Draft 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

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- Safer Products for Washington Cycle 2 Implementation Phase 2: Draft Report of Priority Products to the Legislature[1]
- Safer Products for Washington Cycle 2 Implementation Phase 1: Report to the Legislature on Priority Chemicals[2]
- Safer Products for Washington Cycle 2 Implementation Phase 1: Technical Supporting Documentation for Priority Chemicals[3]
- Safer Products for Washington Cycle 1 Implementation Phase 2: Report to the Legislature on Priority Consumer Products[4]
- Safer Products for Washington Cycle 1.5 Implementation Phase 3: Regulatory Determinations Report to the Legislature[5]
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- Safer Products for Washington Cycle 1 Implementation Phase 3: Final Report to the Legislature on Regulatory Determinations[7]
- Safer Products for Washington Cycle 1 Implementation Phase 4:
    - Chapter 173-337-WAC—Safer Products Restriction and Reporting[8]
    - Concise Explanatory Statement[9]

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[1] https://apps.ecology.wa.gov/publications/SummaryPages/2404049.html
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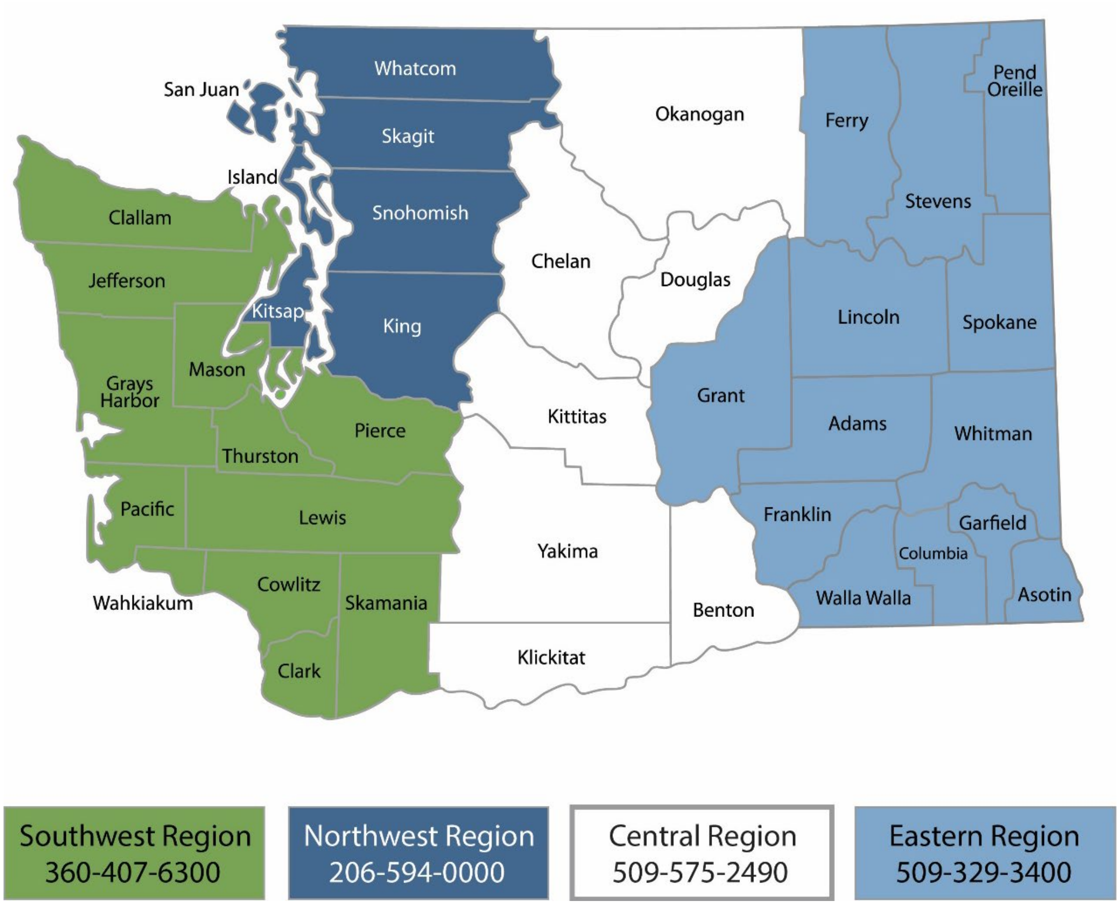

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Chapter 1: Technical Methods

Process overview

We used the criteria in Chapter 70A.350.030 RCW[12] to identify priority products. Many products contain priority chemicals and could meet the criteria in the law to identify as priority products. Therefore, we developed and implemented a prioritization process to help us select products based on a set of guiding principles, those are:

- We base decisions on science and public input.
- We communicate our approach and process to the public.
- We prioritize equitable reduction of exposure to toxic chemicals in people.
- We prioritize the protection of aquatic and terrestrial ecosystems in Washington.
- 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'll continue to refine our process based on input we receive, including on this draft report.

We started by researching products based on exposure potential, volume considerations, environmental release concerns, or public input. Figure 1 shows our approach for prioritizing products.

When researching products, we focused on identifying opportunities to:

- Reduce disproportionate exposures in people.
- Reduce contamination of terrestrial and aquatic ecosystems.

This was an iterative process where we used the information we gathered to inform our continued efforts.

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. This was based on a non-quantitative process that examined how the information about each product moved us toward our goals of equitably reducing exposure 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.

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[12] https://app.leg.wa.gov/RCW/default.aspx?cite=70A.350.030

Figure 1: 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 products were suggested in public input that we hadn't already researched, we expanded the scope of our research to include those products. As we researched products, we looked at where this input and the available scientific information aligned to help set our priorities. For example, if a product was raised 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 less of our resources to continuing research on that product category.

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 (CPID) and manufacturer safety datasheets to support and build upon the 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 is 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 weren’t 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 out 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. However, 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.

We used data from the US Bureau of Labor Statistics when available to estimate the size of worker populations that may have the potential for exposure to certain products. We relied on 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.

- 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 (EIM) 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.-a).
- 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.).

It’s difficult to directly link consumer products to these types of geographic datasets but, when possible, we did consider qualitatively 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. This literature, such as articles from academic journals, often contains the most up-to-date information on 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 allows us to incorporate the most relevant information and understand points of consensus or gaps of knowledge on a particular topic.

Another source of information we use is reports from other government agencies. Some primary examples of government agencies whose reports we consider in our work include (non-exhaustive):

- 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 hasn't been subject to rigorous peer review.) That said, we still view this information as valuable, especially when it supports what was compiled from the primary sources mentioned above.

Focus on equity in decision-making and narrowing our list

Equitably reducing disproportionate exposures is a goal of this program. We recognize that in most cases products are only one factor of many that contribute to exposures to priority chemicals in people. However, by focusing on opportunities to reduce exposures to priority chemicals from products in sensitive populations and populations with higher exposures, we aim to reduce the overall burden of exposure in these populations.

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

- Products with frequent use patterns.
- Products with the potential to contribute to direct exposure in people.
- Products with the potential to contribute to occupational exposures in Washington workers.
- Products that contaminate indoor and outdoor environments with priority chemicals.
- Products with 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):[13]

"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

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

(b) Infants and children

(c) Pregnant women

(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 accomplish this, we considered information on how these populations may be exposed to products; this can include exposure studies specific to the product or studies that evaluate exposure pathways relevant to sensitive populations generally.

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 to better understand the potential for worker exposures that occur through inhalation of BTEX substances that evaporate out of these products as they are used. This included studies looking at concentrations of BTEX substances in the air of nail salons.

We found that the majority of nail salon workers are women of childbearing age. People of childbearing age and children are 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 inadvertent ingestion of dust as a general pathway of exposure that is important in children as a sensitive population. Children have higher exposures to chemicals in dust due to spending more time on the floor and a higher frequency of hand-to-mouth behaviors.

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. Even when 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.

Reducing disproportionate exposures

We considered information that demonstrates the potential for higher exposures in populations to priority chemicals that are present in products. To accomplish this, we looked for studies or information that highlighted disproportionate exposures across populations, including:

- Biomonitoring studies that show disproportionate exposure to priority chemicals to race, ethnicity, sex, or gender.

- Information on differences in frequency of product use that could result in disproportionate exposures by race, ethnicity, sex, or gender.
- Studies that suggest a potential for higher exposures in certain occupations

We considered how intersections of race, occupation, and product use can exacerbate disproportionate exposures to priority chemicals. People who work in occupations with potential for exposure to priority chemicals and who also identify in populations with higher exposures than the general population are likely to experience heightened exposures relative to people who don't share this intersection.

For example, Black women have been shown to have higher exposures to 1,4-dichlorobenzene (1,4-DCB), a priority chemical used in toilet and bathroom 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, 2024a). Janitors and building cleaners are likely to use toilet and bathroom deodorizers as part of their occupation. So, this intersection of race and occupation increases the likelihood that these individuals have disproportionately higher exposures to 1,4-DCB as a priority chemical.

The health impacts of priority chemicals can be exacerbated by increased vulnerability to chemical hazards stemming from other factors, such as 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, and differences in access to community resources (Gee & Payne-Sturges, 2004).

For example, we identified jewelry and accessories as a priority product for lead and lead compounds due to the increased risk of exposure and heightened vulnerability to lead in children, including from overburdened populations in Washington.

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 influences development and brain structure. Research suggests that US children at this intersection who are from low-income families may be more vulnerable to lead exposure and that reducing lead exposure may more 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).

Protecting ecosystems in Washington

Protecting ecosystems in Washington is another ongoing goal of this program. Protecting the environment in Washington is an equity issue; the burdens of environmental harms are higher in more vulnerable populations or those subject to other inequities such as 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 (e.g., 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 disproportionate impacts on overburdened communities

For example, we identified artificial turf as a significant source of microplastics in the environment that contains 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 disproportionately 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[14] (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 a holistic safer alternative that could reduce multiple chemical hazards.

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

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.

1. An example of a performance property is how PFAS are used to impart oil and water resistance on surfaces.
2. 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.

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 the cycle, 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:[15]

> (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.

Considerations in statute

The statute 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[16] as a source of a priority chemical

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

[16] https://apps.leg.wa.gov/rcw/default.aspx?cite=70A.300

or other reports or information gathered under chapters 70A.430 RCW,[17] 70A.405 RCW,[18] 70A.222 RCW,[19] 70A.335 RCW,[20] 70A.340 RCW,[21] 70A.230 RCW,[22] or 70A.400 RCW.[23]

(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.

- 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 and supplemented that with other information that

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[17] https://apps.leg.wa.gov/rcw/default.aspx?cite=70A.430
[18] https://apps.leg.wa.gov/rcw/default.aspx?cite=70A.405
[19] https://apps.leg.wa.gov/rcw/default.aspx?cite=70A.222
[20] https://apps.leg.wa.gov/rcw/default.aspx?cite=70A.335
[21] https://apps.leg.wa.gov/rcw/default.aspx?cite=70A.340
[22] https://apps.leg.wa.gov/rcw/default.aspx?cite=70A.230
[23] https://apps.leg.wa.gov/rcw/default.aspx?cite=70A.400

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 as such it can be difficult for researchers to attribute exposure to a single source or product. Therefore, we considered what 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. 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, but they can help us understand how chemicals contained in a particular product may contaminate indoor dust and contribute to exposures through inadvertent ingestion of dust, which is a particularly 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 considered information on how priority chemicals may be released from the product during use both indoors and outdoors, and whether those chemicals indoors could potentially be transported outdoors, such as through evaporation and movement through the air.
- We considered the ways products may be disposed of, for instance in solid waste to be landfilled, down the drain as a component of wastewater, or direct releases to the environment such as products used outside that may contaminate stormwater.

Additionally, we referred to information that described the degradation of both the product and the associated priority chemicals in the environment. We considered the potential for exposure in 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 aren't completely removed by municipal wastewater treatment.

Sediments and soils can act as sinks for some priority chemicals, especially those that are lipophilic, and this can increase the potential for exposure in benthic organisms that live and feed near sediment or soil organisms, respectively. Conversely, some priority chemicals degrade in the environment; this can reduce the potential for exposure in sensitive species to those chemicals, however, in some cases, priority chemicals may degrade to other chemicals that are even more toxic to organisms (e.g., 6PPD degradation to 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 C.

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 don't 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 didn't 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 alternatives before proposing any regulatory actions.

Consumer products previously identified by the department

We referred to past work by Ecology, including our past Chemical Action Plans,[24] to identify products that have previously been identified as sources or uses of priority chemicals.

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[24] https://ecology.wa.gov/waste-toxics/reducing-toxic-chemicals/addressing-priority-toxic-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.[25]

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[25] https://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’s 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, 2024j).

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

Priority chemical(s)

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”[26] and “Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1”[27] in Chapter 8: Technical Support for 6PPD (Ecology, 2024c, 2024b).

PFAS

PFAS chemicals are defined as a priority chemical class by the Washington State Legislature under RCW 70A.350.010.[28]

Background

Artificial turf is typically comprised 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 be comprised of a variety of materials including nylon, polyethylene, polypropylene, polyurethane, and synthetic rubber. The synthetic rubber is often sourced from crumb rubber from discarded tires or tire materials (Murphy & Warner, 2022).

Artificial grass blades, infill, and backing may contain PFAS. Polymeric PFAS used in the manufacturing process can remain in the product. 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).

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[26] https://apps.ecology.wa.gov/publications/SummaryPages/2404025.html
[27] https://apps.ecology.wa.gov/publications/SummaryPages/2404026.html
[28] https://app.leg.wa.gov/RCW/default.aspx?cite=70A.350.010

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 – 19,000 artificial turf fields in the United States and 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 turf grass blades (TURI, 2020). Fluoropolymers at around 100—1000 ppm are used to help manufacturers of extruded products such as plastic bottles, bags, pipes, cables, and artificial grass reduce processing issues like die buildup and melt fracture (3M, n.d.). Patent literature suggests the potential use of polytetrafluoroethylene (PTFE) as an antistatic agent for turf grass blades (Lambert, 2008). PTFE and polyvinylidene fluoride (PVDF) can be used as coating treatments or the binding matrix in turf-filling materials (Reddick, 2023; Q. Wu, 2016). The manufacturing of artificial turf from recycled materials could incorporate PFAS into artificial turf components (New Jersey DEP, 2023).

While polymeric fluorinated compounds in artificial turf are intentionally used during the manufacturing process, other 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 sample obtained from the manufacturer, Zuccaro et al detected fluorotelomer alcohol (8:2 FTOH) at 300 ppb in artificial turf fiber and 110 ppb in crumb rubber (Zuccaro et al., 2023). Fluorotelomer alcohols have the potential to biodegrade or environmentally degrade 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.

A 2020 study in Sweden tested the turf blades, infill, and backing from 17 athletic turf fields in Stockholm (Lauria et al., 2022). They performed 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 1). 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. TOPA conducted on ten selective samples generated negligible formation of PFCAs following oxidation.

Table 1: 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%^

Table notes:
* 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 isn't included in the list of targeted PFAS analytes.

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

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[29] were detected in the backing, and six individual PFAS were detected in the infill samples.
- The TOP assay resulted in four, six, and eight individual PFAS detections in the infill, backing, and turf blades, respectively.

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 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

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[29] 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

backing of an old turf manufactured in 2004. They found 44 – 255 ppm total fluorine in eight artificial turf fiber samples (Ecology Center, 2019).

The research on all the chemicals in artificial turf is still ongoing with gaps in data but the limited number of results provide us with evidence for the presence of PFAS in artificial turf. 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 degradation. 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, in tire samples from recycling plants, and in 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 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 also 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 2 below.

Table 2: 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)
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)

Table note: * 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, it was estimated that there were between 18,000 and 19,000 artificial turf fields in the US, with approximately 1,200 to 1,500 new installations each year of which most use recycled tire crumb rubber as infill (US EPA, 2024j).

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).

We don't know the exact number of artificial turf fields installed in Washington but based on online research and outreach efforts we identified more than 100 known artificial turf fields installed throughout the state. Since we don't 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 – 2021 (King County Parks, 2024). The average size of a field ranges from approximately 57,000 ft^2 t 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 lbs. infill per square foot (160 – 500 tons) 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 about 220 –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 can't 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 6PPD and PFAS during the manufacturing, use, and disposal of artificial turf. Figure 2 demonstrates known and potential exposure pathways for sensitive species and populations for 6PPD and PFAS from artificial turf.

The primary exposure pathways for sensitive populations are inhalation, inadvertent 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.

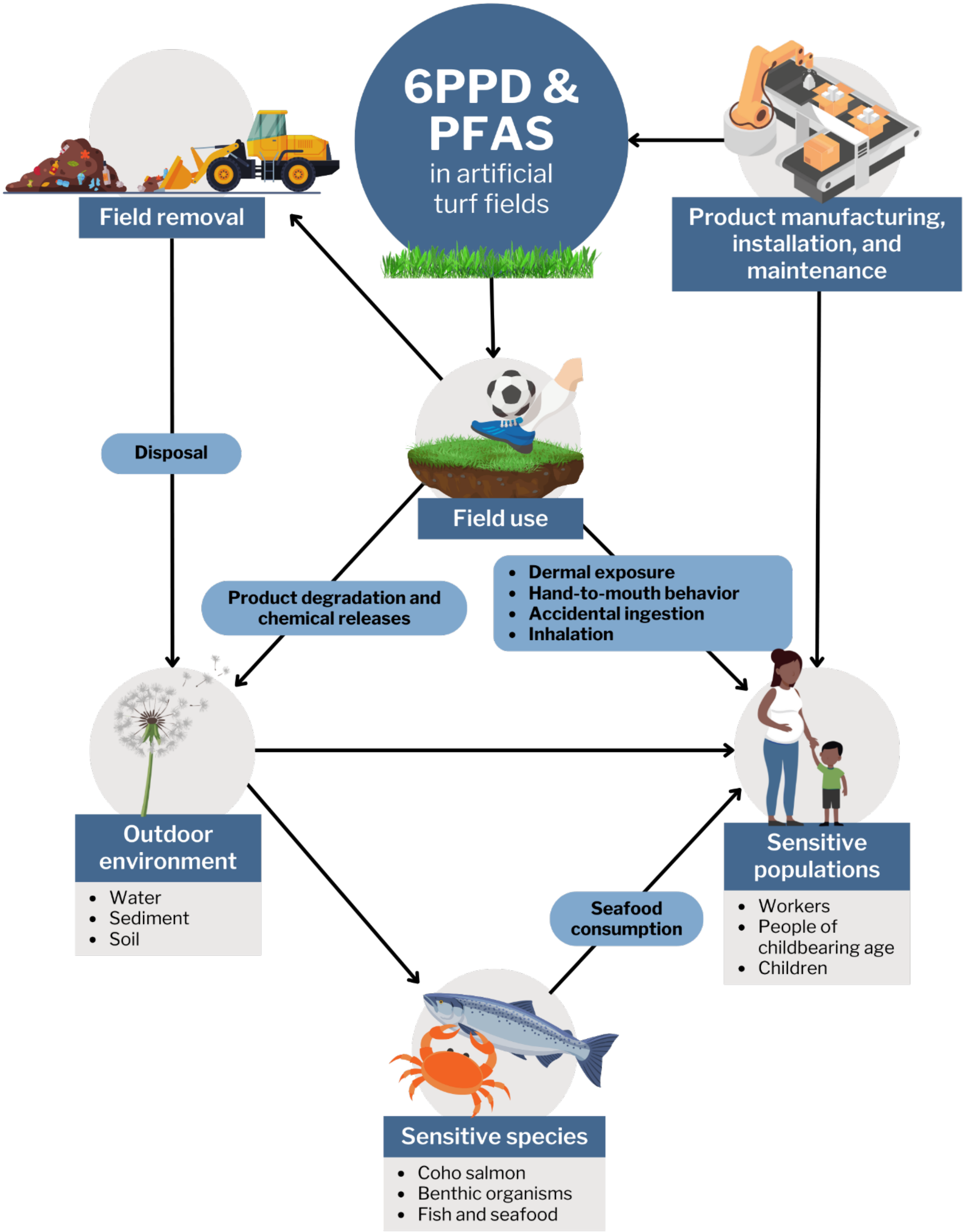

Figure 2: Pathways of potential exposure to PFAS and 6PPD from artificial turf in sensitive populations and sensitive species.

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).

6PPD and PFAS chemicals have been identified as reproductive toxicants. 6PPD exposure in laboratory rodents causes difficult birth (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, 2024k, 2024j).

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, 2024k, 2024j). 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, 2024j).

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 we located. However, evidence suggests that some PFAS can penetrate skin layers (Ragnarsdóttir et al., 2022, 2024). Dermal penetration may be more likely for neutral PFAS (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 contact crumb rubber granules, chemicals can migrate out of the rubber into the sweat layer on the skin but do not address whether the chemical then crosses 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, 2024j). 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, 2024j).

Take home exposure

Exposure to artificial turf components does not stop at the field (Kole et al., 2023). A majority of participants in the one study noted tire crumbs on their bodies, cars, and in their homes (US EPA, 2024j). This highlights the potential for a take-home exposure pathway for 6PPD in crumb rubber that could expose other members of the household. Similarly, turf grass blades may stick to people and their gear after field use and end 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. 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). PFAS are persistent in the environment, and some bioaccumulate and are toxic to aquatic organisms (T. Ma et al., 2022). Therefore, the release of PFAS, 6PPD, and 6PPD-quinone from artificial turf has the potential to impact sensitive species.

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 disperse in 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), and the authors surmise 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 of the samples (de Haan et al., 2023). At the end of life, artificial turf materials that are landfilled may act as a source of PFAS in the environment, including microplastics. This suggests that, though there are some information gaps, PFAS are likely released into the environment from artificial turf as a component of microplastic particles and fibers, and that some proportion of these releases will end up as persistent pollutants in aquatic systems where sensitive species may be exposed.

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 tire wear particles that contain 6PPD and 6PPD-quinone into the environment in significant quantities.

In a review article focused on tire particles released from artificial turf fields, it was estimated that without mitigation measures, 948 kg of tire 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 doesn't 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, Click or tap here to enter text.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 the amount of refill (crumb rubber added to maintain the field) used for a regular-sized field each year and reported an average of 3,312 kg refill required per year. The authors suggest the difference of 1534 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 tire wear 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 tire wear particles, such as those used in 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 avoid the use of PFAS and 6PPD. 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 proposing any regulatory actions.

- Natural grass turf fields are natural alternatives to artificial turf fields. 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 potentially reduce exposure to PFAS and 6PPD.

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

- 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 virgin 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 replacing 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: Cleaning and Household Care Products

Overview

Priority product

The scope of this priority product includes cleaning and household care products and aligns with that category in the Chemicals and Products Database (CPDat) and the EPA ChemExpo (Isaacs et al., 2020; US EPA, n.d.-a). This includes products intended for professional or non-professional use.

Examples of products in scope include (non-exhaustive):

- Air fresheners
- Bathroom cleaners
- Carpet, floor, and upholstery cleaners, deodorizers, and polishes
- Dishwasher and dish soaps and detergents
- Drain products
- Laundry and fabric treatments
- Oven, washing machine, and dishwasher cleaners
- Surface, glass, and heavy-duty cleaners
- Wood and metal cleaners and polish

The scope of this priority product doesn't include drugs or biological products regulated by the United States Food and Drug Administration (FDA) such as antiseptics or antimicrobial drugs. The scope doesn't include chemical products used to produce agricultural commodities as defined in RCW 17.21.020.[30]

Priority chemicals

Ortho-phthalates

Phthalates were defined as a priority chemical class by the Washington State Legislature under RCW 70A.350.010[31] as "synthetic chemicals esters of phthalic acid". We further clarified that this definition of phthalates includes only ortho-phthalates and doesn't include synthetic esters of isophthalic acid or terephthalic acid (i.e., isophthalates or terephthalates) in our previous report, "Regulatory Determinations Report to the Legislature: Safer Products for Washington Cycle 1 Implementation Phase 3." [32]

Formaldehyde and formaldehyde releasers

Formaldehyde and formaldehyde releasers were defined as a priority chemical class in our previous legislative reports, "Identification of Priority Chemicals Report to the Legislature: Safer

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[30] https://app.leg.wa.gov/RCW/default.aspx?cite=17.21.020

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

[32] https://apps.ecology.wa.gov/publications/SummaryPages/2204018.html

Products for Washington Cycle 2 Implementation Phase 1" [33] and "Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1" [34] in Chapter 6: Technical Support for Formaldehyde and Formaldehyde Releasers (Ecology, 2024c, 2024b).

Background

Ortho-phthalates

Cleaning and household care products may contain ortho-phthalates. Ortho-phthalates are sometimes used as a component of fragrance ingredients in these products. Ortho-phthalates are used as fixatives in fragrance formulations to make scents last longer. This is akin to their use in personal care and beauty products which we evaluated during Cycle 1 of Safer Products for Washington (Ecology, 2020, 2022b).

Formaldehyde and formaldehyde releasers

Cleaning and household care products may contain formaldehyde and formaldehyde releasers which are used as preservatives in these products. Formaldehyde has antimicrobial and antifungal activity and is used to extend the shelf life of products. Formaldehyde releasers added to products slowly release formaldehyde over time (Ecology, 2024c).

Volume estimates for priority product-chemical combinations

The volume of priority chemicals associated with the product

Ortho-phthalates

Cleaning and household care products are a significant use of ortho-phthalates. Based on our research, ortho-phthalates are likely used in these products primarily as a component of fragrances (Viñas et al., 2015). Ortho-phthalates have been reported in cleaning and household care products in several peer-reviewed articles, but the data is somewhat limited. In general, the concentrations of ortho-phthalates reported in cleaning and household care products are lower than those reported in personal care products (Ecology, 2020). For context, the mean concentrations in personal care products reported in studies ranged from 6 ppm to 7,813 ppm (Ecology, 2020).

A 2012 study reported ortho-phthalates in various cleaning and household care products in composite samples consisting of multiple products from categories including:

- Laundry detergents
- Stain removers, carpet cleaners
- Toilet bowl cleaners
- A borax product (Dodson, Nishioka, et al., 2012).

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[33] https://apps.ecology.wa.gov/publications/SummaryPages/2404025.html

[34] https://apps.ecology.wa.gov/publications/SummaryPages/2404026.html

The study reported detections of individual ortho-phthalates in the composite samples in concentration ranges. The most frequently detected phthalate was diethyl phthalate (DEP) with the concentrations in products reported as 1–100 ppm in (Dodson, Nishioka, et al., 2012):

- Dish liquids (four products)
- Laundry bleach (four products)
- Stain remover (five products),
- Carpet cleaners (six products),
- Polish/wax (seven products) and
- Toilet bowl cleaners (two products).

Polish/wax (seven products) was reported to contain di-n-butyl phthalate (DnBP) in the range of 100 – 1000 ppm (Dodson, Nishioka, et al., 2012).

A study of phthalate esters in cleaning and personal care products using mass spectrometry analyzed 33 cleaning products and seven personal care products from Spain for six ortho-phthalates: dimethyl phthalate (DMP), diethyl phthalate (DEP), benzyl butyl phthalate (BBP), dibutyl phthalate (DBP), di(2-ethylhexyl) phthalate (DEHP) and dioctyl phthalate (DOP) (Table 3) (Viñas et al., 2015).

DEP was detected in all cleaning products tested at concentrations ranging from 58 ng/g to 81,663 ng/g, with a median of 2889 ng/g across all cleaning and personal care products tested. BBP was detected in all products tested ranging from 135 ng/g to 35,392 ng/g, with a median of 1162 ng/g across all cleaning and personal care products in the study (Viñas et al., 2015).

A separate study by the same group measured the same six ortho-phthalates in 27 cleaning products and detected ortho-phthalates in 14 products ranging from 100 ng/g – 21,000 ng/g (Cacho et al., 2015).

Table 3: Ortho-phthalates measurements reported in cleaning products, adapted from Vinas et al., 2015, concentrations reported in ng/g converted to ppm. (Viñas et al., 2015).

Product type (number of products)	Diethyl phthalate (DEP) (CAS: 84-66-2) Concentration Range (ppm)	Benzyl butyl phthalate (BBP) (CAS: 85-68-7) Concentration Range (ppm)	Dibutyl phthalate (DBP) (CAS: 84-74-2) Concentration Range (ppm)
Glass cleaner (3)	0.824–81.663	0.143–1.149	ND–1.195
Degreaser (5)	0.609–2.124	0.330–5.272	0.282–2.790
Floor (5)	0.171–13.106	1.015–35.392	0.125–9.648
Dishwashing detergent (2)	0.058–4.370	0.629–1.035	0.877–1.870
Laundry detergent (2)	0.488–10.045	1.483–9.948	6.943–8.410
Softener (2)	2.981–13.494	8.179–10.068	3.337–68.160
Stain remover (1)	53.238	9.900	12.053
Jam cleaner (1)	1.883	0.986	0.863
Active oxygen (1)	3.843	0.135	0.371
De-scaler (1)	0.154	1.873	2.112
Bath cleaner (3)	0.589–4.481	0.557–20.908	1.798–15.560

A recent study of ortho-phthalates in propellant- and trigger-type consumer spray products from South Korea reported detections of several ortho-phthalates in cleaning and household care products (Table 4) (Hwang et al., 2024). The authors measured six ortho-phthalates (DiBP, DnBP, BBP, DEHP, DINP, and DIDP) in 30 propellent-type cleaning products and 16 propellent-type aromatic/deodorant products. They measured the same six ortho-phthalates in 43 trigger-type cleaning products and 23 trigger-type aromatic/deodorant products.

Notably, the study didn't measure DEP in the products.

- For propellent-type products, the authors reported mean total phthalate concentrations of 2.24 ppm and 0.92 ppm for cleaning and aromatic/deodorant products, respectively.
- For trigger-type products, the mean total phthalate concentration in cleaning products was 4.54 ppm, and 4.33 ppm for aromatic/deodorant products (Hwang et al., 2024).

Table 4: The phthalate concentrations in propellant- and trigger-type consumer spray products (adapted from Hwang et al., 2024).

Product Type	Release type	Number of products	Mean total ortho-phthalates concentration (ppm ± SD)
Cleaning	Propellant	30	2.24 ± 3.77
Aromatic/deodorant	Trigger	16	0.92 ± 0.78
Cleaning	Propellant	43	4.54 ± 6.43
Aromatic/deodorant	Trigger	23	4.33 ± 3.84

In addition to the literature studies described above, a non-governmental organization, the Natural Resources Defense Council (NRDC) reported detections of ortho-phthalates in 12 of 14 air fresheners tested (86%). Ortho-phthalates detected in the study included DEP, DBP, diisobutylphthalate (DiBP), and dimethyl phthalate (DMP). The highest concentrations reported were for DEP and ranged from 0.8 – 7,300 ppm (NRDC, 2007).

None of the products tested in the study listed ortho-phthalates as an ingredient on their product labeling (NRDC, 2007).

We referred to information in the Consumer Product Information Database to assess ortho-phthalates used in cleaning and household care products. We found 53 cleaning and household care products in the Consumer Product Information Database reported to contain diethyl phthalate (DEP) in the categories of commercial/institutional, home maintenance, inside the home, and auto products (CPID, n.d.).

The concentration of DEP in the product wasn't disclosed for most products, but concentrations reported in products ranged from less than 0.1 – 5.0% of the formulation (CPID, n.d.). We didn't find cleaning and household care products containing either BBP or DBP in the CPID.

As another resource, we queried the EPA ChemExpo database for cleaning and household care products that contain ortho-phthalates. We found 35 products that contain DEP, 18 products that contain DBP, nine products that contain DEHP, and one product reported to contain diisodecyl phthalate (DIDP) (US EPA, n.d.-a).

In many cases, manufacturers don't appear to disclose the presence of ortho-phthalates in these products or their concentrations in safety data sheets. Further, ortho-phthalates are often components of fragrance ingredients in these products, and we suspect manufacturers of the cleaning and household care products may not know they are present in some formulations if it hasn't been disclosed to them by the fragrance supplier. For this reason, it is reasonable to consider the number of cleaning and household care products that contain fragrance ingredients generally. As such, we searched the Mintel GNPD for cleaning and household care products that listed fragrance or parfum as an ingredient as they have the potential to contain ortho-phthalates (Figure 3).

We don't know if these products contain ortho-phthalates, but we do know that ortho-phthalates are commonly used as a component of fragrance ingredients to make scents last longer after product use. This was one of our findings from Cycle 1 of Safer Products for Washington when we evaluated ortho-phthalates used as a component of fragrances in personal care and beauty products (Ecology, 2022b). We found 5,655 products in the category of 'household' that contain fragrance ingredients input to the Mintel GNPD from the North American market in the last ten years (2014–2024) out of a total of 9,576 product records with ingredient information available (Figure 3) (Mintel, n.d.).

