

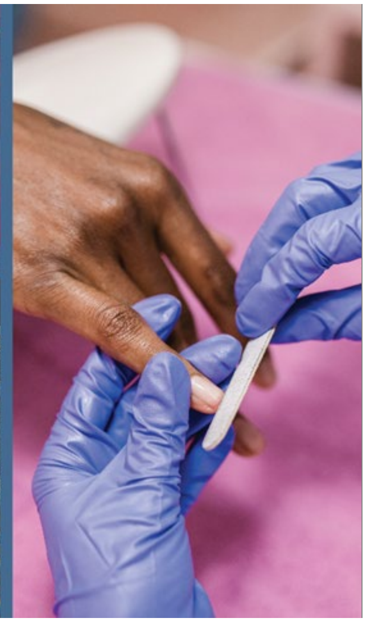

Technical Supporting Documentation for Priority Products

Safer Products for Washington
Cycle 2 Implementation Phase 2

Hazardous Waste and Toxics Reduction Program

Washington State Department of Ecology

Olympia, Washington

June 2025 | Publication 25-04-031

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State of Washington

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Related information

This publication is the technical companion to the Identification of Priority Products Report to the Legislature: Safer Products for Washington Cycle 2, Phase 2.[1]

Additional related documents include:

Safer Products for Washington Cycle 2

- Cycle 2, Phase 1: Report to the Legislature on Priority Chemicals[2]
- Cycle 2, Phase 1: Technical Supporting Documentation for Priority Chemicals[3]

Safer Products for Washington Cycle 1.5

- Cycle 1.5, Phase 3: Regulatory Determinations Report to the Legislature[4]
- Cycle 1.5, Phase 3: Technical Supporting Documentation for Regulatory Determinations[5]
- Cycle 1.5, Phase 4: Rulemaking[6]

Safer Products for Washington Cycle 1

- Cycle 1, Phase 2: Report to the Legislature on Priority Consumer Products [7]
- Cycle 1, Phase 3: Final Report to the Legislature on Regulatory Determinations[8]
- Cycle 1, Phase 4: Chapter 173-337-WAC—Safer Products Restriction and Reporting[9]
- Cycle 1, Phase 4: Concise Explanatory Statement[10]
- Cycle 1, Phase 4: Rulemaking webpage[11]

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[1]apps.ecology.wa.gov/publications/summarypages/2504030.html
[2]apps.ecology.wa.gov/publications/summarypages/2404025.html
[3]apps.ecology.wa.gov/publications/summarypages/2404026.html
[4]apps.ecology.wa.gov/publications/summarypages/2404023.html
[5]apps.ecology.wa.gov/publications/summarypages/2404024.html
[6]ecology.wa.gov/regulations-permits/laws-rules-rulemaking/rulemaking/wac-173-337-nov2023
[7]apps.ecology.wa.gov/publications/summarypages/2004019.html
[8]apps.ecology.wa.gov/publications/summarypages/2204018.html
[9]app.leg.wa.gov/wac/default.aspx?cite=173-337
[10]apps.ecology.wa.gov/publications/summarypages/2304033.html
[11]ecology.wa.gov/regulations-permits/laws-rules-rulemaking/closed-rulemaking/wac-173-337-may2023

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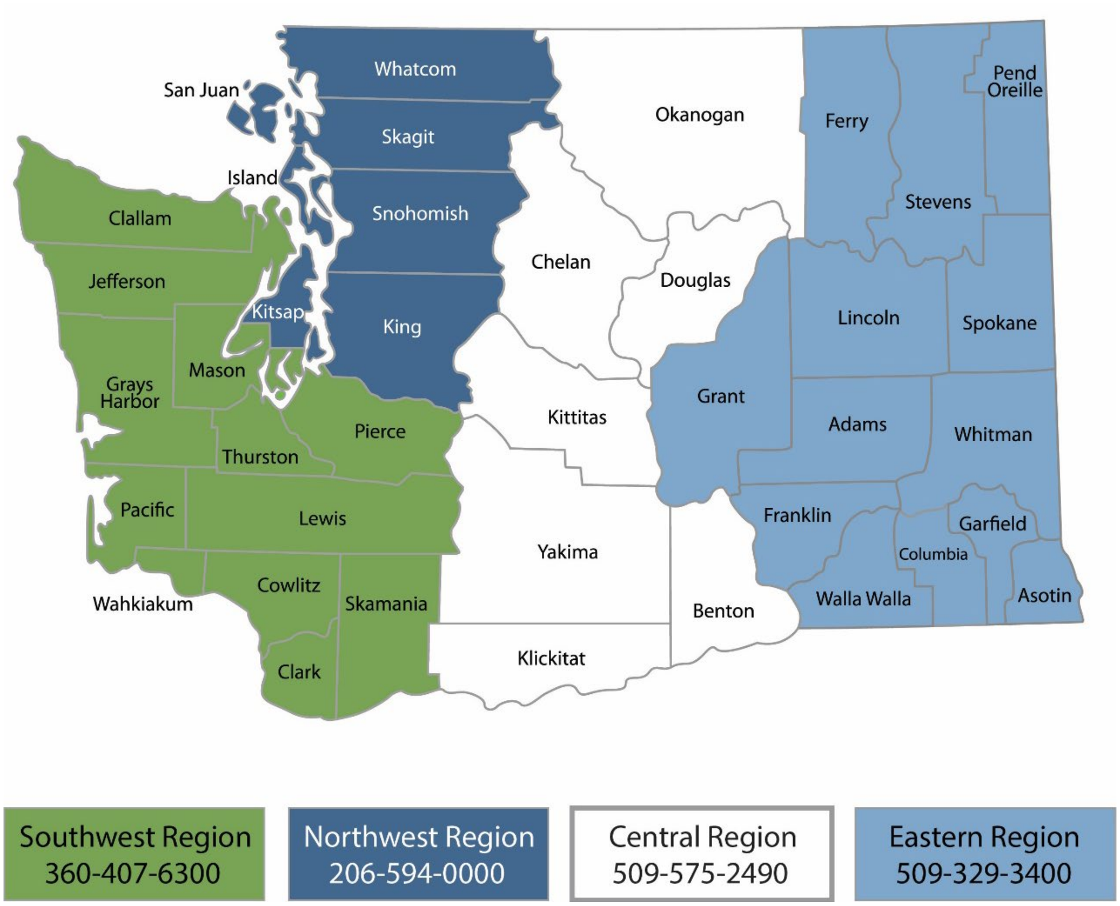

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Table of Contents

List of Figures and Tables

Figures

Tables

Executive Summary

This publication is the technical companion to the Priority Products Report to the Legislature: Safer Products for Washington Cycle 2, Phase 2.[14]

In 2019, the Washington State Legislature directed the Washington State Department of Ecology (Ecology, we), in consultation with the Department of Health, to implement a regulatory program to reduce toxic chemicals in consumer products (Chapter 70A.350 RCW).[15] The implementation program for this statute is called Safer Products for Washington.

Safer Products for Washington is a four-phase process that repeats every five years (Figure 1). The first review cycle took place from 2019 to 2023 and reviewed six priority chemical classes in 11 categories of priority consumer products.

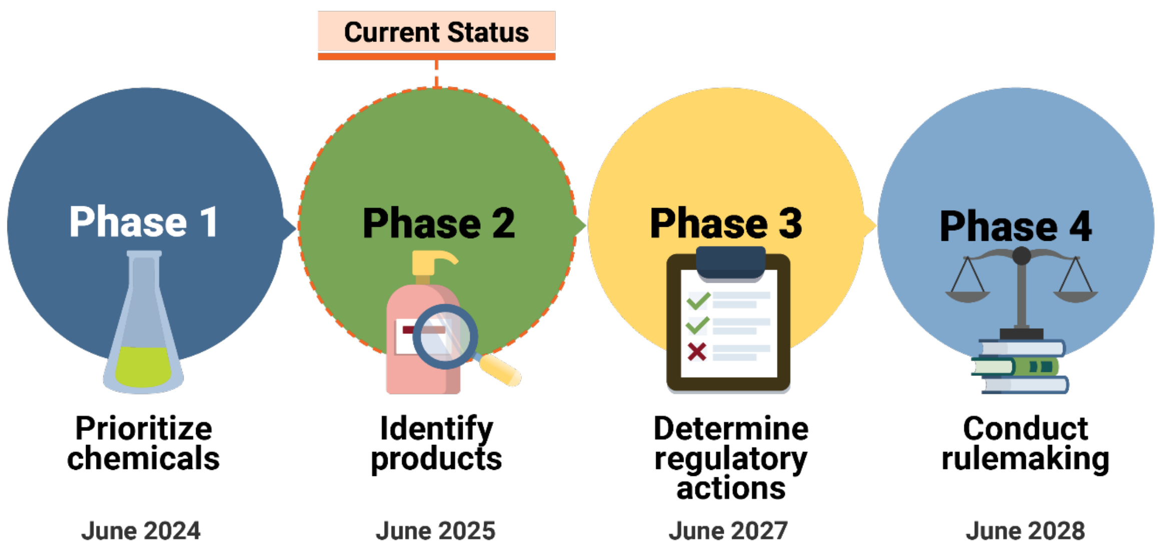

Figure 1: The four phases of a Safer Products for Washington implementation cycle, including the statutory deadlines for completing each phase of cycle 2.

We're currently working on the second review cycle. In May 2024, we published Safer Products for Washington Cycle 2 Implementation Phase 1: Report to the Legislature on Priority Chemicals,[16] which identified seven new priority chemical classes. The second review cycle will focus on these chemicals, in addition to the priority chemical classes listed in RCW 70A.350.010(14) (Ecology, 2024b).[17]

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[14] apps.ecology.wa.gov/publications/summarypages/2504030.html
[15] app.leg.wa.gov/rcw/default.aspx?cite=70A.350
[16] apps.ecology.wa.gov/publications/summarypages/2404025.html
[17] app.leg.wa.gov/rcw/default.aspx?cite=70A.350.010

To identify priority consumer products (referred to as "priority products") for review in the second phase of this cycle, we narrowed our focus to products that are significant sources or uses of priority chemical classes. We considered how products may contribute to the potential for exposure to priority chemicals and chemical classes in sensitive populations and species.

This report summarizes the information and research Ecology relied on when identifying priority products for further review. Each category of consumer products has a separate chapter that provides:

- An overview of the product category
- Estimates of the volume of each for priority product-chemical combination sold in Washington
- Information about the potential for exposure to priority chemicals from the product
- Information about the availability of potential safer alternatives

An additional report chapter provides information about existing priority products—those addressed in prior Safer Products review cycles—that Ecology will continue to work on in this review.

The technical report also contains appendices:

- Detailing laws and legislation in other jurisdictions on consumer products containing priority chemicals
- Summarizing Washington's various regulations addressing toxics in consumer products
- Providing a citation list that identifies the peer-reviewed science, studies, reports, and other sources of information used to support our identification of priority consumer products

During the next phase of implementation, Ecology technical staff will conduct research on the use of priority chemicals in the listed categories of consumer products and consult with relevant manufacturers and other interested parties to determine whether safer alternatives are feasible and available. Based on that work, we will recommend draft regulatory actions based on additional research as well as input from affected parties and the public.

The statute sets out three types of regulatory actions Ecology, in consultation with Health, can recommend:

- Restrictions on the use of priority chemicals in a priority consumer product
- A requirement for manufacturers to report the use of priority chemicals in covered products
- No action at this time

Ecology will invite the public to comment on draft regulatory actions in late 2026. We must report recommended regulatory determinations to the Legislature by June 2027. This allows the Legislature an opportunity to amend the recommended regulatory actions before we adopt them in rule (Chapter 173-337 WAC).[18]

At the same time we develop the above draft regulatory action reports, Ecology will start a rulemaking in late 2026. We intend to invite public comment on the preliminary draft rule in the summer of 2027. In early 2028, Ecology expects to release the formal draft rule for public comment and host hearings for people to provide formal testimony. The law requires we adopt regulatory actions in rule by June 2028.

These efforts are in addition to our ongoing Safer Products for Washington work. Currently, Ecology is engaged in ongoing compliance support for the cycle 1 rules adopted on May 31, 2023 (Chapter 173-337 WAC).[19] Additional rulemaking[20] is also ongoing for PFAS in products identified in our Per-and Polyfluoroalkyl Substances Chemical Action Plan[21] and for firefighting personal protective equipment (PPE) as directed by RCW 70A.350.090.[22] We refer to this work as cycle 1.5. The deadline to adopt new rules for cycle 1.5 priority products is December 2025.

[18] app.leg.wa.gov/wac/default.aspx?cite=173-337
[19] app.leg.wa.gov/wac/default.aspx?cite=173-337
[20] ecology.wa.gov/regulations-permits/laws-rules-rulemaking/rulemaking/wac-173-337-nov2023
[21] apps.ecology.wa.gov/publications/summarypages/2104048.html
[22] app.leg.wa.gov/rcw/default.aspx?cite=70A.350.090

Introduction

Chapter 70A.350 RCW[23] directs Ecology, in consultation with the Department of Health (Health), to implement a regulatory program to reduce toxic chemicals in consumer products. This implementation program is called Safer Products for Washington and has four distinct phases:

1. Identification of priority chemicals and chemical classes of concern.
2. Identification of priority consumer products that are significant sources or uses of one or more priority chemicals.
3. Determination of needed regulatory actions.
4. Adoption of regulations to implement any needed restrictions or reporting requirements.

These phases are implemented over a repeating five-year cycle. For each of the first three phases in the cycle, Ecology must submit a report to the Legislature summarizing the agency's decisions.

This report fulfills the requirement for the consumer products phase (phase 2) of the second review cycle of Safer Products for Washington, which began in 2023.

Statutory requirement

RCW 70A.350.030[24] requires us to identify priority consumer products that are significant sources or uses of priority chemicals after considering the following criteria:

- The estimated volume of the priority chemical in the consumer product and the estimated volume of the consumer product sold or present in the state.
- The potential for exposure to sensitive populations or sensitive species when the consumer product is used or disposed of.
- The potential for the priority chemical to be found in the outdoor environment when the consumer product is used or disposed of.
- Regulatory actions by other states or nations.
- The availability and feasibility of safer alternatives.
- Whether we have already identified the product in a chemical action plan completed under Chapter 70A.300 RCW[25] or similar reports.

[23] app.leg.wa.gov/rcw/default.aspx?cite=70A.350
[24] app.leg.wa.gov/rcw/default.aspx?cite=70A.350.030
[25] app.leg.wa.gov/rcw/default.aspx?cite=70A.300

This report explains our process for fulfilling these requirements. It describes the volume and exposure potential of priority chemicals associated with each product, with a focus on sensitive species and populations.

Overview of the prioritization process

Safer Products for Washington follows a hazard-based approach for reducing sources and uses of hazardous chemicals in consumer products. In our May 2024 report,[26] we identified priority chemicals and chemical classes found in consumer products that are hazardous to human health and the environment. Our current work focuses on identifying consumer products that are significant sources or uses of priority chemicals or chemical classes. This includes both the chemical classes we identified in our May 2024 report and those listed in RCW 70A.350.010(14).[27]

Many consumer products contain these priority chemicals and chemical classes. For the second review cycle, we prioritized products where we saw potential opportunities to prevent the use of priority chemicals. To help guide this prioritization process, we developed a set of guiding principles for this work:

- We base decisions on science and public input.
- We communicate our approach and process to the public.
- We prioritize reduction of exposure to toxic chemicals in people, with a focus on sensitive populations.
- We prioritize the protection of aquatic and terrestrial ecosystems in Washington, with a focus on sensitive species.
- We must demonstrate that priority products meet the criteria in the law.

We built on our past and ongoing outreach efforts to better understand which products matter most to the public and interested parties in Washington. This included using:

- Public survey responses from the survey conducted November 2021–January 2022.
- Public comment on previous draft reports.
- Public comment on the draft of the priority chemicals report, which we finalized and published in May 2024.

We researched these products using peer-reviewed literature, authoritative sources, databases, and other tools to understand the prevalence and use of priority chemicals in the products.

We used this research to understand the potential for exposure to the priority chemicals from the product to people, including in sensitive populations. We considered how the products may contribute to the release of priority chemicals into the environment, the behavior of those chemicals in the environment, and how this affects potential exposure in sensitive species.

[26] apps.ecology.wa.gov/publications/summarypages/2404025.html
[27] app.leg.wa.gov/rcw/default.aspx?cite=70A.350.010

We provided multiple opportunities for the public to participate. We conducted an additional public survey to help us learn more about which products people were concerned about and how they used and disposed of them. The survey ran between March 2024 and April 2024 and was available in multiple languages; Ecology received more than 150 responses to the survey statewide. In the survey results,[28] we considered which other products participants wanted us to add to our continued research. On July 11, 2024, we hosted a public webinar to outline our process and invite feedback and ideas from the public and other interested parties. These responses will inform future review cycles of Safer Products for Washington in addition to our current work on products.

We used feedback and our research on products to focus our continued prioritization work. As part of this effort, we referenced:

- Biomonitoring studies.
- Occupational exposure studies.
- Information on product use.

This helped us to identify populations that have the potential for higher exposure to priority chemicals.

We also reviewed studies on the release of priority chemicals during product manufacturing, use, and disposal to assess their potential presence in the environment.

In addition, we considered how the presence of those chemicals in the environment contributes to the potential for exposure in people and sensitive species. This includes both the priority chemicals themselves as well as chemicals resulting from their breakdown in the environment, where applicable.

Based on this research, we refined our list to focus on products where we saw opportunities to reduce exposures in sensitive populations and minimize contamination of aquatic and terrestrial ecosystems with priority chemicals. We gathered information on how the priority chemicals are used in the products and defined the scope of product categories with this in mind.

Finally, we evaluated the products concerning the requirements in the law. This included determining whether the products were significant sources or uses of the priority chemicals as required by RCW 70A.350.030(1)[29] and in consideration of the criteria listed in the statute under RCW 70A.350.030(2)(a)–(g).

Evaluation of priority consumer products

We evaluated potential priority products against the law's criteria by reviewing existing regulations, peer-reviewed science, government reports, and other scientific evidence. Based

[28]apps.ecology.wa.gov/publications/summarypages/2404057.html
[29]app.leg.wa.gov/rcw/default.aspx?cite=70A.350.030

on this review, we identified the following new priority consumer products that are significant sources or uses of priority chemical classes, as required by RCW 70A.350.030.

Artificial turf

Artificial and synthetic turf are generally intended to simulate the experience of playing, practicing, or competing on grass fields indoors or outdoors. Turf includes artificial grass, infill, and backing.

Artificial turf is a significant use of per- and polyfluoroalkyl substances (PFAS) and 6PPD. We made this determination after considering the estimated volume of 6PPD and PFAS associated with artificial turf and the potential for exposure to sensitive populations and species. The manufacturing process for artificial grass blades uses PFAS (TURI, 2020), and studies report multiple types of artificial turf infill materials may contain PFAS.

6PPD is used as an anti-oxidant and antiozonant in tires that are recycled into crumb rubber for artificial turf fields.

People may be exposed to PFAS and 6PPD from artificial turf during product installation, use, maintenance, and disposal. Children may have higher exposure potential because they spend more time playing on artificial turf fields, are closer to the ground, and engage in more hand-to-mouth behaviors than adults.

Over time, artificial turf breaks down, releasing PFAS and PFAS-containing microplastics into the environment (Kole et al., 2023; Lauria et al., 2022; Zuccaro et al., 2023). PFAS are persistent in the environment and some bioaccumulate in wildlife or travel in our waterways.

Crumb rubber particles contain 6PPD. Its highly toxic transformation product, 6PPD-quinone, can be released in runoff and reach sensitive species (Y. Jiang et al., 2024; Kole et al., 2023). 6PPD and 6PPD-quinone in the environment can harm salmon and other aquatic species. Reducing releases of 6PPD and 6PPD-quinone to the environment is critical for preserving and restoring salmon populations in Washington State.

Artificial turf is of significant interest to the public and interested parties in Washington and may offer an opportunity to reduce exposure to 6PPD and PFAS while preventing their release into the environment.

Cosmetics

These are products intended to be rubbed, poured, sprinkled, or sprayed on, introduced into, or otherwise applied to the human body for cleansing, beautifying, promoting attractiveness, or altering appearance as defined in RCW 70A.560.010(1)[30] and RCW 69.04.012.[31]

Cosmetics are a significant source and use of cyclic volatile methylsiloxanes (cVMS). They contribute to potential exposure in people, releases to the environment, and potential for exposure in sensitive species.

[30] app.leg.wa.gov/rcw/default.aspx?cite=70A.560.010
[31] app.leg.wa.gov/rcw/default.aspx?cite=69.04.012

Cosmetics are a major contributor to the presence of cVMS in indoor and outdoor environments (ECHA, 2019; Fromme, 2019; S. Xu et al., 2019). Members of the cVMS chemical class have been associated with reproductive and developmental toxicity as well as endocrine disruption (Ecology, 2024c). Cosmetic products can expose sensitive populations, such as people of childbearing age and children, to cVMS through product use, as well as expose workers during manufacturing or occupational use.

cVMS released from cosmetics into the environment can expose aquatic and terrestrial organisms, including sensitive species. cVMS are human-made, high-production volume chemicals that are not found in the natural environment (ECHA, 2019).

Cosmetics disposed of in wastewater can release cVMS into the environment through evaporation into the air and contamination of sediments (Ecology, 2024c).

cVMS are persistent in the environment and there is evidence they bioaccumulate in some food chains. In addition, cVMS may act as chronic aquatic toxicants in some species. cVMS released from cosmetics have the potential for long-range transport in the environment (Ecology, 2024c).

Due to concerns around the persistence and bioaccumulation potential of cVMS, the European Chemicals Agency has recently restricted their use in products in the European Union, including in cosmetics (ECHA, 2024).

Insulation

These products include materials used in buildings to provide thermal insulation between indoor and outdoor spaces or between two indoor spaces.

Insulation is a significant source and use of organohalogen flame retardants (OFRs). People and wildlife can be exposed to these chemicals during the manufacturing, installation, use, and disposal of insulation. Many OFRs used in insulation can be released during installation, demolition, and gradually over time in buildings. OFRs and their breakdown products can be released during structure fires.

OFRs from insulation have been found in house dust, a key exposure pathway for infants and young children. These sensitive populations spend more time on or near the floor, frequently put their hands in their mouths, and ingest dust (Bi et al., 2018; Drage et al., 2020; Fromme et al., 2014; Stapleton et al., 2008, 2014; Young et al., 2021).

Some insulation materials, like spray foam insulation, contain OFRs that can contaminate the air during installation or spray application. This increases the potential for occupational exposure, making workers a sensitive population to this product-chemical combination (Bello et al., 2018; Estill et al., 2019, 2020, 2024; Minet et al., 2021). Firefighters entering burning buildings with OFRs-containing insulation may face higher exposure to OFRs and their breakdown products.

Inhaling OFRs from insulation is a potentially important route of exposure, as they are consistently found in indoor air, dust, and personal air samples from building occupants (La Guardia & Hale, 2015; Schreder et al., 2016; F. Xu et al., 2016).

OFRs used in insulation have a history of causing environmental concerns (US EPA, 2022b, 2022a). While the most problematic ones, like polybrominated diphenyl ethers (PBDEs), have been phased out, newer OFRs–such as tris(2-chloroisopropyl) phosphate (TCPP)–demonstrate exposure potential, environmental persistence, and toxicity that is concerning for sensitive species (Ecology, 2022b).

OFRs used in insulation have been widely detected in construction waste, fish, and the environment (Alvarez et al., 2014; Counihan et al., 2014; Duan et al., 2016; Ecology, 2016, 2018, 2019).

Jewelry and accessories

These products are ornamental articles and accessories intended to be worn by a person. Examples include necklaces, watches, and hair accessories. This category also includes craft and DIY kits sold for making jewelry and accessories. See Chapter 5 for more examples.

Jewelry and accessories are a significant source and use of lead and cadmium. The size of Washington's jewelry industry, its projected market growth, and the frequent detection of lead and cadmium in these products suggest that a significant amount of jewelry containing these metals is present in the state (ECHA, 2023c; Ecology, 2023a; Jurowski, 2023; US Census Bureau, 2017b).

Jewelry and accessories can potentially expose people and wildlife to lead and cadmium. Lead and cadmium are toxic heavy metals with well-established hazards (Ecology, 2024c). Exposure to lead and cadmium is especially concerning for sensitive populations such as children, pregnant people, and workers.

Lead and cadmium are linked to human and environmental hazards that impact sensitive species and populations. Lead, in particular, can harm brain development and have lifelong effects on children. There is no known safe level of lead exposure, especially for children.

Workers, people of childbearing age, and children can be exposed to lead and cadmium from jewelry and accessories during product manufacturing, use, and disposal (Ferrreira et al., 2019; Illinois Department of Public Health, 2021; Mishra et al., 2003; Patil et al., 2007; Salles et al., 2018, 2021). Exposure pathways include handling products before eating or putting hands in the mouth, accidental ingestion, or inhaling vapors during manufacturing.

Washington State already restricts the presence of lead and cadmium in children's products,[32] including in children's jewelry. However, exposure resulting from use in other jewelry products and accessories is still a concern.

Nail products

This category includes nail products broadly, examples include:

- Nail art products
- Nail coatings

[32]app.leg.wa.gov/rcw/default.aspx?cite=70A.430

- Nail glues
- Nail hardeners
- Nail polish removers
- Nail polish thinners

Nail products are a significant source and use of benzene, toluene, ethylbenzene, and xylenes (BTEX) substances. Toluene and xylenes are the most common BTEX substances used as solvents in nail products and are reported to be used in products at concentrations ranging from 5 to 25% (DTSC, 2023b). They are also found as contaminants along with benzene and ethylbenzene in nail products.

Nail products containing BTEX substances are available for purchase in Washington stores and online. We estimate that about 2.3 million women in Washington used nail products in 2020, along with an unknown number of children, men, and nonbinary people.

BTEX substances in nail products evaporate during product use, exposing people to these chemicals when they are inhaled. This is especially concerning for nail salon workers and their clients, but home use of nail polish can also lead to exposure (Alaves et al., 2013; Harrichandra et al., 2020; Quach et al., 2011; Zhong et al., 2019).

Sensitive populations–including children, people of childbearing age, pregnant people, and workers–may be especially vulnerable to BTEX from nail products due to higher exposures and increased sensitivity. Workers in the nail salon industry in the United States are mostly women of color who are of childbearing age. The majority are low-income workers, and many speak a first language other than English (Sharma et al., 2018).

Architectural paints

Architectural paints (referred to as "paints") include coatings designed for interior and exterior building surface applications. This category includes paints intended for both non-professional and professional uses. This category includes paints, primers, and clearcoats such as varnishes or lacquers.

Paints are a significant use of per- and polyfluoroalkyl substances (PFAS) and alkylphenol ethoxylates (APEs). We made this determination after considering the uses and concentrations of PFAS and APEs reported in paint, the anticipated market size for paint in Washington, and the potential for exposure to PFAS and APEs from paint in sensitive populations and sensitive species.

Manufacturers have reported PFAS use in architectural paint formulations (OECD, 2022). Product testing studies on paint have found that around half of paint products tested contain organic fluorine (an indicator of PFAS) or 6:2 fluorotelomer alcohols, which are volatile PFAS chemicals (Cahuas et al., 2022; Healthy Building Network, 2023). APEs are also used in architectural paint formulations (DTSC, 2018; Ecology, 2021).

People may be exposed to PFAS and APEs from paint when applying paint to surfaces, during drying of paint, and over time as paint degrades (Cahuas et al., 2022; Danish EPA, 2015; US EPA, 2010). Workers may have higher exposures to PFAS and APEs from paint due to more frequent use and proximity to paints that may release volatile PFAS during application and drying.

Children may have higher exposure potential through indoor dust because they spend more time on the floor and have a higher frequency of hand-to-mouth behaviors (Hauptman & Woolf, 2017).

Paint is a potential source of PFAS and APEs release to the environment. It can release volatile PFAS when drying which can contaminate outdoor air during application to structures. Paints that are washed into municipal wastewater or septic systems can introduce PFAS and APEs into the environment (Danish EPA, 2015). This may occur when paint brushes or clothing are washed, or if the paint is improperly disposed of down the drain (Cahuas et al., 2022).

There is an ongoing need for affordable housing in Washington. The Department of Commerce estimates that more than 1.1 million new homes will be needed in the next 20 years (WA Department of Commerce, 2023). This will require a large amount of indoor and outdoor paint to cover the surfaces of these structures. In addition, maintenance and renovation of existing structures will require use of a large amount of paint products as well. As such, working to identify safer alternatives to the use of PFAS and APEs in paint may be an opportunity to reduce human exposure to these chemicals and their release into the environment from this significant use.

Plastic packaging

These products include single and multi-component plastic packaging. Packaging includes packages and packaging components as defined in RCW 70A.222.010.[33]

Plastic packaging is a significant use of organochlorine substances. The focus of this category is the polymers used in packaging materials. Polyvinyl chloride (PVC) and polyvinylidene chloride (PVDC) are organochlorine substances used as plastics in packaging and often comprise a large part of the packaging material. In some cases PVC and PVDC can be used in thin layers, such as in metal cans, and are a small component of the packaging.

People can potentially be exposed to organochlorine substances in plastic packaging materials. Akin to other plastics, plastic packaging polymers such as PVC and PVDC break down into PVC and PVDC microplastics (defined as particles smaller than 5 mm in their longest dimension) that people, including sensitive populations, can inhale or ingest. PVC and PVDC microplastics are organochlorine substances.

Microplastics, such as those made of PVC, are found in several types of human tissues, including in reproductive organs, and have been associated with adverse effects in human cells (ITRC, 2023b, 2023c). Microplastics can harm wildlife and contribute to adverse effects in organisms including invertebrates, fish, and mammals (Zolotova et al., 2022).

The manufacture of PVC uses vinyl chloride, a hazardous organochlorine substance that can be detectable in packaging materials as a residual from manufacturing. While exposure to vinyl chloride can cause cancer, packaging is not considered a major source of exposure for the general population (ATSDR, 2024).

[33]app.leg.wa.gov/rcw/default.aspx?cite=70A.222

Many manufacturers use processes to minimize residual vinyl chloride in polymerized PVC products like packaging (ATSDR, 2024). However, vinyl chloride can still be released into the environment during PVC production and transport.

PVC and PVDC pose challenges to achieving a circular economy for packaging in Washington. The recycling rate for post-consumer PVC and PVDC in Washington is extremely low because no facilities in the state can recycle these materials at scale (Eunomia, 2023). Most packaging made from these materials ends up in landfills, and some is incinerated or burned.

As these materials break down in landfills, they generate PVC and PVDC microplastics which are persistent in the environment. Microplastics accumulate in landfill leachate and may harm people and ecosystems if released into the environment (Kabir et al., 2023).

Burning PVC and PVDC materials can form dioxins, another group of hazardous organochlorine substances (Baca et al., 2023). Formation of dioxins is higher in uncontrolled burning events such as landfill fires and backyard burning in comparison to commercial incineration. Dioxins are persistent organic pollutants that accumulate in animals and contaminate food.

Sealants, caulks and adhesives

These products include sealants, caulks, and adhesives used in architectural or home maintenance applications. Sealants are products used to seal or fill joints and seams between building materials, they are often intended to create a waterproof or weatherproof barrier. In contrast, caulks are a type of sealant often characterized as more rigid when dry and adhesives are used to bond two building materials together.

Sealants, caulks, and adhesives are a significant use of ortho-phthalates, contributing to the potential for exposure in people, including sensitive populations. These products can also release ortho-phthalates into the environment, potentially exposing to sensitive species through outdoor use, disposal, or the breakdown of treated materials.

The advisory committee members raised concerns about sealants, caulks, and adhesives and recommended them for consideration by Safer Products for Washington in our Phthalates Action Plan (Ecology, 2023b).[34]

Sealants, caulks, and adhesives use ortho-phthalates as plasticizers, and they can make up a large percentage of these products by weight (CPID, n.d.). Sealants, caulks, and adhesives may release ortho-phthalates during application or over time and contaminate indoor air and dust. Sensitive populations, such as children, can be exposed to ortho-phthalates through inhalation of indoor air or incidental ingestion of dust particles (Dodson et al., 2017; Mitro et al., 2016; Sears et al., 2020; Zhu, Hajeb, et al., 2023).

Leftover or unused sealants, caulks, and adhesives are washed down the drain in wastewater or disposed of in landfills. When used outdoors, these products may contribute to the release of ortho-phthalates into the environment, potentially exposing aquatic and terrestrial organisms.

[34] apps.ecology.wa.gov/publications/summarypages/2304067.html

Solid deodorizers

The product includes deodorizer products sold as solids. Examples include:

- Toilet, garbage, and urinal deodorizer blocks
- Other solid continuous-action air fresheners

Solid deodorizer products are a significant use of 1,4-dichorobenzene (1,4-DCB), an organochlorine substance. People are potentially exposed to 1,4-DCB when they come into contact with deodorizers. This includes inhalation exposure and dermal exposure through vapor emissions, mists, and dust (US EPA, 2020b).

1,4-DCB is found in surface waters, likely due to long-term use of toilet deodorizer blocks (ATSDR, 2006). 1,4-DCB in these products is often washed down the drain into municipal wastewater. This can lead to potential exposure in aquatic and terrestrial organisms, as demonstrated by detections of 1,4-DCB in aquatic environments and biota (ATSDR, 2006).

Solid deodorizer products account for a large proportion of 1,4-DCB released to indoor and outdoor air, with the potential to travel long distances and expose sensitive species (ATSDR, 2006).

Additional evaluation information

For further information about evaluation of these priority products, please see the dedicated methods and products chapters that follow in this report.

For each of the priority products identified, we considered:

- The volume of priority chemicals found in the product.
- The volume of the product sold or present in Washington.
- The potential for exposure to sensitive populations.
- The potential for exposure to sensitive species.
- The potential for environmental releases.
- The availability and feasibility of safer alternatives.
- Existing regulations from other jurisdictions.

See Appendix B for a summary of existing and pending regulations from other jurisdictions.

We based our review of priority products on:

- Product testing data
- Ingredient lists
- Patents
- Sales data
- Market research
- Exposure biomonitoring data
- Occupational exposure data
- Environmental monitoring data
- Product databases and tools

- Peer-reviewed literature

See Appendix E of this report for a detailed citation list.

Reducing exposure in sensitive populations

Reducing sources and uses of priority chemical classes can help lower exposure for those most affected and promote equity in health outcomes. People are not exposed equally to toxic chemicals. Exposures are related to where people live, where they work, what they eat and drink, and the kinds of consumer products they purchase and use.

People are exposed to and impacted by chemicals that accumulate in their bodies throughout their lives. Inadequate diets may increase the absorption of chemicals, such as lead and cadmium. Exposures to the priority chemical classes can have more impact on sensitive populations, including people with occupational exposures and communities that are highly impacted by toxic chemicals.

Focusing on the priority products identified in this report allows us to reduce exposures that are higher or may have increased impact in sensitive populations.

Preventing environmental releases

Reducing priority chemicals in the priority products identified in this report can reduce environmental contamination. The cheapest and most effective way to reduce environmental contamination is to avoid it in the first place.

Reducing sources and uses of priority chemicals is important because many of the priority chemical classes have members that are already national cleanup priorities. For example, common contaminants found at National Priorities List Superfund sites include lead, BTEX substances, and PFAS, among others.

The products identified in this report are significant sources or uses of these priority chemicals and could be opportunities to reduce the use of these chemicals and releases to the environment.

Existing priority consumer products

During our second cycle, we plan to assess several priority consumer products identified in previous cycles or by statute (Table 1). We are continuing the work we started in 2022 on PFAS in firefighting personal protective equipment (PPE), cookware, hard surface sealers, and floor waxes and polishes. Other continuing work includes further review of PCBs in printing inks from the first review cycle and 6PPD in motor vehicle tires according to RCW 70A.350.110.[35] We describe the products and our rationale for revisiting them in the last chapter of this report.

[35] app.leg.wa.gov/RCW/default.aspx?cite=70A.350.110

Table 1: Priority chemicals and products from previous review cycles of Safer Products for Washington or as directed by the legislature.

Safer Products for Washington Review Cycle	Chemical(s) prioritized	Product(s) prioritized
Cycle 1	PCBs	Printing inks
Cycle 1.5	PFAS	Cookware and kitchen supplies, hard surface sealers, floor waxes and polishes, firefighting PPE
Cycle 2	6PPD	Motor vehicle tires

Crossover with existing laws and regulations

Some new priority products identified in this report have existing regulations in Washington. Table 2 lists existing regulations that may overlap with the new priority products identified in this report.

Table 2: Restrictions and reporting requirements for toxic chemicals in consumer products relevant to new priority products identified in this report.

RCW/WAC	Description	Chemical(s) in existing regulation	Products covered in existing regulation	Relevant new priority products identified in this report
Chapter 70A.430 RCW[36]	Children's Safe Products	Lead, cadmium, ortho-phthalates, specified flame retardants, and chemicals listed as high concern for children	Children's products, including jewelry and cosmetics	Jewelry and accessories, Cosmetics, Nail products
Chapter 70A.222 RCW[37]	Toxics in packaging	Lead, cadmium, mercury, and hexavalent chromium	Packages and packaging components	Plastic packaging
Chapter 70A.222 RCW	Toxics in packaging	PFAS	Plant fiber-based food packaging	Plastic packaging
Chapter 70A.405 RCW[38]	Flame retardants	Brominated flame retardants (PBDEs)	Noncombustible products	Insulation

[36]app.leg.wa.gov/rcw/default.aspx?cite=70A.430
[37]app.leg.wa.gov/rcw/default.aspx?cite=70A.222
[38]app.leg.wa.gov/rcw/default.aspx?cite=70A.405

RCW/WAC	Description	Chemical(s) in existing regulation	Products covered in existing regulation	Relevant new priority products identified in this report
Chapter 70A.560 RCW[39]	Toxics in cosmetics	Ortho-phthalates, PFAS, formaldehyde and formaldehyde releasers, methylene glycol, mercury, triclosan, m-phenylenediamine, o-phenylenediamine, and lead	Cosmetic and personal care products	Cosmetics, Nail products
Chapter 173-337 WAC[40]	Safer Products Restrictions and Reporting	Ortho-phthalates	Fragrances in beauty and personal care products	Cosmetics, Nail products

There are other existing regulations for consumer products in Washington. For a full list of restrictions and reporting requirements for toxic chemicals in consumer products in Washington, please refer to Appendix C.

[39] app.leg.wa.gov/rcw/default.aspx?cite=70A.560
[40] app.leg.wa.gov/wac/default.aspx?cite=173-337

Chapter 1: Technical Methods

Process overview

We used the criteria in RCW 70A.350.030[41] to identify priority consumer products. Many products contain priority chemicals and could meet the criteria in the law to identify as priority consumer products. Therefore, we established guiding principles to help us develop and implement a prioritization process for the selection of products. The guiding principles are:

- We base decisions on science and public input.
- We communicate our approach and process to the public.
- We prioritize reduction of exposure to toxic chemicals in people with a focus on sensitive populations.
- We prioritize the protection of aquatic and terrestrial ecosystems in Washington with a focus on sensitive species.
- We must demonstrate that priority products meet the criteria in the law.

We held a public webinar in July 2024 to share an overview of our proposed methods and to ask for input and feedback from the public, stakeholders, and other interested parties. We will continue to refine our process based on input we receive for future implementation cycles of Safer Products for Washington.

We started by broadly researching candidate product categories that contain priority chemicals, focusing on exposure potential, volume considerations, environmental release concerns, and public input. Figure 2 shows our approach for prioritizing products.

When researching products, we focused on identifying opportunities to reduce exposures in people with a focus on sensitive populations and reduce contamination of terrestrial and aquatic ecosystems.

Our research was an iterative process. We used information we gathered to keep refining the product categories for this cycle.

We used the information we collected on products–such as concentrations of priority chemicals in products, exposure potential, and product use–to narrow our list of potential products. Using a qualitative process, we examined how each product's information moved us toward our goals of reducing exposures in sensitive populations and preventing releases to the environment. We used our research to define the scope of the product categories.

Finally, we evaluated the products we identified using the criteria in the law. We describe these steps below.

[41] app.leg.wa.gov/rcw/default.aspx?cite=70A.350.030

Figure 2: Process for identifying priority products

Identifying priority products

Beginning with public input

We used the public input we received previously on the Safer Products for Washington program activities to guide our initial research, including:

- Cycle 1 public survey responses (conducted November 2021 – January 2022).
- Cycle 1 and Cycle 1.5 public comment on draft reports.
- Cycle 2, Phase 1 public comment on draft priority chemicals report.

We used this information to ground our work in public input. It helped us to understand where the people of Washington want us to focus our work and what products are important to them.

If public input suggested products we had not yet researched, we expanded the scope of our research to include those products. As we researched products, we looked for alignment between public input and the available scientific information to help set our priorities. For example, if a product was mentioned in public input and we found information demonstrating the potential for exposure or environmental contamination from that product, we dedicated more time to continuing work on that product category as it was more likely to be a good priority for the program. Conversely, if we found there was insufficient information available on a product to demonstrate it was a significant source or use of a chemical, we allocated fewer resources to continuing research on that product category. We also referred to our past action plans and chemical action plans to help guide our initial product research.

Research on potential priority products

We used many tools and resources to research potential products. The primary goals of this research were to gain a better understanding of:

- How priority chemicals were used in products
- How people may be exposed to priority chemicals from products
- Who uses the products
- How priority chemicals in products might impact the environment in Washington

Product data

Product databases helped us understand the use of priority chemicals in products. For example, we used the US Environmental Protection Agency (EPA) ChemExpo web application to research what product categories had a higher number of products reported to contain priority chemicals (US EPA, n.d.-a).

We cross-referenced this information with other databases such as the Consumer Product Information Database and manufacturer safety datasheets to support and build upon EPA data (CPID, n.d.).

We referred to the Mintel Global New Products Database (GNPD) to gain a better understanding of the market prevalence and use of priority chemicals based on product labeling (Mintel, n.d.).

Some product categories had additional databases available to help with this research.

- The California Safe Cosmetic Program Product Database contains reporting information on cosmetic products sold in California (CDPH, n.d.).
- The Habitable Pharos Database, International Future Living Institute Declare Database, and the Health Product Declaration Collaborative Public Repository contain information on the use of chemicals in building products and materials (Habitable, n.d.; HPD Collaborative, n.d.; International Future Living Institute, n.d.).

Industry statistics

To better understand the volume of products used in Washington, we used available information on the industries that manufacture and sell those products. For some industries, US Census data are available that describes the market size for industries or products. In some cases, industry associations have voluntarily made available information on product sales volume, often focused on the United States or North American market. In other cases, we were not able to find industry-reported data and instead relied on estimates by organizations with expertise in market statistics, such as Statista (Statista, n.d.-c). We often scaled these national statistics to the relative population size of Washington using US Census Bureau data to estimate the volume of products sold in Washington (US Census Bureau, n.d.).

Population statistics

We sought information and statistics to help us better understand the populations that use products that contain priority chemicals. In some cases, the use of products is expected to be similar across the general population. In other cases, particular demographics or occupations may use products that contain priority chemicals more often or in ways that could contribute to an increased potential for exposure.

When available, we used data from the US Bureau of Labor Statistics to estimate the size of worker populations that may have the potential for exposure to certain products. We consulted data published by the Hazardous Waste Management Program in King County that estimates the burden of occupational exposures among workers and by race/ethnicity (Peckham & Stephan-Recaido, 2023).

Washington data

We consider other Washington-specific data to inform our work. For example:

- We used the Washington Environmental Reports Tracking System (ERTS) to understand the prevalence of improper disposal of some products, such as illegal burning of wastes.
- We referred to the Washington Environmental Information Management Database to investigate concentrations of priority chemicals measured in the environment to provide context on the potential releases of priority chemicals from products (Ecology, n.d.-c).
- For lead and lead compounds, the Washington Tracking Network had data available on exposure in children who live in Washington and how the risk of lead exposure from housing relates to other factors such as income status (Health, n.d.-b).

It is difficult to directly link consumer products to these types of geographic datasets. When possible, though, we qualitatively considered how product manufacturing, use, or disposal may contribute to disparities in the potential for exposure to priority chemicals.

Broadly applicable information

One of the primary sources of information we rely upon is peer-reviewed literature. Published research, such as academic journal articles, often provides the latest information on the presence or concentration of chemicals in products and how those products may contribute to the potential for exposure in people or releases to the environment.

To use our resources efficiently, we often begin with recent review articles that summarize what is known about a topic, such as the use of a chemical class in products. We seek to build upon the information contained in the review by incorporating individual studies referenced in the review or supplementing the information with recent articles not included in the review article. This approach helps us use the most relevant information and identify areas of agreement or gaps in knowledge on a particular topic.

