine) General	35 to <2 µm	GB	General Population	1980	8 (0.75)	38104320.0	Medium
(Kay, 1974)	General	3 um	CA	General Population	1972	6 (1.00)	N/R	Medium
Thom cell and optical microscope								
(Zielina et al., 2007)	General	>10 µm <10 µm	PL	General Population	2007	39 (N/R)	N/R	Medium
CA = Canada; GB = Great Britain; PL = Poland; US = United States								

H.4.3 Groundwater

Overall measured concentrations of asbestos in groundwater with unit of f/cc, extracted from 6 sources, are summarized in Figure_Apx H-13 and supplemental information is provided in Table_Apx H-22. More than one analysis method was reported and summarized in the bullets that follow:

- Overall, concentrations for EDS ranged from not detected to 1.076863 f/cc from two samples collected in 2016 in one country (Italy). Location types were categorized as General Population and Near Facility. Reported detection frequency was 1.0.
- Overall, concentrations for TEM ranged from not detected to 34,204,000.0 f/cc from 52 samples collected between 1980 and 2011 in 3 countries (Canada, Great Britain, and United States). Location types were categorized as General Population and Near Facility. Reported detection frequency ranged from 0.7 to 1.0.



Figure_Apx H-13. Concentrations of Asbestos (f/cc) in Groundwater from 1980 to 2016

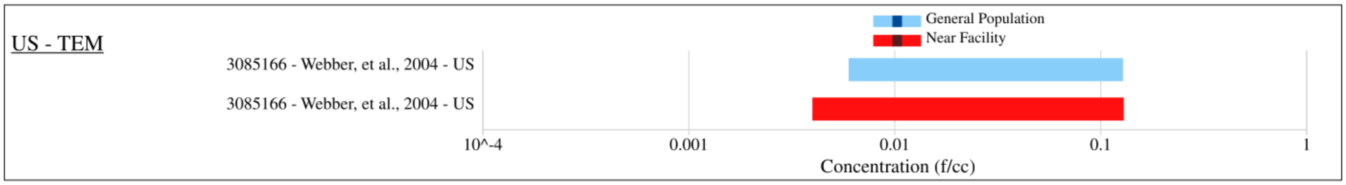
* = Reference used in risk determination

Table_Apx H-22. Summary of Peer-Reviewed Literature that Measured Asbestos (f/cc) Levels in Groundwater

Citation	Fiber Type	Fiber Size	Country	Location Type	Sampling Year(s)	Sample Size (Frequency of Detection)	Detection Limit (f/cc)	Overall Quality Level
EDS								
(Turci et al., 2016)	Chrysotile (asbestiform of mineral serpentine)	0.8µm	IT	General Population	2016	1 (1.00)	N/R	Medium
(Turci et al., 2016)	Chrysotile (asbestiform of mineral serpentine)	0.8µm	IT	Near Facility	2016	1 (1.00)	N/R	Medium
TEM								
(ATSDR, 2012a)	Chrysotile (asbestiform of mineral serpentine)	> 5 µm	US	Near Facility	2009–2011	23 (0.70)	200.0	Medium
(Hayward, 1984)	Chrysotile (asbestiform of mineral serpentine)	N/R	US	Near Facility	1982	7 (1.00)	N/R	Medium
(Puffer et al., 1983)	General Crocidolite (asbestiform of mineral riebeckite)	N/R 1.0 µm	US	General Population	1981–1982	8 (1.00)	N/R	Medium
(Bacon et al., 1986)	General	N/R	CA	General Population	1981	2 (1.00)	N/R	Medium
(Bacon et al., 1986)	General	N/R	CA	Near Facility	1981	4 (1.00)	N/R	Medium
(Conway and Lacey, 1984)	Chrysotile (asbestiform of mineral serpentine) General	35 µm to < 2 µm	GB	Near Facility	1980	8 (1.00)	43,208,550.0	Medium
CA= Canada; GB = Great Britain; IT = Italy; US = United States								

H.4.4 Sediment

Measured concentrations of Asbestos in Sediment with unit of f/cm3, extracted from one source, are summarized in Figure_Apx H-14 and supplemental information is provided in Table_Apx H-23. Overall, concentrations ranged from not detected to 0.13 f/cm3 from 16 samples collected between 1995 and 1998 in 1 country (United States). Location types were categorized as General Population and Near Facility. Reported detection frequency ranged from 0.88 to 1.0.



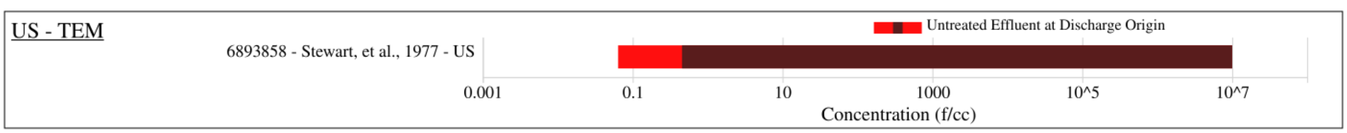
Figure_Apx H-14. Concentrations of Asbestos (f/cm^3) in the TEM Method of Sediment from 1995 to 1998

Table_Apx H-23. Summary of Peer-Reviewed Literature that Measured Asbestos (f/cm3) Levels in the TEM Method of Sediment

Citation	Fiber Type	Fiber Size	Country	Location Type	Sampling Year	Sample Size (Frequency of Detection)	Detection Limit (f/cm^3)	Overall Quality Level
(Webber et al., 2004)	Chrysotile (asbestiform of mineral serpentine) Anthophyllite	N/R	US	General Population	1995–1998	8 (0.88)	N/R	Medium
(Webber et al., 2004)	Chrysotile (asbestiform of mineral serpentine) Anthophyllite	N/R	US	Near Facility	1995–1998	8 (1.00)	N/R	Medium
US = United States								

H.4.5 Wastewater

Measured concentrations of asbestos in wastewater with unit of f/cc, extracted from one source, are summarized in Figure_Apx H-15 and supplemental information is provided in Table_Apx H-24. Overall, concentrations ranged from 0.064 to 10,000,000 f/cc from seven samples collected in 1975 in one country (United States). Location types were categorized as Untreated Effluent at Discharge Origin. Reported detection frequency was 0.57.



Figure_Apx H-15. Concentrations of Asbestos (f/cc) in the TEM Method of Wastewater in Untreated Effluent at Discharge Origin Locations in 1975

Table_Apx H-24. Summary of Peer-Reviewed Literature that Measured Asbestos (f/cc) Levels in the TEM Method of Wastewater

Citation	Fiber Type	Fiber Size	Country	Location Type	Sampling Year	Sample Size (Frequency of Detection)	Detection Limit (f/cc)	Overall Quality Level
(Stewart et al., 1977)	Chrysotile (asbestiform of mineral serpentine) General	>5	US	Untreated Effluent at Discharge Origin	1975	7 (0.57)	N/R	Medium
US = United States								

H.5 Soil

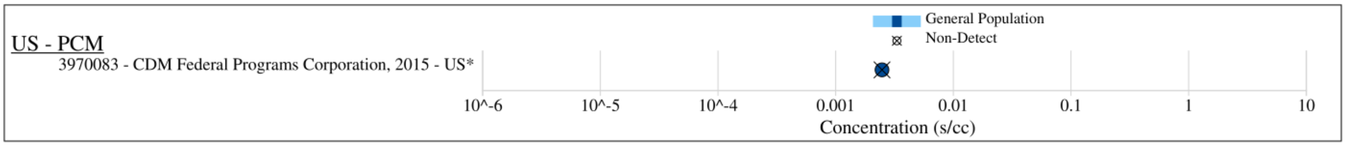
Measured concentrations of asbestos in soil with unit of f/cc, extracted from one source, are summarized in Figure_Apx H-16 and supplemental information is provided in Table_Apx H-25. Overall, concentrations ranged from 0.013 to 0.86 f/cc from four samples collected in 2010 in one country (United States). Location types were categorized as Near Facility. Reported detection frequency was not reported.

Figure_Apx H-16. Concentrations of Asbestos (f/cc) in the TEM Method of Soil in near Facility Locations in 2010
* = Reference used in risk determination

Table_Apx H-25. Summary of Peer-Reviewed Literature that Measured Asbestos (f/cc) Levels in the TEM Method of Soil

Citation	Fiber Type	Fiber Size	Country	Location Type	Sampling Year	Sample Size (Frequency of Detection)	Detection Limit (f/cc)	Overall Quality Level
(Jones et al., 2010)	General	N/R	US	Near Facility	2010	4 (N/R)	N/R	Medium
US = United States								

Measured concentrations of asbestos in soil with unit of s/cc, extracted from one source, are summarized in Figure_Apx H-17 and supplemental information is provided in Table_Apx H-26. Overall, concentrations were not detected s/cc from 1,000 samples collected between 2001 and 2012 in 1 country (United States). Location types were categorized as General Population. Reported detection frequency was not reported.



Figure_Apx H-17. Concentrations of Asbestos (s/cc) in the PCM Method of Soil in General Population Locations from 2001 to 2012
* = Reference used in risk determination

Table_Apx H-26. Summary of Peer-Reviewed Literature that Measured Asbestos (s/cc) Levels in the PCM Method of Soil

Citation	Fiber Type	Fiber Size	Country	Location Type	Sampling Year(s)	Sample Size (Frequency of Detection)	Detection Limit (s/cc)	Overall Quality Level
(CDM Federal Programs Corporation, 2015)	General	N/R	US	General Population	2001–2012	1,000 (N/R)	0.005	High
US = United States								

Appendix I ENVIRONMENTAL HAZARD DETAILS

I.1 Approach and Methodology

For aquatic species, EPA estimates hazard by calculating a concentration of concern (COCs) for a hazard threshold. COCs can be calculated using a deterministic method by dividing a hazard value by an assessment factor (AF) according to EPA methods (Suter, 2016; U.S. EPA, 2013, 2012) and Equation_Apx I-1.

Equation_Apx I-1.

$$COC = \text{toxicity value}/AF$$

COCs can be calculated using deterministic or probabilistic methods. For asbestos, EPA used a deterministic method to calculate the acute and both chronic COCs. Two chronic COCs were calculated due to the physiological differences between fish and mollusks.

I.2 Hazard Identification

I.2.1 Weight of Scientific Evidence

EPA used the strength-of-evidence and uncertainties from (U.S. EPA, 2021a) for the hazard assessment to qualitatively rank the overall confidence using evidence Table 4-3 for environmental hazard. Confidence levels of robust (+ + +), moderate (+ +), slight (+), or indeterminant are assigned for each evidence property that corresponds to the evidence considerations (U.S. EPA, 2021a). The rank of the Quality of the Database consideration is based on the systematic review data quality rank (high, medium, or low) for studies used to calculate the hazard threshold, and whether there are data gaps in the toxicity data set. Another consideration in the Quality of the Database is the risk of bias (*i.e.,* how representative is the study to ecologically relevant endpoints). Additionally, because of the importance of the studies used for deriving hazard thresholds, the Quality of the Database consideration may have greater weight than the other individual considerations. The high, medium, and low systematic review ranks correspond to the evidence table ranks of robust (+ + +), moderate (+ +), or slight (+), respectively. The evidence considerations are weighted based on professional judgment to obtain the Overall Confidence for each hazard threshold. In other words, the weights of each evidence property relative to the other properties are dependent on the specifics of the weight of scientific evidence and uncertainties that are described in the narrative and may or may not be equal. Therefore, the overall score is not necessarily a mean or defaulted to the lowest score. The confidence levels and uncertainty type examples are described below.

Confidence Levels

- Robust (+ + +) confidence suggests thorough understanding of the scientific evidence and uncertainties. The supporting weight of scientific evidence outweighs the uncertainties to the point where it is unlikely that the uncertainties could have a significant effect on the exposure or hazard estimate.
- Moderate (+ +) confidence suggests some understanding of the scientific evidence and uncertainties. The supporting scientific evidence weighed against the uncertainties is reasonably adequate to characterize exposure or hazard estimates.
- Slight (+) confidence is assigned when the weight of scientific evidence may not be adequate to characterize the scenario, and when the assessor is making the best scientific assessment

possible in the absence of complete information. There are additional uncertainties that may need to be considered.
- Indeterminant (NA) corresponds to entries in evidence tables where information is not available within a specific evidence consideration.

Types of Uncertainties
The uncertainties may be relevant to one or more of the weight of scientific evidence considerations listed in Table 4-3 are integrated into that property's rank in the evidence table.

- Scenario uncertainty: Uncertainty regarding missing or incomplete information needed to fully define the exposure and dose.
  - The sources of scenario uncertainty include descriptive errors, aggregation errors, errors in professional judgment, and incomplete analysis.
- Parameter uncertainty: Uncertainty regarding some parameter.
  - Sources of parameter uncertainty include measurement errors, sampling errors, variability, and use of generic or surrogate data.
- Model uncertainty: Uncertainty regarding gaps in scientific theory required to make predictions on the basis of causal inferences.
  - Modeling assumptions may be simplified representations of reality.

Table_Apx I-1 summarizes the weight of scientific evidence and uncertainties, while increasing transparency on how EPA arrived at the overall confidence level for each exposure hazard threshold. Symbols are used to provide a visual overview of the confidence in the body of evidence, although de-emphasizing an individual ranking that may give the impression that ranks are cumulative (*e.g.*, ranks of different categories may have different weights).

Table_Apx I-1. Considerations that Inform Evaluations of the Strength of the Evidence within an Evidence Stream (*i.e.*, Apical Endpoints, Mechanistic, or Field Studies)

Consideration	Increased Evidence Strength (of the Apical Endpoints, Mechanistic, or Field Studies Evidence)	Decreased Evidence Strength (of the Apical Endpoints, Mechanistic, or Field Studies Evidence)
The evidence considerations and criteria laid out here guide the application of strength-of-evidence judgments for an outcome or environmental hazard effect within a given evidence stream. Evidence integration or synthesis results that do not warrant an increase or decrease in evidence strength for a given consideration are considered "neutral" and are not described in this table (and, in general, are captured in the assessment-specific evidence profile tables).		
Quality of the database[a] (risk of bias)	• A large evidence base of *high*- or *medium*-quality studies increases strength. • Strength increases if relevant species are represented in a database.	• An evidence base of mostly *low*-quality studies decreases strength. • Strength also decreases if the database has data gaps for relevant species, *i.e.*, a trophic level that is not represented. • Decisions to increase strength for other considerations in this table should generally not be made if there are serious concerns for risk of bias; in other words, all the other considerations in this table are dependent upon the quality of the database.[a]
Consistency	Similarity of findings for a given outcome (*e.g.*, of a similar magnitude, direction) across independent studies or experiments increases strength, particularly when consistency is observed across species, life stage, sex, wildlife populations, and across or within aquatic and terrestrial exposure pathways.	• Unexplained inconsistency (*i.e.*, conflicting evidence; see U.S. EPA (2005)) decreases strength. • Strength should not be decreased if discrepant findings can be reasonably explained by study confidence conclusions; variation in population or species, sex, or life stage; frequency of exposure (*e.g.*, intermittent or continuous); exposure levels (low or high); or exposure duration.
Strength (effect magnitude) and precision	• Evidence of a large magnitude effect (considered either within or across studies) can increase strength. • Effects of a concerning rarity or severity can also increase strength, even if they are of a small magnitude. • Precise results from individual studies or across the set of studies increases strength, noting that biological significance is prioritized over statistical significance. • Use of probabilistic model (*e.g.*, Web-ICE, SSD) may increase strength.	Strength may be decreased if effect sizes that are small in magnitude are concluded not to be biologically significant, or if there are only a few studies with imprecise results.
Biological gradient/dose-response	• Evidence of dose-response increases strength. • Dose-response may be demonstrated across studies or within studies and it can be dose- or duration-dependent. • Dose-response may not be a monotonic dose-response (monotonicity should not necessarily be	• A lack of dose-response when expected based on biological understanding and having a wide range of doses/exposures evaluated in the evidence base can decrease strength. • In experimental studies, strength may be decreased when effects resolve under certain experimental conditions (*e.g.*, rapid reversibility after removal of exposure).