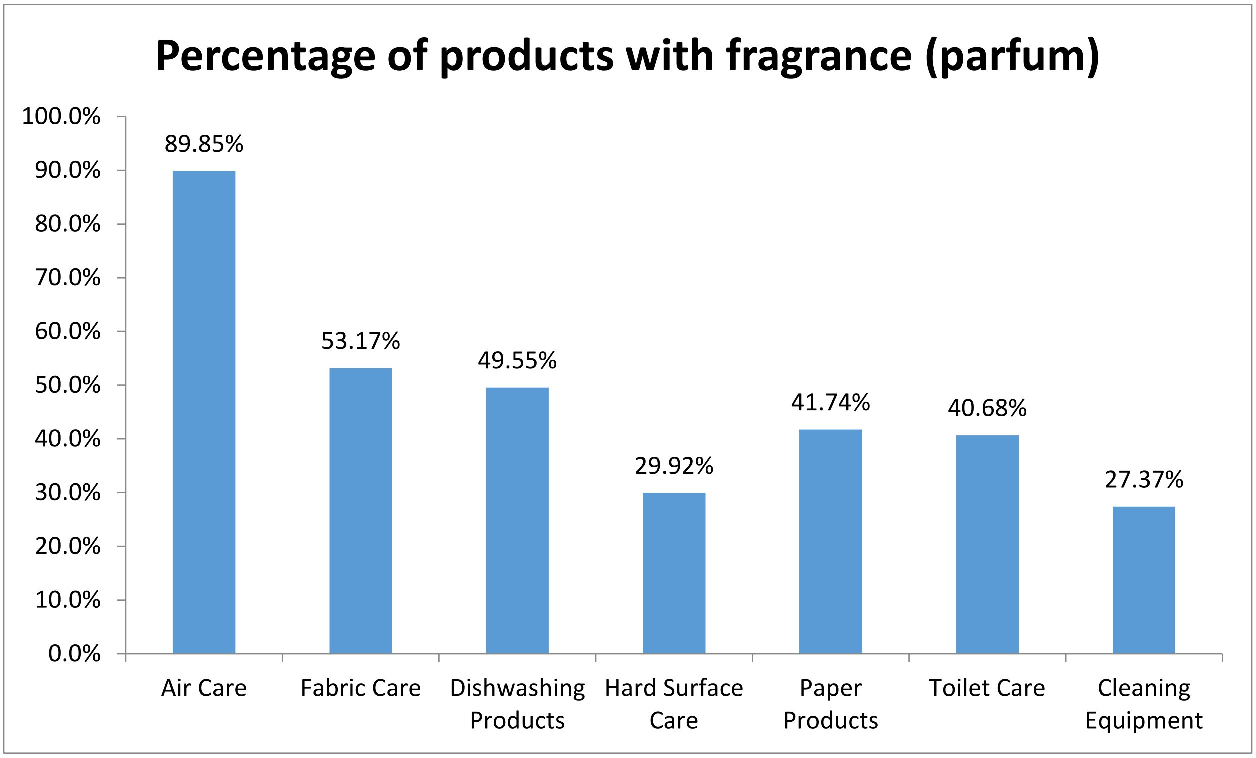

Figure 3: Percentage of products in the household category in Mintel GNPD that contain fragrance (parfum). The results are limited to products with ingredient information available and product entries from the last ten years (2014–2024); 9,576 total product records (Mintel, n.d.).

Formaldehyde and formaldehyde releasers

Formaldehyde and formaldehyde releasers are present in a variety of different cleaning and household care products. The primary use of formaldehyde releasers in these products is as preservatives in formulations. Information on the concentration of formaldehyde and formaldehyde releasers used in cleaning and household care products is limited, but it appears the concentrations used are generally less than 1% of the formulation.

A study, that examined data submitted to the Danish Product Register Database, reported formaldehyde and 2-bromo-2-nitropropane-1,3-diol (bronopol, CAS: 52-51-7) were the most common preservatives in the priority chemical class reported in cleaning products (Schwensen et al., 2017). Of the total of 3,459 products registered in the cleaning and washing agent's category, 87 were reported to contain formaldehyde at up to 0.4%, and 69 products were reported to contain bronopol, a formaldehyde releaser, at up to 0.4% (Schwensen et al., 2017). We don't know how accurately the products in the Danish market reflect those found in Washington.

To investigate whether cleaning and household care products in North America contain formaldehyde and formaldehyde releasers, we referred to publicly available ingredient disclosures, and product databases including Consumer Product Information Database, ChemExpo, and Mintel GNPD. For these searches, we focused on products that are in the scope as described in the priority product section above, based on available information.

The information in these databases is expected to overlap to some degree, but these sources together demonstrate the use of formaldehyde and various formaldehyde releasers in cleaning and household care products broadly. Tables 5, 6, and 7 show products reported to contain formaldehyde and formaldehyde releasers as reported in the CPID, Mintel GNPD, and ChemExpo databases, respectively (CPID, n.d.; Mintel, n.d.; US EPA, n.d.-a).

Table 5: The number of cleaning and household care products listed in the CPID for formaldehyde and various formaldehyde releasers in categories of commercial/institutional, home maintenance, inside-the-home, and auto products (CPID, n.d.).

Chemical	Number of products	Product subcategory (number of products)
2-bromo-2-nitro-1,3-propanediol (Bronopol) (CAS: 52-51-7)	60	Commercial and institutional (7), home maintenance (2), inside-the-home (47), auto products (4)
DMDM hydantoin (CAS: 6440-58-0)	40	Commercial and institutional (6), home maintenance (1), inside-the-home (33)
Formaldehyde (CAS: 50-00-0)	30	Commercial and institutional (9), home maintenance (21)
Quaternium-15 (CAS: 4081-31-3; 51229-78-8)	12	Commercial and institutional (2), inside-the-home (10)
MDM hydantoin (CAS: 27636-82-4)	8	Commercial and institutional (1), inside-the-home (2), auto products (5)
Dimethylol glycol (CAS: 3586-55-8)	7	Inside-the-home (7)
Sodium hydroxymethylglycinate (CAS: 70161-44-3)	5	Inside-the-home (5)
Polyoxymethylene melamine (CAS: 9003-08-1)	4	Inside-the-home (4)
Glyoxal (CAS: 107-22-2)	3	Inside-the-home (3)
Methylal (CAS: 109-87-5)	3	Inside-the-home (3)
Dimethylol urea (CAS: 140-95-4)	1	Inside-the-home (1)

Table 6: The number of cleaning and household care products listed in Mintel GNPD for various formaldehyde releasers (Mintel, n.d.).

Chemical	Number of products	Product subcategory (number of products)
DMDM hydantoin (CAS: 6440-58-0)	47	Dishwashing products (21), hard surface care (14), fabric care (7), air care (5)
2-bromo-2-nitro-1,3-propanediol (Bronopol) (CAS: 52-51-7)	14	Hard surface care (11), fabric care (2), air care (1)
Diazolidinyl urea (CAS: 78491-02-8)	9	Dishwashing products (1), hard surface care (3), fabric care (1), air care (4)
Quaternium-15 (CAS: 4081-31-3; 51229-78-8)	7	Dishwashing products (6), fabric care (1)
Polyoxymethylene melamine (CAS: 9003-08-1)	4	Fabric care (4)
Sodium hydroxymethylglycinate (CAS: 70161-44-3)	2	Hard surface care (2)

Table 7**.** The number of cleaning and household care products listed in ChemExpo for formaldehyde and various formaldehyde releasers (US EPA, n.d.-a).

Chemical	Total number of products	Product subcategory (number of products)
2-bromo-2-nitro-1,3-propanediol (Bronopol) (CAS: 52-51-7)	120	Drain products (1), general household cleaning (1), laundry and fabric treatment (108), wood specific (7)
Formaldehyde (CAS: 50-00-0)	71	Bathroom (1), carpet and floor (15), dishwasher and dishes (5), drain products (1), general household cleaning (16), lamp oil/lighter fluid (1), laundry and fabric treatment (15), lime remover (1), wood specific (1)
Quaternium-15 (CAS: 4081-31-3; 51229-78-8)	7	Bathroom (3), general household cleaning (1), laundry and fabric treatment (3)
Sodium hydroxymethylglycinate (CAS: 70161-44-3)	4	Hand cleaner (4)
DMDM hydantoin (CAS: 6440-58-0)	4	Dishwasher and dishes (2), general household cleaning (2)
Dimethoxymethane (CAS: 109-87-5)	1	Laundry and fabric treatment (1)

The volume of the product sold or present in the state

The home and laundry care market revenue in the United States is projected at $32.17 billion for 2024 (Statista, 2024a). For this estimate, the market definition didn't include professional products for industry use or household cleaning services. The total revenue of products in scope is expected to be higher and this is likely an underestimate.

Washington State accounts for approximately 2.3% of the United States population (US Census Bureau, 2024). Based on this, Washington's share of the home and laundry care industry revenue would be expected at around $739 million.

The average annual expenditure on laundry and or cleaning supplies for a household in the United States in 2022 was approximated at $169.83 per consumer unit (Statista, 2023). Washington State's population is approximately 7.8 million people so this would suggest around $1.3 billion in sales of these products in Washington annually (US Census Bureau, 2024). Together, these data demonstrate a large market and volume of cleaning and household care products sold or present in Washington.

We didn't estimate the precise volume of ortho-phthalates or formaldehyde and formaldehyde releasers attributable to cleaning and household care products in Washington. This was due to the limited data on concentrations of ortho-phthalates, and formaldehyde and formaldehyde releasers used in cleaning and household care products.

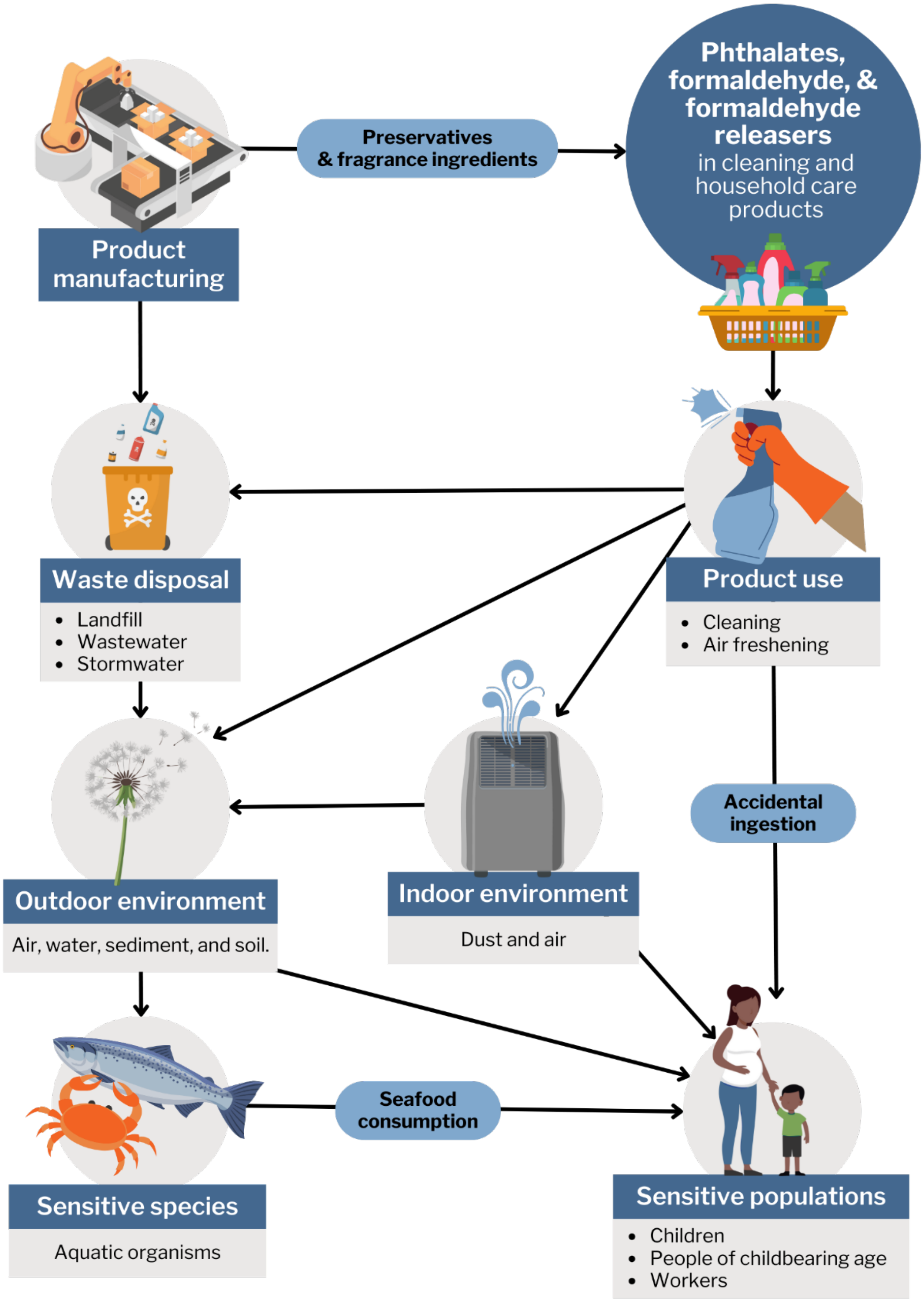

Figure 4: Pathways of potential exposure to ortho-phthalates, and formaldehyde and formaldehyde releasers from cleaning and household care products in sensitive populations and sensitive species.

Potential for exposure to priority chemicals from the product

Cleaning and household care products are widely used in homes, schools, workplaces, health care facilities, and other indoor environments (Figure 4). People have the potential for exposure to formaldehyde and ortho-phthalates in cleaning and household care products primarily through inhalation and skin contact. There is some potential for exposure via inadvertent ingestion of dust for the ortho-phthalates.

Formaldehyde and ortho-phthalates in cleaning and household care products are volatile or semi-volatile chemicals, respectively. As such, they have the potential to contaminate indoor air during the use of these products, especially when products are used as aerosols, mists, or sprayed.

Cleaning and household care products are often spread thinly on surfaces as part of their intended use, increasing the potential for evaporation to indoor air. Air care products that may contain ortho-phthalates or, formaldehyde and formaldehyde releasers, are available in the form of aerosols, sprays, gels, and oil diffusers and are intended to dispel into the air as part of their use.

People have the potential for exposure to ortho-phthalates and formaldehyde in these products through skin contact with the products during use (Meesters et al., 2018). It's important to note that people frequently use more than one cleaning or household care product, resulting in inhalation or skin contact from multiple sources and exposure to chemical mixtures (Trantallidi et al., 2015).

Ortho-phthalates

Ortho-phthalates are released into indoor air when cleaning and household care products are used. When ortho-phthalates are present in the air, whether as gases or aerosols, they can enter the body through inhalation.

- A study in South Korea detected several ortho-phthalates in the room air after use of spray and aerosol household care products, including cleaning and air freshening products (Hwang et al., 2024).
- A study of custodians reported that biological markers of exposure to diethyl phthalate (DEP) increased with increasing intensity of use of cleaning products (Cavallari et al., 2015).

As semi-volatile chemicals and due to widespread use in consumer products, ortho-phthalates are very common in-house dust (Mitro et al., 2016). The ortho-phthalates in cleaning and household care products have the potential to adsorb to dust particles after they are released from the product. Dust is a particularly important route of exposure for infants and young children.

Ortho-phthalates have the potential to contaminate the environment, such as air and water, during the use and disposal of cleaning and household care products. We reported that fragrances used in personal care products were one of the leading contributors of ortho-phthalates to Washington's environment as part of Cycle 1 of Safer Products for Washington (Ecology, 2020). Less is known about the contribution of fragrances or other uses of ortho-phthalates in cleaning and household products to environmental releases of ortho-phthalates in Washington state.

Many cleaning products end up being washed down the drain as part of their intended use and become a component of wastewater. This suggests that any ortho-phthalates contained in the products not removed by wastewater treatment will eventually enter the environment.

It’s expected that some of these volatile and semi-volatile chemicals in indoor air and dust will eventually make their way into the outdoor environment as well. Ortho-phthalates aren’t persistent in the environment, but their ongoing significant use can result in a continuous presence in the environment (Goldenman et al., 2017).

Formaldehyde and formaldehyde releasers

Formaldehyde is released into the air from numerous cleaning products (Harding-Smith et al., 2024; Temkin et al., 2023). Although formaldehyde and formaldehyde releasers are used at relatively low concentrations in products (generally less than 1%), the amount of formaldehyde released from these products may be significant for human health. For example, the reference concentration of formaldehyde published by the EPA IRIS program in 2024 is 0.007 mg/m^3 for inhalation exposure based on noncancer health effects. This reference concentration is an estimate of a continuous inhalation exposure concentration of the chemical in the human population that is likely to be without risk of deleterious noncancer effects during a lifetime; 0.007 mg/m^3 is approximately equivalent to a concentration of 0.006 ppm or 0.00000006% in the air (US EPA, 2024d). Although this doesn’t reflect the specific exposure scenario for the use of cleaning and household care products, it highlights the point that potential exposures to formaldehyde from these products in indoor air warrant attention and should be reduced when feasible.

Formaldehyde isn't persistent in the environment and doesn’t bioaccumulate (Ecology, 2024c). The fate of formaldehyde releasers used in cleaning and household care products in the environment is less clear. For example, quaternium-15 is a formaldehyde releaser that has been described as persistent and resistant to metabolic degradation in the environment by some scientists, while other sources report it is degradable (Impellitteri et al., 2024; PubChem, n.d.-b).

A study on bronopol, a commonly used formaldehyde releaser, reported that its degradation products in the environment were predicted to be more persistent and toxic than the parent chemical (Cui et al., 2011). The bronopol transformation products highlighted were bromonitromethane and 2-bromo-2-nitroethanol. Since the intended function of formaldehyde releasers, as preservatives implies degradation to formaldehyde primarily through hydrolysis, environmental persistence of the parent chemicals isn’t expected in most cases for these chemicals.

Sensitive populations

Workers, children, and people of childbearing age are identified in the statute as sensitive populations. These populations may be disproportionately impacted due to elevated exposure or because they are sensitive to the health hazards of ortho-phthalates or formaldehyde. These groups are exposed to cleaning and household care products that can contain ortho-phthalates and formaldehyde releasers, and we're concerned about higher exposure to workers.

The hazards of formaldehyde are well-established and include carcinogenicity, adverse respiratory effects, and skin and respiratory sensitization (Ecology, 2024c). Ortho-phthalates are associated with health hazards, including endocrine disruption, and reproductive and developmental toxicity (Ecology, 2022b).

Workers

People who use cleaning products at work may be a highly exposed group. An analysis of King County occupations found that cleaning agents are likely to be the most common source of chemical exposure to workers. Biocides (including disinfectants) were the third most common chemical exposure, and formaldehyde was the seventh most common (Peckham & Stephan-Recaido, 2023).

To develop their findings, the King County researchers applied data from a job-exposure matrix that classified exposures to toxic agents for over 30,000 jobs held by 8,912 Canadian workers, based on expert assessment (Siemiatycki & Lavoué, 2018). King County exposures weren't directly measured. The industries identified in King County with exposure to cleaning agents included food service, health care, building services, assisted living, and personal care services (Peckham & Stephan-Recaido, 2023).

The potential for job-related exposure to cleaning products, biocides, and formaldehyde in the King County analysis was disproportionately high for workers who identified as racial and ethnic minorities (Peckham & Stephan-Recaido, 2023). In particular, the proportions of Black and Hispanic workers employed in the occupational classes that have potential exposure to biocides and cleaners were higher than the proportion of White workers. Formaldehyde exposure, analyzed separately from cleaning products, was more likely in workers identified as Black, Indigenous, and people of color (BIPOC) in the study.

A report from the Washington Department of Labor and Industries suggests disproportionate exposure to cleaning agents in Washington may extend beyond King County. The 2022 Janitorial Workload Study described the population of janitorial workers in Washington as "more racially diverse" than the general population, with lower household incomes (WA Labor & Industries, 2022). On a national scale, the US Bureau of Labor Statistics reports that people who identify as Hispanic or Latino ethnicity are over-represented in janitor/building cleaner and maid/housekeeping cleaner occupations nationwide (US BLS, 2024b).

Exposure to cleaning products can contribute to health effects in workers. People who work with cleaning products, including hotel, office, and healthcare workers as well as domestic cleaners, have elevated rates of respiratory symptoms as reported in numerous epidemiology studies (Clausen et al., 2020; Folletti et al., 2014). While the causal agents aren't usually identified in epidemiological studies, both formaldehyde and phthalate exposure have been associated with respiratory effects (Bølling et al., 2020; US EPA, 2024h).

Non-worker populations

People are exposed to chemicals in cleaning products in indoor environments and settings where cleaners are used, whether through the use of the product or as bystanders.

Several studies associate adverse effects on children's respiratory health with household use of cleaning products. Wheeze was associated with the number of cleaning products used in the household by a large cohort of children (Parks et al., 2020). The specific chemicals in the cleaning products that drove the association with health effects weren't characterized and couldn't be directly linked to the health outcomes. However, both formaldehyde and phthalate exposure have been linked to respiratory and other allergic symptoms, it's plausible that these chemical classes contributed to the observed effects of cleaning products in Parks et al. (Bølling et al., 2020; US EPA, 2024h).

Children with asthma may be more sensitive to exposure to cleaning products with ortho-phthalates and formaldehyde. Rates of asthma among children are disproportionate by race, with Black, American Indian, and Alaska Native children experiencing significantly higher asthma burden than White children (CDC, 2023). The impact of respiratory irritation and symptoms due to inhalation of formaldehyde and ortho-phthalates from cleaning products may be disproportionate in these populations with existing health inequities. Children are additionally sensitive to ortho-phthalates exposure because ortho-phthalates have been associated with neurodevelopmental effects (Eales et al., 2022; Engel et al., 2021).

Pregnant people are a sensitive population to exposure to ortho-phthalates in cleaning products due to the adverse effects of ortho-phthalates on the developing fetus, pre-term birth, and risk of gestational diabetes (Eberle & Stichling, 2022; James-Todd et al., 2022; Radke et al., 2019; Welch et al., 2023).

Formaldehyde was present in 50% of air samples collected during routine non-occupational household cleaning (Harley et al., 2021). In this study, 50 Latina women in CA performed their usual cleaning routines in the kitchens and bathrooms of their homes while wearing backpacks equipped with personal samplers (Harley et al., 2021).

Men of childbearing age may be sensitive to ortho-phthalates in cleaning products too, although there is lower confidence in the observed effects of phthalate exposure on sperm quality than in fetal development (Radke et al., 2018).

Sensitive species

Ortho-phthalates

Cleaning and household care products have the potential to expose sensitive species to ortho-phthalates when released to the environment through use and disposal, primarily as components of air and wastewater. Governor Inslee's Southern Resident Orca Task Force named ortho-phthalates as chemicals of emerging concern (Ecology, 2020; Southern Resident Orca Recovery, n.d.). Ortho-phthalates and their metabolites are associated with endocrine disruption in aquatic organisms which may lead to impaired reproduction and development as well as other adverse effects (Zhang et al., 2021).

Formaldehyde and formaldehyde releasers

Cleaning and household care products have the potential to expose sensitive species to formaldehyde and formaldehyde releasers when released to the environment through use and disposal, primarily as components of air and wastewater. However, as stated in our priority chemicals report, environmental concentrations of formaldehyde suggest current exposure levels aren't a concern for sensitive species at this time (Ecology, 2024c).

Availability of potential safer alternatives

Alternative products may be currently available on the market that don't contain phthalate or formaldehyde and formaldehyde releasers. There are over 1,900 Safer Choice-Certified Products listed on the US EPA Safer Choice website, and the majority of these are cleaning and household care products (US EPA, 2024i). Safer Choice-Certified products must pass stringent criteria in the Safer Choice Standard to earn the label, and EPA reviews product ingredient information to make this determination (US EPA, 2024e). We haven't yet reviewed the ingredients of these products to determine whether they would meet our criteria for safer under Safer Products for Washington, but the Safer Choice Certification is a strong indicator the list may contain safer alternative products to those containing ortho-phthalates or formaldehyde and formaldehyde releasers.

Chapter 4: Cosmetics

Overview

Priority product

The scope of this priority product includes cosmetic products as defined by the Federal Food, Drug, and Cosmetic Act (FD&C Act). The FD&C Act defines cosmetics as “articles 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.” [FD&C Act, sec. 201(i)] (US FDA, 2024).

Cosmetics with active ingredients are included in this definition. However, active ingredients themselves aren’t 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 are, a non-exhaustive list, (US FDA, 2024):

- Cleansing shampoos
- Deodorant
- Fingernail polishes
- Hair colors
- Lipsticks
- 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” [35] and “Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1”[36] 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%, but sometimes up to 95% of the product by weight (ECHA, 2019). Cosmetic products release cVMS into indoor and outdoor environments through volatilization into the air during product use. The most common cVMS used in cosmetics are octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), and dodecamethylcyclohexasiloxane (D6).

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[35] https://apps.ecology.wa.gov/publications/SummaryPages/2404025.html
[36] https://apps.ecology.wa.gov/publications/summarypages/2404026.html

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 8). 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 8**:** 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.

A peer-reviewed article 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. 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 predominant 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%), and 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 highlight that taken together, these studies suggest “the US and Canadian markets of C&PCPs are remarkably similar in terms of cVMS levels” and comparable to those purchased 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 (CIR) (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 queried 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 with greater than 10% of the market containing cVMS included make-up 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.

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 9). D6 was reported at a maximum use concentration of up to 50% in products (Table 10) (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's important to note that the median concentrations reported by ECHA represent only products where cVMS are used as ingredients and aren't median concentrations across all cosmetic products generally.

Table 9: 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 10: 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

The volume of the product sold or present in the state

Cosmetic products are used daily by most American consumers, 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 don’t know the precise volume of cosmetic products this represents, together this information suggests a large volume of cosmetic products containing cVMS are sold in Washington.

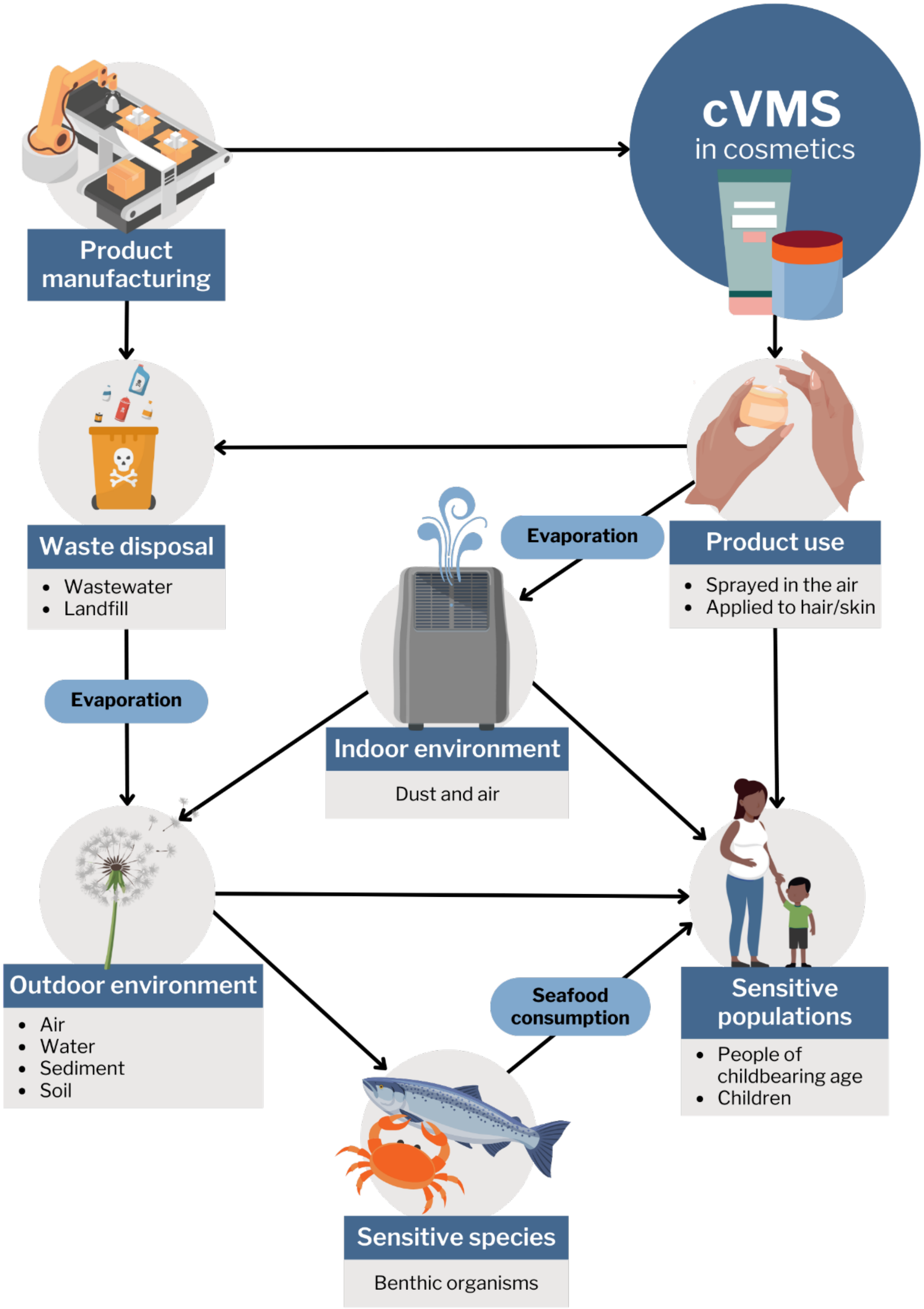

Figure 5: Pathways of potential exposure to cVMS from cosmetics in sensitive populations and sensitive species.

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 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 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/m3 for D6 to 0.13 ug/m3 for D5 (Fromme, 2019).
- A recent study in New York City, NY found median levels of cVMS ranging from 11 ng/m3 for D3 to 230 ng/m3 for D5 in ambient air. In the same study, maximum concentrations detected ranged from 62 ng/m3 to 1400 ng/m3 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 isn't 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 volatilizes 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 don't know the precise amount of cVMS entering the environment from cosmetic products in Washington, we can extrapolate 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, they 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 proportion of estimated releases of cVMS stemming from cosmetic products in Washington would be similar to that of the European Union, even though the volume of total releases will be different. We recognize that these are estimates and that the overall contribution to releases may not precisely reflect those in Washington. However, even considering potential differences between locales, the analysis by ECHA makes clear that cosmetics are a dominant source of cVMS entering the environment concerning 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 have the potential for exposure to cVMS through indoor air as bystanders to the use of cosmetic products by others. cVMS are associated with hazards that include reproductive and developmental toxicity as well as endocrine disruption, and this raises concern for exposure in these 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 is consistent with a survey conducted by the Environmental Working Group (EWG) which found that on average women use 13 personal care products daily while men average only 11 per day (EWG, 2023). Together this suggests women likely have disproportionately 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 hasn't 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. Further, children are more prone to exposure through ingestion of dust contaminated with cVMS from cosmetics due to spending more time on the floor and their more frequent hand-to-mouth behaviors.

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 disproportionately 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 don't occur naturally in the environment but can be released from products into the air during product use or disposal in wastewater. The majority of cVMS in cosmetic formulations volatilize 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 and 1,607 ug/day (mean) for air emissions, with D5 as a predominant 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 for reducing cVMS in water (removal rate greater than 90%), however, removal doesn't occur through degradation of cVMS but rather through transfer to other matrices including sludge and the atmosphere (Capela et al., 2017). Due to the transfer of cVMS into sludge during wastewater treatment, they 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 in or near sedimentary habitats (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

Analysis by ECHA indicates that alternatives to cVMS in cosmetics are “available and economically feasible” (ECHA, 2019). This is based in part on data showing that for most subcategories, D4, D5, and D6 are only present in a minority of current product formulations, suggesting they aren’t 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 doesn’t 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’ll evaluate alternatives and determine whether they meet our criteria as safer, feasible, and available before proposing any regulatory actions.

Chapter 5: 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.[37]

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.

Plastic foam insulations such as polystyrene, polyisocyanurate, and polyurethanes are sometimes 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 due to their flammability. Since plastic foam insulation materials are highly flammable, OFRs are used in these materials to meet building and fire safety codes (Baby et al., 2020; NAMBA, 2020; Parcheta-Szwindowska et

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

al., 2024). While OFRs are used in these plastic foam insulations to meet flammability standards, they 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're not chemically bound to the material and can migrate out of the material. Reactive flame retardants are chemically bound to the material and aren't expected to migrate out of the material unless it degrades.

Additive OFRs have been a popular choice for manufacturers because of their effectiveness and ease of implementation in the manufacturing process. However, their documented hazards to the environment and human health have resulted in restrictions on their use. There's a long history of regrettable substitution with OFRs.

Harmful OFRs such as polybrominated diphenyl ethers have been phased out from use only for other hazardous OFRs, such as hexabromocyclododecane (HBCD) and tris(chloropropyl) phosphate (TCPP), to increase in use and subsequently contaminate indoor and outdoor environments. Demolition of buildings and disposal of insulation materials at end-of-life releases OFRs and their breakdown products to the environment (Babrauskas et al., 2012; Duan et al., 2016).

We're 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 performance of the material. 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 in the market (SpecialChem, n.d.).

Polyisocyanurate is another thermosetting type of plastic available as a liquid-sprayed foam or rigid foam board. It can be used to make laminated insulation panels with a variety of facings to be used in applications such as 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).

Polyurethane is a third thermoset foam insulation material available as a liquid sprayed foam or a rigid foam board. Spray polyurethane foam (SPF) insulation is a two-part product combined and reacted on site. It’s available in either a closed-cell formula in which the high-density cells are closed and filled with a gas to help foam expand and fill the spaces around it, or an open-cell formula which isn’t as dense and is 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% (Healthy Building Network, 2018; Poppendieck et al., 2021). Table 11 provides information on the concentrations of flame retardants found in plastic insulation materials currently available in the market.

Table 11: 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 – 5	(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 – 12 million pounds of spray polyurethane foam was available in Washington in 2019. This estimate doesn’t 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 (WCRER) reported existing single-family housing stock of over 2 million in Washington for the second quarter of 2023 (WCRER, 2024). Looking to the future, the Washington State Department of Commerce estimates that over 1.1 million new homes (apartments, multiplexes, and single-family homes) will be needed to keep pace with housing needs in the state (WA Department of Commerce, 2023). Taken together, 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 building areas when insulation becomes exposed. 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. Figure 6 shows exposure pathways for sensitive populations and species.

