# Data Gaps, Research Needs, and Recommendations to inform 6PPD Action Plan work

A product of the 6PPD Action Plan advisory committee.
Production period: December 2023 to May 2024

## Introduction

This document includes work completed by Ecology, Washington state agency partners, and the 6PPD Action Plan advisory committee from December 2023 to May 2024. It contains recommendations, data gaps, research needs, and an overview of the current science around 6PPD and 6PPDQ. The document will inform state agency planning for immediate 6PPD action needs, support planning for work in the 2025-2027 biennium, identify opportunities to expand 6PPD work, and provide fundamental information for the 6PPD Action Plan. Washington state agency partners and advisory committee members may refer to this document when developing priority plans for 6PPD work and developing proposals, strategies, and workplans. **Please note: This is not a draft 6PPD Action Plan. It is a starting point to inform future 6PPD Action Plan work and development of the final 6PPD Action Plan**.

The problem of 6PPD use in tires has broad impacts that requires a multi-disciplinary approach to solve. Ecology and a team of subject matter experts from Washington state partner agencies began working on the 6PPD Action Plan in fall 2023. This included identifying data needs and drafting preliminary recommended actions to reduce impacts from 6PPD and 6PPDQ. Staff from the following partner agencies helped scope, draft, and provide feedback on recommendations:

- Washington State Department of Ecology
- Washington State Department of Health
- Washington State Department of Fish and Wildlife
- Washington State Department of Commerce
- Washington State Department of Transportation
- Washington State Department of Natural Resources
- Washington State Recreation and Conservation Office
- Puget Sound Partnership

In January 2024, Ecology convened an advisory committee consisting of 52 members, including Federal, municipal, and Tribal government partners, researchers, industry experts, and community-based organizations. Advisory committee members worked closely with state agency staff to review and further develop the recommendations. Their feedback and insights helped us consider as many perspectives and approaches as possible. Additionally, advisory committee members:

- Offered ideas for recommendations.
- Shared implementation barriers within their areas of expertise.
- Identified data gaps and research needs surrounding 6PPD.

Some of the recommendations have been included in Ecology's and partner agencies' 2025-2027 budget packages. Assuming they are funded, Washington state agencies will begin work on these recommendations. Other recommendations are still under consideration. Ecology, Health, and other agency partners are currently exploring feasibility, authority, and implementation. We have divided the recommendations section into two parts. One section lists the recommendations that have been included in budget packages and the other lists recommendations that are still under consideration.

Ecology will continue to lead 6PPD Action Plan development, in consultation with Washington state partner agencies and the advisory committee, to develop long-term, robust actions that address 6PPD and 6PPDQ.

# Background

Tire manufacturers began adding 6PPD to tires in the 1960s. Since then, 6PPD has become a widely used antioxidant and antiozonant in rubber due to its capacity to quickly react with ozone. This reaction promotes tire longevity, performance, and safety by reducing cracking, preventing blowouts, and increasing durability in tires.

Several transformation products, including 6PPDQ, are created during this reaction. 6PPDQ causes rapid mortality to species of cultural and environmental significance like the coho salmon (Tian et al., 2021, 2022). This byproduct is also harmful to other fish, including rainbow trout, brook trout, and white-spotted char.

Because of 6PPD's role in promoting tire safety and performance, tire manufacturers need to identify an alternative. Although research on potential alternatives to 6PPD in tires has progressed since the discovery of 6PPDQ, there are still many questions and no identified safer alternative.

Tires shed microplastics and other particulates, known as tire wear particles, into the environment. Tires continuously release these particles as they contact impervious surfaces from actions such as driving, braking, and turning. When it rains, stormwater runoff that contains tire wear particles transports these tire wear contaminants, including 6PPD and 6PPDQ, into rivers, streams, and estuaries.

Coho salmon are currently considered to be the species that is most sensitive to 6PPDQ with a median lethal concentration ($LC_{50}$) of <0.1 µg/L (Brinkmann et al., 2022). This value indicates that 6PPDQ is the second most toxic chemical to aquatic life. Parathion is the first most toxic chemical ever tested and its use is now banned in the U.S. 6PPDQ is more toxic than DDT (dichloro-diphenyl-trichloroethane). The use of DDT has been banned in the U.S. for more than 30 years.

The parent chemical 6PPD causes skin allergies. It can also cause reproductive problems in laboratory rats and is classified as harmful to reproduction in people (ECHA, 2023; ToxServices, LLC, 2021). Emerging data indicates that 6PPDQ can cause toxicity to internal organs in mice, including the liver (Fang et al., 2023), lungs (He et al., 2024), and testis (Yao et al., 2024).

Due to the presence of tire wear particles and tire chemicals in the environment, people can breathe or ingest 6PPD and 6PPDQ from air, dust, water, and food, as well as have skin contact with the chemicals. Researchers have detected both 6PPD and 6PPDQ in urine and blood samples in most people that have been studied (Du et al., 2022; Mao et al., 2024; Song et al., 2024).

The Interstate Technology and Regulatory Council's 6PPD guidance document provides a thorough overview of what is known today about 6PPD and 6PPDQ. Ecology will share a link to this resource when it is available.

# Current Knowledge

## Uses of 6PPD

### What we know

Researchers have detected 6PPD and 6PPDQ in consumer products besides tires. This includes products that are used in indoor environments, such as flooring, and outdoor recreational surfaces (ECHA, 2023). A recent study in Washington also found 6PPD in a small sample of household products like shoe soles and doormats (Zhao et al., 2023a).

Other PPD chemicals are also present in consumer products. Some of these PPDs share similar antioxidant functions to 6PPD and could be considered as alternatives to 6PPD. Aside from their use as antioxidants, these chemicals may be used for other purposes. For example, the chemical after which this group is named, para-phenylenediamine, reduces fading and promotes products longevity in some hair dye products. It has been long recognized as a chemical sensitizer (DTSC, 2023).

### Data gaps and research needs

We don't know the extent of 6PPD use in non-tire products, including its presence in recycled tire products like crumb rubber. An accredited lab method would enable us to test products and reuse materials that contain 6PPD and other related PPDs of concern.

Additionally, we need more data to further assess the chemical and toxicological properties of other PPDs to prevent the use of a regrettable substitute. This effort to evaluate potential alternatives may include defining a chemical class or classes that include 6PPD and other related PPDs of concern.

## Ecotoxicology

### What we know

Coho salmon are a sentinel species (an organism used by researchers as an early warning indicator for chemical exposures) for 6PPDQ. They are currently considered to be the most sensitive species to 6PPDQ due to the dramatic toxic effect of 6PPDQ, known as urban runoff mortality syndrome (Chow et al., 2019; Tian et al., 2022; Greer et al., 2023).

6PPDQ is also harmful to other fish, including rainbow trout *(Oncorhynchus mykiss)*, brook trout (*Salvelinus fontinalis*), and white-spotted char (*Salvelinus leucomaenis*). Sensitive fish species exposed to 6PPDQ have all exhibited symptoms of gasping, spiraling, and loss of equilibrium prior to dying (Brinkmann et al., 2022).

Recently, a study in the Pearl River Estuary in southern China confirmed that 6PPDQ and other tire-related compounds have a strong tendency to bioaccumulate and biomagnify in fish and invertebrates (Wei et al., 2024). Our understanding of the bioaccumulation and biomagnification of 6PPD and 6PPDQ within Puget Sound species is limited.

### Data gaps and research needs

Researchers do not currently know the mode of action of 6PPD and 6PPDQ on salmonid species. The mode of action refers to how a chemical interacts with living organisms to cause toxicity or another effect. More research is necessary to understand the toxic effect of these chemicals on coho salmon and other salmonids. This research may help us determine what other species are similarly affected. Similarly, knowing the mode of action may help determine potential alternative chemicals and avoid regrettable substitutions with similar structure and/or function.