We also use reports from other government agencies as a source of information. Some primary examples of government agencies whose reports we consider in our work:

- US Environmental Protection Agency (EPA)
- US Consumer Product Safety Commission (CPSC)
- US Food and Drug Administration (FDA)
- US Center for Disease Control and Prevention (CDC)
- US Agency for Toxic Substances and Disease Registry (ATSDR)
- California Department of Toxic Substances Control (DTSC)
- European Chemicals Agency (ECHA)
- Environment Canada and Health Canada

In addition to peer-reviewed literature and reports from other government agencies, we refer to secondary sources such as reports from non-governmental organizations and industry associations. This information is considered secondary because it often has not been subject to detailed peer review. Even so, we still see this information as valuable, especially when it supports the primary sources mentioned above.

Focus on sensitive populations and narrowing our list

Reducing exposures in sensitive populations is a goal of this program. We recognize that consumer products are usually just one factor of many that contribute to people's exposure to priority chemicals. By focusing on opportunities to reduce these exposures in sensitive populations and populations with higher exposures, we aim to reduce the overall exposure.

To help us identify opportunities for reduction, we looked for products in the context of several factors including consumer products with:

- Frequent use patterns
- Potential to contribute to direct exposure in people to the priority chemical
- Potential to contribute to occupational exposures in Washington workers
- Potential to contaminate indoor and outdoor environments with priority chemicals
- Potential for long-term or generational impacts

Reducing exposures in sensitive populations

Sensitive populations are defined in our statute under RCW 70A.350.010(16):[42]

> "'Sensitive population' means a category of people that is identified by the department that may be or is disproportionately or more severely affected by priority chemicals, such as:
>
> (a) Men and women of childbearing age;
>
> (b) Infants and children;
>
> (c) Pregnant women;

[42]app.leg.wa.gov/rcw/default.aspx?cite=70A.350.010

(d) Communities that are highly impacted by toxic chemicals;

(e) Persons with occupational exposure;

(f) The elderly."

We worked to identify products that contribute to exposures in sensitive populations as defined by our statute. To do this, we reviewed information on how these populations may be exposed to products, including product-specific exposure studies and studies on exposure pathways for sensitive populations generally. When we could not find data on exposure pathways and population exposure patterns specific to Washington, we used data from other states, national databases, and selected research populations from peer-reviewed literature.

For example, in our work on nail products for BTEX (benzene, toluene, ethylbenzene, and xylenes) substances:

- We identified studies on occupational exposures in nail salons. This helped us better understand the potential for worker exposures that occur through inhalation of BTEX substances that evaporate out of these products as they are used.
- We reviewed studies that measured concentrations of BTEX substances in nail salon air or workers' personal air, as well as studies identifying nail products as a source.
- We considered studies that linked BTEX measured in air to data from human biomonitoring samples such as blood or urine.

We also considered which populations may be more sensitive to hazards associated with chemicals or chemical classes, such as developmental toxicity in children.

For example, in our work on nail products for BTEX:

- We found that the majority of nail salon workers are women of childbearing age. People of childbearing age and children are also customers in nail salons.
- BTEX substances are hazardous to reproduction and development, and children and people of childbearing age are more susceptible to these hazards.
- Taken together, this led us to prioritize these products in part due to the potential opportunity to reduce exposure to BTEX substances in these sensitive populations.

We considered unintentional dust ingestion as a common exposure pathway, especially for children, who are a sensitive population for many of our priority products. Even when chemical concentrations in dust are not linked to specific sources, their presence in products used in homes, the physiochemical properties of those chemicals, and the frequency of detection in dust helped inform our prioritization decisions to reduce exposures to priority chemicals in children as a sensitive population.

For example, we considered that:

- Children are exposed to more chemicals in dust because they spend more time on the floor and put their hands in their mouths more often. This makes them more vulnerable to chemicals in dust than adults.

- Several of the priority chemical classes we have identified are commonly found in house dust. In some cases, the concentrations in dust can be linked directly to specific products, but more often they are the result of a combination of sources in the home.

We reviewed information showing that exposure to priority chemicals in products can vary across the general population, with some groups experiencing higher exposure levels. In support of this, we looked for studies or information that highlighted potential for higher exposures across populations, including:

- Biomonitoring studies that show higher exposure to priority chemicals across race, ethnicity, sex, gender, or socioeconomic status.
- Information on differences in frequency of product use that could result in higher exposures by race, ethnicity, sex, gender, or socioeconomic status.
- Studies of exposure levels in air, dust, or products during use by population groups.
- Studies that show higher exposures or suggest a potential for higher exposures in certain occupations.

We considered how intersections of race, occupation, socioeconomic status, and product use can exacerbate exposures to priority chemicals in sensitive populations. People who work in occupations with potential exposure to priority chemicals and belong to groups with higher exposures than the general population are likely to experience even greater exposure.

For example, in our work on solid deodorizers for 1,4-dichlorobenzene (1,4-DCB), we found:

- Black women have been shown to have higher exposures to 1,4-DCB, a priority chemical used in solid deodorizing products, than white women across the general population (Nguyen et al., 2020).
- In addition, 16.7 percent of janitors and building cleaners identify as Black or African American, which is higher than the general working population where only 12.8 percent identify as Black or African American (US BLS, 2024).
- Janitors and building cleaners are likely to use solid deodorizers as part of their occupation. So, this intersection of race and occupation increases the likelihood that these individuals have higher exposures to 1,4-DCB as a priority chemical.

The health impacts of priority chemicals can be made worse by increased vulnerability to chemical hazards due to factors like social stresses from poverty and racism (Clougherty et al., 2014; Hickman et al., 2024; Payne-Sturges et al., 2023). People may have heightened vulnerability to impacts from priority chemicals due to where they live or work, as well as differences in access to community resources (Gee & Payne-Sturges, 2004).

For example, in our work on jewelry and accessories as a priority product for lead and cadmium, we found:

- Some children in Washington face a higher risk of exposure and greater vulnerability to lead.

- Childhood lead exposure is linked to lifelong impacts in cognitive function and is associated with lower socioeconomic status.
- The risk of lead exposure in Washington is higher in children in low-income households and those who live near former smelter sites (Ecology, 2024c; US CDC, 2024b).
- In addition, socioeconomic status affects development and brain structure. Research suggests that US children from low-income families may be more vulnerable to lead exposure, and reducing lead exposure could greatly benefit children experiencing more adversity (Marshall et al., 2020).
- Recent immigrant and refugee populations, including the Afghan community in Washington, are at higher risk of lead exposure (US CDC, 2024a).

Diet can contribute to exposure to priority chemicals in some populations. For example, in our work on products that contain organohalogen flame retardants and PFAS, we found:

- Exposure to persistent and bioaccumulative chemicals, such as organohalogen flame retardants and PFAS, can occur through consumption of seafood.
- For populations who consume larger amounts of seafood, this may lead to higher exposures through diet.
- In 2013, Ecology estimated between 140,000 to 380,000 adults and 29,000 children were high fish consumers in Washington (defined as at or above the 90 percentile for national per capita consumption) (Ecology, 2013).

Protecting ecosystems in Washington

Protecting ecosystems in Washington is another ongoing goal of this program. Protecting the environment in Washington benefits everyone, but some populations may gain more from stronger protections. Environmental harms are higher in more sensitive populations, such as children and those facing inequities in health outcomes, income, and education. Products contribute to environmental contamination and potential harm to ecosystems at multiple points in their lifecycle, including during manufacture, use, reuse, and disposal. To help us identify opportunities to reduce environmental contamination and potential harm from products, we considered several factors including:

- Products with potential for direct release to the environment (for example in stormwater)
- Products that are likely disposed of down the drain
- Products that may contribute to the release of priority chemicals during the manufacture
- Products used or disposed of in high volumes
- Products with the potential to contaminate ecosystems leading to additional adverse impacts on communities with health disparities

For example, we identified artificial turf as a source of microplastics in the environment that may contain 6PPD and perfluoroalkyl and polyfluoroalkyl substances (PFAS). PFAS and 6PPD are hazardous to both human health and to organisms in the environment. Particularly, 6PPD and its transformation product 6PPD-quinone have been identified as toxic to several species of fish, and 6PPD-quinone is one of the most potent acutely lethal chemicals ever discovered for coho salmon (Z. Tian et al., 2022).

Salmon are both economically and culturally important to Washington and are foundational to our ecosystem. Tribal populations are more adversely impacted by salmon loss. American Indians and Alaska Natives have a higher burden of health disparities in Washington. These health disparities are the result of trauma from historical and present injustices and structural inequities faced by Tribal populations as described in the Governor's Indian Health Advisory Council's 2022–23 Biennial Report[43] (Governor's Indian Health Advisory Council, 2023). This underscores the critical need to eliminate or reduce the use and release of these hazardous chemicals to protect salmon and the ecosystem in Washington.

Potential for impact

When narrowing our list of potential priority products, we considered what the potential was for positive impacts and successful outcomes and whether prioritizing a product within Safer Products for Washington was the most appropriate path forward. Some factors that we included in this qualitative decision-making include:

- The volume of the chemical in the product or product volume in Washington
- The uses of the chemicals and products, and the potential for identifying safer alternatives
- If other regulatory structures already exist or there are more effective paths to address a specific product-chemical combination than our program
- If the product contains more than one priority chemical and there is the potential for an overall safer alternative that could reduce multiple chemical hazards

Defining the scope of product categories

We worked to define the scope of product categories based on the information from our research on products. In some cases, we defined product categories broadly to cover many products that may contain priority chemicals. In other cases, we defined the product categories more narrowly to focus specifically on products with information showing they can contain priority chemicals or when the information we had did not speak to a broader category.

Function of priority chemicals

The function that priority chemicals serve in a product can help inform the appropriate breadth of a product category. Function in this context may refer to the performance properties that a priority chemical contributes to a product, or how the chemical facilitates the performance of other aspects of the formulation. An example of a performance property is how PFAS are used to impart oil and water resistance on surfaces; an example of a priority chemical facilitating the performance of other formulation aspects is BTEX substances in nail products, which act as solvents to help keep other ingredients dissolved in a liquid solution.

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[43] dfi.wa.gov/sites/default/files/reports/2022-2023-dfi-biennial-report.pdf

Some priority chemicals serve no function in products and are present as contaminants or residuals from manufacturing.

Breadth of product categories

We considered the feasibility of identifying alternatives when scoping product categories as well. For example, a broad product category may contain certified products that suggest safer alternatives are likely available for a subset of products, but maybe not for the entire category. Then, it may make sense to narrow the scope of the category to focus on a subset of products to increase the likelihood we will be able to identify safer, feasible, and available alternatives that apply to the scope of the product category.

This often relates to the shared function of priority chemicals in product categories—broader categories sometimes contain products where the function of priority chemicals differs between individual products. Likewise, narrower product categories contain priority chemicals serving similar or identical functions, and this can make the identification of alternatives applicable to the category more straightforward.

In this phase of implementation, we were intentionally broad when defining some product categories unless there was a clear rationale for defining a narrow scope. This approach allows us to benefit from broader engagement with industry stakeholders and interested parties as the cycle progresses so we can make more informed decisions about priority chemicals in products.

As we move forward in our review, we can narrow product categories based on continued research and input to focus our product scope as appropriate. In contrast, if we define product categories too narrowly in this phase of implementation, it would be more difficult to expand those categories based on new information or input later in implementation because industry stakeholders and other interested parties would have less notice and time to provide substantiative input on the broader category.

Evaluating priority products against criteria in statute

Significant source or use of priority chemicals

The statute requires that the department identify priority consumer products that are significant sources **or** uses of priority chemicals as described in RCW 70A.350.030:[44]

> "(1) Every five years, and consistent with the timeline established in RCW 70A.350.050, the department, in consultation with the department of health, shall identify priority consumer products that are a significant source of or use of priority chemicals. The department must submit a report to the appropriate committees of the legislature at the time that it identifies a priority consumer product."

To evaluate whether a product is a significant source or use of priority chemicals, we considered several factors including those identified by the statute as described below.

[44] app.leg.wa.gov/rcw/default.aspx?cite=70A.350.030

The statute further requires that the department consider, at a minimum, the following criteria as described in RCW 70A.350.030:

> "(2) When identifying priority consumer products under this section, the department must consider, at a minimum, the following criteria:
>
> > (a) The estimated volume of a priority chemical or priority chemicals added to, used in, or present in the consumer product;
> >
> > (b) The estimated volume or number of units of the consumer product sold or present in the state;
> >
> > (c) The potential for exposure to priority chemicals by sensitive populations or sensitive species when the consumer product is used, disposed of, or has decomposed;
> >
> > (d) The potential for priority chemicals to be found in the outdoor environment, with priority given to surface water, groundwater, marine waters, sediments, and other ecologically sensitive areas, when the consumer product is used, disposed of, or has decomposed;
> >
> > (e) If another state or nation has identified or taken regulatory action to restrict or otherwise regulate the priority chemical in the consumer product;
> >
> > (f) The availability and feasibility of safer alternatives; and
> >
> > (g) Whether the department has already identified the consumer product in a chemical action plan completed under Chapter 70A.300 RCW[45] as a source of a priority chemical or other reports or information gathered under Chapters 70A.430 RCW,[46] 70A.405 RCW,[47] 70A.222 RCW,[48] 70A.335 RCW,[49] 70A.340 RCW,[50] 70A.230 RCW,[51] or 70A.400 RCW.[52]
>
> (3) The department is not required to give equal weight to each of the criteria in subsection (2)(a) through (g) of this section when identifying priority consumer products that use or are a significant source of priority chemicals."

Volume estimates

To estimate the volume of a priority chemical or priority chemicals added to, used in, or present in consumer products, we used multiple approaches. Information available for specific product-chemical combinations varies depending on several factors such as the consumer market for a particular product and what requirements exist for ingredient disclosure.

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[45] app.leg.wa.gov/rcw/default.aspx?cite=70A.300
[46] app.leg.wa.gov/rcw/default.aspx?cite=70A.430
[47] app.leg.wa.gov/rcw/default.aspx?cite=70A.405
[48] app.leg.wa.gov/rcw/default.aspx?cite=70A.222
[49] app.leg.wa.gov/rcw/default.aspx?cite=70A.335
[50] app.leg.wa.gov/rcw/default.aspx?cite=70A.340
[51] app.leg.wa.gov/rcw/default.aspx?cite=70A.230
[52] app.leg.wa.gov/rcw/default.aspx?cite=70A.400

- For some product categories, manufacturer data sheets were available that adequately described the concentration or concentration range of priority chemicals in the product.
- For other categories, we instead had to rely on product testing studies which reported measured concentrations of priority chemicals in products.
- In some cases, we included non-peer-reviewed product testing information. These studies are identified to the reader and are never the only source of information we considered.

To estimate the volume or number of units of consumer products sold or present in the state, we leveraged information including market and population statistics. In most instances, there is inadequate market data available for products specific to Washington State. Therefore, we often relied on national statistics on product volume or sales and then scaled that information to the population size of Washington.

Although we recognize there are likely differences in the precise amount of consumer products in a particular category sold or present in our state relative to other locales, this approach still allowed us to make reasonable estimates for Washington to inform our decisions.

Characterizing the potential for exposure in sensitive populations

To characterize the potential for exposure to priority chemicals by sensitive populations from the use, disposal, or decomposition of the product, we relied on peer-reviewed literature and reports from authoritative sources. We supplemented these sources of information with others that described product purchase, use, and disposal by people and worker populations who interact with the products as part of their occupation.

When available, we focused on literature that demonstrated exposure to priority chemicals from the specific product. However, people are exposed to priority chemicals from multiple sources, and it can be difficult for researchers to attribute exposure to a single source or product. Therefore, we considered which pathways of exposure from the product were realistic and feasible based on our understanding of the product's use and the physiochemical properties of the priority chemical or chemical class of interest.

For example, several of the priority chemical classes we identified contain volatile chemicals that can evaporate from the product during use. This increases the likelihood that people will be exposed to those chemicals through an inhalation pathway, particularly when these products are used in indoor environments with limited air flow. This inference can be strengthened by studies that demonstrate the presence of the priority chemicals in indoor air where the products are present or used.

Similarly, measurements of priority chemicals in dust samples may not point to a specific product as a source. They can, however, help us understand how chemicals contained in a particular product may contaminate indoor dust and contribute to exposures through unintentional ingestion of dust—an important consideration for children.

We examined whether priority chemicals released into the environment could become another source of exposure in people. For example, some priority chemicals are persistent and bioaccumulative, and this means that when those chemicals are released from products to the environment they may accumulate in other organisms. If those organisms, such as fish, are consumed by people, this could be another indirect source of exposure to the chemicals from both the product and other sources.

Characterizing environmental release and potential for exposure in sensitive species

To characterize the potential for environmental contamination, we considered several factors. To better understand the potential for chemicals to be found in the outdoor environment when consumer products are used, disposed of, or have decomposed, we again referred primarily to peer-reviewed literature and reports from authoritative sources. We looked at how priority chemicals might be released from the product during use, both indoors and outdoors, and whether chemicals used indoors could potentially spread outside through evaporation and movement through the air. We also considered how products might be disposed of, such as in landfills as solid waste, washed down the drain into wastewater, or released directly into the environment—for example, products used outdoors that may contaminate stormwater.

Additionally, we referred to information that described the breakdown of both the product and the associated priority chemicals in the environment. We considered the potential for exposure of sensitive species to be relatively higher when priority chemicals released from products are persistent in the environment. This can be particularly important, for instance, if chemicals are present in wastewater and are not completely removed by municipal wastewater treatment.

Sediments and soils can trap some priority chemicals, especially those that dissolve in fats or are lipophilic. This can increase the potential for exposure of benthic organisms that live and feed near sediment or soil organisms. On the other hand, some priority chemicals break down in the environment, which can lower the potential for exposure of sensitive species. However, in some cases, priority chemicals may break down into other chemicals that are even more toxic to organisms (for example, 6PPD transforming into 6PPD-quinone).

Regulations in other states and nations

Many chemicals of concern have already been, or are in the process of being, regulated in products in other states and nations. Although we do our analysis under the Safer Products for Washington criteria, we learn from actions taken in other jurisdictions. This is particularly true when regulations in other jurisdictions are accompanied by supporting documentation that describes the rationale and justification for the regulation.

For example, when The European Chemical Agency (ECHA) proposes to restrict a chemical or class of chemicals in products, they develop and publish a background document that discusses the science surrounding the chemicals. These documents serve as helpful summaries of the scientific literature we use to inform our work. A summary of regulations in other states and nations can be found in Appendix B.

Availability and feasibility of safer alternatives

We review readily available information that discusses potential alternatives to priority chemicals in products or that describes products as “free-of” priority chemicals. We look to see if companies report product formulations that do not contain priority chemicals, and what other chemicals in the formulation may serve the same or a related function.

We refer to summaries that describe potential alternatives that may be able to replace, reduce, or eliminate priority chemicals in products. For this phase of implementation, we did not assess whether the potential alternatives we identified met our criteria as safer, feasible, and available.

During Phase 3, we will expand our search for alternatives and evaluate alternatives to determine whether they meet our criteria to be considered safer, feasible, and available before recommending any regulatory actions.

Consumer products previously identified by the department

We referred to past work by Ecology, including our past Chemical Action Plans,[53] to identify products that have previously been identified as sources or uses of priority chemicals.

In the following technical chapters, we use the methods described above to demonstrate that the priority products identified in this report are significant sources or uses of priority chemicals and that we considered the criteria as directed in RCW 70A.350.030.[54]

[53]ecology.wa.gov/waste-toxics/reducing-toxic-chemicals/addressing-priority-toxic-chemicals
[54]app.leg.wa.gov/rcw/default.aspx?cite=70A.350.030

Chapter 2: Artificial Turf

Overview

Priority product

Artificial turf includes artificial or synthetic turf intended for use on indoor or outdoor surfaces. It is commonly used in parks, schools, colleges, universities, and professional and non-professional sports facilities. Artificial turf is generally intended to simulate the experience of playing, practicing, or competing on grass fields (US EPA, 2024f). Artificial turf also has residential uses such as landscaping, rooftop gardens, and for indoor and outdoor golf putting greens.

Artificial turf is typically comprised of multiple layers of materials, including artificial grass blades, infill, and backing. This product includes all components of artificial turf.

Priority chemical(s)

PFAS

PFAS chemicals are defined as a priority chemical class by the Washington State Legislature under RCW 70A.350.010.[55]

PFAS are defined in RCW 70A.350.010(10) as:

"Perfluoroalkyl and polyfluoroalkyl substances" or "PFAS chemicals" means a class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom.

6PPD

6PPD was defined as a priority chemical in our previous legislative reports Identification of Priority Chemicals Report to the Legislature: Safer Products for Washington Cycle 2 Implementation Phase 1[56] and Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1[57] in Chapter 8: Technical Support for 6PPD (Ecology, 2024c, 2024b).

Background

Artificial turf is typically made of multiple layers of materials. The surface layer is made of plastic grass fibers which are supported by one or more layers of infill materials. An underlayer described as backing material is used to provide additional support (Lauria et al., 2022; Murphy & Warner, 2022). Other layers may be present to provide properties such as shock absorption and to prevent weed infiltration.

Artificial turf layers can consist of a variety of materials including nylon, polyethylene, polypropylene, polyurethane, synthetic rubber, and thermoplastics, as well as natural materials

[55] app.leg.wa.gov/rcw/default.aspx?cite=70A.350.010
[56] apps.ecology.wa.gov/publications/summarypages/2404025.html
[57] apps.ecology.wa.gov/publications/summarypages/2404026.html

such as cork, walnut shells, and sand. The synthetic rubber is often sourced from crumb rubber from discarded tires or tire materials (Murphy & Warner, 2022).

Some artificial grass blades, infill, and backing may contain PFAS or fluoropolymers. Further, PFAS used in the manufacturing process of other PFAS chemicals and fluoropolymers can remain in the finished products (Lohmann et al., 2020). Over time, as artificial turf wears, PFAS and PFAS-containing microplastics can be released into the environment (de Haan et al., 2023; Kole et al., 2023; Lauria et al., 2022; Zuccaro et al., 2023).

Crumb rubber sourced from tires or tire materials is commonly used as infill in artificial turf products. 6PPD is added to synthetic rubber used in tires to protect the material from ozone present in the atmosphere. As such, crumb rubber used in artificial turf has been found to contain 6PPD and its related ozonated transformation product, 6PPD-quinone (Armada et al., 2023; NTP, 2019; Schneider, de Hoogd, Madsen, et al., 2020; F. Zhao et al., 2024; H. N. Zhao et al., 2023).

There are an estimated 18,000 to 19,000 artificial turf fields in the United States. In our research, we identified at least 100 such fields in Washington. Artificial turf fields have the potential to expose sensitive populations and sensitive species as well as release 6PPD, 6PPD-quinone, and PFAS to the environment. This is described in additional detail in the sections that follow.

Volume estimates for priority product-chemical combinations

The volume of priority chemicals associated with the product

PFAS in artificial turf

PFAS are used during the manufacturing process of artificial turf and may be present in artificial turf products. Fluoropolymers are used as processing aids during the extrusion of polymers used for turf grass blades (TURI, 2020). Fluoropolymers, at about 100 – 1,000 ppm, help manufacturers of extruded products–like plastic bottles, bags, pipes, cables, and artificial grass–reduce processing issues such as die buildup and melt fracture (3M, n.d.).

Patent literature suggests the potential use of a fluoropolymer, such as polytetrafluoroethylene (PTFE), as an antistatic agent for turf grass blades (Lambert, 2008). PTFE and polyvinylidene fluoride (PVDF), both of which are fluoropolymers, can be used as coating treatments or the binding matrix in turf-filling materials (Reddick, 2023; Q. Wu, 2016). Since PFAS used during fluoropolymer production can still exist in the finished products (Lohmann et al., 2020), fluoropolymers in artificial turf can still contain PFAS. The manufacturing of artificial turf from recycled materials could also incorporate PFAS into artificial turf components (New Jersey DEP, 2023).

While fluoropolymers in artificial turf are intentionally used during the manufacturing process, PFAS compounds have been detected when different components of the artificial turf are tested (Lauria et al., 2022; Zuccaro et al., 2023). Peer-reviewed studies are discussed below.

In an analysis of a single new artificial turf fiber and crumb rubber infill sample obtained from the manufacturer, Zuccaro et al. (2023) detected fluorotelomer alcohol (8:2 FTOH) at 300 ppb (parts per billion) in artificial turf fiber and 110 ppb in crumb rubber infill (Zuccaro et al., 2023). Fluorotelomer alcohols have the potential to biodegrade or environmentally break down into perfluorocarboxylic acids (PFCAs) such as perfluorooctanoic acid (PFOA) and perfluorononanoic acid (PFNA) (Dinglasan et al., 2004; Wallington et al., 2006). The Zuccaro et al. study was limited to one new sample but provides evidence for PFAS in a newly manufactured turf sample.

During public comment on the draft of this report, the United States Tire Manufacturers Association (USTMA) shared information that their members report no use of fluorotelomer alcohols (including 8:2 FTOH) in the manufacturing of tires (USTMA, 2024). This suggests that the 8:2 FTOH detected in the Zuccaro et al. study may not come from its use in the manufacture of tires reused as crumb rubber infill. Instead, it may have entered the material from another source, such as the artificial turf fibers, which were also reported to contain 8:2 FTOH.

A 2020 study in Sweden tested the turf blades, infills of various types, and backing from 17 athletic turf fields in Stockholm (Lauria et al., 2022). Infill materials in the study consisted of a variety of materials, including ethylene propylene diene monomer (EDPM), styrene butadiene rubber (SBR), thermoplastic elastomer (TPE), thermoplastic olefin (TPO), organic materials (for example, cork, bark and coconut), and sand mixed with unknown material(s). They performed several analyses including total fluorine (TF), extractable organic fluorine (EOF), target PFAS analysis, and total oxidizable precursor assay (TOPA) on their samples.

Total fluorine analysis detected fluorine to be present in all samples (Table 3). Analysis using EOF found detectable levels of organic fluorine at a lower magnitude in less than 42% of the samples. For targeted analysis of PFAS, long-chain PFCAs were detected most frequently and at the highest concentrations in the turf backing. Long-chain PFCAs typically refers to compounds with seven or more fluorinated carbon atoms (Ecology, 2022a). TOPA conducted on ten selective samples generated negligible formation of PFCAs following oxidation.

Table 3: Results for total fluorine, EOF, and targeted PFAS analysis in Stockholm, Sweden (Lauria et al., 2022).

Turf component	Total fluorine (ppm)	Extractable organic Fluorine (ppb)	Detection Frequency (%)	Targeted Total PFAS analysis (ppb)	Detection Frequency (%)
Backing	16–313	ND–145	35	ND–0.63*	71
Infill	12–310	ND–179	35	ND–0.15	18
Blades	24–661	ND–192	53	ND	0^

* Some examples of the long-chain PFCAs detected include perfluorooctanoic acid (PFOA), perfluorododecanoic acid (PFDoDA), and perfluorotetradecanoic acid (PFTeDA), however, reproducible patterns were not observed in the PFCA profile.

^ Detection of total fluorine and extractable organic fluorine in the blade samples indicate the presence of some form of PFAS, most likely polymeric, which is not included in the list of targeted PFAS analytes.

PFAS in artificial turf has not been studied as extensively as PAHs, metals, and other volatile chemicals. However, the findings from the few peer-reviewed studies are consistent with testing done by non-peer-reviewed sources, as discussed below.

In a thesis published by H. D. Whitehead (2023), they analyzed 27 artificial turf blades for total fluorine, PFAS compounds, and organic fluorine (Whitehead, 2023). The total fluorine ranged from below the limit of detection (<LOD) to 2.9 µg F/cm^2. Four of the 27 samples did not contain target PFAS above the limit of quantitation (LOQ). Six PFAS above the LOQ were measured in the remaining 23 samples:

- perfluorobutanoic acid (PFBA) (0.69–19 ppb)
- perfluorobutane sulfonate (PFBS) (4.1–32 ppb)
- perfluoropentane sulfonate (PFPeS) (0.24–1.2 ppb)
- perfluorohexane sulfonate (PFHxS) (0.10–2.2 ppb)
- PFOA (0.41 – 5.0 ppb)
- perfluorodecanoic acid (PFDA) (0.37–1.3 ppb)

Municipalities have also performed targeted PFAS analysis in artificial turf. In 2022, the city of Portsmouth, NH tested a recently installed artificial turf field for the potential presence of PFAS (TRC Companies Inc., 2022). Two primary PFAS analyses (target PFAS analysis and TOP Assay) were conducted on representative samples obtained directly from the supplier.

- Targeted PFAS analysis did not detect any PFAS in the grass blades, but three individual PFAS[58] were detected in the backing, and six individual PFAS were detected in the walnut-based infill samples.
- The TOP assay resulted in four, six, and eight individual PFAS detections in the walnut-based infill, backing, and turf blades, respectively.

In 2024, the King County Department of Natural Resources and Parks, Water and Land Resources Division tested fifteen samples of artificial turf infill for the presence of EOF. None of the tested samples contained EOF higher than the detection limit (230–250 ppb) (King County, 2024).

In 2019, non-profit organizations Public Employees for Environmental Responsibility and The Ecology Center tested and reported detecting certain PFAS chemicals in the backing of the turf used for artificial fields. They reported 300 parts-per trillion (ppt) of 6:2 Fluorotelomer sulfonic acid (6:2 FTSA) in the backing of a brand-new turf and 190 ppt of perfluorooctanesulfonic acid (PFOS) in the backing of an old turf manufactured in 2004. They found 44–255 ppm total fluorine in eight artificial turf fiber samples (Ecology Center, 2019).

Research on chemicals in artificial turf is still ongoing, and data gaps remain. However, the limited results available provide us with evidence for the presence of PFAS in artificial turf. We note that fluorine and PFAS detections in artificial turf samples do not appear to be limited to a

[58]For a detailed list of PFAS detected please refer to the report attached to the TRC technical memorandum (TRC Companies Inc., 2022): https://www.cityofportsmouth.com/sites/default/files/2022-06/Technical%20Memorandum_Portsmouth_Final.pdf

specific component of the turf (for example, infill, backing, or blades). Similarly, detections reported for total fluorine and PFAS in infill are not limited to a specific material type. Together, this highlights the need to examine artificial turf as a whole product rather than focus only on specific components or types of materials used as infill. Due to the magnitude and the size of each turf field, the presence of these harmful chemicals in any concentration should be carefully considered.

6PPD in artificial turf

6PPD is used in tires at 0.4–2% (4,000–20,000 ppm) during manufacture as an antiozonant to protect the tire from breaking down. 6PPD slowly migrates from the tread to the surface of the tire where it reacts with oxidants like ozone to produce 6PPD-quinone and slow down the tire degradation process (Tian et al., 2021).

Studies show that 6PPD is still present in used tires, tire samples from recycling plants, and crumb rubber infills made from recycled tires used in indoor and outdoor artificial turf fields (Duque-Villaverde et al., 2024; Kawakami et al., 2022; Schneider, de Hoogd, Madsen, et al., 2020; F. Zhao et al., 2024; H. N. Zhao et al., 2023).

EPA tentatively identified 6PPD in tire samples from tire recycling plants and samples from turf infill during the non-targeted analysis conducted under the federal research action plan on artificial turf fields and recycled tire crumb rubber (US EPA, 2019). As reported by California DTSC, a California study detected 6PPD in crumb rubber collected from outdoor artificial turf fields (OEHHA, 2019).

A study in 14 European countries found 6PPD at average levels of 571 µg/g (571 ppm) in crumb rubber collected from artificial turf sports fields (Schneider, de Hoogd, Madsen, et al., 2020). A study in Japan found 6PPD in commercial samples of crumb rubber for turf fields at up to 2916 ppm (Kawakami et al., 2022).

More recently, a study in Spain aimed at developing methods for testing chemicals in turf fields detected 6PPD in new crumb rubber infill samples at up to 2085 ppm (Duque-Villaverde et al., 2024). This study found similar levels of 6PPD in car tire and commercial samples, but alternative infill and playground samples had a much lower detection level. This suggests turf fields with crumb rubber infill are likely a larger contributor to 6PPD in the environment. Some of the studies that detected 6PPD in crumb rubber are listed in Table 4 below.

Table 4: Analytical results of 6PPD found in rubber samples used as infill in artificial turf fields.

Product types	6PPD Concentrations (ppm)	Detection Frequency	Reference
Crumb rubber from turf fields	0.37–2085	8/8 (100%)	(Duque-Villaverde et al., 2024)
Commercial crumb rubber samples	62–2916	37/46 (80%)*	(Kawakami et al., 2022)

Product types	6PPD Concentrations (ppm)	Detection Frequency	Reference
Uncoated crumb rubber from manufacturer	595–2912	25/25 (100%)	(Schneider, de Hoogd, Madsen, et al., 2020)
Uncoated crumb rubber from sports fields	5.1–2064.8	47/47 (100%)	(Schneider, de Hoogd, Madsen, et al., 2020)
Crumb rubber samples from turf fields in schools and parks	0.047–95	9/9 (100%)	(H. N. Zhao et al., 2023)
Rubber samples from school fields in China	0.180–12.87	40/40 (100%)	(F. Zhao et al., 2024)

*6PPD was not detected in synthetic rubber (EPDM) samples and Thermoplastic elastomer (TPE) samples.

Volume of the product sold or present in the state

As of 2024, an estimated 18,000 and 19,000 artificial turf fields existed in the US, with approximately 1,200 to 1,500 new fields installed each year, most using recycled tire crumb rubber as infill (US EPA, 2024f). Other filling materials include ethylene propylene diene monomer (EPDM), thermoplastic elastomers (TPE), or natural materials such as sand, cork, coconut fiber, or walnut shells (Lauria et al., 2022).

The Synthetic Turf Council highlights the growing demand for artificial turf fields with more than 8,000 multi-use artificial turf sports fields being used in schools, colleges, parks, and professional sports stadiums in North America (Synthetic Turf Council, n.d.). According to their 2020 report, North America had over 265 million square feet of installed turf and 777 million pounds of infill (Synthetic Turf Council, 2020).

The exact number of artificial turf fields installed in Washington is unknown, but online research and outreach efforts have identified more than 100 known artificial turf fields across the state. Since we do not have an accurate estimate on the total number of fields in Washington, we used available information to demonstrate the volume of priority products in some bigger population areas of the state, such as King County and Seattle.

According to information received through correspondence, King County Parks has installed 23 crumb rubber artificial turf fields from 2006 to 2021 (King County Parks, 2024). The average size of a field ranges from approximately 57,000 ft^2 for a football field to 81,000 ft^2 for a soccer field. This equates to approximately 1.3 to 1.9 million ft^2 of artificial turf installed just in King County parks. Each field has been reported to use between approximately 20,000–40,000 tires for crumb rubber infill (Gomes et al., 2021).

Seattle Parks and Recreation has 27 artificial turf fields with plans to add another two by 2030 (Seattle Parks and Recreation, 2024). An artificial turf field requires about 4 to 15 pounds infill per square foot and 20 tons of other additional plastics (Claudio, 2008). This equates to an estimate of 1.54 million ft^2–2.19 million ft^2 of artificial turf, 4,320–13,500 tons of infill, and 540 tons of additional plastic use in communities within the Seattle Parks and Recreation.

According to a turf recycling company, each field lasts up to ten years with proper maintenance and weighs around 220 to 240 tons (Re-Match, n.d.). Recycling options for turf fields are currently limited in the United States, and it was estimated that the turf industry will generate one to four million tons of waste in the next ten years (York Daily Record, 2019). Due to limitations in turf recycling, all turf fields that cannot be recycled end up in our landfills, making them unsuitable for a circular economy (Murphy & Warner, 2022).

Potential for exposure to priority chemicals from the product

People and wildlife can be exposed to PFAS and 6PPD during the manufacturing, use, and disposal of artificial turf. Figures 3 and 4 demonstrate known and potential exposure pathways for sensitive species and populations for PFAS and 6PPD from artificial turf.

The primary exposure pathways for sensitive populations are inhalation, unintentional ingestion of inhaled particles, absorption through the skin, or transfer to the mouth after skin contact. PFAS and 6PPD can be released into the environment during product degradation, use, and disposal. Once in the environment sensitive species, such as coho salmon, can be exposed to 6PPD. The potential exposure pathways for sensitive populations and sensitive species are discussed below.

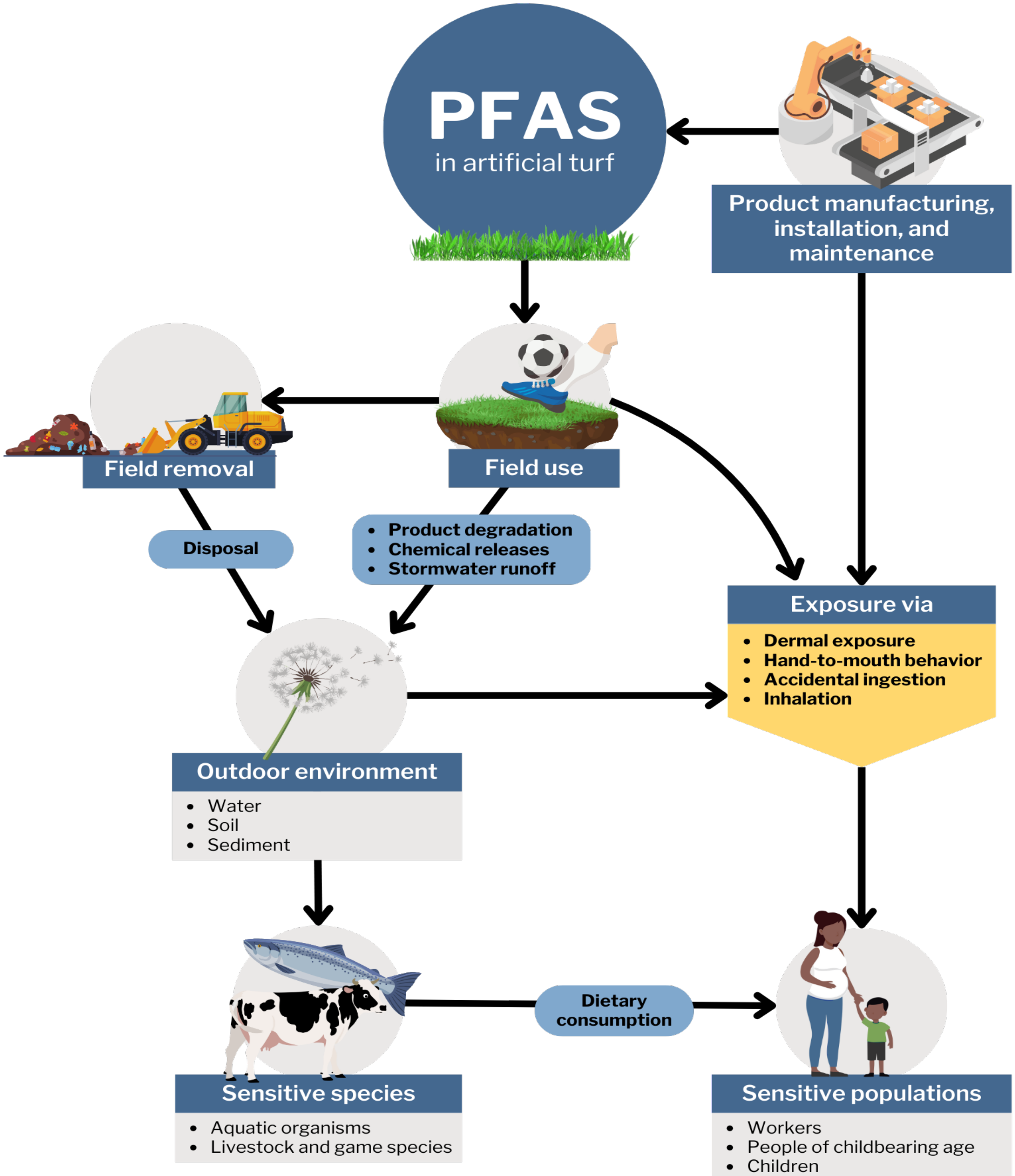

Figure 3: Pathways of potential exposure to PFAS from artificial turf in sensitive populations and sensitive species.(See Appendix D for a step-by-step description of this figure.)

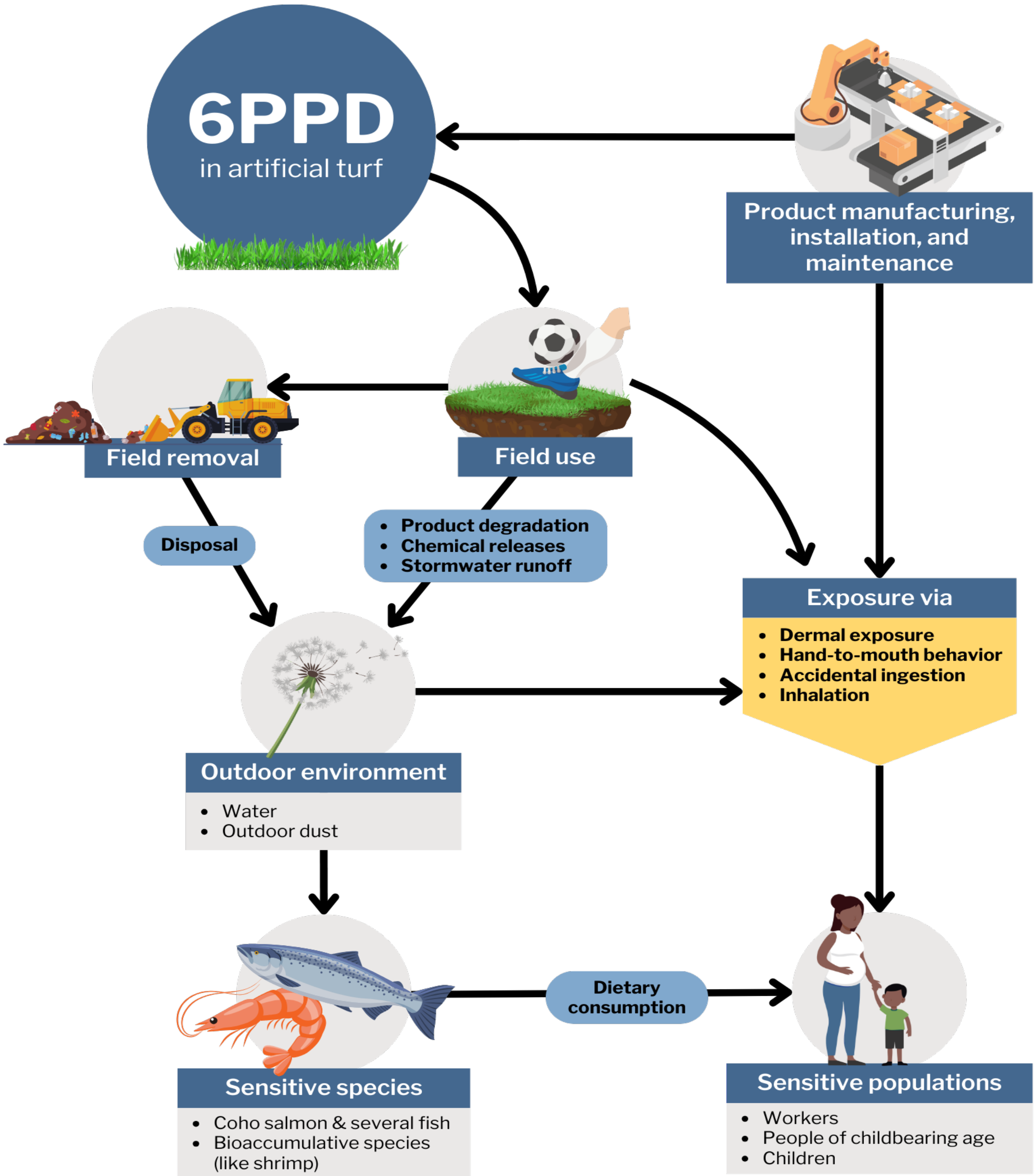

Figure 4: Pathways of potential exposure to 6PPD from artificial turf in sensitive populations and sensitive species. (See Appendix D for a step-by-step description of this figure.)

Sensitive populations

Sensitive populations–including children, people of childbearing age, and workers–are potentially exposed to PFAS and 6PPD from artificial turf. Children are biologically susceptible to developmental and immune system health effects associated with PFAS exposure (Ecology, 2022a). Artificial turf fields are commonly used by children, resulting in the potential for widespread exposure to PFAS and 6PPD.

Washington Youth Soccer reports 93,000 children are registered for youth soccer leagues all across the state, which accounts for greater than 7% of Washington State school-aged children (OFM, 2019; Washington Youth Soccer League, n.d.). In addition to soccer, children participate in sports and recreational activities on athletic fields, including football, lacrosse, ultimate frisbee, general physical education, and play. Soccer is the top field sport among King and Pierce County children but ultimate frisbee and flag football are fast-growing field sports in Washington, identified as the second and third most common field sports for King County youth after soccer (Aspen Institute, 2019).