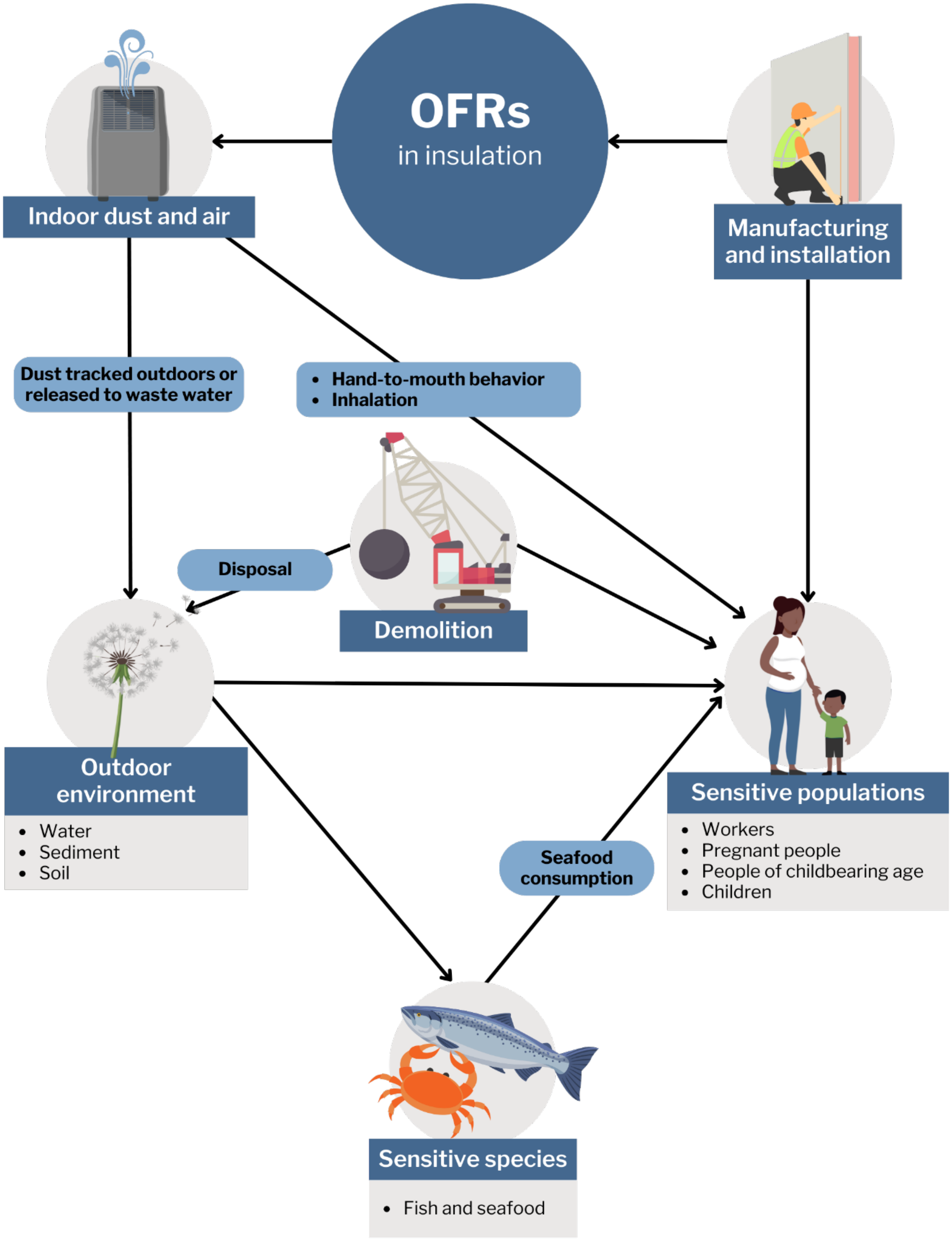

Figure 6: The potential pathways for exposure to OFRs from insulation.

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.

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). 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).

While HBCD has largely been phased out, it has been detected 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, 2022).

TCPP now appears to be a commonly used OFR in insulation. While TCPP has other uses it has been estimated that over 80% of TCPP is used in rigid polyurethane foams, primarily for construction (Banasik, 2015).

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, Perovich, et al., 2012). More recently, a study of 54 low-income homes in Texas detected TCPP in dust from surfaces and HVAC filters and proposed 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).

People can be exposed to OFRs from insulation when they ingest, inhale, or touch dust. OFR concentrations in house dust correlated with concentrations in samples collected from wipes of children's hands (Stapleton et al., 2014). Handwipe concentrations were correlated with flame retardant chemicals in children's urine, 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).

Flame retardants associated with insulation have been found in indoor air and can cause inhalation exposure. TCPP isn't chemically bound to the insulation material and slowly migrates into room air over time (Kemmlein et al., 2003; Liang et al., 2018). 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 migrate within homes and other buildings after release from the insulation.

Dietary intake is an important route of exposure to OFRs for the general population through contaminated foodstuffs (J. Li et al., 2019; Schecter et al., 2010). Releases to the environment from migration out of the product, demolition, and disposal in landfills may result in contamination of food sources. Infants can be exposed to OFRs from breast milk although the contribution of insulation products to levels in breast milk isn't known (Y. Li et al., 2023; Rawn et al., 2024).

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 to flame retardants at higher levels 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. Sprayer air samples averaged over the full workday were 87 ug/m^3 and their helpers 30 ug/m^3.

A separate study of TCPP exposure in spray polyurethane foam workers found 26-35 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 can't be assumed to 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 a wall, or other building area, and rigid products are cut onsite, OFRs may be released. Workers are directly exposed to the flame retardants in insulation products during insulation and total or partial (remodeling, for example) demolition processes (Estill et al., 2020). Inhalation and direct dermal 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).

The EPA recently concluded that HBCD poses an unreasonable risk to the environment from many conditions of use, including commercial use and disposal. Environmental exposures to HBCD were associated with risks to aquatic life (US EPA, 2022). While HBCD has largely been phased out, it demonstrates that OFRs used in insulation have the potential to expose sensitive species and this increases concern over newer OFRs in insulation as well.

An analysis of TCPP in house dust and laundry effluent in Washington State found TCPP in both the dust and laundry detergent at higher concentrations than other flame retardants (Schreder & La Guardia, 2014). OFRs aren't effectively removed by wastewater treatment plants (G. Xu et al., 2021).

OFRs, including TCPP, have been detected in surface water and sediment (Bester, 2005; Ecology, 2020). TCPP has been detected in stormwater surface water, stormwater sediment, lake surface water, lake sediment, Columbia River surface water, and Columbia River sediment (Alvarez et al., 2014; Counihan et al., 2014; Ecology, 2018, 2019). There are no manufacturers of OFRs in Washington to our knowledge. Since most TCPP is used in insulation, the TCPP detected in our environment is likely to be from insulation.

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

Availability of potential safer alternatives

In 2014, the 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:

1. Comply with fire safety codes.
2. Maintain the physical properties of the foam.
3. Be compatible with manufacturing processes and formulas.

However, the EPA didn't 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 identified as one of the alternatives seems to have been widely adopted by the polystyrene insulation industry.

EPA identified some alternative materials that can be used instead of the extruded polystyrene and expanded polystyrene foams for certain functional uses but didn't find alternatives for all uses. Replacing plastic foam insulation with other alternative materials such as fiberglass, mineral wool, cellulose, natural fibers, etc. could reduce the significant use of OFR chemicals. Product selection guidance for choosing different insulation materials based on function and application is available, but the availability, feasibility, and safety of these alternative materials and chemical alternatives will be further evaluated in Phase 3 (Habitable, 2023).

Chapter 6: 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 but aren't limited to:

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

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"[38] and "Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1"[39] 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"[38] and "Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1"[39] in Chapter 3: Technical Support for Lead and Lead Compounds (Ecology, 2024b, 2024c).

Background

Lead is used in jewelry to make articles heavier and brighten colors while cadmium is used to make the coatings on the jewelry shiny (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 the jewelry as part of a metal alloy or solder and as pigments or stabilizers in non-metal components (M. Meijer, 2023).

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[38] https://apps.ecology.wa.gov/publications/SummaryPages/2404025.html

[39] https://apps.ecology.wa.gov/publications/SummaryPages/2404026.html

Metals such as copper and tin are alloyed with around 6% lead to make jewelry that can be surface-treated with rhodium, palladium, gold, and silver (ECHA, 2010).

Volume estimates for priority product-chemical combination

The volume of priority chemicals associated with the product

Lead and cadmium in jewelry aren't easily distinguishable and each item has to be tested individually to determine if it contains lead or cadmium. 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 parts per million (ppm). Some recent reports and studies of lead and cadmium in jewelry are summarized in Table 12 and Table 13 below.

Table 12: Lead levels found in jewelry products, a non-exhaustive list, 2017—present.

Concentration^ (ppm)	**Detection Frequency**	**Study Region**	**Reference**
57000 – 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 – 3450	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)

Table Notes:
^ Some numbers have been rounded to 3 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 13: 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 – 6540	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)

Table notes:
^Some numbers have been rounded to 3 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 the 2017 United States Census Bureau data, the total retail sales in the US for costume and novelty (fashion) jewelry amounted to $10.8 billion while sales in Washington were reported to be around $370 million (US Census Bureau, 2017b). The fine jewelry[40] and watches market was larger with $38 billion in total US sales and $1.5 billion in Washington (US Census Bureau, 2017b).

The fashion jewelry market in the US is estimated to grow at a Compound Annual Growth Rate of 6.9% for the forecast period of 2023-2031 (Straits Research, n.d.). The expansion of e-commerce and social media along with the desire for fashionable pieces, awareness of one's look, and affordability are reported as driving the fashion jewelry market upwards (Straits Research, n.d.). It has been estimated that nearly half of people 18-49 years old, own fashion jewelry and that Americans spend on average $647 on jewelry every year (Statista, 2018, 2019). The sales volume and growth forecast reports support the finding there is a widespread presence of jewelry in Washington State.

Jewelry with high levels of lead or cadmium has been consistently recalled by the US Consumer Product Safety Commission (CPSC) because it poses unreasonable risks of serious injury or

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[40] Fine jewelry category includes the retail sales of all diamond jewelry, pearl jewelry, gemstone jewelry, karat gold jewelry, karat platinum jewelry, and all loose gemstones including diamond and colored gemstones. All watches, watchbands, and parts are included in this category, and all estate, antique jewelry sales, and watch batteries are excluded.

death. Multiple recalls of jewelry items with high levels of lead or cadmium as recent as 2024, suggest their continued presence in the jewelry market (CPSC, 2024b, 2024a).

Because of the variability in price per piece of jewelry and limited testing, it's difficult to estimate the number of pieces of jewelry with lead and cadmium present in the state. However, considering the multimillion-dollar size of the fashion jewelry industry, its predicted market growth, and the pervasive detection of lead and cadmium, suggests that a significant volume of jewelry that contains lead or cadmium is 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 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.
- Some jewelry can be recycled into new pieces which can contribute to continued exposure.

Jewelry made from less precious materials may be disposed of and could eventually contaminate the environment. This is a concern as we're beginning to understand the impacts of textile-based "fast-fashion" on our environment and can expect potential similar impacts of jewelry and accessory trends (Niinimäki et al., 2020).

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

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 lead and cadmium 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 cadmium and lead in jewelry (US EPA, 2011a; Weidenhamer & Clement, 2007).

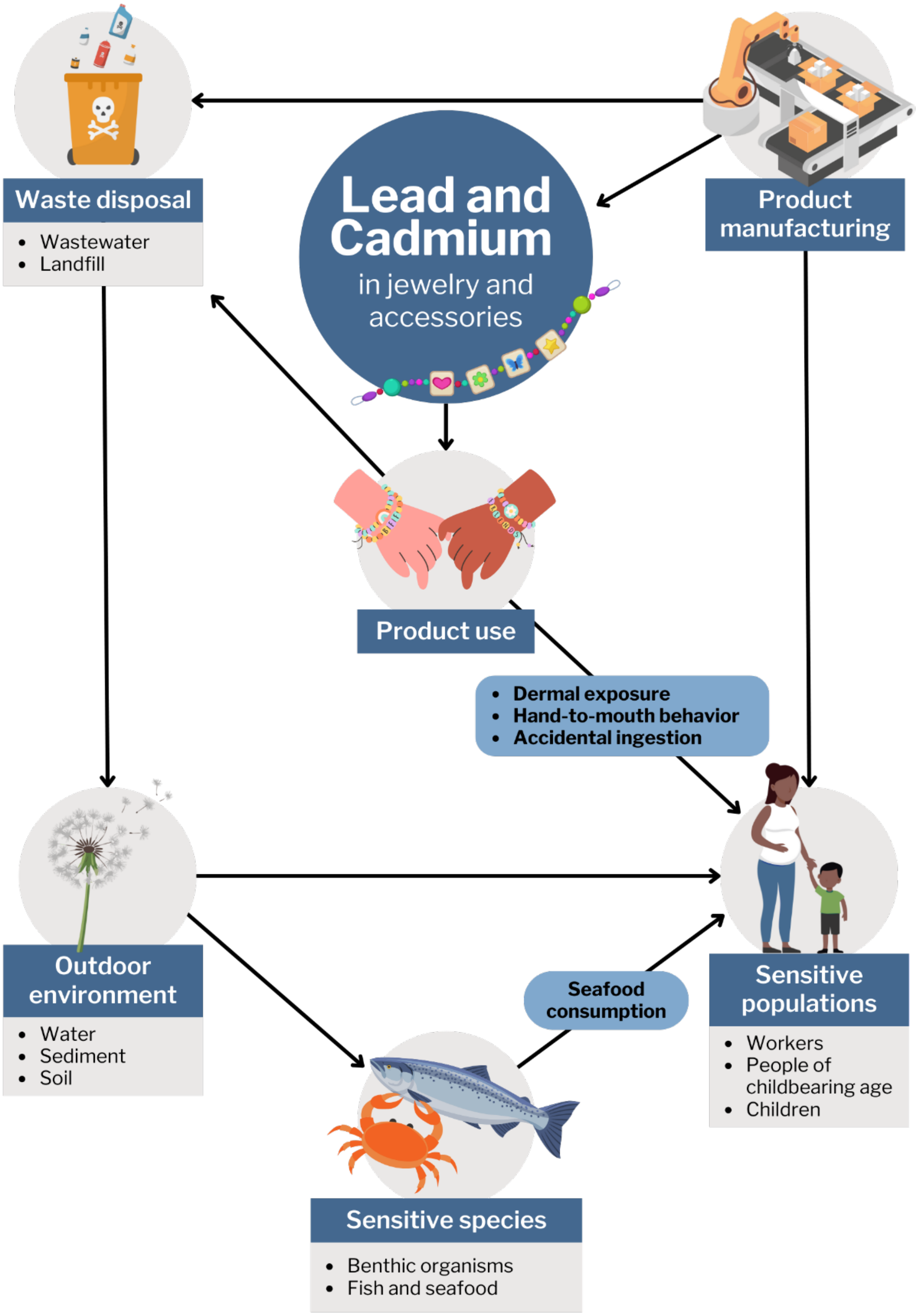

Figure 7: Pathways of potential exposure to lead and cadmium from jewelry and accessories in sensitive populations and sensitive species.

In fact, in a review of children's blood lead levels, approximately 38% of elevated blood lead levels in children were attributed to consumer products. Studies demonstrate that simulated mouthing of jewelry releases cadmium and lead and that cadmium released from jewelry was higher if the jewelry was damaged (Kern et al., 2021; Weidenhamer & Clement, 2007). Children are 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)[41] and other jurisdictions (Appendix C). These regulations reduced lead in children's jewelry (Cox & Green, 2010; Negev et al., 2022). However, children can be exposed to jewelry that isn't specifically marketed or sold to them.

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 also 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's 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. 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 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-led products (Niinimäki et al., 2020; Remy et al., 2016). These products have environmental impacts and contribute to the disposal of products (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 increase the production of jewelry using cheaper materials that may be more likely to contain lead and cadmium as well as the disposal of those 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).

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

Availability of potential safer alternatives

Lead and cadmium aren’t major metals used in making jewelry. 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 didn’t evaluate whether these materials are safer, feasible, and available and 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 isn’t treated in a way that adds lead or cadmium.
- Elastic, fabric, ribbon, rope, or string that doesn’t contain intentionally added lead or cadmium.
- Glass, ceramic, or crystal decorative components, including cat’s eye, cubic zirconia, including cubic zirconium or CZ, 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 7: 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"[42] and "Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1"[43] 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 commonly used BTEX substance in nail products is toluene, however, benzene, ethylbenzene, and xylenes are found in nail products. BTEX substances are volatile liquids used as solvents. At room temperature, BTEX substances volatilize from the liquid state to a gas, 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 concentrations of BTEX species in this broad product category are dependent on the type of nail product and the chemical function within the product.

In a 2020 call-in request for information from the California Department of Toxic Substances Control (DTSC), various manufacturers reported toluene as a residual or contaminant with concentrations up to 0.1% in traditional nail polish products, and as a solvent in topcoats and thinners with concentration ranging from 5% to 25% (DTSC, 2023b). Xylenes were reported as

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[42] https://apps.ecology.wa.gov/publications/SummaryPages/2404025.html
[43] https://apps.ecology.wa.gov/publications/SummaryPages/2404026.html

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 14) (DTSC, 2012, 2023a; NIOSH, 2019; Zhong et al., 2019; Zhou et al., 2016).

Table 14: 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)

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

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 100.89 million women in the United States used nail polish or other nail products in 2020 with a projected increase in 2024 to 102.13 million (Statista, 2024c). 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 15).

Table 15: 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
Base coats	0.2	0.052 – 0.13	3.796 – 9.49	29,647 – 74,117
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 conducted these estimates using estimates from the Cosmetic, Toiletry and Fragrance Association and cosmetic companies of frequency of use 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.

There is a large volume of nail salons in Washington. In 2016, Washington was reported to have 1073 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 products in the product use category of nails that contain toluene, one product that contains xylenes, and one product that contains ethylbenzene, which includes 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 volatilize 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 of particular concern for workers regularly applying nail products, women of childbearing age, and children.

Nail products that contain BTEX substances have the potential to contaminate outdoor air and water during use and disposal. Since BTEX substances are volatile chemicals, they’re 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 to wastewater are predicted to partition primarily to water or soil (Ecology, 2024c).

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

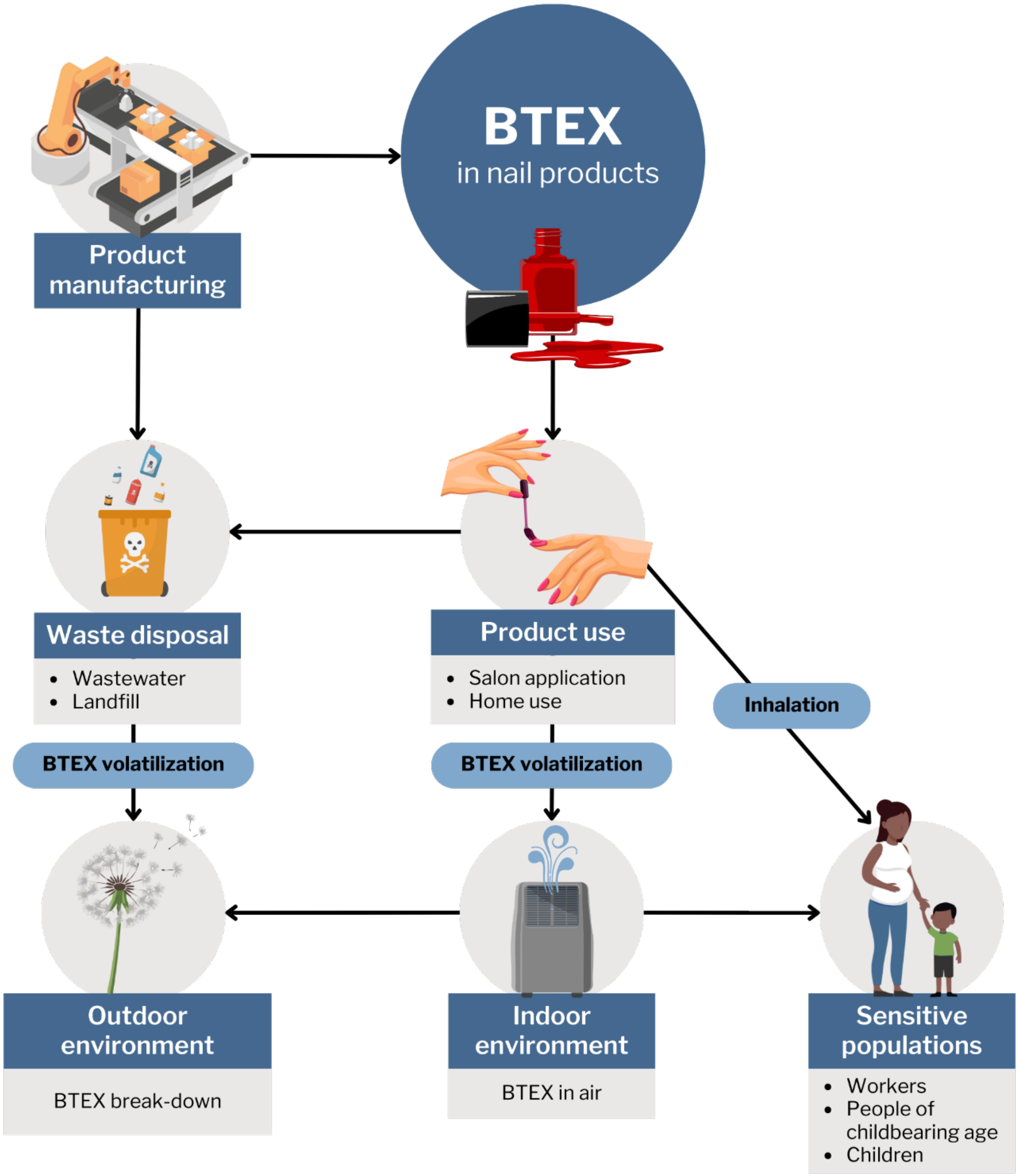

Figure 8: Pathways of potential exposure to BTEX substances from nail products in sensitive populations.

Sensitive populations

Workers

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

Studies of BTEX chemicals in salon air and the personal air of workers demonstrate 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 range widely but in some cases, exposure exceeded health guidance levels for chronic exposure (DTSC, 2020). The variability in air concentrations is important because nail products are used in the personal breathing zone, such that people inhale air that is close to the product (Yeoman et al., 2022). Two studies that compared personal exposure of nail technicians to toluene to concentrations in room air report approximately two-fold higher personal exposure in comparison to measurements of the room air (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 as 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 years, a sensitive population to exposure to BTEX chemicals which 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 nail product chemicals may increase the risk of some health outcomes associated 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 disproportionate by race/ethnicity. Workers in the nail industry are disproportionately 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).

A deeper dive into the nail technician workforce was carried out by the University of California Los Angeles Labor Center. They report a higher number of women and Asian American workers than is represented in the national statistics: 81% women, 79% foreign-born, and predominantly Vietnamese (Sharma et al., 2018). The majority are low-income workers, and many are non-native English speakers (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).[44] Children can be exposed to BTEX in indoor air when they accompany adults to salons for work or as customers, or 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.

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[44] https://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% over 5 years living in respondents' households used self-applied nail polish.

A similar study of Washington use patterns wasn't 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 don't consider potential exposure to BTEX substances from nail products 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 and
- 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 6-7% 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 a few examples of products listed in the report where these solvents have been used.

The ingredients listed above haven't yet been evaluated as safer alternatives and 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 as safer, feasible, and available before proposing any regulatory actions.

Chapter 8: Paints (architectural)

Overview

Priority product

Architectural paints (hereby referred to as “paints”) include architectural coatings intended to be applied to the 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, n.d.).

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.[45]

Background

Why are PFAS used in paints?

PFAS can serve multiple functions in paints. Common functions include reducing surface tension to improve wetting and leveling or flow characteristics of the formulation and to provide an antifouling or anticorrosive property to the cured paint coating (OECD, 2022).

Both short-chain PFAS and polymeric PFAS are in paints. Short-chain PFAS function as surfactants in paints to provide improved wetting and leveling properties (OECD, 2022). This is reported as more common in paints for use indoors and in general household applications.

Paints with polymeric PFAS, or fluoropolymer paints, can be used in applications where anti-corrosion resistance is needed due to harsh conditions of use (salt, moisture, corrosive chemicals). Some short-chain PFAS have been used to improve corrosion resistance (OECD, 2022).

Volume estimates for priority product-chemical combination

The volume of priority chemicals associated with the product

A recent study analyzed samples taken from 27 commercial paints purchased in Oregon between 2021 and 2022 (Cahuas et al., 2022). The samples represented 14 brands manufactured by 14 coating firms and were reported to represent 75% of the United States

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

market share. The authors tested paints for volatile and non-volatile PFAS as well as total fluorine content.

For volatile PFAS, 6:2 FTOH was able to be quantified in 14 of 27 of the paint samples, with reported concentrations ranging from 0.92 – 83 ug/g (0.92 – 83 ppm, 0.033 – 3.0 umol F/g) (Cahuas et al., 2022). In the study, all of the paints for which 6:2 FTOH (6:2 fluorotelomer alcohol) was detected were listed as “low” or “zero volatile organic compounds”.

The authors highlight that this could be misunderstood by consumers since the paints do contain volatile PFAS. In general, volatility refers to how readily a chemical evaporates or exists as a gas. Volatile organic compounds (VOCs) are generally classified as having a boiling point of less than 260 °C, however for some regulations or certifications ‘low’ or ‘zero volatile organic compounds’ may refer only to a specific list of VOCs, or may exempt specific chemicals (US EPA, 2024b, 2024l). 6:2 FTOH is often used as a precursor for the production of other PFAS molecules, and it is unknown whether it is intentionally added to the paints or present as a residual from the manufacture of other PFAS ingredients or a degradation product (Cahuas et al., 2022).

- 6:2 FTOH concentrations were higher in exterior paint samples compared to interior paints.
- For non-volatile PFAS, 6:2 diPAP (6:2 fluorotelomer phosphate diester) was able to be quantified in 14 of 27 paint samples, with reported concentrations ranging from 0.073 – 58 ug/g (0.073 - 58 ppm, 0.0030 – 1.9 umol F/g).

Again, it is unknown whether 6:2 diPAP is added to the paints as an ingredient or associated with manufacturing or degradation of other PFAS ingredients (Cahuas et al., 2022).

The authors measured total fluorine in 14 of the 27 paint samples. In paints that had measurable levels of 6:2 FTOH, total fluorine concentrations ranged from 14 – 48 umol F/g. Based on these results, the authors note 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). This suggests that additional PFAS molecules are present in the paints that have yet to be identified.

In a review article that summarized results from 20 products over four separate studies for 16 PFAS, total measured PFAS concentrations reported in paints ranged from 0.0020 ppm to 75.67 ppm, with a mean reported concentration of 6.25 ppm (Dewapriya et al., 2023). This review didn’t include the data from the Cahuas et al., 2022 previously described.

In addition, a non-peer-reviewed study by Healthy Building Network (HBN) reported similar results for PFAS 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 were reported to include 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 – 688 ppm (Healthy Building Network, 2023).

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 accounts for 2.3% of the United States population, and so together these figures would suggest around 19 million gallons of architectural coatings with a corresponding value of $294 million as Washington's share of the market in 2019 (US Census Bureau, 2024). This estimate is for the total volume of architectural coatings for a single year.

Washington has an architectural paint stewardship program which has a statewide industry-led program to ensure proper management of leftover paint (Ecology, n.d.-c). The program reported that over 13.8 million gallons of new paint eligible for the program sold in 2023, and of that, approximately 929,000 gallons of excess paint, or 6.7% of that sold, were recovered by the program (PaintCare, 2024). It is clear from the American Coatings Association and PaintCare reports 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 or 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. This is in addition to paint required for other structures, such as businesses, and for maintenance and renovation of existing structures.

As described above, paint has been reported to contain PFAS on the order of single to hundreds of parts per million in formulations, and based on the volume estimates above this represents a significant source and use of PFAS in Washington.

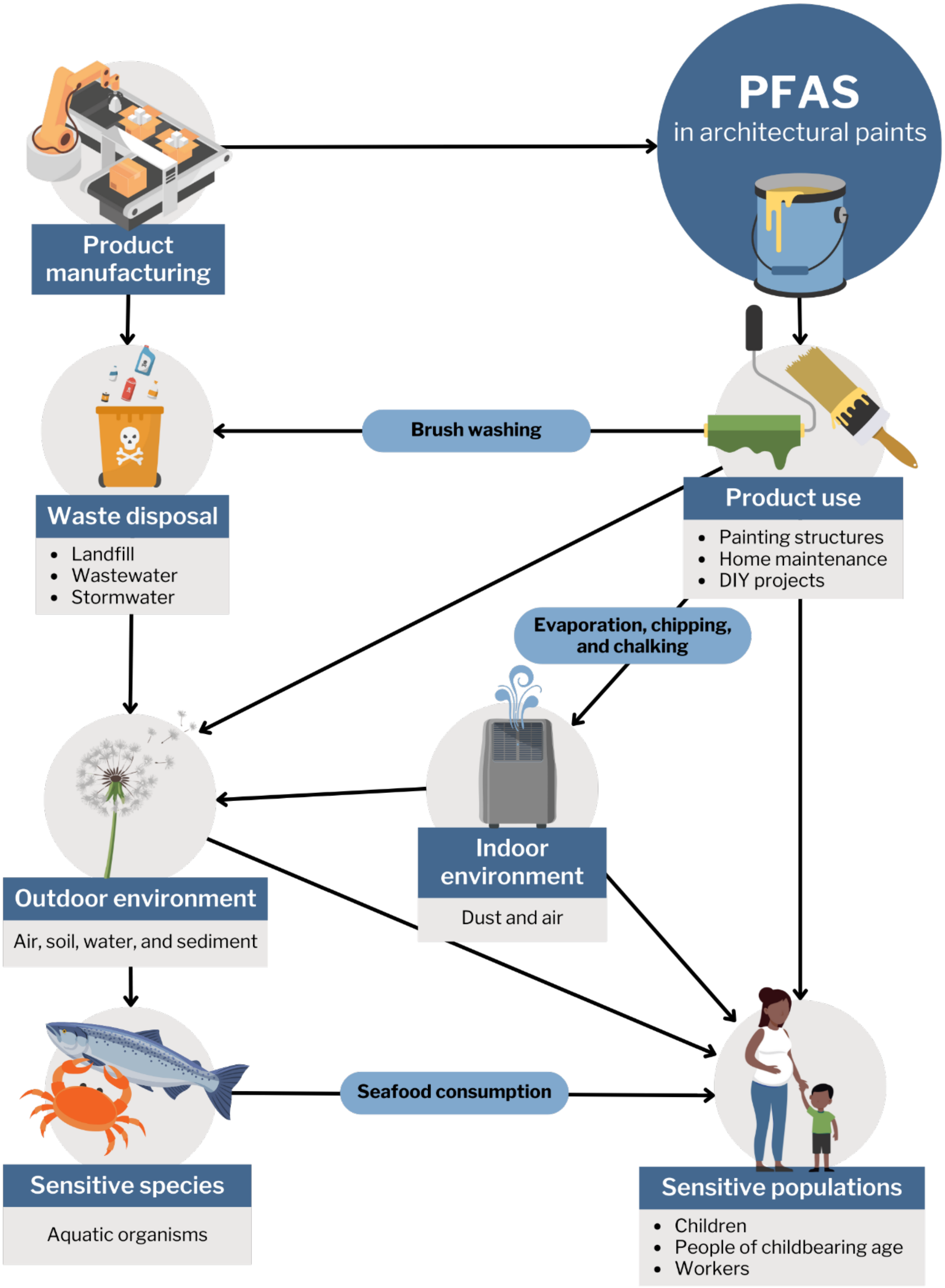

Figure 9: Pathways of potential exposure to PFAS from paints in sensitive populations and sensitive species.

Potential for exposure to the priority chemical from the product

There's potential for exposure to PFAS from paint in people, including sensitive populations (Figure 9). People may be exposed to volatile PFAS in paint through inhalation, or to non-volatile PFAS in paint from inadvertent ingestion of dust as described below:

- In terms of inhalation exposure, a study of a volatile PFAS, 6:2 FTOH, reported that PFAS are released from paint as it dries (Cahuas et al., 2022). The authors calculated the total amount of 6:2 FTOH volatilized from a paint sample over three hours in a closed chamber and estimated the air concentration based on the chamber volume. The authors confirmed that 6:2 FTOH volatilized from the paint as it dries, and this suggests there is a potential for exposure in people.
- The authors estimated the peak air concentration of 6:2 FTOH and exposure to 6:2 FTOH via inhalation for eight paint samples in children, women, and men (Cahuas et al., 2022). One paint sample exceeded the reference dose of 5ug/kg-day for 6:2 FTOH in children, women, and men, and had a peak air concentration predicted of 190 ug/m^3 (Cahuas et al., 2022). Although these are only estimates, the study indicates that there is the potential for inhalation exposure to volatile PFAS from paint.

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 are a type of PFAS that can degrade in the atmosphere or be metabolized into more stable PFAAs (perfluoroalkyl acids). FTOHs (fluorotelomer alcohols) and PFAAs are associated with adverse health effects in people and other organisms (Rice et al., 2020; US EPA, 2023b).

Some PFAS from paint sources are likely ingested or inhaled after they chip and become household dust. We know that PFAS has previously been found in household dust, and that dust inhalation and ingestion are known exposure pathways for PFAS (De Silva et al., 2021).

Building materials, including paints and coatings, have been suggested to be a potential source of PFAS-contaminated household dust (Cahuas et al., 2022; Savvaides et al., 2021).

- Paints, both indoor and outdoor, are exposed to elements that weather and degrade it.
- Indoor architectural paints are susceptible to temperature and humidity changes, age, and UV exposure.

All of these elements can lead to paint peeling and eventually chipping and becoming household dust.

Outdoor architectural paints are susceptible to weathering, UV exposure, and seasonal temperature changes that may cause chipping and chalking (Nored et al., 2022). Chalking occurs when the pigment and binder in paints are degraded and the top layer of paint becomes chalky (Resene, n.d.; Sherwin-Williams, n.d.). The chalk can be washed off during precipitation events and introduced into the environment.

PFAS are widely distributed in the environment and studies have described consumer products as sources of these chemicals released to the environment. We don’t know the specific contribution of paints to the overall release of PFAS to the environment. However, in the studies described, which measured PFAS in paints, the authors noted that the paints tested were water-based and that cleaning of brushes can introduce PFAS to wastewater or septic systems and the environment (Cahuas et al., 2022). Paint improperly disposed of down the drain may contribute to releases of PFAS to the environment. Similarly, PFAS from paint may enter wastewater from washing clothes soiled directly with paint or with house dust that contains paint particles. PFAS present in the environment from paint has the potential to expose sensitive species.

Sensitive populations

People of childbearing age

Several members of the PFAS class are associated with reproductive or developmental toxicity as we described previously in our legislative report, “Regulatory Determinations Report to the Legislature – Safer Products for Washington Cycle 1 Implementation Phase 3” (Ecology, 2022b).[46]

People may be exposed to PFAS when applying paints or over time as paint coatings on surfaces degrade. The American Coatings Association estimated that in 2019 around 36% of architectural coatings, including paints, were applied by non-professional, do-it-yourself (DIY) users (ACA, 2019). Many of the people painting their own homes are of childbearing age or lower income adults according to recent data by CivicScience and The Farnsworth Group (CivicScience, 2023; The Farnsworth Group, n.d.).