Because most existing research focuses on coho salmon and other salmonid species, researchers have tested few other organisms for their susceptibility to 6PPD and 6PPDQ. As a result, other species of cultural, economic, and ecological significance in the Pacific Northwest have unknown exposure sensitivity to 6PPD and 6PPDQ. Such species may include filter feeders (including oysters or freshwater and marine mussels) and other aquatic organisms (like lamprey, herring, and recreational fishes). Many of these species are edible and may be key food sources for Tribes with lands and traditional territories in Washington, as well as state residents.

Ongoing research is currently investigating acute effects of 6PPD and 6PPDQ on salmonid species like coho salmon and rainbow trout; however, little is known about the toxicity of these chemicals on other species that inhabit freshwater and marine habitats. Acute lethal toxicity has been noted in some other species, like *Daphnia pulex* (Li et al., 2023). A large data gap still exists in terms what, if any, effects these contaminants may have on animal fitness at chronic and/or sublethal concentrations (Wang et al., 2023). This data is necessary to inform and/or predict potential population-level effects.

## Human Health and Exposure

The Washington Department of Health evaluated what is known about the potential human health effects of 6PPD and 6PPDQ and the ways people can be exposed to these chemicals. 6PPDQ was discovered due to its toxic effects on fish, and most published research is focused on understanding how the chemicals move through water and affect fish. The exposure routes and health effects in people are still uncertain. In comparison to 6PPDQ, the toxicity of 6PPD has been studied more because of decades of use in tires and other products. 6PPD is considered a reproductive toxicant and skin sensitizer in people. In contrast, 6PPDQ toxicity data is still scarce.

### What we know

#### 6PPD toxicity

6PPD is classified as a reproductive toxicant and skin sensitizer for people and is associated with liver toxicity in rodents (ECHA 2022); (ToxServices, LLC 2021). 6PPD does not appear to have mutagenic or carcinogenic properties (ECHA, 2024).

The reproductive toxicity classification for 6PPD is based on findings of dystocia (difficult birth) in exposed laboratory rats.

6PPD in blood was correlated with some indicators of liver damage, in a study of 281 people in China (Song et al., 2024). Liver damage has been seen in laboratory animals too. Long-term exposure to 6PPD causes liver toxicity in rats (OSPAR Commission, 2006) and mice (Fang et al., 2023). Long-term exposure to 6PPD also causes anemia in rats (OSPAR Commission, 2006).

6PPD is classified as a skin sensitizer to people, based on results in laboratory animals and from human skin patch testing (OECD, 2004). Over time, exposure can cause some people to develop allergic skin responses to 6PPD. 6PPD is part of a class of chemicals with para-phenylene diamine structures. Researchers found that people who are sensitized to one member of this chemical class can react to other members of this chemical class (Yamano and Shimizu, 2009).

#### 6PPDQ toxicity

Since 6PPDQ was first detected in 2020, the focus of toxicity studies has been on salmonids and other aquatic species. Research findings on mammals are emerging but are limited in scope and depth. As described above for 6PPD, higher 6PPDQ blood levels correlated with higher levels of liver damage biomarkers in humans with liver disease (Song et al., 2024). Long-term studies of mice provide further evidence that 6PPDQ causes toxicity to the liver (Fang et al., 2023; He, Gu, and Wang, 2023).

Studies have found that 6PPDQ causes toxicity to other internal organs in mice including the lung (He, Gu, and Wang, 2023), kidney (He, Gu, and Wang, 2023), brain (He, Gu, and Wang, 2023), and testes (Yao et al., 2024; He, Gu, and Wang, 2023).

Supporting evidence for the neurotoxic potential of 6PPDQ is shown in *C. elegans,* a roundworm that is used as a model organism in toxicology (Hua and Wang, 2023); (He, Gu, and Wang, 2023); Hua and Wang, 2024). Experiments with nerve cells in vitro (J. Fang et al., 2024) also reported effects of 6PPDQ.

6PPDQ disrupted the intestinal barrier of mice (Yang et al., 2024) and *C. elegans* (Hua et al., 2023), and 6PPDQ-induced intestinal toxicity is noted in zebrafish (S.-Y Zhang et al., 2023; Varshney et al., 2022).

### Other breakdown products of 6PPD

6PPD undergoes chemical transformation in the environment into 6PPDQ but also a number of other chemicals (Zhao et al., 2023a; Song et al., 2024). The toxicity of most identified breakdown products has not been studied. Given the high use of 6PPD, and ongoing, pervasive environmental release from tires, people may be exposed to a variety of breakdown products in the environment.

### Exposure sources and pathways

People can be exposed to 6PPD and 6PPDQ from direct contact with rubber products that contain 6PPD, and from inhaling, ingesting, or touching environmental media that is contaminated.

Exposure to people is documented in a growing number of peer-reviewed publications that report 6PPD or 6PPDQ in different kinds of samples from people in China. Biomonitoring studies of people in the United States are not yet available, but due to the widespread use of 6PPD in tires, it is likely that Washingtonians are similarly exposed. 6PPD and 6PPDQ were detected in human urine and serum samples (Du et al., 2022); (Mao et al., 2024); (Song et al., 2024); (J. Zhang et al., 2024); (Liu et al., 2024); (Deng et al., 2024). 6PPD was detected in the blood of rubber industry workers (ECHA, 2024), and in 52 percent of breastmilk samples in one study (Liang et al., 2024). 6PPDQ was detected in cerebrospinal fluid in one study (J. Fang et al., 2024).

In experiments with laboratory mice, 6PPD and 6PPDQ cross the placenta to expose the fetus (Zhao, et al., 2023b). There is no data yet to confirm if the same patterns of fetal exposure occur in people.

Due to the presence of tire wear particles and tire chemicals in environmental media, it is reasonable to propose that people can breathe, ingest, and have skin contact with 6PPD and 6PPDQ. Exposure pathways from sources and environmental media are summarized below.

**Air and Dust**: 6PPD and 6PPDQ are widely reported in particulate matter in outdoor air and in dust samples from a variety of indoor and outdoor settings, primarily in China (Jiang et al., 2024); (Olubusoye et al., 2023); (Cao et al., 2022); (W. Wang et al., 2022); (Jin et al., 2023); (Z. Zhang et al., 2024); (Y. Zhang et al., 2022; Y.-J. Zhang et al., 2022). One study, which included samples from US residences, found 6PPD in indoor dust, but the samples were not analyzed for 6PPDQ (Wu, Venier, and Hites, 2020). People can inhale air and dust particles, touch them, and inadvertently swallow them. Data on the concentration of 6PPD and 6PPDQ in air and dust samples from US locations is still minimal, but as analytical methods improve, there should be a clearer understanding of the extent of people's exposure from air and dust in the future.

**Drinking water:** 6PPD was detected in tap water in Singapore (Marques dos Santos and Snyder, 2023) but no studies reported analytical data for 6PPD or 6PPDQ in US finished drinking water samples. Regarding the possibility of exposure through drinking groundwater, the solubility,

reactivity, and other chemical characteristics of 6PPD and 6PPDQ suggest that movement from surface runoff into groundwater is limited. However, some infiltration to groundwaters is possible. One study in South China found 6PPDQ in groundwaters (R. Zhang et al., 2023). Further, many Washingtonians drink treated surface waters, or groundwater that is influenced by surface water. These sources may be more vulnerable to contamination with 6PPD and 6PPDQ than more isolated groundwater sources.

**Dietary sources**: Food is another possible exposure route. Many people are concerned about ingesting 6PPD and 6PPDQ in foods, particularly Tribes and other groups who consume aquatic plants and animals. 6PPD and 6PPDQ were found in edible fish caught in China and in fish purchased at a Chinese market, but it's unknown whether these chemicals are in fish caught and consumed in Washington (Wei et al 2024; Ji et al 2022). With documented presence of 6PPD and 6PPDQ in fine ambient air particulate matter (W. Wang et al 2022), biosolids (Dennis, Braun, and Gan, 2024), and roadside soil (Cao et al., 2022), there is potential for distribution to food crops. 6PPDQ was detected in leafy vegetables grown in Israel, Switzerland, Italy, and Spain (Sherman et al., 2024). We did not find any studies that reported testing US crops and marketed foods.