PFAS and 6PPD chemicals have been identified as reproductive toxicants. 6PPD exposure in laboratory rodents causes difficult birth or prolonged labor that can lead to death of offspring (DTSC, 2022b). Some members of the PFAS chemical class are associated with low birth weight, hypertension of pregnancy, or decreased sperm quality (Ecology, 2022a). Given these health hazards, people of childbearing age, including pregnant people, are a sensitive population. People of childbearing age and pregnant people exposed to artificial turf fields include both recreational users and occupational groups such as coaches and staff of sports leagues and professional athletes.

In addition to people exposed through field activities, workers who install, maintain, and remove artificial turf fields may be exposed to PFAS and 6PPD in their occupation.

People with allergic contact dermatitis or positive patch test results to other PPD chemicals may be especially sensitive to the skin-sensitizing potential of 6PPD. This could include occupationally exposed people who handle crumb rubber infill during installation, maintenance, or removal, as well as people of all ages who recreate on these surfaces.

Sensitive populations can be exposed to PFAS and 6PPD from a variety of exposure pathways. Exposure pathways relevant to sensitive populations are described below.

Ingestion pathway

Ingestion exposure can occur when turf components including grass blades or infill fragments are inadvertently swallowed through hand-to-mouth transfer after skin contact with turf materials (Lopez-Galvez et al., 2022; US EPA, 2024g, 2024f).

Questionnaires and analysis of video footage show that turf users demonstrate hand-to-mouth behaviors that can potentially lead to exposure (OEHHA, 2019; US EPA, 2024g, 2024f). In the federal study of exposure to crumb rubber infill, questionnaires were administered to turf users to identify behaviors that can cause exposure. Drinking beverages, hand or body contact, and sitting with bare skin touching the turf were exposure-related behaviors identified in questionnaires by 81%, 75%, and 50% of participants, respectively. Video analysis showed that youth football players had particularly high object-to-mouth activity because of mouthguard use (US EPA, 2024f).

Although findings have varied, some studies suggest that 6PPD can be bioavailable in the gastrointestinal tract after ingestion. An in vitro bioaccessibility study published by the US National Toxicology Program extracted and detected 6PPD from crumb rubber when using simulated saliva followed by simulated gastric fluid (NTP, 2019). Another laboratory study tested 11 artificial turf crumb rubber samples and found 6PPD to have the highest bioaccessible fraction in simulated gastric and gastrointestinal fluid out of 19 other rubber-derived chemicals (McMinn et al., 2024). In contrast, a migration and monitoring study on 10 crumb rubber samples detected no migration of 6PPD into simulated saliva and gastric fluid (Schneider, de Hoogd, Haxaire, et al., 2020).

Dermal exposure pathway

There is potential for exposure to PFAS and 6PPD from skin contact with turf field components, adherence of granules and smaller particles to the skin, and broken skin. Researchers have analyzed the turf field chemicals present on hand and skin wipes from field users, but 6PPD and PFAS were not assessed in the peer-reviewed studies of hand wipes that we located. However, evidence suggests that some ionic PFAS, such as perfluorocarboxylic acids (PFCAs) can penetrate skin layers (Ragnarsdóttir et al., 2022, 2024). Dermal penetration may be more likely for neutral PFAS, but FTOHs were not included in the list of neutral PFAS with potential for dermal absorption (Kissel et al., 2023). Because there is little information about which PFAS chemicals can be present in artificial turf it is difficult to assess the extent that dermal penetration contributes to exposure.

Regarding 6PPD, laboratory experiments have found that 6PPD and 6PPD-quinone are released from tire crumb rubber granules into simulated sweat fluid (Armada et al., 2023; Schneider, de Hoogd, Haxaire, et al., 2020). These studies suggest that when people come into contact with crumb rubber granules, chemicals can from the rubber into the sweat on the skin. However, they do not address whether the chemicals then pass through the skin into the body.

Inhalation pathway

Some members of the PFAS chemical class are volatile enough to result in inhalation from the gas phase (Zuccaro et al., 2023). PFAS chemicals are present in household dust, including the fine respirable fraction, and may be present in dust on artificial turf surfaces (Gustafsson et al., 2022). Similarly, 6PPD-quinone can be found in the gas phase of urban air samples (L. Tian et al., 2024). Testing has not yet determined whether gas phase concentrations of 6PPD-quinone are elevated at turf fields. High physical activity levels, such as adults and children engaged in sports, increase the potential for inhalation exposure because of elevated respiration rates (US EPA, 2011b).

Another potential exposure pathway is the inhalation of particles and dust that carry 6PPD or PFAS. As plastic and rubber components of artificial turf wear and degrade through mechanical shear during use, dust, and microplastic particles could be generated that may result in inhalation exposure to 6PPD and PFAS (DTSC, 2024; Eunomia, 2018; Kole et al., 2023).

Fine dust from the surface and infill of turf fields were collected in the federal research studies on crumb rubber (US EPA, 2024f). Sieved dust and drag samples were analyzed for selected chemicals, but neither PFAS nor 6PPD were included in the analysis. However, the report concluded that due to "the small particle sizes, field dust may be an important medium for inhalation, dermal and ingestion exposures" to other chemicals present in artificial turf fields (US EPA, 2024f).

Take home exposure

Exposure to artificial turf components does not stop at the field (Kole et al., 2023). In one study, a majority of participants noted tire crumbs on their bodies, and in their cars and homes (US EPA, 2024f). This highlights the potential for a take-home exposure pathway for 6PPD in crumb rubber that could expose other members of a household. Similarly, turf grass blades may stick to people and their gear after field use, ending up in cars and homes.

Sensitive species

Sensitive species have the potential to be exposed to PFAS, 6PPD, and 6PPD-quinone released from artificial turf to the environment.

PFAS are persistent in the environment, and some are bioaccumulative and toxic to aquatic organisms (T. Ma et al., 2022). Some PFAS can be absorbed by chickens, livestock, and dairy animals, bioaccumulating in their organs or passing into their eggs, meat, and milk (Health, n.d.-a).

6PPD and 6PPD-quinone are toxic to several fish species, and 6PPD-quinone is acutely lethal to coho salmon at extremely low concentrations (95 ng/L LC_{50}) (Z. Tian et al., 2022). Research on the bioaccumulation of 6PPD and its breakdown products, including 6PPD-quinone, into organisms is ongoing. Current evidence suggests 6PPD has low to moderate bioaccumulation potential (ITRC, 2024; US EPA, n.d.-b). Researchers were able to recover 6PPD and 6PPD-quinone from some fish (Ji et al., 2022), as well as shrimp (Q. Zhang et al., 2024) found at aquafarms and local markets in Shanghai.

PFAS release potential

Both total fluorine and measurement of specific PFAS have been conducted on artificial turf samples and results indicate the presence of both types of PFAS in these materials (Ecology Center, 2019; Lauria et al., 2022). It was suggested that the primary source of fluorine in samples is likely fluoropolymers (Lauria et al., 2022). However, other non-polymeric PFAS have been detected in samples of artificial turf (Ecology Center, 2019; Lauria et al., 2022; TRC Companies Inc., 2022; Zuccaro et al., 2023). Therefore, there is the potential for the release of both polymeric PFAS (fluoropolymers) in the form of microplastics as well as non-polymeric PFAS from artificial turf.

Artificial turf infill, blade fibers, and backing materials have the potential to spread across the environment as microplastics as the materials degrade over time. This may be particularly important concerning stormwater runoff from artificial turf fields. Studies suggest that artificial turf generates greater runoff than natural grass due to its porous nature (Cheng et al., 2014). It has been reported that some artificial turf fields incorporate built-in drainage systems into their design, facilitating increased runoff (Cheng et al., 2014). Microplastics from artificial turf have the potential to be mobilized to the environment through physical processes such as adherence to clothes and shoes of people who participate in recreational or maintenance activities on artificial turf fields (Kole et al., 2023).

It has been estimated that wear of artificial grass fibers (which the authors refer to as grass piles) would result in particle loss of 63 kg per year from a regular-sized turf field (7,526 m^2). The authors infer that this could be a source of PFAS entering the environment (Kole et al., 2023). For backing materials, it was estimated that a regular-sized field would generate 271 kg per year of backing material particles; although, due to the location of these particles at the bottom layer, it is unclear what proportion may migrate and be released from the field (Kole et al., 2023).

In addition, artificial turf grass fibers were detected in 50% of samples collected from the Mediterranean Sea surface and river waters. The authors reported that artificial turf fibers represented 15% of the meso- and microplastic content from the samples (de Haan et al., 2023). When artificial turf is discarded in landfills, it may release PFAS into the environment, including microplastics. This suggests that, despite some information gaps, PFAS are likely released into the environment from artificial turf as a microplastic particles and fibers. Some of these pollutants may persist in aquatic systems, where they can expose sensitive species.

6PPD release potential

6PPD can be released from artificial turf to the environment. Stormwater runoff from roads where tires are used is well documented as a source of tire wear particles, 6PPD, and 6PPD-quinone entering the environment (Y. Jiang et al., 2024). Similarly, artificial turf releases crumb rubber particles that may contain 6PPD and 6PPD-quinone into the environment in significant quantities.

In a review article focused on crumb rubber particles released from artificial turf fields, it was estimated that without mitigation measures, 948 kg of crumb rubber particles would potentially enter the environment each year from a single regular-sized artificial turf field (7,526 m^2) by known pathways (Kole et al., 2023). This estimate does not take into account snow removal from the artificial turf field, which would apply in colder climates such as those found in some areas of Washington. Taking into account snow removal, the authors estimate an additional 830 kg would potentially enter the environment each year from a regular-sized field, for a total of 1,778 kg per year (Kole et al., 2023).

Pathways considered in this estimate, per Kole et al., 2023, include:

- Snow clearing (830 kg per yr)
- Brushing (567 kg per yr)
- Grass verges (203 kg per yr)
- Surface water (125 kg per yr)
- Particles carried by players (46kg per yr)
- Raking (5kg per yr)
- Loss during application of refill (2kg per yr).

Notably, the authors estimated that a regular-sized field requires an average of 3,312 kg of refill (crumb rubber added to maintain the field) each year. The authors suggest the difference of

1,534 kg per year in these estimates is due to the contribution of unknown pathways of tire particle release to the environment that require additional study.

Stormwater is efficiently transported through some artificial turf materials, and the associated runoff contains other chemicals found in the crumb rubber such as other hydrocarbons and metals. This highlights that artificial turf is a potential source of 6PPD and 6PPD-quinone, as well as crumb rubber particles in the form of microplastics that contain 6PPD and 6PPD-quinone entering the environment.

Further, once in the environment, 6PPD and 6PPD-quinone from crumb rubber particles used as artificial turf infill can expose sensitive species. This includes coho salmon, which are highly susceptible to these chemicals as described previously (Ecology, 2024c).

Availability of potential safer alternatives

There are alternative products on the market that may avoid the use of PFAS and 6PPD. We have not determined whether these alternatives are feasible to meet the range of performance requirements for the varied uses of artificial turf products. Potential alternatives are discussed below. During the next phase of implementation of Safer Products for Washington (Phase 3), we will evaluate alternatives and determine whether they meet our criteria as safer, feasible, and available before recommending any regulatory actions.

- Natural grass turf fields are natural alternatives to artificial turf fields (TURI, 2019). The Toxic Use Reduction Institute at UMass Lowell has published guidance for developing maintenance programs for organic grass athletic fields (TURI, 2021). The majority of playing fields in Washington are still natural grass turf fields.
- Entire artificial turf field systems claiming to be PFAS-free are currently available in the market (AstroTurf, n.d.; Watersavers Turf, n.d.).

Finding alternatives for a single or specific components of the artificial turf field, and chemicals used in manufacturing processes could reduce use of PFAS and 6PPD. A hazard-based analysis of some infill materials in relation to crumb rubber highlighted the complexity of comparing alternatives, although the analysis did not focus on PFAS or 6PPD (Massey et al., 2020). The article suggested organically managed natural grass as a safer alternative to artificial turf (Massey et al., 2020).

Some materials available as alternatives are listed below (Synthetic Turf Council, n.d.; TURI, 2019).

- Coated Rubber Infill: Crumb rubber infill is completely encapsulated with colorants, sealers, or anti-microbial to provide additional aesthetic appeal and reduce dust during the manufacturing process.
- Ethylene Propylene Diene Monomer Infill: A durable elastomer manufactured from synthetic rubber produced with mostly non-recycled materials. This infill has high resistance to abrasion and can be used in all types of climates.
- Organic Infill: Organic materials such as cork, or coconut shell fibers are currently available as an alternative to the crumb rubber infill. They can be utilized in sports applications as well as for landscaping and recycled directly into the environment at

the end of life. However, organic material may be too light and float on the surface and are more prone to bacterial contamination (King County Parks, 2024).

- Sand (silica) Infill: Pure silica sand infill is one of the original infilling materials that can be used as a standalone product or in combination with crumb rubber infill systems. Pure silica sand may contain crystalline sand that is much smaller in size compared to regular beach sand which may have particles small enough to be respirable (Santa Clara County Medical Association, 2024).
- Coated Silica Sand Infill: High-purity silica sand is coated with a soft or rigid coating of elastomeric or acrylic substances to seal it from bacteria and provide superior performance and durability. It is available in different sizes and is used as a homogeneous infill providing ballast and shock-absorbing qualities to an artificial turf field.
- Thermoplastic Elastomer (TPE) Infill: TPE infill is similar to recycled crumb rubber infill that is available in many different variations. They are usually copolymers of ethylene, butadiene and styrene or polyurethane elastomers depending on the formulation. Currently, there are a lot of manufacturers offering eco-friendly and bio-based TPE systems to be used as infills in artificial turf fields (Franplast, n.d.; Guardian Innovations LLC, n.d.). King County Parks is currently planning to move away from recycled crumb rubber and replace it with TPE infill (King County Parks, 2024).

Potential alternatives to PFAS-containing polymer processing aids (PPA) are currently available in the market. These may help reduce PFAS in the plastic components of turf. Silike's PFAS-free PPA is an organically modified polysiloxane product that has a wide range of applications. The manufacturer claims it can be used in the extrusion of artificial grass (Siliketech, 2024).

Chapter 3: Cosmetics

Overview

Priority product

The scope of this priority product includes cosmetics intended to be rubbed, poured, sprinkled, or sprayed on, introduced into, or otherwise applied to the human body for cleansing, beautifying, promoting attractiveness, or altering the appearance as defined in RCW 70A.560.010(1)[59] and RCW 69.04.012.[60]

Cosmetics with active ingredients are included in this definition. However, active ingredients themselves are not subject to potential regulation. The scope of this product category includes products intended for non-professional or professional use.

Example products included in this definition include, but are not limited to:

- Cleansing shampoos
- Deodorant
- Fingernail polishes
- Hair colors
- Shaving creams
- Makeup
- Perfumes
- Permanent waves
- Skin moisturizers

Priority chemical

Cyclic volatile methylsiloxanes (cVMS) were defined as a priority chemical class in our previous legislative reports, Identification of Priority Chemicals Report to the Legislature: Safer Products for Washington Cycle 2 Implementation Phase 1[61] and Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1[62] in Chapter 7: Technical Support for Cyclic Volatile Methylsiloxanes (Ecology, 2024b, 2024c).

Background

cVMS are used as solvents or as hair- or skin-conditioning agents in cosmetic formulations at concentrations generally between 5–20%, and sometimes up to 95% of the product by weight (ECHA, 2019). Cosmetic products release cVMS into indoor and outdoor environments through evaporating into the air during product use. The most common cVMS used in cosmetics are

[59]app.leg.wa.gov/rcw/default.aspx?cite=70A.560.010
[60]app.leg.wa.gov/rcw/default.aspx?cite=69.04.012
[61]apps.ecology.wa.gov/publications/summarypages/2404025.html
[62]apps.ecology.wa.gov/publications/summarypages/2404026.html

octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), and dodecamethylcyclohexasiloxane (D6).

Volume estimates for priority product-chemical combination

The volume of priority chemicals associated with the product

Cosmetics are a significant use of cVMS, and this is demonstrated by:

- Concentrations of cVMS reported in cosmetic products
- Market prevalence of cVMS in cosmetic products
- Frequency of cosmetic product use in the general US population
- Multi-million-dollar industry for cosmetic products in Washington

The most common cVMS found in cosmetics are D4, D5, and D6; these cVMS are all high-production volume chemicals as defined by EPA (Table 5). The largest use of cVMS is in manufacturing silicone polymers and compounds, followed by use in formulations such as cosmetics. cVMS are intentionally added to cosmetics as ingredients.

The primary uses of D4, D5, and D6 in cosmetic products are as hair-conditioning agents, skin-conditioning agents (emollients), or as solvents/diluents (ECHA, 2019). D4, D5, and D6 are used in producing silicone polymers used in cosmetics and are present as residuals in these ingredients.

Table 5: The 2019 Nationally Aggregated Production Volume for select cVMS (US EPA, n.d.-b).

cVMS	2019 Production Volume (lbs.)
Octamethylcyclotetrasiloxane (D4), CASRN: 556-67-2	250,000,000 – <500,000,000
Decamethylcyclopentasiloxane (D5), CASRN: 541-02-6	100,000,000 – <250,000,000
Dodecamethylcyclohexasiloxane (D6), CASRN: 540-97-6	1,000,000 – <10,000,000

ECHA evaluated these three common cVMS (D4, D5, and D6) and proposed a restriction for their use in consumer and professional products in the European Union (ECHA, 2019). Some of the information presented in ECHA's restriction proposal, such as functional uses and concentrations of cVMS in cosmetics products, is assumed to be similar to the market in Washington.

Concentrations of cVMS used in cosmetics described in ECHA's report range, with median concentrations of D5 use reported as 5–20%, and a maximum concentration of up to 95% in products (Table 6). D6 was reported at a maximum use concentration of up to 50% in products (Table 7) (ECHA, 2019).

The use of silicone polymers is common in cosmetics; however, evidence suggests residual formulation concentrations of cVMS in cosmetics associated with the use of silicone polymers would be generally less than 0.1% (ECHA, 2019). It is important to note that the median concentrations reported by ECHA represent only products where cVMS are used as ingredients and are not median concentrations across all cosmetic products generally.

Table 6: The concentration of D5 used in cosmetic products (excluding wash-off products). Adapted from Table 4 of ECHA Annex XV Restriction Report for D4, D5, and D6 (ECHA, 2019).

Product Category	Median reported Concentration (%w/w)	Maximum reported concentration (%w/w)
Skincare products	5	90
Make-up and makeup-removing products	10	90
Deodorant and antiperspirants	10	60
Hair care (leave-on)	20	95
Others (lip, sun protection, tanning products, etc.)	5	75

Table 7: The concentrations of D6 in cosmetic products (rinse-off and leave-on products). Adapted from Table 4 of ECHA Annex XV Restriction Report for D4, D5, and D6 (ECHA, 2019).

Product Category	Maximum reported concentration (%w/w)
Skincare products	18
Make-up and makeup-removing products	18
Deodorant and antiperspirants	18
Hair care (leave-on)	18
Others (lip, sun protection, tanning products, etc.)	50
Wash-off	18
Wipes	8

A peer-reviewed article by Dudzina et al. (2014) used to support ECHA's report highlights two important points:

1. cVMS chemicals used in products may vary in purity or be used as mixtures.
2. Cosmetic formulations are similar across several markets (United States, Canada, and the European Union) for cVMS concentrations in products (Dudzina et al., 2014).

In their analysis of cosmetics purchased in the Netherlands in 2011, 47 of 51 cosmetic and personal care products contained D4, D5, or D6 (Dudzina et al., 2014). The high detection frequency was likely due to the author's product selection criteria, which included the examination of ingredient lists and the selection of products they thought would contribute the most to cVMS exposure (Dudzina et al., 2014).

- D5 was the most common cVMS detected, with an average concentration of 60.5 mg/g or around 6% by weight and a maximum concentration of 35% (Dudzina et al., 2014).

- Concentrations of D4 were much lower, with an average of 0.18 mg/g (0.018%). The authors suggest this is likely a result of contamination of D5 and D6 used as ingredients in these products rather than the intentional use of D4 (Dudzina et al., 2014).

The analysis from Dudzina et al. is consistent with two previous studies that found D5 and D6 are the most common cVMS in cosmetics and personal care products (Horii & Kannan, 2008; R. Wang et al., 2009). The authors note that, overall, these studies suggest “the US and Canadian markets of C&PCPs are remarkably similar in terms of cVMS levels” and comparable to those in the Netherlands and Switzerland (C&PCPs refers to cosmetics and personal care products) (Dudzina et al., 2014). These results are generally consistent with the concentration ranges reported by the Cosmetic Ingredient Review (Johnson et al., 2011).

To further understand the prevalence of cVMS in cosmetic products, we referred to the Chemicals and Products Database (CPDat), accessed through the EPA ChemExpo application. For the three most common cVMS, the number of personal care product results found in ChemExpo were (US EPA, n.d.-a):

- 49 product entries for D4
- 9,159 entries for D5
- 2,206 entries for D6

These figures are out of a total of 98,285 entries in ChemExpo for personal care products, indicating an overall presence for cVMS of around 11.6% (US EPA, n.d.-a).

In addition, we consulted the Mintel GNPD for D4, D5, D6, and cyclomethicone (a mixture of cVMS) in beauty and personal care products in North America. The Mintel GNPD collects information from product labeling, including ingredient and formulation information. The search results in over 14,000 product entries that contain cVMS out of a total of around 365,000 products (Mintel, n.d.). Product types in Mintel GNPD with cVMS listed as ingredients include skincare, color cosmetics, hair products, deodorants, fragrances, soap and bath products, and shaving and depilatories. This further supports the finding that the use of cVMS in cosmetics spans a diverse range of product subtypes (Mintel, n.d.).

We used Mintel GNPD to estimate the market prevalence of cVMS in cosmetics by querying beauty and personal care products in North America over the last ten years (2014–2024). The calculated market prevalence of cVMS ranged from 0.25% of products for D4, to 7.2% of products for D5 (Mintel, n.d.).

For comparison, ECHA reported that 11% of cosmetic formulations contain D4, D5, or D6 above a concentration of 0.1%. Product types where greater than 10% of products on the market contain cVMS included makeup and lipsticks, skincare, deodorants and antiperspirants, both sun and self-tanning products, and hair styling products (ECHA, 2019).

Additionally, cosmetics reported to the California Safe Cosmetics Program demonstrated the use of cVMS in these products, with 9 products reported for D4, 714 products reported for D5, and 148 products reported for D6 (CDPH, n.d.). A silicone polymer ingredient was reported in 108 products (Siloxanes and silicones, di-Me, hydrogen-terminated (Bis-hydrogen dimethicone;

Hydrogen dimethicone), CAS RN: 70900-21-9)—this ingredient may contain cVMS as residuals from manufacturing (ECHA, 2019).

The volume of the product sold or present in the state

Most American consumers daily use cosmetic products, and most people use 6 to 12 cosmetics products each day (US FDA, 2023). The beauty and personal care market in the United States is estimated to generate revenue of approximately $100 billion in 2024 (Statista, n.d.-a). Washington accounts for approximately 2.3% of the United States population, suggesting an estimated market revenue for cosmetic products of around $2.3 billion for Washington in 2024 (US Census Bureau, 2024). Although we do not know the precise volume of cosmetic products this represents, this information suggests that a large volume of cosmetic products containing cVMS are sold in Washington.

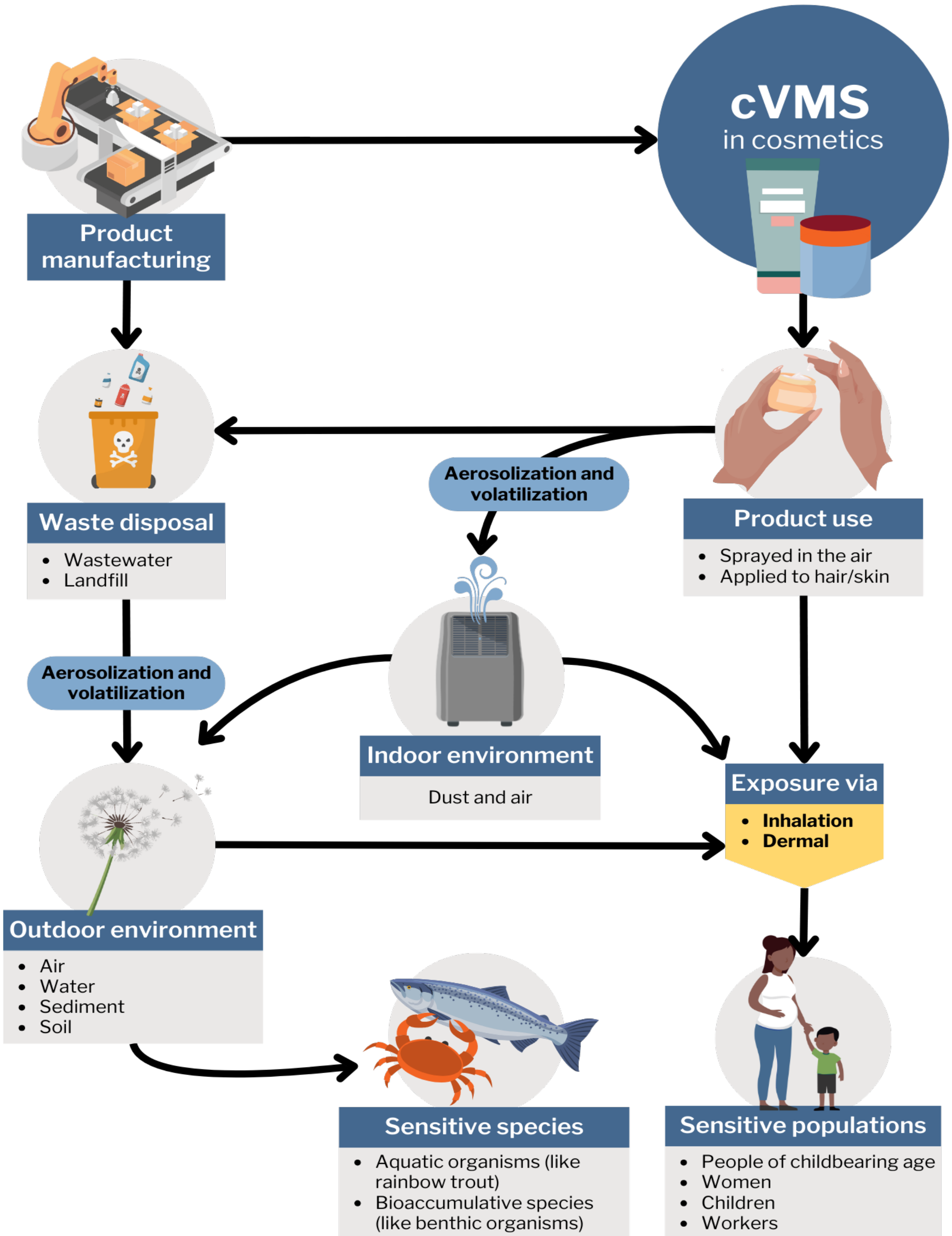

Figure 5: Pathways of potential exposure to cVMS from cosmetics in sensitive populations and sensitive species. (See Appendix D for a step-by-step description of this figure.)

Potential for exposure to priority chemicals from the product

People and wildlife can be exposed to cVMS from cosmetics through several pathways (Figure 5). People, including sensitive populations, are exposed to cVMS from cosmetics primarily through inhalation. It has been reported that over 90% of cVMS in personal care products are released into the air during product application (S. Xu et al., 2019).

As a result, cVMS are found as indoor air contaminants, and the concentrations measured reflect the use of cosmetic products (Fromme, 2019). For example, in a study of 70 offices in the United States, higher cVMS concentrations were related to the density of persons per room and it was suggested that this was due to the use of personal body care products. The highest concentrations measured were typically for D5, the most common cVMS used in cosmetics. Levels increased during the day compared to at night, which further supports the assertion that indoor air concentrations of cVMS are related to personnel occupancy and use of products (Fromme, 2019).

To our knowledge, there is no data available on cVMS in outdoor ambient air in Washington. However, studies in other areas have found cVMS in ambient air. In a study in Chicago, IL, cVMS concentrations in ambient air ranged from a median of 0.004 ug/m^3 for D6 to 0.13 ug/m^3 for D5 (Fromme, 2019). A recent study in New York City, NY found median levels of cVMS ranging from 11 ng/m^3 for D3 to 230 ng/m^3 for D5 in ambient air. In the same study, maximum concentrations detected ranged from 62 ng/m^3 to 1,400 ng/m^3 for D3 and D5, respectively (Brunet et al., 2024).

The authors note this is consistent with several other studies that find D5 is usually observed at the highest concentration in ambient air relative to other cVMS (Brunet et al., 2024).

Dermal exposure is not expected to be a primary route of exposure to cVMS from cosmetics. However, studies have demonstrated that there is a potential for exposure through skin contact with products that contain cVMS, secondary to inhalation. In a review of dermal exposure to cVMS, it was reported that the majority of cVMS applied to the skin evaporates from the surface, but a minimal amount is absorbed through the skin (<0.1–1%) (Clewell et al., 2024).

Cosmetic products are a significant source of cVMS entering the environment in Washington with the potential to expose sensitive species. Although we do not know the precise amount of cVMS entering the environment from cosmetic products in Washington, we can infer this finding from an analysis conducted by ECHA for the European Union.

Analysis by ECHA concluded, "Cosmetic products represent by far the largest use and releases of D4, D5, and D6 to the environment" (ECHA, 2019). In their analysis, ECHA estimated the releases for two scenarios for D4, D5, and D6, which they described as a "low release scenario" and a "high release scenario". The "low release scenario" considered only estimated releases to water, while the "high release scenario" considered releases to all environmental compartments (including atmospheric) (ECHA, 2019).

The analysis estimated the releases for the primary uses of cVMS, including:

- Leave-on cosmetic products
- Pharmaceutical products and medical devices

- Wash off cosmetic products
- Detergents, household care, and vehicle maintenance products
- Dry cleaning, polyurethane foam, cleaning of art and antiques
- Formulation of mixture (industrial)
- Impurity in silicone polymers (excluding cosmetics)
- Impurity in silicone polymers used in cosmetics

In their analysis, ECHA estimated that cosmetic products account for 91% of overall releases of D4, D5, and D6 to the environment. This estimate increases to 94% when releases from impurities in silicone polymers used in cosmetic products are considered (ECHA, 2019).

We expect the share of estimated cVMS releases from cosmetic products in Washington to be similar to that in the European Union, even though the total volume of releases will differ. We recognize that these are estimates and that the overall contribution to releases may not precisely reflect those in Washington. Despite potential differences between locales, ECHA's analysis clearly shows that cosmetics are a major source of cVMS entering the environment from consumer products.

Sensitive populations

Cosmetics such as personal care products are used by sensitive populations including children, women, people of childbearing age, and workers. Sensitive populations may be exposed to cVMS through indoor air as bystanders when others use cosmetic products. cVMS are linked to hazards such as reproductive and developmental toxicity and endocrine disruption, raising concerns about exposure in sensitive populations (Ecology, 2024c).

Women

In general, women use more cosmetic products than men and they have an increased potential for exposure to cVMS from cosmetics relative to men. According to a Groupon Merchant survey, women spend an average of $3,756 per year on cosmetics while men spend less, averaging $2,928 per year (GROUPON Merchant, 2024). This aligns with a survey conducted by the Environmental Working Group (EWG), which found that women use an average of 13 personal care products daily, while men use 11 (EWG, 2023). This suggests women likely have higher exposures to cVMS from cosmetic products.

This assertion is supported by a study of college students in southwestern China, which found levels of cVMS were an order of magnitude higher (around 10 times higher) in blood plasma samples from female students than in samples from male students (Guo et al., 2022). Differences in spending and potential for exposure to cVMS from cosmetics may reflect the types of products and frequency of use by women relative to men, such as as more frequent use of makeup and makeup remover products. However, to our knowledge, this link has not been definitively established.

Children

Children have been reported to have higher exposure doses to cVMS relative to adults (Tran et al., 2019). Children have higher surface area to volume ratios for potential inhalation exposure to cVMS from cosmetics.

cVMS have been measured in the indoor air of schools and daycare centers, indicating a potential for exposure. The highest concentrations measured were for D5, the most common cVMS in cosmetics, and ranged from 0.65 ug/m^3 (mean) measured in a study of 6 schools in the USA, up to 10.6 ug/m^3 (median) measured in 63 schools in Germany (Fromme, 2019). Other cVMS have been measured across several studies in schools and daycare centers, and detections were reported for D3, D4, and D6 as well (Fromme, 2019).

Workers

Some occupations may have higher exposures to cVMS from cosmetic products due to a high frequency of cosmetic use and the techniques used with products as part of their work. cVMS are found in many hair care products and contaminate indoor air during the use of these products. Additionally, high-temperature styling tools applied to hair can increase cVMS emissions by 50–310% (J. Jiang et al., 2023).

In occupations where these products are used regularly, such as hair salons, workers likely have higher exposures to cVMS from these cosmetic products. A study in the 1990s reported air concentrations of 0.12 mg/m^3 for barbers and beauticians workplaces (Fromme, 2019). Air concentrations of D5 ranging from 0.03 mg/m^3 up to 33.7 mg/m^3 have been reported in workplaces that formulate cosmetic products, highlighting the potential for exposure in manufacturing occupations as well (Fromme, 2019).

Sensitive species

Cosmetic products have the potential to expose sensitive species to cVMS when released through product use or disposal. cVMS do not occur naturally in the environment but can be released from products into the air during product use (Brunet et al., 2024) or disposal in wastewater (Shoeib et al., 2016). The majority of cVMS in cosmetic formulations evaporate to air during product use and this contaminates indoor and outdoor air. Cosmetic products are washed or disposed of down the drain, and this contaminates wastewater.

For total methyl siloxanes used in personal care products and cosmetics, *per capita* emissions were estimated at 1,817 ug/day (mean) for down-the-drain releases and 1,607 ug/day (mean) for air emissions, with D5 being the main contributor in both scenarios (Capela et al., 2016).

cVMS in wastewater may strongly adhere to and contaminate sediments in the environment when removal from treatment processes is incomplete. Wastewater treatment is mostly effective at reducing cVMS in water, with a removal rate over 90%. However, this removal happens by transferring cVMS to other outputs such as sludge and the atmosphere, rather than breaking it down (Capela et al., 2017).

Due to the transfer of cVMS into sludge during wastewater treatment, cVMS have been detected in biosolid-amended soils (D.-G. Wang et al., 2013). cVMS in sediments can persist for long periods and bioaccumulate in some food webs. This may be of concern for benthic organisms who live in or near sedimentary habitats (W. Chen et al., 2024). cVMS are chronic toxicants for some species of aquatic organisms including rainbow trout (Oncorhynchus mykiss) and water flea (Daphnia magna) (Ecology, 2024c). In addition, cVMS have the potential for long-range transport in the environment, and this creates a potential for exposure in species at distant sites (Ecology, 2024c).

Availability of potential safer alternatives

ECHA's analysis indicates that alternatives to cVMS in cosmetics are "available and economically feasible" (ECHA, 2019). This is partly based on data showing that for most subcategories, D4, D5, and D6 are present in only a minority of current product formulations, suggesting they are not essential for any specific product type.

In terms of performance, it was reported that 3,469 cosmetic products are available that fulfill the Nordic Swan Ecolabel criteria. The Nordic Swan Ecolabel criteria does not allow for D4, D5, or D6 in products and requires that products have demonstrated performance characteristics. Cosmetics products with the Nordic Swan Ecolabel span across a variety of cosmetic product subcategories, suggesting alternatives may be broadly available and applicable for use in cosmetic formulations (ECHA, 2019).

During the next phase of implementation of Safer Products for Washington (Phase 3), we will evaluate alternatives and determine whether they meet our criteria as safer, feasible, and available before recommending any regulatory actions.

Chapter 4: Insulation

Overview

Priority product

The scope of this priority product includes materials used in buildings to provide thermal insulation between indoor and outdoor spaces or between two indoor spaces.

Applications where insulation may be used in buildings include (US Dept. of Energy, n.d.-d):

- Attics
- Ducts
- Floors
- Ceilings
- Walls (exterior and interior)
- Foundations
- Slab-on-Grade
- Basements and Crawlspaces

Types of insulation in scope include (US Dept. of Energy, n.d.-c):

- Blanket batt and roll insulation
- Insulating concrete forms or concrete block insulation
- Foam board or rigid foam board insulation
- Loose-fill and blown-in insulation
- Rigid fibrous or fiber insulation
- Sprayed foam or foamed-in-place insulation
- Structural insulated panels
- Radiant barrier and reflective insulation
- Spray foam insulating sealant

Priority chemical(s)

Organohalogen flame retardants (OFRs) were defined as a priority chemical class by the Washington State Legislature under RCW 70A.350.010.[63]

Background

Insulation added to homes and buildings provides resistance to heat flow and improves energy efficiency and comfort (US Dept. of Energy, n.d.-a). Fiberglass, plastic foam insulations, cellulose, mineral wool, and natural fibers are currently the most widely used insulation materials in residential and commercial buildings. Different insulating materials have different efficiency and flammability ratings.

[63]app.leg.wa.gov/rcw/default.aspx?cite=70A.350.010

Plastic foam insulations such as polystyrene, polyisocyanurate, and polyurethanes are used as an option where high efficiency is desired, such as in zero-energy buildings (ACC, n.d.; National Association of the Remodeling Industry, 2015). Manufacturers use different types and amounts of flame retardants in insulating materials to meet flammability standards. Since plastic foam insulation materials are highly flammable, OFRs are often used in these materials to meet building and fire safety codes (Baby et al., 2020; NAMBA, 2020; Parcheta-Szwindowska et al., 2024). However, the use of OFRs in plastic foam can be sources of exposure to these chemicals (NAMBA, 2020).

Flame retardants can be added to plastic foam insulations as an additive or reacted into the polymer of the insulation material (US EPA, 2014). Additive flame retardants are different-sized molecules coated or blended into the material during the manufacturing process. They are not chemically bound to the material and can transfer out of the material.

Additive OFRs have been a popular choice for manufacturers because of their effectiveness and ease of use in the manufacturing process. However, because they are known to harm the environment and human health, some uses have been restricted. There is a long history of regrettable substitution with OFRs. Harmful OFRs such as polybrominated diphenyl ethers (PBDEs) have been phased out from use and replaced by other OFRs, such as hexabromocyclododecane (HBCD) and tris(chloropropyl) phosphate (TCPP). HBCD is now also considered hazardous and is being phased out.

Reactive and polymeric flame retardants are designed to reduce potential exposure over the lifetime of a product (ACC, 2024b). Reactive flame retardants are chemically bonded to the material and are not expected to transfer out unless the material breaks down or contains unreacted residues.

Larger molecule polymeric flame retardants were introduced as alternatives to reduce the migration potential of OFRs from the insulation material. However, polymeric OFRs and their breakdown products can still be released to the environment after disposal (Koch & Sures, 2019). Demolition of buildings and disposal of insulation materials at end-of-life can also release OFRs the environment (Babrauskas et al., 2012; Duan et al., 2016).

We are identifying insulation as a priority product because it is a significant use of OFRs, a potential source of exposure in sensitive populations, and a source of OFRs in the environment. We know that residential and commercial buildings in Washington must meet both energy and fire safety requirements in the Washington State Building Code and that this is directly relevant to the selection of insulation materials for building projects (SBCC, 2024). These will be important considerations as we consider the feasibility of potential alternatives in the next phase of implementation for Safer Products for Washington.

Volume estimates for priority product-chemical combination

The volume of priority chemicals associated with the product

OFRs can be used in a variety of plastic foam insulation materials. Polystyrene is a thermoplastic commonly used in various types of building insulation applications. It can be used to make foam board or bead board insulation, concrete block insulation, and loose-fill insulation consisting of small polystyrene beads. Extruded polystyrene (XPS) and expanded polystyrene (EPS) are the most widely used polystyrene-based insulation systems that can be used as insulation for structural insulating panels and insulating concrete forms (US Dept. of Energy, n.d.-b).

Hexabromocyclododecane (HBCD) was used widely as an additive flame retardant in expanded polystyrene and extruded polystyrene products until it was phased out due to hazards to health and the environment. HBCD was used because it adds flame retardancy at low concentrations without the loss of thermal or physical material performance. Typical loading of HBCD is around 0.5% by weight in expanded polystyrene, and 0.5–1% by weight in extruded polystyrene (US EPA, 2014).

HBCD is being phased out and replaced with bromine-containing polymeric flame-retardant additives such as PolyFR, which is a block copolymer of polystyrene and brominated polybutadiene (Kuribara et al., 2019; Minet et al., 2021). Polymeric flame retardants, which typically contain 65% bromine, are being used at up to 5% in polystyrene-based insulation products (ARXX BRASIL S.A., 2022; Insulfoam, 2023; Owens Corning, 2023; Y. Wang et al., 2019). While HBCD-based flame retardants are being phased out, some HBCD-containing flame retardants compatible with extruded polystyrene and expanded polystyrene are still available on the market (SpecialChem, n.d.).

Polyisocyanurate (polyiso) is a closed-cell thermoset plastic available as a rigid foam board insulation or insulated metal panels. It is generally used as roof insulation, high density roof cover boards, insulated wall panels, and ceiling panels. A phosphorous containing OFR, TCPP, is used as an additive flame retardant at concentrations of approximately 2–10% in these products (Healthy Building Network, 2018). According to the Polyisocyanurate insulation manufacturers association , concentrations of TCPP in polyiso board ranges from 3.8% to 6.4% (PIMA, 2024).

Polyurethane is another thermoset plastic material available as spray foam, rigid foam boards, insulated metal panels, or flexible foam. Rigid polyurethane foam boards can be used in walls, roofs, attic and crawl spaces, and under-slab insulation in some cases. It is used to create laminated insulation panels with different facings for applications such as exterior roofs and walls. Flexible polyurethane foam is used mostly in residential, commercial, and industrial settings to insulate pipes and ducts.

Spray polyurethane foam (SPF) insulation is a two-part product combined and reacted on site. It comes in two types: a closed-cell formula, where tightly packed cells are filled with a gas to help foam expand and fill gaps, and an open-cell formula, which is less dense and filled with air.

Generally, TCPP is added to open-cell foam (low density) at 25%, closed-cell foam (medium density) at 4%, and roofing foam at 8%. Brominated flame retardants can be used in closed-cell foam at 6% (SPFA, 2013). Typical concentrations of TCPP in SPF range from 4–45% . Table 8 provides information on the concentrations of flame retardants found in plastic insulation materials currently available in the market.

Table 8: The concentrations of common OFRs found in different types of building insulation materials.

Material type	Common flame retardants	Concentration (%)	References
SPF (open cell)	TCPP	30–40	(Huntsman Building Solutions, 2024)
SPF (roofing)	TCPP	5–10	(BASF, 2022)
SPF (closed cell)	TCPP	15–45	(ICP Construction Inc, 2022)
SPF Insulation Sealant	TCPP	5–10	(Dow, 2016)
XPS foam board	Polymeric FR (Benzene, ethenyl polymer with 1,3-butadiene, brominated)	0.1–2	(Owens Corning, 2023)
EPS foam	Polymeric FR (undisclosed)	1–5	(Insulfoam, 2023)
Closed cell polyiso foam board	TCPP	2–6	(PIMA, 2024; Soprema, 2024)
EPS (ICF)	Polymeric FR (Benzene, ethenyl polymer with 1,3-butadiene, brominated)	0.0–0.53	(ARXX BRASIL S.A., 2022)

Volume of the product sold or present in the state

According to the economic impact studies done by the American Chemistry Council (ACC), the economic output for total insulation manufacturing in the US increased from $17.8 billion in 2020 to $24.9 billion in 2022 (ACC, 2021, 2023). Considering Washington accounts for 2.3% of the total US population, this suggests Washington's share of the economic output for insulation manufacturing was around $570 million in 2022 (ACC, 2023; US Census Bureau, 2024).

Based on available information, we can estimate the relative economic output and sales of some specific plastic foam materials over the years attributable to Washington. According to US Census Bureau survey data, sales for polystyrene foam products for construction in 2018 were $1.5 billion and $1.6 billion in 2017 (US Census Bureau, 2017a). Again, assuming Washington's population accounts for 2.3% of the US population we estimate the polystyrene foam sales in Washington to be around $34.5 million in 2018 and $36.8 million in 2017.

The ACC economic impact study estimated that polystyrene insulation manufacturing amounted to $3.1 billion in economic output in the US for 2022. Given the 2.3% share of the US population attributable to Washington, we estimate that polystyrene insulation in Washington contributed around $71 million to manufacturing economic output in 2022.