Consideration	Increased Evidence Strength (of the Apical Endpoints, Mechanistic, or Field Studies Evidence)	Decreased Evidence Strength (of the Apical Endpoints, Mechanistic, or Field Studies Evidence)
	expected, *e.g.*, different outcomes may be expected at low vs. high doses due to activation of different mechanistic pathways or induction of systemic toxicity at very high doses). • Decreases in a response after cessation of exposure (*e.g.*, return to baseline fecundity) also may increase strength by increasing certainty in a relationship between exposure and outcome (this particularly applicable to field studies).	• However, many reversible effects are of high concern. Deciding between these situations is informed by factors such as the toxicokinetics of the chemical and the conditions of exposure [see U.S. EPA (1998)], endpoint severity, judgments regarding the potential for delayed or secondary effects, as well as the exposure context focus of the assessment (*e.g.*, addressing intermittent or short-term exposures). • In rare cases, and typically only in toxicology studies, the magnitude of effects at a given exposure level might decrease with longer exposures (*e.g.*, due to tolerance or acclimation). • Like the discussion of reversibility above, a decision about whether this decreases evidence strength depends on the exposure context focus of the assessment and other factors. • If the data are not adequate to evaluate a dose-response pattern, then strength is neither increased nor decreased.
Biological relevance	Effects observed in different populations or representative species suggesting that the effect is likely relevant to the population or representative species of interest (*e.g.*, correspondence among the taxa, life stages, and processes measured or observed and the assessment endpoint).	An effect observed only in a specific population or species without a clear analogy to the population or representative species of interest decreases strength.
Physical/chemical relevance	Correspondence between the substance tested and the substance constituting the stressor of concern.	The substance tested is an analogue of the chemical of interest or a mixture of chemicals which include other chemicals besides the chemical of interest.
Environmental relevance	Correspondence between test conditions and conditions in the region of concern.	The test is conducted using conditions that would not occur in the environment.

[a] Database refers to the entire data set of studies integrated in the environmental hazard assessment and used to inform the strength of the evidence. In this context, database does *not* refer to a computer database that stores aggregations of data records such as the ECOTOX Knowledgebase.

Appendix J CONSUMER EXPOSURE DETAILS

J.1 Concentrations of Asbestos in Activity-Based Scenarios

Studies identified in Table 3-5 were used to estimate exposure concentrations for each activity-based scenario. The following subsections are organized by COU and subcategory; each subsection discusses the activity-based scenario's study methods and identifies the applicable data chosen for use in this exposure assessment. The concentrations identified for bystanders were generally either reported area air concentrations or approximated concentrations using a reduction factor (RF). For activity-based scenarios that have reported both personal data (which represents DIY users) and area data (which represents bystanders), RFs were calculated by dividing the personal exposure concentration by the area exposure concentration. The resulting RFs were averaged across all activity-based scenarios to obtain an overall average default RF value of 6. This RF was used to approximate concentrations for activity-based scenarios that did not have bystander (area) data reported. For these scenarios, the reported personal exposure concentration for DIY users was divided by 6 to obtain the bystander exposure concentration. The scenarios evaluated quantitatively extracted data are summarized in Table 3-6.

J.1.1 Construction, Paint, Electrical, and Metal Products COU

The activity-based scenarios evaluated under this COU relate to construction and building material products; the activities consist of disturbing, maintaining or repairing the products or removing the products. Disturbance, maintenance, or repair activities may involve product modification such as sanding, cutting, or drilling of products and cleaning after the activities. Removing the products may also involve product modification such as breaking and cutting.

New installation activities were not considered due to the low likelihood of consumers acquiring new or unused commercial asbestos-containing products to use or install. In the United States, due to health concerns, asbestos-containing construction products are no longer produced and have been replaced by substitute materials that do not contain asbestos (U.S. EPA, 1989). Furthermore, the product modification actions consumers might undertake during installations are likely similar to those during maintenance or repair (*e.g.,* cutting and sanding). It is assumed that product installation may take a longer amount of time but might be done on a less frequent basis, while repair work may take a shorter amount of time but might be done more often. Overall, potential exposures are expected to be comparable, therefore the exposures evaluated for maintenance and repair activities can also represent installation activities.

The activity-based scenarios and studies are summarized below, and the selected concentration data for quantitative evaluation are shown in Table 3-6. For each scenario, low-end, central tendency, and high-end concentrations were determined where possible, as described below.

Subcategory: Construction and Building Materials Covering Large Surface Areas

Outdoor, Disturbance/Repair (Sanding or Scraping) of Roofing Materials: Mowat et al. (2007) evaluated five chrysotile asbestos-containing commercial roofing products that were sold in the 1950s, 1960s and 1970s. The products included two "plastic roof cements" that contained 4.3 to 15.5 percent chrysotile and three "fibered roof coatings" that contained 3.04 to 4.24 percent chrysotile. These products were tested in exposure simulations of six activities related to roof repair: application, wet sanding, removal from laundered clothing, removal from soiled tools, hand sanding and hand scraping. Personal (n = 84) and perimeter (n = 49) samples were collected during each 30-min test and analyzed for total fiber concentration by phase-contrast microscopy (PCM) and for asbestos fiber count by transmission electron microscopy (TEM). For samples that had detectable asbestos fibers, the total fiber concentration obtained by PCM was converted to a PCM-equivalent (PCME) asbestos concentration. EPA used data for the hand sanding and hand scraping activities only, as the other activities involved wet, uncured product. Sanding and scraping data from Table 4 was averaged to represent the repair of roofing materials scenario for a DIY user. The average of the reported minimums was used for low end exposures, the average of the reported arithmetic means was used for central tendency exposures, and the average of the reported maximums was used for high end exposures. For bystanders, EPA used a default average RF of 6.

Outdoor, Removal of Roofing Materials: Lange et al. (2008) studied exposure to airborne asbestos during abatement of ceiling material, window caulking, floor tile, and roofing material at schools in eastern United States. These commercial abatement activities were considered to provide an adequate proxy for concentrations encountered during DIY roofing activities. Personal, excursion limit (30 minute), and area (2 hours at perimeter within 10 feet) samples were collected and analyzed by PCM. All work generally followed OSHA requirements for asbestos. Roofing removal work was performed without any containment. EPA used personal and perimeter data to evaluate DIY users and bystanders, respectively. As the results were below the detection limit, the reported detection limit was used for high-end exposures and one-half of the detection limit was used for central tendency and low-end exposures.

Indoor, Removal of Plaster: Lange et al. (2008) was also used for indoor removal of plaster. These commercial abatement activities were considered to provide an adequate proxy for concentrations encountered during DIY ceiling removal activities. Plaster abatement involved establishment of critical barriers and full enclosure (plastic sealed over all openings) with a decontamination chamber. For DIY users, EPA used the personal minimum for low-end exposures, arithmetic mean for central tendency exposures and maximum for high-end exposures. For bystanders, the results were below the detection limit, so the detection limit was used for high-end exposures and one-half of the detection limit was used for central tendency and low-end exposures.

Indoor, Disturbance (Sliding) of Ceiling Tiles: Boelter et al. (2016) studied exposure associated with maintenance and installation of dropped ceiling systems and lay-in ceiling panels that may have contained asbestos prior to the late 1970s. The authors conducted two field studies to evaluate exposures to maintenance workers and bystanders and one chamber study to understand retrospective installation exposures. As the chamber study was intended to represent historical work scenarios, EPA only used data from the field studies to evaluate DIY users and bystanders. These commercial maintenance activities were considered to provide an adequate proxy for concentrations encountered during DIY ceiling disturbance activities. Bulk ceiling panel samples analyzed by polarized light microscopy (PLM) found 1 to 4.25 percent amosite and 0.25 to 1.5 percent chrysotile asbestos fibers. In the field studies, an experienced asbestos abatement worker removed, slid, and replaced ceiling panels and a certified industrial hygienist (CIH) observed the work. Personal 30-minute and 8-hour TWA samples were collected for both individuals and analyzed by PCM and TEM. PCME results were calculated by multiplying the PCM result by the TEM fraction. EPA used the personal 30-minute PCME data from Table 1 for DIY users and bystanders. As the results were below the quantitation limit, the quantitation limit was used for high-end exposures and ½ of the quantitation limit was used for central tendency and low-end exposures.

Indoor, Removal of Ceiling Tiles: Lange et al. (1993) measured asbestos fibers during removal of asbestos-containing ceiling tiles at a public school in Pennsylvania. After a roof leak from a heavy rainstorm, saturated ceiling tiles fell to the floor. An abatement containment was established, and the fallen ceiling tile and remaining in-tact ceiling tile was removed. These commercial abatement activities were considered to provide an adequate proxy for concentrations encountered during DIY ceiling removal activities. Air samples were collected inside and outside the containment on each day of the abatement activities and were analyzed by PCM or TEM. EPA used the TEM results from Table 1 to evaluate DIY users. The minimum (detection limit) was used for low end exposures, maximum for high end exposures and detected mid-point value for central tendency exposures. For bystanders, EPA used a default average RF of 6.

Indoor, Maintenance (Chemical Stripping, Polishing or Buffing) of Vinyl Floor Tiles: Lundgren et al. (1991) studied asbestos exposure to workers associated with installation, maintenance, and removal of vinyl asbestos floor tile. These commercial maintenance activities were considered to provide an adequate proxy for concentrations encountered during DIY floor tile disturbance activities. Personal and static (area) samples were analyzed by PCM and scanning electron microscope (SEM). The maintenance work involved chemical stripping of the existing floor polish, cleaning of the floor tile surface, and then polishing and buffing of the tile surface; the personal monitoring was performed for 43 minutes. Though the PCM analysis detected fibers, the SEM analysis found zero quantifiable asbestos fibers (Table 5), and detection limits were not provided in the study. As the results indicate no evidence of asbestos fiber release associated with floor tile maintenance work, this scenario is not quantitatively evaluated.

Indoor, Removal of Vinyl Floor Tiles: Lundgren et al. (1991) was also used to evaluate this scenario. The authors studied both hot and cold removal techniques. Hot removal involved using heat guns to heat the underlying adhesive and then scrape the tile off, which took 30 minutes. Cold removal involved using dry ice to freeze the underlying adhesive and then remove the tile, which took 45 minutes. The authors described the hot removal method as "less destructive," so EPA conservatively used the cold removal method data to represent consumers. The SEM personal sampling result for cold removal was used for DIY users and the static sampling result was used for bystanders. As only one value was reported, this was used to represent all exposures (low-end, high-end, and central tendency).

Flooring Materials, Felt: EPA did not identify monitoring studies measuring asbestos fibers releases during renovation or disturbance of flooring felt. In the absence of product specific releases during removal or disturbance activities is not further evaluated for DIY users or bystanders quantitatively and is evaluated qualitatively by using the indoor removal of vinyl floor tiles as a proxy to assess exposures and risk.

Indoor, Disturbance/Repair (Cutting) of Attic Insulation: Ewing et al. (2010) evaluated asbestos exposure in homes containing zonolite (expanded vermiculite) attic insulation. Fieldwork was done at three homes, and a variety of tasks were performed including cleaning storage items or areas in the attic, cutting a hole in the ceiling below insulation, moving insulation using wet and dry methods and removing insulation with a shop vacuum. Personal and area air, surface dust and bulk samples were collected. The amphibole asbestos identified by PLM consisted of tremolite, richterite, winchite and actinolite. The air samples were analyzed by PCM and TEM, and PCME results were calculated and reported. EPA used the ceiling cutting task (which took 24 minutes to complete with a drill and hand saw) to represent the consumer disturbance/repair scenario. The Table 3 personal PCME result was used for DIY users and an average of three reported area results was used for bystanders. These concentrations were used to represent all exposures, (low-end, high-end and central tendency).

Indoor, Moving and Removal (with Vacuum) of Attic Insulation: Ewing et al. (2010) was also used to evaluate this scenario. The moving task consisted of removing insulation from between flooring/floor joints and using a broom and dustpan to remove debris. This work took 29 minutes to complete. EPA conservatively used the dry removal method data to represent consumers as wet removal methods generally result in lower exposures. For the removal task, insulation from a trough at the perimeter of the attic was vacuumed, and the vacuum was emptied seven times. This work took 44 minutes to complete. The Table 5 personal PCME result for the moving task was used for high end exposures, the Table 6 personal PCME result for the removal task was used for low end exposures, and an average was used for central tendency exposures for DIY users. The same pattern was followed to develop exposure concentrations for bystanders, except averages of reported area results were used.

Paper Articles: EPA did not identify monitoring studies measuring asbestos fibers releases during renovation or disturbance of paper article products. Therefore, these products were not further evaluated for DIY users or bystanders and is evaluated qualitatively. Based on the finding of fiber releases for other products within this COU and the potential of these products to release fibers during some activity that modifies the product, EPA assumes similar exposure and risk patterns.

Metal Articles: EPA did not identify monitoring studies measuring asbestos fibers releases during renovation or disturbance of metal article products such as stove gaskets and rings, fireplace embers, and Galbestos. These products were not further evaluated for DIY users or bystanders and are evaluated qualitatively. Because these products are not friable and are unlikely to be modified by consumers via sanding or cutting, EPA concludes asbestos fibers are not to be released from an undisturbed item and hence no exposure is expected.

Subcategory: Machinery, mechanical appliances, electrical/ electronic articles
Plastics and Electro-mechanical Parts: EPA did not identify monitoring studies measuring asbestos fibers releases during renovation or disturbance of plastics, such as reinforced plastic in appliances and electro-mechanical parts, such as deep fryers, frying pans and grills, mixers, popcorn poppers, slow cookers, refrigerators, curling irons, electric blankets, portable heaters, safes, safety boxes, filing cabinets, and kilns and incinerators. These products were not further evaluated for DIY users or bystanders and are evaluated qualitatively. Because these products are not friable and are unlikely to be modified by consumers via sanding or cutting, EPA concludes asbestos fibers are not to be released from an undisturbed item and hence no exposure is expected.

Subcategory: Filler and Putties
Indoor, Removal of Floor Tile/Mastic: The Lange et al. (2008) study that was used for removal of roofing materials was also used for this scenario. These commercial abatement activities were considered to provide an adequate proxy for concentrations encountered during DIY mastic removal activities. Floor tile mastic abatement involved establishment of critical barriers and full enclosure (plastic sealed over all openings) with a decontamination chamber. EPA used personal and perimeter monitoring data from Table 1 to evaluate DIY users and bystanders, respectively. As the results were below the detection limit, the reported detection limit was used for high-end exposures and ½ of the detection limit was used for central tendency and low-end exposures.

Indoor, Removal of Window Caulking: Lange et al. (2008) was also used for this scenario. These commercial abatement activities were considered to provide an adequate proxy for concentrations encountered during DIY caulking removal activities. Caulking removal had a critical barrier enclosure (plastic sealed over all openings) around windows. EPA used personal and perimeter data from Table 1 to evaluate DIY users and bystanders, respectively. As the results were below the detection limit, the reported detection limit was used for high-end exposures and ½ of the detection limit was used for central tendency and low-end exposures.

Indoor, Disturbance (Pole or Hand Sanding and Cleaning) of Spackle: Rohl et al. (1975) acquired 15 samples of consumer spackling and patching compounds from hardware stores in NYC prior to 1975. The samples were analyzed by PLM, X-Ray Diffraction (XRD) and TEM to identify asbestos presence. Three samples contained 5 to 10 percent chrysotile, one contained 4 to 6 percent tremolite and one contained 10 to 12 percent anthophyllite. The asbestos fibers ranged in length from 0.25 to 8.0 µm, with shorter than 5 µm in length. The authors measured air concentrations in the breathing zone of drywall construction workers, and the samples were analyzed by PCM and TEM. The workers performed tasks including hand sanding, pole sanding, dry mixing and sweeping. Perimeter area samples were also collected in the same room and adjacent room. The sampling durations were not reported, and "peak fiber concentration" PCM results of fibers longer than 5 µm were reported. To evaluate consumer exposures, EPA used data for sanding and sweeping only, as dry mixing is related to installation activities. The average of the reported minimums was used for low-end exposure, the average of reported means was used for central tendency exposure, and the average of the reported maximums was used for high-end exposure. Personal data was used for DIY users and averages of perimeter area data in the same room and adjacent room was used for bystanders. For low end exposures, the bystander's minimum concentrations in the same room were greater than the primary worker's concentrations during sanding activities. This suggests fibers may remain suspended and bystander exposures may not necessarily always be lower than DIY user exposures.

Indoor, Disturbance (Sanding and Cleaning) of Coatings, Mastics and Adhesives: Paustenbach et al. (2004) measured asbestos in air during application, spill cleanup, sanding, removal, and cleaning of adhesives, coatings and mastics. These products were representative of those produced in the 1960s and contained 1 to 9 percent chrysotile asbestos. The tasks were performed for 30 minutes, and personal and area samples were collected and analyzed by PCM and TEM. PCME calculated results were presented in Table 6 for those samples that had measured asbestos fibers (only sanding, spill cleanup and cleaning tests had asbestos fibers present; application and removal tests did not have asbestos fibers present). For DIY users, EPA used the personal sanding concentration for high end exposures and the spill cleanup concentration for central tendency and low-end exposures. The same pattern was followed for bystanders with area data.