**Consumer products**: Products that contain rubber may contain 6PPD and 6PPDQ. In a small sampling of rubber consumer products in Washington, 6PPD and 6PPDQ were detected in doormats, sneaker soles, and laboratory stoppers (Zhao, et al., 2023a). 6PPD was found in garden hoses (Zhao, et al., 2023a), and in rubber components for plumbing materials, potentially contributing to the levels detected in the tap water (Marques dos Santos and Snyder, 2023). More research is needed to determine if people who use these products are exposed to concentrations of 6PPD and 6PPDQ high enough to cause health effects.

**Artificial turf:** Artificial turf fields frequently use crumb rubber infill made from scrap tires. 6PPD and 6PPDQ were present in a small sample of crumb rubber from turf fields in Washington State (Zhao, et al., 2023a), and in Europe (Armada et al., 2023). 6PPDQ was found in the crumb rubber used in artificial turf fields in China (F. Zhao et al., 2024). In studies prior to the discovery of 6PPDQ, 6PPD was detected in crumb rubber in Europe (Schneider et al., 2020) and the US (CDC/EPA 2019)[1]. 6PPD and 6PPDQ may be absorbed by people who accidentally ingest the crumb rubber, inhale fine particles, or have skin contact with the infill material.

## Potential sensitive populations

Considering the possible exposure pathways described, there are likely populations in Washington who experience higher exposure or are more likely to experience impacts from exposure to 6PPD and 6PPDQ. Some preliminary possibilities are noted here, however further investigation is required to better define vulnerable and sensitive populations.

The presence of 6PPD and 6PPDQ in dusts and airborne particles suggests that people who live, work, recreate, or go to school near heavily trafficked roadways may have higher risk of exposure than the general population to 6PPD and its breakdown products. Elevated exposure near-roads is documented for other vehicle-derived pollutants (Boehmer, et al., 2013; (X. Wang

[1] https://www.epa.gov/chemical-research/july-2019-report-tire-crumb-rubber-characterization-0

et al., 2023). For 6PPD and 6PPDQ, tire wear particles carry the chemicals into airborne particulate and dusts that result in exposure to people from inhalation, ingestion, and skin contact (W. Wang et al., 2022).

Drinking water sources that are vulnerable to contamination by stormwater runoff from roadways could expose populations who drink from these sources. At this time, drinking water sources have not been analyzed for 6PPD and 6PPDQ.

If aquatic food sources are found that contain 6PPD and 6PPDQ, people who fish and gather aquatic food may be vulnerable to higher exposure.

An area of public concern is whether use of recycled tire rubber in recreational surfaces such as athletic fields and playgrounds could cause exposure to children and others to 6PPD and 6PPDQ. Washington Youth Soccer (WYS) reported that 93,000 children participated in youth soccer leagues, a significant proportion of the state's children (WYS website[2]; Office of Financial Management website[3]). Children participate in many sports and recreational activities on athletic fields, and can unintentionally ingest turf granules, get them on skin, and carry them home in shoes, clothes, and bags. The number of fields that contain crumb rubber is not known, but exposure could be widespread.

People with occupational exposures may also be vulnerable. Working near and on busy roads, handling tires, or working to recycle the rubber in tires potentially exposes workers more (W. Wang et al 2022). Some studies from China on 6PPD and 6PPDQ in dusts from roads, parking areas (cited above), and solid waste recycling facilities (Y.-J. Zhang et al., 2022) support concern for increased exposures in some occupations.

Health impacts from environmental contaminants likely go beyond exposure to the chemicals. 6PPD may indirectly impact people due to the direct effects of environmental contamination on salmon health. Some Washingtonians and Tribes rely on healthy salmon populations for food sovereignty, economic stability, cultural traditions, and more (Windward Environmental LLC, 2016). These groups are more vulnerable to the indirect effects of 6PPD in the environment because of declining salmon populations (Donatuto et al., 2011).

## Information gaps and research needs for human health and exposure

There are many gaps in the information that is currently available to support evaluating the public health impacts of 6PPD in tires. By evaluating reports, studies and other data to support a draft Action Plan and working with an external Advisory Committee, we identified where information is still needed and made preliminary recommendations for actions that can begin to fill information gaps.

### Health effects information gaps

Despite recent research findings in laboratory mice and rats, it's still unknown whether 6PPDQ is toxic to humans and at what exposure levels health effects might occur. This is the most

[2] https://washingtonyouthsoccer.org/about-us/

[3] https://ofm.wa.gov/washington-data-research/statewide-data/washington-trends/population-changes/distribution-washington-population-age-and-gender

critical gap in current knowledge. Toxicity to fish does not mean the same toxicity pattern is expected in people. There are also gaps in our understanding of 6PPD toxicity. We don't know if the reproductive effects of 6PPD observed in rats also occur in people or at what exposure levels there could be concern for reproduction.

Health-based standards are not yet available to support public health assessments. Safe exposure levels have not been established for 6PPD or 6PPDQ by The Environmental Protection Agency (EPA) or other authorities. Derived no-effect levels for exposure to 6PPD were reported in the EU under REACH legislation, but to our knowledge, no health-based safe exposure levels have been developed by any authorities for 6PPDQ due to a lack of toxicological data that would be appropriate to use for this purpose.

6PPDQ is a transformation product of 6PPD that is highly toxic to salmonids, but 6PPD can produce many other breakdown products during use and environmental release that have not been characterized for their toxicological effects. Other 6PPD breakdown products besides 6PPDQ need to be evaluated for potential health impacts in people.

There is a need to better understand the indirect ways that people's health and well-being in Washington are affected by 6PPDQ in the environment and the resulting effects on fish and ecosystem health. Partnerships with affected populations are needed to characterize impacts and determine solutions.

### Information gaps related to exposure:

1. **Understanding exposure pathways:** Several exposure pathways were described above, but which pathways for exposure are important in Washington is unknown. We need to understand which exposure pathways contribute the most to people's total exposure or to disproportionate exposures across groups of people. These higher impact exposures could then be prioritized for reduction through protective public health policies and programs.
2. **Identify vulnerable populations:** Identifying the vulnerable populations in Washington is needed to understand who is most affected by exposure, and which pathways of exposure have the greatest public health impact or disproportionate impact. This requires gathering information about how exposures vary across different groups of people, particularly vulnerable populations and people with occupational exposure. Factors that modify exposure levels and impact could include age, gender, cultural practices, geographic region, occupation, proximity to roadways, diet, pre-existing health conditions, socioeconomic status, and ethnicity.
3. **What are the sources:** The possibility of exposure from 6PPD in products other than tires needs to be considered. Many other products are manufactured with rubber incorporate antioxidants. Based on a small pilot study of consumer products conducted in Washington (Zhao, et al., 2023a), it is plausible that there may be products in homes, schools, and workplaces that increase exposure for people who use these products.
4. **Recreational exposure levels:** How much exposure occurs through contact with recycled tire rubber in turf fields and other recreational surfaces is also an important

information gap. Data on how many fields in the state contain crumb rubber would be a place to start.

## Environmental Science and Ecosystem Health

### What we know

Traffic and road characteristics influence where and how many tire wear particles are shed and, thus, where higher levels of 6PPDQ may accumulate and contaminate stormwater runoff. The following factors may influence the amount of 6PPDQ released into the environment from tire wear particles:

- The number of cars on the road
- Areas that experience stop-and-go traffic
- Vehicle types (passenger cars, heavy trucks)
- Acceleration and deceleration areas
- Change in speed limit
- Stop signs and stop lights
- On/off ramps
- Curves/turn lanes
- Traffic circles/roundabouts
- Proximity of roads to water

### Data gaps and research needs

Researchers do not yet understand where 6PPD, 6PPDQ, and tire wear particles are most prevalent, nor how long these chemicals stay in the environment. Gaining information about where these chemicals are and how they move in the environmental can improve treatment strategies and stormwater effectiveness research. Research needs include understanding how traffic density, land use, and other characteristics affect 6PPDQ concentrations. We can use data and models to further characterize 6PPDQ in stormwater and in the environment.