Likely, young adults of childbearing age who are not professionals and are painting their own homes to save money may not expend additional funds on obtaining professional PPE or have training on chemical hazards. According to a press release by 3M that describes the result of a 2012 National Safety Council survey on DIY safety, only 39 percent of respondents reported using respiratory protection when working on home improvement projects, indicating around 60% are not using PPE (3M, 2012). This increases the potential for exposure to PFAS from paint in non-professionals, including people of childbearing age and those with lower incomes.

Children

Ingestion of dust is an important exposure pathway for PFAS in infants and children. Children and infants spend more time on the floor than adults and engage in more frequent hand-to-mouth behaviors which increases their exposure through inadvertent ingestion of indoor dust (US EPA, 2024f).

The presence of PFAS in indoor dust is well-established and many sources have been identified, including various consumer products and building materials (De Silva et al., 2021). Less is known about the precise contribution of PFAS in paints to concentrations found in dust. However, due

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[46] https://apps.ecology.wa.gov/publications/summarypages/2204018.html

to the large surface area and volume of paints applied indoors, it is reasonable to assume that the degradation of paint on surfaces contributes to PFAS found in indoor dust and the potential for exposure in children.

Workers

Certain occupations, such as professional painters, who use paint products routinely as part of their work, likely have higher exposures to PFAS from paint. This is supported by the study described above in which emissions of volatile PFAS in the form of 6:2 FTOH were measured from paint following application (Cahuas et al., 2022).

Although the authors did not estimate the relative exposure in workers, they highlighted this finding as an important potential route of exposure in occupations such as professional painters. In addition, the American Coatings Association noted that in 2019, an estimated 64% of architectural coatings, including paints, were applied by professionals (American Coatings Association, 2019). Again, this indicates that workers may have higher exposures as they apply a large volume share of architectural coatings sold.

Occupations working with buildings in hazardous environments, such as firefighters entering burning structures, or crews working with demolition may be at risk of higher exposure. 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 thermally transform into volatile PFAS such as FTOHs, including from PFAS in paints (Cahuas et al., 2022; Hakeem et al., 2024). This could lead to higher exposures in firefighters entering burning structures.

Construction and demolition debris contains PFAS, and this implies there is a potential for worker and bystander exposure to PFAS in dust from demolition activities (Y. Liu et al., 2024). This has been observed for other chemicals found in paint such as lead (Farfel et al., 2005).

Sensitive species

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

PFAS are found in construction and demolition debris which is often disposed of in landfills (Y. Liu et al., 2024). PFAS has been widely detected in municipal landfill leachate across Washington (Capozzi et al., 2023). This included 6:2 FTOHs and their degradation products, which have been detected in paint samples as described above (Cahuas et al., 2022). The contribution of paint wasn’t directly estimated in the study, but it highlights the need for reducing sources of PFAS in landfills, which include paints.

PFAS in landfills and landfill leachate are one of the main point sources of PFAS releases to the environment (Malovanyy et al., 2023). Treatment and removal of PFAS from landfill leachate is difficult and costly, and again this highlights the need for source reduction (Malovanyy et al., 2023; Tolaymat et al., 2023).

PFAS released to the environment from paints in water or solid waste is a concern for sensitive species and ecosystems, including aquatic and terrestrial organisms (Cousins et al., 2022; ITRC, 2023a). Considering the millions of gallons of paint sold each year in Washington and the presence of paint in construction and demolition debris, this represents a significant source of potential exposure to PFAS in sensitive species.

Availability of potential safer alternatives

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 species 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 for improved stain resistance, wetting performance via surface tension reduction, and mitigate surface contamination effects during paint application (3M, 2016).

Fluoropolymers are commonly used as resins and these chemicals allow for decreased temperatures of the applied substrates via UV protection, particularly for outdoor application (OECD, 2022).

Alternative chemistries such as silicone-based polymers such as siloxanes or silicone-based surfactants have been used to perform similar functions and subsequently provide similar physicochemical properties to that of PFAS in existing paint products (OECD, 2022).

Ingredients aren’t often disclosed for paint formulations or components used in paint products. GreenSeal is a leading industry standard certification that is in the process of revising its current standards set for paints and coatings to include a prohibition on PFAS (Green Seal, n.d.).

The current standard doesn’t set limits or require disclosure of PFAS in certified products. However, when the standard is updated, it may help with the identification of paints that don’t contain PFAS and may be potential safer alternatives. Alternative chemistries with similar performance characteristics conferred by PFAS paint products have been explored in trials conducted by Arkema and published by the American Coating Association (Arkema Inc., 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 proposing any regulatory actions.

Chapter 9: 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):[47]

“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):[47]

“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 doesn’t 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).

Priority chemical

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[48] and Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1[49] in Chapter 4: Technical Support for Organobromine or Organochlorine Substances (Ecology, 2024c, 2024b).

Background

Why are organochlorine substances used in plastic packaging?

Plastic packaging is a significant source and use of organochlorine substances. The focus of this category is the polymers used in packaging materials. The most common organochlorine polymers used in packaging are polyvinylchloride (PVC) and polyvinylidene chloride (PVDC).

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[47] https://app.leg.wa.gov/rcw/default.aspx?cite=70A.222.010

[48] https://apps.ecology.wa.gov/publications/summarypages/2404025.html

[49] https://apps.ecology.wa.gov/publications/SummaryPages/2404026.html

PVC and PVDC are organochlorine substances. Some plastic containers and packaging are made entirely out of organochlorine polymers such as PVC, while others may use plastic polymer coatings made from organochlorine substances such as 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 doesn't affect the taste of packaged foods.
- PVDC can provide similar properties but rather than being used alone as a bulk material it's 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.).

We didn't find examples of organobromine substances used as packaging polymers. This is likely because polyvinyl bromide, the related organobromine polymer to PVC, isn't stable at room temperature (National Toxicology Program, 2021).

Additional, non-polymeric, organobromine, or organochlorine substances may be present in plastic packaging, such as chlorinated paraffins or organohalogen flame retardants, but those aren't the focus of this chapter (Pivnenko et al., 2017).

Examples of organochlorine substances 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 (also 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 10).

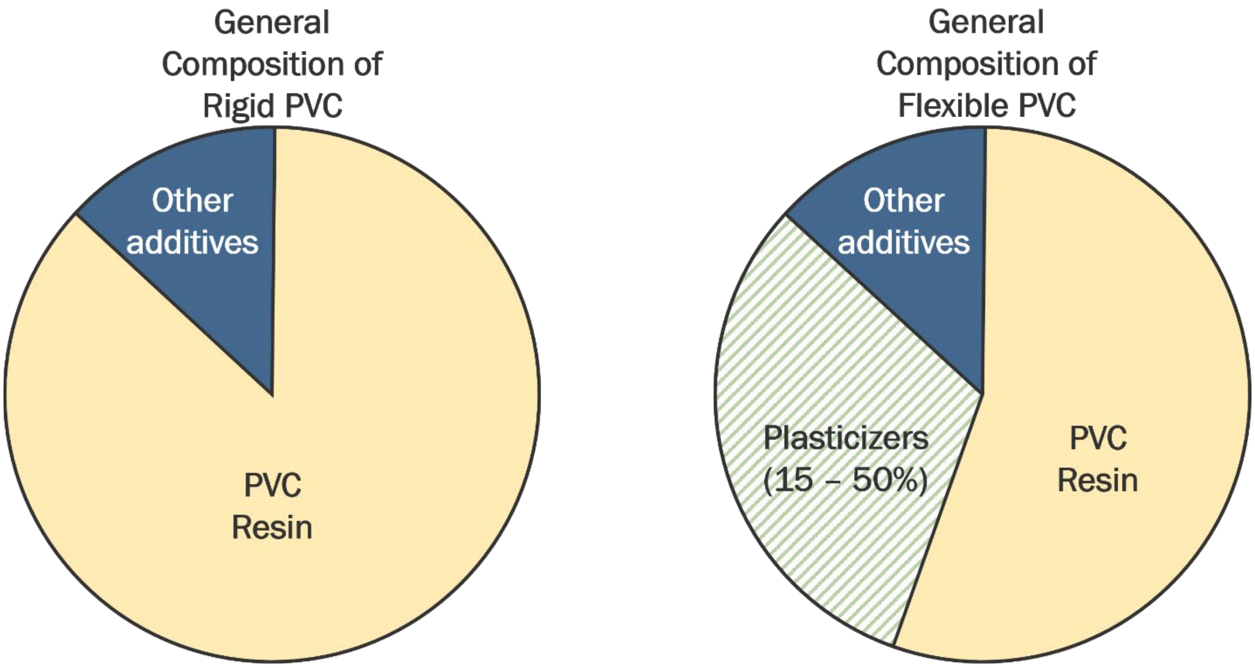

Figure 10: Composition of PVC resin used in rigid and flexible packaging products, which may change according to end-use products. Pie slices are approximations of a general composition and don’t represent precise percentages or a specific product.

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 about 40, 60, 90, and 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 organochlorine substances (PVC, 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 aren’t 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 aren’t recyclable at scale, after consumer use, in the United States, including in Washington.

In addition, PVC used in packaging contributes to a larger percentage of the PVC waste generated 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 aren’t 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 16: 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%

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

In a 2023 report published by Eunomia[50], 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 16).

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 overall flexible plastics in Washington is very low because only 1% of households in Washington have access to flexible film recycling through curbside collection. 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 doesn't 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 isn't recycled at all after consumer use (Table 16).

While end-of-life analysis provided us with information on the amount of the priority product disposed of and its recyclability, it doesn't provide a complete picture of the amount produced

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[50] WA 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.

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, 2024b). 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 16). This aligns with our understanding that PVC and PVDC packaging aren't the most prevalent types of packaging materials used, but still contribute to a significant amount of packaging use and waste generated in Washington.

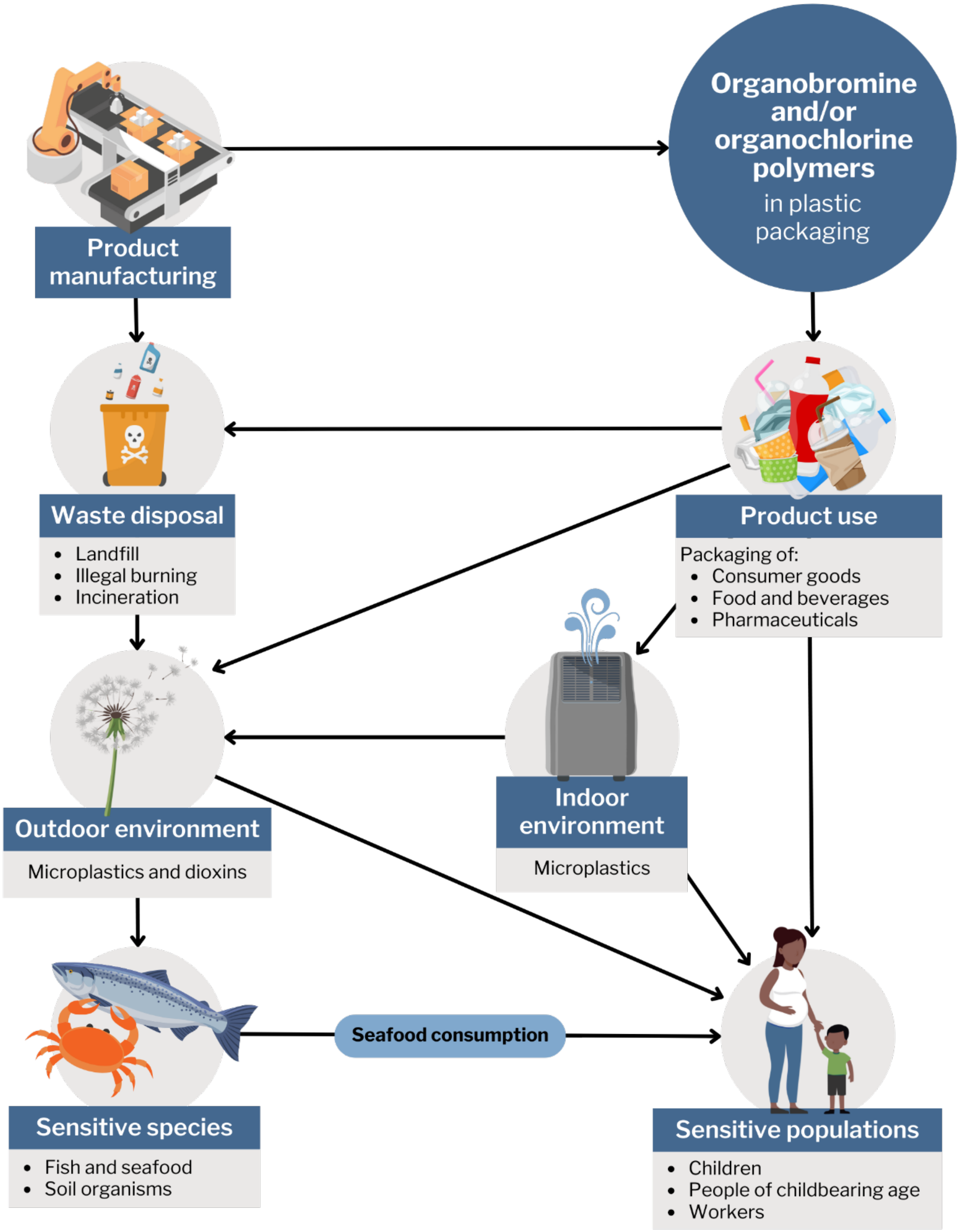

Figure 11: Pathways of potential exposure to organobromine or organochlorine substances from plastic packaging in sensitive populations and sensitive species.

Potential for exposure to priority chemicals from the product

People and wildlife have the potential to be exposed to organochlorine substances throughout the lifecycle of plastic packaging polymers made from these substances (Figure 11). As described above, plastic packaging made from polymers that are organochlorine substances, such as PVC and PVDC, are used for a variety of applications including consumer products and food packaging.

People routinely come into contact with plastic packaging made using PVC or PVDC and have the potential to be exposed to microplastics generated from the materials, or any manufacturing residuals present in the materials. Plastic packaging materials made from PVC or PVDC can break down to form microplastics (defined as particles smaller than 5 mm in their longest dimension) throughout their lifecycle and contaminate indoor and outdoor environments (ITRC, 2023c). This includes during use and when these materials are disposed of at the end of life.

Due to the lack of recycling capability for plastic packaging that contains chlorine in its structure (PVC, PVDC), it can be assumed that the vast majority becomes solid waste in Washington at the end of life, while a smaller fraction is incinerated or burned (Figure 11).

According to a study contracted by Ecology, essentially none of PVC or PVDC packaging waste in Washington is recycled after consumer use (Eunomia, 2023). Further, although packaging is estimated to represent only a small percentage of the total use volume of PVC plastics, it is a much larger contributor to the amount of PVC waste generated.

As mentioned earlier, in Europe packaging is estimated to account for around 7% of PVC use but contributes 20% of PVC waste generated after consumer use (ECHA, 2023a, 2023b). This is because plastic packaging has a short useful lifetime, with most PVC packaging entering the waste stream within one year from when it is produced (ECHA, 2023b). As such, packaging made from PVC or PVDC is likely to contribute to environmental contamination during manufacture and use and at the end of life.

Sensitive populations

Packaging materials such as PVC and PVDC have the potential to expose sensitive populations to organochlorine substances. People, including sensitive populations, have the potential to be exposed to microplastic particles from plastic packaging made from organochlorine substances, such as PVC.

The potential for exposure to PVC and PVDC microplastics generated from packaging is an important consideration. Microplastics can be generated from plastic packaging during normal use when it is opened by cutting, tearing, or twisting (Sobhani et al., 2020). 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).

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 studies indicating that microplastics are potentially hazardous to human health (Blackburn & Green, 2022). It hasn't been established that the health hazards of microplastics made of organochlorine polymers, such as PVC, are greater than those from other types of polymers (ITRC, 2023b). Sensitive populations with the potential for exposure to microplastics made from organochlorine substances include children, people of childbearing age, and workers.

In addition to exposure to polymeric materials, there is the potential for exposure to chemicals present in packaging from manufacturing. PVC is manufactured using hazardous organochlorine substances and past occupational exposures in workers have been documented (ATSDR, 2024).

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 as well, 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 (ECVM) 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 aren't the focus of this chapter, it's 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 couldn't be excluded (ECHA, 2023b).

Plastic packaging materials that are organochlorine substances, such as PVC and PVDC, may expose people and sensitive populations to hazardous substances when disposed of at the end of life. Due to the negligible recycling rate of PVC and PVDC packaging in Washington, it is expected that the majority of these materials will be landfilled, incinerated, or burned at end of life (Eunomia, 2023).

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 exposure to these particles (Kabir et al., 2023; Wojnowska-Baryła et al., 2022).

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). This is more of a concern when plastics are burned illegally as waste or accidentally in landfill fires; the uncontrolled nature of those fires can increase the amount of dioxins and other harmful transformation products formed relative to industrial incineration.

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

Sensitive species

Terrestrial and aquatic organisms have the potential to be exposed to plastic packaging made from polymers which are organochlorine substances (Figure 11). 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).

PVC as a material undergoes photodegradation which can produce microplastic particles (Ziani et al., 2023). Microplastic particles are widely distributed in the environment including in air, water, sediments, and soil. They aren’t 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 terrestrial 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 has been suggested that due to the chemical characteristics of PVC resulting from additives or weathering processes, its presence might be underestimated in the environment (Fernández-González et al., 2022).

Taken together, it’s clear that plastic packaging made from PVC and PVDC has the potential to contribute to environmental contamination, including pollution from the bulk materials themselves, the breakdown, and transformation of 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 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 terrestrial systems, 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. Plastic resins that use less additives and are more recyclable are already available and currently used in many 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.

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 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 proposing any regulatory actions.

Chapter 10: 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 doesn’t include hard surface sealants used to seal porous surfaces. It doesn’t 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”[51] in Chapter 6: Ortho-phthalates (Ecology, 2022b):

“RCW 70A.350.010[52] 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 doesn’t 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.).

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[51] https://apps.ecology.wa.gov/publications/summarypages/2204018.html

[52] https://apps.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 aren't 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're 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 phthalate concentration ranges is displayed in Table 17, below. This information was identified from the CPID 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 weren't identified and instead listed as a proprietary phthalate esters mixture.

Table 17**:** 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)
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)

Product Type (based on manufacturer description)	Formulation Type (based on manufacturer description or ingredients)	Chemical(s)	Reported Concentration (range or max %)	Reference
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)
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 18) (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 18: 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
Di(2-ethylhexyl) phthalate (CAS: 117-81-7)	Caulk/sealant	8
Di(2-ethylhexyl) phthalate (CAS: 117-81-7)	Adhesives and adhesive removers	5

Chemical	Product use category	Number of products
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, 2024g).

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, ACS reported around 17% was for building and construction uses and 6.5% were for consumer DIY/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/retail uses, this suggests a reasonably low estimate for Washington’s share of around 45 million pounds.

For sealants, ACS reported that 57.5% was for building and construction uses and 11.8% were for consumer DIY/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/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/retail. This demonstrates a significant volume of these products present in Washington.

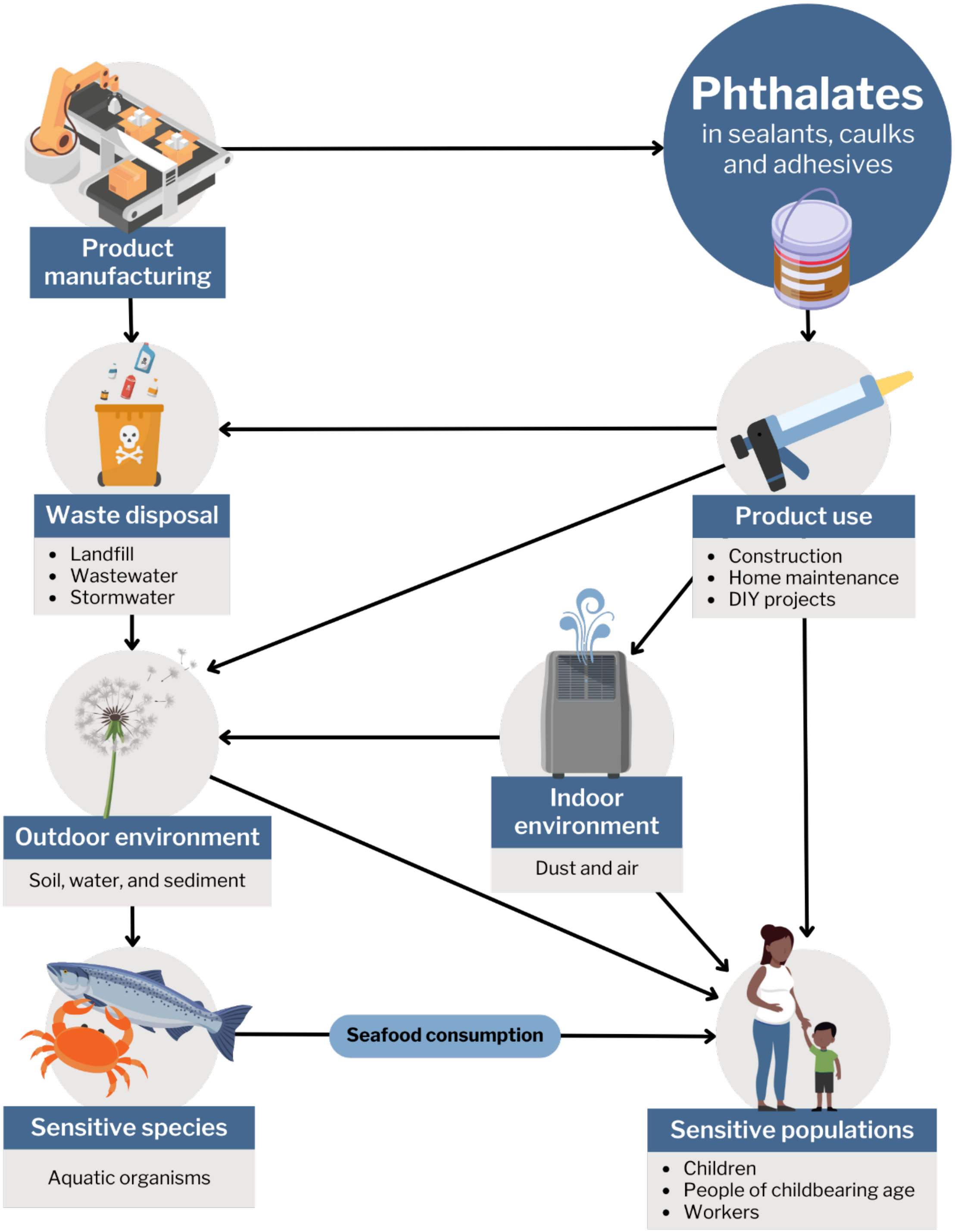

Figure 12: Pathways of potential exposure in sensitive populations and sensitive species resulting from the use of ortho-phthalates in sealant, caulk, and adhesive products.

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 12). Ortho-phthalates used in sealants, caulks and adhesives can contaminate indoor and outdoor environments during product application and over time.

Ortho-phthalates are semi-volatile organic compounds that are released slowly from products. They don't 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, 2024c).

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 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 didn't 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 17) 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). 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 17). Other ortho-phthalates used as plasticizers in these products don't absorb through the skin to the same extent as DBP (US EPA, 2024c).

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 absorb dust and contaminate soils (US EPA, 2024c).

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 aren't 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 weren’t 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 12).

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 17).

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 17).

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; 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). Governor Inslee's 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 don't 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 when making regulatory determinations for these products in the next phase of Safer Products for Washington (Phase 3).

Chapter 11: Toilet and Bathroom Deodorizers

Overview

Priority product

The scope of this priority product includes toilet and bathroom deodorizer products sold as solids that contain organobromine or organochlorine substances.

Products included in this definition (this is a non-exhaustive list) are:

- Toilet, garbage, and urinal deodorizer blocks.
- Other continuous-action air fresheners intended for bathroom use.

This product category doesn't include toilet and bathroom 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 sublime, volatilize, or vaporize into air.

Priority chemical(s)

Organobromine or 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"[53] and "Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1"[54] in Chapter 4: Technical Support for organobromine or organochlorine substances (Ecology, 2024c, 2024b).

Background

Toilet and bathroom deodorizer products are often sold as solids intended to sublime or volatilize into air to mitigate odors. 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 bathroom fixtures elsewhere in the room.

The primary organochlorine substance used in these products is 1,4-dichlorobenzene (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. Sublimation means the chemical goes directly from a solid to a gaseous state without becoming liquid as an intermediate phase.

Volume estimates for priority product-chemical combination

The volume of priority chemicals associated with the product

Toilet and bathroom 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.,

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[53] https://apps.ecology.wa.gov/publications/summarypages/2404025.html

[54] https://apps.ecology.wa.gov/publications/summarypages/2404026.html

2013). 1,4-DCB listed on many manufacturer safety data sheets as comprising up to 99.9 percent of the product formulation (Table 19). We identified this information using several resources including a use report for 1,4-DCB published by the US EPA in 2020, the CPID, and supplemental searches on manufacturer or distributor websites (CPID, n.d.; US EPA, 2020b).

Table 19: Examples of concentrations of 1,4-DCB found in toilet and bathroom deodorizers.

Concentration of 1,4-DCB in product (%)	Reference(s)
99.65	(Big D Industries Inc, 2023; US EPA, 2020b)
99	(Fresh Products LLC, 2023; US EPA, 2020b)
99	(Essendant Co., 2016; US EPA, 2020b)
99	(Essendant Co., 2015; US EPA, 2020b)
90 - 100	(Jasol, 2021; US EPA, 2020b)
Not disclosed	(The Home Depot, 2019; US EPA, 2020b)*
99.9	(Triple S, 2015; US EPA, 2020b)
99	(Nassco Inc., 2023)
99	(Uline Inc, 2019)
95+	(Willert Home Products, 2006)

Table note:
* 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 CDR 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, 2020b). However, even with this uncertainty, it's clear that a large volume of 1,4-DCB is used in toilet and bathroom deodorizers in Washington, and this represents a significant source or use of organobromine or organochlorine substances.

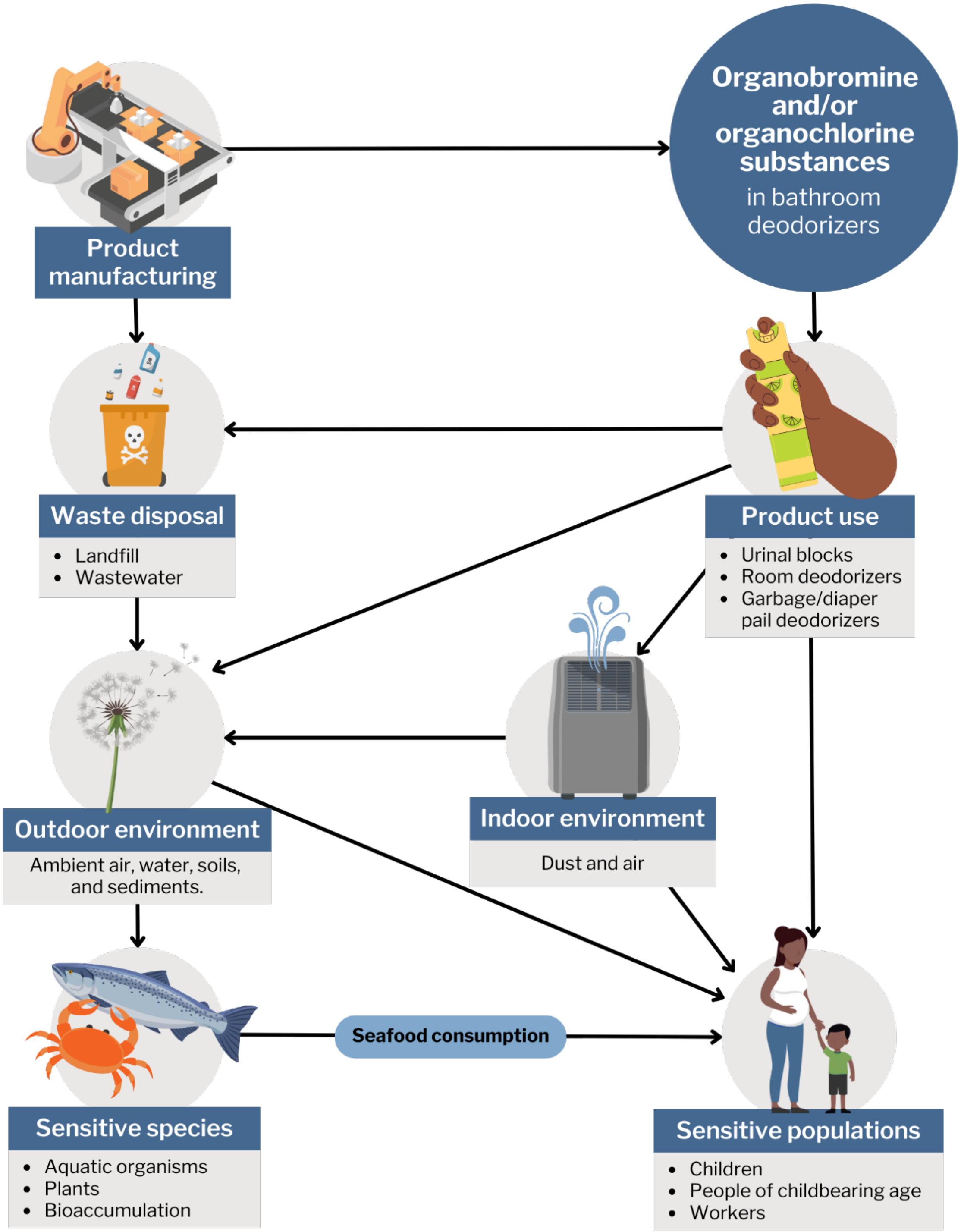

Figure 13. Pathways of potential exposure to organobromine or organochlorine substances from toilet and bathroom deodorizers in sensitive populations and sensitive species.

Potential for exposure to priority chemicals from the product

Organochlorine substances in toilet and bathroom deodorizing products are sold to consumers and commercial users as solids. People can be exposed by inhalation and through their skin when they handle solid products (Figure 13).

As described above, the primary organochlorine substance used in these products is 1,4-DCB. 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.

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 toilet deodorizers may occur when handling the solid product. In addition, there is some evidence that 1,4-DCB released from solid products can sorb from mist and vapor into clothing articles and become available for potential dermal exposure from the clothing (Guerrero, 2013). Guerrero studied clothing articles, but not other textiles commonly found in homes such as bedding, carpet, and upholstery.

While we didn't 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 and increase the likelihood of dermal exposure to residents of homes with 1,4-DCB deodorizing products.

Accidental ingestion

In rare cases, toilet deodorizers can be accidentally ingested, most likely by very young children (ATSDR, 2006). We didn't identify cases of direct ingestion poisoning in Washington during the preparation of this report.

Environmental contamination

Toilet and bathroom 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 toilet 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 don't appear to have changed, it seems reasonable that estimates of the contribution of toilet and bathroom deodorizer to releases would remain similar even as the volume of releases has most likely changed over time (PubChem, n.d.-a). 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, toilet and bathroom 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 then quickly is discharged down the drain into municipal wastewater systems or septic tanks during normal toilet flushing. 1,4-DCB isn't 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).

Although 1,4-DCB is only slightly soluble in water (80.0 mg/L at 25 °C), this contributes to environmental release although 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.-a). 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 toilet deodorizing products. Studies showing disproportionate exposure to 1,4-DCB by 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 toilet 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 the lifetime (Barton et al., 2005).

Workers may be a sensitive population of concern for 1,4-DCB exposure. Toilet 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, 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 disproportionate by race and ethnicity. In biomonitoring data of adult women from the NHANES, participants who identified as Mexican, Hispanic, or Black had disproportionately 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 weren't directly linked to the use of toilet 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).

Disproportionate exposure suggests disproportionate 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 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 toilet deodorizers. Whether children who have decreased lung function are more sensitive hasn't 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 or organobromine 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 toilet and bathroom 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.

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 toilet bathroom 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 toilet and bathroom 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 proposing any regulatory actions.