Subcategory: Solvent-Based/Water-Based Paint

Indoor, Disturbance of Coatings or Textured Paint: Sawyer (1977) studied a ceiling fire- and sound-retardant coating that was a spray-applied mixture of asbestos and fibrous glass at a Yale school building. The material gradually deteriorated over time due to normal air movement and vibration and accidental or intentional contact by maintenance workers. Air sampling was conducted under quiet conditions and during custodial service, and samples were analyzed by PCM. EPA determined that the scenarios described in this paper represent indoor air and occupational exposure and are not representative of a consumer performing an activity that may release friable asbestos fibers from solvent-based or water-based paint. Additionally, the systematic review process rated the overall study as low because its description of sampling and analytical methods and approaches lacked sufficient details. Therefore, this scenario is not further evaluated for DIY users or bystanders.

J.1.2 Furnishing, Cleaning, Treatment Care Products COU

Subcategory: Construction and Building Materials Covering Large Surface Areas, Including Fabrics, Textiles, and Apparel

Asbestos Textiles Including Yarn, Thread, Wick, Cord, Rope, Tubing (Sleeving), Cloth, Tape: EPA did not identify monitoring studies measuring asbestos fibers releases during renovation or disturbance of textile products such as yarn, thread, wick, cord, rope, tubing, cloth or tape. Therefore, these products were not further evaluated for DIY users or bystanders and is evaluated qualitatively. These products are not friable and are unlikely to be modified by consumers via sanding or cutting, EPA concludes asbestos fibers are not to be released from an undisturbed item and hence no exposure is expected. However, should these products remain in general use like cord, tubing and cloth, based on the finding of fiber releases for other products, mittens, within this COU and the potential of these products to release fibers during some activity that modifies the product, EPA assumes similar exposure and risk patterns.

Subcategory: Furniture and Furnishings, Including Stone, Plaster, Cement, Glass, and Ceramic Articles; Metal Articles; or Rubber Articles

Use of Mittens for Glass Manufacturing, (Proxy for Oven Mittens and Potholders): EPA did not identify any study related to oven mitts, potholders, or similar products. A United Kingdom study, Cherrie et al. (2005) assessed asbestos exposures to workers using chrysotile asbestos gloves or mitts in a glass manufacturing plant. EPA used this data in proxy of oven mittens, potholders and similar products used as protective clothing for high temperature tasks. In the study, three tasks were observed in conditions without ventilation and high ventilation. The tasks were rotating a steel pole to row molten glass, removing, and replacing a glass window, and removing and replacing a side seal. Personal air samples were collected for 30 minutes for each task which was continuously repeated. The samples were analyzed by Health & Safety Executive (HSE) Methods for the Determination of Hazardous Substances (MDHS) 39/4, which is a PCM method. Observations of the tests showed that abrasion of the mitts on sharp metal edges resulted in the release of airborne dust. EPA determined that the rowing task might be most applicable to a consumer using oven mitts or gloves and used the rowing data with no ventilation from Figure 1. The minimum was used for low-end exposures, the maximum was used for high-end exposure, and the arithmetic average was used for central tendency exposures for DIY users. For bystanders, EPA used a default average RF of 6.

EPA did not identify monitoring studies measuring asbestos fibers releases during renovation or disturbance of burner mats. Therefore, these products were not further evaluated for DIY users or bystanders and is evaluated qualitatively. These products are not friable and are unlikely to be modified by consumers via sanding or cutting, EPA concludes asbestos fibers are not to be released from an undisturbed item and hence no exposure is expected. However, should burner mats remain in general use, based on the finding of fiber releases for other products, mittens, within this COU and the potential of these products to release fibers during some activity that modifies the product, EPA assumes similar exposure and risk patterns.

J.1.3 Packaging, Paper, Plastic, Toys, Hobby Products COU

Subcategory: Packaging (Excluding Food Packaging), Including Rubber Articles; Plastic Articles (Hard); Plastic Articles (Soft)

Plastic Articles and Asbestos Reinforced Plastics: EPA did not identify monitoring studies measuring asbestos fibers releases during renovation or disturbance of plastics, such as reinforced plastic. These products were not further evaluated for DIY users or bystanders and are evaluated qualitatively. Because these products are not friable and are unlikely to be modified by consumers via sanding or cutting, EPA concludes asbestos fibers are not to be released from an undisturbed item and hence no exposure is expected.

Subcategory: Toys Intended for Children's Use, Including Fabrics, Textiles, and Apparel; or Hard Plastic Articles

Mineral Kits: EPA did not identify monitoring studies measuring asbestos fibers releases during the modification of mineral kits nor studies providing asbestos concentrations in these products. Therefore, this products were not further evaluated for DIY users or bystanders and is evaluated qualitatively. Based on the description of mineral kits uses in which children and adults scrape, sand, and breakdown the kits to extract "gems" or fossils, it is expected that particulate can be uplifted and exposure via inhalation of asbestos containing particulate occurs.

Coloring of Crayons: Saltzman and Hatlelid (2000) evaluated three brands of children's crayons to determine whether asbestos was present and to measure children's potential exposure. Crayons were analyzed by PLM and TEM, and trace amounts of asbestos were found (below detection limit to 0.03%). Air samples were collected during a 30-minute simulation of aggressive use, where crayons were used to draw, shade, and trace with considerable force. Crayons were rubbed and broken to simulate typical crayon use patterns. The study reported no asbestos fibers were measured during this simulation, and the authors concluded risk to children is "extremely low".

J.1.4 Automotive, Fuel, Agriculture, Outdoor Use Products COU

Subcategory: Lawn and Garden Care Products

Use of Vermiculite Soil Treatment: U.S. EPA (2000a) measured asbestos from personal breathing zone air inside a containment (simulating a greenhouse) and personal breathing zone air outdoors during the use of gardening products that contain vermiculite, sourced from Libby, Montana. This study reported vermiculite concentrations in gardening products from 2000 and earlier from various sources. In summary, the non-Superfund sites reported non-detects or below detection limits for asbestos concentrations. This product was reformulated in the early 2000s, and most vermiculite fibers in the product have been subject to weatherization processes that result in the breakage of fibers to less than 5 µm in addition to mixing in with deeper soil layers. EPA concludes that exposure to this product and its legacy use do not pose an asbestos exposure risk.

J.1.5 Chemical Substances in Products not Described by Other Codes

Subcategory: Other (Artifacts), Vintage Artifacts in Private Collections; Vintage Cars, Articles, Curios

Metal Dedener: EPA did not identify monitoring studies measuring asbestos fibers releases during renovation or disturbance or modification of metal deders. These products were not further evaluated for DIY users or bystanders and are evaluated qualitatively. Because these products are not friable and are unlikely to be modified by consumers via sanding or cutting, EPA concludes asbestos fibers are not to be released from an undisturbed item and hence no exposure is expected.

J.2 Consumer DIY Exposure Risk Estimate

Consumer and bystander activity-based exposure concentrations and risks were calculated using Equation_Apx J-1, which is the general equation for estimating cancer risks for lifetime and less than lifetime exposure from inhalation of asbestos, from the *Office of Land and Emergency Management Framework for Investigating Asbestos-contaminated Superfund Sites* (U.S. EPA, 2008).

Equation_Apx J-1. Equation to Calculate Human Exposure Concentration

$$Human\ Exposure\ Concentration = EPC \times TWF_{Lifetime\ or\ Chronic}$$

Where:

Human Exposure Concentration = Lifetime Cancer or non-cancer chronic concentration from monitoring studies

EPC = Exposure Point Concentration, the concentration of asbestos fibers in air (f/cc) for the specific activity being assessed

TWF = Time Weighting Factor, this factor accounts for less-than-continuous exposure during a 1-year exposure and is given by:

Equation_Apx J-2. TWF for Lifetime Cancer Exposure Concentrations

$$TWF_{Lifetime} = \left[\frac{Exposure\ time\ (\frac{hr}{day})}{24\ hr}\right] \times \left[\frac{Exposure\ frequency\ (\frac{day}{yr})}{365\ day}\right]$$

Equation_Apx J-3. TWF for Non-cancer Chronic Exposure Concentrations

$$TWF_{Non-Cancer\ Chronic} = TWF_{Lifetime} \times \left[\frac{Exposure\ duration\ (yr)}{Averaging\ time\ (yr)}\right]$$

All of the activity-based scenarios considered people 16 years of age and older for all genders for DIY users and, and all ages and genders for bystanders. The exposure duration is 62 years for DIY users and 78 years for bystanders, and the Averaging time is 78 years. The non-cancer chronic TWF are calculated using Equation_Apx J-1 and are summarized in Table_Apx J-1. The values are based on assumptions related to the activity type (*e.g.*, disturbance/repair or removal) rather than the specific product.

For repair activities, it was assumed that a DIY user may perform one repair or renovation task where they may disturb ACM per year, and the length of time spent on the task varies for low-end, high-end, and central tendency exposure estimates. These time estimates are based on professional judgement. For removal activities, EPA reviewed the frequency of replacement for various home materials such as tiles and roofing, but also considered the likelihood of consumers encountering legacy use ACM.
For example, while industry experts might recommend replacing floor tile every 20 years, only the first replacement job is likely to involve removing asbestos-containing floor tile. It is unlikely that newly installed floor tile that might be replaced again after 20 years would contain asbestos. Therefore, it was assumed for low-end and central tendency estimates, a DIY user perform removal jobs with asbestos-containing products once in their lifetime, and for high-end estimates, a DIY user might remove asbestos-containing products three times over their lifetime. It was assumed that each removal job takes 10 days for central tendency and high-end and estimates and 5 days for low-end estimates. In contrast to repair activities, it was assumed that removal work takes a longer time (*i.e.*, 8 hours per day).

Table_Apx J-1. Non-cancer Chronic Time Weighting Factors Assumptions for All COUs

Activity-Based Scenario	Low- End TWF	Low-End TWF Basis	High-End TWF	High-End TWF Basis	Central Tendency TWF	Central-Tendency TWF Basis
Construction, paint, electrical, and metal products COU: Construction and building materials covering large surface areas subcategory						
Outdoor, disturbance/repair (sanding or scraping) of **roofing materials**	0.000045	Assumed 1 repair/year, taking 1 day, lasting 30 min/day	0.00027	Assumed 1 repair/year, taking 1 day, lasting 3 hr/day	0.000091	Assumed 1 repair/year, taking 1 day, lasting 1 hr/day
Outdoor, removal of **roofing materials**	0.0036	Assumed 1 removal job in lifetime taking 5 days lasting 8 hr/day	0.022	Assumed 3 removal jobs in lifetime taking 10 days lasting 8 hr/day	0.0073	Assumed 1 removal job in lifetime taking 10 days lasting 8 hr/day
Indoor, removal of **plaster**	0.0036	Assumed 1 removal job in lifetime taking 5 days lasting 8 hr/day	0.022	Assumed 3 removal jobs in lifetime taking 10 days lasting 8 hr/day	0.0073	Assumed 1 removal job in lifetime taking 10 days lasting 8 hr/day
Indoor, disturbance (sliding) of **ceiling tiles**	0.000045	Assumed 1 repair/year, taking 1 day, lasting 30 min/day	0.00027	Assumed 1 repair/year, taking 1 day, lasting 3 hr/day	0.000091	Assumed 1 repair/year, taking 1 day, lasting 1 hr/day
Indoor, removal of **ceiling tiles**	0.0036	Assumed 1 removal job in lifetime taking 5 days lasting 8 hr/day	0.022	Assumed 3 removal jobs in lifetime taking 10 days lasting 8 hr/day	0.0073	Assumed 1 removal job in lifetime taking 10 days lasting 8 hr/day
Indoor, maintenance (chemical stripping, polishing or buffing) of **vinyl floor tiles**	0.000045	Assumed 1 repair/year, taking 1 day, lasting 30 min/day	0.00027	Assumed 1 repair/year, taking 1 day, lasting 3 hr/day	0.000091	Assumed 1 repair/year, taking 1 day, lasting 1 hr/day
Indoor, removal of **vinyl floor tiles**	0.0036	Assumed 1 removal job in lifetime taking 5 days lasting 8 hr/day	0.022	Assumed 3 removal jobs in lifetime taking 10 days lasting 8 hr/day	0.0073	Assumed 1 removal job in lifetime taking 10 days lasting 8 hr/day
Indoor, disturbance/repair (cutting) of **attic insulation**.	0.000045	Assumed 1 repair/year, taking 1 day, lasting 30 min/day	0.00027	Assumed 1 repair/year, taking 1 day, lasting 3 hr/day	0.000091	Assumed 1 repair/year, taking 1 day, lasting 1 hr/day
Construction, paint, electrical, and metal products COU: fillers and putties subcategory						
Indoor, disturbance (pole or hand sanding and cleaning) of **spackle**	0.000045	Assumed 1 repair/year, taking 1 day, lasting 30 min/day	0.00027	Assumed 1 repair/year, taking 1 day, lasting 3 hr/day	0.000091	Assumed 1 repair/year, taking 1 day, lasting 1 hr/day
Indoor, disturbance (sanding and cleaning) of	0.000045	Assumed 1 repair/year, taking 1 day, lasting 30 min/day	0.00027	Assumed 1 repair/year, taking 1 day, lasting 3 hr/day	0.000091	Assumed 1 repair/year, taking 1 day, lasting 1 hr/day

Activity-Based Scenario	Low- End TWF	Low-End TWF Basis	High-End TWF	High-End TWF Basis	Central Tendency TWF	Central-Tendency TWF Basis
coatings, mastics and adhesives						
Indoor, removal of **floor tile/mastic**	0.0036	Assumed 1 removal job in lifetime taking 5 days lasting 8 hr/day	0.022	Assumed 3 removal jobs in lifetime taking 10 days lasting 8 hr/day	0.0073	Assumed 1 removal job in lifetime taking 10 days lasting 8 hr/day
Indoor, removal of **window caulking**	0.0036	Assumed 1 removal job in lifetime taking 5 days lasting 8 hr/day	0.022	Assumed 3 removal jobs in lifetime taking 10 days lasting 8 hr/day	0.0073	Assumed 1 removal job in lifetime taking 10 days lasting 8 hr/day
Furnishing, cleaning, treatment care products COU: Construction and building materials covering large surface areas, including fabrics, textiles, and apparel Subcategory						
Use of mittens for glass manufacturing, (proxy for **oven mittens and potholders**)	0.00015	Assumed BBQ[a] mittens used more than other hobbies. People grill on average 1 hr/day, 1 day per week (52 days per year), using an ACM mitt for 2 years over their lifetime	0.00076	Assumed BBQ mittens used more than other hobbies. People grill on average 1 hr/day, 1 day per week (52 days per year), using an ACM mitt for 10 years over their lifetime	0.00038	Assumed BBQ mittens used more than other hobbies. People grill on average 1 hr/day, 1 day per week (52 days per year), using an ACM mitt for 5 years over their lifetime
[a] EPA assumed a cooking or grilling activity-based scenario, which is likely performed in higher frequencies and durations than other hobbies requiring the need for protective clothing such as mittens and potholders under this COU. Bolded text in Activity-Based Scenario column highlights product examples for easier finding.						

Appendix K EPIDEMIOLOGIC COHORTS FOR DOSE-RESPONSE

Table_Apx K-1 and Table_Apx K-2 below provides a summary of each of the epidemiological cohorts for dose response and the corresponding overall quality determination (OQD) ratings.