In addition, we need more research to determine if reused and recycled whole tires are a potential source of 6PPD and 6PPDQ. This includes investigating whether crumb rubber applications are a significant source of 6PPDQ over time. Land uses of interest include turf fields, playgrounds, and other areas with sources of crumb rubber.

## Stormwater Treatment

### What we know

We expect that several types of common stormwater treatment best management practices (BMPs) will help manage 6PPD and 6PPDQ. Ecology and partners are conducting research to

better understand: 1) how effective existing treatments are; and 2) what other treatments might helpful. Some potentially effective stormwater treatments include:

- **Source control BMPs**: Prevent stormwater contamination with methods that control pollutants from tires, tire products, and tire wear particulates. Street sweeping is an example of a source control BMP.
- **Flow control BMPs**: Slow down runoff and reduce runoff volumes by holding water back via infiltration. Flow control BMPs include ponds, infiltration basins, and bioretention.
- **Runoff treatment BMPs**: Reduce concentrations of 6PPDQ through physical filtration or chemical sorption media. Runoff treatment BMPs include biofiltration swales, bioretention, and manufactured treatment devices.

Results from Ecology-funded laboratory testing indicates that 6PPDQ sorbs to bioretention soil mixes, stormwater compost, granular activated carbon, and biochar. This means that BMPs with these components reduce 6PPDQ concentration in stormwater. Several Ecology-funded and external studies suggest that bioretention using a bioretention soil mix or high-performance bioretention soil mix can reduce toxicity in stormwater and prevent acute mortality to coho salmon. Ecology-approved bioretention soil mix is composed of 60% sand and 40% stormwater compost. The Ecology-approved high-performance bioretention soil mix[4] is a specialized bioretention soil mix designed for sensitive watersheds to reduce nutrient output into waterways. We are now testing these BMPs in the field to confirm laboratory results.

## Data gaps and research needs

We do not yet know how effective commonly installed BMPs, such as bioretention (e.g., swales, cells, and planter boxes) and detention ponds, are at reducing or eliminating 6PPDQ. A BMP effectiveness report[5] ranked common BMPs (high, medium, and low) in terms of their potential effectiveness at reducing 6PPDQ. More research is needed to verify these rankings.

Additionally, we do not know whether BMPs perform at the same level of effectiveness across regions (for example, Western Washington vs. Eastern Washington) or if they perform the same in laboratory versus field environments. We need more research to assess the effectiveness of commonly used BMPs (e.g., grassy swales) to determine if there is a need to redesign these systems to maximally treat 6PPDQ. Additionally, bioretention is not feasible in some areas due to site characteristics. Therefore, research is ongoing to provide several BMP options that will be effective at addressing 6PPDQ under varying site conditions.

We are still learning how structural BMPs may help us manage 6PPDQ. Structural BMPs are physical facilities and structures that reduce or prevent contaminants from entering stormwater runoff and waterways. Structural BMPs can include:

- Unamended soils.

[4] https://apps.ecology.wa.gov/publications/SummaryPages/2110023.html
[5] https://fortress.wa.gov/ecy/ezshare/wq/Permits/Flare/2019SWMMWW/Content/Resources/DocsForDownload/2022_SWTreatmentOfTireContaminants-BMPEffectiveness.pdf

- Common TAPE[6] devices.
- Vegetation.
- Filtration inserts.

We need to learn more about:

- How effective unamended soils are and how long unamended soils retain 6PPDQ.
- What vegetation types reduce 6PPDQ concentrations.
- Which TAPE devices are viable for removing 6PPDQ from stormwater.
- Whether there is a filtration insert that can effectively catch 6PPDQ.

Finally, we need to conduct more research on Source control BMPs. Source control BMPs, such as street sweeping, prevent stormwater contaminants from entering storm drain systems. We do not have data on how often street sweeping is needed. We also don't know what treatments may be needed at decant facilities before liquid and solid street wastes can be safely disposed of.

You can read more about our current stormwater effectiveness research projects on our 6PPD stormwater research page.[7]

## Alternatives

### What we know

### Hazard Assessment

In 2021, the Legislature directed Ecology to complete a hazard assessment to determine whether an existing chemical could replace 6PPD in tires. A hazard assessment is often conducted as a first step in an alternatives assessment.

We provided the Legislature with a hazard assessment of 6PPD[8] in November 2021. Hazard assessments provide an overview of known toxicological hazards of chemicals. Understanding the hazards of a chemical of concern and potential alternatives can help avoid replacing 6PPD with a chemical with unknown hazards.

We used the GreenScreen® for Safer Chemicals method in our hazard assessment. This is a method of comparing chemical hazards. We have used this tool in multiple alternative assessments to characterize chemicals of high concern and possible safer alternatives. In this case, we used GreenScreen® and the results from the hazard assessment as a screening step to identify chemicals that could be addressed in the 6PPD Alternatives Assessment.

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[6] https://ecology.wa.gov/regulations-permits/guidance-technical-assistance/stormwater-permittee-guidance-resources/emerging-stormwater-treatment-technologies

[7] https://www.ezview.wa.gov/site/alias__1962/40944/6ppd_stormwater_best_management_practices_research.aspx#kingcounty2

[8] https://www.ezview.wa.gov/Portals/_1962/Documents/6ppd/6PPD%20Alternatives%20Technical%20Memo.pdf

In the GreenScreen® for Safer Chemicals methodology, chemicals receive a combined "benchmark score" based on the assessments of 18 types of hazards, such as whether they cause cancer or are toxic. GreenScreen® benchmark scores also include the known toxic effects of any transformation products.[9]

For each type of hazard (called an "endpoint"), the chemical is scored as very low, low, moderate, high, or very high. The results for all 18 hazards are combined to create a single GreenScreen® Benchmark score:

- **Benchmark-1** – Avoid: chemical of high concern
- **Benchmark-2** – Use but search for safer substitutes
- **Benchmark-3** – Use but still opportunity for improvement
- **Benchmark-4** – Prefer: safer chemical

Although the benchmark scores will not be included in the quantitative assessment of our 6PPD Alternatives Assessment, we used the scores to give us a starting point to determine how other anti-ozone chemicals compared to 6PPD. We also used this information to determine further toxicity research needs.

***Table 1.*** *GreenScreen® benchmark scores for select 6PPD alternatives.*

| Chemical | GreenScreen® Benchmark Score |
|---|---|
| 6PPD (#793-24-8) | Benchmark-1 |
| 77PD (#3081-14-9) | Benchmark-2 |
| CCPD (#4175-38-6) | Benchmark-1 |
| IPPD (#101-72-4) | Benchmark-1 |
| 7PPD (#3081-01-4) | Benchmark-1 |
| TMQ (#147-47-7) | Benchmark-2 |
| 6QDI (#52870-46-9) | Benchmark-1 |
| NBC (#13927-77-0) | Benchmark-1 |
| Ethoxyquin (#91-53-2) | Benchmark-2 |
| Dilauryl thiodipropionate (#123-28-4) | Benchmark-3 with data gap |

The results from our 2021 hazard assessment showed that four of the chemicals considered in the analysis had scores that showed they might be safer than 6PPD.

### 6PPD Alternatives Assessment

At the time of this report, we do not have sufficient data to determine whether there are any existing replacement chemicals that will provide the same performance and safety function in tires and whether any of those chemicals are safer than 6PPD. A completed alternatives assessment would help answer both those questions.

[9] Transformation products are chemicals that are made when a parent chemical interacts with other chemicals (such as ozone) in the environment.

In 2022, the Legislature provided funding and directed Ecology to, "complete a full safer alternatives assessment of the 6PPD compounds used in tires. The assessment shall incorporate and evaluate toxicity data of alternatives on Coho and other species."[10] At that time, we contracted with researchers at University of Washington – Tacoma and Washington State University to conduct toxicity testing and purchase equipment.