Similarly, the 2022 ACC economic study estimated manufacturing economic output for polyurethane and polyiso insulation in the US to be $9.3 billion. Again, Washington accounts for 2.3% of the total US population, so we estimate Washington accounts for around $210 million of the manufacturing economic output for polyurethane and polyiso insulation.

For spray foam volume, according to the voluntarily reported data to the ACC, the total spray polyurethane foam (open, closed, and roofing) shipment volume in the US for 2019, was 560 million pounds (ACC, 2019). For the Pacific region which includes Alaska, California, Hawaii, Oregon, and Washington it was 36.6 million pounds. Based on the 2023 population data for these states, Washington accounts for 13% of the population within these five states and 2.3% of the US population. We roughly estimate that 4.5 million pounds to 12 million pounds of spray polyurethane foam was available in Washington in 2019. This estimate does not include any rigid polyurethane foam.

The volume of insulation used in homes in Washington is large. A survey conducted by Home Innovation Research Labs estimated around 22% of insulation used in single-family housing is plastic foam board or spray foam (Home Innovation Research Labs, 2019). We anticipate the majority of this plastic foam insulation contains OFRs based on our research.

The Washington Center for Real Estate Research reported existing single-family housing stock of over 2 million in Washington for the second quarter of 2023 (WCRER, 2024). Looking ahead, the Washington State Department of Commerce estimates that over 1.1 million new homes (for example, apartments, multiplexes, and single-family homes) will be needed to keep pace with housing needs in the state (WA Department of Commerce, 2023). Overall, this demonstrates that a large volume of insulation containing OFRs is sold and present in Washington.

Potential for exposure to priority chemicals from the product

People can be exposed to OFRs used in insulation during manufacture, installation, and disposal of the products, and during demolition of buildings (Figure 6). Building occupants may be exposed to insulation chemicals while the material is in use. OFRS released from insulation can be released to the environment where sensitive species may be exposed.

We recognize there are differences in the anticipated exposure and environmental release when comparing additive, reactive, and polymeric OFRs. Polymeric OFRs may have a more favorable hazard profile when compared to additive OFRs because of their larger molecular weight and reduced bioavailability. Studies on the breakdown of a polymeric OFR in insulation materials suggest that the resulting breakdown products are unlikely to be acutely toxic to aquatic organisms, though long-term effects may still be a concern (Beach et al., 2021; Koch & Sures, 2019). These differences in the potential for exposure and environmental release will be important considerations as we evaluate potential safer, feasible, and available alternatives in the next phase of implementation.

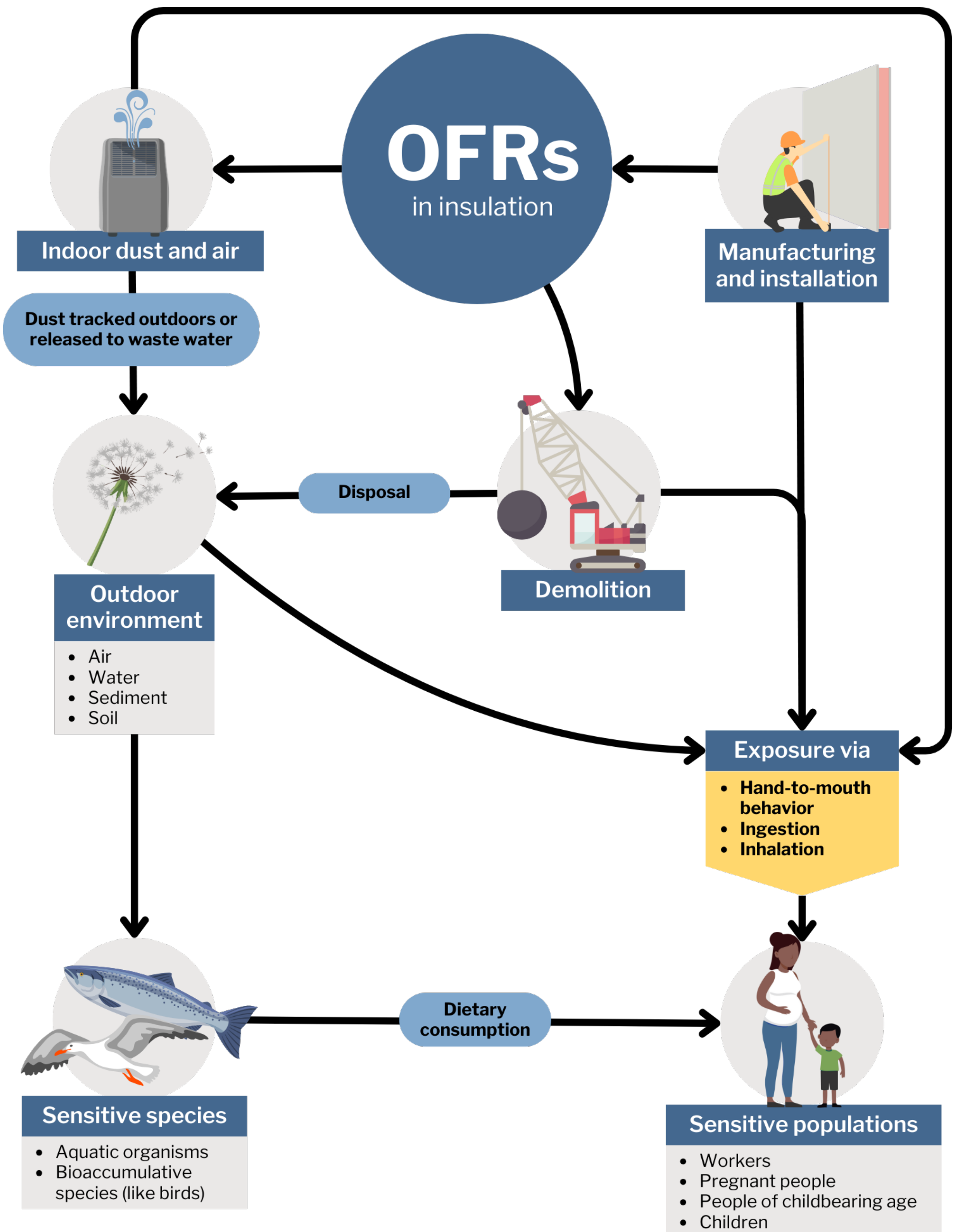

Figure 6: Potential pathways for exposure to OFRs from insulation in sensitive populations and sensitive species. (See Appendix D for a step-by-step description of this figure.)

Indoor dust

For the general population, indoor dust is recognized as a major pathway of exposure to flame retardants including the OFRs that are used in insulation (TERA, 2016). As an example, HBCD was primarily used (>95% of uses) as a flame retardant in insulation before its classification as a persistent organic pollutant (Drage et al., 2018). Although HBCD has mostly been phased out, it can still be found in house dust (Drage et al., 2020; Fromme et al., 2014; Stapleton et al., 2008). This demonstrates that flame retardants, likely from insulation, can be present in dust. Exposure to HBCD from building insulation remains high and in 2022 EPA found that HBCD is associated with an unreasonable risk to human health and the environment (US EPA, 2022b).

Indoor air

OFR in insulation commonly use TCPP. TCPP is not chemically bonded to the insulation material and slowly transfers into room air over time (Kemmlein et al., 2003; Liang et al., 2018). While there are other uses for TCPP, it is estimated that over 80% of TCPP is used in rigid polyurethane foams, primarily for construction (Banasik, 2015).

In a study of chlorinated organophosphate flame retardants including TCPP in indoor air from homes in Washington State, the authors calculated that inhalation exposure may exceed exposure to dust (Schreder et al., 2016).

The National Institute of Standards and Technology reported that TCPP was emitted into building air from spray polyurethane foam, and emissions continued two years after the insulation was installed (Poppendieck et al., 2017). The insulation was in the basement of a test building, and TCPP was detected on the second floor, where no other sources were identified. This finding suggests that TCPP can spread within homes and in other buildings after release from the insulation. A recent analysis also found that upholstered furniture containing polyurethane foam releases TCPP over time (Plaisance et al., 2025). Although this study did not examine insulation, the study suggests that polyurethane foam materials containing TCPP emit TCPP to air over the lifetime of the material.

Dietary consumption

For most people, diet is a key way OFRs enter the body through contaminated food (J. Li et al., 2019; Schecter et al., 2010). These contaminants can come from products breaking down, demolition, and disposal in landfill waste, which can lead to OFRs in food sources.

Sensitive populations

Sensitive populations, such as children and workers, can be exposed to OFRs in insulation through several pathways, including contact with air or dust containing OFRs.

Children

Children can be exposed to OFRs from insulation when they ingest, inhale, or touch dust. Infants can be exposed to OFRs from breast milk, although the contribution of insulation products to levels in breast milk is not known (Y. Li et al., 2023; Rawn et al., 2024).

OFR concentrations in house dust were linked to concentrations found in wipe samples from wipes of children's hands (Stapleton et al., 2014). Handwipe concentrations were linked to flame retardant chemicals in children's urine, further highlighting the importance of the dust exposure pathway—particularly for young children who may touch their face or mouth more often than adults (Phillips et al., 2018).

In house dust collected in Washington State, TCPP was the most prevalent chlorinated flame retardant (Schreder & La Guardia, 2014). Concentrations of TCPP were higher in dust collected in Washington than in previous studies collected in California (Dodson et al., 2012). A recent study of 54 low-income homes in Texas found TCPP in dust from surfaces and HVAC filters, and suggested polyurethane insulation as a likely source (Bi et al., 2018). Exposed insulation, typically used as a wrap for water pipes, in college campus rooms was associated with elevated indoor dust concentrations of a group of 19 organophosphate OFRs (Young et al., 2021).

Workers

Workers can be exposed to OFRs from insulation during manufacturing, installation, and demolition of insulation (Estill et al., 2024; Minet et al., 2021). The ACC estimates that there are approximately 21,000 people employed in Washington as insulation contractors and installers (ACC, 2023).

Spray polyurethane foam applicators are exposed higher levels of flame retardants than the general population. For example, a study of 29 spray polyurethane foam workers found metabolic product of TCPP in urine samples at significantly higher levels than are found in the general population (Estill et al., 2019). The exposure concentrations in samples of personal air varied with the task performed. Air samples from sprayers averaged 87 ug/m^3 over a full workday, while their helpers averaged 30 ug/m^3.

A separate study of TCPP exposure in spray polyurethane foam workers found 26 to 35 times higher concentrations of urinary biomarkers of exposure compared to the general population (Bello et al., 2018). Bello et al. detected air concentrations as high as 1,850ug/m^3 for certain tasks. In the two worker studies discussed above, the use of personal protective equipment (PPE) such as gloves, respirators, and coveralls varied. Bello et al. concluded that PPE does not completely eliminate occupational TCPP exposure (Bello et al., 2018). Consumers using spray foam insulation products can have direct contact during application and may be less likely to use PPE.

Beyond spray foam applicators, other workers in the building trades may have greater exposure to the OFRs used in insulation compared to the general population. When workers remove or install walls or other building structures, cutting rigid materials onsite may release OFRs. Workers are directly exposed to the flame retardants in insulation products during installation and full or partial demolition, such as during remodeling (Estill et al., 2020). Inhalation and direct skin contact with insulation products are additional routes of exposure for workers to the OFRs in insulation (Estill et al., 2024).

Sensitive species

OFRs enter Washington's environment from manufacturing, installation, use, and disposal of insulation. Once in the environment, there is the potential for exposure to sensitive species.

TCPP and HBCD can be released from insulation during installation and demolition. HBCD has been identified in construction waste, particularly in polyurethane foam scrap as well as landfill leachate (Daso et al., 2017; Duan et al., 2016).

Products containing OFRs in landfills can release OFRs into the atmosphere (Harrad et al., 2020; Kerric et al., 2021; Morin et al., 2017). OFRs in the atmosphere can then be transported to remote areas (Möller et al., 2011; Vorkamp & Rigét, 2014; Xiao et al., 2012), which can lead to exposure to sensitive species in remote areas (de Wit et al., 2006; Xiong et al., 2024). Landfills are also known as sources of OFRs exposure for birds (Kerric et al., 2021; Sorais et al., 2020, 2021).

The EPA recently concluded that HBCD poses an unreasonable environmental risk under many conditions of use, including commercial applications and disposal. Environmental exposure to HBCD has been linked to with risks for aquatic life (US EPA, 2022b). While its use in insulation has largely been phased out, this highlights the potential for OFRs in insulation to impact sensitive species, raising concerns about newer OFRs in insulation as well.

TCPP is an additive OFR that is currently used in some insulation products. An analysis of TCPP in house dust and laundry effluent in Washington State found high concentrations of TCPP in both dust and laundry detergent compared to other flame retardants (Schreder & La Guardia, 2014). Wastewater treatment plants do not effectively remove OFRs (G. Xu et al., 2021).

OFRs, including TCPP, have been detected in surface water and sediment (Bester, 2005; Ecology, 2020). In Washington, TCPP has been found in stormwater, lake water, and Columbia River waters, as well as sediments of these waters. (Alvarez et al., 2014; Counihan et al., 2014; Ecology, 2018, 2019). To our knowledge, there are no manufacturers of OFRs in Washington. Since TCPP is primarily used in insulation, a proportion of the TCPP detected in the environment is likely from insulation materials.

OFRs can be persistent, bioaccumulative, and toxic. These attributes make the potential exposure to sensitive species more concerning. HBCD was primarily used in insulation, was identified as a PBT, and is associated with unreasonable risk to the environment. TCPP is less bioaccumulative than HBCD, but its use in insulation, as well as its environmental persistence and aquatic toxicity raises similar concerns for sensitive species.

Availability of potential safer alternatives

In 2014, EPA released its alternative assessment report on HBCD (US EPA, 2014). EPA identified some feasible chemical alternatives for HBCD in expanded polystyrene and extruded polystyrene foam insulation products based on its ability to:

- Comply with fire performance requirements in building codes
- Maintain the physical properties of the foam
- Be compatible with manufacturing processes and formulas

However, EPA did not find any non-OFR alternatives that fit the performance and economic criteria at that time. Based on Health Product Declarations and Safety Data Sheets for expanded polystyrene and extruded polystyrene products available in the market currently, a brominated styrene-butadiene copolymer that was identified as one of the alternatives seems to have been widely adopted by the polystyrene insulation industry. EPA identified some alternative materials that can replace extruded polystyrene and expanded polystyrene foams for certain functions but did not find alternatives for all uses.

Manufacturers of insulation and flame retardants noted in public comments on the draft of this report that modern construction requires different insulation products for different applications. Certain types of insulation are chosen to meet specific needs. For example, SPF is used as a sealant to prevent moisture intrusion and as an air barrier to improve energy efficiency, helping reduce greenhouse gas emissions. We will consider function and specific applications as factors when evaluating alternative chemicals or materials.

Product selection guidance for choosing different insulation materials based on function and application is available, and replacing plastic foam insulation with other alternative materials such as fiberglass, mineral wool, cellulose, and natural fibers where feasible could reduce a significant use of OFR chemicals (Habitable, 2023). We have not determined whether these alternatives are feasible to meet the range of performance requirements for the varied uses of insulation products in buildings. During the next phase of implementation of Safer Products for Washington (Phase 3), we will evaluate alternatives and determine whether they meet our criteria as safer, feasible, and available before recommending any regulatory actions.

Chapter 5: Jewelry and Accessories

Overview

Priority product

This priority product category includes ornamental articles and accessories intended to be worn by a person. Examples of jewelry include:

- Anklets
- Arm cuffs
- Body piercings
- Bracelets
- Brooches
- Chains
- Crowns
- Cuff links
- Earrings
- Hair accessories
- Necklaces
- Pins
- Rings
- Watches

This category includes craft and DIY kits sold for making jewelry and accessories.

Inaccessible electronic components of products are excluded from the scope of this product category.

Priority chemical(s)

Cadmium and cadmium compounds were defined as a priority chemical class in our previous legislative reports Identification of Priority Chemicals Report to the Legislature: Safer Products for Washington Cycle 2 Implementation Phase 1[64] and Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1[65] in Chapter 2: Technical Support for Cadmium and Cadmium Compounds (Ecology, 2024b, 2024c).

Lead and lead compounds were defined as a priority chemical class in our previous legislative reports Identification of Priority Chemicals Report to the Legislature: Safer Products for Washington Cycle 2 Implementation Phase 1 and Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1 in Chapter 3: Technical Support for Lead and Lead Compounds (Ecology, 2024b, 2024c).

[64] apps.ecology.wa.gov/publications/summarypages/2404025.html
[65] apps.ecology.wa.gov/publications/summarypages/2404026.html

Background

Lead is added to jewelry to make articles heavier and enhance colors, while cadmium is used to create shiny coatings (DTSC, n.d.-b, n.d.-a). They are both used in non-metal applications to stabilize or soften plastic for making jewelry.

Earlier studies have shown lead contamination in jewelry made from recycled materials and lead-based paints to make glossy coatings (Weidenhamer & Clement, 2007; Yost & Weidenhamer, 2008). Small amounts of cadmium may be added to jewelry in metal alloys, solder, or as pigments and stabilizers in non-metal parts (M. Meijer, 2023). Metals like copper and tin are mixed with about 6% lead to create jewelry that can be coated with rhodium, palladium, gold, or silver (ECHA, 2010).

Volume estimates for priority product-chemical combination

The volume of priority chemicals associated with the product

Lead and cadmium in jewelry are not easily identifiable, so each piece must be tested individually to determine their presence. The amount of lead or cadmium in a jewelry item can vary in each product with concentrations ranging from a detectable range of 1 ppm to high percent values of 98%. Many studies, including recent product testing, have identified lead and cadmium in jewelry and accessory products. Lead and cadmium are routinely detected in jewelry and accessories at concentrations over 100 ppm. Some recent reports and studies of lead and cadmium in jewelry are summarized in Table 9 and Table 10 below.

Table 9: Lead levels found in jewelry products, a non-exhaustive list, 2017–present.

Concentration^ (ppm)	Detection Frequency	Study Region	Reference
57,000–640,000	5/11 (45%)	USA	(CEH, 2023)
1–510,000	32/78 (41%)	USA	(Ecology, 2023a)
358–966,000	118 products	USA	(DTSC, 2017)
95–3,450	23/106 (21.6%)	EU	(Jurowski, 2023)
Greater than 500⁺	45/415 (11%)	EU	(ECHA, 2023c)
160–24,500	12/100 (12%)*	Nigeria	(Adie et al., 2020)
19–21,000	34/87 (39%)	Israel	(Negev et al., 2018)

^ Some numbers have been rounded to three significant figures.

⁺ Reported as non-compliant at greater than 500 ppm.

* The frequency is for the number of samples with detections above the European Union (EU) limit.

Table 10: Cadmium levels found in jewelry products, a non-exhaustive list, 2017–present.

Concentration^ (ppm)	Detection Frequency	Study Region	Reference
14,000–520,000	3/11 (27%)	USA	(CEH, 2023)
20–459,000	32/80 (40%)	USA	(Kern et al., 2021)
1–966,000	27/78 (35%)	USA	(Ecology, 2023a)
100–6,540	54/106 (51%)	EU	(Jurowski, 2023)
Greater than 100+	55/459 (12%)	EU	(ECHA, 2023c)
17–922,000	63/100 (63%)*	Nigeria	(Adie et al., 2020)
18–583,000	22/87 (25%)	Israel	(Negev et al., 2018)

^ Some numbers have been rounded to three significant figures.

+ Reported as non-compliant at greater than 100 ppm.

* The frequency is for the number of samples with detections above the EU limit.

The volume of the product sold or present in the state

According to United States Census Bureau data from 2017, total retail sales in the US for costume and novelty (fashion) jewelry amounted to $10.8 billion, with sales in Washington reported to be around $370 million (US Census Bureau, 2017b). The market for fine jewelry[66] and watches were larger, with $38 billion in total US sales and $1.5 billion in Washington (US Census Bureau, 2017b).

The US fashion jewelry market is estimated to grow at a compound annual rate of 6.9% from 2023 to 2031 (Straits Research, n.d.). The growth of e-commerce and social media, along with the desire for fashionable pieces, awareness of one's look, and affordability, are driving the fashion jewelry market upward (Straits Research, n.d.). Nearly half of people aged 18 to 49 are estimated to own fashion jewelry, and Americans spend an average of $647 on jewelry each year (Statista, 2018, 2019). The sales volume and growth forecast reports support the finding that there is a widespread presence of jewelry in Washington State.

The US Consumer Product Safety Commission has consistently recalled jewelry with high levels of lead or cadmium due to serious risk of injury or death. Multiple jewelry recalls for high lead or cadmium levels, as recently as 2024, suggest these metals are still present in the market (CPSC, 2024b, 2024a).

Because of the variability in price per piece of jewelry and limited testing, it is difficult to estimate the number of pieces with lead and cadmium present in the state. Given the

[66]The fine jewelry category includes the retail sales of all diamond, pearl, gemstone, karat gold, and karat platinum jewelry, as well as all loose gemstones. It also covers watches, watchbands, and parts, but excludes estate and antique jewelry sales and watch batteries.

multimillion-dollar size of the fashion jewelry industry, its predicted market growth, and the widespread detection of lead and cadmium, a significant amount of jewelry containing these metals is likely present in Washington.

Potential for exposure to priority chemicals from the product

People and wildlife can be exposed to lead and cadmium during the manufacturing, use, and disposal of jewelry (Figure 7). Workers can be exposed through inhalation of lead and cadmium-containing vapors during the manufacturing process (Ferrreira et al., 2019; Illinois Department of Public Health, 2021; Mishra et al., 2003; Patil et al., 2007; Salles et al., 2018, 2021).

Relevant human exposure pathways during jewelry use are (CDC, 2024):

- Ingestion of lead and cadmium through accidental swallowing of jewelry or mouthing of jewelry
- Ingestion of lead and cadmium if people put their hands in their mouth or touch food after handling jewelry
- Continued exposure when some jewelry are recycled into new pieces

Jewelry made from less valuable materials is often discarded, which can contribute to environmental contamination. As we learn more about the environmental impacts of textile-based "fast fashion," we should also consider the potential impacts of similar trends in jewelry and accessories (Niinimäki et al., 2020).

These exposure pathways are of particular concern for sensitive populations and sensitive species.

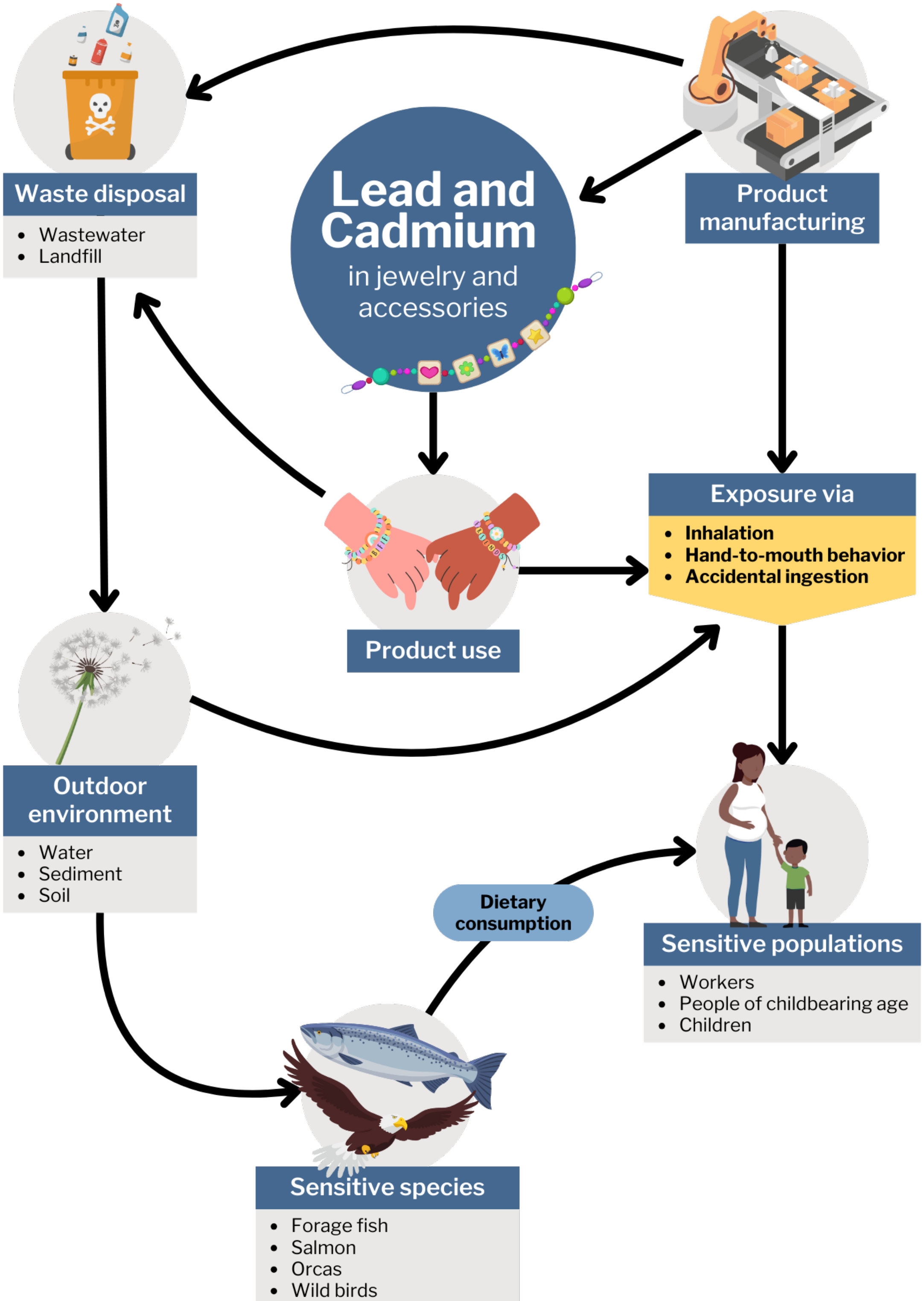

Figure 7: Pathways of potential exposure to lead and cadmium from jewelry and accessories in sensitive populations and sensitive species. (See Appendix D for a step-by-step description of this figure.)

Sensitive populations

Sensitive populations, including children, people of childbearing age, and workers, can be exposed to lead and cadmium from jewelry. Children and people of childbearing age are more sensitive to exposures to lead and cadmium because these metals impact development (Al osman et al., 2019).

This is particularly true for neurodevelopment effects (Naranjo et al., 2020). Children younger than six years old are more likely than adults to engage in mouthing and hand-to-mouth behaviors that increase exposure to lead and cadmium in jewelry (US EPA, 2011a; Weidenhamer & Clement, 2007).

A review of children's blood lead levels found that about 38% of elevated cases in children were linked to consumer products. Studies show that simulated mouthing of jewelry can release cadmium and lead, with even higher cadmium levels released when jewelry is damaged (Kern et al., 2021; Weidenhamer & Clement, 2007). Children are also more likely to accidentally swallow jewelry (Boisclair et al., 2010).

These concerns have prompted restrictions on lead and cadmium in children's jewelry in Washington (Chapter 70A.430 RCW)[67] and other jurisdictions (Appendix B). These regulations reduced lead in children's jewelry (Cox & Green, 2010; Negev et al., 2022). However, children can be exposed to jewelry that is not specifically marketed or sold to them.

Additionally, workers and hobbyists can be exposed to lead and cadmium when making or manufacturing jewelry. Jewelry construction can involve lead soldering. As lead is melted, vapors can be inhaled and workers and hobbyists can be exposed (Illinois Department of Public Health, 2021). While less exposure monitoring is available for hobbyists, a couple of studies have documented higher exposures to lead and cadmium in jewelry workers. For example, Patil et al. (2007) found elevated blood lead levels in silver jewelry workers (Patil et al., 2007). Mishra et al. (2003) found that immune responses were modified in lead-exposed occupations, including silver jewelry makers (Mishra et al., 2003).

Internationally, there is increasing concern over home-based informal jewelry production. It is unclear to what extent informal jewelry production occurs in Washington. Informal jewelry production is associated with high concentrations of lead and cadmium in products, potential exposures to families and workers as well as potential releases to the environment (Ferrreira et al., 2019; Salles et al., 2018, 2021).

Sensitive species

Sensitive species can be exposed to lead and cadmium in the environment. Lead and cadmium can be released into the environment during the manufacturing and disposal of jewelry through wastewater. The impacts and prevalence of cadmium and lead in the environment are described in our Priority Chemical Report to the Legislature (Ecology, 2024c). Figure 7 highlights

[67]app.leg.wa.gov/rcw/default.aspx?cite=70A.430

pathways that contribute to the potential for sensitive species to be exposed to lead and cadmium from jewelry.

Recent trends in the fashion industry show an increase in the production and purchasing of low-priced, trend-driven products (Niinimäki et al., 2020; Remy et al., 2016). These products have environmental impacts and contribute to increased waste (Niinimäki et al., 2020). While most fashion impacts studied to date are related to textile production and disposal, industry reports suggest that jewelry may be following this trend (KBeau Jewelry, n.d.; Statista, n.d.-b).

These trends may lead to increased production of jewelry made from cheaper materials, which are more likely to contain lead and cadmium, as well as higher disposal rates of these products (Kern et al., 2021; Streicher-Porte et al., 2008). Statista projects over 88% of jewelry will be non-luxury in the future (Statista, n.d.-b).

Availability of potential safer alternatives

Lead and cadmium are not the most common metals used in making jewelry, and alternatives appear to be widely available. Lead and cadmium in children's jewelry are already restricted in Washington and we anticipate similar materials and quality assurance processes may be transferable.

California statute provides a list of materials that can be used to make lead or cadmium-free jewelry (State of California, n.d.). We did not evaluate whether these materials are safer, feasible, and available, but we will continue that research in Phase 3.

The materials California identified as lead and cadmium-free are:

- A gemstone that is cut and polished for ornamental purposes, excluding aragonite, bayldonite, boleite, cerussite, crocoite, ekanite, linarite, mimetite, phosgenite, samarskite, vanadinite, and wulfenite
- All-natural decorative material, including amber, bone, coral, feathers, fur, horn, leather, shell, or wood, that is in its natural state and is not treated in a way that adds lead or cadmium
- Elastic, fabric, ribbon, rope, or string that does not contain intentionally added lead or cadmium
- Glass, ceramic, or crystal decorative components, including cat's eye, cubic zirconia, including cubic zirconium, rhinestones, and cloisonné
- Karat gold
- Natural or cultured pearls
- Platinum, palladium, iridium, ruthenium, rhodium, or osmium
- Stainless or surgical steel
- Sterling silver

In addition, lead and cadmium may be present in non-metal jewelry and accessories if they are used as stabilizers. Alternative stabilizers appear to be widely available for polyvinyl chloride (ECVM, n.d.-b).

This preliminary research suggests that alternatives to lead and cadmium are already on the market. Moving forward we will continue research to determine whether alternatives to lead and cadmium are safer, feasible, and available.

Chapter 6: Nail Products

Overview

Priority product

The scope of this priority product includes nail products broadly, examples include:

- Nail art products
- Nail coatings (solvent-based, UV-gel)
- Nail glues
- Nail hardeners
- Nail polish removers
- Nail polish thinners

Priority chemical(s)

Benzene, ethylbenzene, toluene, and xylenes (BTEX) substances were defined as a priority chemical class in our previous legislative reports Identification of Priority Chemicals Report to the Legislature: Safer Products for Washington Cycle 2 Implementation Phase 1[68] and Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1[69] in Chapter 5: Technical Support for BTEX substances (Ecology, 2024c, 2024b). BTEX is defined as a six-membered aromatic carbon ring containing up to a single ethyl substituent, or up to two methyl substituents. They are volatile organic compounds, used as solvents in consumer products, and have shared hazards that can cumulatively harm people and the environment (Ecology, 2024c).

Background

BTEX substances are used in nail products. The most used BTEX substance in nail products is toluene; however, benzene, ethylbenzene, and xylenes are also found in nail products. BTEX substances are volatile liquids used as solvents to help with product application. They support an even color distribution in nail coatings and quicker drying times. At room temperature, BTEX substances evaporate from liquids into the air, which means people applying nail products may inhale them. BTEX substances may be present in products as residuals from manufacturing or contaminants.

Volume estimates for priority product-chemical combination

The volume of priority chemicals associated with the product

BTEX substances can be found in high concentrations in nail products. The concentration of specific BTEX substances in this broad product category depends on the type of nail product and its chemical function.

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[68]apps.ecology.wa.gov/publications/summarypages/2404025.html
[69]apps.ecology.wa.gov/publications/summarypages/2404026.html

In a 2020 information request from the California Department of Toxic Substances Control (DTSC), manufacturers reported toluene as a residual or contaminant in traditional nail polish products at concentrations up to 0.1%. It was also reported as a solvent in topcoats and thinners, with concentration ranging from 5% to 25% (DTSC, 2023b). Xylenes were reported as residuals, contaminants, or solvents in 178 different products at concentration ranges of more than zero but less than 50% (DTSC, 2023b). Analytical results from testing of nail products conducted by DTSC, along with other nail products testing studies, confirm these reported concentrations to be reasonably within what is found in the market (Table 11) (DTSC, 2012, 2023a; NIOSH, 2019; Zhong et al., 2019; Zhou et al., 2016).

Table 11: The concentration ranges of BTEX substances detected in nail products.

Product Type	Chemical	Detection Frequency	Concentration (%)	Reference
Various nail products	Toluene	27/156	0.003–18.7	(DTSC, 2023a)
Various nail products	Ethylbenzene	10/156	ND–0.71	(DTSC, 2023a)
Various nail products	Benzene	8/156	ND–0.03	(DTSC, 2023a)
Various nail products	Xylenes^	11/156	ND–3.43	(DTSC, 2023a)
Nail polishes	Toluene	4/35	0.001–0.002*	(Zhong et al., 2019)
Nail polishes	Toluene	32 products tested	ND–0.9+	(NIOSH, 2019)
Various nail products	Toluene	26/34	0.0001–17.3	(Zhou et al., 2016)
Various nail products	Toluene	18/25	ND–17.7	(DTSC, 2012)

^ Xylenes describes three isomers combined (o-xylene, m-xylene, and p-xylene).

* Headspace toluene concentration of individual nail products expressed in grams per cubic meter converted to % by weight.

+ Results in µg/mL converted to % by weight where density is assumed as 1g/mL.

The volume of the product sold or present in the state

A large volume of nail products are widely sold and present in Washington. We base this conclusion on the number of people using nail products, the amount of nail polish people use, and the number of nail salons in the state.

United Nations data and Simmons National Consumer Survey data, used by Statista, showed that 100.89 million women in the United States used nail polish or other nail products in 2020. This number is projected to increase to 102.13 million in 2024 (Statista, 2024b). Washington accounts for approximately 2.3% of the United States population, and so we estimate around 2.3 million women in Washington used nail polish or other nail products in 2020 along with an unknown number of children, men, and nonbinary people (US Census Bureau, 2024).

Using data from the EPA exposure factors handbook, we estimate that between 29,647 and 74,117 kilograms of base coats, 136,831 and 171,039 kilograms of nail polishes and enamels, and 777,657 and 1,679,033 kilograms of nail polish remover are used each year in Washington (Table 12).

Table 12: Estimate of the volume of base coats, polish, enamel, and removers used each year in Washington.

Example Nail product	Grams per use	Uses per day	Grams per year per person	Kilograms per year used in WA
Polish and enamel	0.3	0.16–0.2	17.52–21.9	136,831–171,039
Polish and enamel remover	3.1	0.088–0.19	99.572–214.99	777,657–1,679,033

We based these estimates on data from the Cosmetic, Toiletry, and Fragrance Association, as well as cosmetic companies, using frequency of use information from Table 17-3 in the EPA Exposure Factors Handbook (US EPA, 2011c). For example, if 0.3 grams of nail polish are applied per use and it is used on average 0.16 times per day, we would estimate that 17.5 grams are used each year, per person.

Since there are 7.81 million people in Washington, and the average frequency of use includes users and non-users, we would multiply 17.5 by 7.81 million to estimate that 136,831 kilograms of nail polish are used per year in Washington. It is important to note that both these use frequency estimates are dated, and trends may have changed over time.

Washington has a high number of nail salons. In 2016, Washington had 1,073 registered nail salons, according to an analysis by the California Healthy Nail Salon Collaborative and the University of California Los Angeles Labor Center, using data from County Business Patterns (Sharma et al., 2018). The authors suggest this number is likely an underestimate, as it doesn’t capture unregistered or unincorporated businesses.

BTEX-containing products can be purchased online and in brick-and-mortar stores (DTSC, 2020; EWG, n.d.-b). Mintel’s Global New Products Database lists 166 products with benzene, toluene, ethylbenzene, or xylene as ingredients in nail color cosmetics and hand/nail care products (Mintel, n.d.).

The EPA’s ChemExpo database lists 36 nail products containing toluene, one containing xylenes, and one containing ethylbenzene. These include nail polish and nail treatment products (US EPA, n.d.-a).

While we acknowledge that many in the industry have moved away from using BTEX substances as solvents in their nail products, the information we have gathered suggests products containing BTEX substances are still available on the market.

Potential for exposure to priority chemicals from the product

People can be exposed to BTEX substances through the manufacturing, use, and disposal of nail products (Figure 8). The primary concern is the potential to inhale BTEX substances from nail products during application. Multiple studies have shown that BTEX substances can evaporate from nail products and contaminate indoor air (DTSC, 2020; Han et al., 2022; G. X. Ma et al., 2019; Zhong et al., 2019). This is particularly concerning for workers that regularly apply nail products, women of childbearing age, and children.

Nail products containing BTEX substances can contaminate outdoor air and water during use and disposal. Since BTEX substances are volatile chemicals, they are expected to primarily be released into the air during product use.

Nail products may be disposed of down the drain and contaminate wastewater. BTEX substances released into wastewater are expected to end up in water or soil (Ecology, 2024c).

However, BTEX substances are expected to break down quickly in the environment, including in air, soil, and water. BTEX substances have low to moderate bioaccumulation potential (Ecology, 2024c). Taken together, we do not expect nail products to be a substantial source of BTEX substances in the outdoor environment.

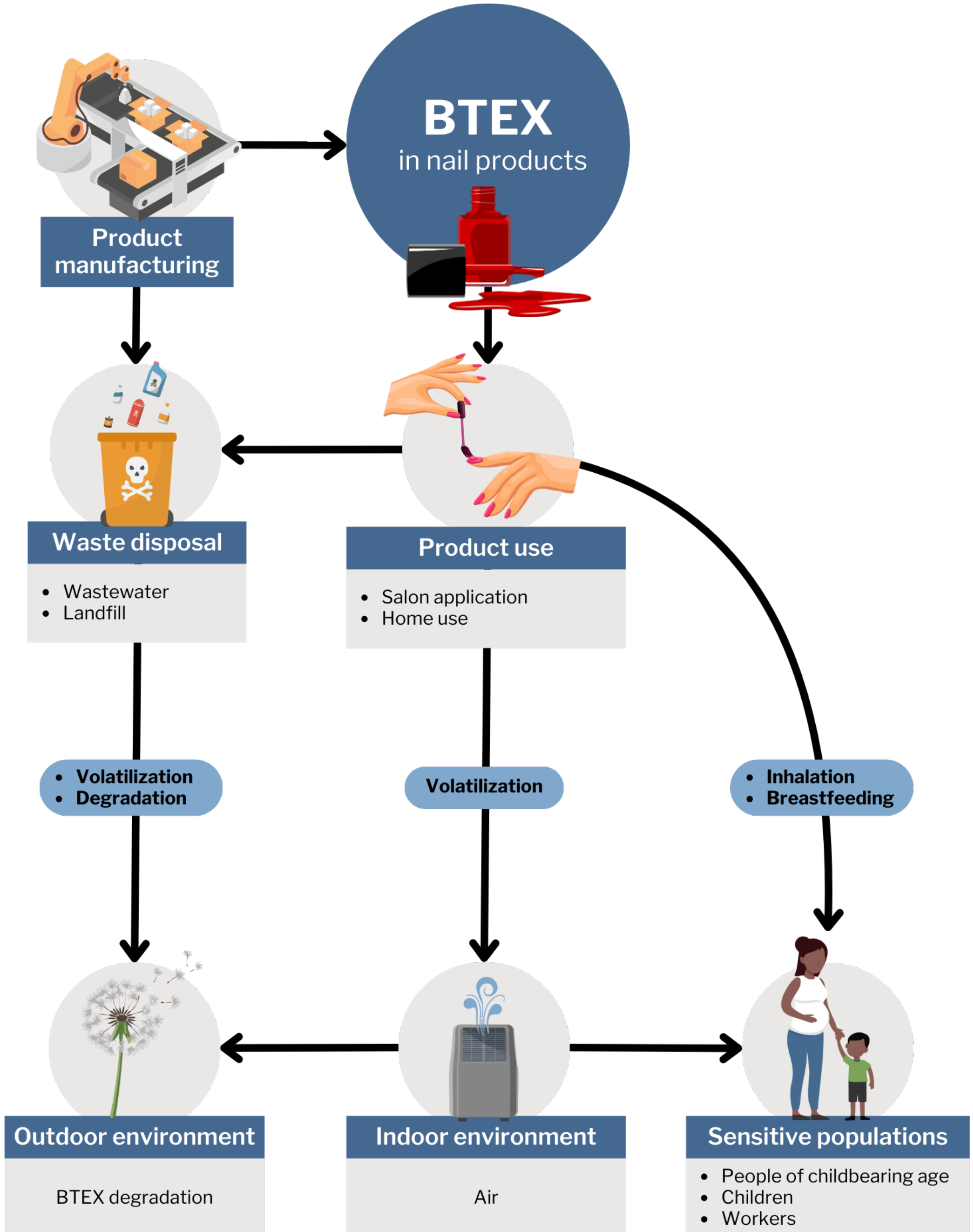

Figure 8: Pathways of potential exposure to BTEX substances from nail products in sensitive populations. (See Appendix D for a step-by-step description of this figure.)

Sensitive populations

Workers

People who work in the nail industry are exposed to BTEX substances from nail products.

Studies on BTEX chemicals in salon air and workers' personal air show that both workers and clients are exposed (Alaves et al., 2013; Harrichandra et al., 2020; Quach et al., 2011). Several studies documenting this exposure pathway were summarized in 2020 by California's Safer Consumer Products program (DTSC, 2020). Additional studies have been published highlighting the potential for exposure in workers (Han et al., 2022; G. X. Ma et al., 2019).

Across all these studies, reported exposure concentrations vary widely, but in some cases, exposure exceeded health guidance levels for chronic exposure (DTSC, 2020). Variability in air concentrations is important because nail products are used within a person's breathing zone, meaning they inhale air that is close to the product (Yeoman et al., 2022). Two studies comparing technician's personal exposure to toluene with room air concentrations found that personal exposure was approximately twice as high as room air measurements (Ceballos et al., 2019; McNary & Jackson, 2007).

BTEX chemicals in salon air get into the body. A small study of nail salon workers found that toluene levels in blood increased in post-shift samples compared to pre-shift samples. The median blood levels of toluene were significantly higher in these workers than in the general population (defined by study authors as participants in the National Health and Nutrition Examination Survey (NHANES) 2013–2014 for female nonsmokers) (Ceballos et al., 2019).

A significant number of workers are exposed in nail salons in Washington. The Department of Labor reports that 5,220 people were employed as nail technicians in Washington in 2023. *Nails Magazine* 2017–2018 Industry Statistics reported a higher figure of 7,300 nail technicians in Washington State, based on a computer compilation of currently licensed professionals and businesses (Nails Magazine, 2018).

Many nail salon workers are women of childbearing age. *Nails Magazine* publishes industry statistics on an annual basis based on market research, surveys of readers who work in the nail industry, and other data sources. *Nails* reports that 97% of survey respondents identified as female (Nails Magazine, 2019). The age distribution was wide, but the majority are women of childbearing age, a population sensitive to BTEX exposure that can affect fetal development.

Chronic and repeated exposure is a concern for people who work with nail products regularly. Half of the respondents to the 2019 *Nails Magazine* survey reported doing nails for over 12 years. Long-term chronic exposure to chemicals in nail products may increase the risk of some health effects linked with BTEX chemicals and increase the likelihood of exposure during pregnancy. Of note, 13% of respondents were home-based, which can result in exposure to other sensitive household members.

Occupational exposure to BTEX in nail products is unequal when considering race/ethnicity. Workers in the nail industry are predominantly female and Asian American. National data from the Bureau of Labor Statistics shows that, while Asian Americans made up 6.9% of the national workforce in 2023, 39% of people employed in "nail salons and other personal care services" were Asian American (US Bureau of Labor Statistics, 2024).

The University of California Los Angeles Labor Center conducted an in-depth study of the nail technician workforce, highlighting a higher proportion of woman and Asian American workers than national statistics suggest. The study found that 81% of nail technicians are women, 79% are foreign-born, with most being Vietnamese (Sharma et al., 2018). The majority are also low-income workers, and many speak a language other than English as their first language (Sharma et al., 2018).