Appendix A. Acronyms

Table A-1: 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
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
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

Term	Definition
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
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
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
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

Term	Definition
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
non-PE	non-polyethylene
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
OPA	oriented polyamide
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
PFTeDA	perfluorotetradecanoic acid
PP	polypropylene
PPA	polymer processing aid
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
ppq	parts per quadrillion
PTFE	Polytetrafluoroethylene
PVC	polyvinylchloride
PVDF	polyvinylidene fluoride
RCW	revised code of Washington
RfC	reference concentration
SBCC	Washington State Building Code Council
SD	standard deviation

Term	Definition
SIPs	structural insulating panels
SPF	spray polyurethane foam
SS	Safer States
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. References

3M. (n.d.). 3M Polymer Processing Additives. Retrieved August 12, 2024, from https://www.3m.com/3M/en_US/p/c/advanced-materials/polymer-processing-additives/

3M. (2012). 3MTM TEKK ProtectionTM Brand and National Safety Council Unveil New DIY Safety Survey with Start of National Safety Month. https://news.3m.com/2012-06-05-3M-TM-TEKK-Protection-TM-Brand-and-National-Safety-Council-Unveil-New-DIY-Safety-Survey-with-Start-of-National-Safety-Month

3M. (2016). 3MTM Fluorosurfactants For Paints and Coatings. https://multimedia.3m.com/mws/media/624307O/3m-fluorosurfactants-for-paints-and-coating.pdf

3M Company. (2022). 3M Sealant 740 UV, White, Gray and Black. https://multimedia.3m.com/mws/mediawebserver?mwsId=SSSSSuUn_zu8l00xMYt1o8m94v70k17zHvu9lxtD7SSSSSS--

3M Company. (2024). 3M Hybrid Adhesive Sealant 760, White, Gray and Black. https://multimedia.3m.com/mws/mediawebserver?mwsId=SSSSSuUn_zu8l00xMYt1oYtvov70k17zHvu9lxtD7SSSSSS--

ACC. (n.d.). Polyurethane and Polyisocyanurate Foams. Retrieved September 30, 2024, from https://www.americanchemistry.com/content/download/4859/file/Polyurethane-and-Polyisocyanurate-Foams-Insulation-that-Works.pdf

ACC. (2019). Spray Polyurethane Foam Shipments. https://www.americanchemistry.com/content/download/5185/file/ACC-Spray-Foam-Q4-2019.pdf

ACC. (2021). The Contributions of Insulation to the U.S. Economy in 2020. https://www.americanchemistry.com/content/download/9396/file/contributions-of-insulation-to-US-2020.pdf

ACC. (2023). The Contributions of Insulation to the U.S. Economy in 2022. https://www.americanchemistry.com/content/download/14686/file/Contributions-of-Insulation-to-the-US-Economy-in-2022.pdf

Adgate, J. L., Church, T. R., Ryan, A. D., Ramachandran, G., Fredrickson, A. L., Stock, T. H., Morandi, M. T., & Sexton, K. (2004). Outdoor, Indoor, and Personal Exposure to VOCs in Children. Environmental Health Perspectives, 112(14), 1386–1392. https://doi.org/10.1289/ehp.7107 adhesives+coatings. (n.d.-a). Super glue & other adhesives for home repairs. Retrieved September 8, 2024, from https://www.adhesivesandcoatings.com/adhesives/about-adhesives/super-glue-and-other-adhesives-small-home-repairs/

adhesives+coatings. (n.d.-b). Types of sealants for home. Retrieved July 22, 2024, from https://www.adhesivesandcoatings.com/adhesives/about-adhesives/types-of-sealants-for-home/

Adie, G. U., Oyebade, E. O., & Atanda, B. M. (2020). Preliminary Study of Heavy Metals in Low-Cost Jewelry Items Available in Nigerian Markets. Journal of Health and Pollution, 10(28). https://doi.org/10.5696/2156-9614-10.28.201202

Al osman, M., Yang, F., & Massey, I. Y. (2019). Exposure routes and health effects of heavy metals on children. BioMetals, 32(4), 563–573. https://doi.org/10.1007/s10534-019-00193-5

Alain Malnou. (2014). US8883126B2 - Water-based nail-polish composition. https://patents.google.com/patent/US8883126B2/en

Alaves, V. M., Sleeth, D. K., Thiese, M. S., & Larson, R. R. (2013). Characterization of indoor air contaminants in a randomly selected set of commercial nail salons in Salt Lake County, Utah, USA. International Journal of Environmental Health Research, 23(5), 419–433. https://doi.org/10.1080/09603123.2012.755152

Alvarez, D., Perkins, S., Nilsen, E., & Morace, J. (2014). Spatial and temporal trends in occurrence of emerging and legacy contaminants in the Lower Columbia River 2008–2010. Science of The Total Environment, 484, 322–330. https://doi.org/10.1016/j.scitotenv.2013.07.128

American Coatings Association. (n.d.). Types of Coatings - American Coatings Association. Retrieved October 7, 2024, from https://www.paint.org/about/industry/types-of-coatings/

American Coatings Association. (2019). Entering The Second Decade of the 21st Century: The State of the U.S. Paint and Coatings Industry. https://www.paint.org/coatingstech-magazine/articles/entering-second-decade-21st-century-the-state-u-s-paint-and-coatings-industry/

Arkema Inc. (2024). Improved Performance in a Waterborne All-Acrylic Latex Produced without PFAS. https://www.paint.org/wp-content/uploads/2024/03/waterborne-woPFAS_MarApr2024.pdf

Armada, D., Martinez-Fernandez, A., Celeiro, M., Dagnac, T., & Llompart, M. (2023). Assessment of the bioaccessibility of PAHs and other hazardous compounds present in recycled tire rubber employed in synthetic football fields. Science of The Total Environment, 857, 159485. https://doi.org/10.1016/j.scitotenv.2022.159485

ARXX BRASIL S.A. (2022). Bloco ARXX Prime (AP190), Bloco ARXX Prime (AP100), Bloco ARXX Veda (AV40). https://hpdrepository.hpd-collaborative.org/repository/HPDs/1161_Bloco_ARXX_Prime_AP190_Bloco_ARXX_Prime_AP100_Bloco_ARXX_Veda_AV40_.pdf

ASC. (2023). Adhesives and Sealants. https://assets-002.noviams.com/novi-file-uploads/asc/PDFs/Adhesives___Sealants_Impact___Overview_Infographic.pdf

Aspen Institute. (2019). State of Play Seattle-King County. https://www.aspeninstitute.org/wp-content/uploads/2019/08/2019-SOP-Seattle-KingCounty-Web-FINAL.pdf

AstroTurf. (n.d.). PFAS-free Synthetic Turf. Retrieved August 12, 2024, from https://astroturf.com/pfas-free-synthetic-turf/

ATSDR. (2006). TOXICOLOGICAL PROFILE FOR DICHLOROBENZENES. https://www.atsdr.cdc.gov/toxprofiles/tp10.pdf

ATSDR. (2024). Toxicological Profile for Vinyl Chloride. https://www.atsdr.cdc.gov/toxprofiles/tp20.pdf

Babrauskas, V., Lucas, D., Eisenberg, D., Singla, V., Dedeo, M., & Blum, A. (2012). Flame retardants in building insulation: a case for re-evaluating building codes. Building Research & Information, 40(6), 738–755. https://doi.org/10.1080/09613218.2012.744533

Baby, A., Tretsiakova-McNally, S., Arun, M., Joseph, P., & Zhang, J. (2020). Reactive and Additive Modifications of Styrenic Polymers with Phosphorus-Containing Compounds and Their Effects on Fire Retardance. Molecules, 25(17), 3779. https://doi.org/10.3390/molecules25173779

Baca, D., Monroy, R., Castillo, M., Elkhazraji, A., Farooq, A., & Ahmad, R. (2023). Dioxins and plastic waste: A scientometric analysis and systematic literature review of the detection methods. Environmental Advances, 13, 100439. https://doi.org/10.1016/j.envadv.2023.100439

Banasik, M. (2015). Tris(2-Chloro-1-Methylethyl) Phosphate (TCPP). In Hamilton & Hardy’s Industrial Toxicology (pp. 845–854). John Wiley & Sons, Inc. https://doi.org/10.1002/9781118834015.ch84

Barton, H. A., Cogliano, V. J., Flowers, L., Valcovic, L., Setzer, R. W., & Woodruff, T. J. (2005). Assessing Susceptibility from Early-Life Exposure to Carcinogens. Environmental Health Perspectives, 113(9), 1125–1133. https://doi.org/10.1289/ehp.7667

BASF. (2022). SKYTITE C3-3.0 S Resin. https://hpdrepository.hpd-collaborative.org/repository/HPDs/823_SKYTITE_C3_3_0_S_Resin.pdf

Bello, A., Carignan, C. C., Xue, Y., Stapleton, H. M., & Bello, D. (2018). Exposure to organophosphate flame retardants in spray polyurethane foam applicators: Role of dermal exposure. Environment International, 113, 55–65. https://doi.org/10.1016/j.envint.2018.01.020

Bester, K. (2005). Comparison of TCPP concentrations in sludge and wastewater in a typical German sewage treatment plant—comparison of sewage sludge from 20 plants. Journal of Environmental Monitoring, 7(5), 509. https://doi.org/10.1039/b502318a

Bhaskar, T., Tanabe, M., Muto, A., Sakata, Y., Liu, C.-F., Chen, M.-D., & Chao, C. C. (2005). Analysis of chlorine distribution in the pyrolysis products of poly(vinylidene chloride) mixed with polyethylene, polypropylene or polystyrene. Polymer Degradation and Stability, 89(1), 38–42. https://doi.org/10.1016/j.polymdegradstab.2004.12.022

Bi, C., Maestre, J. P., Li, H., Zhang, G., Givehchi, R., Mahdavi, A., Kinney, K. A., Siegel, J., Horner, S. D., & Xu, Y. (2018). Phthalates and organophosphates in settled dust and HVAC filter dust of U.S. low-income homes: Association with season, building characteristics, and childhood asthma. Environment International, 121, 916–930. https://doi.org/10.1016/j.envint.2018.09.013

Bi, C., Wang, X., Li, H., Li, X., & Xu, Y. (2021). Direct Transfer of Phthalate and Alternative Plasticizers from Indoor Source Products to Dust: Laboratory Measurements and Predictive Modeling. Environmental Science & Technology, 55(1), 341–351. https://doi.org/10.1021/acs.est.0c05131

Big D Industries Inc. (2023). Big D Para Products. https://www.bigdind.com/_files/ugd/d3f87f_a63e922516974b4f8c67e41e11448927.pdf

Blackburn, K., & Green, D. (2022). The potential effects of microplastics on human health: What is known and what is unknown. Ambio, 51(3), 518–530. https://doi.org/10.1007/s13280-021-01589-9

Boisclair, S., Rousseau-Harsany, E., & Nguyen, B. (2010). Jewellery- and ornament-related injuries in children and adolescents. Paediatrics & Child Health, 15(10), 645–648. https://doi.org/10.1093/pch/15.10.645

Bølling, A. K., Sripada, K., Becher, R., & Bekö, G. (2020). Phthalate exposure and allergic diseases: Review of epidemiological and experimental evidence. Environment International, 139, 105706. https://doi.org/10.1016/j.envint.2020.105706

Brunet, C. E., Marek, R. F., Stanier, C. O., & Hornbuckle, K. C. (2024). Concentrations of Volatile Methyl Siloxanes in New York City Reflect Emissions from Personal Care and Industrial Use. Environmental Science & Technology, 58(20), 8835–8845. https://doi.org/10.1021/acs.est.3c10752

Cacho, J. I., Campillo, N., Viñas, P., & Hernández-Córdoba, M. (2015). Direct sample introduction gas chromatography and mass spectrometry for the determination of phthalate esters in cleaning products. Journal of Chromatography A, 1380, 156–161. https://doi.org/10.1016/j.chroma.2014.12.067

Cahuas, L., Muensterman, D. J., Kim-Fu, M. L., Reardon, P. N., Titaley, I. A., & Field, J. A. (2022). Paints: A Source of Volatile PFAS in Air–Potential Implications for Inhalation Exposure. Environmental Science & Technology, 56(23), 17070–17079. https://doi.org/10.1021/acs.est.2c04864

Capela, D., Alves, A., Homem, V., & Santos, L. (2016). From the shop to the drain — Volatile methylsiloxanes in cosmetics and personal care products. Environment International, 92–93, 50–62. https://doi.org/10.1016/j.envint.2016.03.016

Capela, D., Ratola, N., Alves, A., & Homem, V. (2017). Volatile methylsiloxanes through wastewater treatment plants – A review of levels and implications. Environment International, 102, 9–29. https://doi.org/10.1016/j.envint.2017.03.005

Capozzi, S. L., Leang, A. L., Rodenburg, L. A., Chandramouli, B., Delistraty, D. A., & Carter, C. H. (2023). PFAS in municipal landfill leachate: Occurrence, transformation, and sources. Chemosphere, 334, 138924. https://doi.org/10.1016/j.chemosphere.2023.138924

CARB. (2004). HEALTH RISK AND NEEDS ASSESSMENT FOR THE AIRBORNE TOXIC CONTROL MEASURE FOR PARA-DICHLOROBENZENE SOLID AIR FRESHENERS AND TOILET/URINAL CARE PRODUCTS. https://ww2.arb.ca.gov/sites/default/files/barcu/regact/conprod/ch7.pdf

Carlos, K. S., de Jager, L. S., & Begley, T. H. (2018). Investigation of the primary plasticisers present in polyvinyl chloride (PVC) products currently authorised as food contact materials. Food Additives & Contaminants: Part A, 35(6). https://doi.org/10.1080/19440049.2018.1447695

Cavallari, J. M., Simcox, N. J., Wakai, S., Lu, C., Garza, J. L., & Cherniack, M. (2015). Characterization of Urinary Phthalate Metabolites Among Custodians. Annals of Occupational Hygiene, 59(8), 982–999. https://doi.org/10.1093/annhyg/mev050

CDC. (2023). Most Recent National Asthma Data. https://www.cdc.gov/asthma/most_recent_national_asthma_data.htm

CDC. (2024). About Lead in Consumer Products. https://www.cdc.gov/lead-prevention/prevention/consumer-products.html

CDPH. (n.d.). California Safe Cosmetics Program (CSCP) Product Database. Retrieved July 8, 2024, from https://cscpsearch.cdph.ca.gov/search/publicsearch

Ceballos, D. M., Craig, J., Fu, X., Jia, C., Chambers, D., Chu, M. T., Fernandez, A. T., Fruh, V., Petropoulos, Z. E., Allen, J. G., Vallarino, J., Thornburg, L., & Webster, T. F. (2019). Biological and environmental exposure monitoring of volatile organic compounds among nail technicians in the Greater Boston area. Indoor Air, ina.12564. https://doi.org/10.1111/ina.12564

CEH. (2023). Testing Finds High Levels of Lead and Cadmium in Urban Outfitters Jewelry. https://ceh.org/latest/press-releases/testing-finds-high-levels-of-lead-and-cadmium-in-urban-outfitters-jewelry/

Chaudhary, B. I., Liotta, C. L., Cogen, J. M., & Gilbert, M. (2016). Plasticized PVC. In Reference Module in Materials Science and Materials Engineering. Elsevier. https://doi.org/10.1016/B978-0-12-803581-8.02631-X

Chen, W., Lee, S., & Moon, H.-B. (2024). Cyclic and linear siloxane contamination in sediment and invertebrates around a thermal power plant in Korea: Source impact, distribution, seasonal variation, and potential for bioaccumulation. Chemosphere, 349, 140779. https://doi.org/10.1016/j.chemosphere.2023.140779

Cheng, H., Hu, Y., & Reinhard, M. (2014). Environmental and Health Impacts of Artificial Turf: A Review. Environmental Science & Technology, 48(4), 2114–2129. https://doi.org/10.1021/es4044193

Chin, J.-Y., Godwin, C., Jia, C., Robins, T., Lewis, T., Parker, E., Max, P., & Batterman, S. (2013). Concentrations and risks of p-dichlorobenzene in indoor and outdoor air. Indoor Air, 23(1), 40–49. https://doi.org/10.1111/j.1600-0668.2012.00796.x

Churchill, J. E., Ashley, D. L., & Kaye, W. E. (2001). Recent Chemical Exposures and Blood Volatile Organic Compound Levels in a Large Population-Based Sample. Archives of Environmental Health: An International Journal, 56(2), 157–166. https://doi.org/10.1080/00039890109604068

CivicScience. (2023). DIY Work Gains Momentum Among Home Improvement Intenders. https://civicscience.com/diy-work-gains-momentum-among-home-improvement-intenders/

Claudio, L. (2008). Synthetic Turf: Health DebateTakes Root. Environmental Health Perspectives, 116(3). https://doi.org/10.1289/ehp.116-a116

Clausen, P. A., Frederiksen, M., Sejbæk, C. S., Sørli, J. B., Hougaard, K. S., Frydendall, K. B., Carøe, T. K., Flachs, E. M., Meyer, H. W., Schlünssen, V., & Wolkoff, P. (2020). Chemicals inhaled from spray cleaning and disinfection products and their respiratory effects. A comprehensive review. International Journal of Hygiene and Environmental Health, 229, 113592. https://doi.org/10.1016/j.ijheh.2020.113592

Clewell, H., Greene, T., & Gentry, R. (2024). Dermal absorption of cyclic and linear siloxanes: a review. Journal of Toxicology and Environmental Health, Part B, 27(3), 106–129. https://doi.org/10.1080/10937404.2024.2316843

Clougherty, J. E., Shmool, J. L. C., & Kubzansky, L. D. (2014). The Role of Non-Chemical Stressors in Mediating Socioeconomic Susceptibility to Environmental Chemicals. Current Environmental Health Reports, 1(4), 302–313. https://doi.org/10.1007/s40572-014-0031-y

Cosmetic Ingredient Review. (2019). Safety Assessment of Diacetone Alcohol as Used in Cosmetics. https://www.cir-safety.org/sites/default/files/diacet122019slr.pdf

Counihan, T. D., Waite, I. R., Nilsen, E. B., Hardiman, J. M., Elias, E., Gelfenbaum, G., & Zaugg, S. D. (2014). A survey of benthic sediment contaminants in reaches of the Columbia River Estuary based on channel sedimentation characteristics. Science of The Total Environment, 484, 331–343. https://doi.org/10.1016/j.scitotenv.2014.03.013

Cousins, I. T., Johansson, J. H., Salter, M. E., Sha, B., & Scheringer, M. (2022). Outside the Safe Operating Space of a New Planetary Boundary for Per- and Polyfluoroalkyl Substances (PFAS). Environmental Science & Technology, 56(16), 11172–11179. https://doi.org/10.1021/acs.est.2c02765

Cox, C., & Green, M. (2010). Reduction in the Prevalence of Lead-Containing Jewelry in California Following Litigation and Legislation. Environmental Science & Technology, 44(16), 6042–6045. https://doi.org/10.1021/es903745b

CPID. (n.d.). Consumer Product Information Database (CPID). Retrieved July 22, 2024, from https://www.whatsinproducts.com/pages/index/1

CPSC. (2024a). Fossil Group Recalls Bracelet Sold with Skechers Jewelry Gift Sets Due to High Levels of Lead and Cadmium. https://www.cpsc.gov/Recalls/2024/Fossil-Group-Recalls-Bracelet-Sold-with-Skechers-Jewelry-Gift-Sets-Due-to-High-Levels-of-Lead-and-Cadmium

CPSC. (2024b). Yaomiao Children’s Rhinestone Silver Tiaras Recalled Due to Violation of Federal Lead Content Ban; Sold Exclusively on Amazon.com by LordRoadS. https://www.cpsc.gov/Recalls/2024/Yaomiao-Childrens-Rhinestone-Silver-Tiaras-Recalled-Due-to-Violation-of-Federal-Lead-Content-Ban-Sold-Exclusively-on-Amazon-com-by-LordRoadS

Cui, N., Zhang, X., Xie, Q., Wang, S., Chen, J., Huang, L., Qiao, X., Li, X., & Cai, X. (2011). Toxicity profile of labile preservative bronopol in water: The role of more persistent and toxic transformation products. Environmental Pollution, 159(2), 609–615. https://doi.org/10.1016/j.envpol.2010.09.036

Cverenkárová, K., Valachovičová, M., Mackuľak, T., Žemlička, L., & Bírošová, L. (2021). Microplastics in the Food Chain. Life, 11(12), 1349. https://doi.org/10.3390/life11121349

DAP Global Inc. (2023a). 3.0 Concrete & Masonry Self-Leveling Sealant - Gray. https://www.dap.com/media/3686/1005001english.pdf

DAP Global Inc. (2023b). DAP 3.0 Gutter & Flashing Sealant Crystal Clear. https://www.dap.com/media/3695/1160801english.pdf

DAP Products Inc. (2018). Kwik Seal Plus Premium Kitchen & Bath Adhesive Sealant - All Colors. https://images.thdstatic.com/catalog/pdfImages/9e/9eab1739-6fa3-4ea6-bc21-1fe57f19284e.pdf

Daso, A. P., Rohwer, E. R., Koot, D. J., & Okonkwo, J. O. (2017). Preliminary screening of polybrominated diphenyl ethers (PBDEs), hexabromocyclododecane (HBCDD) and tetrabromobisphenol A (TBBPA) flame retardants in landfill leachate. Environmental Monitoring and Assessment, 189(8), 418. https://doi.org/10.1007/s10661-017-6131-z

de Haan, W. P., Quintana, R., Vilas, C., Cózar, A., Canals, M., Uviedo, O., & Sanchez-Vidal, A. (2023). The dark side of artificial greening: Plastic turfs as widespread pollutants of aquatic environments. Environmental Pollution, 334, 122094. https://doi.org/10.1016/j.envpol.2023.122094

De Silva, A. O., Armitage, J. M., Bruton, T. A., Dassuncao, C., Heiger-Bernays, W., Hu, X. C., Kärrman, A., Kelly, B., Ng, C., Robuck, A., Sun, M., Webster, T. F., & Sunderland, E. M. (2021). PFAS Exposure Pathways for Humans and Wildlife: A Synthesis of Current Knowledge and Key Gaps in Understanding. Environmental Toxicology and Chemistry, 40(3), 631–657. https://doi.org/10.1002/etc.4935

Dewapriya, P., Chadwick, L., Gorji, S. G., Schulze, B., Valsecchi, S., Samanipour, S., Thomas, K. V., & Kaserzon, S. L. (2023). Per- and polyfluoroalkyl substances (PFAS) in consumer products: Current knowledge and research gaps. Journal of Hazardous Materials Letters, 4, 100086. https://doi.org/10.1016/j.hazl.2023.100086

Dhavamani, J., Beck, A. J., Gledhill, M., El-Shahawi, M. S., Kadi, M. W., Ismail, I. M. I., & Achterberg, E. P. (2022). The effects of salinity, temperature, and UV irradiation on leaching and adsorption of phthalate esters from polyethylene in seawater. Science of The Total Environment, 838, 155461. https://doi.org/10.1016/j.scitotenv.2022.155461

Dinglasan, M. J. A., Ye, Y., Edwards, E. A., & Mabury, S. A. (2004). Fluorotelomer Alcohol Biodegradation Yields Poly- and Perfluorinated Acids. Environmental Science & Technology, 38(10), 2857–2864. https://doi.org/10.1021/es0350177

Dodson, R. E., Nishioka, M., Standley, L. J., Perovich, L. J., Brody, J. G., & Rudel, R. A. (2012). Endocrine Disruptors and Asthma-Associated Chemicals in Consumer Products. Environmental Health Perspectives, 120(7), 935–943. https://doi.org/10.1289/ehp.1104052

Dodson, R. E., Perovich, L. J., Covaci, A., Van den Eede, N., Ionas, A. C., Dirtu, A. C., Brody, J. G., & Rudel, R. A. (2012). After the PBDE Phase-Out: A Broad Suite of Flame Retardants in Repeat House Dust Samples from California. Environmental Science & Technology, 46(24), 13056–13066. https://doi.org/10.1021/es303879n

Dodson, R. E., Udesky, J. O., Colton, M. D., McCauley, M., Camann, D. E., Yau, A. Y., Adamkiewicz, G., & Rudel, R. A. (2017). Chemical exposures in recently renovated low-income housing: Influence of building materials and occupant activities. Environment International, 109, 114–127. https://doi.org/10.1016/j.envint.2017.07.007

Dow. (2016). GREAT STUFF Window and Door Insulating Foam Sealant. https://images.thdstatic.com/catalog/pdfImages/05/051df917-fc6e-456d-ab0a-0deea2bf69c9.pdf

Drage, D. S., Sharkey, M., Abdallah, M. A.-E., Berresheim, H., & Harrad, S. (2018). Brominated flame retardants in Irish waste polymers: Concentrations, legislative compliance, and treatment options. Science of The Total Environment, 625, 1535–1543. https://doi.org/10.1016/j.scitotenv.2018.01.076

Drage, D. S., Waiyarat, S., Harrad, S., Abou-Elwafa Abdallah, M., & Boontanon, S. K. (2020). Temporal trends in concentrations of legacy and novel brominated flame retardants in house dust from Birmingham in the United Kingdom. Emerging Contaminants, 6, 323–329. https://doi.org/10.1016/j.emcon.2020.08.003

DTSC. (n.d.-a). Cadmium in Children's Jewelry. Retrieved July 28, 2024, from https://dtsc.ca.gov/toxics-in-products/cadmium-in-childrens-jewelry/

DTSC. (n.d.-b). Lead in Jewelry. Retrieved July 28, 2024, from https://dtsc.ca.gov/toxics-in-products/lead-in-jewelry/

DTSC. (2012). SUMMARY OF DATA AND FINDINGS FROM TESTING OF A LIMITED NUMBER OF NAIL PRODUCTS. https://dtsc.ca.gov/wp-content/uploads/sites/31/2023/11/DTSC-2012-Nail-Salon-Product-Testing_Remediated.pdf

DTSC. (2017). Toxic Jewelry Samples, 2017. https://dtsc.ca.gov/wp-content/uploads/sites/31/2022/07/Toxic-Jewelry-Photos-2017.pdf

DTSC. (2020). Product-Chemical Profile for Nail Products Containing Toluene. https://dtsc.ca.gov/wp-content/uploads/sites/31/2021/10/Final-Profile_Toluene-in-Nail-Products.pdf

DTSC. (2022a). Potential Alternatives to Toluene in Nail Products. https://dtsc.ca.gov/wp-content/uploads/sites/31/2022/12/Public-Toluene-in-Nail-Products-Alternatives-Accessible.pdf

DTSC. (2022b). Product - Chemical Profile for Motor Vehicle Tires Containing N-(1,3-Dimethylbutyl)-N′-phenyl-p-phenylenediamine (6PPD). https://dtsc.ca.gov/wp-content/uploads/sites/31/2022/05/6PPD-in-Tires-Priority-Product-Profile_FINAL-VERSION_accessible.pdf

DTSC. (2023a). Laboratory Study of Chemicals in Nail Products. https://dtsc.ca.gov/wp-content/uploads/sites/31/2023/11/SCP-Report_Nail-Products-Lab-Study_Final-Accessible-New.pdf

DTSC. (2023b). Summary of Findings on DTSC's Information Call-in on Nail Products. https://dtsc.ca.gov/wp-content/uploads/sites/31/2023/03/DTSCs-Nail-Products-Information-Call-in-Report_Final-Accessible.pdf

DTSC. (2024). Background Document on Candidate Chemicals in Artificial Turf. https://dtsc.ca.gov/wp-content/uploads/sites/31/2024/07/Background-Document-on-Candidate-Chemicals-in-Artificial-Turf.pdf

Du, S., Zhu, R., Cai, Y., Xu, N., Yap, P.-S., Zhang, Y., He, Y., & Zhang, Y. (2021). Environmental fate and impacts of microplastics in aquatic ecosystems: a review. RSC Advances, 11(26), 15762–15784. https://doi.org/10.1039/D1RA00880C

Duan, H., Yu, D., Zuo, J., Yang, B., Zhang, Y., & Niu, Y. (2016). Characterization of brominated flame retardants in construction and demolition waste components: HBCD and PBDEs. Science of The Total Environment, 572, 77–85. https://doi.org/10.1016/j.scitotenv.2016.07.165

Dudzina, T., von Goetz, N., Bogdal, C., Biesterbos, J. W. H., & Hungerbühler, K. (2014). Concentrations of cyclic volatile methylsiloxanes in European cosmetics and personal care products: Prerequisite for human and environmental exposure assessment. Environment International, 62, 86–94. https://doi.org/10.1016/j.envint.2013.10.002

Duque-Villaverde, A., Armada, D., Dagnac, T., & Llompart, M. (2024). Recycled tire rubber materials in the spotlight. Determination of hazardous and lethal substances. Science of The Total Environment, 929, 172674. https://doi.org/10.1016/j.scitotenv.2024.172674

Eales, J., Bethel, A., Galloway, T., Hopkinson, P., Morrissey, K., Short, R. E., & Garside, R. (2022). Human health impacts of exposure to phthalate plasticizers: An overview of reviews. Environment International, 158, 106903. https://doi.org/10.1016/j.envint.2021.106903

Eberle, C., & Stichling, S. (2022). Environmental health influences in pregnancy and risk of gestational diabetes mellitus: a systematic review. BMC Public Health, 22(1), 1572. https://doi.org/10.1186/s12889-022-13965-5

ECHA. (2010). Lead and its Compounds in Jewellery. https://echa.europa.eu/documents/10162/ce186db0-b707-24cc-070b-39068d041afb

ECHA. (2019). Annex XV Restriction Report - D4, D5 and D6. https://echa.europa.eu/documents/10162/13641/rest_d4d5d6_axvreport_en.pdf/c4463b07-79a3-7abe-b7a7-5c816e45bb98

ECHA. (2023a). Appendices A and B to the Investigation Report on PVC and PVC Additives. https://echa.europa.eu/documents/10162/17233/rest_pvc_investigation_report_appendix_a_b_en.pdf

ECHA. (2023b). Investigation Report on PVC and PVC Additives. https://echa.europa.eu/documents/10162/17233/rest_pvc_investigation_report_en.pdf/98134bd2-f26e-fa4f-8ae1-004d2a3a29b6?t=1701157368019

ECHA. (2023c). REF-10 project report on: Integrated chemical compliance of products. https://echa.europa.eu/documents/10162/17086/ref-10_project_report_en.pdf/83661988-378d-6268-3f28-182da198e8ac

ECHA. (2023d). Table of harmonised entries in Annex VI to CLP. https://echa.europa.eu/information-on-chemicals/annex-vi-to-clp

Ecology. (n.d.-a). Environmental Information Management System (EIM). Retrieved August 13, 2024, from https://apps.ecology.wa.gov/eim/search/

Ecology. (n.d.-b). Outdoor and residential burning. Retrieved July 29, 2024, from https://ecology.wa.gov/Air-Climate/Air-quality/Smoke-fire/Outdoor-residential-burning

Ecology. (n.d.-c). Paint stewardship: PaintCare. Retrieved October 7, 2024, from https://ecology.wa.gov/waste-toxics/reducing-recycling-waste/our-recycling-programs/paint-stewardship

Ecology. (2018). Clark County Local Source Control Partnership Monitoring, Findings and Recommendations 2017. https://apps.ecology.wa.gov/publications/documents/1803018.pdf

Ecology. (2019). Flame Retardants in Ten Washington State Lakes, 2017-2018. https://apps.ecology.wa.gov/publications/documents/1903021.pdf

Ecology. (2020). Priority Consumer Products Report to the Legislature: Safer Products for Washington Implementation Phase 2. https://apps.ecology.wa.gov/publications/summarypages/2004019.html

Ecology. (2022a). Per- and Polyfluoroalkyl Substances Chemical Action Plan. https://apps.ecology.wa.gov/publications/documents/2104048.pdf

Ecology. (2022b). Regulatory Determinations Report to the Legislature: Safer Products for Washington Cycle 1 Implementation Phase 3. https://apps.ecology.wa.gov/publications/summarypages/2204018.html

Ecology. (2023a). Cadmium and Other Metals in Children's Jewelry 2018, Follow-up Study. https://apps.ecology.wa.gov/publications/documents/2303004.pdf

Ecology. (2023b). Phthalates Action Plan. https://apps.ecology.wa.gov/publications/documents/2304067.pdf

Ecology. (2024a). 2022-2023 Washington Statewide Recycling & Organics Characterization Study. https://apps.ecology.wa.gov/publications/summarypages/2407007.html

Ecology. (2024b). Identification of Priority Chemicals Report to the Legislature: Safer Products for Washington Cycle 2 Implementation Phase 1. https://apps.ecology.wa.gov/publications/SummaryPages/2404025.html

Ecology. (2024c). Technical Supporting Documentation for Priority Chemicals: Safer Products for Washington Cycle 2 Implementation Phase 1. https://apps.ecology.wa.gov/publications/SummaryPages/2404026.html

Ecology Center. (2019). Toxic "Forever Chemicals" Infest Artificial Turf. https://www.ecocenter.org/toxic-forever-chemicals-infest-artificial-turf

Ecology Center. (2023a). 2019 and 2021 Caulk and Sealants. https://www.ecocenter.org/sites/default/files/2023-04/Caulks-and-Sealants-Test-Results-Ecology-Center.pdf

Ecology Center. (2023b). Phthalates in Caulks and Sealants. https://www.ecocenter.org/our-work/healthy-stuff-lab/reports/phthalates-caulks-and-sealants

ECVM. (n.d.-a). About PVC. Retrieved September 4, 2024, from https://pvc.org/about-pvc/

ECVM. (n.d.-b). Additives: Stabilisers, plasticisers and others. Retrieved July 28, 2024, from https://pvc.org/sustainability/industry-responsible-care/additives-stabilisers-plasticisers-and-others/

ECVM. (n.d.-c). PVC in packaging. Retrieved July 29, 2024, from https://pvc.org/pvc-applications/pvc-in-packaging/

ECVM. (n.d.-d). Vinyl chloride monomer (VCM) production. Retrieved July 15, 2024, from https://pvc.org/about-pvc/vinyl-chloride-monomer-vcm-production/

ECVM. (2024). Vinyl Chloride Monomer (VCM) - ECVM. https://pvc.org/sustainability/vinyl-chloride-monomer-vcm/

Ellen MacArthur Foundation and McKinsey & Company. (2016). The New Plastics Economy - Rethinking the future of plastics. http://www.ellenmacarthurfoundation.org/publications

Elliott, L., Longnecker, M. P., Kissling, G. E., & London, S. J. (2006). Volatile Organic Compounds and Pulmonary Function in the Third National Health and Nutrition Examination Survey, 1988–1994. Environmental Health Perspectives, 114(8), 1210–1214. https://doi.org/10.1289/ehp.9019

Engel, S. M., Patisaul, H. B., Brody, C., Hauser, R., Zota, A. R., Bennet, D. H., Swanson, M., & Whyatt, R. M. (2021). Neurotoxicity of Ortho-Phthalates: Recommendations for Critical Policy Reforms to Protect Brain Development in Children. American Journal of Public Health, 111(4), 687–695. https://doi.org/10.2105/AJPH.2020.306014

Essendant Co. (2015). Para Block and Screen. https://www.abilityone.com/file/products/BWKPBS_SDS.PDF

Essendant Co. (2016). 4 oz Bowl Block. https://www.catawbacountync.gov/site/assets/files/10110/toilet_bowl_block.pdf

Estill, C. F., Mayer, A. C., Chen, I.-C., Slone, J., LaGuardia, M. J., Jayatilaka, N., Ospina, M., Sjodin, A., & Calafat, A. M. (2024). Biomarkers of Organophosphate and Polybrominated Diphenyl Ether (PBDE) Flame Retardants of American Workers and Associations with Inhalation and Dermal Exposures. Environmental Science & Technology, 58(19), 8417–8431. https://doi.org/10.1021/acs.est.3c09342

Estill, C. F., Slone, J., Mayer, A. C., Phillips, K., Lu, J., Chen, I.-C., Christianson, A., Streicher, R., Guardia, M. J. La, Jayatilaka, N., Ospina, M., & Calafat, A. M. (2019). Assessment of spray polyurethane foam worker exposure to organophosphate flame retardants through measures in air, hand wipes, and urine. Journal of Occupational and Environmental Hygiene, 16(7), 477–488. https://doi.org/10.1080/15459624.2019.1609004

Estill, C. F., Slone, J., Mayer, A., Chen, I.-C., & La Guardia, M. J. (2020). Worker exposure to flame retardants in manufacturing, construction and service industries. Environment International, 135, 105349. https://doi.org/10.1016/j.envint.2019.105349

Eunomia. (2018). Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products - Final report. https://eunomia.eco/reports/investigating-options-for-reducing-releases-in-the-aquatic-environment-of-microplastics-emitted-by-products/

Eunomia. (2023). Consumer Packaging & Paper Products Study. https://apps.ecology.wa.gov/publications/documents/2207022.pdf

Everkem Diversified Products. (2015). SilTex 40. https://www.everkemproducts.com/wp-content/uploads/2015/06/SilTex-40-Siliconized-Acrylic-Latex-Sealant-SDS.pdf

EWG. (n.d.-a). EWG Skin Deep - Diacetone alcohol. Retrieved July 29, 2024, from https://www.ewg.org/skindeep/ingredients/701916-diacetone-alcohol/

EWG. (n.d.-b). Products that contain TOLUENE. Retrieved July 24, 2024, from https://www.ewg.org/skindeep/browse/ingredients/706577-TOLUENE/

EWG. (2023). Survey finds use of personal care products up since 2004 – what that means for your health. https://www.ewg.org/research/survey-finds-use-personal-care-products-2004-what-means-your-health

Farfel, M. R., Orlova, A. O., Lees, P. S. J., Rohde, C., Ashley, P. J., & Julian Chisolm, J. (2005). A study of urban housing demolition as a source of lead in ambient dust on sidewalks, streets, and alleys. Environmental Research, 99(2), 204–213. https://doi.org/10.1016/j.envres.2004.10.005

Fernández-González, V., Andrade-Garda, J. M., López-Mahía, P., & Muniategui-Lorenzo, S. (2022). Misidentification of PVC microplastics in marine environmental samples. TrAC Trends in Analytical Chemistry, 153, 116649. https://doi.org/10.1016/j.trac.2022.116649

Ferrreira, A. P. S. da S., Pereira, E. C., Salles, F. J., Silva, F. F. da, Batista, B. L., Handakas, E., & Olympio, K. P. K. (2019). Home-based and informal work exposes the families to high levels of potentially toxic elements. Chemosphere, 218, 319–327. https://doi.org/10.1016/j.chemosphere.2018.11.083

Folletti, I., Zock, J.-P., Moscato, G., & Siracusa, A. (2014). Asthma and rhinitis in cleaning workers: a systematic review of epidemiological studies. Journal of Asthma, 51(1), 18–28. https://doi.org/10.3109/02770903.2013.833217

Formulated Polymer Products Ltd. (2019). Potential of PVDC Coating in Reducing Plastic Packaging in Food. https://www.polymers.co.uk/blog/could-pvdc-coating-reduce-plastic-packaging-in-food

Fortune Union. (n.d.). Materials for Blister Packaging Film. Retrieved July 15, 2024, from http://www.fortuneunion.net/materials-for-blister-packaging-film/

Franplast. (n.d.). TPE Infill. Retrieved August 12, 2024, from https://www.franplast-tpe.com/tpe-infill-manufacturers/

Fresh Products LLC. (2023). Para Urinal Blocks. https://www.grainger.com/sds/pdf/260978.pdf

Fromme, H. (2019). Cyclic Volatile Methylsiloxanes: Occurrence and Exposure. In Encyclopedia of Environmental Health (pp. 805–812). Elsevier. https://doi.org/10.1016/B978-0-12-409548-9.11241-2

Fromme, H., Hilger, B., Kopp, E., Miserok, M., & Völkel, W. (2014). Polybrominated diphenyl ethers (PBDEs), hexabromocyclododecane (HBCD) and “novel” brominated flame retardants in house dust in Germany. Environment International, 64, 61–68. https://doi.org/10.1016/j.envint.2013.11.017

Gee, G. C., & Payne-Sturges, D. C. (2004). Environmental Health Disparities: A Framework Integrating Psychosocial and Environmental Concepts. Environmental Health Perspectives, 112(17), 1645–1653. https://doi.org/10.1289/ehp.7074

Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science Advances, 3(7). https://doi.org/10.1126/sciadv.1700782

Glüge, J., Scheringer, M., Cousins, I. T., DeWitt, J. C., Goldenman, G., Herzke, D., Lohmann, R., Ng, C. A., Trier, X., & Wang, Z. (2020). An overview of the uses of per- and polyfluoroalkyl substances (PFAS). Environmental Science: Processes & Impacts, 22(12), 2345–2373. https://doi.org/10.1039/D0EM00291G

Godwin, A. D. (2011). Plasticizers. In Applied Plastics Engineering Handbook (pp. 487–501). Elsevier. https://doi.org/10.1016/B978-1-4377-3514-7.10028-5

Goldenman, G., Pedersen, R., Bradley, H., Fernandez, M., Weber, R., Scheringer, M., & Fantke, P. (2017). Study for the strategy for a non-toxic environment of the 7th EAP - Sub-study d: Very Persistent Chemicals.