In 2023, the Legislature provided additional funding to, "complete a safer alternatives assessment of the 6PPD compound used in tires, including any data necessary to complete the alternatives assessment."[11] In summer 2023, we developed 6PPD Alternatives Assessment Hazard Criteria[12] to standardize how we would determine whether a chemical is safer than 6PPD. We accepted public comment on these criteria from June 14, 2023 to July 14, 2023, and received feedback from individuals representing academic institutions, industry, federal and local government, and the general public. We carefully reviewed these comments and then updated our criteria. You can read more about the changes we made based on this public comment period in our 6PPD Hazard Criteria Responsiveness Summary.[13]

The process of developing our 6PPD hazard criteria enabled us to determine what additional data we needed to complete the Alternatives Assessment. We used these criteria to develop a list of toxicity, feasibility, and performance data needs for:

- The potential alternatives identified in the 6PPD hazard assessment; and
- Other alternatives identified through collaboration with industry partners.

Ecology is currently funding research to fill these data needs.

When completed, the Alternatives Assessment will assess and compare possible alternatives to 6PPD and identify whether any feasible alternatives are safer to Coho salmon, other aquatic life, and humans. If we find safer alternatives exist, we must recommend regulatory, policy, or legislative actions to advance safer alternatives. In the 2024 Legislative session, legislators passed Substitute Senate Bill 5931,[14] amending the Safer Products for Washington statute to add 6PPD as a priority chemical[15] and motorized vehicle tires containing 6PPD as a priority consumer product. If a safer alternative is feasible and available, we could restrict the sale of tires containing 6PPD under Chapter 70A.350 RCW,[16] commonly referred to as the Safer Products for Washington program.

To identify a chemical as a safer alternative under Safer Products for Washington, it must be safer and fulfill the same function as the priority chemical it would replace. A performance evaluation is not part of a hazard criteria but is a requirement to determine feasibility under the Safer Products for Washington program. Thus, we asked tire manufacturers and associations to

[10] https://lawfilesext.leg.wa.gov/biennium/2021-22/Pdf/Bills/Session%20Laws/Senate/5693-S.SL.pdf
[11] https://lawfilesext.leg.wa.gov/biennium/2023-24/Pdf/Bills/Session%20Laws/Senate/5187-S.SL.pdf
[12] https://apps.ecology.wa.gov/publications/SummaryPages/2304036.html
[13] https://apps.ecology.wa.gov/publications/SummaryPages/2304061.html
[14] https://lawfilesext.leg.wa.gov/biennium/2023-24/Pdf/Bills/Session%20Laws/Senate/5931-S.SL.pdf
[15] https://apps.ecology.wa.gov/publications/SummaryPages/2304038.html
[16] https://app.leg.wa.gov/RCW/default.aspx?cite=70a.350

review the identified alternative chemicals and share information about their known performance in tires.

The U.S. Tire Manufacturers Association shared concerns about the performance of the four alternatives that might be safer than 6PPD (see Table 1). Their review indicated that none of the chemicals identified as potentially safer than 6PPD provides the same level of tire performance and safety. They also indicated that chemicals similar to 6PPD are the most likely to be acceptable substitutes from a performance perspective but are also likely to form a quinone compound and have unknown impacts on Coho salmon.

## Hazard criteria

We published 6PPD Alternatives Assessment Hazard Criteria[17] in October 2023 for use in the Alternatives Assessment. Hazard criteria provide a standard way to determine whether alternatives are safer than 6PPD for use in tires.

Alternatives assessments include assessing toxicity data on a wide range of endpoints to comprehensively understand a chemical's hazards. We modeled our 6PPD Alternatives Assessment hazard criteria on the Safer Products for Washington program hazard criteria.[18]

These criteria score 16 human and environmental hazards, such as whether a chemical causes cancer, is toxic to reproduction and development, affects endocrine activity, is toxic to aquatic life, and if it persists in the environment. The criteria also set maximum hazard profiles based on hazard endpoint scoring, which determine when an alternative could be called "safer." Because 6PPDQ is so extremely toxic to Coho salmon, we added criteria to ensure alternatives are safer:

- Alternatives must have data on acute aquatic toxicity to Coho salmon and Rainbow trout, as well as data on two other trophic levels.
- Alternatives must have data on the toxicity of transformation products after exposure to ozone.
- We will place a limit on the acute toxicity lethal concentration ($LC_{50}$) values allowed in the minimum criteria.

During the 6PPD Alternatives Assessment, we'll evaluate the hazards of possible alternative chemicals using these criteria. Ecology will consider all relevant information as researchers continue their studies on possible alternatives. Alternatives that don't have all the needed data or that exceed the toxicity limit cannot be considered "safer," even if they otherwise would be based on the rest of the endpoints.

Relevant information may include results from the preliminary alternatives analyses submitted to California's Department of Toxic Substances Control.[19] In October 2023, California's

[17] https://apps.ecology.wa.gov/publications/SummaryPages/2304036.html
[18] For a list of these criteria, see Appendix C of "Regulatory Determinations Report to the Legislature Safer Products for Washington Cycle 1 Implementation Phase 3" at https://apps.ecology.wa.gov/publications/summarypages/2204018.html
[19] https://calsafer.dtsc.ca.gov/cms/priorityproductdetail/?rid=1014

Department of Toxic Substances Control began regulating 6PPD in motor vehicles tires through its Safer Consumer Products Program. Each tire manufacturer selling tires in California is required to submit a preliminary alternatives analysis by March 29, 2024. Manufacturers provided a list of potential alternatives they are considering. The final reports they are expected to submit in mid-2025 (with an opportunity for extension) should provide a more in-depth analysis of chosen alternatives.

## Current toxicity research and preliminary results

We are currently funding research on specific species of concern (e.g., Coho salmon, Rainbow trout, Brook trout) to help us fill data gaps and compare the toxicity of 6PPD, 6PPDQ, and selected alternative chemicals. This research includes acute aquatic toxicity testing for 6PPD and potential alternative compounds. Enthalpy Analytical performed toxicity tests on Rainbow trout. University of Washington – Tacoma tested the leaching rate and presence of tire compounds from used and new truck and passenger tires. Washington State University is performing toxicity tests on Coho salmon. Final reports from Enthalpy Analytical and University of Washington – Tacoma, and a preliminary report from Washington State University, are included on our project webpage, Research and Proposed Alternatives to 6PPD.[20]

Based on the findings in the hazard assessment, we funded toxicity research on 7PPD, 77PD, and TMQ. We chose these chemicals because each of them is currently used in tires in conjunction with 6PPD. Additionally, TMQ and 77PD have benchmark scores that indicated they may be safer than 6PPD. The U.S. Tire Manufacturers Association indicated that 7PPD may be closest to 6PPD in performance due to its very similar chemical structure.

Table 2 shows the preliminary results from the toxicity research. Listed values are all approximate concentrations due to potential differences in sample purity and how easily it dissolves. This could mean that the reported values are actually lower, and thus more toxic, than listed in Table 2.

***Table 2.*** *Summary of $LC_{50}$ values for Rainbow trout and Coho salmon for possible 6PPD alternatives*

| Chemical | $LC_{50}$ of Test Chemical for Rainbow Trout | $LC_{50}$ of Test Chemical for Coho Salmon |
|---|---|---|
| 6PPD | 375 ug/L | 200-500 ug/L |
| 6PPDQ | 1.8 ug/L | .04 ug/L (established through other studies) |
| Ozonated 6PPD | 128 ug/L | Data forthcoming |
| 7PPD | 643 ug/L | 707 ug/L |
| Ozonated 7PPD | >240 ug/L | Data forthcoming |
| 77PD | 321 ug/L | 159 ug/L |
| Ozonated 77PD | >240 ug/L | Data forthcoming |

[20] https://www.ezview.wa.gov/site/alias__1962/37732/research_and_proposed_alternatives_to_6ppd.aspx

| Chemical | $LC_{50}$ of Test Chemical for Rainbow Trout | $LC_{50}$ of Test Chemical for Coho Salmon |
|---|---|---|
| TMQ | >2000 ug/L | No planned testing |

Results showed the following:

- 7PPD is less toxic than 6PPD towards Coho salmon and Rainbow trout.
- 77PD is more toxic than 6PPD, but ozonated 6PPD is more toxic than ozonated 7PPD or ozonated 77PD.
- TMQ did not show toxicity towards Rainbow trout at tested levels; however, manufacturers indicated that it does not have sufficient anti-ozone performance to replace 6PPD by itself.