Further, regarding business owners, the US Census survey of business owners in 2012 reported that 73% of the 2314 nail salons in Washington were Asian American owned (US Census Bureau, 2012). In 2015, the Collaborative for Health and Environment-Washington reported that 80% of King County nail salons were Vietnamese-owned (King County, 2015).

Women of childbearing age

Women of childbearing age are exposed to BTEX substances from nail products.

Women can be exposed to BTEX substances when applying nail products or visiting nail salons. In a study of nail polish purchasing habits, nearly 92% of women reported using nail products at least once a month (C. Sun et al., 2015).

While most of the air and biomonitoring data on BTEX and nail products have been gathered from nail salons, it is reasonable to expect that similar exposures could occur during home use. In the same survey referenced above, two-thirds of women reported using nail products at home, while four percent reported only using nail products in salons (C. Sun et al., 2015). Even though salon exposures may be higher due to the number of products in use, the frequency of home use suggests this exposure pathway is relevant for women of childbearing age.

Children

Children have the potential to be exposed to BTEX in nail products.

Benzene, ethylbenzene, and toluene are listed in Washington as chemicals of high concern to children (Children's Safe Products Act, Chapter 70A.430 RCW).[70] Children can be exposed to BTEX in indoor air when they accompany adults to salons for work or as customers, or when these chemicals are present in home settings. Ingestion is likely to be a minor pathway of exposure. However, ingestion is possible for infants who consume breast milk of mothers who are exposed to BTEX in nail products (Kim et al., 2007).

Children represent a growing customer sector for nail salons according to industry research. *Nails Magazine* reported a 31% increase in bookings for children's nail appointments in 2023, over 2022 (Nails Magazine, 2023). In a California survey of consumers, 53% of female respondents who were parents of young children reported using self-applied nail polish (X.

[70] app.leg.wa.gov/rcw/default.aspx?cite=70A.430

(May) Wu et al., 2010). In the same study, 45% of female children aged 5 and under and 79% of those over age 5 in respondents' households used self-applied nail polish.

A similar study of Washington use patterns was not identified, and different state demographics could lead to different frequencies of use in our state.

Sensitive species

BTEX in the environment is a concern for sensitive species such as salmon (Ecology, 2024c). However, most data on harm in salmon stem from studies of oil spills and oil contamination, which are other significant sources of BTEX in the environment. Nail products are expected to contribute only a small amount of BTEX releases in the environment relative to other sources such as motor vehicle and aircraft emissions. As such, we do not consider potential exposure to BTEX substances from nail products in sensitive species to be a primary factor for the identification of nail products as a priority product.

Availability of potential safer alternatives

Data from publicly available ingredient lists of nail polish products and other published reports show that many alternative solvents for nail polishes are currently available and are already being used in many nail polish products. Alternatives may be achieved by designing water-based nail products.

Butyl acetate and ethyl acetate are some of the commonly found solvents currently used in over 90% of nail polishes (INCI Beauty, n.d.-c, n.d.-a). Butyl acetate is found in over 80% of other nail products such as topcoats, basecoats, and nail hardeners. Isopropanol is commonly used as a solvent in conjunction with these solvents to allow for the components of the nail polish to stay in a liquid state. As of July 2024, Mintel GNPD shows 3,223 products in the categories of nail color cosmetics and nail enamel removers that contain butyl acetate, ethyl acetate, or isopropanol individually or in combination (Mintel, n.d.).

Propyl acetate and n-butyl alcohol are other solvents that serve multiple functions and are concurrently used in nail polishes. According to the International Nomenclature Cosmetic Ingredient (INCI) database(INCI Beauty, n.d.-d, n.d.-e) propyl acetate is currently found in 11.73% of nail polish products and butyl alcohol is used in:

- 40.64% of nail polishes
- 5% of varnish bases
- 21.27% of topcoats
- 14.68% of nail treatments

Diacetone alcohol is reported in 223 nail formulations according to the 2019 FDA Voluntary Cosmetic Registration Program survey data (Cosmetic Ingredient Review, 2019). This ingredient is reported to be present in 54.22% of nail polish products and approximately 6 to 7% of nail treatments and semi-permanent polish products (INCI Beauty, n.d.-b). As of July 2024, the EWG Skin Deep Database lists 623 nail polish, 18 nail treatments, and one nail glue product containing diacetone alcohol with solvent, masking, and fragrance ingredient functions (EWG, n.d.-a).

Water-based nail polish products are currently available in the market. Water-based nail polishes rely on the use of dispersions or suspensions of polymers in water instead of the nitrocellulose resins in large proportions of organic solvents. Suspensions of acrylic copolymers, vinyl copolymers, polyesters, polyurethanes, etc. are some of the common polymers used with a coalescing solvent and plasticizer to achieve a nail polish product similar to a solvent-based product (Alain Malnou, 2014).

Some other possible alternatives to toluene in nail products listed in DTSC's potential alternatives report include methyl soyate, ethyl lactate, dipropylene glycol, N-methyl-pyrrolidone (NMP), n-heptane, and methyl ethyl ketone (DTSC, 2022a). There are also a few examples of products listed in the report where these solvents have been used.

The ingredients listed above have not yet been evaluated as safer alternatives as part of our Safer Products for Washington process. During the next phase of implementation of Safer Products for Washington (Phase 3), we will evaluate alternatives and determine whether they meet our criteria for safer, feasible, and available before recommending any regulatory actions.

Chapter 7: Architectural Paints

Overview

Priority product

Architectural paints (referred to as “paints”) include coatings designed for application on interior and exterior surfaces of buildings and other structures. This category includes paints intended for both non-professional and professional uses. Paints are often used to protect surfaces or improve their appearance (American Coatings Association, 2023).

This category includes paints, primers, and clearcoats such as varnishes or lacquers.

This category doesn’t include automotive paints, special purpose, or industrial original equipment manufacturer coatings, applied in factory settings.

Priority chemical

PFAS

PFAS chemicals were defined as a priority chemical class by the Washington State Legislature under RCW 70A.350.010.[71]

PFAS are defined in RCW 70A.350.010(10) as:

> "Perfluoroalkyl and polyfluoroalkyl substances" or "PFAS chemicals" means a class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom.

APEs

Alkylphenol ethoxylates (APEs) were listed as a priority chemical class by the Washington State Legislature under RCW 70A.350.010.

Ecology defined APEs as a chemical class in our Regulatory Determinations Report to the Legislature – Safer Products for Washington Cycle 1 Implementation Phase 3.[72]

Background

Why are PFAS used in paints?

Paint formulations can contain different types of PFAS, including short-chain PFAS and fluorosurfactants. Short-chain PFAS refer to compounds with six or less fluorinated carbon atoms. When added to paints, short-chain PFAS improve the paint’s wetting property, helping it maintain contact with solid surfaces, as well as its levelling property by reducing surface defects (OECD, 2022). Fluorosurfactants help make paint resist oil and feel and appear less sticky. Some examples of short-chain PFAS fluorosurfactants in paints include Hexafor (C6-phosphate diester based) and PolyFox (C2-PFAS based) (OECD, 2022).

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[71] app.leg.wa.gov/rcw/default.aspx?cite=70A.350.010

[72] apps.ecology.wa.gov/publications/summarypages/2204018.html

Some paints contain fluoropolymers, which help resist corrosion and weather damage, increase durability, and prevent staining (OECD, 2022). Fluoropolymers also provide corrosion resistance in harsh conditions, such as exposure to salt, moisture, and corrosive chemicals. Examples of fluoropolymers in paints include (OECD, 2022):

- fluorinated ethylene propylene (FEP)
- polyvinylidene fluoride (PVDF)
- polytetrafluoroethylene (PTFE)
- ethylene-chlorotrifluoroethylene (ECTFE)
- fluoroethylene vinyl ether (FEVE)

Long-chain PFAS are used as polymerization aids for PVDF and PTFE (Lohmann et al., 2020). Long-chain PFAS typically refers to compounds with six or more fluorinated carbon atoms for perfluorosulfonic acids (PFSAs) or seven or more fluorinated carbon atoms for perfluorocarboxylic acids (PFCAs) (Ecology, 2022a). A monomer of ECTFE, namely hexafluoroisobutylene, is a short-chain PFAS (Korzeniowski et al., 2023). A monomer of FEP, namely hexafluoropropylene, is also a short-chain PFAS. Since PFAS used during fluoropolymer production can still exist in the finished products (Lohmann et al., 2020), fluoropolymers in paints can contain short- or long-chain PFAS.

Some fluorinated solvents are PFAS according to [RCW 70A.350.010](). An example of a PFAS fluorinated solvent used in paints is parachlorobenzotrifluoride (PCBTF) (Kim-Fu et al., 2024; Stockwell et al., 2021). Recent legislation changes in California now categorize PCBTF as a carcinogen under Proposition 65 (OEHHA, n.d.).

Why are APEs used in paints?

Paint formulations contain APEs mainly as surfactants and emulsifiers, helping paint spread evenly, mix well, and stay stable. The most commonly used APEs in paints are nonylphenol ethoxylates (NPE) and octylphenol ethoxylates (OPE). APEs can be used in both solvent- and waterborne formulations (Ecology, 2021). In 2015, paints and coatings were reported to account for around 13% of NPE usage globally (DTSC, 2018).

Volume estimates for priority product-chemical combinations

The volume of priority chemicals associated with the product

PFAS

Several studies analyzed paints for the presence of various types of PFAS. A study from Norway reported non-volatile PFAS concentrations between 0.10 and 5.8 µg/g in two of three tested paints (Herzke et al., 2012). Another study detected PFAS in paint samples, but didn't quantify the PFAS concentrations (Janousek et al., 2019). A 2021 study in China collected 16 paints containing fluoropolymers, analyzed the paints for non-volatile PFAS, and reported concentrations ranging from 0.00011 to 75 µg/g (Jia et al., 2021). The OECD estimates that fluoropolymer-containing architectural paints make up approximately 1% of the global market share (OECD, 2022).

A recent study analyzed 27 exterior and interior building paints purchased in Oregon between 2021 and 2022 (Cahuas et al., 2022). The samples included 14 brands from four coating firms representing 75% of the United States market share. The authors tested paints for PFAS and total fluorine content.

The PFAS results are as follows:

- For non-volatile PFAS, 6:2 fluorotelomer phosphate diester (diPAP) was quantified in 14 of 27 paint samples, with reported concentrations range of 0.073–58 µg/g (0.073–58 ppm, 0.0030–1.9 umol F/g) (Cahuas et al., 2022).
- Notably, 6:2 diPAP contains the same phosphate diester functional group found in a type of fluorosurfactant (Maflon, n.d.). However, it is unknown whether 6:2 diPAP is added to the paints as an ingredient or associated with manufacturing or degradation of fluorosurfactants in paints (Cahuas et al., 2022).
- For volatile PFAS, 6:2 fluorotelomer alcohol (FTOH) was quantified in 14 of 27 paint samples, with reported concentrations range of 0.92–83 µg/g (0.92–83 ppm, 0.033–3.0 umol F/g) (Cahuas et al., 2022). The 6:2 FTOH concentrations were higher in exterior paint samples compared to interior paint samples.
- While 6:2 FTOH is often used as a precursor to produce other PFAS molecules, it's unknown whether 6:2 FTOH measured in paints is intentionally added or is present as a residual from the manufacture of other PFAS ingredients or as a breakdown product of fluorosurfactants (Cahuas et al., 2022).
- All paints with 6:2 FTOH detections were listed as "low" or "zero volatile organic compounds (VOCs)." The authors noted that the "low" or "zero VOCs" labels could be misleading to consumers since the paints contained volatile PFAS (Cahuas et al., 2022).
- The authors measured total fluorine in 14 of the 27 paint samples. In paints with measurable levels of 6:2 FTOH, total fluorine concentrations ranged from 14–48 umol F/g. Based on these results, the authors noted that the measured concentrations of 6:2 FTOH and 6:2 diPAP only account for a small fraction of the total fluorine content of these paints (between 1.5% and 17% of total fluorine) (Cahuas et al., 2022). Results from Cauhas et al. suggested that additional fluorinated chemicals that have yet to be identified were present in the paints. The Cahuas et al. study did not analyze for the presence of any fluoropolymers in their paint samples.

More recently, Kim-Fu et al. collected ten bridge paints between 2023 and 2024 from two Pacific Northwest regional transportation facilities (Kim-Fu et al., 2024). The authors analyzed the samples for the presence volatile and non-volatile PFAS, PTFE, and PCBTF. Volatile and non-volatile PFAS were below detection limits, and no PTFE was found in any bridge paints. Six of the ten bridge paints contained PCBTF with the concentrations ranging from 440 to 16,000 µg/g (Kim-Fu et al., 2024).

In addition, a non-peer-reviewed study by Healthy Building Network (HBN) reported total fluorine in paint products (Healthy Building Network, 2023). The study by HBN examined 94 samples for total fluorine and reported an overall detection frequency of approximately 50%. The paint samples included gloss, base, and colorants and represented eight manufacturers, covering over 65% of the North American market share. Total fluorine was detected in paint samples from all manufacturers, and in paints with measurable fluorine the concentrations ranged from 42 to 688 ppm (Healthy Building Network, 2023).

APEs

We referenced publicly available information from manufacturers and EPA data to evaluate the use of APEs in paints. Based on this information we determined paints are a significant use of APEs.

The data in Table 13, Table 14, and Table 15 are derived from publicly available Safety Data Sheets (SDS) and Health Product Declarations (HPD) (HPD Collaborative, n.d.). They provides examples of paints containing APEs, with reported concentration ranges and chemical types.

Reported concentrations of APEs vary across different product types, formulations, and intended applications. While most interior acrylic paints tend to contain less than 0.5% APEs, some high-performance coatings can be formulated with higher concentrations of APEs up to 5%.

Table 13: Examples of nonylphenol ethoxylates (NPEs) and their concentration ranges as reported in various paint products and formulation types.

Chemical(s) in product (CAS Registry Numbers)	Reported Concentration (range or max %)	Product Type (based on manufacture description)	Formulation Type (based on manufacturer description or ingredients)	Reference
Nonylphenol, branched, ethoxylated (CAS: 68412-54-4)	5	Exterior paint	Acrylic	(Benjamin Moore & Co., 2018)
Nonylphenol, branched, ethoxylated (CAS: 68412-54-4)	0–1	High performance coating	Acrylic/Aliphatic Polyurethane	(Richard's Paint, 2017)
Nonylphenol, branched, ethoxylated (CAS: 68412-54-4)	0.05–0.1	High-performance coating	Acrylic-polyurethane	(HPD Collaborative, n.d.; Wolf-Gordon, 2024a)
Nonylphenol, branched, ethoxylated (CAS: 127087-87-0)	0–0.3	Interior paint	Acrylic	(HPD Collaborative, n.d.; PPG Architectural Finishes, 2024a)

Chemical(s) in product (CAS Registry Numbers)	Reported Concentration (range or max %)	Product Type (based on manufacture description)	Formulation Type (based on manufacturer description or ingredients)	Reference
Nonylphenol, branched, ethoxylated (CAS: 127087-87-0)	0.3–0.6	Interior paint	Acrylic	(HPD Collaborative, n.d.; PPG Architectural Finishes, 2024b)
Nonylphenol, branched, ethoxylated (CAS: 68412-54-4)	0.1–0.5	Interior paint	Acrylic	(HPD Collaborative, n.d.; Peintures MF/MF, 2024b)
Nonylphenol, branched, ethoxylated (CAS: 68412-54-4)	0.1–1.0	Interior paint	Acrylic Latex	(HPD Collaborative, n.d.; Peintures MF/MF, 2024c)
Nonylphenol, branched, ethoxylated (CAS: 68412-54-4)	0–0.5	Interior paint	Acrylic Latex	(HPD Collaborative, n.d.; Peintures MF/MF, 2024f)
Nonylphenol, branched, ethoxylated (CAS: 68412-54-4)	0.1–0.3	Interior paint	Acrylic latex	(HPD Collaborative, n.d.; PPG Architectural Finishes, 2023)
Nonylphenol, ethoxylated (CAS: 9016-45-9)	0.1–0.5	Interior, industrial coating	Acrylic Epoxy	(Benjamin Moore & Co., 2022b; HPD Collaborative, n.d.)
Nonylphenol, branched, ethoxylated (CAS: 68412-54-4)	0.1–1.0	Interior/exterior paint	Acrylic	(HPD Collaborative, n.d.; Peintures MF/MF, 2024a)
Nonylphenol, ethoxylated (CAS: 9016-45-9)	0.05–0.4	Primer for interior use	Ceramic reinforced acrylic	(HPD Collaborative, n.d.; ICP Group, 2020)

Table 14: Examples of octylphenol ethoxylates (OPEs) and their concentration ranges in various paint products and formulation types.

Chemical(s) in product (CAS Registry Numbers)	Reported Concentration (range or max %)	Product Type (based on manufacture description)	Formulation Type (based on manufacturer description or ingredients)	Reference
Octylphenol, ethoxylated, (CAS: 9036-19-5)	0.1–0.5	Chalkboard paint	Acrylic	(Benjamin Moore & Co., 2023c; HPD Collaborative, n.d.)
Octylphenol, ethoxylated, (CAS: 9036-19-5)	0.1–0.5	Exterior paint	Acrylic	(Benjamin Moore & Co., 2022e; HPD Collaborative, n.d.)
Octylphenol, ethoxylated, (CAS: 9036-19-5)	0.5–1.0	Exterior paint	Acrylic	(Benjamin Moore & Co., 2023d; HPD Collaborative, n.d.)
Octylphenol, ethoxylated, (CAS: 9036-19-5)	0.05–1.0	Exterior paint	Acrylic	(Benjamin Moore & Co., 2022f; HPD Collaborative, n.d.)
Octylphenol, ethoxylated, (CAS: 9036-19-5)	0.1–0.5	High build coating	Acrylic Blending Latex	(Benjamin Moore & Co., 2024b; HPD Collaborative, n.d.)
Octylphenol, ethoxylated, (CAS: 9036-19-5)	0.1–0.5	High performance coating	Acrylic	(Benjamin Moore & Co., 2022g; HPD Collaborative, n.d.)

Chemical(s) in product (CAS Registry Numbers)	Reported Concentration (range or max %)	Product Type (based on manufacture description)	Formulation Type (based on manufacturer description or ingredients)	Reference
Octylphenol, ethoxylated, (CAS: 9036-19-5)	0.1–0.5	High performance coating	Acrylic Latex	(Benjamin Moore & Co., 2022d; HPD Collaborative, n.d.)
Octylphenol, ethoxylated, (CAS: 9036-19-5)	0.01–0.04	High performance coating	Acrylic-polyurethane	(HPD Collaborative, n.d.; ICP Group, 2022)
Octylphenol, ethoxylated, (CAS: 9036-19-5)	0.15–0.25	High performance coating	Acrylic-polyurethane	(HPD Collaborative, n.d.; Wolf-Gordon, 2024b)
Octylphenol, ethoxylated, (CAS: 9036-19-5)	0.1–0.5	Interior/exterior paint	Acrylic Urethane	(Benjamin Moore & Co., 2023a; HPD Collaborative, n.d.)
Octylphenol, ethoxylated, (CAS: 9036-19-5)	0.5–1.0	Interior/exterior paint	Epoxy Modified Acrylic, Latex	(Benjamin Moore & Co., 2022a; HPD Collaborative, n.d.)
Octylphenol, ethoxylated, (CAS: 9036-19-5)	0.5–1.0	Primer	Acrylic	(Benjamin Moore & Co., 2024a; HPD Collaborative, n.d.)
Octylphenol, ethoxylated, (CAS: 9036-19-5)	0.1–0.5	Primer for exterior use	Acrylic	(Benjamin Moore & Co., 2023b; HPD Collaborative, n.d.)

Table 15: Examples of mixtures of multiple nonylphenol ethoxylates (NPEs) and octylphenol ethoxylates (OPEs) and their reported concentration ranges in various paint products.

Chemical(s) in product (CAS Registry Numbers)	Reported Concentration (range or max %)	Product Type (based on manufacture description)	Formulation Type (based on manufacturer description or ingredients)	References
Nonylphenol, ethoxylated (9016-45-9) ***and*** Octylphenol, ethoxylated (9036-19-5)	0.5–1.0 ***and*** 0.1–0.5	High performance coating	Acrylic	(Benjamin Moore & Co., 2023e; HPD Collaborative, n.d.)
Nonylphenol, branched, ethoxylated (68412-54-4) ***and*** Nonylphenol, branched, ethoxylated, phosphated (68412-53-3)	1.0–2.5 ***and*** 1.0–2.5	High performance coating	Acrylic	(Rust-Oleumn Corporation, 2024)
Nonylphenol, branched, ethoxylated (127087-87-0) ***and*** Nonylphenol, branched, ethoxylated (68412-54-4)	0–0.5 ***and*** 0–1.0	Interior paint	Acrylic Latex	(HPD Collaborative, n.d.; Peintures MF/MF, 2024d)

Chemical(s) in product (CAS Registry Numbers)	Reported Concentration (range or max %)	Product Type (based on manufacture description)	Formulation Type (based on manufacturer description or ingredients)	References
Nonylphenol, branched, ethoxylated (127087-87-0) ***and*** Nonylphenol, branched, ethoxylated (68412-54-4)	0–0.5 ***and*** 0–0.5	Interior paint	Acrylic Latex	(HPD Collaborative, n.d.; Peintures MF/MF, 2024e)
Nonylphenol, branched, ethoxylated (68412-54-4) ***and*** Octylphenol, ethoxylated (9036-19-5)	0.1–0.5 ***and*** 0.1–0.5	Primer	Acrylic Blended Latex	(Benjamin Moore & Co., 2022c; HPD Collaborative, n.d.)

We searched the EPA ChemExpo database and found that APEs are reported in several paint products. Table 16 summarizes the data on APEs in paint and related products, as reported in the EPA ChemExpo database.

Table 16: The number of paint products reported in EPA ChemExpo with NPEs or OPEs.

Chemical	Number of products*
Nonylphenol, branched, ethoxylated (CAS: 127087-87-0)	2
Nonylphenol, branched, ethoxylated (CAS: 68412-54-4)	16
Octylphenol, ethoxylated, (CAS: 9036-19-5)	35
Polyoxyethylated nonylphenol (CAS: 9016-45-9)	14

* The number of products in the paint, stain, and related product use category as reported in EPA ChemExpo. Paint thinners, strippers, and other products outside our priority product scope were excluded in the number of products.

Past analysis of APEs in paints by the Danish EPA and ECHA reported that NPEs were typically used in concentrations of 0.6% to 3% (Danish EPA, 2013; ECHA, 2012). Additionally, an industry expert stated that APEs are used in paints at concentrations between 0.25% and 1%, and that the industry is exploring potential alternatives (BASF, 2018). Comparing the more recent data in Tables 13—15 to earlier references shows that APEs are still used in paints in part of the market, with concentrations similar to those in past reports.

Volume of the product sold or present in the state

The American Coatings Association, representing the United States paint and coatings industry, estimated a market volume of 832 million gallons of architectural coatings for 2019, valued at $12.8 billion (American Coatings Association, 2019). Washington makes up 2.3% of the United States population, suggesting that in 2019, the state's share of the market included around 19 million gallons of architectural coatings, valued at $294 million (US Census Bureau, 2024). This estimate is for the total volume of architectural coatings for a single year.

Washington has a statewide, industry-led architectural paint stewardship program to ensure proper management of leftover paint (Ecology, n.d.-e). In 2023, the program reported that over 13.8 million gallons of new paint eligible for the program were sold in Washington. Approximately 929,000 gallons of excess paint–6.7% of sold paints–were recovered by the program (PaintCare, 2024). Based on the reports by American Coatings Association and PaintCare, it is clear that a large volume of paints are sold in Washington.

We expect the trend of large volumes of paint sold each year in Washington to continue and possibly increase over time. The Washington State Department of Commerce estimates that 1.1 million new homes will be required in Washington over the next twenty years (WA Department of Commerce, 2023). These new homes will require a significant volume of paint. Future paint use will also include paint needed for businesses and for maintaining and renovating existing structures.

As noted above, paint has been reported to contain PFAS at parts-per-million concentrations in formulations. Given volume estimates, PFAS-containing paints represent a significant use of PFAS in Washington.

APEs are also used in paint formulations at concentrations of up to 5% (Tables 13–15). Based on the paint volume estimates above, this represents a significant use of APEs in Washington.

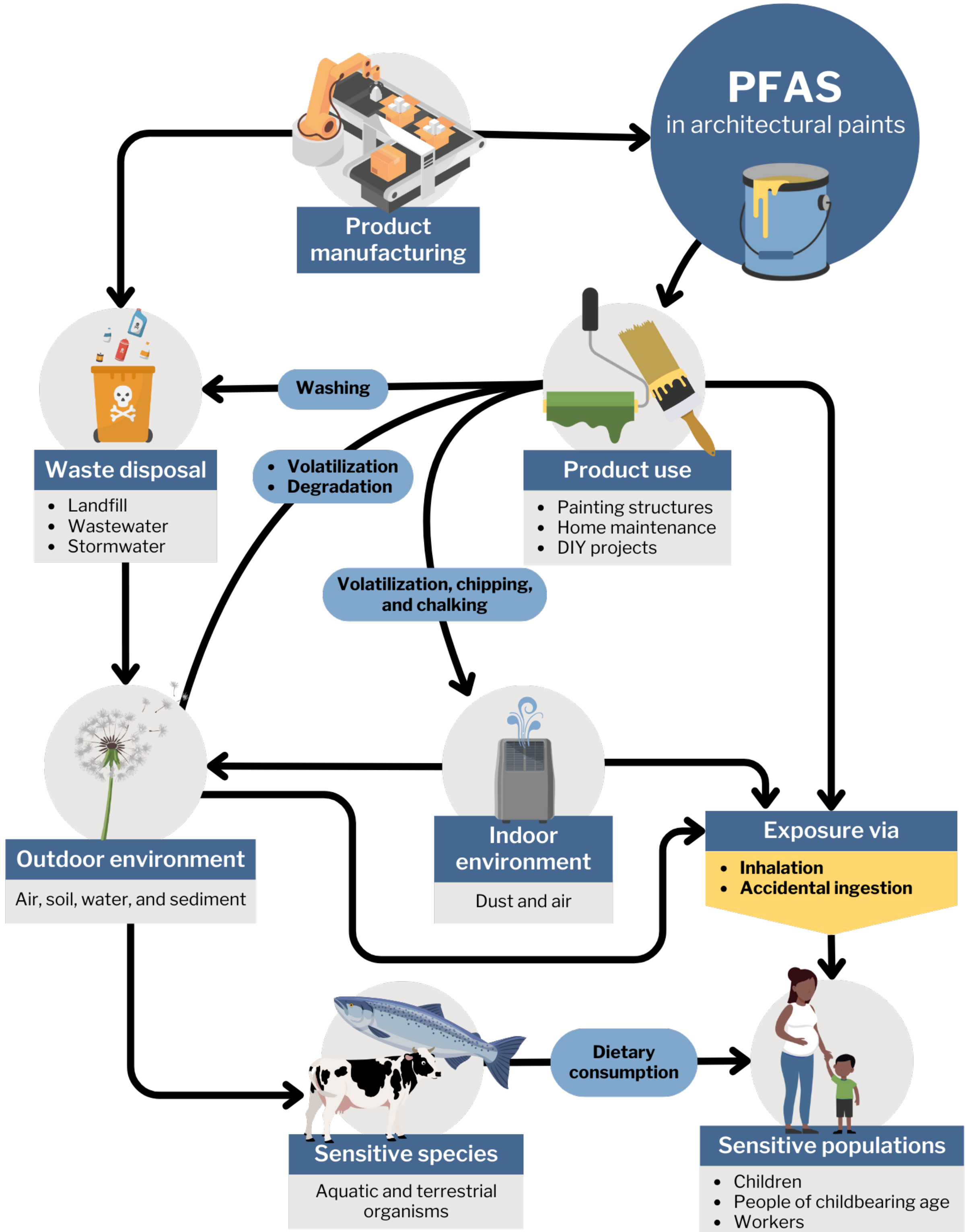

Figure 9: Pathways of potential exposure to PFAS from paints in sensitive populations and sensitive species. (See Appendix D for a step-by-step description of this figure.)

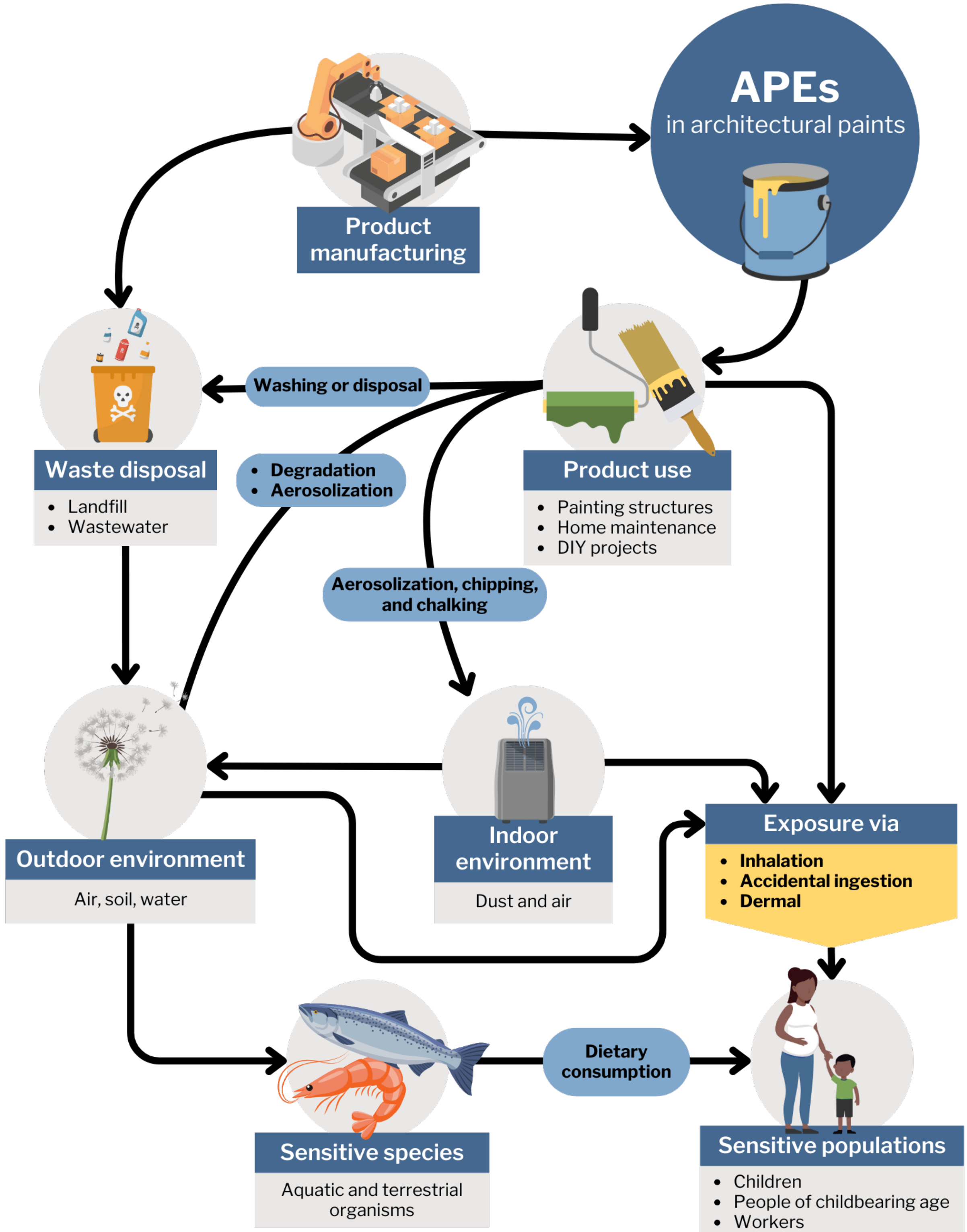

Figure 10: Pathways of potential exposure to APEs from paints in sensitive populations and sensitive species. (See Appendix D for a step-by-step description of this figure.)

Potential for exposure to the priority chemical from the product

People and wildlife can be exposed to chemicals in paint like PFAS and APEs from manufacture, use, and disposal of paint (Figure 9 and Figure 10). People can be exposed to these chemicals when applying paint, and workers who manufacture or apply paint routinely may have higher exposures.

In public comments submitted by the American Coatings Association, several practices were outlined to help reduce chemical exposure while painting (American Coatings Association, 2024). These include restricting access to painting areas–especially for children and people of childbearing age–and improving ventilation by opening a window and using fans to circulate air.

People can also be exposed to PFAS and APEs as paint coatings break down over time. Indoor architectural paints can be affected by temperature and humidity changes, aging, and UV exposure. These factors can cause paint to peel and eventually chip, which contributes to household dust. Some PFAS and APEs from paint sources can be ingested or inhaled after the paint chips and becomes household dust. People can also be exposed to PFAS and APEs through dietary consumption of contaminated food or drinking water (Health, n.d.-a).

PFAS and APEs can be released into the environment when paints are applied to surfaces or improperly disposed. PFAS and APEs from water-based paints and can enter wastewater or septic systems when equipment or clothing is washed.

PFAS and APEs can also be released into the environment as outdoor paints degrade. Outdoor architectural paints can be affected by weathering, UV exposure, and seasonal temperature changes that may cause chipping and chalking (Nored et al., 2022). Chalking happens when the paint's pigment and binder break down, causing the top layer of paint to become chalky (Resene, n.d.; Sherwin-Williams, n.d.). The chalk residue can be washed away by rain or other precipitation, introducing it into the environment.

PFAS and APEs released in the environment could expose sensitive species. In addition, APEs can breakdown to alkylphenols (APs) and expose sensitive species like fish and aquatic invertebrates. The potential for exposure to PFAS and APEs from paint in sensitive populations and species is an important consideration as these chemicals are associated with hazards to human health and the environment.

Several PFAS chemicals can harm reproduction and development, as explained in our legislative report, "Regulatory Determinations Report to the Legislature – Safer Products for Washington Cycle 1 Implementation Phase 3" (Ecology, 2022b).[73]

APEs and APs are linked to endocrine disruption, as well as harms to development and reproduction, as explained in that same report (ECHA, 2023d; Ecology, 2022b; US EPA, 2010).

[73] apps.ecology.wa.gov/publications/summarypages/2204018.html

The following sections discuss potential exposure pathways for PFAS and APEs from paint for sensitive populations and species.

Sensitive populations

People of childbearing age

People can be exposed to PFAS and APEs when applying paint or as paint coatings break down over time. In 2019, the American Coatings Association estimated that about 36% of architectural coatings, including paints, were applied by homeowners and other non-professional painters (American Coatings Association, 2019). Recent data from CivicScience and The Farnsworth Group suggest that many of these individuals are adults of childbearing age or lower-income households (CivicScience, 2023; The Farnsworth Group, n.d.).

Additionally, young adults of childbearing age who paint their own homes to save money are less likely to invest in professional personal protective equipment (PPE) or have training on chemical hazards. A 2012 National Safety Council survey on home improvement safety, cited in a 3M press release, found that only 39 percent of respondents used respiratory protection while working on home projects—meaning around 60% did not use personal protective equipment (3M, 2012). This increases the potential for exposure to APEs and PFAS from paint, especially for non-professional painters, including individuals of childbearing age and those with lower incomes.

PFAS

People may inhale volatile PFAS from paint as reported by Cahaus et al., 2022. Volatile PFAS, such as 6:2 FTOH, are released from paint as it dries (Cahuas et al., 2022). The authors calculated the total amount of 6:2 FTOH evaporated from an interior paint sample over three hours in a closed chamber and estimated the air concentration based on the chamber's volume. Their findings confirmed that 6:2 FTOH evaporated as the paint dried, suggesting potential inhalation exposure for people.

The authors also estimated the peak air concentration of 6:2 FTOH and inhalation exposure for eight paint samples in children, women, and men (Cahuas et al., 2022). One interior paint sample exceeded the reference dose of 5 µg/kg/day for all groups and had a predicted peak air concentration of 190 $\mu g/m^3$ (Cahuas et al., 2022). Although these are only estimates, the study suggests potential inhalation exposure to volatile PFAS from paint.

FTOHs are a type of PFAS that can break down in the atmosphere or be metabolized into more stable perfluoroalkyl acids (PFAAs). 6:2 FTOH has been reported as one of the most abundant volatile PFAS detected in studies of indoor air (Morales-McDevitt et al., 2021). FTOHs and PFAAs are associated with adverse health effects in people and other organisms (Rice et al., 2020; US EPA, 2023b).

APEs

People can potentially be exposed to APEs through inhalation and skin contact when applying paint. NPEs and OPEs are highly water-soluble and semi-volatile, while NPs and OPs are less water-soluble and considered moderately volatile (Staples et al., 2008; US EPA, 2010).

According to the Danish EPA, OPEs are primarily released into air when paint is applied by spraying (Danish EPA, 2015).

Studies on the skin absorption of NPEs and NPs found that NP absorption was negligible, while NPE absorption was less than 1% (US EPA, 2007). OPEs are also expected to have low skin absorption. However, some OPs, such as 4-tert-octylphenol, have been reported to be more easily absorbed through the skin (NICNAS, 2018).

Beyond direct exposure during painting, people of childbearing age can also be exposed to APEs or APs through contaminated food, such as seafood.

Children

The potential ingestion of dust is a primary way infants and children are exposed to PFAS and APEs. Because children spend more time on the floor and frequently put their hands in their mouths, they are more likely to swallow indoor dust unintentionally (US EPA, 2024c).

PFAS

Some PFAS from paint sources can be ingested or inhaled after they chip and become household dust. The presence of PFAS in indoor dust is well-documented, with many sources identified, including consumer products (De Silva et al., 2021). Building materials, including paints and coatings, are considered a potential source of PFAS-contaminated household dust (Cahuas et al., 2022; Savvaides et al., 2021). However, the specific contribution of PFAS from paints to dust concentrations is less understood.

Dust inhalation and ingestion are known exposure pathways for PFAS (De Silva et al., 2021). Given the large surface area and volume of indoor paints, it is reasonable to assume that as paint breaks down, it may contribute to PFAS in indoor dust and increase exposure potential for children.

APEs

Studies on the amount of APEs and alkylphenols in indoor dust have shown various concentrations across home, childcare, and office environments (Rudel et al., 2001, 2003; Wilson et al., 2003). A study from South Africa found that APEs in indoor dust samples were linked to a high mean estimated daily ingestion rate of 74.3 ng/kg bw/day for toddlers in home environments (Abafe et al., 2017). This study also reported lower APEs and APs concentrations in indoor dust compared to other studies from the United States, suggesting that US dust samples may correspond to an even higher estimated daily ingestion rate for toddlers. However, we did not find a study that specifically measures how much paints contribute to APEs and APs contamination in indoor dust compared to other sources.

While research shows that children can be exposed to APEs and APs through dust ingestion, exposure can occur through other routes. Studies have confirmed the presence of NPs (either directly or as a breakdown product of NPEs) in breast milk and umbilical cord blood (US EPA, 2010). Based on the highest level of NPs found in breast milk, an infant’s maximum estimated daily ingestion rate through breastfeeding was 3.9 ug/kg/day.

This is especially concerning in children because APs have been linked to endocrine disruption, neurotoxicity, and immune system harm (Ecology, 2022b). Both NPs and OPs are listed on Washington's Chemicals of High Concern to Children (CHCC) reporting list under the Children's Safe Products Act.

Workers

The American Coatings Association reported that in 2019, an estimated 64% of architectural coatings, including paints, were applied by professionals (American Coatings Association, 2019). This suggests that workers may have higher exposure to PFAS and APEs since they handle a large portion of paint sold and used. Construction and demolition workers may also have higher exposures.

PFAS

Certain occupations, such as professional painters who regularly use paint products, may have higher exposures to PFAS from paint. This is supported by the study mentioned earlier, which measured emissions of volatile PFAS, specifically 6:2 FTOH, from paint after application (Cahuas et al., 2022). While the Cahaus et al. study did not estimate the worker exposure levels, the authors highlighted their findings as an important potential route of exposure for occupations such as professional painters.

However, in public comments, the American Coatings Association also noted that professional painters are trained in risk-reducing practices, such as using personal protective equipment and ensuring proper ventilation in the work area. These measures may help lower potential exposure to chemicals released during painting.

Certain jobs in hazardous environments, such as firefighters entering burning buildings or crews handling demolition, may face higher exposure to PFAS from paint. Firefighters are exposed to higher levels of PFAS from smoke and house dust in burning structures (Mazumder et al., 2023). Research has shown that non-volatile PFAS can break down under high heat into volatile PFAS, such as FTOHs—including those found in paints (Cahuas et al., 2022; Hakeem et al., 2024). This could increase exposure potential for firefighters working in these conditions.

Construction and demolition work also involves potential PFAS exposure. Debris from buildings contains PFAS, which can become airborne as dust during demolition, creating potential for exposure to workers and bystanders (Y. Liu et al., 2024). Similar exposure potential has been observed with other hazardous chemicals in paint, such as lead (Farfel et al., 2005).

APEs

Occupational exposure to APEs in paints is not well studied, but past research provides some insight. The European Commission has previously estimated exposure levels from mixing paint and spray application, as referenced in US EPA's 2010 NP and NPEs Action Plan (US EPA, 2010).When sprayed, professional application can result in release of APEs into the air (Danish EPA, 2015). Without proper PPE and ventilation, workers may be exposed to APEs through inhalation.

Workers can also be exposed to APEs in paint through skin contact during manufacturing or use, though this exposure potential may be lower than other routes. As noted above, proper use of PPE and ventilation can help reduce worker exposure to APEs from paints.

Sensitive species

PFAS and APEs released to the environment from paint have the potential to expose sensitive species. PFAS, APEs, and APs are persistent in the environment and can bioaccumulate in organisms. As discussed earlier, paint samples that contain PFAS and APEs include water-based paints, which may be washed into municipal wastewater or septic systems from brush washing or improper disposal.

Environmental contamination

PFAS

PFAS are widely distributed in the environment, and studies have identified consumer products as sources of these chemicals released to the environment. In Cahuas et al., the authors note that since the tested paints were water-based, cleaning the brushes can introduce PFAS to wastewater, septic systems, and the environment (Cahuas et al., 2022). When paint is improperly disposed of down the drain, it may contribute to releases of PFAS to the environment.

PFAS are present in construction and demolition debris, which is often disposed of in landfills (Y. Liu et al., 2024). Across Washington, PFAS have been widely detected in municipal landfill leachate (Capozzi et al., 2023). This includes 6:2 FTOHs and their breakdown products, chemicals also found in paint samples, as mentioned earlier (Cahuas et al., 2022). While the Capozzi et al. (2023) study did not directly estimate the contribution of paint to PFAS in landfills, it underscores the importance of reducing PFAS sources, including those from paints.

Landfills and landfill leachate are major sources of PFAS releases to the environment (Malovanyy et al., 2023). Treating and removing of PFAS from landfill leachate is difficult and costly, further emphasizing the need to reduce PFAS at the source (Malovanyy et al., 2023; Tolaymat et al., 2023).

Landfill gas contains PFAS, with FTOHs being the most common type (Goukeh et al., 2023; Y. Liu et al., 2024; Titaley et al., 2023; Tolaymat et al., 2023). In landfills, FTOHs can break down into perfluorocarboxylic acids in either leachate (Y. Chen et al., 2023; Smallwood et al., 2023) or in the atmosphere (Ellis et al., 2004; Q. Wang et al., 2020). Once in the atmosphere, perfluorocarboxylic acids from degraded FTOHs can travel long distances (Ellis et al., 2004; Saini et al., 2023; Shoeib et al., 2006), potentially exposing sensitive species in remote areas (Dai et al., 2025; Muir et al., 2019).

PFAS released to the environment from paints in water or solid waste is a concern for sensitive species and ecosystems, including aquatic and land-based organisms (Cousins et al., 2022; ITRC, 2023a). In addition, fluoropolymer paints are thought to represent around only 1% of the paint market, but a study by Jia et al. highlighted the potential for release of non-polymeric PFAS such as PFOA from fluoropolymer paints as well (Jia et al., 2021; OECD, 2022).

Given the millions of gallons of paint sold each year in Washington and the presence of paint in construction and demolition debris, paint represents a significant source of potential exposure to PFAS for sensitive species.

APEs

APEs in paint can be released into air, surface water, wastewater, soil, and solid waste (Danish EPA, 2015; Ecology, 2021). Most releases are expected to occur through wastewater and solid waste (Danish EPA, 2015; Ecology, 2021). While the amount APEs released into the air from paints is relatively small, paints are considered a major source of OPEs and NPEs to wastewater (Danish EPA, 2015; Ecology, 2021). Additionally, APEs from paint that end up in landfills may potentially leach into groundwater, further contributing to environmental contamination (US EPA, 2010). The exact contribution of paints to APEs in the environment compared to other sources is still not well understood.