Gomes, F. O., Rocha, M. R., Alves, A., & Ratola, N. (2021). A review of potentially harmful chemicals in crumb rubber used in synthetic football pitches. Journal of Hazardous Materials, 409, 124998. https://doi.org/10.1016/j.jhazmat.2020.124998

Governor’s Indian Health Advisory Council. (2023). 2022-23 Biennial Report. https://www.hca.wa.gov/assets/program/final-biennial-indian-health-improvement-advisory-plan-2023.pdf

Green Seal. (n.d.). Green Seal to Prohibit All PFAS in Certified Paints, Coatings, and Floor Care Products. Retrieved October 7, 2024, from https://greenseal.org/press-release/green-seal-to-prohibit-all-pfas-in-certified-paints-coatings-and-floor-care-products/

GROUPON Merchant. (2024). True Cost of Beauty: Survey Reveals Where Americans Spend Most. https://www.groupon.com/merchant/trends-insights/market-research/true-cost-beauty-americans-spend-most-survey

Guardian Innovations LLC. (n.d.). Guardian turf infill. Retrieved August 12, 2024, from https://shop.guardiansports.com/products/guardian-turf-infill

Guerrero, P. A. (2013). p-Dichlorobenzene and Naphthalene: Emissions and Related Primary and Secondary Exposures in Residential Buildings. https://repositories.lib.utexas.edu/server/api/core/bitstreams/3d7d84b7-864d-4b3a-9398-e54fbabeea6a/content

Guo, J., Zhou, Y., Wang, Y., Chen, Y., Zhang, B., & Zhang, J. (2022). Methylsiloxanes risk assessment combining external and internal exposure for college students. Science of The Total Environment, 845, 157379. https://doi.org/10.1016/j.scitotenv.2022.157379

Gustafsson, Å., Bergman, Å., & Weiss, J. M. (2022). Estimated daily intake of per- and polyfluoroalkyl substances related to different particle size fractions of house dust. Chemosphere, 303, 135061. https://doi.org/10.1016/j.chemosphere.2022.135061

Habitable. (n.d.). Pharos. Retrieved September 23, 2024, from https://pharos.habitablefuture.org/

Habitable. (2022). Sealant Product Guidance - Informed. https://informed.habitablefuture.org/product-guidance/10-sealants

Habitable. (2023). Insulation Product Guidance. https://informed.habitablefuture.org/product-guidance/7-insulation

Hakeem, I. G., Halder, P., Patel, S., Selezneva, E., Rathnayake, N., Marzbali, M. H., Veluswamy, G., Sharma, A., Kundu, S., Surapaneni, A., Megharaj, M., Batstone, D. J., & Shah, K. (2024). Current understanding on the transformation and fate of per- and polyfluoroalkyl substances before, during, and after thermal treatment of biosolids. Chemical Engineering Journal, 493, 152537. https://doi.org/10.1016/j.cej.2024.152537

Hammel, S. C., Levasseur, J. L., Hoffman, K., Phillips, A. L., Lorenzo, A. M., Calafat, A. M., Webster, T. F., & Stapleton, H. M. (2019). Children's exposure to phthalates and non-phthalate plasticizers in the home: The TESIE study. Environment International, 132, 105061. https://doi.org/10.1016/j.envint.2019.105061

Han, I., Seo, J. Y., Barr, D. B., Panuwet, P., Yakimavets, V., D'Souza, P. E., An-Han, H., Afshar, M., & Chao, Y.-Y. (2022). Evaluating Indoor Air Phthalates and Volatile Organic Compounds in Nail Salons in the Greater New York City Area: A Pilot Study. International Journal of Environmental Research and Public Health, 19(19), 12411. https://doi.org/10.3390/ijerph191912411

Harding-Smith, E., Shaw, D. R., Shaw, M., Dillon, T. J., & Carslaw, N. (2024). Does green mean clean? Volatile organic emissions from regular versus green cleaning products. Environmental Science: Processes & Impacts, 26(2), 436–450. https://doi.org/10.1039/D3EM00439B

Harley, K. G., Calderon, L., Nolan, J. E. S., Maddalena, R., Russell, M., Roman, K., Mayo-Burgos, S., Cabrera, J., Morga, N., & Bradman, A. (2021). Changes in Latina Women's Exposure to Cleaning Chemicals Associated with Switching from Conventional to "Green" Household Cleaning Products: The LUCIR Intervention Study. Environmental Health Perspectives, 129(9). https://doi.org/10.1289/EHP8831

Harrichandra, A., Roelofs, C., & Pavilonis, B. (2020). Occupational Exposure and Ventilation Assessment in New York City Nail Salons. Annals of Work Exposures and Health, 64(5), 468–478. https://doi.org/10.1093/annweh/wxaa035

Health. (n.d.). Washington Tracking Network. Retrieved September 23, 2024, from https://doh.wa.gov/data-and-statistical-reports/washington-tracking-network-wtn

Healthy Building Network. (2018). Flame Retardants in Building Insulation. https://doh.wa.gov/sites/default/files/legacy/Documents/4000/fr_buildingInsulation.pdf

Healthy Building Network. (2023). PFAS in Paints. https://habitablefuture.org/wp-content/uploads/2024/03/97-pfas-in-paints.pdf

Henkel. (2014). Loctite PL Polyurethane Concrete Crack and Masonry Sealant. https://hdsupplysolutions.com/wcsstore/ThdsMroUs/product/fm/additional/14/145428-SDS.pdf

Henkel, C., Hüffer, T., & Hofmann, T. (2022). Polyvinyl Chloride Microplastics Leach Phthalates into the Aquatic Environment over Decades. Environmental Science & Technology, 56(20), 14507–14516. https://doi.org/10.1021/acs.est.2c05108

Henkel Corp. (2017). TERESON MS 5510 WH known as LOCTITE 5510 ELASTIC ADHESI. https://www.natconusa.com/wp-content/uploads/2020/04/Teroson-MS-5510-WH-SDS.pdf

Henkel Corp. (2018). GE Paintable Silicone Supreme. https://images.thdstatic.com/catalog/pdfImages/77/77fc0fba-f9b0-47b7-8ac6-51f0e44bd4c4.pdf

Henry Company. (2014). HE224 - Silicone Fortified Window & Door Sealant. https://www.whatsinproducts.com/brands/show_msds/1/15514

Herrick, R. F., McClean, M. D., Meeker, J. D., Baxter, L. K., & Weymouth, G. A. (2004). An Unrecognized Source of PCB Contamination in Schools and Other Buildings. Environmental Health Perspectives, 112(10), 1051–1053. https://doi.org/10.1289/ehp.6912

Hickman, E., Frey, J., Wylie, A., Hartwell, H. J., Herkert, N. J., Short, S. J., Mills-Koonce, W. R., Fry, R. C., Stapleton, H. M., Propper, C., & Rager, J. E. (2024). Chemical and non-chemical stressors in a postpartum cohort through wristband and self-report data: Links between increased chemical burden, economic, and racial stress. Environment International, 191, 108976. https://doi.org/10.1016/j.envint.2024.108976

Home Depot. (n.d.). Types of Caulks and Sealants for Your Projects. Retrieved July 22, 2024, from https://www.homedepot.com/c/ab/types-of-caulks-and-sealants-for-your-projects/9ba683603be9fa5395fab90d0b119c3

Home Innovation Research Labs. (2019). Insulation Choices Revealed in New Study. https://www.homeinnovation.com/trends_and_reports/trends/insulation_choices_revealed_in_new_study

Horii, Y., & Kannan, K. (2008). Survey of Organosilicone Compounds, Including Cyclic and Linear Siloxanes, in Personal-Care and Household Products. Archives of Environmental Contamination and Toxicology, 55(4), 701–710. https://doi.org/10.1007/s00244-008-9172-z

HPD Collaborative. (n.d.). HPD Public Repository. Retrieved October 7, 2024, from https://hpdrepository.hpd-collaborative.org/Pages/Results.aspx

Hu, C. J., Garcia, M. A., Nihart, A., Liu, R., Yin, L., Adolphi, N., Gallego, D. F., Kang, H., Campen, M. J., & Yu, X. (2024). Microplastic presence in dog and human testis and its potential association with sperm count and weights of testis and epididymis. Toxicological Sciences. https://doi.org/10.1093/toxsci/kfae060

Huang, S., Huang, X., Bi, R., Guo, Q., Yu, X., Zeng, Q., Huang, Z., Liu, T., Wu, H., Chen, Y., Xu, J., Wu, Y., & Guo, P. (2022). Detection and Analysis of Microplastics in Human Sputum. Environmental Science & Technology, 56(4), 2476–2486. https://doi.org/10.1021/acs.est.1c03859

Hun, D. E., Siegel, J. A., Morandi, M. T., Stock, T. H., & Corsi, R. L. (2009). Cancer Risk Disparities between Hispanic and Non-Hispanic White Populations: The Role of Exposure to Indoor Air Pollution. Environmental Health Perspectives, 117(12), 1925–1931. https://doi.org/10.1289/ehp.0900925

Huntsman Building Solutions. (2024). Classic Ultra. https://hpdrepository.hpd-collaborative.org/repository/HPDs/902_Classic_Ultra.pdf

Hwang, S. H., Oh, G. T., Park, J. Y., Lee, K., Zho, K.-D., & Yoon, C. (2024). Characteristics of phthalate concentrations in propellant- and trigger-type consumer spray products. Air Quality, Atmosphere & Health. https://doi.org/10.1007/s11869-024-01560-z

ICP Construction Inc. (2022). HandiFoam FR HFO B-side. https://images.thdstatic.com/catalog/pdfImages/3d/3dc408b6-8ca9-4ea6-8b9e-6771c0a6c651.pdf

Illinois Department of Public Health. (2021). Lead Safety For Hobbyists. https://dph.illinois.gov/content/dam/soi/en/web/idph/files/publications/lead-safety-hobbyists-041516.pdf

Impellitteri, F., Riolo, K., Multisanti, C. R., Zicarelli, G., Piccione, G., Faggio, C., & Giannetto, A. (2024). Evaluating quaternium-15 effects on Mytilus galloprovincialis: New insights on physiological and cellular responses. Science of The Total Environment, 918, 170568. https://doi.org/10.1016/j.scitotenv.2024.170568

INCI Beauty. (n.d.-a). BUTYL ACETATE - Ingredient INCI Beauty. Retrieved July 24, 2024, from https://incibeauty.com/en/ingredients/3885-butyl-acetate

INCI Beauty. (n.d.-b). DIACETONE ALCOHOL. Retrieved July 29, 2024, from https://incibeauty.com/en/ingredients/9111-diacetone-alcohol

INCI Beauty. (n.d.-c). ETHYL ACETATE - Ingredient INCI Beauty. Retrieved July 24, 2024, from https://incibeauty.com/en/ingredients/5534-ethyl-acetate

INCI Beauty. (n.d.-d). N-BUTYL ALCOHOL. Retrieved July 29, 2024, from https://incibeauty.com/en/ingredients/17756-n-butyl-alcohol

INCI Beauty. (n.d.-e). PROPYL ACETATE. Retrieved July 29, 2024, from https://incibeauty.com/en/ingredients/6109-propyl-acetate

Inpro Corp. (2018). Fastfill Color Matched Caulk. https://www.inprocorp.com/globalassets/resource-documents/fastfill-color-matched-caulk-safety-data-sheet.pdf

Insulfoam. (2023). Insulfoam EPS, Platinum (GPS), R-Tech. https://www.insulfoam.com/wp-content/uploads/2016/08/Insulfoam-EPS-Safety-Data-Sheet.pdf

International Future Living Institute. (n.d.). Declare. Retrieved October 7, 2024, from https://declare.living-future.org/

Isaacs, K. K., Dionisio, K., Phillips, K., Bevington, C., Egeghy, P., & Price, P. S. (2020). Establishing a system of consumer product use categories to support rapid modeling of human exposure. Journal of Exposure Science & Environmental Epidemiology, 30(1), 171–183. https://doi.org/10.1038/s41370-019-0187-5

ITRC. (2023a). Human and Ecological Health Effects of select PFAS. https://pfas-1.itrcweb.org/7-human-and-ecological-health-effects-of-select-pfas/#7_2

ITRC. (2023b). Human Health and Ecological Effects - Microplastics. https://mp-1.itrcweb.org/human-health-and-ecological-effects/

ITRC. (2023c). Introduction - Microplastics. https://mp-1.itrcweb.org/introduction/

ITW Consumer. (2008). WeldIt All Purpose Adhesive. https://www.whatsinproducts.com/brands/show_msds/1/11644

James-Todd, T., Ponzano, M., Bellavia, A., Williams, P. L., Cantonwine, D. E., Calafat, A. M., Hauser, R., Quinn, M. R., Seely, E. W., & McElrath, T. F. (2022). Urinary phthalate and DINCH metabolite concentrations and gradations of maternal glucose intolerance. Environment International, 161, 107099. https://doi.org/10.1016/j.envint.2022.107099

Jasol. (2021). Mountain Breeze Tablets. https://www.jasol.com.au/product/mountain-breeze-new/

Jiang, J., Ding, X., Patra, S. S., Cross, J. N., Huang, C., Kumar, V., Price, P., Reidy, E. K., Tasoglou, A., Huber, H., Stevens, P. S., Boor, B. E., & Jung, N. (2023). Siloxane Emissions and Exposures during the Use of Hair Care Products in Buildings. Environmental Science & Technology, 57(48), 19999–20009. https://doi.org/10.1021/acs.est.3c05156

Jiang, Y., Wang, C., Ma, L., Gao, T., & Wāng, Y. (2024). Environmental profiles, hazard identification, and toxicological hallmarks of emerging tire rubber-related contaminants 6PPD and 6PPD-quinone. Environment International, 187, 108677. https://doi.org/10.1016/j.envint.2024.108677

Johnson, W., Bergfeld, W. F., Belsito, D. V., Hill, R. A., Klaassen, C. D., Liebler, D. C., Marks, J. G., Shank, R. C., Slaga, T. J., Snyder, P. W., & Andersen, F. A. (2011). Safety Assessment of Cyclomethicone, Cyclotetrasiloxane, Cyclopentasiloxane, Cyclohexasiloxane, and Cycloheptasiloxane. International Journal of Toxicology, 30(6_suppl), 149S-227S. https://doi.org/10.1177/1091581811428184

Jurowski, K. (2023). The toxicological assessment of hazardous elements (Pb, Cd and Hg) in low-cost jewelry for adults from Chinese E-commerce platforms: In situ analysis by portable X-ray fluorescence measurement. Journal of Hazardous Materials, 460, 132167. https://doi.org/10.1016/j.jhazmat.2023.132167

Kabir, M. S., Wang, H., Luster-Teasley, S., Zhang, L., & Zhao, R. (2023). Microplastics in landfill leachate: Sources, detection, occurrence, and removal. Environmental Science and Ecotechnology, 16, 100256. https://doi.org/10.1016/j.ese.2023.100256

Karimi, K., & Faghri, A. (2021). The Issues of Roadside Litter: A Review Paper. Current Urban Studies, 09(04), 779–803. https://doi.org/10.4236/cus.2021.94046

Kaseke, T., Lujic, T., & Cirkovic Velickovic, T. (2023). Nano- and Microplastics Migration from Plastic Food Packaging into Dairy Products: Impact on Nutrient Digestion, Absorption, and Metabolism. Foods, 12(16), 3043. https://doi.org/10.3390/foods12163043

Kawakami, T., Sakai, S., Obama, T., Kubota, R., Inoue, K., & Ikarashi, Y. (2022). Characterization of synthetic turf rubber granule infill in Japan: Rubber additives and related compounds. Science of The Total Environment, 840, 156716. https://doi.org/10.1016/j.scitotenv.2022.156716

KBeau Jewelry. (n.d.). Fast Fashion in the Jewelry Industry. Retrieved September 4, 2024, from https://www.kbeau.com/blogs/news/fast-fashion-in-the-jewelry-industry

Kemmlein, S., Hahn, O., & Jann, O. (2003). Emissions of organophosphate and brominated flame retardants from selected consumer products and building materials. Atmospheric Environment, 37(39–40), 5485–5493. https://doi.org/10.1016/j.atmosenv.2003.09.025

Kern, M. S., Boron, M. L., & Weidenhamer, J. D. (2021). Buyer beware: Inexpensive, high cadmium jewelry can pose severe health risks. Science of The Total Environment, 764, 142926. https://doi.org/10.1016/j.scitotenv.2020.142926

Kim, S. R., Halden, R. U., & Buckley, T. J. (2007). Volatile Organic Compounds in Human Milk: Methods and Measurements. Environmental Science & Technology, 41(5), 1662–1667. https://doi.org/10.1021/es062362y

King County. (2015). Healthy Nail Salon Project Reducing Chemical Exposures in Nail Salons. https://www.healthandenvironment.org/docs/NailSalons2015-1-8.pdf

King County Parks. (2024). Personal Communication - Claire Jonson.

Kissel, J. C., Titaley, I. A., Muensterman, D. J., & Field, J. A. (2023). Evaluating Neutral PFAS for Potential Dermal Absorption from the Gas Phase. Environmental Science & Technology, 57(12), 4951–4958. https://doi.org/10.1021/acs.est.2c08835

Kohler, M., Tremp, J., Zennegg, M., Seiler, C., Minder-Kohler, S., Beck, M., Lienemann, P., Wegmann, L., & Schmid, P. (2005). Joint Sealants: An Overlooked Diffuse Source of Polychlorinated Biphenyls in Buildings. Environmental Science & Technology, 39(7), 1967–1973. https://doi.org/10.1021/es048632z

Kole, P. J., Van Belleghem, F. G. A. J., Stoorvogel, J. J., Ragas, A. M. J., & Löhr, A. J. (2023). Tyre granulate on the loose; How much escapes the turf? A systematic literature review. Science of The Total Environment, 903, 166221. https://doi.org/10.1016/j.scitotenv.2023.166221

Kop Coat Marine Group. (2020). Advanced Hybrid Sealant - White. https://pettitpaint.com/media/4897/pettit-sds-advanced-hybrid-sealant-white.pdf

Kuribara, I., Kajiwara, N., Sakurai, T., Kuramochi, H., Motoki, T., Suzuki, G., Wada, T., Sakai, S., & Takigami, H. (2019). Time series of hexabromocyclododecane transfers from flame-retarded curtains to attached dust. Science of The Total Environment, 696, 133957. https://doi.org/10.1016/j.scitotenv.2019.133957

Lambert. (2008). Polyrthylene composition for artificial turf - US2008/0090955A1. United States. https://peer.org/wp-content/uploads/2019/10/US20080090955A1.pdf

Lanco Mfg. Corp. (2016a). Acrylic Plus White. https://www.lancopaints.com/usa/wp-content/uploads/sites/7/2017/08/SDS-Acrylic-Plus-Caulk-CC757-EN.pdf

Lanco Mfg. Corp. (2016b). Latex Sealant. https://www.lancopaints.com/usa/wp-content/uploads/sites/7/2017/08/SDS-Acrylic-Painters-Caulk-20yrs-CC756-USA-EN-1.pdf

Lauria, M. Z., Naim, A., Plassmann, M., Fäldt, J., Sühring, R., & Benskin, J. P. (2022). Widespread Occurrence of Non-Extractable Fluorine in Artificial Turfs from Stockholm, Sweden. Environmental Science & Technology Letters, 9(8), 666–672. https://doi.org/10.1021/acs.estlett.2c00260

Li, J., Zhao, L., Letcher, R. J., Zhang, Y., Jian, K., Zhang, J., & Su, G. (2019). A review on organophosphate Ester (OPE) flame retardants and plasticizers in foodstuffs: Levels, distribution, human dietary exposure, and future directions. Environment International, 127, 35–51. https://doi.org/10.1016/j.envint.2019.03.009

Li, Y., Wang, X., Zhu, Q., Xu, Y., Fu, Q., Wang, T., Liao, C., & Jiang, G. (2023). Organophosphate Flame Retardants in Pregnant Women: Sources, Occurrence, and Potential Risks to Pregnancy Outcomes. Environmental Science & Technology, 57(18), 7109–7128. https://doi.org/10.1021/acs.est.2c06503

Liang, Y., Liu, X., & Allen, M. R. (2018). Measurements of Parameters Controlling the Emissions of Organophosphate Flame Retardants in Indoor Environments. Environmental Science & Technology, 52(10), 5821–5829. https://doi.org/10.1021/acs.est.8b00224

Lin, Y. S., Egeghy, P. P., & Rappaport, S. M. (2008). Relationships between levels of volatile organic compounds in air and blood from the general population. Journal of Exposure Science & Environmental Epidemiology, 18(4), 421–429. https://doi.org/10.1038/sj.jes.7500635

Liu, S., Wang, C., Yang, Y., Du, Z., Li, L., Zhang, M., Ni, S., Yue, Z., Yang, K., Wang, Y., Li, X., Yang, Y., Qin, Y., Li, J., Yang, Y., & Zhang, M. (2024). Microplastics in three types of human arteries detected by pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS). Journal of Hazardous Materials, 469, 133855. https://doi.org/10.1016/j.jhazmat.2024.133855

Liu, Y., Lin, A., Thompson, J., Bowden, J. A., & Townsend, T. G. (2024). Per- and polyfluoroalkyl substances (PFAS) in construction and demolition debris (CDD): discerning sources and fate during waste management. Journal of Hazardous Materials, 472, 134567. https://doi.org/10.1016/j.jhazmat.2024.134567

Liu, Y., Zhang, J., Zhao, H., Cai, J., Sultan, Y., Fang, H., Zhang, B., & Ma, J. (2022). Effects of polyvinyl chloride microplastics on reproduction, oxidative stress and reproduction and detoxification-related genes in Daphnia magna. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology, 254, 109269. https://doi.org/10.1016/j.cbpc.2022.109269

Lopez-Galvez, N., Claude, J., Wong, P., Bradman, A., Hyland, C., Castorina, R., Canales, R. A., Billheimer, D., Torabzadeh, E., Leckie, J. O., & Beamer, P. I. (2022). Quantification and Analysis of Micro-Level Activities Data from Children Aged 1–12 Years Old for Use in the Assessments of Exposure to Recycled Tire on Turf and Playgrounds. International Journal of Environmental Research and Public Health, 19(4), 2483. https://doi.org/10.3390/ijerph19042483

M. Meijer. (2023). Results of Proficiency Test Total Metals in Metal/Metal Alloy. https://www.iisnl.com/pdf/iis23V24%20Report.pdf

Ma, G. X., Wei, Z., Husni, R., Do, P., Zhou, K., Rhee, J., Tan, Y., Navder, K., & Yeh, M.-C. (2019). Characterizing Occupational Health Risks and Chemical Exposures Among Asian Nail Salon Workers on the East Coast of the United States. Journal of Community Health, 44(6), 1168–1179. https://doi.org/10.1007/s10900-019-00702-0

Ma, T., Ye, C., Wang, T., Li, X., & Luo, Y. (2022). Toxicity of Per- and Polyfluoroalkyl Substances to Aquatic Invertebrates, Planktons, and Microorganisms. International Journal of Environmental Research and Public Health, 19(24), 16729. https://doi.org/10.3390/ijerph192416729

Malovanyy, A., Hedman, F., Bergh, L., Liljeros, E., Lund, T., Suokko, J., & Hinrichsen, H. (2023). Comparative study of per- and polyfluoroalkyl substances (PFAS) removal from landfill leachate. Journal of Hazardous Materials, 460, 132505. https://doi.org/10.1016/j.jhazmat.2023.132505

Manus Products, Inc. (2023). MANUS-BOND 75-AM N33-1 Fast Cure. https://www.manus.net/dp/path=/asset/sds/man-015-manus-bond-75-am-n33-1-sds.pdf

Mapei. (2009). Keracaulk S. https://www.whatsinproducts.com/brands/show_msds/1/10721

Marshall, A. T., Betts, S., Kan, E. C., McConnell, R., Lanphear, B. P., & Sowell, E. R. (2020). Association of lead-exposure risk and family income with childhood brain outcomes. Nature Medicine, 26(1), 91–97. https://doi.org/10.1038/s41591-019-0713-y

Mazumder, N.-U.-S., Hossain, M. T., Jahura, F. T., Girase, A., Hall, A. S., Lu, J., & Ormond, R. B. (2023). Firefighters' exposure to per-and polyfluoroalkyl substances (PFAS) as an occupational hazard: A review. Frontiers in Materials, 10. https://doi.org/10.3389/fmats.2023.1143411

McNary, J. E., & Jackson, E. M. (2007). Inhalation Exposure to Formaldehyde and Toluene in the Same Occupational and Consumer Setting. Inhalation Toxicology, 19(6–7), 573–576. https://doi.org/10.1080/08958370701270946

Meesters, J. A. J., Nijkamp, M. M., Schuur, A. G., & te Biesebeek, J. D. (2018). Cleaning Products Fact Sheet: Default parameters for estimating consumer exposure: Updated version 2018. https://www.ncbi.nlm.nih.gov/books/NBK561658/

Minet, L., Blum, A., Fernández, S. R., Rodgers, K. M., Singla, V., Soehl, A., & Diamond, M. L. (2021). High Production, Low Information: We Need To Know More About Polymeric Flame Retardants. Environmental Science & Technology, 55(6), 3467–3469. https://doi.org/10.1021/acs.est.0c08126

Mintel. (n.d.). Mintel Global New Products Database. Retrieved July 8, 2024, from https://www.mintel.com/products/gnpd/

Mishra, K. P., Singh, V. K., Rani, R., Yadav, V. S., Chandran, V., Srivastava, S. P., & Seth, P. K. (2003). Effect of lead exposure on the immune response of some occupationally exposed individuals. Toxicology, 188(2–3), 251–259. https://doi.org/10.1016/S0300-483X(03)00091-X

Mitro, S. D., Dodson, R. E., Singla, V., Adamkiewicz, G., Elmi, A. F., Tilly, M. K., & Zota, A. R. (2016). Consumer Product Chemicals in Indoor Dust: A Quantitative Meta-analysis of U.S. Studies. Environmental Science & Technology, 50(19), 10661–10672. https://doi.org/10.1021/acs.est.6b02023

Momentive. (2010). GE22764 Acrylic Latex Caulk. https://www.whatsinproducts.com/brands/show_msds/1/10903

Momentive. (2011). M90025 Silicone Sealant. https://www.whatsinproducts.com/brands/show_msds/1/10901

Mon-Eco. (2018). Mono-Tack Spray Adhesive 22-65. https://mon-ecoindustries.com/wp-content/uploads/2020/10/22-65-Safety-Data-Sheet.pdf

Morales-McDevitt, M. E., Becanova, J., Blum, A., Bruton, T. A., Vojta, S., Woodward, M., & Lohmann, R. (2021). The Air That We Breathe: Neutral and Volatile PFAS in Indoor Air. Environmental Science & Technology Letters, 8(10), 897–902. https://doi.org/10.1021/acs.estlett.1c00481

Murphy, M., & Warner, G. R. (2022). Health impacts of artificial turf: Toxicity studies, challenges, and future directions. Environmental Pollution, 310, 119841. https://doi.org/10.1016/j.envpol.2022.119841

Nails Magazine. (2018). 2017-2018 Industry Statistics Highlights. https://beautyimages.bobitstudios.com/upload/_migratednails/files/Handouts/NABB2017-18stats-LR.pdf

Nails Magazine. (2019, December). Nails Magazine December 2019 Issue. https://www.nailsmag.com/magazines/nails-magazine/2019-12

Nails Magazine. (2023). Kid's Manicure Services Are Part of Back-to-School Prep. https://www.nailsmag.com/1088406/kids-services-a-back-to-school-report

NAMBA. (2020). Facts About Flame Retardants & Foam Plastic Insulation. https://www.modernbuildingalliance.us/wp-content/uploads/3-Facts-About-Flame-Retardants.pdf

Naranjo, V. I., Hendricks, M., & Jones, K. S. (2020). Lead Toxicity in Children: An Unremitting Public Health Problem. Pediatric Neurology, 113, 51–55. https://doi.org/10.1016/j.pediatrneurol.2020.08.005

Nassco Inc. (2023). Para Urinal Block 4 oz. https://www.nasscoinc.com/SDS/N-02073/SDS%20Sheet/Para4oz.pdf

National Association of the Remodeling Industry. (2015). Net Zero Energy Homes. https://www.nari.org/Remodelers-Contractors/Other-Resources/NARI-Blog/March-2015/Net-Zero-Energy-Homes

National Toxicology Program. (2021). Report on Carcinogens, Fifteenth Edition. https://www.ncbi.nlm.nih.gov/books/NBK590769/

Negev, M., Berman, T., Goulden, S., Reicher, S., Barnett-Itzhaki, Z., Ardi, R., Shammai, Y., & Diamond, M. L. (2022). Lead in children's jewelry: the impact of regulation. Journal of Exposure Science & Environmental Epidemiology, 32(1), 10–16. https://doi.org/10.1038/s41370-021-00308-6

Negev, M., Berman, T., Reicher, S., Sadeh, M., Ardi, R., & Shammai, Y. (2018). Concentrations of trace metals, phthalates, bisphenol A and flame-retardants in toys and other children's products in Israel. Chemosphere, 192, 217–224. https://doi.org/10.1016/j.chemosphere.2017.10.132

New Jersey DEP. (2023). PFAS in Artificial Turf - Technical Memorandum. https://dep.nj.gov/wp-content/uploads/dsr/pfas-artificial-turf-memo-2023.pdf

Nguyen, V. K., Kahana, A., Heidt, J., Polemi, K., Kvasnicka, J., Jolliet, O., & Colacino, J. A. (2020). A comprehensive analysis of racial disparities in chemical biomarker concentrations in United States women, 1999–2014. Environment International, 137, 105496. https://doi.org/10.1016/j.envint.2020.105496