Table_Apx K-1. Cohorts Identified for Consideration in Asbestos Part 2 Non-cancer Dose-Response Analysis

Cohort Name (Reference[s])	Cohort Description	Non-cancer Outcome(s)	Overall Quality Determination (OQD) Rating
IRIS Libby Amphibole Asbestos Assessment, 2014			
O.M. Scott Marysville, OH, Plant Cohort (Lockey et al., 1984) (Rohs et al., 2008)	• Cohort included 530 workers with known vermiculite exposure participated in the 1980 investigation. Eight different worksite operations at the ore processing plant were represented. • Monitoring of industrial hygiene at the facility started in 1972, including personal breathing zone sampling. PCM measurements beginning after 1976. • Job exposure matrix used to determine cumulative exposures. • Follow-up including chest x-rays and interview information from 280 of the 431 workers who were known to be alive between 2002 and 2005. • Followed up on the respiratory effects in the cohort conducted in 2012.	Pulmonary function Mortality Pleural plaques DPT Asbestosis	High
Libby, MT, Vermiculite Mining and Milling Cohort	• Participants were white men who had worked for at least 1 year in the mine and mill. • Reports based on follow-up data from 1960 to 2006. • Air sampling data were used to build a job-exposure matrix assigning daily exposures (8-hour TWA) for selected job codes. • Individual work histories and the mine and mill job-exposure matrix were used to determine individual exposure metrics.	Mortality	Medium
Cohorts not included in previous EPA assessments for non-cancer effects			
SC Textiles Cohort	• Textile plant in Charleston, SC and used asbestos from 1909 to 1977. • Original cohort of textile workers limited to white males employed for at least 1 month between 1940 and 1965. Later expanded to included non-whites and females. • Individual-level exposures estimates derived from detailed work histories and extensive air measurements using PCM and conversion of dust measurements from analysis of paired sampling.	Mortality	Medium

Cohort Name (Reference[s])	Cohort Description	Non-cancer Outcome(s)	Overall Quality Determination (OQD) Rating
SC Vermiculite Miners Cohort (W. R. Grace & Co, 1988)	• Cohort composed of 194 men hired between 1949 and 1974 in mining/milling of vermiculite in Enoree, SC. • 58 air samples collected in 1986 and analyzed by PCM.	Mortality, parenchymal abnormalities including pleural thickening and sputum analysis	Medium
Anatolia, Turkey, Villagers Cohort (Metintas et al., 2005)	• Field-based, cross-sectional study of 991 villagers from 10 randomly selected villages with known asbestos-containing white soil. • Indoor and outdoor air sample taken for each village; fibers counted by PCM.	Pleural plaques, asbestosis, diffuse pleural fibrosis	High
Wittenoom, Australia, Residents Cohort	• Residential cohort included 4659 individuals residing for at least 1 month in Wittenoom between 1943 and 1992. Mine workers excluded. • Follow-up in 1993, 2000, and 2004 • Ambient exposures from nearby crocidolite assigned based on dates of residence, assigned exposure intensity, and period personal monitoring after operations ceased.	Mortality	Medium
Chinese Chrysotile Textile Factory Cohort (Huang, 1990)	• Cohort of 776 workers employed for at least 3 years in chrysotile textile product factory; Shanghai. • 17 workplaces in the factory selected for routine sampling; dust and fiber measurements collected by membrane filters. • Follow-up through September 1982 for asbestos diagnosis.	Asbestosis incidence	Medium

Table_Apx K-2. Cohorts Identified for Consideration in Asbestos Part 2 Cancer Dose-Response Analysis

Cohort Name	Cohort Description	Cancer Outcomes[a]	Overall Quality Determination (OQD) Rating
Risk Evaluation for Asbestos Part 1: Chrysotile Asbestos, 2020			
NC Textiles Cohort	• Four textile plants imported raw chrysotile fibers to make yarns and woven goods. • 5,770 workers employed for at least 1 day between 1950 and 1973. • Cohort followed through 2003.	Mesothelioma, pleural cancer, lung cancer	High
SC Textiles Cohort	• Textile plant in Charleston, SC, and used asbestos from 1909 to 1977. • Original cohort of textile workers limited to white males employed for at least 1 month between 1940 and 1965. Later expanded to included non-white and females. • Individual-level exposures estimates derived from detailed work histories and extensive air measurements using PCM and conversion of dust measurements from analysis of paired sampling.	Lung cancer, mesothelioma	Medium
Quebec, Canada Asbestos Mines and Mills Cohort	• Study of chrysotile miners and mill in Thetford mines in Quebec, Canada. • The original cohort was made up of men who were born between 1891 and 1920 and who had worked for at least 1 month in the mines and mills. • Cohort followed from first employment in 1904 to May 1992. • Detail work histories as well as total dust measurement from 4,000 midget impinger dust counts in mppcf per year were analyzed.	Mesothelioma, lung cancer	Medium
Qinghai, China Asbestos Mine Cohort	• Study of chrysotile mine in Qinghai Province, China. • Cohort made up of 1,539 male workers who were on the registry January 1, 1981, and who had worked for at least 1 year. • Occupational and work history of cohort was obtained from personnel records and employee. • Cohort followed for vital stats from 1981 to 2006. • Total dust concentrations were measured by area sampling in fixed locations and converted to fiber/cc.	Lung cancer, gastrointestinal cancer	Medium
Chongqing, China Asbestos	• Chrysotile asbestos plant in Chongqin, China, which produces textile, asbestos	Lung cancer	High

Cohort Name	Cohort Description	Cancer Outcomes[a]	Overall Quality Determination (OQD) Rating
Products Factory Cohort	cement products, friction materials, rubber products and heat-resistant materials. • Cohort of 515 men were followed from January 1, 1972, to December 31, 1996; workers (men and women) who had worked for less than 1 year were excluded. • Cohort followed until 2008 when women who were employed between 1970 and 1972 were added to analysis. • Airborne dust and fiber concentrations were measured from personal samplers.		
Balangero, Italy Mining Cohort	• Balangero mine and mill of the Amiantifera Company started in 1916 and produced pure chrysotile asbestos. • Cohort consisted of 1,056 men who worked in mines for at least 1 year between January 1, 1930, and December 31, 1975. • Cohort followed up from January 1, 1946, or date of first employment, to December 31, 2003, or when subjects reached 80 years of age. • Information on cohort collected from mine records. • First fiber counts were first carried out in 1969 and exposure levels before 1969 were reconstructed to represent earlier years.	Lung cancer, laryngeal cancer, gastrointestinal cancer, , mesothelioma	Medium
Salonit Anhovo, Slovenia Asbestos Factory Cohort	• Salonit Anhovo factory in western Slovenia produced asbestos-cement products made from chrysotile and amphibole asbestos. • Cohort made up of 6,714 workers who had worked for at least 1 day between 1964 and 1994. • Air sampling measurements taken at fixed location close to worker's breathing zone. • Work histories were obtained from personnel files.	Lung cancer	Medium
IRIS Libby Amphibole Asbestos Assessment, 2014			

Cohort Name	Cohort Description	Cancer Outcomes[a]	Overall Quality Determination (OQD) Rating
Libby, MT, Vermiculite Mining and Milling Cohort	• Cohort included 1,871 vermiculite miners, millers, and processors hired prior to 1970 and employed for at least 1 year at the Montana site. • Subjects followed through December 2006. • Historical air sampling data used to estimate 8-hour TWA. • Work histories including job title and dates of employment were obtained and used to calculate cumulative fiber exposures.	Lung cancer, mesothelioma	Medium (lung cancer) High (mesothelioma)
IRIS Asbestos Assessment, 1988			
US Asbestos Company Employees Cohort	• Cohort consisted of 1,075 men obtained from company records. • Subjects were retired between 1941 and 1967 and receiving a pension from company. • Cohort followed through 1973. • Total dust measured in mppcf.	Mesothelioma, lung cancer, digestive cancer	Medium
New Orleans Asbestos Cement Building Material Plants Cohort	• Includes two asbestos cement building material plant producing products containing chrysotile, crocidolite, and amosite asbestos. • Cohort consisted of 5,645 men who had worked in either plant and had at least 20 years of follow up. • Detail work history obtained from plant records.	Lung cancer, mesothelioma, digestive cancer	High
Ontario, Canada Asbestos Cement Factory Cohort	• Cohort included 241 production and maintenance employees who worked for at least 9 years at the factory prior to 1960. • Impingers were used to prior to 1973 and membranes fiber counts used thereafter. • Mortality was followed through October 1980.	Lung cancer, mesothelioma, gastrointestinal cancer	Medium
NY-NJ Asbestos Insulation Workers Cohort	• Cohort located in Paterson, NJ, and manufactured amosite products. • Cohort included 820 men that worked for at least 5 years in factory. • Cohort followed through 1982. • No fiber counts available, but used counts for similar plant in Tyler, TX.	Lung cancer	Medium
Asbestos Textile Workers Cohort	• Cohort consisted of white males who worked at the plant for at least 1 month prior to January 1, 1959. • Work histories obtained from this U.S. textile cohort included all 1,261 white	Lung cancer, mesothelioma	Medium

Cohort Name	Cohort Description	Cancer Outcomes[a]	Overall Quality Determination (OQD) Rating
	males who worked at the plant for at least a month between January 1, 1940, and December 31, 1965. All workers who had a social security administration (SSA) record and had worked for at least 1 month prior to January 1, 1959, were considered to be part of the cohort. The cumulative dust exposures were assigned to each study participant using the same data that (Dement et al., 2008) used to calculate historical exposures.		
International Association of Heat and Frost Insulators and Asbestos Workers Cohort	• Plant located in the NY-NJ metro area and produced chrysotile and amosite products between 1943 and 1976. • Cohort included 623 men employed prior to 1943 and 833 men employed after 1943. • Follow-up in 1962 and 1976. • Asbestos concentration in facilities not measured but used counts from other U.S. insulation facilities that operated between 1968 and 1971.	Mesothelioma	Medium
Cohort not included in existing EPA assessments			
Wittenoom, Australia, Residents Cohort	• Residential cohort included 4,659 individuals residing for at least 1 month in Wittenoom between 1943 and 1992. Mine workers excluded. • Follow-up in 1993, 2000, and 2004. • Ambient exposures from nearby crocidolite assigned based on dates of residence, assigned exposure intensity, and period personal monitoring after operations ceased.	Lung cancer, ovarian cancer, mesothelioma,	Medium

[a] As indicated in Section 1.3 and the Final Scope document, Part 2 of the risk evaluation will focus on mesothelioma and lung, ovarian, and laryngeal cancers.

Appendix L TAKE−HOME EXPOSURE DETAILS

L.1 Data Used for Take-Home Analysis

Eight experimental studies were selected for further review; and one study, upon further full-text review, was excluded, leaving seven studies for use in determining the take-home slope factor. Table_Apx L-1 below provides the study activity type, job-related loading event information, take-home exposure event information, and sampling details of the seven studies.

Table_Apx L-1. Description of Selected Monitoring Studies of Clothes Handling for Take-Home Analysis

Study/Overall Quality Determination/ Activity Type	Job-Related Loading Event	Take-Home Exposure Event	Sampling Details
Used in regression analysis			
(Abelmann et al., 2017) *Medium* Cutting asbestos cement pipe (AC)	**Description:** Cutting asbestos cement (AC) pipe outdoors using a power saw, simulating in-ground (trench) and above ground AC pipe repair in low-wind conditions. Cutting events were 2 minutes each and the worker remained in the area for 30 minutes total. PCME values were not reported.	**Description:** Unfolding and shaking of 2 sets of contaminated clothes (2 long sleeve shirts and 2 jeans) for approx. 1 minute, followed by no activity, for a total of 30 minutes of sampling per event (4 separate events). Min and Max are the lowest and highest event averages out of 4 events. Avg is the average of all events.	• Handler: Personal air samples collected for four 30-minute clothing shake-out events (n = 4 per event) • Bystander: Area air samples collected for four 30-minute clothing shake-out events; samples collected at breathing zone height, 1.2 m from the shake-out activity (n = 4 per event) • Sampling was performed in a 58 m^3 chamber (4.9 m × 4.9 m × 2.4 m) with • Air changes per hour[a]: 3.2
	Concentrations: PCM, 30 min **Worker:** 5.2 (in-ground) to 12.4 (above ground) f/cc by PCM (Table 1; assumed PCM as proxy for PCME). Average is 8.8 f/cc	**Concentrations:** PCME, 30 min **Handler:** (Table 1) Min: 0.27 f/cc; Avg: 0.52 f/cc; Max: 1.1 f/cc **Bystander:** (Table 2) Min: 0.19 f/cc; Avg: 0.34 f/cc; Max: 0.49 f/cc	
(Madl et al., 2014) *Medium* Vintage maritime valve repair/ replacement	**Description:** Complete overhaul of 10 vintage Edward valves manufactured prior to the 1980s and historically used on maritime vessels; repair work conducted in an enclosed room and consisted of replacing the packing, removing the gasket, and/or installing a new gasket.	**Description:** Shaking and folding six contaminated coveralls for 1–3 minutes (one for a handler and one for a bystander during valve repair on three consecutive days, where new coveralls were used each day, for a total of 3 worker coveralls and 3 bystander coveralls). The total sample duration is not clearly stated but could be presumed to be 16–36 minutes.	• Handler: Personal breathing zone samples collected during one clothes handling event (1–3 minutes per item) • Center/Bystander/Remote: Area air samples collected during one

Study/Overall Quality Determination/ Activity Type	Job-Related Loading Event	Take-Home Exposure Event	Sampling Details
	Concentrations: PCME, 30 min **Worker:** 0.013 f/cc (Table 2, all valve work)	**Concentrations:** PCME, 30 min **Handler:** Avg 0.005 f/cc (Table 2) **Bystander:** Avg 0.0015 (taken as one-half the TEM limit of detection in Table 4)	clothes handling event (1–3 minutes per item) • Air changes per hour[a]: approximately 2–3
(Madl et al., 2009) *Medium* Brake removal and repair of heavy construction equipment (manufactured between 1960 and 1980)	**Description:** Brake wear debris released during brake removal and disassembly from 12 loader/backhoes and tractors manufactured between 1960 and 1980. Coveralls collected after work completed on each piece of equipment and stored in separate plastic-lined bags until clothes handling task conducted.	**Description:** Simulated clothes handling task involved shaking, folding, and turning inside out 11 sets of contaminated clothing (overalls) for 1–3 minutes each set (1 event). The total sample duration is not clearly stated but could be presumed to be 30 min. Whether the samples were taken in a chamber is not clearly stated.	• Breathing zone samples and area samples at bystander, remote, and ambient locations • Air changes per hour[a]: 0.6–1.55
	Concentrations: PCME, 30 min **Worker:** 0.024 f/cc (30 min to 1 hr) by PCME (Abstract)	**Concentrations:** PCME, 30 min **Handler:** (Table 2) Min: 0.032 f/cc; Avg: 0.036 f/cc; Max: 0.039 f/cc **Bystander: (**Table 2) Min: 0.003 f/cc; Avg: 0.010 f/cc; Max: 0.018 f/cc	
(Madl et al., 2008) *Medium* Unpacking and repacking boxes of brakes for vehicles ca. 1946–80	**Description:** Unpacking and repacking 105 boxes of automobile brake pads (n = 62) and shoes (n = 43) for vehicles ~1946–80 obtained from vintage automotive parts suppliers and repair facilities. Coveralls collected after work completed on each piece of equipment and stored in separate plastic-lined bags until clothes handling task conducted.	**Description:** Simulated clothes handling task involved shaking, folding, and turning coveralls inside out for 1–2 min. Handler samples are for 15 minutes. Bystander samples (5 ft from handler) are for 30 minutes.	• Breathing zone samples and area samples at bystander (1.5 m from main activity), remote (7.6–9.1 m from main activity), and ambient (outside testing facility) locations • 30-min sampling duration • Air changes per hour[a]: 0.83 in 2004, 0.39 and 0.66 in 2005
	Concentrations: PCME, 30 min **Worker:** 0.028 to 0.368 f/cc for handling 4–20 boxes of brake pads or brake shoes (abstract). Average of 0.198 f/cc.	**Concentrations:** PCME, 30 min **Handler:** (Table 1, Testing II worker) Min: 0.007 f/cc; Avg: 0.011 f/cc; Max: 0.015 f/cc **Bystander:** (Table 2, bystander) Avg: 0.010 f/cc based on one detected value (of 4)	
(Jiang et al., 2008) *Medium*	**Description:** Handling, unpacking, and repacking 27 boxes of automobile clutch discs made prior to the mid-1980s provided	**Description:** Shaking and folding three different pairs of contaminated overalls for approx. 45 seconds (1 event). Handler samples	• Bystander (5 ft from main activity), remote (>50 ft from

Study/Overall Quality Determination/ Activity Type	Job-Related Loading Event	Take-Home Exposure Event	Sampling Details
Unpacking/ repacking or stacking unopened boxes of automotive clutch discs	by automotive parts warehouse. Overalls kept in sealed bag until testing	were collected for two 15-minute intervals and a 60 minute interval (the first 15-minute interval was used in this assessment). Bystander samples (5 ft from handler) were for 30 minutes. Avg is average, Max is maximum	main activity), and ambient (outside testing facility) locations • 30-min sampling duration • Air changes per hour: 0.4, 2.0, 0.3 for 3 days in January
	Concentrations: PCME **Worker:** 0.026 f/cc (one box, 1 min) to 0.212 f/cc (stacking boxes, 30 min) (abstract). Average is 0.119 f/cc	**Concentrations:** PCME **Handler:** 1st 15 minutes (Table 4) Avg: 0.003 f/cc; Max: 0.005 f/cc; **Bystander:** 30 minutes (Table 4) Avg: 0.002 f/cc (taken as one-half the TEM limit of detection in Table 4)	