APEs are linked to endocrine disrupting properties and can cause acute and chronic toxicity in aquatic life. APEs break down more slowly in environments without oxygen and are considered persistent. When they do break down, APEs can become harmful chemicals including nonylphenols (NPs) and octylphenols (OPs) (US EPA, 2010).

APEs and their breakdown products are highly toxic to aquatic organisms and have been linked to endocrine disruption, neurotoxicity, immune system harm, and reproductive and developmental effects (ECHA, 2023d; Ecology, 2022b; US EPA, 2010). For example, NPs have been found to feminize male fish and impair reproduction and development in fish and aquatic invertebrate species (DTSC, 2018).

Studies show that NPs and OPs persist in the environment, and some APEs and APs have the potential to bioaccumulate in organisms such as fish and mollusks (Ecology, 2022b; US EPA, 2010). A 2014 study by Ecology found short-chain NPEs, NPs, and OPs in fish and mussel samples (Ecology, 2021). Contaminated organisms may then expose other sensitive species when eaten, spreading harmful exposures through the food chain.

Availability of potential safer alternatives

PFAS

Paints, as described in this product category, are generally composed of several key components: “pigments,” “resins/binders, “additives,” and “solvents.” PFAS may be used alone or in tandem with other chemicals for a given paint component. According to (Arkema Inc., 2024; Glüge et al., 2020; OECD, 2022) PFAS chemicals are added for:

- Surface tension-lowering properties
- Anti-UV properties
- Oil/dirt repellence
- Chemical weathering resistance
- Leveling and wetting effects in paint products

Short-chained PFAS are used as fluorosurfactants to improve stain resistance, enhance wetting performance by reducing surface tension, and reduce surface contamination during paint application (3M, 2016).

Fluoropolymers are commonly used as resins in paints, helping to lower surface temperatures by providing UV protection—especially in outdoor applications (OECD, 2022). According to the American Coatings Association, fluoropolymers-containing paints are often used to meet specific performance standards, such as the American Architectural Manufacturers Association (AAMA) 2605-20 and the Society for Protective Coatings Paint 47 standards.

Silicone-based alternatives, such as siloxanes and silicone surfactants, are used in some paints to provide similar properties to PFAS (OECD, 2022).

Paint manufacturers often do not disclose the ingredients used in their formulations or components used in paint products. Green Seal, a standard certification organization, is currently revising its paint and coatings standards to prohibit PFAS (Green Seal, 2023). The current standard doesn't limit or require disclosure of PFAS in certified products. However, once updated, it may help identify paints that don't contain PFAS and could serve as safer alternatives. The American Coatings Association has stated that they don't expect this updated standard to significantly impact future paint formulations.

Alternatives to PFAS in paint have been tested in preliminary trials by Arkema and published by the American Coatings Association (Arkema Inc., 2024). However, the American Coatings Association clarified that these trials do not confirm a workable replacement. Many other factors must be considered before a new paint formula can be widely used for certain applications.

During the next phase of implementation of Safer Products for Washington (Phase 3), we'll evaluate alternatives and determine whether they meet our criteria as safer, feasible, and available before recommending any regulatory actions.

APEs

APEs are mainly used as non-ionic surfactants and emulsifiers in paint formulations because they help pigments spread and mix evenly.

A previous alternatives assessment contracted by Ecology found that many paints on the market don't appear to contain APEs or are labeled as NPE-free or APE-free (Ecology, 2021). This suggests the feasibility and availability of alternative ingredients since some are already used in paint formulations. Additionally, the Home Depot previously stated that APEs were eliminated from most of their interior and exterior latex water-based wall paints and committed to a full phase-out by the end of 2019 (Ecology, 2021).

Green Seal offers GS-11 certification for paints, coatings, stains, and sealers (Green Seal, 2021). We searched surfactants in the Green Seal-certified paints and products marketed as "APEs-free." While many products do not disclose the surfactants used in their formulations, we found some alternative surfactants in use, such as alkoxylated siloxanes, alcohol alkoxylates, alkyl sulfonates, and polyalkylene glycol.

A few examples are:

- Ethoxylated branched C11-C14, C13-rich alcohols, CAS: 78330-21-9
- Alcohols, C9-11, ethoxylated, CAS: 68439-46-3
- Polyethylene glycol, CAS: 25322-68-3
- 1-Hexanol, 3,5,5-trimethyl-, ethoxylated, propoxylated, CAS: 204336-40-3
- Alkenes, C14-16 alpha-, sulfonated, sodium salts, CAS: 68439-57-6
- Alcohols, C6-10, ethoxylated propoxylated, CAS: 68987-81-5

In 2012, EPA conducted an alternatives assessment for nonylphenol ethoxylates (NPEs), a subset of APEs, and identified eight safer alternatives, including sorbitan monostearate, sodium lauryl sulfate, and alcohol ethoxylates (US EPA, 2012). While the EPA assessment did not specifically focus on paints and coatings, many of these alternatives have surfactant properties that could be suitable for use in the coatings industry.

Just as some chemicals may be able to replace PFAS in coatings, silicone-based polymers–such as siloxanes and silicone-based surfactants–could also potentially serve the same functions as APEs. These alternatives may provide similar benefits, such as reducing surface tension and improving stability.

During the next phase of implementation of Safer Products for Washington (Phase 3), we'll evaluate alternatives and determine whether they meet our criteria as safer, feasible, and available before recommending any regulatory actions.

Chapter 8: Plastic Packaging

Overview

Priority product

The scope of this priority product includes single and multi-component plastic packaging.

Packaging includes packages as defined in RCW 70A.222.010(3):[74]

> “Package" means a container providing a means of marketing, protecting, or handling a product and shall include a unit package, an intermediate package, and a shipping container. "Package" means, and includes unsealed receptacles such as carrying cases, crates, cups, pails, rigid foil and other trays, wrappers and wrapping films, bags, and tubs.

Packaging components include those as defined in RCW 70A.222.010(4):

> “Packaging component" means an individual assembled part of a package such as, but not limited to, any interior or exterior blocking, bracing, cushioning, weatherproofing, exterior strapping, coatings, closures, inks, and labels.

For this chapter, the term plastic refers to synthetic or semi-synthetic polymers.

Plastic packaging does not include items intended for long-term storage of their products (over one year by the end-consumer). Plastic packaging materials are usually discarded within the same year the products they contain are purchased (US EPA, 2023a).

During public comment on the draft of this report, concerns were raised by industry stakeholders about polyvinyl chloride (PVC) and Polyvinylidene chloride (PVDC) packaging for specific uses including food packaging, pharmaceutical packaging, and dietary supplement packaging. We will consider this input as we determine whether safer alternatives to plastic packaging made from PVC and PVDC are feasible and available in Phase 3 of implementation.

Priority chemical

PVC and PVDC are organochlorine substances and the focus of this priority product. PVC and PVDC are used in various types of plastic packaging as described in this chapter.

Organobromine and organochlorine substances were defined as a priority chemical class in our previous legislative reports Identification of Priority Chemicals Report to the Legislature: Safer Products for Washington Cycle 2 Implementation Phase 1[75] and Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1[76] in Chapter 4: Technical Support for Organobromine or Organochlorine Substances (Ecology, 2024c, 2024b).

[74]app.leg.wa.gov/rcw/default.aspx?cite=70A.222.010
[75]apps.ecology.wa.gov/publications/summarypages/2404025.html
[76]apps.ecology.wa.gov/publications/summarypages/2404026.html

Background

Why are organochlorine substances used in plastic packaging?

Plastic packaging is a significant use of PVC and PVDC, which are organochlorine substances. The focus of this category is the polymers used in packaging materials.

Some plastic containers and packaging are made entirely out of PVC, while others may use plastic polymer coatings or layers made from PVC or PVDC.

Manufacturers and industry associations highlight several reasons why PVC and PVDC are used in packaging for a range of applications (ECVM, n.d.-c; Vinyl Institute, n.d.).

- As a packaging material, PVC is relatively light in weight and inexpensive, and its properties can be modified by formulation with additives to make it suitable for different packaging uses.
- PVC can act as an oxygen and water barrier and these properties can be beneficial for preserving products, including food and beverages.
- PVC is characterized by the industry as having good organoleptic properties, indicating it does not affect the taste of packaged foods.
- PVDC can provide similar properties but rather than being used alone as a bulk material it is often used as a copolymer with other plastics or to coat other types of packaging materials (Formulated Polymer Products Ltd, 2019; Science Direct, n.d.).

Examples of PVC and PVDC used in plastic packaging:

- Polyvinyl chloride (PVC) is used to make packaging materials for a variety of products such as electronics, toys, household items, food, beverages, and cosmetics (Paisley, 2007; Plastic Ingenuity, 2022; Vinyl Institute, n.d.).
- PVC is used for printed labels and shrink sleeves for bottles (Ellen MacArthur Foundation and McKinsey & Company, 2016).
- Polyvinylidene chloride (PVDC) is added as a coating on different substrates to add barrier properties used to protect food (Paisley, 2007).
- PVC liners used in bottle caps and metal cans for food packaging (Carlos et al., 2018).

Volume estimates for priority product—chemical combination

The volume of priority chemicals associated with the product

PVC is a thermoplastic polymer made of 57% chlorine and 43% carbon. It is often supplied in the form of pelletized material (known as compounded PVC) with additives already blended or in a powder form, which needs to be blended with additives to be converted into PVC products (ECVM, n.d.-a).

Plastic packaging products made from PVC can be rigid or flexible. The form of the final product and the amount of PVC resin used in the final product depends on the amounts of additives such as plasticizers, stabilizers, lubricants, fillers, and pigments added to achieve desired properties (Figure 11).

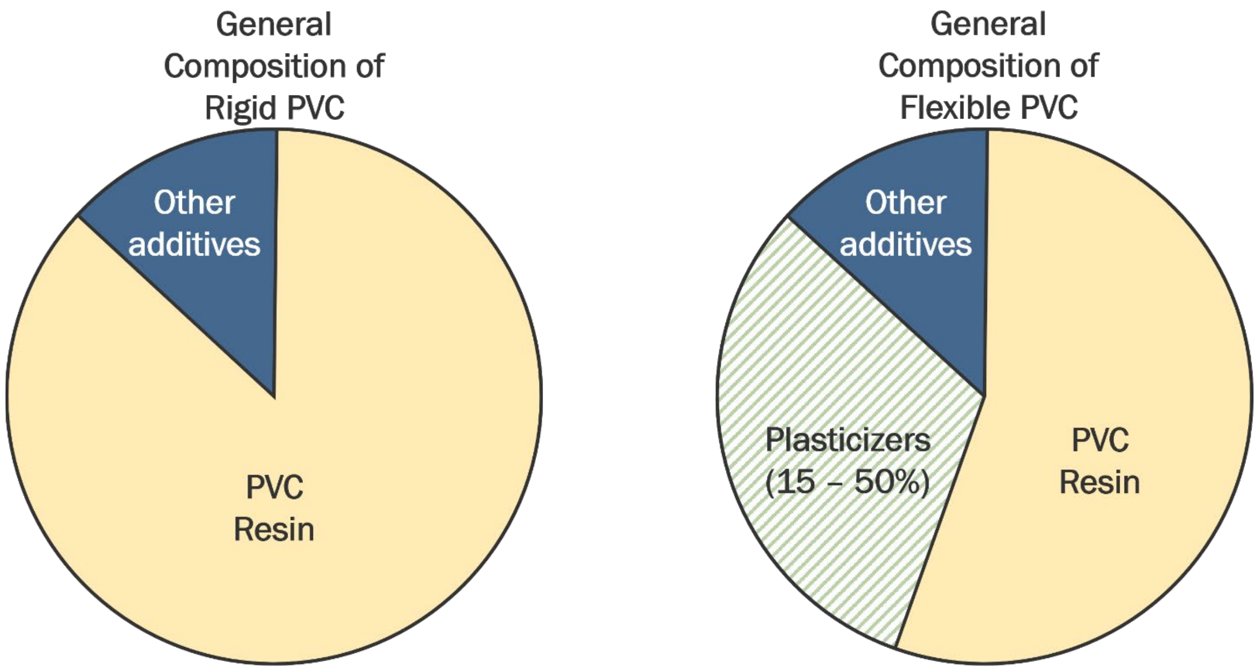

Figure 11: Composition of PVC resin used in rigid and flexible packaging products, which may change according to end-use products. Pie slices are approximations of a general composition and do not represent precise percentages or a specific product.

Rigid PVC films used for packaging applications may contain less than 4% additives by weight (Fortune Union, n.d.). Rigid PVC packaging applications include blister or clamshell packaging for pharmaceutical, food, and consumer goods. Other rigid applications include bottles used for packaging personal care, cleaning, pet care, and some food products.

Flexible packaging uses PVC resin with varying amounts of additives added following the need for different packaging applications. Plasticizers, as a primary example, are used in PVC to achieve flexibility and may comprise around 15–50% of a PVC formulation (Chaudhary et al., 2016). Increasing plasticizer concentration adds flexibility, decreases tensile strength, and reduces the hardness of PVC polymers.

Flexible PVC is used for both retail packaging and for commercial transportation of food, beverages, and other consumer goods. PVC-based shrink wraps are used to provide tight and secure seal around items to prevent tampering or damage during transportation.

PVDC has a higher chlorine content at approximately 73% and is used in packaging applications that require additional barrier properties to reduce the water vapor transmission rate and oxygen transmission rate (Bhaskar et al., 2005; Paisley, 2007). Some examples of PVDC used in such packaging systems are:

- PVDC coated or laminated to PVC
- PVDC coated polypropylene (PP) or polyethylene terephthalate (PET)
- Multilayer films of PVDC/PVC/polyethylene (PE)
- Oriented polyamide (OPA)/aluminum/PVC

In these applications, PVDC coating is rated based on weights per area of the substrate in which it is applied. Common applications require between 40–120 grams/m^2 of PVDC depending on the desired barrier properties (Paisley, 2007; Solvay, 2018).

PVC and PVDC-based flexible stretch films are used in the packaging:

- Of food products (such as meats, cheeses, and bakery products)
- For packaging personal care products
- PVC and PVDC may be used in vinyl liners bottle caps and metal cans

Taken together, this highlights plastic packaging as a significant use of PVC and PVDC as they can be used as both primary packaging polymers, and as components of multilayer packaging.

The volume of the product sold or present in the state

Plastic packaging polymers such as PVC and PVDC are used in large volumes globally, in the United States, and Washington State. The global demand for plastic manufacturing has grown significantly in recent decades, and packaging represents almost 40% of the total plastic demand (Geyer et al., 2017; Tumu et al., 2024; US EPA, 2023a).

The EPA estimates that 14.5 million tons of plastic containers and packaging were produced in the US in 2018, almost 70% of which ended up in landfills (Tumu et al., 2024; US EPA, 2023a). Globally, PVC accounts for approximately 5% of the total plastic packaging market (Ellen MacArthur Foundation and McKinsey & Company, 2016).

Although PVC and PVDC packaging are not the most prevalent types of packaging materials, they are consistently included on the list of problematic consumer packaging materials for achieving sustainability and a circular economy (Ellen MacArthur Foundation and McKinsey & Company, 2016; Eunomia, 2023; US Plastics Pact, 2020). This is in part because PVC and PVDC are not recyclable at scale after consumer use in the United States, including in Washington. In addition, PVC packaging contributes to a larger percentage of the total PVC waste generated relative to its use because the majority is landfilled the same year it is produced or used. For example, in Europe, packaging is estimated to only account for around 7% of PVC use but is estimated to contribute to around 20% of the generated PVC waste after consumer use (ECHA, 2023a, 2023b).

In Washington, limited information is available to track the volume of plastic packaging made from PVC or PVDC. Flexible PVC packaging or PVDC-coated packaging without resin code identifiers are not easily identified in waste characterization studies. They end up being characterized as packaging film plastics, flexible plastic packaging, or other composite plastic packaging (Ecology, 2024a). On the other hand, plastic bottles or containers marked with plastic resin identifier code #3 are identified as PVC but only represent a small percentage of total rigid waste.

Table 17: Relevant plastic packaging waste and recycling rates in Washington (Eunomia, 2023).

Plastic Type	Est. Tons Generated	Recycled	Recycling Rate (%)
Rigid #3 PVC Packaging	54	0	0
Total Rigid Plastics	314,700	68,100	22
Non-PE Plastic Film & Flexible Packaging*	128,600	2,700	2
PE Plastic Bags & Film	104,100	5,300	5

*Only a subset of the Non-PE Plastic Film & Flexible Packaging is assumed to be PVC/PVDC.

In a 2023 report published by Eunomia,[77] all non-PE and composite films, including ones made with PVC and PVDC, were categorized as other "non-PE plastic film and flexible packaging." Average recycling rates for PE plastic bags and film collected from the commercial (6%) and residential (4%) sectors was at around 5% (Table 17).

The recycling rate for mixed non-PE plastic films and packaging was lower at 2% in part because harder-to-recycle materials, such as composite packaging (including packaging containing PVC or PVDC), must be removed before the material is deemed recyclable.

The recycling rate for flexible plastics in Washington is very low because only 1% of households in Washington have access to flexible film recycling through curbside collection; this is the case for PVC and PVDC packaging, as well as other flexible plastics. Municipal Recycling Facilities (MRF) refuse flexible packaging because plastic films clog the sorting infrastructure and contain a higher proportion of harder-to-recycle materials such as composite packaging.

For rigid packaging waste, only a small amount was identified as PVC relative to total rigid plastics, but this likely does not represent all rigid PVC packaging sold or available in Washington. Notably, the recycling rate for total rigid packaging is much higher at 22% compared to rigid PVC packaging which is not recycled at all after consumer use (Table 17).

In a public comment received on the draft of this report, the Vinyl Institute noted it that a significant percentage of PVC used in packaging applications is for metal can liners and glass jar lid liners (Vinyl Institute, 2024). Metal cans and glass jars may be considered highly recyclable, but the liners themselves are not recycled to our knowledge.

[77]The Washington Legislature directed Ecology to assess the amount and types of consumer packaging and paper products sold or supplied into the state and the recycling rates of these materials through existing recycling programs and activities and make recommendations for legislative actions. Eunomia conducted the analysis and published the report in 2023 using state-specific data from the following studies: 2020-2021 Washington Statewide Waste Characterization Study, 2021 Ecology Statewide Disposal Totals, 2021 Ecology Recycling Recovery Data which is reported by facilities, and 2020-2021 King County Material Recovery Assessment.

In a separate public comment provided by the Can Manufacturers Institute, it was noted that PVC liners used in metal cans are thin films, between 1 and 10 micrometers thick, and that in aluminum and steel can recycling the high-temperature processes remove and destroy any coatings on used cans (Can Manufacturers Institute, 2024). The Can Manufacturers Institute highlighted that this thin layer comprises a small fraction of cans used as packaging. In this context, we recognize that metal cans themselves are highly recyclable, apart from the PVC liners that are not recycled as part of this process. This will be an important consideration as we evaluate potential safer, feasible, and available alternatives for specific uses of PVC packaging, such as in metal cans, in the next phase of implementation of Safer Products for Washington.

While end-of-life analysis provided us with information on the amount of the priority product disposed of and its recyclability, it does not provide a complete picture of the amount produced or available. Therefore, we used a recent report from ECHA on PVC and additives along with EPA data on US production volume to better estimate the amount of PVC used for packaging in Washington each year.

In the United States, approximately 7.2 million metric tons or about 8 million US tons of PVC was produced in 2019 (Statista, 2024a). The ECHA report estimated that approximately 7.2% of compounded PVC is used for plastic packaging (ECHA, 2023a).

Compounded PVC refers to PVC resin that has been modified with additives prior to being processed into the final product. Assuming the United States uses approximately this same percentage of PVC for packaging, these figures together would suggest around 570,000 US tons of PVC is used for packaging each year in the United States.

We referred to an analysis by the US Plastics Pact to estimate PVC packaging waste in Washington. Using data from both EPA and industry sources, the US Plastics Pact baseline study reported that PVC bottles, other PVC rigid containers, PVC in bags, sacks, and wraps, and other PVC packaging together were responsible for a total of 390,000 US tons of plastic waste in 2020 (US Plastics Pact, 2020).

We scaled the above estimates of PVC used in packaging and PVC waste to Washington's population to gain a better estimate of these volumes in Washington. Washington's share of the United States population is around 2.3% (US Census Bureau, 2024). A national use volume of 570,000 US tons per year, based on the ECHA and EPA data, would then suggest around 13,000 US tons of PVC used in packaging in Washington per year. Similarly, a national PVC waste volume of 390,000 US tons per year, based on the U.S Plastics Pact data, would suggest around 9,000 US tons of PVC packaging waste generated in Washington per year.

These estimates appear reasonable as they would comprise around 7–10% of the total non-PE plastic film & flexible packaging waste generated in Washington (Table 17). This aligns with our understanding that PVC and PVDC packaging are not the most prevalent types of packaging materials used but still contribute to a significant amount of packaging use and waste generated in Washington.

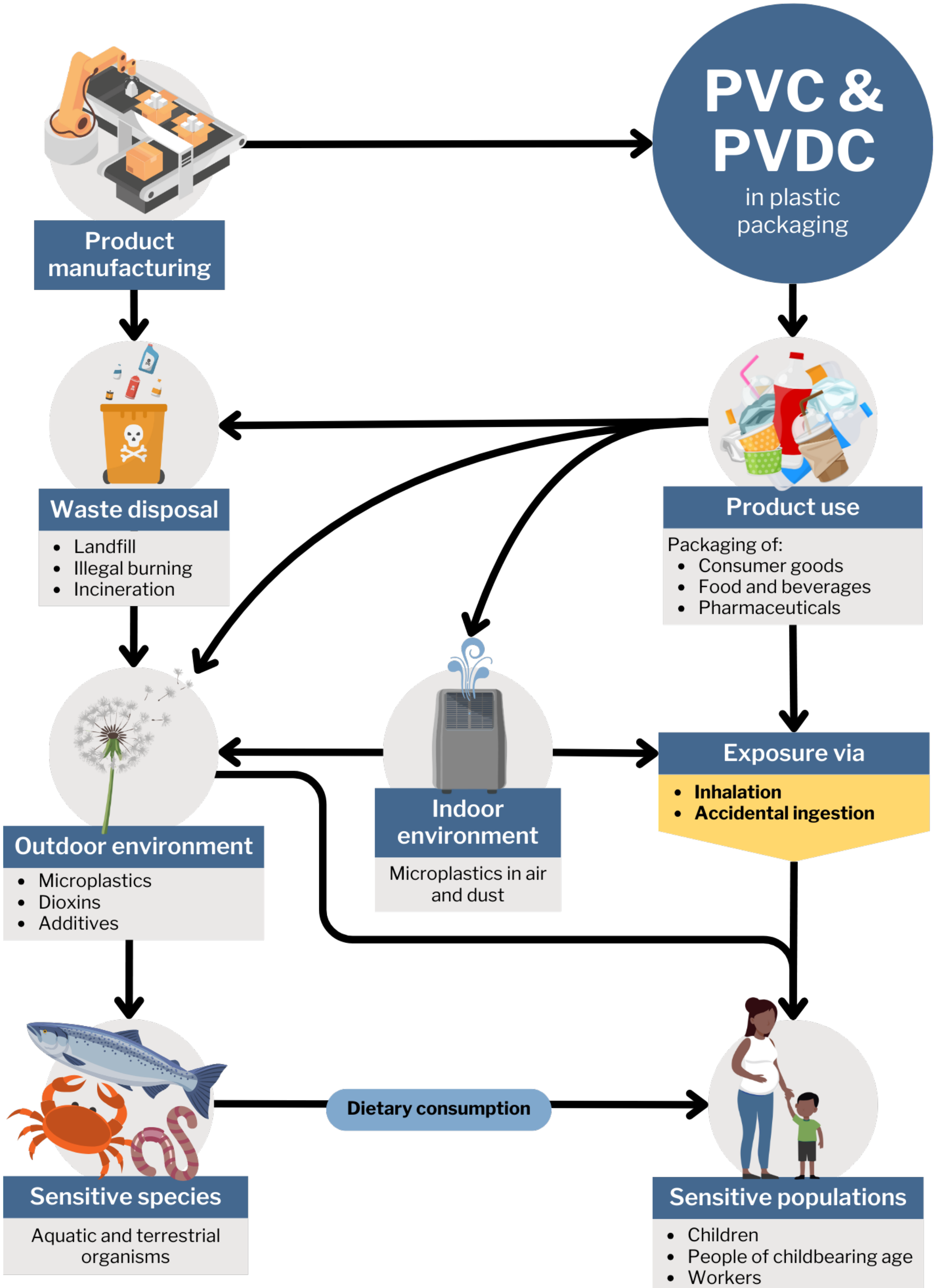

Figure 12: Pathways of potential exposure to organochlorine substances from plastic packaging in sensitive populations and sensitive species. (See Appendix D for a step-by-step description of this figure.)

Potential for exposure to priority chemicals from the product

People and wildlife have the potential to be exposed to organochlorine substances at multiple points in the lifecycle of PVC and PVDC (Figure 12). This includes during manufacture, use, and disposal of PVC and PVDC packaging materials. As described above, plastic packaging made from PVC and PVDC are used for a variety of applications including consumer product and food packaging.

People routinely come into contact with plastic packaging made using PVC or PVDC and have the potential to be exposed to PVC and PVDC microplastics generated from the materials, or any manufacturing residuals or additives present in the materials. PVC and PVDC microplastics are organochlorine substances.

Packaging materials made from a variety of plastic types, including PVC and PVDC, can break down to form microplastics (defined as particles smaller than 5 mm in their longest dimension). This can occur throughout their lifecycle and contaminate indoor and outdoor environments with microplastics (ITRC, 2023c). PVC, PVDC, and other plastics that are disposed of in landfills as solid waste are expected to degrade to microplastics over time. Although this expected decomposition is the case for plastics in general, there are additional factors to consider for PVC and PVDC waste and microplastics as organochlorine substances.

PVC and PVDC are recycled at a lower rate after consumer use relative to other types of plastics used in packaging, such as high-density polyethylene and polyethylene terephthalate. This is in part due to the presence of chlorine in their polymeric structure and the use of other chemical additives in PVC, both of which present unique challenges for recycling of PVC (Ait-Touchente et al., 2024; ECHA, 2023b). PVDC is used in multilayer and multicomponent packaging, and this also creates challenges for recycling.

Due to the lack of recycling capability for PVC and PVDC packaging in Washington, it can be assumed that the vast majority becomes solid waste at the end of life (Eunomia, 2023). A smaller fraction is expected to be incinerated or burned.

During disposal, PVC and PVDC can act a source of chlorine in municipal solid waste. As noted in public comment by the Vinyl Institute, the total chlorine content in municipal solid waste is around 0.5%, and chlorinated plastics account for around 45 percent of that chlorine content, while 55 percent is from salt (NaCl) and chloride-containing food and yard wastes (Themelis, 2010; Vinyl Institute, 2024). Burning of solid waste that contains organic chlorine, such as from PVC, or inorganic chloride from salt can generate a group of organochlorine substances known as dioxins. Dioxins are highly toxic, persistent, and bioaccumulate in organisms.

The potential for exposure to organochlorine substances in sensitive populations related to use of PVC and PVDC in packaging related to manufacturing, microplastics and burning and incineration at end of life are discussed below.

Sensitive populations

Plastic packaging materials made from PVC and PVDC, have the potential to expose sensitive populations to organochlorine substances through manufacture, use, and disposal.

Manufacturing

PVC is manufactured using hazardous organochlorine substances and past occupational exposures in workers have been documented (ATSDR, 2024). In other sensitive populations, there is the potential for exposure to chemicals present in packaging from manufacturing as additives or residuals.

Our understanding is that most manufacturers now employ closed systems to mitigate the potential for occupational exposure in present-day operations (ATSDR, 2024). PVC and PVDC packaging may contain residuals from manufacturing, but many manufacturers have committed to minimizing their presence in products (ECVM, 2024).

Hazardous organochlorine substances used in the manufacture of PVC include 1,2-dichloroethane and vinyl chloride. Vinyl chloride is formed by thermal cracking of 1,2-dichloroethane (ECVM, n.d.-d). Vinyl chloride is classified as a Group A human carcinogen by EPA, and 1,2-dichloroethane is classified as a Group B2 probable human carcinogen (US EPA, 2000a, 2000b). Manufacturers may employ closed systems or automated systems to mitigate the potential for occupational exposures to 1,2-dichloroethane and vinyl chloride from production and use in the manufacture of PVC (ECHA, 2023b).

Occupational exposures to vinyl chloride have been associated with liver diseases including cancer. However, beginning in 1974 the Occupational Health and Safety Administration put into effect regulations that resulted in increased use of engineering controls by manufacturers to reduce airborne levels (ATSDR, 2024).

Our understanding is that many manufacturers have optimized their production processes to minimize the presence of vinyl chloride in finished products to reduce the potential for exposure (ATSDR, 2024). For example, the European Council of Vinyl Manufacturers sets a voluntary concentration limit for residual vinyl chloride in PVC of 1 gram per metric ton of PVC sold for food contact applications, such as in food packaging (ECVM, 2024).

Manufacturing of compounded PVC can introduce chemical additives used as heat stabilizers, plasticizers, and flame retardants. Although additives in PVC are not the focus of this chapter, it is important to note that in an analysis of PVC and PVC additives by the European Chemical Agency, they found that the use of additives in PVC contributes to direct human co-exposures and that synergistic or additive effects of these chemicals could not be excluded (ECHA, 2023b).

PVC and PVDC microplastics

Sensitive populations have the potential to be exposed to PVC and PVDC microplastics from plastic packaging, as well as additives they contain. PVC and PVDC microplastics are organochlorine substances. Sensitive populations with the potential for exposure to PVC and PVDC microplastics include children and people of childbearing age.

The potential for exposure to PVC and PVDC microplastics generated from packaging is an important consideration. People are exposed to microplastics, including those made of PVC, through ingestion and inhalation. Microplastics have been reported in indoor air and dust, drinking water, and food (Salthammer, 2022; Zuri et al., 2023).

Sobhani et al. reported that microplastics can be generated from plastic packaging during normal use when it is opened by cutting, tearing, or twisting (Sobhani et al., 2020). The Sobhani et al. study focused on plastic packaging made from polyethylene, polypropylene, and polyethylene terephthalate, but this general mechanism of microplastic generation is expected to be similar for PVC and PVDC packaging as well.

A proportion of PVC and PVDC packaging is expected to become litter in the environment, as plastic packaging materials have been reported as some of the most prevalent types of litter in composition studies (Karimi & Faghri, 2021). Plastic packaging materials that are disposed of in landfills form microplastics over time, acting as another potential source of release and exposure to these particles (Kabir et al., 2023; Wojnowska-Baryła et al., 2022).

In recent years, PVC microplastics have been detected in human tissues including in sputum, endometrium, testes, placenta, and arteries (Hu et al., 2024; Huang et al., 2022; S. Liu et al., 2024; J. Sun et al., 2024; Zhu, Zhu, et al., 2023). Microplastics from PVC and PVDC plastic packaging may enter food either directly from packaging or they may contaminate food due to their presence in the food chain (Cverenkárová et al., 2021; Kaseke et al., 2023).

There is evidence indicating that microplastics made from PVC and other plastics are potentially hazardous to human health (Blackburn & Green, 2022). However, it has not been established that the health hazards of microplastics made of PVC or PVDC are greater than those from other types of polymers (ITRC, 2023b).

PVC microplastics can expose people to the additives used in PVC materials. PVC has been reported to contain more additives relative to other plastic materials, including plasticizers and heat stabilizers. In addition, use of additives in PVC confers the property of increased environmental persistence to those additives when present in PVC microplastics (ECHA, 2023b).

Incineration and Burning

Burning or incineration of plastic materials can produce toxic transformation products including organochlorine substances known as dioxins, a group of toxic, persistent pollutants. Evidence suggests that levels of these harmful transformations formed are higher for plastics that contain chlorine, such as PVC (Baca et al., 2023). Baca et al. note that previous research studies have established a positive correlation between the concentrations of dioxins generated from combustion and presence of PVC in solid waste (Baca et al., 2023). For example, Shibamoto et al. notes that in incineration experiments of polyethylene, polystyrene, or polyethylene terephthalate plastics mixed with either PVC or NaCl, these mixed wastes produced more dioxins with PVC than with NaCl (Shibamoto et al., 2007).

As noted in a public comment on the draft of this report by the Vinyl Institute, industrial incineration, such as in waste to energy (WTE) facilities, is not thought to contribute to a large amount of dioxin formation relative to other environmental sources (Themelis, 2010; Vinyl Institute, 2024). This is because the controlled conditions in industrial incineration can reduce formation of these harmful transformation products. An inventory of total U.S. dioxin emissions to the atmosphere for the year 2012 estimated that only around 0.09 percent of dioxin emissions are attributable to WTE facilities and around 0.25 percent of dioxin emissions are attributable to waste incineration (Dwyer & Themelis, 2015).

However, aside from industrial incineration, dioxins can be released from uncontrolled fires and burning of waste materials (Dwyer & Themelis, 2015; Lemieux et al., 2000; M. Zhang et al., 2017). The same inventory of total U.S. dioxin emissions to the atmosphere for the year 2012 noted that an estimated 89 percent of the U.S. total dioxin emissions are due to three major non-controlled sources: landfill fires (44.8 percent), forest and brush fires (28.9 percent), and backyard burning (13.3 percent) (Dwyer & Themelis, 2015).

Our research does not suggest landfill fires are common occurrences, but landfill fires can burn or smolder for extended periods of time, sometimes lasting months before being extinguished (Ecology, n.d.-b; United States Fire Administration, 2002). The United States Fire Administration reported in 2002 that an average of 8,400 landfill fires are reported each year to the National Fire Incident Reporting System (NFIRS) in the United States (United States Fire Administration, 2002). The definition used by NFIRS is broad and includes "dump or sanitary landfill: included are refuse disposal areas, trash receptacles, and dumps in open ground."

There have been several landfill fires reported in Washington in recent years, including at historical and active landfills, some of which collect household waste such as packaging. We found recent landfill fires documented in Yakima County, Spokane County, Cowlitz County, Franklin County, and King County between 2019 – 2023 (Cowlitz County, 2023; Ecology, n.d.-f, n.d.-a, n.d.-b; King County, 2019; Yakima Health District, 2022). This is not an exhaustive list of all landfill fires in Washington as that is outside the scope of this report; however, these incidents demonstrate that landfill fires do occur in Washington and are a relevant consideration.

Meanwhile, it is illegal to burn garbage or construction debris in Washington, and this includes plastic packaging materials (Ecology, n.d.-d). However, local and state government agencies including Ecology still occasionally receive reports of illegal burns occurring, indicating this is a potential source of dioxins release as thermal degradation products of plastic packaging made with PVC and PVDC.

Taken together, this information suggests that PVC and PVDC packaging as sources of organic chlorine in municipal solid waste are important to consider with respect to emissions of dioxins from landfill fires and backyard burning.

Sensitive species

Land-based and aquatic organisms have the potential to be exposed to plastic packaging made from PVC and PVDC (Figure 12). Like other plastic materials, PVC and PVDC packaging disposed of in landfills can degrade to microplastics, accumulate in landfill leachate, and have the potential to contaminate the environment (Kabir et al., 2023). As discussed in the above section on sensitive populations, PVC and PVDC contribute to formation of dioxins, and this can lead to exposure in sensitive species.

PVC as a material undergoes photodegradation which can produce PVC microplastic particles (Ziani et al., 2023). Microplastic particles are widely distributed in the environment including in air, water, sediments, and soil. They are not completely removed by wastewater treatment, including treatment of landfill leachate (Kabir et al., 2023). PVC microplastics have a higher density than some other plastic types, such as polyethylene, and so they tend to sink and accumulate in the sediment of aquatic systems (Ziani et al., 2023).

In land-based ecosystems, it has been estimated that up to 10% of microplastics are PVC particles and that they are the third most prevalent type of microplastic in these systems behind polyethylene and polypropylene (Nosova & Uspenskaya, 2023; Surendran et al., 2023).

Although studies broadly demonstrate microplastics in the environment, less research has focused on microparticles from PVC or PVDC packaging, so the precise contribution to the overall environmental burden is unclear. However, it is evident that plastic packaging made from PVC and PVDC has the potential to contribute to environmental contamination, including pollution from the bulk materials themselves, and breakdown and transformation products in the form of microplastics and dioxins.

Evidence on environmental exposure to PVC microplastics in organisms is still emerging, but the available information suggests there is a potential for exposure and impacts on sensitive species (Zolotova et al., 2022). PVC microplastics have been reported to impact the reproduction of Daphnia magna (water flea), which is a common organism used for evaluating toxicity in aquatic ecosystems (Y. Liu et al., 2022). The authors suggest this may be mediated through changes in the expression of genes related to detoxification and regulation of oxidative stress.

Other studies on microplastics, including PVC particles, suggest they may cause both direct mechanical impacts on aquatic organisms through entanglement and swallowing, but also indirectly as carriers of other chemical pollutants (Du et al., 2021).

For example, it has been suggested that PVC microplastics may act as long-term sources of ortho-phthalates into the environment and are predicted to continue to leach ortho-phthalates into aquatic systems over decades (Henkel et al., 2022). In land-based ecosystems, adverse effects of PVC microplastics have been documented in soil organisms such as worms and collembolan (Nosova & Uspenskaya, 2023). It has been reported that PVC microplastics can affect the composition of microbial communities (Nosova & Uspenskaya, 2023).

Availability of potential safer alternatives

A variety of non-plastic, plastic, and emerging bioplastic alternatives are available for use in packaging. We have not determined whether these alternatives are feasible to meet the varied performance requirements for uses of PVC and PVDC in specific packaging applications. Other plastic resins are currently used in several applications (Ellen MacArthur Foundation and McKinsey & Company, 2016). Some examples include:

- Extruded polyethylene foam or cone-liners made from low density polyethylene (LDPE) can be used as cap liners
- PE and PP solutions are readily available for labels.
- PET and HDPE (high density polyethylene) can be used in bottle packaging applications, such as for cosmetics.
- LLDPE (linear low density polyethylene) can be used as pallet stretch wrap.
- PET can be used in blister packaging.

These alternative plastic resins still share end of life issues described in the previous sections for PVC and PVDC, including generation of microplastics and the potential to contribute to dioxin generation when burned along with other sources of chlorine in municipal waste. This will be an important consideration when evaluating whether safer alternatives are feasible and available in the next phase of implementation of Safer Products for Washington.

Some companies have already committed to moving away from PVC in their packaging and are using available alternatives. Such as:

- Unilever committed to eliminating PVC from its packaging in 2009 and by the end of 2012, 99% of Unilever packaging was free of PVC replaced with alternative materials reported to provide the same functional properties as PVC at a viable cost (Unilever, 2012).
- Walmart achieved 97% of its goal to make their general merchandise Private Brand primary plastic packaging free of PVC by 2020 (Walmart, n.d.).
- Wahl Clipper Corporation replaced their PVC packaging with PET (Plastic Ingenuity, n.d.).

During public comment on the draft of this report, other ways of reducing the ecological footprint associated with PVC packaging were noted by industry. For example, companies may seek to improve their ecological footprint and reduce packaging waste though approaches such as lightweighting packaging thereby using less material (Vinyl Institute, 2024).

During the next phase of implementation of Safer Products for Washington (Phase 3), we will evaluate alternatives and determine whether they meet our criteria as safer, feasible, and available before recommendingany regulatory actions.

Chapter 9: Sealants, Caulks, and Adhesives

Overview

Priority product

The scope of this priority product includes sealants, caulks, and adhesives that contain ortho-phthalates used in architectural or home maintenance applications.

- Sealants are products used to seal or fill joints and seams between building materials, they are often intended to create a waterproof or weatherproof barrier.
- Caulks are a sealant characterized as more rigid when dry.
- Adhesives are used to bond two building materials together.

Sealants, caulks and adhesives are grouped as a single product category because there is overlap in the applications in which these products are used. Some products are advertised as more than one of these subcategories (e.g., "adhesive caulk").

This priority product does not include hard surface sealers used to seal porous surfaces. It does not include adhesives not intended for use in architectural or home maintenance applications, such as those used for product labeling.

Priority chemical(s)

This priority chemical class was defined in our previous report Regulatory Determinations Report to the Legislature: Safer Products for Washington Cycle 1 Implementation Phase 3[78] in Chapter 6: Ortho-phthalates (Ecology, 2022b):

> "RCW 70A.350.010[79] defines phthalates as a class of "synthetic esters of phthalic acid" based on their chemical structure. The National Library of Medicine (NLM) defines the term phthalic acid as a "benzenedicarboxylic acid consisting of two carboxy groups at ortho positions" (NLM, n.d.). This definition does not include benzenedicarboxylic acid with two carboxy groups in either the meta or para configurations (e.g., isophthalic acid or terephthalic acid). Thus, the definition of this priority chemical class can be clarified to include only ortho-phthalates."

Background

Why are ortho-phthalates used in sealants, caulks, and adhesives?

Ortho-phthalates are used as plasticizers and can add flexibility to sealants, caulks, and adhesives in product formulations. Ortho-phthalates are used in a wide range of consumer caulking, sealants, and adhesive products for multiple applications. Example applications include kitchen and bath projects, use on windows, doors, siding, and trim, and insulation projects (Home Depot, n.d.).

[78]apps.ecology.wa.gov/publications/summarypages/2204018.html
[79]app.leg.wa.gov/rcw/default.aspx?cite=70A.350&full=true#70A.350.010

These products come in a variety of different forms such as pastes, cartridges, foams, and creams. Sealants, caulks, and adhesives can vary in formulation types, such as acrylic or silicone-based products. The primary function of ortho-phthalates in this product category is that of a plasticizer which alters the formulated product's properties such as durability, flexibility, and temperature tolerance.

What are examples of types and uses of sealants, caulks, and adhesives in scope?

Sealants and caulks (adhesives+coatings, n.d.-b; Habitable, 2022; Home Depot, n.d.):

- Acrylic – these are used for both interior and exterior applications. They are not prone to shrinkage but lack flexibility and are less suitable where movement is expected.
- Butyl – these butyl rubber-based products are often used outdoors and adhere to multiple types of substrate surfaces.
- Polysulfide – these products are more flexible, retain joint elasticity, and are suitable for exterior applications including underwater applications.
- Polyurethane – these products are flexible with strong adhesion and are used for home maintenance due to ease of application.
- Silicone – these are the most commonly used type for home maintenance and have a long useful life once applied; often used in bathrooms due to moisture repellency.
- Water-based latex – paintable sealants that adhere well to many surfaces. Formulations may combine with other types, such as siliconized latex sealants used for moisture repellency.

Adhesives (adhesives+coatings, n.d.-a):

- Super glue – these adhesives are based on cyanoacrylate that will bond to most surfaces, available in thin glue and gel forms.
- Epoxy – these adhesives are one of the strongest and intended for use on large surfaces and in gap filling. Often comes as two components that require mixing immediately before application.
- Wood adhesive – these adhesives are used to soak into porous wood surfaces and create a strong bond. They are often transparent once hardened.
- Silicone – silicone glue is often used as a sealant in applications where strong watertight bonds are required between surfaces, such as in bathrooms.

Volume estimates for priority product-chemical combination

The volume of priority chemicals associated with the product

Sealants, caulks, and adhesives are a significant use of ortho-phthalates. Many sealants, caulk, and adhesive products contain ortho-phthalates as part of their formulation. The specific concentrations of a single or mixture of ortho-phthalates in an individual product formulation are dependent on the product's intended use. For example, a higher phthalate concentration is used when there is a need for increased pliability during application (Godwin, 2011).

Information associated with various sealant, caulk, and adhesive products and their reported ortho-phthalate concentration ranges is displayed in Table 18, below. This information was identified from the Consumer Product Information Database and publicly available manufacturer safety data sheets (CPID, n.d.). The phthalate concentrations reported in these products range from 0.1% up to 40%. In some cases, the specific ortho-phthalates used in the formulation were not identified and instead listed as a proprietary phthalate esters mixture.

Table 18: An example of concentration ranges of ortho-phthalates used in various product types (non-exhaustive).