Niinimäki, K., Peters, G., Dahlbo, H., Perry, P., Rissanen, T., & Gwilt, A. (2020). The environmental price of fast fashion. Nature Reviews Earth & Environment, 1(4), 189–200. https://doi.org/10.1038/s43017-020-0039-9

NIOSH. (2019). Evaluation of Ergonomics, Chemical Exposures, and Ventilation at Four Nail Salons. https://www.cdc.gov/niosh/hhe/reports/pdfs/2015-0139-3338.pdf

NLM. (n.d.). Phthalic acid. PubChem. Retrieved June 7, 2023, from https://pubchem.ncbi.nlm.nih.gov/compound/1017

Nored, A. W., Shedd, J. S., Chalbot, M.-C. G., & Kavouras, I. G. (2022). On the Role of Atmospheric Weathering on Paint Dust Aerosol Generated by Mechanical Abrasion of TiO2 Containing Paints. International Journal of Environmental Research and Public Health, 19(3), 1265. https://doi.org/10.3390/ijerph19031265

Nosova, A. O., & Uspenskaya, M. V. (2023). Ecotoxicological effects and detection features of polyvinyl chloride microplastics in soils: A review. Environmental Advances, 13, 100437. https://doi.org/10.1016/j.envadv.2023.100437

NRDC. (2007). Clearing the Air - Hidden Hazards of Air Fresheners. https://www.nrdc.org/sites/default/files/airfresheners.pdf

NTP. (2019). NTP Research Report on the Chemical and Physical Characterization of Recycled Tire Crumb Rubber. https://doi.org/10.22427/NTP-RR-11

OECD. (2022). Per- and Polyfluoroalkyl Substances and Alternatives in Coatings, Paints and Varnishes (CPVs). https://doi.org/https://doi.org/10.1787/6745457d-en

OEHHA. (2019). Synthetic Turf Scientific Advisory Panel Meeting - Meeting Materials. https://oehha.ca.gov/media/downloads/crnr/may2019turfappendicespdf.pdf

OFM. (2019). Distribution of Washington population by age and gender. https://ofm.wa.gov/washington-data-research/statewide-data/washington-trends/population-changes/distribution-washington-population-age-and-gender

Owens Corning. (2023). Foamular NGX Extruded Polystyrene Insulation. https://hpdrepository.hpd-collaborative.org/repository/HPDs/446_Foamular_NGX_Extruded_Polystyrene_Insulation.pdf

PaintCare. (2024). Washington Paint Stewardship Program 2023 Annual Report. https://www.paintcare.org/wp-content/uploads/docs/wa-annual-report-2023.pdf

Paisley, K. (2007). PVDC - New Developments, New Opportunities. https://www.tappi.org/content/events/07place/papers/paisley.pdf

Parcheta-Szwindowska, P., Habaj, J., Krzemińska, I., & Datta, J. (2024). A Comprehensive Review of Reactive Flame Retardants for Polyurethane Materials: Current Development and Future Opportunities in an Environmentally Friendly Direction. International Journal of Molecular Sciences, 25(10), 5512. https://doi.org/10.3390/ijms25105512

Parks, J., McCandless, L., Dharma, C., Brook, J., Turvey, S. E., Mandhane, P., Becker, A. B., Kozyrskyj, A. L., Azad, M. B., Moraes, T. J., Lefebvre, D. L., Sears, M. R., Subbarao, P., Scott, J., & Takaro, T. K. (2020). Association of use of cleaning products with respiratory health in a Canadian birth cohort. Canadian Medical Association Journal, 192(7), E154–E161. https://doi.org/10.1503/cmaj.190819

Patil, A.J., Bhagwat, V.R., Patil, J.A., Dongre, N.N., Ambekar, J.G., & Das, Kusal K. (2007). Occupational lead exposure in battery manufacturing workers, silver jewelry workers, and spray painters in western Maharashtra (India): effect on liver and kidney function. Journal of Basic and Clinical Physiology and Pharmacology, 18(2), 87–100. https://doi.org/10.1515/JBCPP.2007.18.2.87

Payne-Sturges, D. C., Taiwo, T. K., Ellickson, K., Mullen, H., Tchangalova, N., Anderko, L., Chen, A., & Swanson, M. (2023). Disparities in Toxic Chemical Exposures and Associated Neurodevelopmental Outcomes: A Scoping Review and Systematic Evidence Map of the Epidemiological Literature. Environmental Health Perspectives, 131(9). https://doi.org/10.1289/EHP11750

Peckham, T., & Stephan-Recaido, S. (2023). Estimating the Burden of Occupational Exposures in King County Among All Workers and by Race/Ethnicity: A Job-Exposure Matrix-Based Approach. https://kingcountyhazwastewa.gov/-/media/hazwaste/lhwmp-documents/technical-reports/rsh-estimating-burden-of-occupational-exposure.pdf

Phillips, A. L., Hammel, S. C., Hoffman, K., Lorenzo, A. M., Chen, A., Webster, T. F., & Stapleton, H. M. (2018). Children's residential exposure to organophosphate ester flame retardants and plasticizers: Investigating exposure pathways in the TESIE study. Environment International, 116, 176–185. https://doi.org/10.1016/j.envint.2018.04.013

Pivnenko, K., Granby, K., Eriksson, E., & Astrup, T. F. (2017). Recycling of plastic waste: Screening for brominated flame retardants (BFRs). Waste Management, 69, 101–109. https://doi.org/10.1016/j.wasman.2017.08.038

Plastic Ingenuity. (n.d.). Wahl Transforms Their Packaging from PVC to PET. Retrieved July 29, 2024, from https://www.plasticingenuity.com/customer-story/wahl-pet-packaging/

Plastic Ingenuity. (2022). #3 PVC – Packaging Polymer Series. https://www.plasticingenuity.com/blog/3-pvc-packaging-polymer-series/

Poppendieck, D., Gong, M., & Emmerich, S. (2017). Characterization of emissions from spray polyurethane foam - final report to U.S. Consumer Product Safety Commission. https://doi.org/10.6028/NIST.TN.1921

Poppendieck, D., Gong, M., Zimmerman, S., & Ng, L. (2021). Evaluation of a four-zone indoor exposure model for predicting TCPP concentrations in a low-energy test house. Building and Environment, 199, 107888. https://doi.org/10.1016/j.buildenv.2021.107888

PubChem. (n.d.-a). 1,4-Dichlorobenzene. Retrieved August 13, 2024, from https://pubchem.ncbi.nlm.nih.gov/compound/1_4-Dichlorobenzene

PubChem. (n.d.-b). Quaternium-15. Retrieved August 14, 2024, from https://pubchem.ncbi.nlm.nih.gov/compound/Quaternium-15#section=Environmental-Fate

Quach, T., Gunier, R., Tran, A., Von Behren, J., Doan-Billings, P.-A., Nguyen, K.-D., Okahara, L., Lui, B. Y.-B., Nguyen, M., Huynh, J., & Reynolds, P. (2011). Characterizing Workplace Exposures in Vietnamese Women Working in California Nail Salons. American Journal of Public Health, 101(S1), S271–S276. https://doi.org/10.2105/AJPH.2010.300099

Radke, E. G., Braun, J. M., Meeker, J. D., & Cooper, G. S. (2018). Phthalate exposure and male reproductive outcomes: A systematic review of the human epidemiological evidence. Environment International, 121, 764–793. https://doi.org/10.1016/j.envint.2018.07.029

Radke, E. G., Glenn, B. S., Braun, J. M., & Cooper, G. S. (2019). Phthalate exposure and female reproductive and developmental outcomes: a systematic review of the human epidemiological evidence. Environment International, 130, 104580. https://doi.org/10.1016/j.envint.2019.02.003

Ragnarsdóttir, O., Abdallah, M. A.-E., & Harrad, S. (2022). Dermal uptake: An important pathway of human exposure to perfluoroalkyl substances? Environmental Pollution, 307, 119478. https://doi.org/10.1016/j.envpol.2022.119478

Ragnarsdóttir, O., Abou-Elwafa Abdallah, M., & Harrad, S. (2024). Dermal bioavailability of perfluoroalkyl substances using in vitro 3D human skin equivalent models. Environment International, 188, 108772. https://doi.org/10.1016/j.envint.2024.108772

Rawn, D. F. K., Corrigan, C., Ménard, C., Sun, W.-F., Breton, F., & Arbuckle, T. E. (2024). Novel halogenated flame retardants in Canadian human milk from the MIREC study (2008–2011). Chemosphere, 350, 141065. https://doi.org/10.1016/j.chemosphere.2023.141065

Raysoni, A. U., Stock, T. H., Sarnat, J. A., Chavez, M. C., Sarnat, S. E., Montoya, T., Holguin, F., & Li, W.-W. (2017). Evaluation of VOC concentrations in indoor and outdoor microenvironments at near-road schools. Environmental Pollution, 231, 681–693. https://doi.org/10.1016/j.envpol.2017.08.065

Red Devil Inc. (2013). Advanced Kitchen & Bath Sealant. https://www.whatsinproducts.com/brands/show_msds/1/18035

Red Devil Inc. (2017). 0970 & 0971 & 0972 Polyurethane Sealants. https://www.reddevil.com/Portals/0/Documents/SDS/0970%20&%200971%20&%200972%20-%20Polyurethane%20Sealants%20-%20sds.pdf

Red Devil Inc. (2018). Strong Bond Heavy-Duty Adhesive & Sealant-White. https://www.reddevil.com/Portals/0/Documents/SDS/0956%20-%20Strong%20Bond%E2%84%A2%20Heavy-Duty%20Adhesive%20&%20Sealant%20-%20sds.pdf

Reddick, R. S. (2023). Filler for artificial turf system - US7858148B2. United States. https://patents.google.com/patent/US7858148B2/en

Re-Match. (n.d.). True Recycling. Retrieved August 12, 2024, from https://re-match.com/turf-recycling/

Remy, N., Speelman, E., & Swartz, S. (2016). Style that’s sustainable: A new fast-fashion formula. McKinsey Sustainability. https://www.mckinsey.com/capabilities/sustainability/our-insights/style-thats-sustainable-a-new-fast-fashion-formula

Resene. (n.d.). Paint Chalking - removal & paint preparation. Retrieved October 7, 2024, from https://www.resene.co.nz/homeown/problem-solver/chalking.htm

Rice, P. A., Aungst, J., Cooper, J., Bandele, O., & Kabadi, S. V. (2020). Comparative analysis of the toxicological databases for 6:2 fluorotelomer alcohol (6:2 FTOH) and perfluorohexanoic acid (PFHxA). Food and Chemical Toxicology, 138, 111210. https://doi.org/10.1016/j.fct.2020.111210

Rodriguez, C., Linge, K., Blair, P., Busetti, F., Devine, B., Van Buynder, P., Weinstein, P., & Cook, A. (2012). Recycled water: Potential health risks from volatile organic compounds and use of 1,4-dichlorobenzene as treatment performance indicator. Water Research, 46(1), 93–106. https://doi.org/10.1016/j.watres.2011.10.032

Salles, F. J., Sato, A. P. S., Luz, M. S., Fávaro, D. I. T., Ferreira, F. J., da Silva Paganini, W., & Olympio, K. P. K. (2018). The environmental impact of informal and home productive arrangement in the jewelry and fashion jewelry chain on sanitary sewer system. Environmental Science and Pollution Research, 25(11), 10701–10713. https://doi.org/10.1007/s11356-018-1357-z

Salles, F. J., Tavares, D. J. B., Freire, B. M., Ferreira, A. P. S. da S., Handakas, E., Batista, B. L., & Olympio, K. P. K. (2021). Home-based informal jewelry production increases exposure of working families to cadmium. Science of The Total Environment, 785, 147297. https://doi.org/10.1016/j.scitotenv.2021.147297

Salthammer, T. (2022). Microplastics and their Additives in the Indoor Environment. Angewandte Chemie International Edition, 61(32). https://doi.org/10.1002/anie.202205713

Santa Clara County Medical Association. (2024). RE: Recommendation to use Natural Turf Grass on Santa Clara County Fairgrounds. https://www.sccma.org/LinkClick.aspx?fileticket=C0f6wf5p9uY%3D&portalid=19

Savvaides, T., Koelmel, J. P., Zhou, Y., Lin, E. Z., Stelben, P., Aristizabal-Henao, J. J., Bowden, J. A., & Godri Pollitt, K. J. (2021). Prevalence and Implications of Per- and Polyfluoroalkyl Substances (PFAS) in Settled Dust. Current Environmental Health Reports, 8(4), 323–335. https://doi.org/10.1007/s40572-021-00326-4

Sax, S. N., Bennett, D. H., Chillrud, S. N., Ross, J., Kinney, P. L., & Spengler, J. D. (2006). A Cancer Risk Assessment of Inner-City Teenagers Living in New York City and Los Angeles. Environmental Health Perspectives, 114(10), 1558–1566. https://doi.org/10.1289/ehp.8507

SBCC. (2024). State Building Code. https://sbcc.wa.gov/state-codes-regulations-guidelines/state-building-code

Schecter, A., Haffner, D., Colacino, J., Patel, K., Päpke, O., Opel, M., & Birnbaum, L. (2010). Polybrominated Diphenyl Ethers (PBDEs) and Hexabromocyclodecane (HBCD) in Composite U.S. Food Samples. Environmental Health Perspectives, 118(3), 357–362. https://doi.org/10.1289/ehp.0901345

Schneider, K., de Hoogd, M., Haxaire, P., Philipps, A., Bierwisch, A., & Kaiser, E. (2020). ERASSTRI - European Risk Assessment Study on Synthetic Turf Rubber Infill – Part 2: Migration and monitoring studies. Science of The Total Environment, 718, 137173. https://doi.org/10.1016/j.scitotenv.2020.137173

Schneider, K., de Hoogd, M., Madsen, M. P., Haxaire, P., Bierwisch, A., & Kaiser, E. (2020). ERASSTRI - European Risk Assessment Study on Synthetic Turf Rubber Infill – Part 1: Analysis of infill samples. Science of The Total Environment, 718, 137174. https://doi.org/10.1016/j.scitotenv.2020.137174

Schreder, E. D., & La Guardia, M. J. (2014). Flame Retardant Transfers from U.S. Households (Dust and Laundry Wastewater) to the Aquatic Environment. Environmental Science & Technology, 48(19), 11575–11583. https://doi.org/10.1021/es502227h

Schreder, E. D., Uding, N., & La Guardia, M. J. (2016). Inhalation a significant exposure route for chlorinated organophosphate flame retardants. Chemosphere, 150, 499–504. https://doi.org/10.1016/j.chemosphere.2015.11.084

Schwensen, J. F., Friis, U. F., Menné, T., Flyvholm, M.-A., & Johansen, J. D. (2017). Contact allergy to preservatives in patients with occupational contact dermatitis and exposure analysis of preservatives in registered chemical products for occupational use. International Archives of Occupational and Environmental Health, 90(4), 319–333. https://doi.org/10.1007/s00420-017-1203-5

Science Direct. (n.d.). Polyvinylidene Chloride. Retrieved July 29, 2024, from https://www.sciencedirect.com/topics/engineering/polyvinylidene-chloride

Sears, C. G., Lanphear, B. P., Calafat, A. M., Chen, A., Skarha, J., Xu, Y., Yolton, K., & Braun, J. M. (2020). Lowering Urinary Phthalate Metabolite Concentrations among Children by Reducing Contaminated Dust in Housing Units: A Randomized Controlled Trial and Observational Study. Environmental Science & Technology, 54(7), 4327–4335. https://doi.org/10.1021/acs.est.9b04898

Seattle Parks and Recreation. (2024). Personal Communication - Laura Locklear.

Sexton, K., Adgate, J. L., Church, T. R., Ashley, D. L., Needham, L. L., Ramachandran, G., Fredrickson, A. L., & Ryan, A. D. (2005). Children's Exposure to Volatile Organic Compounds as Determined by Longitudinal Measurements in Blood. Environmental Health Perspectives, 113(3), 342–349. https://doi.org/10.1289/ehp.7412

Sharma, P., Waheed, S., Nguyen, V., Stepick L., Orellana, R., Katz, L., Kim, S., & Lapira, K. (2018). Nail Files: A Study of Nail Salon Workers and Industry in the United States. https://www.labor.ucla.edu/wp-content/uploads/2018/11/NAILFILES_FINAL.pdf

Sherwin-Williams. (n.d.). How to Fix Exterior Paint Chalking. Retrieved October 7, 2024, from https://www.sherwin-williams.com/en-us/project-center/maintenance-repair/paint-chalking

Siemiatycki, J., & Lavoué, J. (2018). Availability of a New Job-Exposure Matrix (CANJEM) for Epidemiologic and Occupational Medicine Purposes. Journal of Occupational & Environmental Medicine, 60(7), e324–e328. https://doi.org/10.1097/JOM.0000000000001335

Sika Corporation. (2017). Sarnacol 2121 Membrane Adhesive. https://usa.sika.com/dam/dms/us01/d/Sarnacol-2121-Membrane-Adhesive.pdf

Siliketech. (2024). PFAS-free PPA Polymer Processing Aids – Why Use Them and What's the Concern with PFAS? https://www.siliketech.com/news/pfas-free-ppa-polymer-processing-aids-why-use-them-and-whats-the-concern-with-pfas/

Siroflex Inc. (2015). Hybri-Sil. https://www.bostik.com/files/live/sites/shared_bostik/files/documents-brochures/united-states/Documents/SDS/hybri-sil-sds.pdf

Sobhani, Z., Lei, Y., Tang, Y., Wu, L., Zhang, X., Naidu, R., Megharaj, M., & Fang, C. (2020). Microplastics generated when opening plastic packaging. Scientific Reports, 10(1), 4841. https://doi.org/10.1038/s41598-020-61146-4

Solvay. (2018). Diofan® PVDC for Thermoformed and Blister Packaging. https://www.solvay.com/sites/g/files/srpend221/files/2018-10/Diofan-PVDC-Thermoformed-and-Blister-Packaging_EN-2.5_0.pdf

Soprema. (2024). SOPRA-ISO V PLUS. https://hpdrepository.hpd-collaborative.org/repository/HPDs/124_SOPRA_ISO_V_PLUS.pdf

Southern Resident Orca Recovery. (n.d.). Identify, prioritize, and take action on chemicals that impact orcas and their prey. Retrieved July 29, 2024, from https://orca.wa.gov/recommendation/30/

SpecialChem. (n.d.). Oceanchem - Hexabromocyclododecane (HBCD). Retrieved August 18, 2024, from https://polymer-additives.specialchem.com/product/a-oceanchem-group-oceanchem-hexabromocyclododecane-hbcd

SPFA. (2013). Life Cycle Assessment of Spray Polyurethane Foam Insulation for Residential & Commercial Building Applications. https://polo14.com/wp-content/uploads/2020/03/SPFA-LCA-Details.pdf

Stapleton, H. M., Allen, J. G., Kelly, S. M., Konstantinov, A., Klosterhaus, S., Watkins, D., McClean, M. D., & Webster, T. F. (2008). Alternate and New Brominated Flame Retardants Detected in U.S. House Dust. Environmental Science & Technology, 42(18), 6910–6916. https://doi.org/10.1021/es801070p

Stapleton, H. M., Misenheimer, J., Hoffman, K., & Webster, T. F. (2014). Flame retardant associations between children’s handwipes and house dust. Chemosphere, 116, 54–60. https://doi.org/10.1016/j.chemosphere.2013.12.100

State of California. (n.d.). ARTICLE 10.1.1. Metal-Containing Jewelry [25214.1 - 25214.4.2]. Retrieved July 28, 2024, from https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=HSC&division=20.&title=&part=&chapter=6.5.&article=10.1.1

Statista. (n.d.-a). Beauty & Personal Care - United States. Retrieved July 10, 2024, from https://www.statista.com/outlook/cmo/beauty-personal-care/united-states

Statista. (n.d.-b). Jewelry - Worldwide. Retrieved July 28, 2024, from https://www.statista.com/outlook/cmo/accessories/watches-jewelry/jewelry/worldwide

Statista. (n.d.-c). Statista - The Statistics Portal for Market Data, Market Research, and Market Studies.

Statista. (2018). Share of Americans who owned fashion jewelry in 2018, by age. https://www.statista.com/statistics/231407/people-who-bought-costume-jewelry-in-the-last-12-months-usa/

Statista. (2019). Average household expenditure on jewelry and watches in the United States from 2008 to 2018. https://www.statista.com/statistics/1075827/average-household-expenditure-on-jewelry-and-watches-us/

Statista. (2023). Average annual expenditure on laundry and cleaning supplies per consumer unit in the United States from 2007 to 2022. https://www.statista.com/statistics/305499/us-expenditure-on-laundry-and-cleaning-supplies/

Statista. (2024a). Home & Laundry Care - United States. https://www.statista.com/outlook/cmo/home-laundry-care/united-states

Statista. (2024b). Polyvinyl chloride production in the United States from 1990 - 2019. https://www.statista.com/statistics/975603/us-polyvinyl-chloride-production-volume/

Statista. (2024c). U.S. population: Usage of nail polish / nail care products from 2011 to 2024. https://www.statista.com/statistics/286905/usage-nail-polish-nail-care-products-us-trend/

Straits Research. (n.d.). Costume Jewelry Market. Retrieved July 28, 2024, from https://straitsresearch.com/report/costume-jewelry-market

Streicher-Porte, M., Buckenmayer, A., & Pfenninger, S. (2008). What goes around comes around? High levels of cadmium in low-cost jewelry. 2008 IEEE International Symposium on Electronics and the Environment, 1–5. https://doi.org/10.1109/ISEE.2008.4562946

Sun, C., Adhikari, K., & Koppel, K. (2015). An Exploratory Study of the Factors That May Affect Female Consumers’ Buying Decision of Nail Polishes. Cosmetics, 2(2), 187–195. https://doi.org/10.3390/cosmetics2020187

Sun, J., Sui, M., Wang, T., Teng, X., Sun, J., & Chen, M. (2024). Detection and quantification of various microplastics in human endometrium based on laser direct infrared spectroscopy. Science of The Total Environment, 906, 167760. https://doi.org/10.1016/j.scitotenv.2023.167760

Surendran, U., Jayakumar, M., Raja, P., Gopinath, G., & Chellam, P. V. (2023). Microplastics in terrestrial ecosystem: Sources and migration in soil environment. Chemosphere, 318, 137946. https://doi.org/10.1016/j.chemosphere.2023.137946

Synthetic Turf Council. (n.d.). Synthetic Turf Council - Frequently Asked Questions. Retrieved August 12, 2024, from https://webcache.googleusercontent.com/search?q=cache%3Ahttps%3A%2F%2Fwww.syntheticturfcouncil.org%2Fpage%2FFAQs&oq=cache%3Ahttps%3A%2F%2Fwww.syntheticturfcouncil.org%2Fpage%2FFAQs&gs_lcrp=EgZjaHJvbWUyBggAEEUYOTIGCAEQRRg60gEINTYyNGowajSoAgCwAgE&sourceid=chrome&ie=UTF-8

Synthetic Turf Council. (2020). Synthetic Turf Council (STC) Releases 2020 Synthetic Turf Market Report for North America. https://www.syntheticturfcouncil.org/news/512350/Synthetic-Turf-Council-STC-Releases-2020-Synthetic-Turf-Market-Report-for-North-America.htm

Temkin, A. M., Geller, S. L., Swanson, S. A., Leiba, N. S., Naidenko, O. V., & Andrews, D. Q. (2023). Volatile organic compounds emitted by conventional and “green” cleaning products in the U.S. market. Chemosphere, 341, 139570. https://doi.org/10.1016/j.chemosphere.2023.139570

TERA. (2016). Flame Retardant Exposure Assessment. https://www.cpsc.gov/s3fs-public/FR-exposure-assessment-contractor-report-18-09282016-with-cover.pdf

The Farnsworth Group. (n.d.). Looking Ahead: 10 DIY Statistics Shaping the Home Improvement Industry in 2022-2025. Retrieved October 7, 2024, from https://www.thefarnsworthgroup.com/blog/10-diy-statistics-shaping-home-improvement

The Home Depot. (2015). The Home Depot Announces Agreement to Acquire Interline Brands. https://ir.homedepot.com/news-releases/2015/07-22-2015-014515131

The Home Depot. (2019). Renown Para Urinal Toss Block 4 Oz – Cherry. https://content.interlinebrands.com/product/document/10113/108961_EPCRA.pdf

Tian, L., Zhao, S., Zhang, R., Lv, S., Chen, D., Li, J., Jones, K. C., Sweetman, A. J., Peng, P., & Zhang, G. (2024). Tire Wear Chemicals in the Urban Atmosphere: Significant Contributions of Tire Wear Particles to PM 2.5. Environmental Science & Technology. https://doi.org/10.1021/acs.est.4c04378

Tian, Z., Gonzalez, M., Rideout, C. A., Zhao, H. N., Hu, X., Wetzel, J., Mudrock, E., James, C. A., McIntyre, J. K., & Kolodziej, E. P. (2022). 6PPD-Quinone: Revised Toxicity Assessment and Quantification with a Commercial Standard. Environmental Science & Technology Letters, 9(2), 140–146. https://doi.org/10.1021/acs.estlett.1c00910

Tian, Z., Zhao, H., Peter, K. T., Gonzalez, M., Wetzel, J., Wu, C., et al. (2021). A ubiquitous tire rubber–derived chemical induces acute mortality in coho salmon. Science, 371(6525), 185–189. https://doi.org/10.1126/science.abd6951

Tolaymat, T., Robey, N., Krause, M., Larson, J., Weitz, K., Parvathikar, S., Phelps, L., Linak, W., Burden, S., Speth, T., & Krug, J. (2023). A critical review of perfluoroalkyl and polyfluoroalkyl substances (PFAS) landfill disposal in the United States. Science of The Total Environment, 905, 167185. https://doi.org/10.1016/j.scitotenv.2023.167185

Tran, T. M., Hoang, A. Q., Le, S. T., Minh, T. B., & Kannan, K. (2019). A review of contamination status, emission sources, and human exposure to volatile methyl siloxanes (VMSs) in indoor environments. Science of The Total Environment, 691, 584–594. https://doi.org/10.1016/j.scitotenv.2019.07.168

Trantallidi, M., Dimitroulopoulou, C., Wolkoff, P., Kephalopoulos, S., & Carrer, P. (2015). EPHECT III: Health risk assessment of exposure to household consumer products. Science of The Total Environment, 536, 903–913. https://doi.org/10.1016/j.scitotenv.2015.05.123

TRC Companies Inc. (2022). Evaluation of PFAS in Synthetic Turf - Technical Memorandum. https://www.cityofportsmouth.com/sites/default/files/2022-06/Technical%20Memorandum_Portsmouth_Final.pdf?fbclid=IwAR195I09bTItEjFzGoTum_I1hvbrXC9ew6S3SV0ufEVXg-g05V7AMFjYsUw

Tremco U.S. Sealants. (2015). Dymonic FC Aluminum Stone. https://www.tremcosealants.com/fileshare/msds/960851_323_U.pdf?v=fd70067b-2ca0-4468-b7b1-3b99cad6ed77

Tremco U.S. Sealants. (2018). TREMGRIP Gray Adh. 12 X 300 ML CTG. https://metrosealant.com/wp-content/uploads/2022/05/TREMGrip-SDS-1823543.pdf

Tremco U.S. Sealants. (2020). VULKEM 116 LV BRONZE 30 CTG/CS. https://www.tremcosealants.com/fileshare/msds/426719L_323_U.pdf?v=02aabcd2-4584-4bd7-8861-49e69d222a91

Triple S. (2015). Triple-S Para Blocks. https://triple-s.com/msds/80/83004_08061_08062_08063_08064_08065_08066_08067_08077_SSS%20Para%20Blocks_SDS.pdf

Tumu, K., Vorst, K., & Curtzwiler, G. (2024). Understanding intentionally and non-intentionally added substances and associated threshold of toxicological concern in post-consumer polyolefin for use as food packaging materials. Heliyon, 10(1), e23620. https://doi.org/10.1016/j.heliyon.2023.e23620

TURI. (2020). Per- and Poly-fluoroalkyl Substances (PFAS) in Artificial Turf Carpet. https://www.turi.org/publications/per-and-poly-fluoroalkyl-substances-pfas-in-artificial-turf-carpet/

Uline Inc. (2019). Para Urinal Blocks. https://www.uline.com/PDF/SS-8129.pdf?msockid=1e212d35851b66b700e33ee584a1676a

Uline Inc. (2020). Urinal Non-Para Block. https://www.uline.com/PDF/RS-19424.PDF

Unilever. (2012). UNILEVER SUSTAINABLE LIVING PLAN. https://www.unilever.com/files/92ui5egz/production/c9eee4b1879b6af98a4b7464d8f2d0b14e201a59.pdf

US BLS. (2024a). Labor Force Statistics from the Current Population Survey - 11. Employed persons by detailed occupation, sex, race, and Hispanic or Latino ethnicity. https://www.bls.gov/cps/cpsaat11.htm

US BLS. (2024b). Labor Force Statistics from the Current Population Survey - 18. Employed persons by detailed industry, sex, race, and Hispanic or Latino ethnicity. https://www.bls.gov/cps/cpsaat11.htm

US Bureau of Labor Statistics. (2024). Labor Force Statistics from the Current Population Survey - 18. Employed persons by detailed industry, sex, race, and Hispanic or Latino ethnicity. https://www.bls.gov/cps/cpsaat18.htm

US CDC. (2024a). Lead - Immigrant and Refugee Health. https://www.cdc.gov/immigrant-refugee-health/hcp/domestic-guidance/lead.html

US CDC. (2024b). Snohomish County, Washington. https://www.cdc.gov/lead-prevention/success-stories-by-state/snohomish-county-washington.html

US Census Bureau. (n.d.). U.S. Census Bureau QuickFacts: United States. Retrieved July 10, 2024, from https://www.census.gov/quickfacts/fact/table/US/PST045222

US Census Bureau. (2012). SB1200CSA01 - Statistics for All U.S. Firms by Industry, Gender, Ethnicity, and Race for the U.S., States, Metro Areas, Counties, and Places: 2012. https://data.census.gov/table?q=nail%20salon&t=Race%20and%20Ethnicity&g=040XX00US53&y=2012

US Census Bureau. (2017a). Economic Census - EC1700NAPCSPRDIND - Manufacturing of building and construction (polyurethane, polystyrene) foam products. https://data.census.gov/table/ECNNAPCSPRD2017.EC1700NAPCSPRDIND?napcs=2036475000:2036500000

US Census Bureau. (2017b). Economic Census - EC1700NAPCSPRDIND - Retail sales costume and novelty jewelry. https://data.census.gov/table/ECNNAPCSPRD2017.EC1700NAPCSPRDIND?napcs=5000455000

US Census Bureau. (2024). State Population Totals and Components of Change: 2020-2023. https://www.census.gov/data/tables/time-series/demo/popest/2020s-state-total.html

US Dept. of Energy. (n.d.-a). Insulation. Retrieved August 18, 2024, from https://www.energy.gov/energysaver/insulation

US Dept. of Energy. (n.d.-b). Insulation Materials. Retrieved August 18, 2024, from https://www.energy.gov/energysaver/insulation-materials

US Dept. of Energy. (n.d.-c). Types of Insulation. Retrieved August 18, 2024, from https://www.energy.gov/energysaver/types-insulation

US Dept. of Energy. (n.d.-d). Where to Insulate in a Home. Retrieved August 18, 2024, from https://www.energy.gov/energysaver/where-insulate-home

US EPA. (n.d.-a). ChemExpo. Retrieved July 8, 2024, from https://comptox.epa.gov/chemexpo/

US EPA. (n.d.-b). CompTox Chemicals Dashboard. Retrieved July 8, 2024, from https://comptox.epa.gov/dashboard/

US EPA. (2000a). Ethylene Dichloride (1,2-Dichloroethane). https://www.epa.gov/sites/default/files/2016-09/documents/ethylene-dichloride.pdf

US EPA. (2000b). Vinyl Chloride. https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/vinyl-chloride.pdf

US EPA. (2011a). Exposure Factors Handbook - Chapter 4—Non-Dietary Ingestion Factors. https://www.epa.gov/sites/default/files/2015-09/documents/efh-chapter04.pdf

US EPA. (2011b). Exposure Factors Handbook - Chapter 6—Inhalation Rates. https://www.epa.gov/sites/default/files/2015-09/documents/efh-chapter06.pdf

US EPA. (2011c). Exposure Factors Handbook - Chapter 17 - Consumer Products. https://www.epa.gov/sites/default/files/2015-09/documents/efh-chapter17.pdf

US EPA. (2014). FLAME RETARDANT ALTERNATIVES FOR HEXABROMOCYCLODODECANE (HBCD). https://www.epa.gov/sites/default/files/2014-06/documents/hbcd_report.pdf

US EPA. (2017). Update for Chapter 5 of the Exposure Factors Handbook. https://www.epa.gov/sites/default/files/2018-01/documents/efh-chapter05_2017.pdf

US EPA. (2019). Synthetic Turf Field Tire Crumb Rubber Research Under the Federal Research Action Plan - Final Report Part 1 – Tire Crumb Rubber Characterization Appendices Volume 2. https://www.epa.gov/sites/default/files/2019-08/documents/synthetic_turf_field_recycled_tire_crumb_rubber_research_under_the_federal_research_action_plan_final_report_part_1_volume_2.pdf

US EPA. (2020a). Final Scope of Risk Evaluation for Dibutyl Phthalate. https://www.epa.gov/sites/default/files/2020-09/documents/casrn_84-74-2_dibutyl_phthalate_final_scope_0.pdf

US EPA. (2020b). Use Report for p-Dichlorobenzene (CAS RN 106-46-7). https://www.regulations.gov/document/EPA-HQ-OPPT-2018-0446-0024

US EPA. (2022). HBCD - Unreasonable Risk Determination. https://www.epa.gov/system/files/documents/2022-06/HBCD_Final%20Revised%20URD_June%202022.pdf

US EPA. (2023a). Containers and Packaging: Product-Specific Data. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/containers-and-packaging-product-specific

US EPA. (2023b). IRIS Toxicological Review of Perfluorohexanoic Acid [PFHxA, CASRN 307-24-4] and Related Salts. https://iris.epa.gov/static/pdfs/0704_summary.pdf