Study/Overall Quality Determination/ Activity Type	Job-Related Loading Event	Take-Home Exposure Event	Sampling Details
(Sahmel et al., 2014) *Medium* Simulated workplace and home environments (sealed chambers); loading by dust generator	**Description:** Chrysotile loading via aerosolized dust generator at 3 different target airborne levels (low 0–0.1, medium 1–2, and high 2–4 f/cc); 2 events each level for 31–43 min	**Description:** Six 30-minute clothes-handling and shake-out events (shook for 15 min, followed by inactivity for 15 min)	• Personal airborne fiber samples collected during each 15-minute period of activity or inactivity and for full 30-minute period • Four area samples (distances varied ~6–12 ft from handling activities) collected each 30–minute handling and shake-out event at breathing zone height of ~5 ft • Air changes per hour[a]: 13–19 during 30-min events
	Concentrations: PCME (SI Table I) **Low:** LOD and 0.010; average taken to be 0.005 f/cc; 32 to 45 min sampling **Medium:** 1.36 and 3.11 f/cc; average 2.235 f/cc; 34 to 61 min sampling **High:** 2.71 and 3.52; average 3.125 f/cc; 37 to 89 min sampling	**Concentrations:** PCME **Handler: (**SI Table II, 15 min) Low: both events are below LOD; Avg 0.007 (taken as one-half the TEM limit of detection) Medium: single event 0.094 f/cc (Avg) High: Event 1: 0.103 fcc; Event 2: 0.155 f/cc; CT: 0.129 f/cc **Bystander:** (SI Table III, 30 min) **Low**: both events are below LOD; Avg: 0.001 (taken as ½ the TEM limit of detection) **Medium:** Event 1 is below LOD; 0.0015 f/cc (taken as one-half the TEM limit of detection); Event 2 is 0.006 f/cc; Avg of the two, 0.00375 f/cc. **High:** Event 1: 0.006 f/cc; Event 2: 0.013 f/cc; average of the two, 0.0095 f/cc	
(Sahmel et al., 2016) *High* Simulated workplace and home environments (sealed chambers); loading by dust generator	**Description:** Chrysotile loading via aerosolized dust generator at 1 different target airborne levels (very high 10 f/cc); 3 different clothing types, 3 garment sets per type, for two different 6.5 hour loading events.	**Description:** Six 45-minute clothes-handling and shake-out events (shook for 15 min, followed by inactivity for 30 min)	• Personal airborne fiber samples collected during 15 min of shake-out and 30 min post shake-out activity periods. • Four area samples (distances varied 1.8–3.7 m from handling activities) collected each shake-out event at breathing zone height of ~5 ft • Air changes per hour[a]: 3.5
	Concentrations: PCME (text, page 51) **Very High:** 11.4 f/cc	**Concentrations:** PCME **Handler: (**SI Table B, 0–15 min SO) Avg: 2.94 f/cc **Bystander:** (SI Table C, 45 min) Avg: 0.62 f/cc	

Study/Overall Quality Determination/ Activity Type	Job-Related Loading Event	Take-Home Exposure Event	Sampling Details
Not used in regression analysis			
(Weir et al., 2001) *Low* Arc grinding of brake shoes	**Description:** Inspection and replacement of light-duty vehicle rear drum brakes at an auto/truck repair facility	**Description:** Nonrigid freeform dynamic flow chamber used to agitate clothing; over 30-min period clothing was agitated and allowed to rest for alternating 5-min intervals **Decision to exclude:** 1. Uncertainty in how representative the experimental method (small chamber) is to real-world samples collected via personal breathing zone or area samples. 2. Only a single sample was collected. 3. Results only provided for PCM, and the study notes that asbestiform was only a small portion (no quantitative TEM or SEM results were provided).	• Air samples extracted from chamber for clothing study • ACH N/R • 30-minute sampling duration
[a] Air changes per hour (ACH) is the process by exchanging the air within a chamber by various means and filters.			

L.2 Take-Home Exposure Concentration Calculations

The data needed to estimate the yearly average concentration for each scenario using the unit exposure approach is summarized in Table 5-7 and are explained in Equation_Apx L-1:

Equation_Apx L-1. Equation to Calculate Yearly Average Concentration Cancer and Non-cancer Risk Estimates

$$Yearly\ Ave\ Concen = EPC \times \left[\frac{Exposure\ time\ (\frac{hr}{day})}{24\ hr}\right] \times \left[\frac{Exposure\ frequency\ (\frac{day}{yr})}{365\ day}\right]$$

Where:

EPC is Exposure Point Concentration, the concentration of asbestos fibers in air (f/cc) for the specific activity being assessed. The second term in Equation_Apx L-1 requires averaging the exposure concentration over a typical day (resulting in the 24-hour TWA, 24-hour TWA concentration) and over the number of days a year that exposure occurs expressed in the third term. Based on the approaches described in Section 3.1.4 and Equation 3-1, Equation_Apx L-1 turns into Equation_Apx L-2 and Equation_Apx L-3, subsequently.

Equation_Apx L-2. Equation to Calculate Yearly Average Concentration for Cancer and Non-cancer Risk Estimates after Slope Factor Approach Substitutions

$$Yearly\ Ave\ Concen = 24hr\ TWA\ Conc \times \left[\frac{Exposure\ frequency\ (\frac{day}{yr})}{365\ day}\right]$$

This exposure concentration is the result from [Y] days of loading a year, where [Y] matches the occupational scenario frequency:

Equation_Apx L-3. Equation to Calculate Yearly Average Concentration for Cancer and Non-cancer Risk Estimates after Slope Factor Approach and Occupational Frequency Substitutions

$$Yeary\ Ave\ Concen = [X\ f/cc] \times take\text{-}home\ slope\ factor \times \left[\frac{[Y\ days]}{365\ days}\right]$$

L.3 Take-Home Risk Estimates for Other Bystander Populations

Table_Apx L-2. Take-Home Inhalation Risk Estimates Summary for All Populations Considered

COUs	OES	Population	Age Group	Chronic Non-cancer (Benchmark MOE = 300)		Cancer Lifetime (Benchmark = 1E−06)	
				CT	HE	CT	HE
Construction, paint, electrical, and metal products and, Furnishing, cleaning, treatment care products	Maintenance, renovation, and demolition	Handler	>16–40 [a]	305,613	88	1.3E−08	4.6E−05
		Bystander	>16–40 [b]	480,378	134	8.4E−09	3.0E−05
		Bystander	0–20 [c]	960,756	268	1.3E−08	4.5E−05
		Bystander	0–78 [d]	246,348	69	2.1E−08	7.6E−05
Construction, paint, electrical, and metal products and, Furnishing, cleaning, treatment care products	Firefighting and other disaster response activities (career)	Handler	>16–40 [a]	280,146	1,615	1.4E−08	2.5E−06
		Bystander	>16–40 [b]	440,347	2,459	9.2E−09	1.6E−06
		Bystander	0–20 [c]	880,693	4,919	9.2E−09	2.5E−06
		Bystander	0–78 [d]	225,819	1,261	2.3E−08	4.1E−06
Construction, paint, electrical, and metal products and, Furnishing, cleaning, treatment care products	Firefighting and other disaster response activities (volunteer)	Handler	>16–40 [a]	840,437	4,846	4.8E−09	8.4E−07
		Bystander	>16–40 [b]	1,321,040	7,378	3.1E−09	5.5E−07
		Bystander	0–20 [c]	2,642,080	14,757	3.1E−09	8.2E−07
		Bystander	0–78 [d]	677,456	3,784	7.7E−09	1.4E−06
Construction, paint, electrical, and metal products	Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	Handler	>16–40 [a]	8,004	47	5.1E−07	8.6E−05
		Bystander	>16–40 [b]	12,581	72	3.2E−07	5.6E−05
		Bystander	0–20 [c]	25,163	144	3.2E−07	8.5E−05
		Bystander	0–78 [d]	6,452	37	8.1E−07	1.4E−04
Construction, paint, electrical, and metal products, Furnishing, cleaning, treatment care products, and Packaging, paper, plastic, toys, hobby products	Handling articles or formulations that contain asbestos (battery insulators, burner mats, plastics, cured coatings/adhesives/ sealants)	Handler	>16–40 [a]	8,150	681	5.0E−07	6.0E−06
		Bystander	>16–40 [b]	12,810	1,037	3.2E−07	3.9E−06
		Bystander	0–20 [c]	25,620	2,074	3.2E−07	5.9E−06
		Bystander	0–78 [d]	6,569	532	7.9E−07	9.8E−06

COUs	OES	Population	Age Group	Chronic Non-cancer (Benchmark MOE = 300)		Cancer Lifetime (Benchmark = 1E−06)	
				CT	HE	CT	HE
Disposal, including distribution for disposal	Waste handling, disposal, and treatment	Handler	>16–40 [a]	44,823	236	9.1E−08	1.7E−05
		Bystander	>16–40 [b]	70,455	360	5.8E−08	1.1E−05
		Bystander	0–20 [c]	140,911	719	5.8E−08	1.7E−05
		Bystander	0–78 [d]	36,131	184	1.4E−07	2.8E−05

Risk values for handlers are less than bystanders for 0-78 age group because handlers have less than lifetime exposure while bystanders have lifetime exposures.
[a] Scenario representative of garment handler patterns similar to those from occupational durations which is the source of asbestos fibers into clothing.
[b] Scenario representing people, spouses and others that live at home and have take-home exposures as bystanders until person and the source of asbestos retires from their work (source of asbestos in clothing).
[c] Scenario representative of children living at home while contaminated clothing is handled during their living at home status, 20 years.
[d] Scenario representing people have take-home exposures at their childhood home from birth and throughout their entire life, whether in the same household or other with similar take-home exposure possibilities.

Appendix M DETERMINATION OF LESS-THAN-LIFETIME INHALATION UNIT RISK (IUR) VALUES

This appendix provides a description on the sources of information and approaches used to obtain the less-than-lifetime (LTL) IUR values used in this Asbestos Part 2 Risk Evaluation and garner the sensitivity in unreasonable risk determination decisions if using the two main LTL IUR values sources. There are two main sources of LTL values:

1. The LTL numbers for the 1988 IUR are here:
   a. *Framework for Investigating Asbestos-Contaminated Comprehensive Environmental Response, Compensation and Liability Act Sites framework for Investigating Asbestos-Contaminated Comprehensive Environmental Response, Compensation and Liability Act Sites* (see Table H-4).
2. The LTL IUR value for the Asbestos Part 1 Risk Evaluation is provided in this appendix.

There are no LTL numbers for Libby Amphibole Asbestos (LAA).

Recommended estimates of the LTL values for Part 2 are the mean of the 1988 LTL values and the Asbestos Part 1 LTL values for the specific age at first exposure and the duration of exposure combinations, rounded up to two significant digits to be protective of public health.

The lifetime exposure scenario already has an IUR or 0.2 per f/cc.

- Scenarios considered under the Asbestos Part 2 Risk Evaluation were for first exposure at birth and then 20 years of duration to represent a child bystander growing up in a contaminated home (*e.g.*, general population): $IUR_{(0,20)}$;
- First exposure at birth, duration for 1 year, and carried on through a lifetime for general population exposed to asbestos from non-stationary activity-based releases (*e.g.*, general population): $IUR_{(0,1)}$
- First exposure at age 16 years and then 40 years of duration (both occupational exposure, and take-home scenarios): $IUR_{(16,40)}$; and
- First exposure at age 16 years and then 62 years of duration (consumer exposure scenarios): $IUR_{(16,62)}$.
- Other LTL IURs were used to perform a sensitivity analysis for the stationary releases of asbestos and exposures to the general population: $IUR_{(20,10)}$, $IUR_{(20,30)}$, $IUR_{(30,10)}$

Table_Apx M-1. Less-than-Lifetime (LTL) IURs for Asbestos: Part2

Age at First Exposure (years)	Duration (years)	1988 LTL IUR (per f/cc)	Part 1 LTL IUR (per f/cc)	Part 2 LTL IUR (per f/cc)
0	1	0.01	0.00414	0.01
0	20	0.14	0.106	0.1
16	10	0.045	0.0292	0.04
16	20	0.072	0.0468	0.06
16	40	0.098	0.0612	0.08
16	62	0.11	0.0641	0.09
20	10	0.039	0.0235	0.03
20	30	0.075	0.0448	0.06
30	10	0.026	0.0132	0.02

EPA compared risk estimate results (*i.e.*, ELCR values) using lifetime and LTL (U.S. EPA, 1986a) IURs and Part 2 IUR values, see Table_Apx M-1. The comparison results are available in a series of tables for each population assessed in this Part 2 Risk Evaluation: workers, take-home, DIYers, and the general population. If the calculated ELCR is greater than the benchmark ELCR (1×10^{-6}), this is a starting point to determine if there are unreasonable cancer risks. A comparison of IUR ELCR values relative to the benchmark values derived from (U.S. EPA, 1986a) and the Part 1 Risk Evaluation is provided in Table_Apx M-2 to Table_Apx M-5. The summary tables below mark with a red "x" those that where above the benchmark for one IUR and below the benchmark for the other. Differing ELCR values only resulted from one high end take-home scenario corresponding to Firefighting and Other Disaster Response Activities (Volunteer) OES; one below the benchmark when using the 0.08 LTL IUR value and above the benchmark when using the 0.098 LTL IUR value. The ELCR value that was calculated with a 0.08 IUR was close to the benchmark and an 18 percent difference between the LTL IUR values resulted in an ELCR values over the benchmark. However, benchmark values are not the only indicators used to determine if there is risk or unreasonable risk.

Table_Apx M-2. Occupational Part 1 and Part 2 IUR ELCR Comparison

Occupational Exposure Scenario (OES)	Significant Exposure Group (SEG)	Exposure Scenario	Chronic, Cancer Exposures (8-hr TWA) ELCR IUR Comp.	
			HE ELCR Comp.	CT ELCR Comp.
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities	Higher-Exposure Workers	8-hr	✓	✓
	Lower-Exposure Workers	8-hr	✓	✓
	ONU	8-hr	✓	✓
	Higher-Exposure Workers	30-min	✓	✓
	Lower-Exposure Workers	30-min	✓	✓
	ONU	30-min	✓	✓
Handling asbestos-containing building materials during firefighting or other disaster response activities	Higher-Exposure Workers	8-hr	✓	✓
	Lower-Exposure Workers	8-hr	✓	✓
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	Higher-Exposure Workers	8-hr	✓	✓
	ONU	8-hr	✓	✓
	Higher-Exposure Workers	30-min	✓	✓
Handling articles or formulations that contain asbestos	Higher-Exposure Workers	8-hr	✓	✓
	Lower-Exposure Workers	8-hr	✓	✓
	ONU	8-hr	✓	✓
	Higher-Exposure Workers	30-min	✓	✓
	Lower-Exposure Workers	30-min	✓	✓
	ONU	30-min	✓	✓
Waste handling, disposal, and treatment	Higher-Exposure Workers	8-hr	✓	✓
	ONU	8-hr	✓	✓
Comparison matrix results: Red "x" are those that one ELCR result exceeds the benchmark while the other does not, check marks are both IUR ELCR estimates are either above or below the benchmark				

Table_Apx M-3. Take-Home Part 1 and Part 2 IUR ELCR Comparison

Scenario/OES	Handler Less Than Lifetime ELCR (16, 40)		Bystander Lifetime ELCR (0,78)	
	CT ELCR Comp.	HE ELCR Comp.	CT ELCR Comp.	HE ELCR Comp.
Maintenance, renovation, and demolition	✓	✓	✓	✓
Firefighting and other disaster response activities (career)	✓	✓	✓	✓
Firefighting and other disaster response activities (volunteer)	✓	✓	✓	×
Use, repair, or removal of industrial and commercial appliances or machinery containing asbestos	✓	✓	✓	✓
Handling articles or formulations that contain asbestos (battery insulators, burner mats, plastics, cured coatings/adhesives/sealants)	✓	✓	✓	✓
waste handling, disposal, and treatment	✓	✓	✓	✓
Comparison matrix results: Red "x" are those that one ELCR result exceeds the benchmark while the other does not, check marks are both IUR ELCR estimates are either above or below the benchmark				

Table_Apx M-4. Consumer DIY Part 1 and Part 2 IUR ELCR Comparison

COU	Subcategory	Product and Activity-Based Scenario	LE ELCR Comp.	CT ELCR Comp.	HE ELCR Comp.
Chemical substances in construction, paint, electrical, and metal products	Construction and building materials covering large surface areas	Outdoor, disturbance/repair (sanding or scraping) of **roofing materials**	✓	✓	✓
		Outdoor, removal of **roofing materials**	✓	✓	✓
		Indoor, removal of **plaster**	✓	✓	✓
		Indoor, disturbance (sliding) of **ceiling tiles**	✓	✓	✓
		Indoor, removal of **ceiling tiles**	✓	✓	✓
		Indoor, maintenance (chemical stripping, polishing or buffing) of **vinyl floor tiles**	✓	✓	✓
		Indoor, removal of **vinyl floor tiles**	✓	✓	✓
		Indoor, disturbance/repair (cutting) of attic **insulation**.	✓	✓	✓
		Indoor, moving and removal with vacuum of **attic insulation**	✓	✓	✓
	Fillers and putties	Indoor, disturbance (pole or hand sanding and cleaning) of **spackle**	✓	✓	✓
		Indoor, disturbance (sanding and cleaning) of **coatings, mastics and adhesives**	✓	✓	✓
		Indoor, removal of **floor tile/mastic**	✓	✓	✓
		Indoor, removal of **window caulking**	✓	✓	✓
Chemical substances in furnishing, cleaning,	Construction and building materials covering large surface areas,	Use of mittens for glass manufacturing, (proxy for **oven mittens and potholders**)	✓	✓	✓

COU	Subcategory	Product and Activity-Based Scenario	LE ELCR Comp.	CT ELCR Comp.	HE ELCR Comp.
treatment care products	including fabrics, textiles, and apparel				
Comparison matrix results: Red "x" are those that one ELCR result exceeds the benchmark while the other does not, check marks are both IUR ELCR estimates are either above or below the benchmark. Bystander results look the same as DIYer, see Supplemental file *Asbestos Part 2 RE – Risk Calculator Consumer - November 2024*.					