These results suggest that neither 7PPDQ nor 77PDQ have as high aquatic toxicity as 6PPDQ, despite their similar chemical structure. The high toxicity towards Coho salmon (and other salmonids) seems to be specific to 6PPDQ. Other PPD-quinones and ozonated PPDs are not nearly as toxic, opening up the possibility that other PPD compounds could be safer alternatives to 6PPD. However, while 7PPD and 77PD may be less toxic than 6PPD, they do not meet the toxicity standards in our 6PPD hazard criteria to be considered safer alternatives. 7PPD is a Benchmark-1 chemical due to reproductive toxicity. 77PD does not meet our hazard criteria due to high aquatic toxicity to Bluegill.

## 6PPD Alternatives Assessment next steps

We will continue to fund research to evaluate potential alternatives to 6PPD. This includes contracts with Washington State University, the United States Geological Survey, and private toxicology and rubber testing labs. Although we rely on manufacturers and other groups to develop alternatives, they are not required to conduct any specific testing. To thoroughly evaluate alternatives against our criteria, we will need to conduct some testing ourselves.

We are interested in testing alternatives identified in the manufacturers' Phase 1 Alternatives Assessments submitted to the California Department of Toxic Substances Control, alternatives mentioned in journal articles, and those promoted by other parties. These alternatives include both PPD and non-PPD compounds.

We currently have contracts extending through late 2025. If no safer alternatives have been identified by then, we may decide to extend those contracts or create new contracts.

### Data gaps and research needs

In addition to toxicological data gaps for potential alternatives, there are many questions about whether potential alternatives can meet the performance requirements of a modern automobile tire. None of the proposed alternatives submitted to the California Department of Toxic Substances Control had sufficient data at this time for manufacturers to commit to manufacture tires without 6PPD. Before 6PPD can be removed from tires, any potential alternative must undergo further toxicity, performance, and formulation testing.

## Solid Waste

### What we know

Circular economies are promoted to minimize waste in Washington state and provide opportunities for reuse of products. Once a tire can no longer be used or fulfill its original intended purpose, it becomes a waste tire. Manufacturers often recycle tires into postconsumer products like crumb rubber and rubber mulch. These products are used in environments that could promote continued leaching of 6PPD and 6PPDQ.

### Data gaps and research needs

There is limited research on 6PPD and 6PPDQ leaching potential in recycled rubber. We need additional data to understand the leaching capabilities from these products and their potential impacts on environmental and human health. We also need broad testing of 6PPD and 6PPDQ in waste generated from secondary tire lifecycle markets (e.g. tire recycling facilities) and waste generated by stormwater mitigation technologies (e.g. street sweeping).

Conducting a fish toxicity study will help us determine if this waste designates as hazardous and whether the waste meets toxicity criteria under WAC 173-303-100, Dangerous Waste Criteria.[21] Without this data, we are unable to develop new methods and guidance to inform proper waste storage, handling, and disposal. We need more research to assess leaching potential before we can implement a tire stewardship program (an initiative designed to manage and recycle discarded tires). This research can inform how waste designation affects reuse options, such as turf fields and playground surfaces.

# Summary of Recommendations

Below we provide summary tables for recommendations supported by state agency budget packages, as well as recommendations still under consideration.

**Table 3.** Summary of recommendations supported by Washington state agency 2025-2027 budget packages.

| Recommendation | Lead Agency | Recommendation Type |
|---|---|---|
| Define a broader class or subclasses of PPD chemicals for consideration as a priority chemical class under Safer Products for Washington and for developing future recommendations in the Action Plan. | Ecology | Policy |

[21] https://apps.leg.wa.gov/WAC/default.aspx?cite=173-303-100

| Recommendation | Lead Agency | Recommendation Type |
|---|---|---|
| Identify consumer products that are sources and uses of PPDs. | Ecology | Policy |
| Assess recycled rubber-based outdoor recreational surfaces in Washington to identify safer options. Develop replacement guidance, stormwater management guidance, and a replacement program. Focus this work on overburdened communities. | Ecology | Policy |
| Complete a fish toxicity study to determine whether wastes from recycled tire products need special handling or stormwater control measures. | Ecology | Policy |
| Assess proper storage, handling, and disposal methods of tires and post-consumer tire waste products. | Ecology | Policy |
| Prioritize waste tire cleanups according to potential harm to the environment and human health. | Ecology | Policy |
| Provide a toolbox for 6PPDQ municipal and industrial stormwater management and retrofit planning by regularly updating Ecology's stormwater manuals, technical guidance documents, and communications materials. Facilitate implementation of new best management practices through comprehensive project management of the Stormwater Work Group. | Ecology and Transportation | Policy |
| Adopt proposed water quality criteria for 6PPDQ to protect aquatic life and apply the new criteria to water quality permits upon approval from EPA. | Ecology | Policy |
| Fund research to assess hazard and performance of potential safer alternatives to 6PPD in tires. | Ecology | Research |

| Recommendation | Lead Agency | Recommendation Type |
|---|---|---|
| Support primary research that investigates which species may be affected by 6PPD and 6PPDQ and how these chemicals exert toxicity. | Ecology | Research |
| Expand research and monitoring of high priority tire-related compound threats to migratory, nearshore, and marine species. | Fish and Wildlife | Research |
| Provide long-term funding to continue research and monitoring of high priority tire-related compound threats to anadromous habitats. | Ecology | Research |
| Continue to assess emerging science and research on human exposure pathways and potential health hazards of 6PPD and its environmental transformation products, including 6PPDQ. | Health | Research |
| Assess the potential for 6PPD and transformation products to reach Washington drinking water sources. | Health | Research |
| Conduct two additional years of research and studies to identify how effective stormwater best management practices are for treating 6PPDQ, including completing laboratory studies currently underway and implementing and monitoring BMPs installed in the field. | Ecology | Research |
| Evaluate the potential for human health impacts of 6PPD due to consumption of aquatic species, including but not limited to salmonids. | Health | Research |
| Investigate holistic effects on people's health resulting from salmon decline due to 6PPD and 6PPDQ. | Health | Research |

| Recommendation | Lead Agency | Recommendation Type |
|---|---|---|
| Form a statewide 6PPD communications collaborative group to support timely information sharing; identify and engage with overburdened communities; and implement reporting and hazard communication on 6PPD and 6PPDQ in overburdened, underserved community media outlets (i.e. radio, newspaper). | Ecology | Management |
| Continue tracking and engaging with ongoing federal 6PPD and 6PPDQ work to ensure Washington's work aligns with current federal knowledge, guidance, and initiatives. | Ecology | Management |
| Implement Tire Pile Removal Program | Natural Resources | Management |