Product Type (based on manufacturer description)	Formulation Type (based on manufacturer description or ingredients)	Chemical(s)	Reported Concentration (range or max %)	Reference
Sealant	Hybrid (polyurethane, silicone)	Benzylbutyl phthalate (BBP) (CAS: 85-68-7)	15–40	(Tremco U.S. Sealants, 2015)
Caulk/Sealant	Hybrid (acrylic, latex)	Benzylbutyl phthalate (BBP) (CAS: 85-68-7)	10–30	(Momentive, 2010)
		Diisoheptyl phthalate (DIHP) (CAS: 41451-28-9)	10–30	(Momentive, 2010)
Sealant	Hybrid (acrylic, silicone)	Benzylbutyl phthalate (BBP) (CAS: 85-68-7)	5–15	(Henry Company, 2014)
Caulk/Sealant	Hybrid (acrylic, silicone)	Benzylbutyl phthalate (BBP) (CAS: 85-68-7)	5–10	(Mapei, 2009)
Sealant	Polyurethane	Bis(2-propylheptyl) phthalate (DPHP) (CAS: 53306-54-0)	5–10	(Henkel, 2014)
Sealant	Polyurethane	Bis(2-propylheptyl) phthalate (DPHP) (CAS: 53306-54-0)	5	(Red Devil Inc., 2017)

Product Type (based on manufacturer description)	Formulation Type (based on manufacturer description or ingredients)	Chemical(s)	Reported Concentration (range or max %)	Reference
Sealant	Polyurethane	Bis(2-propylheptyl) phthalate (DPHP) (CAS: 53306-54-0)	3–7	(Holcim Solutions and Products US, 2024)
Sealant	Polyurethane	Bis(2-propylheptyl) phthalate (DPHP) (CAS: 53306-54-0)	1–5	(Conklin Company, 2023)
Sealant	Acrylic	Dibutyl phthalate (DBP) (CAS: 84-74-2)	0.05–10	(Lanco Mfg. Corp., 2016a)
Sealant	Hybrid (acrylic, latex)	Dibutyl phthalate (DBP) (CAS: 84-74-2)	0.05–10	(Lanco Mfg. Corp., 2016b)
Adhesive	Unknown	Dibutyl phthalate (DBP) (CAS: 84-74-2)	3	(ITW Consumer, 2008)
Adhesive (spray)	Unknown	Dibutyl phthalate (DBP) (CAS: 84-74-2)	5	(Mon-Eco, 2018)
Adhesive (spray)	Unknown	Dibutyl phthalate (DBP) (CAS: 84-74-2)	0.1-1	(Sika Corporation, 2017)
Caulk	Hybrid (silicone, acrylic, latex)	Diisodecyl phthalate (DIDP) (CAS: 26761-40-0)	2.5–10	(Everkem Diversified Products, 2015)
Adhesive/Sealant	Silicone	Diisodecyl phthalate (DIDP) (CAS: 26761-40-0)	1	(Red Devil Inc., 2018)
Adhesive/Sealant	Silicone	Diisodecyl phthalate (DIDP) (CAS: 26761-40-0)	1–5	(Tremco U.S. Sealants, 2018)

Product Type (based on manufacturer description)	Formulation Type (based on manufacturer description or ingredients)	Chemical(s)	Reported Concentration (range or max %)	Reference
Sealant	Polyurethane	Diisodecyl phthalate (DIDP) (CAS: 26761-40-0)	10–25	(Tremco U.S. Sealants, 2020)
Adhesive	Hybrid (silicone, unknown)	Diisodecyl phthalate (DIDP) (CAS: 68515-49-1)	20–30	(Henkel Corp., 2017)
Sealant	Hybrid (silicone, unknown)	Diisodecyl phthalate (DIDP) (CAS: 68515-49-1)	5–10	(Henkel Corp., 2018)
Sealant	Polyurethane	Diisodecyl phthalate (DIDP) (CAS: 68515-49-1)	30	(Red Devil Inc., 2013)
Caulk/Sealant	Unknown	Diisodecyl phthalate (DIDP) (CAS: 68515-49-1)	10–30	(DAP Global Inc., 2023a)
Caulk/Sealant	Hybrid (silicone, unknown)	Diisodecyl phthalate (DIDP) (CAS: 68515-49-1)	15–40	(DAP Global Inc., 2023b)
		Diisononyl phthalate (DINP) (CAS: 28553-12-0)	1–5	(DAP Global Inc., 2023b)
Sealant	Hybrid (silicone, unknown)	Diisodecyl phthalate (DIDP) (CAS: 68515-49-1)	5-10	(3M Company, 2022)
Adhesive/Sealant	Hybrid (silicone, unknown)	Diisodecyl phthalate (DIDP) (CAS: 68515-49-1)	5-15	(3M Company, 2024)
Sealant	Silicone	Diisodecyl phthalate (DIDP) (CAS: 68515-49-1)	10-30	(Momentive, 2011)

Product Type (based on manufacturer description)	Formulation Type (based on manufacturer description or ingredients)	Chemical(s)	Reported Concentration (range or max %)	Reference
Sealant	Hybrid (silicone, polyurethane)	Diisononyl phthalate (DINP) (CAS: 28553-12-0)	10–15	(Siroflex Inc., 2015)
Caulk/Sealant	Unknown	Diisononyl phthalate (DINP) (CAS: 28553-12-0)	5–10	(Inpro Corp., 2018)
Adhesive/Sealant	Hybrid (silicone, unknown)	Diisononyl phthalate (DINP) (CAS: 28553-12-0)	0.1–2	(Manus Products, 2023)
Caulk/Sealant	Hybrid (silicone, unknown)	Proprietary phthalate esters	10–30	(Kop Coat Marine Group, 2020)
Adhesive/Sealant	Hybrid (silicone, unknown)	Proprietary phthalate esters	10–30	(DAP Products Inc., 2018)

We searched for the use of ortho-phthalates in sealant, caulk, and adhesive products in the EPA ChemExpo database (Table 19) (US EPA, n.d.-a). The information in ChemExpo further supports our finding that these products are a significant use of ortho-phthalates. However, many of these products listed in ChemExpo don't appear to be based on recent formulation information, so we don't know if this is representative of the current market.

Table 19: The number of products reported in EPA ChemExpo by phthalate and product use category (US EPA, n.d.-a).

Chemical	Product use category	Number of products
Benzylbutyl phthalate (CAS: 85-68-7)	Caulk/sealant	41
Diisodecyl phthalate (CAS: 26761-40-0)	Caulk/sealant	24
Benzylbutyl phthalate (CAS: 85-68-7)	Adhesives and adhesive removers	19

Chemical	Product use category	Number of products
Di(2-ethylhexyl) phthalate (CAS: 117-81-7)	Caulk/sealant	8
Di(2-ethylhexyl) phthalate (CAS: 117-81-7)	Adhesives and adhesive removers	5
Diisobutyl phthalate (CAS: 84-69-5)	Adhesives and adhesive removers	5
Dimethyl phthalate (CAS: 131-11-3)	Adhesives and adhesive removers	5
Diisoheptyl phthalate (CAS: 41451-28-9)	Caulk/sealant	3
Dimethyl phthalate (CAS: 131-11-3)	Caulk/sealant	2
Di-N-octyl phthalate (CAS: 117-84-0)	Adhesives and adhesive removers	2
Dibutyl tetrachlorophthalate (CAS: 3015-66-5)	Caulk/sealant	1
Ditridecyl phthalate (CAS: 119-06-2)	Adhesives and adhesive removers	1

In addition to manufacturer safety data sheets and product counts from ChemExpo, we found a recent non-peer-reviewed product testing study on caulks and sealants published by the Ecology Center (Ecology Center, 2023b). In their study, it was reported that 6 of 33 sealants, caulks, and adhesives tested contain ortho-phthalates ranging in concentration from 0.2% to greater than 12% (Ecology Center, 2023a).

US EPA has identified adhesives and sealants used for multiple ortho-phthalates (BBP, DBP, DCHP, DEHP, DiBP, DINP, and DIDP) as part of their evaluation process under the Toxic Substances Control Act (TSCA), including both consumer and commercial uses (US EPA, 2024d).

The volume of the product sold or present in the state

To estimate the volume of sealants, caulks, and adhesives sold or present in Washington, we referred to information published by the Adhesive and Sealant Council (ASC). ASC is self-described as a North American trade association that represents more than 75% of the U.S. adhesive and sealant industry.

According to ASC, the North American industry produced 10.3 billion pounds of adhesives and sealants (including caulks) in 2022 (ASC, 2023). Of this, 81.5% of the overall demand was attributed to the U.S., or around 8.4 billion pounds. Washington accounts for approximately

2.3% of the U.S. population, which suggests Washington's share of the total is around 193 million pounds of this market (US Census Bureau, 2024).

We don't know what proportion of the 193 million pounds is attributable to either adhesives or to sealants specifically, as this number represents both volumes combined. However, using the above information we estimated a volume range for relevant market segments in Washington for 2022. We based our volume range estimate on considering either only the lower percent contribution from adhesives (low estimate) or the higher percent contribution from sealants (high estimate), individually. The actual volume is expected to be between these estimates.

In terms of market segment for adhesives, ASC reported around 17% was for building and construction uses and 6.5% were for consumer DIY and retail uses (ASC, 2023). These sectors combined represented around 23.5% of total adhesive use in 2022. If we assume 23.5% of the 193 million pounds attributable to Washington's share of sealants and adhesives is used for either building and construction or DIY and retail uses, this suggests a reasonably low estimate for Washington's share of around 45 million pounds.

For sealants, ASC reported that 57.5% was for building and construction uses and 11.8% were for consumer DIY and retail uses (ASC, 2023). These sectors combined represented around 69.3% of the total sealant use in 2022. If we assume 69.3% of the 193 million pounds attributable to Washington's share of sealants and adhesives is used for either building and construction or DIY and retail uses, this suggests a reasonably high estimate for Washington's share of around 133 million pounds.

Therefore, based upon the above calculations, we estimate the volume of adhesives and sealants used in Washington ranged between 45–133 million pounds in 2022 for two relevant sectors: building and construction, and consumer DIY and retail. This demonstrates a significant volume of these products present in Washington.

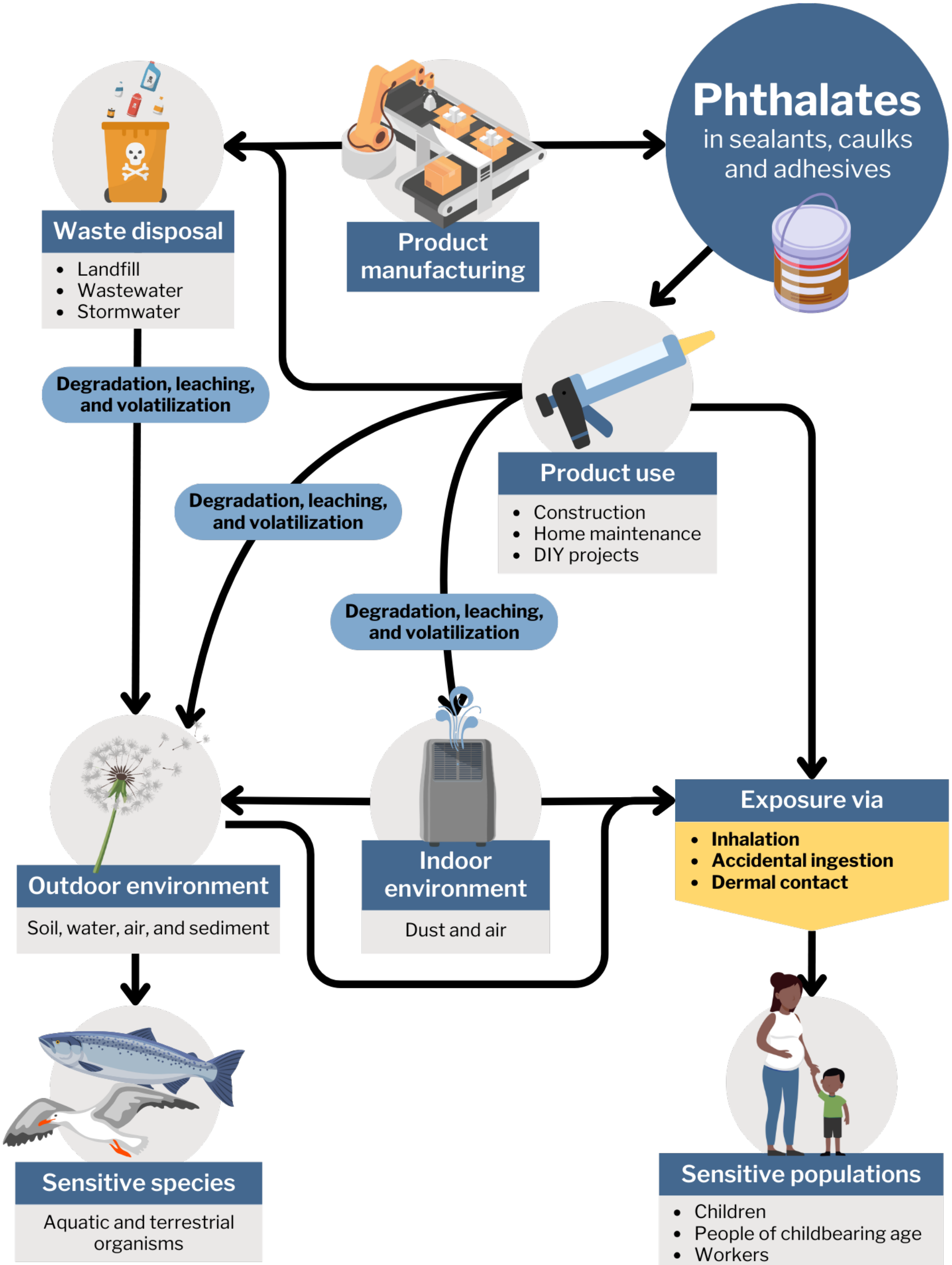

Figure 13: Pathways of potential exposure to ortho-phthalates from the use of sealant, caulk, and adhesive products in sensitive populations and sensitive species. (See Appendix D for a step-by-step description of this figure.)

Potential for exposure to priority chemicals from the product

People and wildlife have the potential for exposure to ortho-phthalates present in sealants, caulks, and adhesives resulting from manufacture, use, and disposal (Figure 13). Ortho-phthalates used in sealants, caulks and adhesives can contaminate indoor and outdoor environments during product application, while the product is in place, and through degradation and disposal.

Ortho-phthalates are semi-volatile organic compounds that are released slowly from products. They do not form strong covalent bonds with other chemicals present in their formulations, including after those products have been applied and undergone a drying or curing process. Abrasion and heat can accelerate the leaching of ortho-phthalates from materials (US EPA, 2024b).

In public comments received on the draft of this report, the American Chemistry Council High Phthalates Panel noted that the drying or curing process for sealants, caulks and adhesives that use polyurethanes or modified silanes is not dependent on evaporative drying (ACC, 2024a). Rather, these products cure by chemical reactions with a catalyst or moisture in the air, this process is also sometimes referred to as crosslinking or vulcanization.

Air and dust exposure pathways

Sealants, caulks and adhesives contribute to the levels of ortho-phthalates in indoor dust when they migrate from the product during application, and through wear and aging of product material left in place over time. People may be exposed to ortho-phthalates during the initial application of these products and by proximity to the cured products. Exposures from these products are expected to be primarily driven by inhalation and inadvertent ingestion of contaminated dust.

Ortho-phthalates are one of the most prevalent groups of synthetic chemicals found in indoor dust sampled from homes, daycares, and workplaces (Dodson et al., 2017; Mitro et al., 2016; Zhu, Hajeb, et al., 2023). When house dust is reduced, children's phthalate exposure decreases (Sears et al., 2020). Reducing household dust through cleaning procedures resulted in lower urinary phthalate metabolite concentrations in children compared to children living in homes without the cleaning intervention (Sears et al., 2020).

We did not identify studies that measured the contribution of aging sealants, caulks, and adhesives to the overall concentration of ortho-phthalates present in indoor dust. However, the migration of ortho-phthalates from vinyl flooring and other products into dust has been documented (Bi et al., 2021) and provides a useful parallel to the ortho-phthalates in sealants, caulks, and adhesives.

In addition, findings from a different group of chemicals present in older caulking and sealant products, polychlorinated biphenyls, support this exposure pathway. Polychlorinated biphenyls were banned in 1979 but ongoing contamination of indoor dusts by polychlorinated biphenyls present in aging caulk has continued decades later (Herrick et al., 2004; Kohler et al., 2005).

Some of the ortho-phthalates used in sealants, caulks and adhesives can be released from the product into the air and inhaled directly without passing through the dust. Most of the ortho-phthalates used as plasticizers in these products are semi-volatile and have low vapor pressures and exposure to these ortho-phthalates is less likely through direct inhalation. However, we identified several products that incorporate more volatile ortho-phthalates like dibutyl phthalate (Table 18) for which there is an inhalation concern. Further, some adhesives and sealants are manufactured as spray products that are applied into the air and are more available for inhalation (Home Depot, n.d.; US EPA, 2020a).

Skin contact pathway

Extensive skin contact with ortho-phthalates in sealants, caulks and adhesives could contribute to people's total exposure to ortho-phthalates from these products (Weschler et al., 2015). Exposure through skin is thought to be less for ortho-phthalates relative to other routes such as ingestion (Giovanoulis et al., 2018). However, dermal uptake can contribute to the overall exposure burden and may be significant for some ortho-phthalates, especially those that are lower molecular weight (Hopf et al., 2024). Some ortho-phthalates such as DBP have a greater capacity to cross through the skin into the body. We identified DBP use in a subset of sealant and adhesive products (Table 18). Other ortho-phthalates used as plasticizers in these products do not absorb through the skin to the same extent as DBP (US EPA, 2024b).

Environmental pathways

Ortho-phthalates are expected to be released from sealants, caulks, and adhesives into the outdoor environment during use and disposal. Ortho-phthalates in outdoor air can adsorb to dust and contaminate soils (US EPA, 2024b).

Ortho-phthalates may be released to wastewater during the application or disposal of these products when washed down the drain. In addition, some of these products are intended to be applied underwater. We are not aware of any studies that demonstrate the leaching of ortho-phthalates from sealants, caulks, or adhesives into aquatic systems directly; however, this has been demonstrated for other materials that contain ortho-phthalates, including polymeric materials (Dhavamani et al., 2022; Henkel et al., 2022). Based on this, it can be assumed that some fraction of ortho-phthalates in sealant, caulk, and adhesive products applied underwater will leach into water.

Disposal of unused sealants, caulks and adhesives, or disposal of materials that these products have been applied to in landfills has the potential to contribute to environmental contamination through landfill leachate or volatilization to air.

Sensitive populations

We identified sensitive populations with the potential for exposure to ortho-phthalates from sealants, caulks, and adhesives. Ortho-phthalates are endocrine-disrupting chemicals that have been associated with a wide range of health hazards. Ortho-phthalates are associated with reproductive toxicity including premature birth, disruption of developing reproductive and nervous systems during fetal growth and in young children, organ toxicity, respiratory effects, and dysregulation of thyroid and metabolic functions (Ecology, 2023b).

Children

Children are a sensitive population to the endocrine-disrupting effects of ortho-phthalates. Ortho-phthalates exposure has been linked to asthma and impacts on neurodevelopmental outcomes (Ecology, 2023b). In addition to their biological vulnerability, young children are more highly exposed to house dust per unit body weight than adults due to hand-to-mouth and mouthing behaviors, and proximity to the floor (US EPA, 2017).

We know children are exposed to ortho-phthalates through house dust. In a study of over 200 households in North Carolina, researchers collected hand wipes and urine samples from young children along with samples of house dust (Hammel et al., 2019). Ortho-phthalates were present in greater than 95% of dust samples, 90% of children's handwipes, and all children's urine samples and often correlated between the types of samples.

Sealants, caulks, and adhesives were not specifically addressed as covariates of exposure but study authors concluded that sources of ortho-phthalates present in the home environment are useful indicators of phthalate exposure to children aged three to six (Hammel et al., 2019).

People of childbearing age

Adults of childbearing age are sensitive to the reproductive toxicity of ortho-phthalates and other health effects of ortho-phthalates that are thought to be endocrine-mediated. Phthalate exposure has been linked to increased odds of preterm birth (Welch et al., 2022), increased risk of gestational diabetes (Eberle & Stichling, 2022; James-Todd et al., 2022), and lower sperm quality (Eales et al., 2022). As with children, the primary exposure pathway to the ortho-phthalates in sealants, caulks, and adhesives is likely via indoor dust. People who live in homes that contain older phthalate-containing sealant, caulk, and adhesive products that contribute to dust as they age and wear may be at greater risk of exposure and reproductive health effects.

Workers

Occupationally exposed persons are a sensitive population. People employed in the manufacturing or application of sealants, caulks and adhesives at work likely have higher exposures to the ortho-phthalates. Exposure from handling and applying these products can occur through inhalation, dermal contact, and inadvertent ingestion after hand-to-mouth transfer. Examples of occupations of potential exposure concern are construction trades and facilities maintenance personnel.

The National Bureau of Labor Statistics estimates there were approximately 232,000 workers employed in the construction industry in the private sector in Washington as of June 2024 (US Bureau of Labor Statistics, 2024). Some portion of these workers are expected to use sealants, caulks, and adhesives in their occupations and can be exposed to the ortho-phthalates in these products. Similarly, we presume that a portion of workers who maintain and repair commercial facilities use sealants, caulks, and adhesives at work. Workers of reproductive age in these and other occupations with the potential for elevated exposure to ortho-phthalates in sealants, caulks and adhesives are a sensitive population.

Sensitive species

Ortho-phthalates released to the environment from consumer products, including sealants, caulks, and adhesives, have the potential to expose sensitive species and contribute to adverse effects in aquatic and terrestrial organisms (Figure 13). Ecology's monitoring of ortho-phthalates in Puget Sound sediments has found that DEHP is the most frequently detected phthalate and BBP is the second most frequently detected (Ecology, 2023b). We noted in the volume section above that BBP is present in several sealant and caulk formulations reported in manufacturer safety data sheets at concentrations up to 40% by weight (Table 18).

In a recent statewide survey of ortho-phthalates, it was noted that DINP was detected at concentrations higher than DEHP in some marine sediments (Ecology, 2023b). However, that same statewide study found low detection frequencies overall and concluded additional monitoring was a low priority for newer ortho-phthalates, including DINP. DINP is reported in several sealant, caulk, and adhesive formulations in manufacturer safety data sheets (Table 18).

Ortho-phthalates and their metabolites are associated with endocrine disruption in organisms which may lead to impaired reproduction, development, and other adverse effects (Ecology, 2023b; Y. Zhang et al., 2021). Species expected to have relatively higher exposures to ortho-phthalates include those that "inhabit or feed in the sediments, water column, or undergo sensitive life stages in the nearshore environments that experience frequent stormwater runoff" (Ecology, 2023b).

Most studies of phthalates have focused on species of fish, including common model organisms such as zebrafish (Danio rerio) but also in some species found in Washington such as rainbow trout (Oncorhynchus mykiss) (Y. Zhang et al., 2021). Researchers highlight the importance of fish in aquatic ecosystems and note that adverse effects on fish can directly affect the sustainability of aquatic ecosystems (Y. Zhang et al., 2021). Adverse effects have been observed in non-fish species present in Washington including Manila clam (Venerupis philippinarum) and abalone (Haliotis diversicolor supertexta) (Y. Zhang et al., 2021). The Southern Resident Orca Task Force has named ortho-phthalates as chemicals of emerging concern (Ecology, 2020; Southern Resident Orca Recovery, n.d.).

Availability of potential safer alternatives

There appear to be several sealant, caulk, and adhesive products currently marketed that do not contain ortho-phthalates in their formulations. Diethylene glycol dibenzoate and dipropylene glycol dibenzoate are potential alternatives for sealants, caulks, and adhesives, and are available on the market in the United States (CPID, n.d.). Dioctyl terephthalate is another potential alternative that we previously evaluated and determined was a safer, feasible, and available alternative to ortho-phthalates in vinyl flooring products (terephthalates are a related but distinct class of chemicals not included in the priority chemical class definition of ortho-phthalates) (Ecology, 2022b).

Additional evaluation of these and other potential alternatives will be necessary before making regulatory determinations for these products in the next phase of Safer Products for Washington, Phase 3.

Chapter 10: Solid Deodorizers

Overview

Priority product

The scope of this priority product includes deodorizer products sold as solids that contain 1,4-dichlorobenzene (1,4-DCB).

Products included in this definition (this is a non-exhaustive list) are:

- Toilet, garbage, and urinal deodorizer blocks
- Other solid continuous-action air fresheners

This product category does not include deodorizer products sold in liquid form, as packs or powders intended to dissolve completely in water. The focus of this product category is solid products intended to gradually spread into the air.

Priority chemical(s)

Organobromine or organochlorine substances were defined as a priority chemical class in our previous legislative reports. See our

Identification of Priority Chemicals Report to the Legislature: Safer Products for Washington Cycle 2 Implementation Phase 1[80] and Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1[81] in Chapter 4: Technical Support for organobromine or organochlorine substances (Ecology, 2024c, 2024b).

1,4-DCB is a member of the organobromine and organochlorine substances priority chemical class. 1,4-DCB is the specific chemical we are focused on for this product-chemical combination.

Background

Deodorizer products are often sold as solids intended to sublime into air to mitigate odors. Sublimation means the chemical goes directly from a solid to a gaseous state without becoming liquid as an intermediate phase. These products may be used directly in urinals as blocks or hung from the edge of a toilet bowl. Some of these products are sold as room deodorizers and are intended to be hung outside of fixtures elsewhere in the room, including in garbage pails.

The primary organochlorine substance used in these products is 1,4-DCB, which can comprise nearly one hundred percent of some product formulations. 1,4-DCB is a volatile chemical that sublimes to room air over time.

[80] apps.ecology.wa.gov/publications/summarypages/2404025.html
[81] apps.ecology.wa.gov/publications/summarypages/2404026.html

Volume estimates for priority product-chemical combination

The volume of priority chemicals associated with the product

Deodorizers are on the market that contain 1,4-DCB. It appears many of these products are solid blocks of 1,4-DCB for use in toilets and urinals. Some of the products are marketed to serve as deodorizers in garbage cans or diaper pails (ATSDR, 2006; Chin et al., 2013). 1,4-DCB listed on many manufacturer safety data sheets as comprising up to 99.9 percent of the product formulation (Table 20). We identified this information using several resources including a use report for 1,4-DCB published by the US EPA in 2020, the Consumer Product Information Database, and supplemental searches on manufacturer or distributor websites (CPID, n.d.; US EPA, 2020c).

Table 20: Examples of concentrations of 1,4-DCB found in solid deodorizers.

Concentration of 1,4 DCB in product (%)	Reference(s)
99.65	(Big D Industries Inc, 2023; US EPA, 2020c)
99	(Fresh Products LLC, 2023; US EPA, 2020c)
99	(Essendant Co., 2016; US EPA, 2020c)
99	(Essendant Co., 2015; US EPA, 2020c)
90–100	(Jasol, 2021; US EPA, 2020c)
Not disclosed	(The Home Depot, 2019; US EPA, 2020c)*
99.9	(Triple S, 2015; US EPA, 2020c)
99	(Nassco Inc., 2023)
99	(Uline Inc, 2019)
95	(Willert Home Products, 2006)

*Formerly Interline Brands as cited in US EPA, 2020 (The Home Depot, 2015).

The volume of the product sold or present in the state

For the twenty years preceding 2006, it was reported that 25–55% of all uses of 1,4-DCB were in space deodorants for toilets and refuse containers and for control of moths, molds, and mildews (ATSDR, 2006). Although we expect the proportion of 1,4-DCB used in deodorizers may have declined since then, it appears to still be a primary use of this chemical. In addition, the reported aggregate production volume of 1,4-DCB in the United States increased between 2016–2019 (US EPA, 2024a).

In 2019, the aggregate production volume for 1,4-DCB in the United States was reported at between 100 million to 250 million pounds (US EPA, 2024a). If we use the conservative assumption that 25% of this chemical was used in space deodorants and for moth control (the primary uses) and that the split between those two uses is roughly equal, this suggests around 12.5 million–31.25 million pounds of 1,4-DCB used for deodorants in the United States in 2019 (12.5% of 100–250 million pounds). Washington represents approximately 2.3% of the United States population, so taken together we would estimate around 287,500–718,750 pounds of 1,4-DCB used in deodorizers in Washington in 2019 (US Census Bureau, 2024).

There is a large degree of uncertainty in this estimate, as we don't know the precise amount of 1,4-DCB used for deodorizer products or whether the amount used in Washington is proportional to uses elsewhere throughout the United States. We don't know what proportion of 1,4-DCB production isn't captured in the Chemical Data Reporting data, as manufacturers are only required to report above certain thresholds depending on their size, so the actual United States production volume may be higher than reported (US EPA, 2020c). However, even with this uncertainty, it's clear that a large volume of 1,4-DCB is used in solid deodorizers in Washington, and this represents a significant source or use of an organochlorine substance.

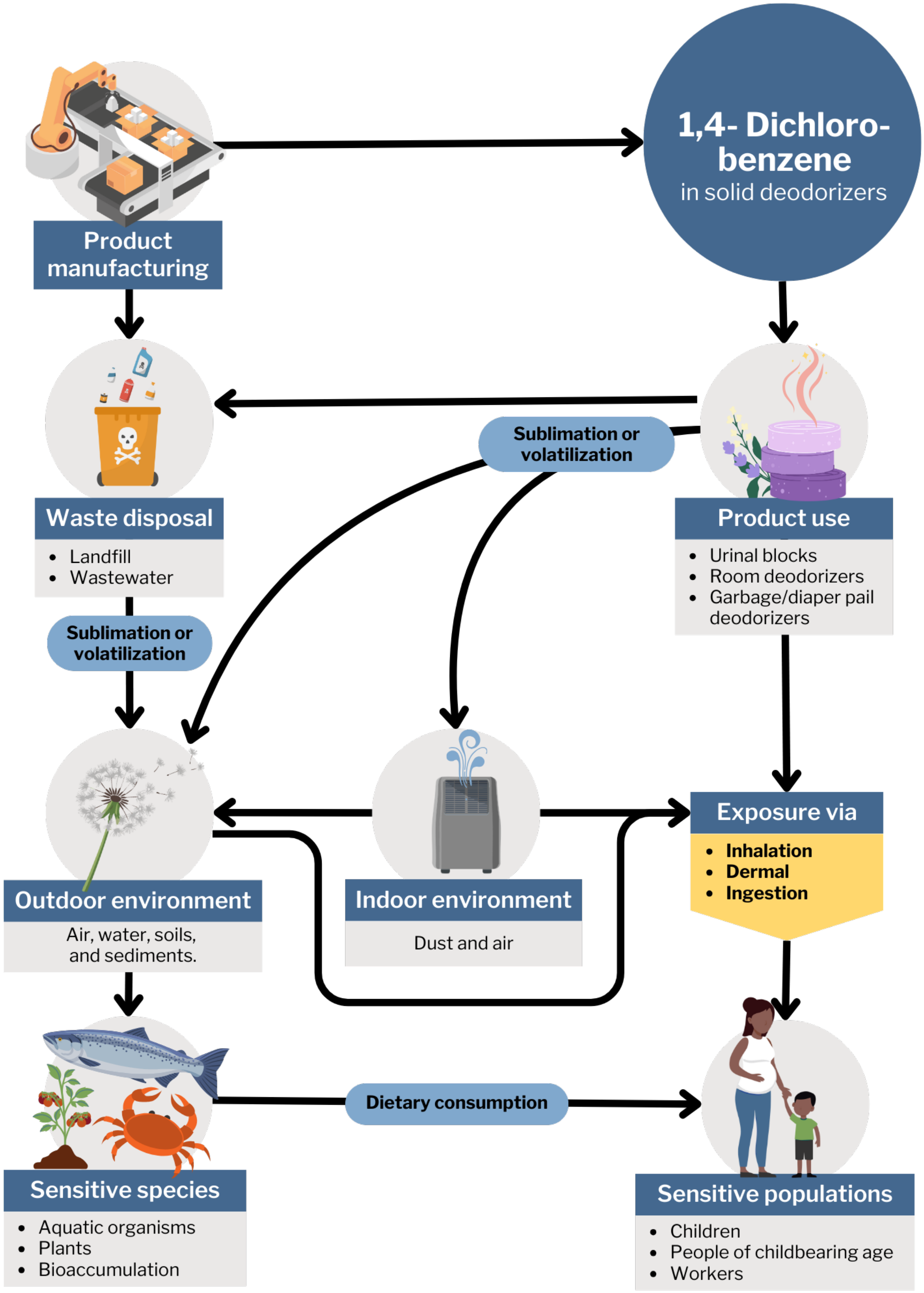

Figure 14: Pathways of potential exposure to 1,4-DCB from solid deodorizers in sensitive populations and sensitive species. (See Appendix D for a step-by-step description of this figure.)

Potential for exposure to priority chemicals from the product

Deodorizing products comprised of 1,4-DCB are sold to consumers and commercial users as solids. The solids may be placed in locations such as urinals, toilets, diaper pails, and waste bins. 1,4-DCB in deodorizers vaporizes directly from the solid product into room air. People can be exposed by inhalation and through their skin when they handle solid products (Figure 14).

Inhalation exposure

Inhalation of indoor air is the major route of exposure to 1,4-DCB (ATSDR, 2006). 1,4-DCB has been measured in indoor air of homes at concentrations that can exceed health guidance values (ATSDR, 2006; Chin et al., 2013). Large differences in concentration are observed between homes in most studies and have been linked to the variable consumer use of deodorizers and mothballs containing 1,4-DCB (Adgate et al., 2004; Chin et al., 2013; Wallace et al., 1989). Toilet deodorizer blocks had the highest emission rate in a study that tested several 1,4-DCB-containing consumer products (Guerrero, 2013).

Inhaled 1,4-DCB gets into the body. Concentrations of 1,4-DCB in air are positively correlated with 1,4-DCB in people's blood (Lin et al., 2008; Sexton et al., 2005). A study of Japanese children showed that the concentration of 1,4-DCB in room air statistically linked to the level of metabolized 1,4-DCB in urine (Yoshida et al., 2021). Blood levels of 1,4-DCB in adults were significantly higher in study participants who reported recent exposure to solid toilet deodorizers (Churchill et al., 2001). The biomonitoring results overall support the inhalation of 1,4 DCB from toilet deodorizers as a key route of exposure.

Dermal exposure

Skin contact with 1,4-DCB in deodorizers may occur when handling the solid product. There is limited data on the hazards of 1,4-DCB for dermal exposure (ATSDR, 2006). There is some evidence that 1,4-DCB released from solid products can transfer from mist and vapor into clothing articles and become available for potential dermal exposure from the clothing (Guerrero, 2013). Guerrero (2013) studied clothing articles, but not other textiles commonly found in homes such as bedding, carpet, and upholstery.

While we did not locate data specific to 1,4-DCB for these other household textiles, research has found that a highly similar chemical, 1,2-dichlorobenzene (1,2-DCB) can be absorbed into carpeting (Won et al., 2001). Taken together, these findings suggest that carpets could absorb 1,4-DCB, like the clothing articles that were tested by Guerrero (2013), and increase the likelihood of dermal exposure to residents of homes with 1,4-DCB deodorizing products.

Ingestion

In rare cases, deodorizers can be accidentally ingested, most likely by very young children (ATSDR, 2006). We did not identify cases of direct ingestion poisoning in Washington during the preparation of this report.

1,4-DCB has been reported to bioaccumulate and is expected to bioconcentrate in aquatic organisms (ATSDR, 2006). Studies have shown that various plants absorb 1,4-DCB into their roots, leaves, and vegetables (ATSDR, 2006). This suggests that consumption of bioaccumulative species may result in oral exposure to 1,4-DCB.

Environmental contamination

Solid deodorizers have the potential to contaminate the environment with 1,4-DCB. There are no natural sources of 1,4-DCB in the environment, and the vast majority of releases to the environment are expected to be a result of its use in deodorizer products and mothballs (ATSDR, 2006).

Many studies on 1,4-DCB releases from these products are from several decades ago. However, as the general uses of this chemical do not appear to have changed, it seems reasonable that estimates of the contribution of deodorizers to releases would remain similar even as the volume of releases has most likely changed over time (PubChem, n.d.). For example, in 1972 it was estimated that 70–90% of the annual US production of 1,4-DCB is released to the atmosphere through use in toilet bowl deodorants, garbage deodorants, and use in moth control (ATSDR, 2006).

1,4-DCB released to air has the potential to be transported over long distances as a component of the atmosphere, and studies suggest it may return to surface waters and soil through rain and snow events (ATSDR, 2006).

Further, deodorizer products are commonly placed directly in toilet fixtures in areas that routinely contact and may contaminate water as part of their intended use. Contaminated water is then quickly discharged down the drain into municipal wastewater systems or septic tanks during normal toilet flushing. 1,4-DCB is not completely removed by wastewater treatment and has been reported in both influent and effluent samples in studies of wastewater treatment plants (ATSDR, 2006; Rodriguez et al., 2012). 1,4-DCB is only slightly soluble in water (80.0 mg/L at 25 °C) and so this pathway contributes to environmental release to a lesser extent than releases to air (ATSDR, 2006). It was reported that less than 1% of environmental releases of 1,4-DCB are to surface water, but the main contributor is thought to be through the use of toilet deodorizers (ATSDR, 2006).

1,4-DCB has been detected in samples of landfill leachate, groundwater, soil, and sediment, including in Washington (ATSDR, 2006; Ecology, n.d.-c). 1,4-DCB volatilizes from surface waters, soils, and has an atmospheric half-life estimated to be 14–31 days (ATSDR, 2006). There is some evidence 1,4-DCB can undergo aerobic but not anaerobic biodegradation in water; this is minor relative to volatilization. 1,4-DCB can accumulate in sediment and soils, with volatilization again as the primary removal mechanism (ATSDR, 2006).

Sensitive populations

Sensitive populations for 1,4-DCB exposure include children and persons with occupational exposure to deodorizing products. Studies showing higher exposure to 1,4-DCB across race and ethnicity are a concern. In addition, people with decreased lung function may be sensitive to 1,4-DCB-containing products.

Studies show that children are exposed to 1,4-DCB at home and school through the use of deodorizers, and some exposures exceed acceptable levels of cancer risks (Adgate et al., 2004;

Raysoni et al., 2017; Sax et al., 2006). Children are especially susceptible to exposure because early-life exposure to cancer-causing substances like 1,4-DCB increases the risk of developing cancer from the chemical over a lifetime (Barton et al., 2005).

Workers may be a sensitive population of concern for 1,4-DCB exposure. Deodorizers are used in non-residential indoor environments, such as public and institutional facilities that are cleaned and serviced by janitorial or custodial workers.

1,4-DCB exposure is common in the general population, but higher in populations with lower education and income (S.-W. Wang et al., 2009). Wang et al. analyzed data from a study of personal exposures to VOCs (volatile organic compounds), including 1,4-DCB conducted as part of the 1999-2000 NHANES. NHANES is designed to be a representative sample of the US population and includes demographic information including age, gender, education, race/ethnicity, and the ratio of family income to the poverty threshold.

For the VOC study, participants were equipped with a personal monitoring device, and the samplers were then analyzed for the presence of 1,4-DCB and other chemicals. The VOC study included a questionnaire about people’s housing and their activities during the sampling period. The results showed that participants with lower family incomes had notably higher personal exposure to 1,4-DCB. In an earlier NHANES data cycle, the odds of having blood levels of 1,4-DCB above the 90th percentile were significantly higher for participants who reported recent exposure to toilet deodorizers (Churchill et al., 2001).

Exposure to 1,4-DCB is reported as higher in some populations by race and ethnicity. In biomonitoring data of adult women from the NHANES, participants who identified as Mexican, Hispanic, or Black had elevated blood levels of 1,4-DCB relative to white participants (Churchill et al., 2001; Elliott et al., 2006; Nguyen et al., 2020; S.-W. Wang et al., 2009).

While exposure disparities were not directly linked to the use of deodorizers in all reports, exposure to 1,4-DCB is driven by indoor air, and the two most prevalent consumer products containing this chemical that emit to indoor air are deodorizers and moth repellants (ATSDR, 2006).

Higher exposure suggests increased potential for health impacts. Hispanic Americans were estimated to have higher cancer risk from 1,4-DCB than a comparison non-Hispanic white population (Hun et al., 2009). Hun et al. (2009) attributed exposure disparity to indoor sources of 1,4-DCB including deodorizers and mothballs. Further, questionnaires from the study participants showed that 59% of Hispanics in the study used air fresheners including toilet deodorizers, but only 6% reported the use of moth repellants, suggesting that the disparity in exposure and cancer risk from 1,4-DCB found in the study was more likely to be due to use of deodorizers.

1,4-DCB exposure measured by blood levels of 1,4-DCB, was associated with decreased pulmonary function in a national population of 953 adults (Elliott et al., 2006). Therefore, adults who have reduced lung function may be especially sensitive to the effects of exposure to 1,4-DCB-containing deodorizers. Whether children who have decreased lung function are more sensitive has not been studied to our knowledge, but it’s plausible given the observations in adults.

Sensitive species

As described in our priority chemicals report, many organochlorine substances have been shown to bioaccumulate in organisms; this is a property shared by 1,4-DCB with other members of the chemical class. 1,4-DCB is reported to have moderate bioaccumulation potential and is expected to bioconcentrate in aquatic organisms.

Bioconcentration factors (BCFs) reported for 1,4-DCB in aquatic organisms range from 15–720 (ATSDR, 2006). Studies on various types of plants indicate that 1,4-DCB can be absorbed into roots, leaves, and vegetables. This suggests another potential pathway of exposure regarding 1,4-DCB from plants grown in soils contaminated through atmospheric deposition or sewage-sludge application (ATSDR, 2006).

1,4-DCB is classified as both an acute (very toxic to aquatic life, hazard statement code H400) and chronic aquatic toxicant (very toxic to aquatic life with long-lasting effects, hazard statement code H410) by ECHA (ECHA, 2023d).

Availability of potential safer alternatives

Product alternatives for deodorizers without 1,4-DCB are currently available on the market (Uline Inc, 2020; Waxie Sanitary Supply, 2019). These are frequently marketed as non-para blocks, indicating that they are free of 1,4-DCB.

The California Air Resources Board described alternatives to 1,4-DCB in these products as part of their rulemaking to prohibit 1,4-DCB containing solid air fresheners or toilet/urinal care products that contained 1,4-DCB from sale, manufacture, or use in California beginning in 2006 (CARB, 2004).

An alternative process to the use of deodorizers and similar products would be to perform cleaning methods that mitigate the need for deodorizer use in between cleaning periods. Modifications or emphasis on prioritizing airflow and ventilation systems may be an alternative method to the use of deodorizers.

During the next phase of implementation of Safer Products for Washington (Phase 3), we will evaluate alternatives and determine whether they meet our criteria as safer, feasible, and available before recommending any regulatory actions.

Chapter 11: Existing Priority Consumer Products

During our second cycle, we plan to assess four priority products identified in previous cycles or by statute. We describe the products and our rationale for revisiting them below.

Cookware and kitchen supplies

We previously reviewed cookware and kitchen supplies in our Cycle 1.5 Regulatory Determination Report to the Legislature.[82] This product category includes:

- Bakeware
- Cooking pots
- Cooking utensils
- Frying pans
- Griddles
- Reuseable baking liners
- Rice cookers
- Waffle irons

Non-stick coatings for cookware contain PFAS. People can be exposed to PFAS when they cook or eat food that has been prepared with PFAS-containing cookware.

We recommended a reporting requirement in our Cycle 1.5 Regulatory Determinations Report to the Legislature and are conducting a rulemaking[83] to adopt the reporting requirement in Chapter 173-337 WAC. [84]We found that cookware and kitchen supplies are a significant source and use of PFAS, but we did not evaluate safer, feasible, and available alternatives due to resource limitations. In cycle 2, we intend to continue to work on PFAS in cookware and could change our recommendation from a reporting requirement to a restriction if safer alternatives are feasible and available.

Firefighting PPE

We previously reviewed firefighting PPE in our Cycle 1.5 Regulatory Determinations Report to the Legislature. "Firefighting personal protective equipment" (referred to as firefighting PPE) is defined in RCW 70A.400.005(4)37[85] as, "any clothing designed, intended, or marketed to be worn by firefighting personnel in the performance of their duties, designed with the intent for use in fire and rescue activities, including jackets, pants, shoes, gloves, helmets, and respiratory equipment."

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[82]apps.ecology.wa.gov/publications/summarypages/2404023.html
[83]ecology.wa.gov/regulations-permits/laws-rules-rulemaking/rulemaking/wac-173-337-nov2023
[84]app.leg.wa.gov/wac/default.aspx?cite=173-337
[85]app.leg.wa.gov/rcw/default.aspx?cite=70A.400

PFAS can be added to firefighting PPE and components to meet specifications for protection against water, heat, oil, fuel, or pathogens. Firefighters can be exposed to PFAS by wearing and using firefighting PPE. This exposure can lead to health impacts.

We did not identify safer, feasible, and available alternatives in our Cycle 1.5 Regulatory Determinations report to the Legislature. We recommended a reporting requirement and are conducting a rulemaking to adopt the reporting requirement in Chapter 173-337 WAC. In cycle 2, we intend to continue to work on PFAS in firefighting PPE and could change the reporting requirement to a restriction if safer alternatives are feasible and available.