Table_Apx M-5. General Population Part 1 and Part 2 IUR ELCR Comparison

OES	COU(s)	Distance from the Source (m)							
		10	30	60	100	100–1,000	2,500	5,000	10,000
Low-end tendency lifetime cancer ELCR (f/cc) (benchmark = 1E−06 to 1E-4)									
Waste handling, disposal, and treatment fugitive [a]	COU: Disposal, including distribution for disposal	✓	✓	✓	✓	✓	✓	✓	✓
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities fugitive [b]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	✓	✓	✓	✓	✓	✓	✓	✓
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos fugitive [b]	COU: Construction, paint, electrical, and metal products	✓	✓	✓	✓	✓	✓	✓	✓
Handling articles or formulations that contain asbestos fugitive [a]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products COU: Packaging, paper, plastic, toys, hobby products	✓	✓	✓	✓	✓	✓	✓	✓
Central tendency lifetime cancer ELCR (benchmark = 1E−06 to 1E-4)									
Waste handling, disposal, and treatment fugitive [a]	COU: Disposal, including distribution for disposal	✓	✓	✓	✓	✓	✓	✓	✓
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities fugitive [b]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	✓	✓	✓	✓	✓	✓	✓	✓
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos fugitive [b]	COU: Construction, paint, electrical, and metal products	✓	✓	✓	✓	✓	✓	✓	✓
Handling articles or formulations that contain asbestos fugitive [a]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products COU: Packaging, paper, plastic, toys, hobby products	✓	✓	✓	✓	✓	✓	✓	✓
Handling asbestos-containing building materials during firefighting or other disaster response activities fugitive [b]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	✓	✓	✓	✓	✓	✓	✓	✓
High-end tendency lifetime cancer ELCR (f/cc) (benchmark = 1E−6 to 1E-4)									
Waste handling, disposal, and treatment fugitive [a]	COU: Disposal, including distribution for disposal	✓	✓	✓	✓	✓	✓	✓	✓

OES	COU(s)	Distance from the Source (m)							
		10	30	60	100	100–1,000	2,500	5,000	10,000
Handling asbestos-containing building materials during maintenance, renovation, and demolition activities fugitive [b]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	✓	✓	✓	✓	✓	✓	✓	✓
Use, repair, or disposal of industrial and commercial appliances or machinery containing asbestos fugitive [b]	COU: Construction, paint, electrical, and metal products	✓	✓	✓	✓	✓	✓	✓	✓
Handling articles or formulations that contain asbestos fugitive [a]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products COU: Packaging, paper, plastic, toys, hobby products	✓	✓	✓	✓	✓	✓	✓	✓
Handling asbestos-containing building materials during firefighting or other disaster response activities fugitive [b]	COU: Construction, paint, electrical, and metal products COU: Furnishing, cleaning, treatment care products	✓	✓	✓	✓	✓	✓	✓	✓

[a] The lifetime cancer risk exposure duration is 20 years which is the number of years residents are assumed to reside in a single residential location for stationary OES. The exposure starting age is zero (birth) to consider highly exposed and sensitive population. The Averaging time for exposure years is 78 years representing the number of years an individual is assumed to live (*Exposure Factors Handbook*, (U.S. EPA, 2011)).
[b] The lifetime cancer risk exposure duration is 1 year for non-stationary OES which is the smallest available IUR value.
Comparison matrix results: Red "x" are those that one ELCR result exceeds the benchmark while the other does not, check marks are both IUR ELCR estimates are either above or below the benchmark.

Appendix N GENERAL POPULATION

The general population exposure concentrations and inhalation lifetime cancer risk are calculated using Equation_Apx N-1 and Equation_Apx N-2. Lifetime cancer and non-cancer chronic risk estimates are available in *Asbestos Part 2 RE - Risk Calculator for Consumer - November 2024* (U.S. EPA, 2023c) (see Appendix C).

Equation_Apx N-1. Equation to Calculate Excess Lifetime Cancer Risk

$$ELCR = EPC \times IF \times TWF \times IUR_{Lifetime\ or\ LTL}$$

Where:

ELCR	=	Excess Lifetime Cancer Risk, the risk of developing cancer as a consequence of the site-related exposure
EPC	=	Exposure Point Concentration, the concentration of asbestos fibers in air (f/cc) for the specific activity being assessed
IF	=	Infiltration factor, 0.5
$IUR_{Lifetime\ or\ LTL}$	=	Inhalation Unit Risk per f/cc for Lifetime or Less-Than-Lifetime (LTL). Various LTL IUR values were used, $IUR_{(0,1)}$, $IUR_{(0,20)}$, $IUR_{(20,30)}$, and $IUR_{Lifetime}$ ($IUR_{(0,78)}$)
TWF	=	Time Weighting Factor that accounts for less than continuous exposure during a 1-year exposure or a lifetime exposure

Equation_Apx N-2. Equation to Calculate TWF for Lifetime Cancer

$$TWF_{Lifetime\ or\ LTL} = \left[\frac{Exposure\ time\ (hr/day)}{24\ hours}\right] \times \left[\frac{Exposure\ frequency\ (day/yr)}{365\ days}\right]$$

Where:

Exposure time	=	15.8 hr/day for CT and LE and 23.8 hr/day for HE scenarios
Exposure frequency	=	365 day/yr.

The Exposure time parameters were taken from EPA's *Exposure Factors Handbook* (U.S. EPA, 2011), Table 16-1, using the 18 to 65 group age indoor spending time value provided in that table. The mean was used for central (CT) and low-end (LE) tendency scenarios, and 95th percentile was used for the high-end (LE) tendency scenarios. EPA assumes the general population scenario is for indoor exposures for people living at certain distance from the asbestos releases. In addition, EPA assumes the inside asbestos concentration is the same as outside. An infiltration factor can be used, but generally these can be influenced by air change rates, window opening behaviors, ventilation systems, house cleaning behaviors among other factors that would result in high variability and uncertainty. Assuming the concentration inside and outside are the same will result in overestimation of risk, but it will also represent the high exposure populations.

The non-cancer chronic risk, also known as the MOE, is calculated via Equation_Apx N-3.

Equation_Apx N-3. Equation to Calculate Non-cancer Chronic Margin of Exposure

$$MOE_{\ Non-Cancer\ Chronic} = \frac{Point\ of\ Departure\ (POD)}{Non-Cancer\ Chronic\ Exposure\ Concentration}$$

The POD is discussed in Section 5.2.2.1. The non-cancer chronic ambient air inhalation exposure concentration is calculated using the concentration from the AERMOD modeling efforts described in Section 3.3.1.3, Table 3-11, and using Equation_Apx N-4.

Equation_Apx N-4. Equation to Calculate Non-cancer Chronic Concentration (NCCC) for Ambient Air Inhalation Pathway

$$NCCC = Ambient\ Air\ Conc \times IF \times \frac{Exp\ time}{24\ hr} \times \frac{Exp\ freq}{365\ day} \times \frac{ED}{AT}$$

Where:

NCCC	=	Non-cancer chronic concentration for general population ambient air inhalation pathway
Ambient Air Conc	=	AERMOD modeled concentration for ambient air in Section 3.3.1.3 and Table 3-11
IF	=	Infiltration factor, 0.5
Exp time	=	Exposure time in hours per day is equal to 15.8 hr/day for CT and 23.8 hr/day for HE
Exp freq	=	Exposure frequency in days per year equal to 365 day/yr
ED	=	Exposure duration, 1, 20, 30, and 78 years, short duration activities/releases, children residential duration, adult residential duration, and lifetime exposures, respectively
AT	=	Averaging time for exposure years is 78 years representing the number of years a person is assumed to live (U.S. EPA, 2011).

The first three terms in Equation_Apx N-4 are the concentrations summarized in Section 3.3.1.3, Table 3-11, and the $TWF_{\text{Lifetime or LTL}}$ used for the calculation of ELCR. The only difference is the ED and AT terms which are not in the calculation of ELCR because these are already included in the calculation of IURs.

Additional exposure durations (ED) and less-than-lifetime (LTL) IUR lifetime cancer and non-cancer chronic risk estimates were calculated to compare risk estimates. Table_Apx N-1 and Table_Apx N-2 summarize the comparison of lifetime cancer (ELCR) risk estimates with multiple LTL IUR values, and non-cancer chronic (MOE) risk estimates with multiple ED values, respectively.

ED and LTL IUR (0,20) considers exposures starting at birth and ending at 20 years of age and carrying it throughout a person's entire lifespan, 78 years. Twenty years is an expert opinion and assumption when most children move from their childhood residences. ED and LTR (20,30) considers exposures starting at 20 years and ending 30 years later (50) and following no exposure to the end of a person's entire lifespan, 78 years. This (20,30) scenario considers young and mature adults that move out of their childhood residence and remain in their next residence for 30 years. The lifetime (0,78) considers people that remain at their childhood residence throughout their entire lifespan, 78 years.

Table_Apx N-1. Lifetime Cancer Risk Estimate Comparison for Various LTL IUR Values

LE/ CT/ HE	Distance from Release Source (m)	ELCR Using IUR (0,20)		ELCR Using IUR (20,30)		ELCR Using IUR (Lifetime (0, 78)	
		Waste Handling	Handling Articles and Formulations	Waste Handling	Handling Articles and Formulations	Waste Handling	Handling Articles and Formulations
LE	10	1.3E−04	2.0E−05	7.7E−05	1.2E−05	2.6E−04	4.1E−05
	30	1.7E−05	1.4E−05	1.0E−05	8.2E−06	3.4E−05	2.7E−05
	60	3.4E−06	1.3E−05	2.0E−06	7.8E−06	6.8E−06	2.6E−05
	100	9.4E−07	1.2E−05	5.6E−07	7.3E−06	1.9E−06	2.4E−05
CT	10	3.0E−04	3.0E−05	1.8E−04	1.8E−05	6.0E−04	6.0E−05
	30	5.1E−05	1.6E−05	3.1E−05	9.4E−06	1.0E−04	3.1E−05
	60	1.2E−05	1.3E−05	7.0E−06	8.1E−06	2.3E−05	2.7E−05
	100	3.5E−06	1.3E−05	2.1E−06	7.7E−06	6.9E−06	2.6E−05
HE	10	8.6E−04	8.2E−05	5.2E−04	4.9E−05	1.7E−03	1.6E−04
	30	1.8E−04	3.2E−05	1.1E−04	1.9E−05	3.6E−04	6.3E−05
	60	4.4E−05	2.2E−05	2.7E−05	1.3E−05	8.8E−05	4.5E−05
	100	1.4E−05	2.1E−05	8.1E−06	1.2E−05	2.7E−05	4.1E−05
Highlighted cells indicate benchmark exceedances, ELCR benchmark = 1E−06 to 1E−04							

Table_Apx N-2. Non-cancer Chronic Risk Estimate Comparison for Various ED Values

LE/ CT/ HE	Distance from Release Source (m)	ELCR Using IUR (0,20)		ELCR Using IUR (20,30)		ELCR Using IUR (Lifetime (0, 78)	
		Waste Handling	Handling Articles and Formulations	Waste Handling	Handling Articles and Formulations	Waste Handling	Handling Articles and Formulations
LE	10	79	498	53	332	79	498
	30	604	740	403	493	604	740
	60	2,992	785	1,995	523	2,992	785
	100	10,791	829	7,194	553	10,791	829
CT	10	34	337	23	225	34	337
	30	199	650	133	433	199	650
	60	865	756	576	504	865	756
	100	2,918	795	1,946	530	2,918	795
HE	10	12	123	8	82	12	123
	30	57	320	38	214	57	320
	60	229	453	153	302	229	453
	100	751	494	500	329	751	494
Highlights cells indicate benchmark exceedances, MOE benchmark = 300							

Appendix O AGGREGATE ANALYSIS

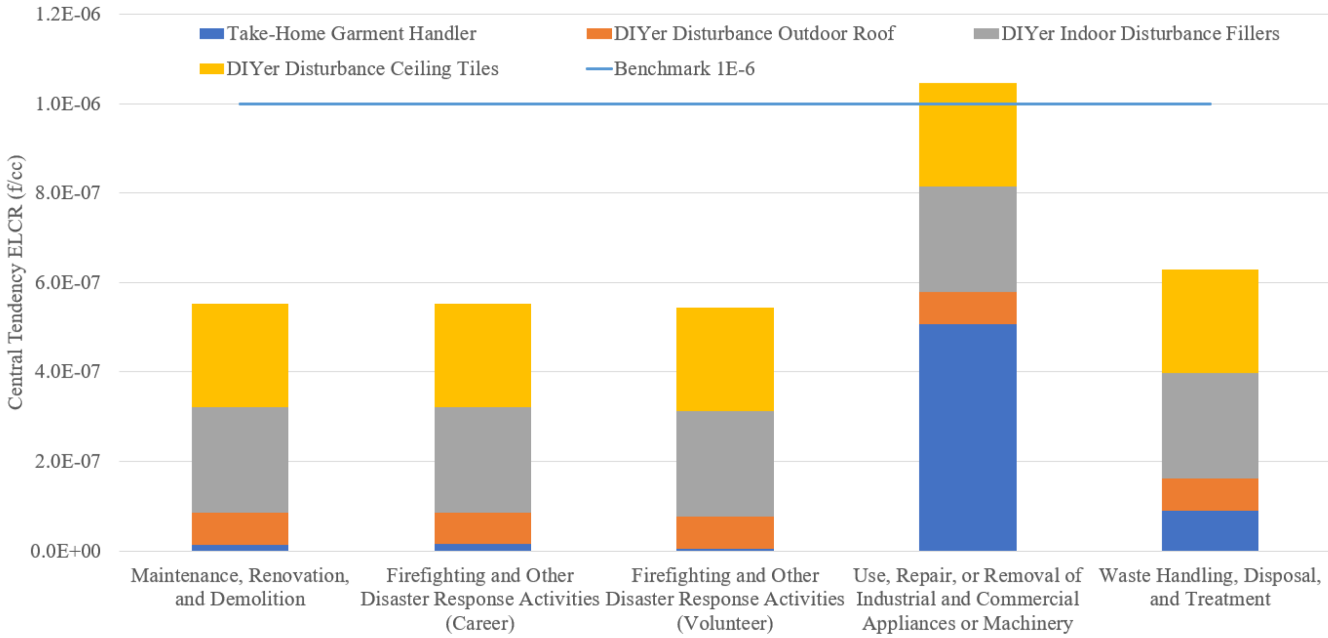
Section 6.1.1 describes the approach to aggregate exposures in the Part 2 Risk Evaluation of Asbestos. As described in Section 5.1, EPA considered sentinel exposures by considering risks to populations who may have upper bound exposures; for example, workers and ONUs who perform activities with higher exposure potential, or consumers who have higher exposure potential (*e.g.*, those involved with DIY projects). EPA characterized high-end exposures in evaluating exposure using both monitoring data and modeling approaches. Where statistical data are reasonably available, EPA typically uses the 95th percentile value of the reasonably available data set to characterize high-end exposure for a given condition of use. For consumer and bystander exposures, EPA characterized sentinel exposure through a "high-intensity use" category based on both product and user-specific factors. In cases where sentinel exposures result in MOEs or ELCRs greater than the benchmark or cancer risk lower than the benchmark (*i.e.*, risks were not identified), EPA did no further analysis because sentinel exposures represent the highly exposed. The aggregate analysis across exposure scenarios and COUs figures and summaries are available in *Asbestos Part 2 RE - Aggregate Analysis - November 2024* (U.S. EPA, 2023a) (see Appendix C).

This analysis only aggregates individual risk estimates from scenarios that were not above the benchmark and assumes the possibility of people engaging in the scenario activities being aggregated. In addition, EPA aims to identify not random combinations but within the central tendency (CT) and high-end (HE) tendencies what kind and number of non-occupational and occupational activities are needed in the aggregation to exceed benchmarks.