**Table 4.** Summary of recommendations still under consideration.

| Recommendation | Lead Agency | Recommendation Type |
|---|---|---|
| Assess the feasibility of a tire industry fee program to support funding for tire contaminant research. | Ecology | Policy |
| When Ecology opens Chapter 173-350 WAC (Solid Waste Handling Standards) for revision, revise the current WAC 173-350-350 (Waste Tire Storage) using current studies to evaluate the waste tire permit threshold. Additionally, establish location standards similar to those required for inert waste landfills. | Ecology | Policy |
| Revise requirements for using the statewide environmental vendor pool for 6PPDQ and contaminants of emerging concern. | Department of Enterprise Services | Policy |
| Expand lab capacity to support additional 6PPDQ monitoring and research. | Ecology | Policy |
| Develop a Washington State Tribal Leaders Advisory Board to support continuous engagement and participation in projects related to 6PPD and salmon recovery. | Ecology | Management |
| Provide capacity to review Ecology's Environmental Information Monitoring database (EIM) to determine optimization needs for storing 6PPD data. | Ecology | Management |
| Create incentives and invest in initiatives to identify sustainable chemistry and materials for use in tires and other products that use PPDs. | Ecology | Management |

| Recommendation | Lead Agency | Recommendation Type |
|---|---|---|
| Support Tribes exercising their Tribal Treaty Rights and sovereign rights when managing toxics in stormwater, including prioritizing salmon recovery in Usual and Accustomed Areas and maximizing the health and abundance of salmon at a watershed scale. | Ecology | Management |
| Create a dedicated funding pool for creating community co-benefits and addressing environmental injustices through the installation, operation, monitoring, and maintenance of stormwater BMPs. | Ecology, Transportation, and State Parks | Management |
| Dedicate funding toward evaluating and implementing stormwater operations and maintenance best practices to ensure the long-term effectiveness of BMPs that address 6PPD. | Ecology | Management |
| Support local efforts to implement the Retrofit Prioritization Framework developed by the Puget Sound Stormwater and Transportation Charter Group. | Ecology | Management |
| Conduct a barriers analysis of factors that inhibit installation of stormwater BMPs for municipalities and permittees. | Ecology | Management |
| Investigate alternative methods of funding stormwater BMP installation to reduce impacts to overburdened communities and permittees. | Ecology | Management |
| Implement the low-risk, high-reward stormwater treatment demonstration projects identified by the Federal Puget Sound Leadership Task Force Stormwater and Transportation Charter Group. | Department of Transportation | Management |

| Recommendation | Lead Agency | Recommendation Type |
|---|---|---|
| Research the extent to which state programs that are intended to reduce vehicle miles traveled can reduce the volume of 6PPD and 6PPDQ released into highway stormwater. | Transportation | Research |
| Develop a 6PPDQ field method training and outreach program to support standardized spatial and temporal occurrence sampling and surveys to inform treatment prioritization efforts. | Ecology | Research |

## 2025-27 Budget Package Recommendations

Advisory committee members supported the development of recommendations prioritized for the 2025-27 budget proposal. The following recommendations are included in the Legislative report and are also supported by the agency 2025-27 budget packages.

## Policy Recommendations

### Define a broader class or subclasses of PPD chemicals for consideration as a priority chemical class under Safer Products for Washington and for developing future recommendations in the Action Plan.

#### Lead agency

Department of Ecology

#### Proposed partners for implementation

Department of Health

#### Justification

6PPD is one chemical in a larger group of para-phenylenediamine (PPDs) derivatives that may share chemical and toxicological properties. PPDs have a variety of uses in commerce, most prominently as antioxidant additives in products. A recent study of urine samples in China reported co-exposure to multiple PPDs (Mao et al., 2024). While this finding has not been confirmed in a U.S. population, it raises concern for PPDs as a class. Regulating groups of chemicals as classes (rather than individually) helps prevent the use of regrettable substitutes.

A regrettable substitute can occur when one chemical is recognized as toxic or is subjected to use restrictions and manufacturers then switch to a closely related chemical that shares hazard traits. While chemicals similar to 6PPD are most likely to be acceptable for performance, they are also likely to have similar hazard concerns for people and the environment.

Ecology and Health should work together to define a chemical class or classes that includes 6PPD and other related PPD chemicals of potential concern. This definition of PPDs as a class can be taken into consideration for inclusion as a priority chemical class under Safer Products for Washington, as well as used by other programs as relevant. Future phases of the action plan should consider recommendations related to the uses and releases of this broader class of PPDs that result in human health exposures and environmental contamination.

A recent report provides a starting place to define a PPD class. Using chemical structure descriptors, California has proposed a group of 1849 PPDs for identification as candidate chemicals for their Safer Consumer Products program (DTSC, 2023). The California program has significant differences from Safer Products for Washington. That said, Ecology can leverage the research that supports the California candidate chemicals listing as we develop information and criteria for PPD chemicals. Ecology's Safer Products for Washington program can use this research to define priority chemical classes for consideration.

## Identify consumer products that are sources and uses of PPDs.

### Lead agency

Department of Ecology

### Proposed partners for implementation

Department of Health

Ecology should reach out to other potential partners to gauge their interest in participating in implementation of this recommendation. Potential partners may include commerce and economic development councils across the state.

### Environmental justice opportunities

Prioritize products used, made, or handled by vulnerable populations.

### HEAL Act alignment

Community engagement

### Justification

Manufacturers often recycle tires into post-consumer products, including playground surfaces, traffic control devices, pavements, synthetic turf infill, flooring, and rubber mulch. These secondary consumer products are sources of 6PPD and 6PPDQ. These products are used in environments that could promote continued leaching of 6PPD and 6PPDQ.

Other PPD chemicals are also present in products. This can result in human exposure and environmental contamination. Other PPDs share the antioxidant functions of 6PPD. These PPDs could be considered as alternatives to 6PPD if regulatory action is taken on 6PPD in tires and other products. Aside from the major use as antioxidants, other functions of these chemicals should be addressed. For example, the chemical after which this group is named, para-phenylenediamine, has been long recognized as a chemical sensitizer. Para-phenylenediamine is used in some hair dye products (DTSC, 2023).

Ecology and Health should evaluate available information on PPD chemicals used in products. Additionally, they should evaluate potential for exposure to people and the environment in Washington. The departments should begin with 6PPD and expand to classes of PPD chemicals.

Ecology and Health should use the available information on product use, the concentrations of PPDs in products, and potential for exposure to inform prioritization of possible priority products under Safer Products for Washington. The information collected on the uses and releases of PPD chemicals in products can also inform recommendations that we can propose in later phases of our action plan work.

Ecology and Health should take the following steps to conduct this work:

1. Identify product categories, in addition to tires, that may be significant sources and uses of PPDs. Based on this data, make recommendations for Safer Products for Washington to consider in future cycles.
2. Identify downstream uses in products of tires, including end of life disposal, that may contribute to PPD exposure and release into the environment. Based on this data, make recommendations for reducing exposure, including evaluating safer alternatives, providing technical assistance, and considering certain products under the Safer Products for Washington or product replacement programs.
3. Use available tools to assess 6PPD and 6PPDQ in consumer products.

### Related recommendations

- Assess recycled rubber-based outdoor recreational surfaces in Washington to identify safer options. Develop replacement guidance, stormwater management guidance, and a replacement program. Focus this work on overburdened communities.
  Link to recommendation.
- Define a broader class or subclasses of PPD chemicals for consideration as a priority chemical class under Safer Products for Washington and for developing future recommendations in the Action Plan.
  Link to recommendation.

## Assess recycled rubber-based outdoor recreational surfaces in Washington to identify safer options. Develop replacement guidance, stormwater management guidance, and a replacement program. Focus this work on overburdened communities.

### Lead agency

Department of Ecology

### Proposed partners for implementation

Department of Health

Ecology should reach out to other potential partners to gauge their interest in participating in the implementation of this recommendation. Potential partners may include the Recreation

and Conservation Office, Parks and Recreation departments, Office of Superintendent of Public Instruction, manufacturers, athletic associations, and King County.

### Environmental justice opportunities

Prioritize overburdened communities for funding and technical assistance.

### HEAL Act alignment

Service/budget equity

### Justification

Ecology and Health may promote the use of safer alternatives to crumb rubber through one or more of the following options:

- Statutory actions
- Regulatory actions
- Voluntary actions

Ecology and Health should develop programs to address crumb rubber field infill as a source of 6PPD and 6PPDQ. Ecology and Health should pursue the following:

- Research safer alternatives to crumb rubber, including the work by Ecology's Product Replacement Program, and the impact crumb rubber fields have on air and water quality. This research should include information about the feasibility and availability of alternative field materials. Such materials may include sand, coconut fiber, and cork as infill materials for artificial turf, as well as natural grass fields and alternative playground materials, such as woodchips.
- Assess reuse products (e.g. playground surfaces, traffic control devices, pavements, synthetic turf infill, flooring, rubber mulch) as a source of 6PPD and 6PPDQ.
- Share the information collected above with the Safer Products for Washington program.
- Develop informational resources and guidance based on research on available safer alternatives. Share with Tribes, municipalities, school districts, sports clubs, the public, and other parties to inform and support decision making.
- Develop guidance for best management practices to manage stormwater for outdoor recreational surfaces that include crumb rubber. This guidance should also be required in state and local contracting if new projects decide to use crumb rubber materials. This will include the ecological concerns of crumb rubber infill pending replacement actions since the timeline for replacing outdoor recreational surfaces may be lengthy.
- Provide funding to help communities replace their facilities with safer materials. Outdoor recreational surfaces are a critical component of healthy built environments for school and community health. Funding resources must prioritize vulnerable and under-resourced communities and school districts.