US EPA. (2024a). Access Chemical Data Reporting Data. https://www.epa.gov/chemical-data-reporting/access-chemical-data-reporting-data

US EPA. (2024b). Complete List of VOC Exemption Rules. https://www.epa.gov/ground-level-ozone-pollution/complete-list-voc-exemption-rules

US EPA. (2024c). Exposure Assessment Tools by Chemical Classes - Other Organics. https://www.epa.gov/expobox/exposure-assessment-tools-chemical-classes-other-organics#phthalates

US EPA. (2024d). IRIS Toxicological Review of Formaldehyde (Inhalation). https://iris.epa.gov/static/pdfs/0419_summary.pdf

US EPA. (2024e). Learn About the Safer Choice Label. https://www.epa.gov/saferchoice/learn-about-safer-choice-label

US EPA. (2024f). Our Current Understanding of the Human Health and Environmental Risks of PFAS. https://www.epa.gov/pfas/our-current-understanding-human-health-and-environmental-risks-pfas

US EPA. (2024g). Phthalates. https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/phthalates

US EPA. (2024h). Risk Evaluation for Formaldehyde. https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/risk-evaluation-formaldehyde

US EPA. (2024i). Search Products that Meet the Safer Choice Standard. https://www.epa.gov/saferchoice/products

US EPA. (2024j). Synthetic Turf Field Recycled Tire Crumb Rubber Research Under the Federal Research Action Plan - Final Report Part 2 - Exposure Characterization Volume 1. https://www.epa.gov/system/files/documents/2024-04/tcrs-exposure-characterization-volume-1.pdf

US EPA. (2024k). Synthetic Turf Field Recycled Tire Crumb Rubber Research Under the Federal Research Action Plan - Final Report Part 2 - Exposure Characterization Volume 2. https://www.epa.gov/sites/default/files/2019-08/documents/synthetic_turf_field_recycled_tire_crumb_rubber_research_under_the_federal_research_action_plan_final_report_part_1_volume_2.pdf

US EPA. (2024l). Technical Overview of Volatile Organic Compounds. https://www.epa.gov/indoor-air-quality-iaq/technical-overview-volatile-organic-compounds

US FDA. (2023). Modernization of Cosmetics Regulation Act of 2022 (MoCRA). https://www.fda.gov/cosmetics/cosmetics-laws-regulations/modernization-cosmetics-regulation-act-2022-mocra

US FDA. (2024). Is it a Cosmetic, a Drug, or Both? (Or is it soap?). https://www.fda.gov/cosmetics/cosmetics-laws-regulations/it-cosmetic-drug-or-both-or-it-soap

US Plastics Pact. (2020). U.S. Plastics Pact - 2020 Baseline Report. https://usplasticspact.org/wp-content/uploads/2023/06/U.S.-Plastics-Pact-Baseline-Report-FINAL.pdf

Viñas, P., Campillo, N., Pastor-Belda, M., Oller, A., & Hernández-Córdoba, M. (2015). Determination of phthalate esters in cleaning and personal care products by dispersive liquid–liquid microextraction and liquid chromatography–tandem mass spectrometry. Journal of Chromatography A, 1376, 18–25. https://doi.org/10.1016/j.chroma.2014.12.012

Vinyl Institute. (n.d.). Vinyl (PVC) Packaging. Retrieved July 29, 2024, from https://www.vinylinfo.org/uses/packaging/

WA Department of Commerce. (2023). Washington state will need more than 1 million homes in next 20 years. https://www.commerce.wa.gov/washington-state-will-need-more-than-1-million-homes-in-next-20-years/

WA Labor & Industries. (2022). Washington State Janitorial Workload Study. https://lni.wa.gov/safety-health/safety-research/files/2022/102-124-2022%20Janitorial%20Workload%20Study.pdf

Wallace, L. A., Pellizzari, E. D., Hartwell, T. D., Davis, V., Michael, L. C., & Whitmore, R. W. (1989). The influence of personal activities on exposure to volatile organic compounds. Environmental Research, 50(1), 37–55. https://doi.org/10.1016/S0013-9351(89)80047-7

Wallington, T. J., Hurley, M. D., Xia, J., Wuebbles, D. J., Sillman, S., Ito, A., Penner, J. E., Ellis, D. A., Martin, J., Mabury, S. A., Nielsen, O. J., & Sulbaek Andersen, M. P. (2006). Formation of C7F15COOH (PFOA) and Other Perfluorocarboxylic Acids during the Atmospheric Oxidation of 8:2 Fluorotelomer Alcohol. Environmental Science & Technology, 40(3), 924–930. https://doi.org/10.1021/es051858x

Walmart. (n.d.). Sustainable Packaging Progress. Retrieved July 29, 2024, from https://www.walmartsustainabilityhub.com/waste/sustainable-packaging/progress

Wang, D.-G., Steer, H., Tait, T., Williams, Z., Pacepavicius, G., Young, T., Ng, T., Smyth, S. A., Kinsman, L., & Alaee, M. (2013). Concentrations of cyclic volatile methylsiloxanes in biosolid amended soil, influent, effluent, receiving water, and sediment of wastewater treatment plants in Canada. Chemosphere, 93(5), 766–773. https://doi.org/10.1016/j.chemosphere.2012.10.047

Wang, R., Moody, R. P., Koniecki, D., & Zhu, J. (2009). Low molecular weight cyclic volatile methylsiloxanes in cosmetic products sold in Canada: Implication for dermal exposure. Environment International, 35(6), 900–904. https://doi.org/10.1016/j.envint.2009.03.009

Wang, S.-W., Majeed, M. A., Chu, P.-L., & Lin, H.-C. (2009). Characterizing relationships between personal exposures to VOCs and socioeconomic, demographic, behavioral variables. Atmospheric Environment, 43(14), 2296–2302. https://doi.org/10.1016/j.atmosenv.2009.01.032

Wang, Y., Jiang, H., Ni, J., Chen, J., Zhou, H., Wang, X., & Xin, F. (2019). Study on the effect of PolyFR and its FR system on the flame retardancy and foaming behavior of polystyrene. RSC Advances, 9(1), 192–205. https://doi.org/10.1039/C8RA09680E

Washington Youth Soccer League. (n.d.). About Us - Washington Youth Soccer League. Retrieved August 12, 2024, from https://washingtonyouthsoccer.org/about-us/

Watersavers Turf. (n.d.). PFAS-Free Artificial Turf from Watersavers Turf. Retrieved August 12, 2024, from https://www.watersaversturf.com/about/artificial-grass-testing/pfas-free-artificial-turf/

Waxie Sanitary Supply. (2019). WAXIE-Green Urinal Screen w/ Deodorant Block Mango. https://www.waxie.com/pdf/ingredients/162057-WAXIE-Green-Urinal-Screen-with-Deodorant-Block-Mango-INGREDIENTS-DISCLOSURE-STATEMENT.pdf

WCRER. (2024). Washington State Housing Market Report - 2nd Quarter 2024. https://wcrer.be.uw.edu/wp-content/uploads/sites/60/2024/08/Washington-Housing-Market-Report-2nd-Quarter-2024.pdf

Weidenhamer, J. D., & Clement, M. L. (2007). Widespread lead contamination of imported low-cost jewelry in the US. Chemosphere, 67(5), 961–965. https://doi.org/10.1016/j.chemosphere.2006.10.071

Welch, B. M., Keil, A. P., Buckley, J. P., Calafat, A. M., Christenbury, K. E., Engel, S. M., et al. (2022). Associations Between Prenatal Urinary Biomarkers of Phthalate Exposure and Preterm Birth. JAMA Pediatrics, 176(9), 895. https://doi.org/10.1001/jamapediatrics.2022.2252

Welch, B. M., Keil, A. P., Buckley, J. P., Engel, S. M., James-Todd, T., Zota, A. R., et al. (2023). Racial and Ethnic Disparities in Phthalate Exposure and Preterm Birth: A Pooled Study of Sixteen U.S. Cohorts. Environmental Health Perspectives, 131(12). https://doi.org/10.1289/EHP12831

Weschler, C. J., Bekö, G., Koch, H. M., Salthammer, T., Schripp, T., Toftum, J., & Clausen, G. (2015). Transdermal Uptake of Diethyl Phthalate and Di(n -butyl) Phthalate Directly from Air: Experimental Verification. Environmental Health Perspectives, 123(10), 928–934. https://doi.org/10.1289/ehp.1409151

Willert Home Products. (2006). Willert Home Products. https://images.thdstatic.com/catalog/pdfImages/3e/3e61d154-85ed-4e4a-a750-905896d051bd.pdf

Wojnowska-Baryła, I., Bernat, K., & Zaborowska, M. (2022). Plastic Waste Degradation in Landfill Conditions: The Problem with Microplastics, and Their Direct and Indirect Environmental Effects. International Journal of Environmental Research and Public Health, 19(20), 13223. https://doi.org/10.3390/ijerph192013223

Won, D., Corsi, R. L., & Rynes, M. (2001). Sorptive Interactions between VOCs and Indoor Materials. Indoor Air, 11(4), 246–256. https://doi.org/10.1034/j.1600-0668.2001.110406.x

Wu, Q. (2016). Thermoplastic cellulosic fiber granules useful as infill materials for artificial turf - WO2016/205087A1. World Intellectual Property Organization. https://patents.google.com/patent/WO2016205087A1/en

Wu, X. (May), Bennett, D. H., Ritz, B., Cassady, D. L., Lee, K., & Hertz-Picciotto, I. (2010). Usage pattern of personal care products in California households. Food and Chemical Toxicology, 48(11), 3109–3119. https://doi.org/10.1016/j.fct.2010.08.004

Xu, G., Zhao, X., Zhao, S., Chen, C., Rogers, M. J., Ramaswamy, R., & He, J. (2021). Insights into the Occurrence, Fate, and Impacts of Halogenated Flame Retardants in Municipal Wastewater Treatment Plants. Environmental Science & Technology, 55(8), 4205–4226. https://doi.org/10.1021/acs.est.0c05681

Xu, S., Warner, N., Bohlin-Nizzetto, P., Durham, J., & McNett, D. (2019). Long-range transport potential and atmospheric persistence of cyclic volatile methylsiloxanes based on global measurements. Chemosphere, 228, 460–468. https://doi.org/10.1016/j.chemosphere.2019.04.130

Yeoman, A. M., Heeley-Hill, A. C., Shaw, M., Andrews, S. J., & Lewis, A. C. (2022). Inhalation of VOCs from facial moisturizers and the influence of dose proximity. Indoor Air, 32(1). https://doi.org/10.1111/ina.12948

York Daily Record. (2019). “Running out of room”: How old turf fields raise potential environmental, health concerns. https://www.ydr.com/in-depth/news/2019/11/18/old-artificial-turf-fields-pose-huge-waste-problem-environmental-concerns-across-nation/2314353001/

Yoshida, T., Mimura, M., & Sakon, N. (2021). Estimating household exposure to moth repellents p-dichlorobenzene and naphthalene and the relative contribution of inhalation pathway in a sample of Japanese children. Science of The Total Environment, 783, 146988. https://doi.org/10.1016/j.scitotenv.2021.146988

Yost, J. L., & Weidenhamer, J. D. (2008). Lead contamination of inexpensive plastic jewelry. Science of The Total Environment, 393(2–3), 348–350. https://doi.org/10.1016/j.scitotenv.2008.01.009

Young, A. S., Hauser, R., James-Todd, T. M., Coull, B. A., Zhu, H., Kannan, K., et al. (2021). Impact of “healthier” materials interventions on dust concentrations of per- and polyfluoroalkyl substances, polybrominated diphenyl ethers, and organophosphate esters. Environment International, 150, 106151. https://doi.org/10.1016/j.envint.2020.106151

Zhang, Y., Jiao, Y., Li, Z., Tao, Y., & Yang, Y. (2021). Hazards of phthalates (PAEs) exposure: A review of aquatic animal toxicology studies. Science of The Total Environment, 771, 145418. https://doi.org/10.1016/j.scitotenv.2021.145418

Zhao, F., Yao, J., Liu, X., Deng, M., Chen, X., Shi, C., Yao, L., Wang, X., & Fang, M. (2024). Occurrence and Oxidation Kinetics of Antioxidant p -Phenylenediamines and Their Quinones in Recycled Rubber Particles from Artificial Turf. Environmental Science & Technology Letters, 11(4), 335–341. https://doi.org/10.1021/acs.estlett.3c00948

Zhao, H. N., Hu, X., Gonzalez, M., Rideout, C. A., Hobby, G. C., Fisher, M. F., McCormick, C. J., Dodd, M. C., Kim, K. E., Tian, Z., & Kolodziej, E. P. (2023). Screening p-Phenylenediamine Antioxidants, Their Transformation Products, and Industrial Chemical Additives in Crumb Rubber and Elastomeric Consumer Products. Environmental Science & Technology, 57(7), 2779–2791. https://doi.org/10.1021/acs.est.2c07014

Zhong, L., Batterman, S., & Milando, C. W. (2019). VOC sources and exposures in nail salons: a pilot study in Michigan, USA. International Archives of Occupational and Environmental Health, 92(1), 141–153. https://doi.org/10.1007/s00420-018-1353-0

Zhou, W., Wang, P. G., Wittenberg, J. B., Rua, D., & Krynitsky, A. J. (2016). Simultaneous determination of cosmetics ingredients in nail products by fast gas chromatography with tandem mass spectrometry. Journal of Chromatography A, 1446, 134–140. https://doi.org/10.1016/j.chroma.2016.04.003

Zhu, L., Hajeb, P., Fauser, P., & Vorkamp, K. (2023). Endocrine disrupting chemicals in indoor dust: A review of temporal and spatial trends, and human exposure. Science of The Total Environment, 874, 162374. https://doi.org/10.1016/j.scitotenv.2023.162374

Zhu, L., Zhu, J., Zuo, R., Xu, Q., Qian, Y., & AN, L. (2023). Identification of microplastics in human placenta using laser direct infrared spectroscopy. Science of The Total Environment, 856, 159060. https://doi.org/10.1016/j.scitotenv.2022.159060

Ziani, K., Ioniță-Mîndrican, C.-B., Mititelu, M., Neacșu, S. M., Negrei, C., Moroșan, E., Drăgănescu, D., & Preda, O.-T. (2023). Microplastics: A Real Global Threat for Environment and Food Safety: A State of the Art Review. Nutrients, 15(3), 617. https://doi.org/10.3390/nu15030617

Zolotova, N., Kosyreva, A., Dzhalilova, D., Fokichev, N., & Makarova, O. (2022). Harmful effects of the microplastic pollution on animal health: a literature review. PeerJ, 10, e13503. https://doi.org/10.7717/peerj.13503

Zuccaro, P., Licato, J., Davidson, E. A., Thompson, D. C., & Vasiliou, V. (2023). Assessing extraction-analysis methodology to detect fluorotelomer alcohols (FTOH), a class of perfluoroalkyl and polyfluoroalkyl substances (PFAS), in artificial turf fibers and crumb rubber infill. Case Studies in Chemical and Environmental Engineering, 7, 100280. https://doi.org/10.1016/j.cscee.2022.100280

Zuri, G., Karanasiou, A., & Lacorte, S. (2023). Microplastics: Human exposure assessment through air, water, and food. Environment International, 179, 108150. https://doi.org/10.1016/j.envint.2023.108150

Appendix C. Existing and Pending Regulations

This appendix provides a non-exhaustive list of existing and pending regulations for new draft priority product chemical combinations. This isn't 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 didn't identify any regulations on formaldehyde in cleaning products. Other product chemical combinations are discussed below.

Organohalogen flame retardants (OFRs)

We didn't 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 C-20: Existing and proposed regulations for organohalogen flame retardants (OFRs) in relevant consumer products.

Entity	Year	Regulation or Policy	Requirements and standards	Source
CA	2003	AB 302[55]	Prohibits commercial products, or flame-retardant parts of products, containing more than 1/10 of 1% pentaBDE or octaBDE.	Safer States (SS)
HI	2004	HB 2013[56]	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.	SS
IL	2005	HB 2527[57]	Prohibits manufacture or distribution of commercial products, or flame-retardant parts of products, containing more than 1/10 of 1% pentaBDE or octaBDE.	SS
ME	2003	LD 1790[58]	Requires written notice from manufacturers or trade associations prior to the sale or distribution of products containing OFRs.	SS

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[55] http://www.leginfo.ca.gov/pub/03-04/bill/asm/ab_0301-0350/ab_302_bill_20030811_chaptered.html

[56] https://www.capitol.hawaii.gov/sessions/session2004/bills/HB2013_cd1_.htm

[57] https://legiscan.com/IL/bill/HB2527/2023

[58] https://www.mainelegislature.org/legis/bills/bills_121st/billtexts/LD179001-1.asp

Entity	Year	Regulation or Policy	Requirements and standards	Source
MI	2004	HB 4406[59]	Prohibits the manufacture, processing, or distribution of a product or material that contains more than 1/10 of 1% of penta-BDE.	SS
RI	2006	H 7917[60]	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.	SS
United Nations (UN)	2009	UN Stockholm Convention[61]	Listed in the Stockholm Convention under Annex A, to be eliminated from production and as possible by manufacturers and producers.	United Nations Environmental Programme (UNEP)

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[59] https://www.legislature.mi.gov/documents/2003-2004/publicact/pdf/2004-PA-0562.pdf

[60] http://webserver.rilin.state.ri.us/billtext06/housetext06/h7917a.pdf

[61] https://www.pops.int/Implementation/IndustrialPOPs/BDEs/Overview/tabid/5371/Default.aspx

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 C-21: Existing and proposed regulations for lead and cadmium in relevant consumer products.

Entity	Year	Regulation or Policy	Requirements and standards	Source
CA	2008	AB 2694[62]	Prohibits the sale or distribution of children's products containing lead.	SS
CA	2008	AB 2901[63]	Prohibits sale or distribution of jewelry unless made solely from specified materials.	SS
CA	2010	SB 929[64]	Prohibits the manufacturing, shipping, selling, offering for sale, or offering for promotional purposes children's jewelry that contains more than 0.03% cadmium by weight.	SS
CA	2010	SB 1365[65]	Prohibits the sale and distribution of a toy containing toxic substances to include lead.	SS
CA	2010	SB 929	Prohibits the sale and distribution of children's jewelry containing any component or material that is more than 0.03% cadmium by weight.	SS
CT	2010	HB 5314[66]	Bans Cadmium in children's products.	SS
CA	2019	SB 647[67]	Reduces the lead and cadmium content limits for children's jewelry. Went into effect June 1, 2020.	SS

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[62] https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=200720080AB2694

[63] http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_2901-2950/ab_2901_bill_20080929_chaptered.html

[64] https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=200920100SB929&search_keywords=cadmium

[65] http://www.leginfo.ca.gov/pub/09-10/bill/sen/sb_1351-1400/sb_1365_bill_20100927_chaptered.html

[66] https://www.cga.ct.gov/asp/cgabillstatus/cgabillstatus.asp?selBillType=Bill&bill_num=5314&which_year=2010&SUBMIT1.x=10&SUBMIT1.y=12

[67] https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201920200SB647

Entity	Year	Regulation or Policy	Requirements and standards	Source
CT	2008	B 5650[68]	Established standards governing the maximum allowable amount of lead in children's products.	SS
European Union (EU)	2018	Annex XVII[69]	Restricts use and sale of jewelry with a Cadmium concentration of equal or greater than 0.01% by weight of the metal.	European Chemicals Agency (ECHA)
EU	2018	Annex XVII	Restricts use and sale of jewelry with a Lead concentration of equal or greater than 0.05% by weight of the metal.	ECHA
IL	2006	410 ILCS 45/[70]	Restricts the sale and manufacture of lead-bearing children's products including jewelry.	Illinois General Assembly (IGA)
IL	2010	HB 5040[71]	Regulates the sale and distribution of children's products or product components containing cadmium and priority chemicals of high concern.	SS
MD	2011	HB 145[72]	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.	SS
ME	2008	HP 1497[73]	Informs the public of children's products containing lead and requests that stores carrying that product remove it from their shelves.	SS

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[68] https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201920200SB647

[69] https://echa.europa.eu/documents/10162/3bfef8a3-8c97-4d85-ae0b-ac6827de49a9

[70] https://www.ilga.gov/legislation/ILCS/ilcs3.asp?ActID=1523&ChapterID=35

[71] https://www.ilga.gov/legislation/billstatus.asp?DocNum=5040&GAID=10&GA=96&DocTypeID=HB&LegID=49618&SessionID=76

[72] https://mgaleg.maryland.gov/2022RS/fnotes/bil_0005/hb0145.pdf#:~:text=This%20bill%20authorizes%20the%20Commissioner%20of%20Labor%20and,may%20have%20violated%20the%20State%E2%80%99s%20prevailing%20wage%20law.

[73] https://www.mainelegislature.org/legis/bills/bills_123rd/billtexts/HP143701.asp

Entity	Year	Regulation or Policy	Requirements and standards	Source
MI	2007	HB 4132[74]	Prohibits the sale and distribution of children's jewelry containing lead.	SS
MN	2008	SF 1262[75]	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.	SS
MN	2008	SF 1262	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.	SS
NJ	2024	S 1085[76]	Introduced. Prohibits the sale, distribution, and manufacture of jewelry containing cadmium.	SS
NJ	2024	S 1713[77]	Introduced. Prohibits the sale of certain children's products containing lead, mercury, or cadmium.	SS
NJ	2024	A 3800[78]	Introduced. Bans certain children's products containing excessive amounts of lead, mercury, or cadmium.	SS
NJ	2024	A 3801[79]	Introduced. Prohibits the sale, distribution, and manufacture of jewelry containing cadmium.	SS
NY	2019	A 6296A[80]	Restricts the sale and distribution of children's products containing ingredients from the dangerous chemicals list including lead and cadmium.	SS
NY	2024	A 05751[81]	Imposes restrictions on lead-containing products and provides for a private right of action for violations.	SS

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[74] https://www.legislature.mi.gov/documents/2007-2008/publicact/htm/2007-PA-0161.htm
[75] https://www.revisor.mn.gov/bills/bill.php?b=senate&f=SF1262&ssn=0&y=2007
[76] https://www.njleg.state.nj.us/bill-search/2024/S1085
[77] https://www.njleg.state.nj.us/bill-search/2024/S1713
[78] https://www.njleg.state.nj.us/bill-search/2024/A3800
[79] https://www.njleg.state.nj.us/bill-search/2024/A3801
[80] https://www.nysenate.gov/legislation/bills/2019/A6296
[81] https://nyassembly.gov/leg/?default_fld=&leg_video=&bn=A05751&term=2023&Summary=Y&Text=Y

Entity	Year	Regulation or Policy	Requirements and standards	Source
OR	2015	SB 478[82]	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.	SS
VT	2014	S.239[83]	Restricts the sale of children's products containing chemicals of high concern to children. Including children's jewelry and heavy metals.	SS
DE	2008	HB 362[84]	Prohibits the sale and distribution of a toy containing a lead over the 0.06 limit set by 16 CFR 1303.	SS
EU	2018	Annex XVII[85]	Restricts use and sale of jewelry with a Cadmium concentration of equal or greater than 0.01% by weight of the metal.	ECHA
EU	2018	Annex XVII	Restricts use and sale of jewelry with a Lead concentration of equal or greater than 0.05% by weight of the metal.	ECHA
IL	2006	410 ILCS 45/[86]	Restricts the sale and manufacture of lead-bearing children's products including jewelry.	IGA
IL	2010	HB 5040[87]	Regulates the sale and distribution of children's products or product components containing cadmium and priority chemicals of high concern.	SS
MD	2011	HB 145[88]	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.	SS

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[82] https://olis.oregonlegislature.gov/liz/2015R1/Measures/Overview/SB478

[83] https://legislature.vermont.gov/Documents/2014/Docs/ACTS/ACT188/ACT188%20As%20Enacted.pdf

[84] https://legis.delaware.gov/BillDetail?legislationId=18228

[85] https://echa.europa.eu/documents/10162/3bfef8a3-8c97-4d85-ae0b-ac6827de49a9

https://www.ilga.gov/legislation/ILCS/ilcs3.asp?ActID=1523&ChapterID=35[86]

[87] https://www.ilga.gov/legislation/billstatus.asp?DocNum=5040&GAID=10&GA=96&DocTypeID=HB&LegID=49618&SessionID=76

[88] https://mgaleg.maryland.gov/mgawebsite/search/legislation?target=/2011rs/billfile/hb0145.htm

Entity	Year	Regulation or Policy	Requirements and standards	Source
ME	2008	HP 1437[89]	Informs the public of children's products containing lead and requests that stores carrying that product remove it from their shelves.	SS
MI	2007	HB 4132[90]	Prohibits the sale and distribution of children's jewelry containing lead.	SS
MN	2008	SF 1262[91]	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.	SS
MN	2008	SF 1262	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.	SS
NJ	2024	S 1085[92]	Introduced. Prohibits the sale, distribution, and manufacture of jewelry containing cadmium.	SS
NJ	2024	S 1713[93]	Introduced. Prohibits the sale of certain children's products containing lead, mercury, or cadmium.	SS
NJ	2024	A 3800[94]	Introduced. Bans certain children's products containing excessive amounts of lead, mercury, or cadmium.	SS
NJ	2024	A 3801[95]	Introduced. Prohibits the sale, distribution, and manufacture of jewelry containing cadmium.	SS

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[89] https://www.mainelegislature.org/legis/bills/bills_123rd/billtexts/HP143701.asp
[90] https://www.legislature.mi.gov/documents/2007-2008/publicact/htm/2007-PA-0161.htm
[91] https://www.revisor.mn.gov/bills/bill.php?b=senate&f=SF1262&ssn=0&y=2007
[92] https://www.njleg.state.nj.us/bill-search/2024/S1085
[93] https://www.njleg.state.nj.us/bill-search/2024/S1713
[94] https://www.njleg.state.nj.us/bill-search/2024/A3800
[95] https://www.njleg.state.nj.us/bill-search/2024/A3801

Entity	Year	Regulation or Policy	Requirements and standards	Source
NY	2019	A 6296A[96]	Restricts the sale and distribution of children's products containing ingredients from the dangerous chemicals list including lead and cadmium.	SS
NY	2024	A 05751[97]	Imposes restrictions on lead-containing products and provides for a private right of action for violations.	SS
OR	2015	SB 478[98]	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.	SS
VT	2014	S.239[99]	Restricts the sale of children's products containing chemicals of high concern to children. Including children's jewelry and heavy metals.	SS

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[96] https://www.nysenate.gov/legislation/bills/2019/A6296

[97] https://nyassembly.gov/leg/?default_fld=&leg_video=&bn=A05751&term=2023&Summary=Y&Text=Y

[98] https://olis.oregonlegislature.gov/liz/2015R1/Measures/Overview/SB478

[99] https://legislature.vermont.gov/Documents/2014/Docs/ACTS/ACT188/ACT188%20As%20Enacted.pdf

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 C-22: Existing and proposed regulations for PFAS in relevant consumer products.

Entity	Year	Regulation or Policy	Requirements and standards	Source
CT	2023	B 5070[100]	Prohibits municipal and state contracts for the purchase and installation of artificial turf fields.	CT
EU	2023	Annex XV[101]	Proposal to restrict PFAS in mixtures or articles placed on the market with derogations for some uses.	ECHA
MA	2023	H 3948[102]	Introduced. Prohibits state and municipalities from funding the purchase, use, or installation of artificial turf that contains zinc, plastic, or PFAS.	SS
ME	2021	H.P. 1113[103]	Restricts the sale of products containing PFAS in the state of Maine starting January 1, 2030, with an exemption for currently unavoidable uses.	ME Legislature
VT	2024	S.25 § 2494g[104]	Prohibits the manufacturing or sale of artificial turf with PFAS added after July 1, 2024.	SS
MN	2023	Amara's Law (Minn. Stat. § 116.943)[105]	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.	MN legislature

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[100] https://www.cga.ct.gov/2023/TOB/H/PDF/2023HB-05070-R00-HB.PDF
[101] https://echa.europa.eu/documents/10162/f605d4b5-7c17-7414-8823-b49b9fd43aea
[102] https://malegislature.gov/Bills/193/HD958
[103] https://www.mainelegislature.org/legis/bills/getPDF.asp?paper=HP1113&item=5&snum=130
[104] https://legislature.vermont.gov/bill/status/2024/S.25
[105] https://www.revisor.mn.gov/statutes/cite/116.943#stat.116.943

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 C-23: Existing and proposed regulations for cVMS in relevant consumer products.

Entity	Year	Regulation or Policy	Requirements and standards	Source
CA	2005	CSCP[106]	Requires manufacturers, packers, and distributors of cosmetic products to report to the California Department of Public Health (CDPH) all products sold in California, which contain ingredients known or suspected to cause cancer, birth defects, or other reproductive harm.	CA
EU	2019	Annex XV[107]	Restricts D4, D5, and D6 in consumer and professional products.	ECHA
ME	2023	HP 1224[108]	Introduced. Restricts the distribution or sale of cosmetic products containing a restricted substance, including cVMS.	SS
NY	2024	S 4265B[109]	Introduced. Prohibits the sale of personal care or cosmetic products containing a restricted substance as an intentionally added ingredient in any amount.	SS
NY	2023	A 06969B[110]	Introduced. Prohibits the sale of personal care or cosmetic products containing a restricted substance as an intentionally added ingredient in any amount.	SS
VT	2014	S.239[111]	Allows for the prohibition of the sale of children's products containing chemicals of high concern to children. Including children's cosmetics and siloxanes.	SS

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[106] https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/OHB/CSCP/Pages/Cosmetics-Companies.aspx

[107] https://echa.europa.eu/documents/10162/13641/rest_d4d5d6_axvreport_en.pdf/c4463b07-79a3-7abe-b7a7-5c816e45bb98

[108] https://www.mainelegislature.org/legis/bills/display_ps.asp?ld=1908&PID=1456&snum=131

[109] https://www.nysenate.gov/legislation/bills/2023/S4265/amendment/B

[110] https://nyassembly.gov/leg/?default_fld=&leg_video=&bn=A06969&term=2023&Summary=Y&Text=Y

[111] https://legislature.vermont.gov/Documents/2014/Docs/ACTS/ACT188/ACT188%20As%20Enacted.pdf

BTEX

California and the European Union regulate toluene in nail products.

Table C-24: Existing and proposed regulations for BTEX substances in relevant consumer products.

Entity	Year	Regulation or Policy	Requirements and standards	Source
CA	2005	CSCP	Requires manufacturers, packers, and distributors of cosmetic products to report to the California Department of Public Health (CDPH) all products sold in California, which contain ingredients known or suspected to cause cancer, birth defects, or other reproductive harm.	California Department of Public Health (CDPH)
CA	2023	SCP[112]	Lists nail polish with toluene as a priority product that must be reported by manufacturers.	Department of Toxic Substances Control (DTSC)
EU	2009	Annex III[113]	Restricts use of toluene in nail products to a 25% threshold	ECHA
NJ	2024	A 162[114]	Introduced. Prohibits the sale and distribution of nail products containing dibutyl phthalates, toluene, or formaldehyde.	SS
USA	2018	FD&C Act[115]	Under this law, 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.	Food and Drug Administration (FDA)
VT	2014	S.239[116]	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.	SS

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[112] https://dtsc.ca.gov/scp/nail-products-containing-toluene/

[113] https://echa.europa.eu/cosmetics-restricted-substances/-/legislationlist/details/EU-COSM_PROD-ANX_III_RESTRIC-100.003.297-VSK-01022F

[114] https://www.njleg.state.nj.us/bill-search/2024/A1775

[115] https://www.fda.gov/regulatory-information/laws-enforced-fda/federal-food-drug-and-cosmetic-act-fdc-act

[116] https://legislature.vermont.gov/Documents/2014/Docs/ACTS/ACT188/ACT188%20As%20Enacted.pdf

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.

Table C-25: Existing and proposed regulations for ortho-phthalates in relevant consumer products.

Entity	Year	Regulation or Policy	Requirements and standards	Source
CA	2017	SB 58[117]	Requires the manufacturer of cleaning products to disclose specified chemicals on the label and website, including ortho-phthalates.	SS

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.

Table C-26: Existing and proposed regulations for 6PPD in relevant consumer products.

Entity	Year	Regulation or Policy	Requirements and standards	Source
CA	2023	CA Code Reg Ch. 55 § 11[118]	Specifies motor vehicle tires with 6PPD as a priority product/chemical combination.	California Code of Regulations (CCR)
USA	2023	TSCA Sect. 21 Petition[119]	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.	EPA

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[117] https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB258
[118] https://govt.westlaw.com/calregs/Document/I3EA124E01FD411EEB1A4DEEA2C4D3A06?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)
[119] https://www.epa.gov/system/files/documents/2023-11/pet-001845_tsca-21_petition_6ppd_decision_letter_esigned2023.11.2.pdf

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 C-27: Existing and proposed regulations for organobromine and organochlorine substances in relevant consumer products.

Entity	Year	Regulation or Policy	Requirements and standards	Source
CA	2004	CARB Restriction Ch. 7[120]	Prohibits manufacture, sale, or distribution of any solid air fresheners or toilet/urinal care products containing PDCB.	California Air Resources Board (CARB)
CA	2024	AB 2761[121]	Introduced. Seeks to prohibit manufacturing, selling, or distributing plastic packaging containing intentionally added PFAS and PVC.	SS
NC	2023	H 279[122]	Proposed bill to ban the manufacturing and distribution of packaging materials containing certain toxic chemicals to include PVC.	SS
New Zealand	2022	Waste Minimization Act 2022[123]	Prohibits manufacture or sale of specific plastic products to include PVC food containers or trays.	Sustainable Plastics Coalition (SCP)
VT	2024	H 601[124]	Introduced, would prohibit the manufacture and sale of plastic packaging products containing specified chemicals including PVC.	SS

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[120] https://ww2.arb.ca.gov/sites/default/files/barcu/regact/conprod/ch7.pdf

[121] https://legiscan.com/CA/text/AB2761/id/2930517

[122] https://www.ncleg.gov/Sessions/2023/Bills/House/PDF/H279v1.pdf

[123] https://legislation.govt.nz/regulation/public/2022/0069/13.0/whole.html#d1345447e459

[124] https://legislature.vermont.gov/Documents/2024/Docs/BILLS/H-0601/H-0601%20As%20Introduced.pdf