Lifetime Cancer Risk Aggregate Analysis across Exposure Scenarios

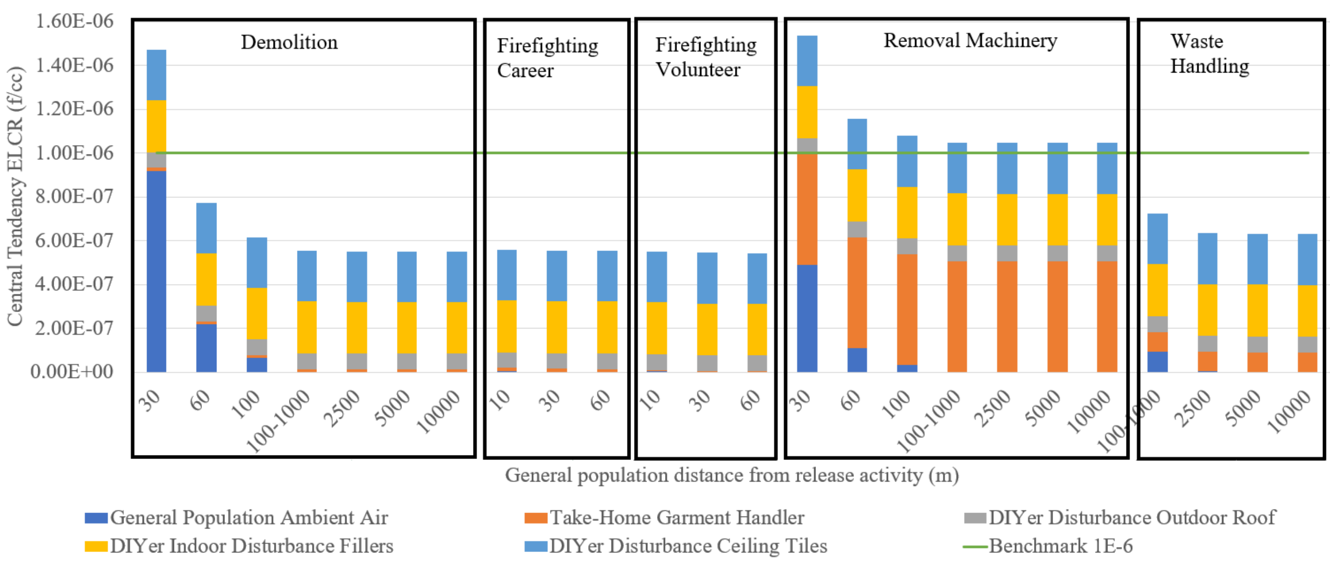
A worker may be involved in multiple activities aside from their work requirements that exposes them to asbestos that have varying occupational exposures. DIYers may perform multiple projects that release and exposes them to asbestos fibers. Take-home exposures can occur to workers and DIYers as they handle asbestos-contaminated clothing and do non-occupational renovation activities. Higher-exposure workers 8-hour TWA lifetime cancer risk values (ELCR) are above the benchmark for a few scenarios for the HE and CT tendencies, which are not used in the aggregate analysis, see Table 5-21. EPA only aggregated across scenarios if the ELCR values for each scenario are below the consumer DIYer benchmark (1×10^{-6} f/cc).

Because very few HE ELCR values can be used in this aggregate analysis, EPA shows some examples of aggregation across scenarios for CT ELCR values in Figure_Apx O-1. EPA used unique parts of the OES labels and the general population distance from the release activity (source of the release) to fit the figure. The OES can then be linked to the COUs in the discussion below each figure.



Figure_Apx O-1. Central Tendency Lifetime Cancer Risk Aggregation across Take-Home and DIY Scenarios

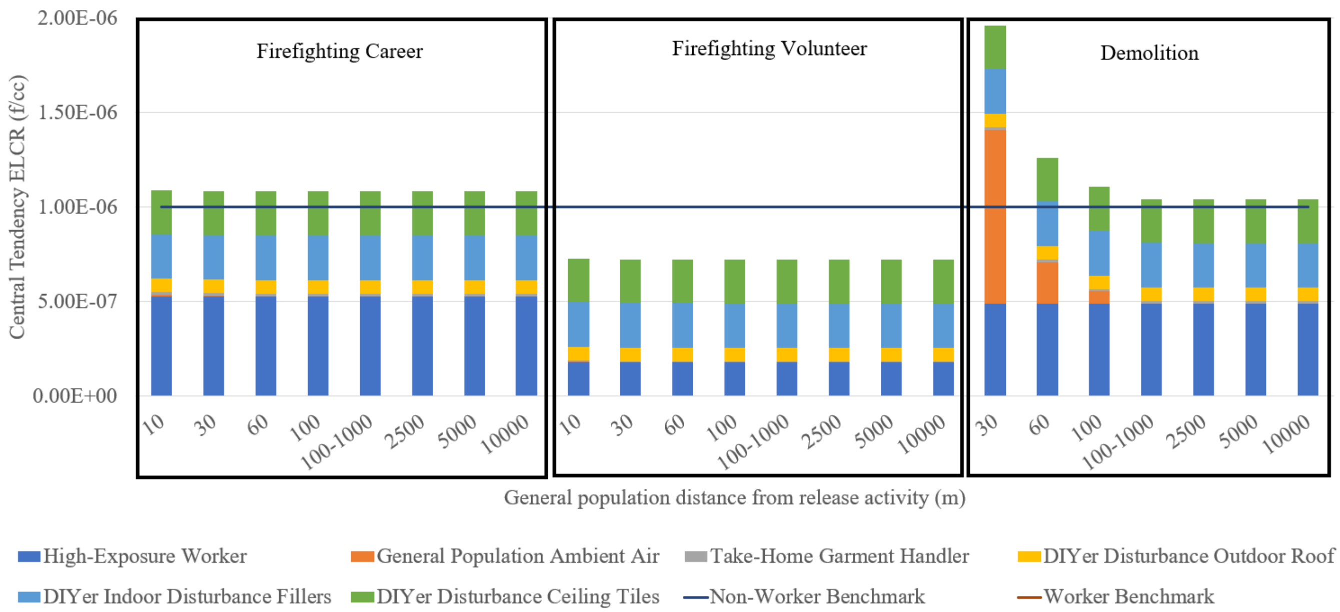
Figure_Apx O-1 shows the combined CT ELCR risks (vertical axis) for take-home exposures resulting from various occupational activities (horizontal axis and blue bar) and those same people doing DIY activities (non-blue bars). The DIY activities used in this aggregation are related to disturbance of asbestos materials, such as sanding, cutting, moving, because activities related to removing or demolishing asbestos were already above the risk benchmark on their own. People exposed to take-home removal/repair of appliances/machinery exposures combined with DIY activities related to the disturbance of products result in over the risk benchmark for lifetime cancer risk.



Figure_Apx O-2. Central Tendency Lifetime Cancer Risk Aggregation across Take-Home, DIYers, and General Population Risks to Occupational Activities Releases to Ambient Air Scenarios

Figure_Apx O-2 shows the combined CT ELCR (vertical axis) values for people living at a distance from various occupational activity releases (horizontal axis and blue bars) as well as those same people doing DIY activities (lighter blue bars) and exposures from take-home (orange bars). This aggregate analysis builds upon Figure_Apx O-1 analysis adding general population to it. This aggregate scenario aims to show all non-occupational populations and which activities drive the aggregation to above the following benchmark values:

- People living within 30 m from demolition activities, performing DIY activities, and handling contaminated garments from demolition activities may have aggregate risks of concern the closer they are to the activity (see demolition box in Figure_Apx O-1).
- People performing removal/maintenance of machinery/appliances activities, DIY activities, and handling contaminated garments (from removal machinery activities) may have aggregate risks of concern (see removal machinery box in figure) and increase risk probabilities by proximity to the activity.



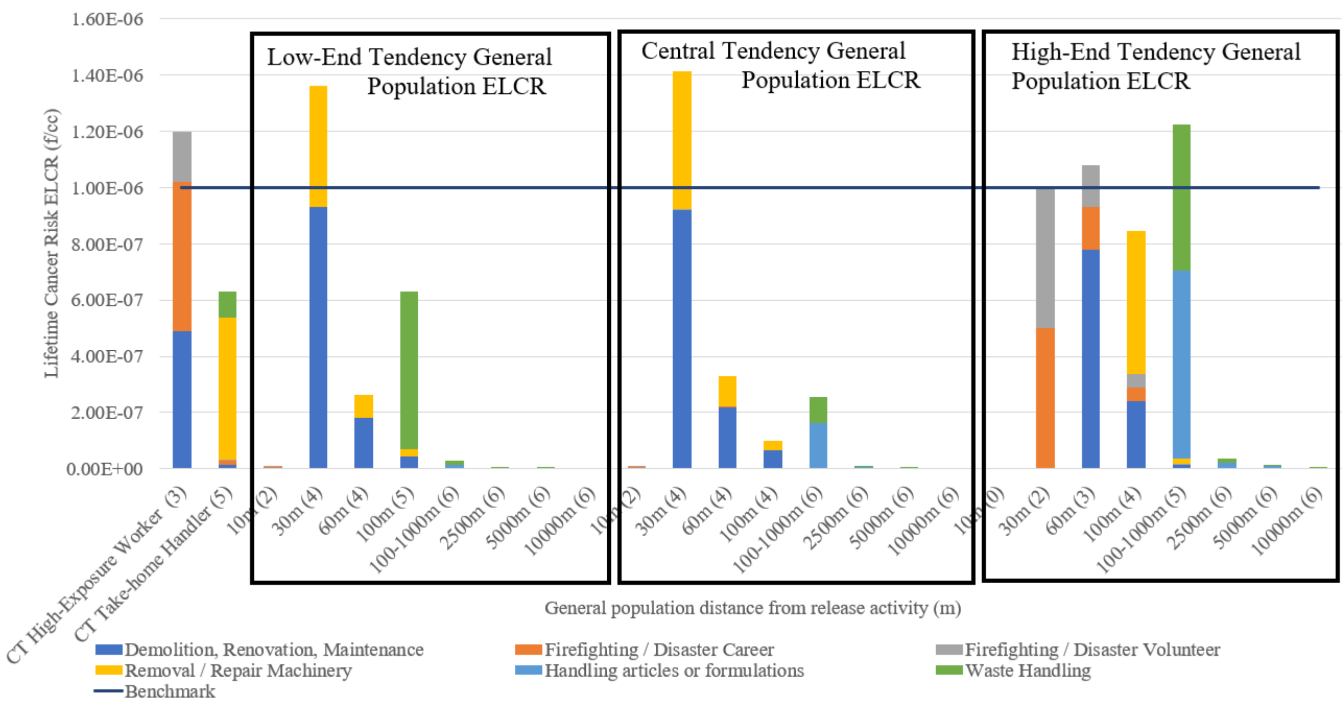
Figure_Apx O-3. Central Tendency Lifetime Cancer Risk Aggregation across Workers, Take-Home, DIYers, and General Population Risks to Occupational Activities Releases to Ambient Air Scenarios

Figure_Apx O-3 shows the combined CT ELCR (vertical axis) values for people living at a distance from various occupational activity releases (horizontal axis), workers (dark blue bars) and those same people doing DIY activities (non-dark blue bars) and exposures from take-home (gray bars, not visible). This aggregate analysis builds upon Figure_Apx O-2 analysis adding worker to it. This aggregate analysis aims to show occupational and non-occupational populations and which activities drive the aggregation to above the following benchmark values:

- Most of the scenarios are driven to above benchmark values by worker and DIY activities related to disturbance of fillers and ceiling tiles containing asbestos.
- Exposure from demolition/renovation/maintenance activities to the general population living within 60 m from the activity are also significant contributors to the overall aggregate risk.
- When combined with DIYer activities like disturbance of fillers or ceiling tiles it puts the scenario over the risk benchmark for lifetime cancer considerations.

Lifetime Cancer Risk Aggregate Analysis across COUs

Figure_Apx O-4 shows aggregation across COUs for LE, CT, and HE ELCR values (boxes in figure) and people living at a distance from an occupational activity release (horizontal axis within boxes) and high-exposure workers and CT take-home (outside boxes). EPA did not include DIYers in this aggregation because only a few scenarios were below the risk benchmark for HE, CT, and LE tendencies and all are from the same COU. Aggregation of DIY lifetime risks is available in aggregation across scenarios in Figure_Apx O-1. Each of the scenarios has a number in parentheses representing the number of OESs in the aggregation that were not individually above the risk benchmark. A total of six OESs can be aggregated. Activities that drive the aggregation above the benchmark are related to workers performing activities related to demolitions, maintenance, renovations and firefighting or other disasters, see LE, CT, and HE boxes with various bars close or above the benchmark line.



Figure_Apx O-4. Lifetime Cancer Risk Aggregation across COUs for General Population, Take-Home Exposures and High-Exposure Workers

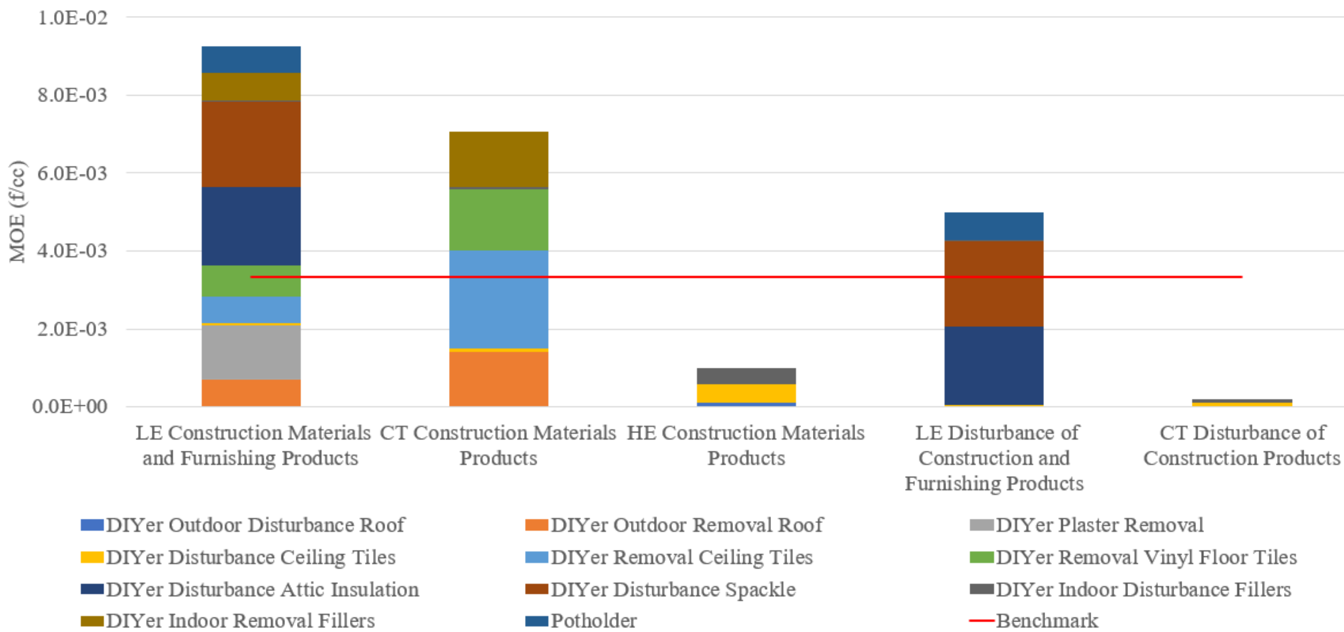
Parenthesis in the horizontal axis are the number of COUs in the specific aggregation scenario. There are a total of six (6) COUs if not included in the aggregation the COU exceeded the benchmark before aggregation.

Non-cancer Chronic Risk Aggregate Analysis Across Scenarios

Figure_Apx O-5 shows the combined LE, CT, and HE non-cancer chronic risks (vertical axis) for DIYers only. This aggregate analysis assumes that a DIYer in their lifetime can perform multiple projects that are captured in the DIY aggregate scenario. The first three bars combine all DIY activities that are individually under the benchmark for construction materials COU only, excluding potholders which belong to the furnitureproducts COU last two bars.