Hard surface sealers

We previously reviewed hard surface sealers in our Cycle 1.5 Regulatory Determinations Report to the Legislature.[86] This product category includes products used to seal hard porous surfaces such as:

- Concrete
- Stone
- Unglazed tile
- Wood

They are designed to protect a variety of surfaces from liquids and soils and can be used for indoor or outdoor applications.

People can be exposed to PFAS during the manufacturing, use, and disposal of sealers containing these chemicals. Certain occupations, such as construction workers, can have higher exposure to PFAS if they are frequently applying PFAS-containing sealers. PFAS from sealers can be released into the environment and expose sensitive species.

We did not determine whether safer alternatives were feasible and available in our Cycle 1.5 Regulatory Determinations Report to the Legislature.[87] We recommended a reporting requirement and are conducting a rulemaking to adopt the reporting requirement in Chapter 173-337 WAC.[88] In cycle 2, we intend to continue to work on PFAS in hard surface sealers and could change the reporting requirement to a restriction if safer alternatives are feasible and available.

Floor waxes and polishes

We previously reviewed floor waxes and polishes in our Cycle 1.5 Regulatory Determinations Report to the Legislature. This product category includes formulated products designed to polish, protect, or enhance a floor's surface.

[86]apps.ecology.wa.gov/publications/summarypages/2404023.html
[87]apps.ecology.wa.gov/publications/summarypages/2404023.html
[88]app.leg.wa.gov/wac/default.aspx?cite=173-337

People can be exposed to PFAS during the manufacture, use, and disposal of floor waxes and polishes containing these chemicals. Certain occupations can have particularly high exposure to PFAS from applying floor waxes and polishes.

We did not identify safer, feasible, and available alternatives to PFAS in floor waxes and polishes in our Cycle 1.5 Regulatory Determinations Report to the Legislature. We recommended a reporting requirement and are conducting a rulemaking to adopt the reporting requirement in Chapter 173-337 WAC. In cycle 2, we intend to continue to work on PFAS in floor waxes and polishes and could change the reporting requirement to a restriction if safer alternatives are feasible and available.

Motor vehicle tires

During the 2024 legislative session, RCW 70A.350.110[89] was amended to identify motor vehicle tires containing 6PPD as a priority product. We were directed by the Legislature to determine regulatory actions and adopt rules. We will take those actions during Cycle 2.

Motor vehicle tires include new or replacement tires for a motorized vehicle intended for on-highway or off-highway use. 6PPD is added to motor vehicle tires as an antioxidant and antiozonant. As it oxidizes, it transforms to 6PPD-quinone, which is highly toxic to coho salmon and likely other aquatic species. Coho salmon mortality events have long been linked to roadway runoff, and now we know a culprit is 6PPD-quinone. Regulatory actions that reduce the use of 6PPD in tires will protect salmon and other wildlife, as well as the people who rely on them for economic, nutritional, or cultural value.

Printing inks

We identified printing inks as a significant source of polychlorinated biphenyl (PCBs) in our 2020 Priority Consumer Products Report to the Legislature.[90]

PCBs are produced during the manufacturing process of chlorinated pigments. When chlorinated pigments are used in printing inks, printed materials become contaminated with PCBs. When recycling or disposing of these materials, these chemicals can contaminate wastewater and may reach the environment.

[89] app.leg.wa.gov/rcw/default.aspx?cite=70A.350.110
[90] apps.ecology.wa.gov/publications/summarypages/2004019.html

PCBs in Washington waterways impact sensitive species. In our 2022 Regulatory Determinations Report to the Legislature,[91] we found that lower concentrations of PCBs were feasible and available, but we believed that federal law limited our ability to set a **different limit** than EPA and we declined to take regulatory action at that time. However, we do not believe we are pre-empted from **prohibitions** on the use of PCBs in products.[92]

Since our 2022 report, several factors have led us to reconsider PCBs in printing inks:

- Washington's current water quality standard for PCBs is 7 parts per quadrillion, and EPA is proposing a limitation on discharges to the Spokane River at 1.3 ppq (US EPA, 2024e).
- These water quality standard levels are extremely low compared to EPA's 25 ppm annual and 50 ppm maximum limits on PCBs in pigments used in inks. Based on the definition of PCBs by EPA, a dichlorinated PCB found in yellow pigments, PCB-11, is allowable at up to 250 ppm in pigments if it is the only PCB present.
- Wastewater treatment technology has not kept up with efforts to limit PCBs in the environment and therefore pollution prevention is necessary (Association of Washington Business et al., 2022).

In this review cycle, we will be researching whether chlorine-free pigments, which do not contain inadvertently generated PCBs, are feasible and available. For more information about our previous work on PCBs in printing inks, please consult:

- 2020 Priority Consumer Products Report to the Legislature: Safer Products for Washington Implementation Phase 2[93]
- 2022 Regulatory Determinations Report to the Legislature: Safer Products for Washington Cycle 1 Implementation Phase 3[94]

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[91]apps.ecology.wa.gov/publications/uipages/summarypages/2204018.html

[92]In 1984, the US Environmental Protection Agency adopted a rule exempting the use of products containing inadvertently generated PCBs below specified concentrations from TSCA's PCB use prohibition. The rule was promulgated under 15 USC Sec. 2605. 15 USC Sec. 2617(d)(2)(B), preserves state preemption as it was in effect under the TSCA prior to the Frank R. Lautenberg Chemical Safety for the 21st Century Act with respect to rules promulgated by the Environmental Protection Agency under 15 USC Sec. 2605. Pre-Lautenberg Act TSCA Sec. 18(a)(1)(B) preempts state regulations of EPA-regulated chemicals unless the state regulation is either identical to EPA's, or "*prohibits* the use of such substance or mixture in such State … (other than its use in the manufacture and processing of other substances or mixtures)." [Emphasis added.] Thus, it appears that TSCA leaves open the possibility of a state adopting a full prohibition on the use of products known to contain PCBs inadvertently generated during manufacturing. We also read the federal law to leave open the possibility of a state rule that merely requires manufacturers to report the concentration of PCBs present in a class of products known to contain PCBs for information gathering purposes.

[93]apps.ecology.wa.gov/publications/summarypages/2004019.html

[94]apps.ecology.wa.gov/publications/summarypages/2204018.html

Appendix A. Acronyms

Table 21: Acronyms and abbreviations with definitions.

Term	Definition
1,2-DCB	1,2-dichlorobenzene
1,4-DCB	1,4-dichlorobenzene
6PPD	N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine
6PPD-quinone	N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine-quinone
AAMA	American Architectural Manufacturers Association
ACA	American Coatings Association
ACC	American Chemistry Council
APEs	Alkylphenol ethoxylates
ASC	Adhesive and Sealant Council
ATSDR	US Agency for Toxic Substances and Disease Registry
BBP	Benzylbutyl phthalate
BCF	Bioconcentration factor
BIAW	Building Industry Association of Washington
BIPOC	Black, Indigenous, and People of Color
BLS	US Bureau of Labor Statistics
BTEX	Benzene, ethyl benzene, toluene and xylene substances
C&PCPs	Cosmetics and personal care products
CDC	US Agency for Disease Control and Prevention
CDPH	California Department of Public Health
CDR	Chemical Data Reporting
CHE-WA	Collaborative Health and Environment-Washington
CIR	Cosmetic Ingredient Review
CPDat	Chemicals and Products Database
CPID	Consumer Product Information Database
CPSC	US Consumer Product Safety Commission
cVMS	Cyclic volatile methylsiloxanes

Term	Definition
CZ	cubic zirconium
D4	octamethylcyclotetrasiloxane
D5	decamethylcylcopentasiloxane
D6	dodecamethylcyclohexasiloxane
DBP	Dibutyl phthalate
DCHP	Dicyclohexyl phthalate
DEHP	Di(2-ethylhexyl)phthalate
DEP	Diethyl phthalate
DiBP	diisobutylphthalate
DIDP	diisodecyl phthalate
DINP	Diisononyl phthalate
diPAP	diesters of polyfluoroalkyl phosphates
DIY	Do It Yourself
DMP	dimethyl phthalate
DnBP	di-n-butyl phthalate
DOP	dioctyl phthalate
DPHP	Bis(2-propylheptyl) phthalate
DTSC	California Department of Toxic Substances Control
ECHA	The European Chemicals Agency
Ecology	Washington Department of Ecology
ECVM	European Council of Vinyl Manufacturers
EIM	Environmental Information Management Database
EO	Ethoxylate
EOF	extractable organic fluorine
EPA	US Environmental Protection Agency
EPA IRIS	EPA's Integrated Risk Information System
EPDM	ethylene propylene diene monomer rubber
EPS	Expanded polystyrene
ERTS	Environmental Reports Tracking System

Term	Definition
EU	European Union
EWG	Environmental Working Group
FD&C Act	Federal Food, Drug, and Cosmetic Act
FDA	US Food and Drug Administration
FP	fluoropolymer paints
FTOHs	fluorotelomer alcohols
FTSA	fluorotelomer sulfonic acid
GNPD	Global New Product Database
HBCD	hexabromocyclododecane
HBN	Healthy Building Network
HDPE	high density polyethylene
Health	Washington Department of Health
HPD	Health Product Declaration
ICFs	insulating concrete forms
IGA	Instrumental Gas Analysis
INCI	International Nomenclature of Cosmetic Ingredients
IRIS	Integrated Risk Information System
ITRC	Interstate Technology and Regulatory Council
LC50	Lethal concentration 50%
LDPE	low density polyethylene
LLDPE	linear low-density polyethylene
Mintel GNPD	Mintel Global New Product Database
MRF	municipal recycling facilities
NAMBA	North American Modern Building Alliance
ND	Not detected
NHANES	National Health and Nutrition Examination Survey
NIOSH	National Institute for Occupational Safety and Health
NLM	National Library of Medicine
NMP	N-methyl-pyrrolidone

Term	Definition
non-PE	non-polyethylene
NP	nonylphenol
NPEs	Nonylphenol ethoxylates
NRDC	Natural Resources Defense Council
OECD	Organisation for Economic Co-operation and Development
OEHHA	California Office of Environmental Health Hazard Assessment
OEM	original equipment manufacturer
OFRs	organohalogen flame retardants
OP	octylphenol
OPA	oriented polyamide
OPEs	organphosphate esters
PBDE	polybrominated diphenyl ethers
PCB	Polychlorinated biphenyls
PE	polyethylene
PEER	Public Employees for Environmental Responsibility
PET	polyethylene terephthalate
PFAA	perfluoroalkyl acids
PFAS	Per and polyfluoroalkyl substances
PFCA	perfluorocarboxylic acid
PFDoDA	perfluorododecanoic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PFSA	perfluorosulfonic acid
PFTeDA	perfluorotetradecanoic acid
PP	polypropylene
PPA	polymer processing aid
ppb	parts per billion
PPE	personal protective equipment

Term	Definition
ppm	parts per million
ppq	parts per quadrillion
PTFE	Polytetrafluoroethylene
PVC	Polyvinyl chloride
PVDC	polyvinylidene chloride
PVDF	polyvinylidene fluoride
RCW	revised code of Washington
RfC	reference concentration
SBCC	Washington State Building Code Council
SD	standard deviation
SIPs	structural insulating panels
SPF	spray polyurethane foam
SS	Safer States
SSPC	Society for Protective Coatings
TCPP	tris(chloropropyl) phosphate
TF	total fluorine
TOPA	total oxidizable precursor assay
TSCA	Toxic Substances Control Act
UCLA	University of California Los Angeles
US EPA	United States Environmental Protection Agency
UV	ultra-violet
VCRP	Voluntary Cosmetic Registration Program
VOC	volatile organic chemicals
WAC	Washington Administrative Code
WCRER	Washington center for real estate research
WTN	Washington Tracking Network
XPS	Extruded Polystyrene

Appendix B. Existing and Pending Regulations in Other Jurisdictions

This appendix provides a non-exhaustive list of existing and pending regulations for new priority product chemical combinations. This is not an exhaustive list of regulations on chemicals and chemical classes, but instead only includes regulations relevant to the products under consideration in this report. We did not identify any regulations on formaldehyde in cleaning products. Other product chemical combinations are discussed below.

Organohalogen flame retardants (OFRs)

We did not identify any existing regulations specific to organohalogen flame retardants in building insulation. The table below identifies regulations on specific organohalogen flame retardants, PBDEs, in consumer products broadly.

Table 22: Existing and proposed regulations for organohalogen flame retardants (OFRs) in relevant consumer products.

Entity	Year	Regulation or Policy	Requirements and standards
CA	2003	CA Health and Safety Code § 108920 et seq[95]	Prohibits commercial products, or flame-retardant parts of products, containing more than 1/10 of 1% pentaBDE or octaBDE.
HI	2004	HRS §332D[96]	Prohibits manufacture, processing, or distribution in commerce of a product, or a flame-retarded part of a product, containing more than one-tenth of one percent, by mass, of pentaBDE, octaBDE, or any other chemical formulation that is part of these classifications.
IL	2005	410 ILCS 48/[97]	Prohibits manufacture or distribution of commercial products, or flame-retardant parts of products, containing more than 1/10 of 1% pentaBDE or octaBDE.
ME	2003	38 MRSA §1609[98]	Requires written notice from manufacturers or trade associations prior to the sale or distribution of products containing brominated flame retardants.

[95]leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=HSC&division=104.&title=&part=3.&chapter=10.&article=
[96]capitol.hawaii.gov/hrscurrent/Vol06_Ch0321-0344/HRS0332D/HRS_0332D-0002.htm
[97]www.ilga.gov/legislation/ilcs/ilcs3.asp?ActID=2707&ChapterID=35
[98]legislature.maine.gov/legis/statutes/38/title38sec1609.html

Entity	Year	Regulation or Policy	Requirements and standards
MI	2004	MCL 451-1994-II-4-147-2[99]	Prohibits the manufacture, processing, or distribution of a product or material that contains more than 1/10 of 1% of penta-BDE.
RI	2006	R.I. Gen. Laws § 23-13.4-3[100]	Prohibits the manufacture, processing, or distributing of a product or flame-retardant part of a product containing more than 1/10 of 1% of penta-BDE.
United Nations (UN)	2009	UN Stockholm Convention on Persistent Organic Pollutants[101]	Listed in the Stockholm Convention under Annex A, to be eliminated from production and as possible by manufacturers and producers.

Lead and cadmium

There are many existing regulations on lead and cadmium in jewelry. Most apply to children's products, but a few entities restrict lead and cadmium in jewelry regardless of whether it is marketed for children.

Table 23: Existing and proposed regulations for lead and cadmium in relevant consumer products.

Entity	Year	Regulation or Policy	Requirements and standards
CA	2008	CA Health & Safety Code § 108555[102]	Prohibits the sale or distribution of children's products coated with paints or lacquers containing lead or cadmium.
CA	2008	CA Health and Safety Code § 25214.2 [103]	Prohibits sale or distribution of jewelry unless made solely from specified materials.
CT	2010	Conn. Gen. Stat. Ch. 416 § 21a-12d[104]	Bans Cadmium in children's products.

[99]legislature.mi.gov/Laws/MCL?objectName=mcl-451-1994-II-4-147-2
[100]webserver.rilegislature.gov//Statutes/TITLE23/23-13.4/23-13.4-3.htm
[101]pops.int/Implementation/IndustrialPOPs/BDEs/Overview/tabid/5371/Default.aspx
[102]leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=HSC&sectionNum=108555.
[103]leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=HSC&sectionNum=25214.2.
[104]cga.ct.gov/current/pub/chap_416.htm#sec_21a-12d

Entity	Year	Regulation or Policy	Requirements and standards
CT	2008	Conn. Gen. Stat. Ch. 420d § 21a-335 et seq[105]	Established standards governing the maximum allowable amount of lead in children's products.
DE	2008	6 Del. C. c. 25C[106]	Prohibits the sale and distribution of a toy containing a lead over the 0.06 limit set by 16 CFR 1303.
European Union (EU)	2009	Directive 2009/48/EC[107]	Restricts the presence of lead and cadmium in toys and components of toys
EU	2011	Regulation (EU) No 494/2011[108]	Restricts the use and sale of jewelry with cadmium concentration of equal to or greater than 0.01% by weight of the metal.
EU	2015	Regulation (EU) No 2015/628[109]	Restricts use and sale of jewelry with a lead concentration of equal or greater than 0.05% by weight of the metal.
IL	2006	410 ILCS 45/[110]	Restricts the sale and manufacture of lead-bearing children’s products including jewelry.
IL	2010	430 ILCS 140/[111]	Regulates the sale and distribution of children's products or product components containing cadmium and priority chemicals of high concern.
MD	2011	Md. Code Ann. Env. § 6-1402[112]	Prohibiting a person, on or after July 1, 2012, from manufacturing, selling, offering for sale, or distributing in the State any children's jewelry that contains cadmium at 0.0075% by weight.

[105]cga.ct.gov/current/pub/chap_420d.htm
[106]delcode.delaware.gov/title6/c025c/index.html
[107]data.europa.eu/eli/dir/2009/48/2022-12-05
[108]data.europa.eu/eli/reg/2011/494/2011-06-10
[109]data.europa.eu/eli/reg/2015/628/oj
[110]ilga.gov/legislation/ILCS/ilcs3.asp?ActID=1523&ChapterID=35
[111]ilga.gov/legislation/ilcs/ilcs3.asp?ActID=3270&ChapterID=39
[112]mgaleg.maryland.gov/mgawebsite/laws/StatuteText?article=gen&section=6-1402&enactments=False&archived=False

Entity	Year	Regulation or Policy	Requirements and standards
ME	2008	22 MRSA § 1316-A[113]	Restricts the manufacture and knowing sale or distribution of lead-containing children's products except as authorized.
MI	2007	MCL 368-1978-5-54B[114]	Prohibits the sale and distribution of children's jewelry containing lead.
MN	2008	MINN. STAT. 325E.3892 Subd. 2[115]	Prohibiting the manufacture, offer for sale, sale, or distribution for free of jewelry, children's jewelry, and any body piercing jewelry unless the jewelry is made of certain classified materials.
NJ	2024	S1085[116]	Introduced. Prohibits the sale, distribution, and manufacture of jewelry containing cadmium. Companion to A3801.
NJ	2024	S1713[117]	Introduced. Prohibits the sale of certain children's products containing lead, mercury, or cadmium. Companion to A3800.
NJ	2024	A3800[118]	Introduced. Bans certain children's products containing excessive amounts of lead, mercury, or cadmium. Companion to S1713.
NJ	2024	A3801[119]	Introduced. Prohibits the sale, distribution, and manufacture of jewelry containing cadmium. Companion to S1085.
NY	2019	N.Y. ENV § 37-0115[120]	Restricts the sale and distribution of children's products containing ingredients from the dangerous chemicals list including lead and cadmium.

[113] legislature.maine.gov/statutes/22/title22sec1316-A.html
[114] legislature.mi.gov/Laws/MCL?objectName=mcl-368-1978-5-54B.&highlight=children%27s,jewelry
[115] revisor.mn.gov/statutes/cite/325E.3892
[116] njleg.state.nj.us/bill-search/2024/S1085
[117] njleg.state.nj.us/bill-search/2024/S1713
[118] njleg.state.nj.us/bill-search/2024/A3800
[119] njleg.state.nj.us/bill-search/2024/A3801
[120] nysenate.gov/legislation/laws/ENV/37-0115

Entity	Year	Regulation or Policy	Requirements and standards
OR	2015	ORS 431A.258[121]	Requires Oregon Health Authority to establish and maintain a list of designated high-priority chemicals of concern for children's health used in children's products and to periodically review and revise the list.
VT	2014	18 V.S.A. Chapter 038A[122]	Restricts the sale of children's products containing chemicals of high concern to children. Including children's jewelry and heavy metals.

PFAS

PFAS are regulated in many products across the US. We identified a few examples of regulations specific to artificial turf, however, the EU, Maine, and Minnesota have broad restrictions on PFAS in consumer products. We didn't identify any regulations specific to PFAS in paints.

Table 24: Existing and proposed regulations for PFAS in relevant consumer products.

Entity	Year	Regulation or Policy	Requirements and standards
EU	2023	Annex XV[123]	Proposal to restrict PFAS in mixtures or articles placed on the market with derogations for some uses.
ME	2021	38 MRSA § 1614[124]	Restricts the sale of products containing PFAS in the state of Maine starting January 1, 2030, with an exemption for currently unavoidable uses.
MN	2023	MINN. STAT. 116.943 Subd. 5[125]	Starting January 2025 PFAS are prohibited in 11 product categories and certain types of packaging. Starting in 2032 all uses are banned with an exemption for currently unavoidable uses.
VT	2024	9 V.S.A. § 2494g[126]	Prohibits the manufacturing or sale of artificial turf with PFAS added after July 1, 2024.

[121]oregon.public.law/statutes/ors_431a.258
[122]legislature.vermont.gov/statutes/chapter/18/038A
[123]echa.europa.eu/documents/10162/f605d4b5-7c17-7414-8823-b49b9fd43aea
[124]legislature.maine.gov/statutes/38/title38sec1614.html
[125]revisor.mn.gov/statutes/cite/116.943#stat.116.943
[126]legislature.vermont.gov/statutes/section/09/063/02494g

cVMS

cVMS are restricted in cosmetics in the European Union. Regulations have been introduced to restrict cVMS in cosmetics in the US but have not been adopted.

Table 25: Existing and proposed regulations for cVMS in relevant consumer products.

Entity	Year	Regulation or Policy	Requirements and standards
CA	2005	CA Health & Safety Code § 111792[127]	California Safe Cosmetics Act of 2005. Requires manufacturers, packers, and distributors of cosmetic products to report to the California Department of Public Health all products sold in California, which contain ingredients known or suspected to cause cancer, birth defects, or other reproductive harm.
EU	2019	Regulation (EU) 2024/1328[128]	Restricts D4, D5, and D6 in consumer and professional products.
VT	2014	18 V.S.A. § 1776[129]	Allows for the prohibition of the sale of children's products containing chemicals of high concern to children. Including children's cosmetics and D4.

BTEX

California and the European Union regulate toluene in nail products.

Table 26: Existing and proposed regulations for BTEX substances in relevant consumer products.

Entity	Year	Regulation or Policy	Requirements and standards
CA	2005	CA Health & Safety Code § 111792[130]	California Safe Cosmetics Act of 2005. Requires manufacturers, packers, and distributors of cosmetic products to report to the California Department of Public Health all products sold in California, which contain ingredients known or suspected to cause cancer, birth defects, or other reproductive harm.

[127] leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=HSC&sectionNum=111792.
[128] data.europa.eu/eli/reg/2024/1328/oj
[129] legislature.vermont.gov/statutes/section/18/038A/01776
[130] leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=HSC&sectionNum=111792.

Entity	Year	Regulation or Policy	Requirements and standards
CA	2023	CA Health & Safety Code § 111792[131]	Lists nail polish with toluene as a priority product that must be reported by manufacturers.
EU	2009	Regulation (EU) No 344/2013 amending Regulation (EC) No 1223/2009[132]	Restricts use of toluene in nail products to a 25% threshold
NJ	2024	A1775[133]	Introduced. Prohibits the sale and distribution of nail products containing dibutyl phthalates, toluene, or formaldehyde.
USA	2018	21 U.S.C. § 364c(c)(4)[134]	Under the federal Food, Drug, and Cosmetics Act, cosmetics sold on a retail basis to consumers, in stores or online, must bear a list of ingredients, with the names of the ingredients listed in descending order of predominance.
VT	2014	18 V.S.A. § 1776[135]	Allows for the prohibition of the sale of children's products containing chemicals of high concern to children. To include children's cosmetics and BTEX.

Ortho-phthalates

We didn’t identify any existing regulations on ortho-phthalates in caulks, sealants, and adhesives. California requires manufacturers to disclose to use of ortho-phthalates in cleaning products.

6PPD

6PPD in motor vehicle tires is a priority product chemical combination in CA and the US EPA granted a petition to begin rulemaking on 6PPD in tires in 2023. There are currently no other jurisdictions that restrict 6PPD in motor vehicle tires.

[131] leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=HSC&sectionNum=111792.
[132] data.europa.eu/eli/reg/2013/344/oj
[133] njleg.state.nj.us/bill-search/2024/A1775
[134] uscode.house.gov/view.xhtml?req=granuleid:USC-prelim-title21-section364c&num=0&edition=prelim
[135] legislature.vermont.gov/statutes/section/18/038A/01776

Table 27: Existing and proposed regulations for 6PPD in relevant consumer products.

Entity	Year	Regulation or Policy	Requirements and standards
CA	2023	22 CCR § 69511.7[136]	Specifies motor vehicle tires with 6PPD as a priority product/chemical combination.
USA	2023	TSCA Sect. 21 Petition[137]	Granting of the petition to USEPA from the Yurok Tribe, the Port Gamble S'Klallam Tribe, and the Puyallup Tribe of Indians to establish regulations prohibiting 6PPD in tires.

Organobromine/Organochlorine substances

1,4-dichlorobenzene is restricted in toilet and urinal care products in California. PVC in packaging has been proposed to be regulated in California, North Carolina, and Vermont but has not been adopted. New Zealand prohibited PVC food trays in 2022.

Table 28: Existing and proposed regulations for organobromine and organochlorine substances in relevant consumer products.

Entity	Year	Regulation or Policy	Requirements and standards
CA	2004	17 CCR § 94509[138]	Prohibits manufacture, sale, or distribution of any solid air fresheners or toilet/urinal care products containing PDCB.
New Zealand	2022	Waste Minimisation Regulations 2022[139]	Prohibits manufacture or sale of specific plastic products to include PVC food containers or trays.

[136] govt.westlaw.com/calregs/Document/I3EA124E01FD411EEB1A4DEEA2C4D3A06?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)
[137] epa.gov/system/files/documents/2023-11/pet-001845_tsca-21_petition_6ppd_decision_letter_esigned2023.11.2.pdf
[138] govt.westlaw.com/calregs/Document/IFD6EE7C35A2011EC8227000D3A7C4BC3?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)
[139] legislation.govt.nz/regulation/public/2022/0069/13.0/whole.html#d1345447e459

Appendix C. Washington's Toxics in Consumer Products Regulations

Table 29: Restrictions and reporting requirements for toxic chemicals in consumer products.

RCW/WAC	Description	Chemical(s) addressed	Products covered
RCW 15.54.820 [140]	Waste-derived fertilizer[141]	Arsenic, cadmium, cobalt, mercury, molybdenum, nickel, lead, selenium, and zinc	Fertilizers made from waste products
Chapter 70A.222 RCW[142]	Toxics in packaging	Lead, cadmium, mercury, and hexavalent chromium	Packages and packaging components
Chapter 70A.222 RCW	Toxics in packaging	PFAS	Plant fiber-based food packaging
Chapter 70A.230 RCW[143]	Mercury reduction	Mercury	Bulk mercury, fluorescent lamps, novelties, manometers, thermometers, thermostats, motor vehicle switches
Chapter 70A.335 RCW[144]	Bisphenol A	Bisphenol A	Food and beverage containers
Chapter 70A.340 RCW[145]	Brake friction material	Copper	Brake pads

[140] app.leg.wa.gov/rcw/default.aspx?cite=15.54.820
[141] Primarily covers agricultural fertilizers but also applies to consumer products such as compost available at retail stores.
[142] app.leg.wa.gov/rcw/default.aspx?cite=70A.222
[143] app.leg.wa.gov/rcw/default.aspx?cite=70A.230
[144] app.leg.wa.gov/rcw/default.aspx?cite=70A.335
[145] app.leg.wa.gov/rcw/default.aspx?cite=70A.340

RCW/WAC	Description	Chemical(s) addressed	Products covered
Chapter 70A.400 RCW[146]	Firefighting agents	PFAS	Firefighting foam and personal protective equipment
Chapter 70A.405 RCW[147]	Flame retardants	Brominated flame retardants (PBDEs)	Noncomestible products
Chapter 70A.430 RCW[148]	Children's Safe Products restrictions	Lead, cadmium, ortho-phthalates, specified flame retardants, and chemicals listed as high concern for children	Children's products, including jewelry and cosmetics
Chapter 70A.435 RCW[149]	Lead wheel weights	Lead	Wheel weights
Chapter 70A.445 RCW[150]	Antifouling paints	Copper, cybuterine	Boat paint
Chapter 70A.560 RCW[151]	Toxics in cosmetics	Ortho-phthalates, PFAS, formaldehyde and formaldehyde releasers, methylene glycol, mercury, triclosan, m-phenylenediamine, o-phenylenediamine, and lead	Cosmetic and personal care products
Chapter 70A.565 RCW[152]	Lead in cookware	Lead	Cookware and cookware components

[146] app.leg.wa.gov/rcw/default.aspx?cite=70A.400
[147] app.leg.wa.gov/rcw/default.aspx?cite=70A.405
[148] app.leg.wa.gov/rcw/default.aspx?cite=70A.430
[149] app.leg.wa.gov/rcw/default.aspx?cite=70A.435
[150] app.leg.wa.gov/rcw/default.aspx?cite=70A.445
[151] app.leg.wa.gov/rcw/default.aspx?cite=70A.560
[152] app.leg.wa.gov/rcw/default.aspx?cite=70A.565

RCW/WAC	Description	Chemical(s) addressed	Products covered
Chapter 173-334 WAC[153]	Children's Safe Products Reporting Rule	As listed in WAC 173-334-130	Children's products
Chapter 173-337 WAC[154]	Safer Products Restrictions and Reporting	PFAS, ortho-phthalates, specified flame retardants, alkylphenol ethoxylates, bisphenols	Aftermarket stain-resistant and water-resistant treatments for application to textile and leather consumer products; carpets and rugs; leather and textile furniture and furnishings; fragrances in beauty and personal care products; vinyl flooring; electric and electronic products; recreational wall padding; polyurethane foam recreational products; laundry detergent; drink can linings; food can linings; and thermal paper
Chapter 173-901 WAC[155]	Better brakes	Asbestiform fibers, cadmium, chromium, lead, mercury, copper	Brake friction materials (for example, pads and drums)

[153] app.leg.wa.gov/wac/default.aspx?cite=173-334
[154] app.leg.wa.gov/wac/default.aspx?cite=173-337
[155] app.leg.wa.gov/wac/default.aspx?cite=173-901

Appendix D. Step-by-Step Pathways of Exposure for Priority Chemicals

The following section provides written explanations for each potential exposure pathway figure in this report (Figures 3-10, 12-14). These descriptions aim to accurately reflect the science behind each exposure pathway and chemical release, while also making the information easier to understand.

The figure descriptions below appear in the same order as in the report. Figure numbers match those listed in the list of figures on page 8.

PFAS in Artificial Turf (Figure 3)

1. Introduction and Use in Turf

Exposure to **PFAS in artificial turf** may occur during the **product manufacturing, installation, and maintenance** phase.

- PFAS are used to manufacture grass blades and are found in artificial turf.

2. Field Use

After artificial turf is installed, PFAS can be released by:

- **Product wear** and **breakdown**
- **Stormwater runoff**
- These processes may result in **environmental releases of PFAS** during field use, leading to potential exposure in sensitive species and people.

3. Field Removal & Disposal

When artificial turf is removed, the **disposal** phase begins.

- This stage can further introduce PFAS into the environment if not properly handled.

4. Outdoor Environment

PFAS are persistent in the environment and do not break down completely.

PFAS released to the **outdoor environment** enter:

- **Water** (for example, streams, lakes, stormwater systems)
- **Soil**
- **Sediments** in bodies of water

5. Impact on Sensitive Species

PFAS are toxic and bioaccumulate in **sensitive species**, including:

- **Aquatic (water-based) organisms**
- **Livestock and game animals**

6. Human Exposure

Humans may also be exposed to PFAS through:

- **Dermal (skin) contact**
- **Hand-to-mouth behavior**
- **Accidental ingestion** of turf particles
- **Eating** contaminated species or **drinking** contaminated water

7. Sensitive Populations

This exposure is a concern for:

- **Workers**
- **People of childbearing age**
- **Children**

6PPD in Artificial Turf (Figure 4)

1. Introduction and Use in Turf

Exposure to **6PPD in artificial turf** may occur during the **product manufacturing, installation, and maintenance** phases.

- 6PPD is found in crumb rubber used to make infill for artificial turf.

2. Field Use

After artificial turf is installed, 6PPD can be released by:

- **Product wear** and **breakdown**
- **Stormwater runoff**
- These processes result in **environmental releases of 6PPD and its breakdown products** during field use, leading to potential exposures in sensitive species and people.

3. Field Removal & Disposal

When artificial turf is removed, the **disposal** phase begins.

- This stage can further introduce 6PPD into the environment if not properly handled.

4. Outdoor Environment

Released chemicals enter the **outdoor environment** through:

- **Water** (for example, streams, lakes, stormwater systems)
- **Outdoor dust** (for example, small particles carried by wind or settling in soil)

5. Impact on Sensitive Species

6PPD and its breakdown products, such as 6PPDQ, affect **sensitive species**, including:

- **Coho salmon** and other fish species
- **Bioaccumulative species** (species that accumulate chemicals from their environment) like shrimp.

6. Human Exposure

Humans may also be exposed to 6PPD through:

- **Dermal (skin) contact**
- **Hand-to-mouth behavior**
- **Accidental ingestion** of turf particles
- **Inhalation** of turf particles
- **Eating** contaminated species or **drinking** contaminated water

7. Sensitive Populations

This exposure is a concern for:

- **Workers**
- **People of childbearing age**
- **Children**

cVMS in Cosmetics (Figure 5)

1. Introduction and Use in Cosmetics

Exposure to **cVMS in cosmetics** may occur in the **product manufacturing phase** or during **product use**.

- cVMS are used to provide a smoother feel to cosmetics.

2. Use and Disposal of Products

cVMS can enter the environment during **product use** and **waste disposal**.

- Exposures occur when cosmetics are **sprayed in the air** or **applied to hair or skin**.
- Disposed products found in **landfills** and **wastewater** can lead to environmental releases.

3. Chemical Releases from Products

As cVMS are released in air, they contaminate **outdoor** and **indoor environments**.

- cVMS are released to **outdoor environments** through **air and water can accumulate in sediment** (bodies of water) and **soil.**
- cVMS are released to **indoor environments** in **air** and build up in **dust**.

4. Impact on Sensitive Species

cVMS may impact sensitive species including:

- **Aquatic (water-based) organisms** like rainbow trout.
- **Bioaccumulative species** (species that accumulate chemicals from their environment) like benthic organisms that live in or near sediment.

5. Human Exposure

Humans may also be exposed to cVMS through:

- **Inhalation**
- **Dermal (skin) contact**

6. Sensitive Populations

This exposure is a concern for:

- **People of childbearing age**
- **Women**
- **Children**
- **Workers**

OFRs in Insulation (Figure 6)

1. Introduction

Exposure to **OFRs in insulation** may occur during the **product manufacturing, installation,** and **demolition** phases.

- OFRs are found in insulation and are used as **flame retardants**.

2. Use and Disposal of Insulation

During and after insulation is installed, OFRs can be released through:

- **Product installation and use** leading to **indoor air releases** and **dust build up**.
- **Dust tracked outdoors** or **released to wastewater.**
- **Demolition** of buildings and **disposal** of materials.

3. Outdoor Environment

If not properly handled, OFRs released to the environment can contaminate:

- **Air**
- **Water**
- **Soil**
- **Sediment**

4. Impact on Sensitive Species

OFRs are toxic to **sensitive species**, including:

- **Aquatic (water-based) organisms**
- **Bioaccumulative species** (species that accumulate chemicals from their environment) like birds.

5. Human Exposure

Humans may be exposed to OFRs through:

- **Dermal (skin) contact**
- **Accidental ingestion**
- **Inhalation**
- **Eating** contaminated species or **drinking** contaminated water

6. Sensitive Populations

This exposure is a concern for:

- **Workers**
- **Pregnant people**
- **People of childbearing age**
- **Children**

Lead and Cadmium in Jewelry and Accessories (Figure 7)

1. Introduction and Use

Exposure to **lead and cadmium in jewelry and accessories** may occur during **product manufacturing** and **product use**.

- Lead and cadmium are used to connect pieces together, as well as make pieces shinier and heavier.

2. Product Use

When jewelry and accessories with lead and cadmium are handled, human exposures can occur.

3. Waste Disposal and Outdoor Environment

When jewelry and accessories are disposed of, lead and cadmium can release into **wastewater** and **landfills**. Over time, these chemicals can enter the environment and contaminate:

- **Water**
- **Sediment**
- **Soil**

4. Impact on Sensitive Species

Lead and cadmium are toxic to **sensitive species**, including:

- **Forage fish**
- **Salmon**
- **Orcas**
- **Wild birds**

5. Human Exposure

Humans can be exposed to lead and cadmium through:

- **Inhalation** (for example, **breathing** of fumes when making products)
- **Hand-to-mouth behavior**
- **Accidental ingestion**
- **Eating** contaminated species or **drinking** contaminated water

6. Sensitive Populations

This exposure is especially concerning for:

- **Children**
- **People of childbearing age**
- **Workers**

BTEX in Nail Products (Figure 8)

1. Introduction and Use

Exposure to **BTEX in nail products** may occur during **product manufacturing** and **product use**.

- BTEX help with even color distribution and quicker drying applications.

2. Product Use

Exposures to BTEX occur when nail products are applied at **salons** or for **personal use**.

3. Waste Disposal and Outdoor Environment

BTEX can be released into **wastewater** and **landfills** when nail products are disposed of.

4. Human Exposure

Humans can be exposed to BTEX through:

- **Inhalation** of fumes during product application.
- **Breastfeeding** children who may be indirectly exposed.

5. Sensitive Populations

This exposure is a concern for:

- **People of childbearing age**
- **Children**
- **Workers**

PFAS in Architectural Paints (Figure 9)

1. Introduction and Use in Architectural Paints

Exposure to **PFAS in architectural paints** may occur during **product manufacturing** and **product use**.

- PFAS are used to improve paint distribution and durability during product use.

2. Product Use and Disposal

During and after use, PFAS can be released through:

- **Product use** leading to **indoor air releases** and **dust build up,** as paint chips or chalks.
- **Outdoor air releases** when paint breaks down.
- **Washing** and **disposing** of brushes and paint products, contaminating **waterways, stormwater,** and **landfills**.

3. Outdoor Environment

PFAS are persistent in the environment and do not break down completely.

PFAS released to the **outdoor environment** enter:

- **Air**
- **Water**
- **Soil**
- **Sediment**

4. Impact on Sensitive Species

PFAS are toxic and bioaccumulate in **sensitive species**, including:

- **Aquatic (water-based) organisms**
- **Livestock and game animals**

5. Human Exposure

Humans can be exposed to PFAS through:

- **Inhalation** (for example, **breathing** in fumes)
- **Accidental ingestion**
- **Dermal (skin) contact**
- **Dietary consumption** of contaminated species

6. Sensitive Populations

This exposure is especially concerning for:

- **Children**
- **People of childbearing age**
- **Workers**

APEs in Architectural Paints (Figure 10)

1. Introduction and Use in Architectural Paints

Exposure to **APEs in architectural paints** may occur during **product manufacturing** and **product use**.

- APEs are used to help paint spread evenly, mix well, and stay stable.

2. Product Use and Disposal

During and after use, APEs can be released through:

- **Product use** leading to **indoor air releases** and **dust build up** due to paint chipping or chalking.
- **Outdoor air releases** when paint breaks down.
- **Washing** and **disposing** of paint products, leading to APEs entering **wastewater** and **landfills**.

3. Outdoor Environment

APEs released to the **outdoor environment** enter:

- **Air**
- **Soil**
- **Water**

4. Impact on Sensitive Species

APEs and their breakdown products are toxic in **sensitive species**, including:

- **Aquatic (water-based) organisms**
- **Livestock and game animals**

5. Human Exposure

Humans may also be exposed to APEs through:

- **Inhalation**
- **Accidental ingestion**
- **Eating** contaminated species or **drinking** contaminated water

6. Sensitive Populations

This exposure is especially concerning for:

- **Children**
- **People of childbearing age**

PVC and PVDC in Plastic Packaging (Figure 12)

1. Introduction and Use in Plastic Packaging

Exposure to **PVC** and **PVDC in plastic packaging** may occur in the **product manufacturing phase** or during **product use**.

- **PVC** and **PVDC** are used in packaging for **consumer goods**, **food and drink containers**, and **pharmaceuticals** to protect products.

2. Use and Disposal of Products

PVC and **PVDC** can enter the environment during **product use** and **waste disposal**.

- Exposures occur when plastic packaging breaks down into **microplastics in indoor air** and **dust**.
- Disposed products found in **landfills**, along with **incineration** and **illegal burning** can lead to environmental releases.

3. Outdoor Environment

As PVC and PVDC are released, they contaminate **outdoor environments** in the form of:

- **Microplastics**
- **Dioxins** when burned.
- **Additives**

4. Impact on Sensitive Species

PVC and PVDC may impact sensitive species including:

- **Aquatic (water-based) organisms** like fish
- **Terrestrial (land-based) organisms**

5. Human Exposure

Humans may also be exposed to PVC and PVDC **microplastics** through:

- **Inhalation**
- **Accidental ingestion**

6. Sensitive Populations

This exposure is a concern for:

- **Children**
- **People of childbearing age**
- **Workers**

Phthalates in Sealants, Caulks, and Adhesives (Figure 13)

1. Introduction and Use in Sealants, Caulks, and Adhesives

Exposure to **phthalates in sealants, caulks, and adhesives** may occur in the **product manufacturing phase** or during **product use**.

2. Use and Disposal of Products

Phthalates can enter the environment during **product use** and **waste disposal**.

- Phthalates are released during and after use **in construction, home maintenance, and DIY projects**.
- Phthalates are also released when products and chemicals are disposed of in **landfills, wastewater, and stormwater**.
- These processes result in **environmental releases of phthalates**, leading to potential exposures in sensitive species and people.

3. Chemical Releases from Products

As sealants, caulks, and adhesives break down over time, phthalates are released to **outdoor** and **indoor environments**.

- Phthalates released to **outdoor environments** enter **soil, water, air, and sediment**.
- Phthalates are released to **indoor environments** in **air** and build up in **dust**.

4. Impact on Sensitive Species

Phthalates may impact sensitive species including **aquatic (water-based)** and **terrestrial (land-based) organisms**.

5. Human Exposure

Humans may also be exposed to phthalates through:

- **Inhalation**
- **Accidental ingestion**
- **Dermal (skin) contact**

6. Sensitive Populations

This exposure is a concern for:

- **Children**
- **People of childbearing age**
- **Workers**

1,4-dichlorobenzene in Solid Deodorizers (Figure 14)

1. Introduction and Use in Solid Deodorizers

Exposure to **1,4- dichlorobenzene in solid deodorizers** may occur in the **product manufacturing phase** or during **product use**.

2. Use and Disposal of Products

1,4- dichlorobenzene is released during **product use** and **waste disposal**.

- **Urinal blocks**, **room deodorizers**, **and garbage/diaper pail deodorizers** release chemicals into the air and in wastewater.
- Disposed products found in **landfills** and **wastewater** can lead to outdoor environmental chemical releases.

3. Chemical Releases from Products

As solid deodorizers break down over time, 1,4-dichlorobenzene enters **outdoor** and **indoor environments**.

- 1,4-dichlorobenzene released to **outdoor environments** enter **air, water, soils, and sediment**.
- 1,4-dichlorbenzene is released **indoor environments** through **air** and builds up in **dust**.

4. Impact on Sensitive Species

1,4-dichlorobenzene may affect sensitive species including **aquatic (water-based) organisms** and **plants**. Over time, this chemical builds up in species.

5. Human Exposure

Humans may also be exposed to 1,4-dichlorobenzene through:

- **Inhalation**
- **Dermal (skin) contact**
- **Ingestion**
- **Eating** contaminated species or **drinking** contaminated water

6. Sensitive Populations

This exposure is a concern for:

- **Children**
- **People of childbearing age**
- **Workers**

Appendix E. References

Overview

The following citation list was developed to meet the requirements outlined in RCW 70A.350.050[156] and 34.05.272.[157] It identifies the peer-reviewed science, studies, reports, and other sources of information used to support our identification of priority consumer products. The following are the types of sources used to support this report:

1. Peer review is overseen by an independent third party.
2. Review is by staff internal to Ecology.
3. Review by persons that are external to and selected by Ecology.
4. Documented open public review process that is not limited to invited organizations or individuals.
5. Federal and state statutes.
6. Court and hearings board decisions.
7. Federal and state administrative rules and regulations.
8. Policy and regulatory documents adopted by local governments.
9. Data from primary research, monitoring activities, or other sources, but that has not been incorporated as part of documents reviewed under other processes.
10. Records of best professional judgment of Ecology employees or other individuals.
11. Sources of information that do not fit into one of the other categories listed.

Citation list

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