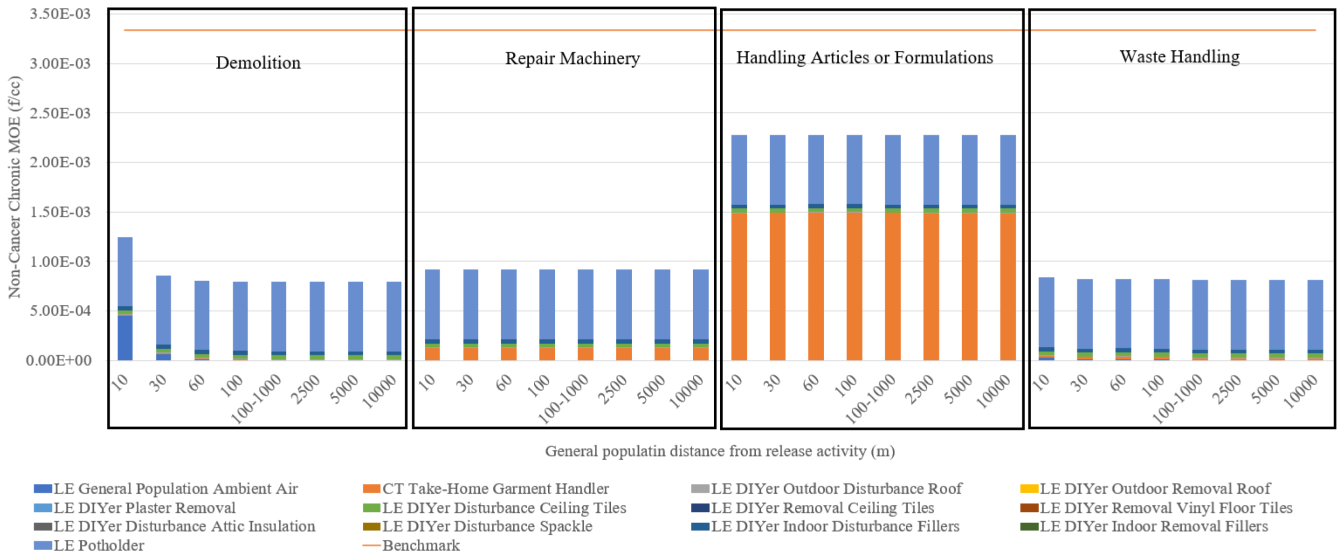
- The majority of the high-end DIY scenarios resulted in MOE values over the benchmark and are not used in the aggregation so very few activities are aggregated in the third bar. Only three high-end DIYer activities are used in this aggregation because they are individually below the risk benchmark and correspond to disturbance of products rather than removal activities (third bar in figure).

- All activities related to removal of a product when aggregated resulted in individual activities over the risk benchmark (not shown in figure). If all product removal activities are taken out of the aggregation and only disturbance (cutting, sanding, moving) of product are left, the results show aggregated risk for disturbance of insulation and spackle (LE disturbance of construction and furnishing products bar in figure).
- An only DIYer aggregate analysis for all DIY scenarios under the MOE benchmark shows that for a DIYer that performs all activities at the low-end tendency will result in over the benchmark risks (first bar in figure).



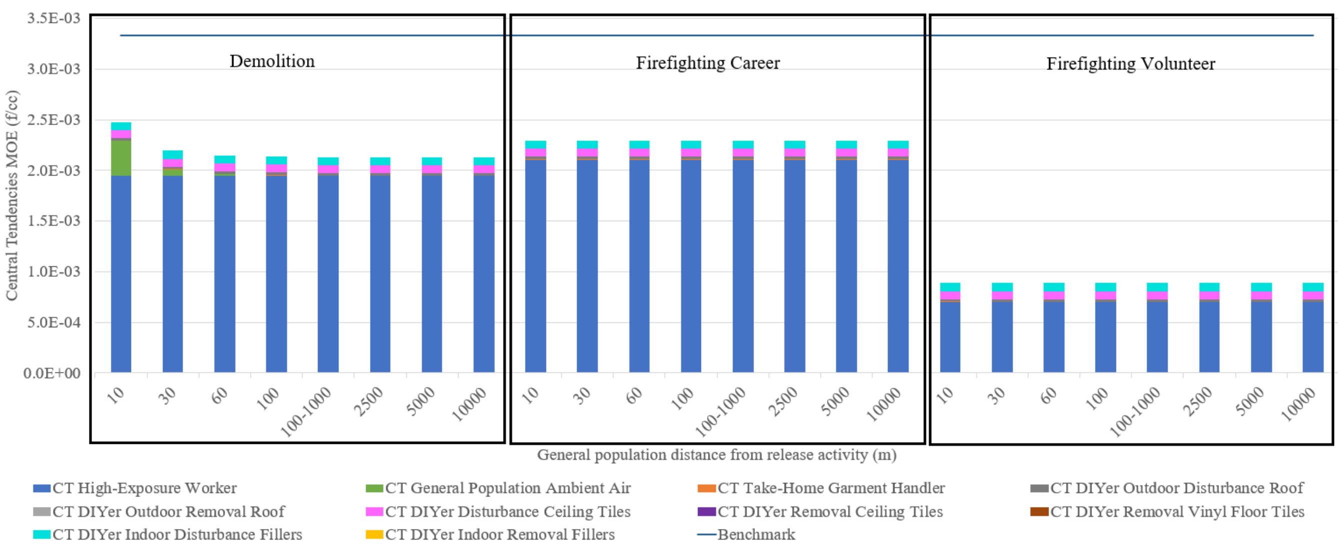
Figure_Apx O-5. Non-cancer Chronic Risk Aggregate across DIY Activities

Figure_Apx O-6 shows the combined CT and LE non-cancer chronic risks for people living at a distance from an occupational release activity (horizontal axis and boxes in figure), take-home (orange bar) and DIYers (all other bars). The HE MOE values for most of the individual activities considered and the exposed populations were above the benchmark and hence not used. When calculating aggregate risk for DIYers, EPA included only the disturbance of product DIY activities which are the only ones that do not individually exceed the risk benchmark. None of the aggregated activities resulted in exceedances over the benchmarks,indicating that it likely requires HE tendencies to result in non-cancer chronic risks.



Figure_Apx O-6. Non-cancer Chronic Aggregate Risk across CT Scenarios for Take-Home, LE DIYers, and LE General Population Risk to Occupational Activities Releases to Ambient Air

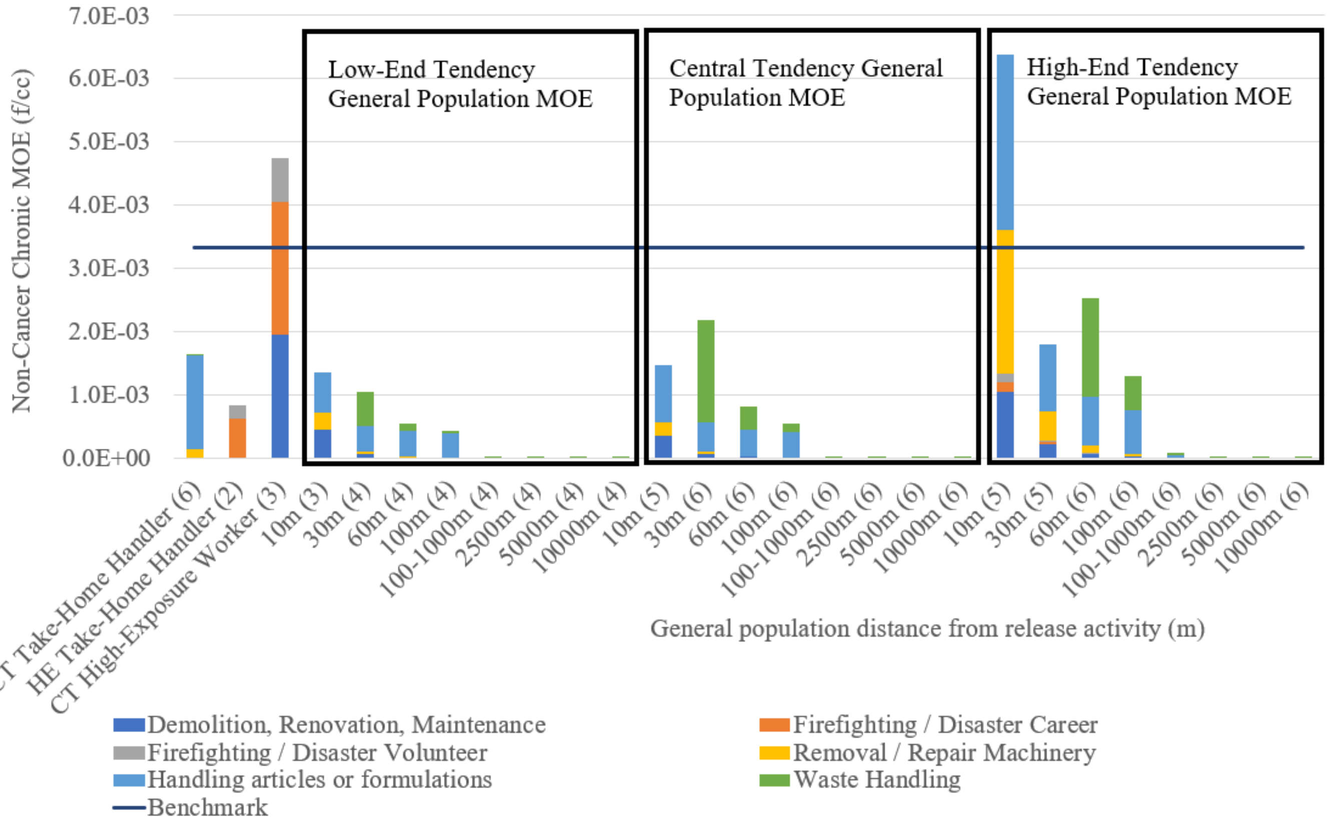
Figure_Apx O-7 shows the combined CT non-cancer chronic risks for people living at a distance from an occupational release activity (horizontal axis and boxes in figure), workers (dark blue bar), take-home (orange bar), and DIYers (all other bars). This scenario build upon Figure_Apx O-6 aggregation scenario approach while adding workers. None of the aggregated activities resulted in exceedances over the benchmark risks indicating that it likely requires HE tendencies to result in non-cancer chronic risks.



Figure_Apx O-7. Central Tendency Non-cancer Chronic Aggregate Risk across Scenarios for Workers, Take-Home, DIYers, and General Population Risk to Occupational Activities Releases to Ambient Air

Non-cancer, Chronic Risk Aggregate Analysis across COUs

Figure_Apx O-8 shows the non-cancer chronic risk aggregate results for general population, higher-exposure workers, and take-home exposures LE, CT, and HE tendencies. There are a total of six OESs that can be aggregated and each of the scenarios (bars in figure) has a number in parenthesis representing the number of OESs in the aggregation that were not individually above the risk benchmark. People living 10 m distance aggregate scenario was done with five of the six OESs, only missing the waste handling COU/OES because it was above the risk benchmark. The CT worker aggregate scenario was done with three of the six OES missing waste handling, removal/repair of machinery, and handling of articles or formulations which were all above the risk benchmark on their own. The aggregation of worker COUs is above the general population benchmark, 1×10^{-6} to $1\text{x}10^{-4}$ f/cc, but not the occupational benchmark, 1×10^{-4} f/cc (not shown in the figure because it would be off the scale). All activities at the HE tendency at the closest distance from occupational releases would be needed to drive the MOE values over the benchmark as shown by the HE tendency box (third box first bar).



Figure_Apx O-8. Non-cancer, Chronic Risk Aggregation across COUs for General Population, Take-Home Exposures, and High-Exposure Workers

Parentheses in the horizontal axis are the number of COUs in the specific aggregation scenario. There are a total of six COUs if not included in the aggregation the COU exceeded the benchmark before aggregation.

Appendix P OCCUPATIONAL EXPOSURE VALUE DERIVATION AND ANALYTICAL METHODS USED TO DETECT ASBESTOS

EPA has calculated a 8-hour existing chemical occupational exposure value to reflect the occupational exposure scenarios and sensitive health endpoints into a single value. This calculated value may be used in support of risk management efforts on asbestos under TSCA section 6(a), 15 U.S.C. 2605. EPA calculated the value to be 0.004 fibers/cc for inhalation exposures to asbestos as an 8-hour time-weighted average (TWA) and for use in workplace settings (see Appendix P.1) based on the lifetime cancer inhalation unit risk (IUR) for lung cancer, mesothelioma, and other cancers.

TSCA requires risk evaluations to be conducted without consideration of cost and other non-risk factors, and thus this occupational exposure value represents a risk-only number. If additional risk management for asbestos follows the final Part 2 Risk Evaluation for Asbestos, EPA may consider cost and other non-risk factors, such as technological feasibility, the availability of alternatives, and the potential for critical or essential uses. Any existing chemical exposure limit (ECEL) used for occupational safety risk management purposes could differ from the occupational exposure value presented in this appendix based on additional consideration of exposures and non-risk factors consistent with TSCA section 6(c).

EPA expects that at the lifetime cancer occupational exposure value of 0.004 f/cc an employee also would be protected against health effects resulting from chronic, non-cancer occupational exposures. In addition, this value would protect against excess risk of cancer above the 1×10^{-4} benchmark value resulting from lifetime exposure if ambient exposures are kept below this value.

Of the identified occupational monitoring data for asbestos, there have been measured workplace air concentrations below the calculated occupational exposure value. A summary table of available monitoring methods from the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), and EPA are included below in Appendix P.2. The table covers validated methods from governmental agencies and is not intended to be a comprehensive list of available air monitoring methods for asbestos. The occupational exposure value is above the limit of detection (LOD) and limit of quantification (LOQ) using at least one of the monitoring methods identified.

For context, OSHA set a permissible exposure limit (PEL) as an 8-hour TWA for asbestos of 0.1 f/cc (https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1000TABLEZ2). However, as noted on OSHA's website, "OSHA recognizes that many of its permissible exposure limits (PELs) are outdated and inadequate for ensuring protection of worker health. Most of OSHA's PELs were issued shortly after adoption of the Occupational Safety and Health Act in 1970 and have not been updated since that time." EPA's calculated occupational exposure value is a lower value and is based on newer information and analysis from this risk evaluation. In addition, OSHA's PEL must undergo both risk assessment and feasibility assessment analyses before selecting a level that will substantially reduce risk under the Occupational Safety and Health Act.

P.1 Occupational Exposure Value Calculations

This section presents the calculations used to estimate the occupational exposure value using inputs derived in this risk evaluation.

Lifetime Cancer Occupational Exposure Value

The EV_{cancer} is the concentration at which the extra cancer risk is equivalent to the benchmark cancer risk of 1×10^{-4} per Equation_Apx P-1,

Equation_Apx P-1.

$$EV_{cancer} = \frac{Benchmark_{Cancer}}{IUR_{(16,40)}} * \frac{AT_{IUR}}{ED * EF * V_{worker}}$$

$$= \frac{1X10^{-4}}{0.08\, per\, \frac{fiber}{cc}} * \frac{24\frac{h}{d} * \frac{365d}{y}}{8\frac{h}{d} * \frac{250d}{y} * 1.5} = 0.004\, fiber/cc$$

Where:

AT_{IUR}	=	Averaging time for the cancer IUR, based on study conditions and any adjustments (24 hr/day for 365 days/yr) (Supplemental File: Releases and Occupational Exposure Assessment; see Appendix C).
EV_{cancer}	=	Exposure limit based on excess cancer risk (1×10^{-4})
ED	=	Exposure duration (8 hr/day) (see Section G.5.4)
EF	=	Exposure frequency (250 days/yr), (see Section G.5.4)
$IUR_{(16,40)}$	=	Partial lifetime inhalation unit risk (0.08 per fiber/cc) for 40-year exposure starting at age 16 (see Appendix M)
V_{worker}	=	Volumetric adjustment factor for workers (1.5) (see Appendix G.5.4)

P.2 Summary of Air Sampling Analytical Methods Identified

EPA conducted a search to identify relevant NIOSH, OSHA, and EPA analytical methods used to monitor for the presence of asbestos in air (see Table_Apx P-1). This table covers validated methods from governmental agencies and is not intended to be a comprehensive list of available air monitoring methods for asbestos. The sources used for the search included the following:

1. NIOSH Manual of Analytical Methods (NMAM); 5th Edition
2. NIOSH NMAM 4th Edition
3. OSHA Index of Sampling and Analytical Methods
4. EPA Environmental Test Method and Monitoring Information

Table_Apx P-1. Limit of Detection (LOD) and Limit of Quantification (LOQ) Summary for Air Sampling Analytical Methods Identified

Air Sampling Analytical Method	Year Published	LOD	LOQ	Notes	Source
NIOSH Method 7400: ASBESTOS and OTHER FIBERS by PCM	2019	0.00675 fibers/cc	0.10 fibers/cc	Appendix E of method includes a table that calculates an LOD and LOQ assuming a 400 L air sample	[NIOSH Manual of Analytical Methods (NMAM 7400)]
NIOSH Method 7402: Asbestos by TEM	2022	One confirmed asbestos fiber above 95% of expected mean blank value	N/A	The LOD depends upon sample volume and quantity of interfering dust and is <0.01 fiber/cc for atmospheres free of interferences; method is used in conjunction with NIOSH Method 7400	[NIOSH Manual of Analytical Methods (NMAM 7402)]
OSHA ID-160: Asbestos in Air	1997	0.001 fibers/cc	Not reported	LOD assumes a sample volume of 2,400 L	[OSHA Salt Lake Technical Center OSHA ID-160]