Ecology's Product Replacement Program is one mechanism for supporting replacement of crumb rubber filled fields with safer alternatives. This program uses funding from the Legislature to reduce the use of toxic chemicals. This occurs through projects that provide reimbursement for replacement, as well as disposal services and technical assistance. Ecology's

Product Replacement Program is committed to investigating turf fields' environmental impact on air and water quality to determine the need for a replacement program that considers safer alternatives.

### Related recommendations

- Identify consumer products that are sources and uses of PPDs. Link to recommendation.

## Complete a fish toxicity study to determine whether wastes from recycled tire products need special handling or stormwater control measures.

### Lead agency

Department of Ecology

### Proposed partners for implementation

To be determined

### Justification

Ecology should conduct broad testing of 6PPD and 6PPDQ in waste generated from secondary tire lifecycle markets (e.g. tire recycling facilities) and waste generated by stormwater treatment technologies (e.g. street sweeping). Testing should use biological testing methods adopted under Washington Administrative Code (WAC) 173-303-110(3) (e.g. fish bioassay). Ecology should use these results to determine if the waste meets toxicity criteria under WAC 173-303-100.

Ecology's Solid Waste Program is directed to[22] conduct "a review of the disposal, repurposing, reuse, recycling, handling, and management of waste tires in the state." The purpose of this analysis is to determine where tire waste is generated and how it is disposed. This analysis would include an assessment of environmental impacts. Ecology should analyze the waste generated at these facilities to provide data for dangerous waste designation. This designation would help the agency determine which disposal requirements do not negatively impact salmonids in Washington state. Additionally, this study could inform a tire stewardship program based on how designation would affect reuse options, such as field turf.

## Assess proper storage, handling, and disposal methods of tires and post-consumer tire waste products.

### Lead agency

Department of Ecology

### Proposed partners for implementation

To be determined

[22] https://legiscan.com/WA/text/SB5950/2023

### Environmental justice opportunities

Inform vulnerable populations that use post-consumer tire waste.

### HEAL Act alignment

Community engagement

### Justification

If the fish toxicity study determines that waste generated by secondary tire lifecycle markets meets toxicity criteria under WAC 173-303-100, the waste will need methods for proper storage, handling, and disposal. These methods would support guidance to the industry that handles waste tires and tire products. Ecology should conduct outreach to provide this guidance to industry, tire wholesalers, auto shops, the public, and anyone handling waste tires and/or products created from waste tires.

### Related recommendations

- Complete a fish toxicity study to determine whether wastes from recycled tire products need special handling or stormwater control measures.
  Link to recommendation.

## Prioritize waste tire cleanups according to potential harm to the environment and human health.

### Lead agency

Department of Ecology

### Proposed partners for implementation

Department of Health, Department of Natural Resources

### Environmental justice opportunities

Prioritize cleanup based on proximity to overburdened communities.

### HEAL Act alignment

Service/budget equity

### Justification

Ecology should prioritize waste tire cleanups based on:

- Proximity to critical areas.
- Proximity to overburdened communities and sensitive populations (environmental justice).
- Streams with impacted species.
- Surface waters.
- Water sources.
- Wetlands.

- Flood plains.
- Other areas with potential impacts to water.

Ecology should take environmental justice into account when prioritizing tire cleanups. Ecology can consult with Health to identify communities of concern using tools like the Washington Environmental Health Disparities Map[23] when prioritizing tire cleanups. Prioritizing tire cleanups based on environmental impacts and environmental justice ensures the department addresses tire piles that have the largest impact on the environment and human health before others.

## Provide a toolbox for 6PPDQ municipal and industrial stormwater management and retrofit planning by regularly updating Ecology's stormwater manuals, technical guidance documents, and communications materials. Facilitate implementation of new best management practices through comprehensive project management of the Stormwater Work Group.

### Lead agency

Department of Ecology and Washington State Department of Transportation

### Proposed partners for implementation

Stormwater Work Group, municipalities, consultants

#### Environmental justice opportunities

Develop effective, accessible, and/or affordable retrofit designs that serve vulnerable populations.

#### HEAL Act alignment

Service/budget equity

### Justification

The 2024 Phase I and II Municipal Stormwater Permits will have new requirements for street sweeping, retrofits, and project thresholds. These requirements are intended to help address 6PPD, 6PPDQ, and a range of other contaminants. However, the type of stormwater best management practices (BMPs) that stormwater managers and permittees will implement depends on site specific characteristics. The Stormwater Management Manuals (SWMMs)[24] of Western and Eastern Washington describe suitable BMPs (based on site characteristics) that stormwater managers and permittees can install. It also describes the BMPs that we know are

[23] https://doh.wa.gov/data-and-statistical-reports/washington-tracking-network-wtn/washington-environmental-health-disparities-map

[24] https://ecology.wa.gov/regulations-permits/guidance-technical-assistance/stormwater-permittee-guidance-resources/stormwater-manuals

effective at addressing 6PPD. Ecology should also use the Emerging Stormwater Treatment Technologies (TAPE) website[25] as a resource for communicating 6PPDQ guidance.

Ecology should incorporate new information on 6PPD into regulatory documents in a timely manner. This ensures permittees have the most up-to-date methods for removing pollutants; improving stormwater management for 6PPD and other pollutants; and improving the health of watersheds. Therefore, Ecology is also preparing to reissue the Municipal Stormwater Permits in 2029. Ecology should include 6PPD BMP effectiveness research in permit requirements.

Many permittees have indicated that they would appreciate a clearer resource, or toolbox, for implementing BMPs to manage 6PPD and 6PPDQ. Therefore, this recommendation seeks to add additional Ecology permitting staff to translate stormwater BMP effectiveness research into permit, manual, and technical guidance. These new permit staff will regularly improve upon the SWMMs, TAPE website, and the 2029-2034 Municipal Stormwater Permits by:

- Attaching new 6PPDQ guidance to the digital SWMMs.
- Updating the emerging guidance section of the SWMMs focused on 6PPDQ.
- Updating guidance on the TAPE website to include 6PPDQ.
- Creating outreach materials like focus sheets, blogs, listservs, etc. to announce new additions to the SWMMs and the TAPE website.
- Writing a fact sheet that compiles all relevant 6PPDQ information from the SWMMs and the TAPE website into one document.
- Translating research findings from 6PPD BMP effectiveness research into permit requirements for the 2029-2034 Municipal Stormwater Permits.

Together, these resources would seek to communicate:

- The relative effectiveness of BMPs for managing 6PPD.
- The BMPs that could feasibly be installed based on site characteristics.
- Implementation and maintenance costs of BMPs.
- Job creation or investment needs.
- An assessment of existing stormwater projects that 6PPDQ management could be added onto (i.e. culvert removal).
- How permittees could include Tribal Treaty Rights and environmental justice in stormwater management planning.
- How climate change could impact effectiveness of BMPs across Washington state.
- How BMPs help meet new permit requirements.
- Considerations from other regulatory frameworks, such as the Technology Assessment Protocol – Ecology (TAPE), Stormwater Testing and Evaluation for Products and

[25] https://ecology.wa.gov/regulations-permits/guidance-technical-assistance/stormwater-permittee-guidance-resources/emerging-stormwater-treatment-technologies

Practices, the State Environmental Policy Act, the Endangered Species Act, and the Clean Water Act.

### Adopt proposed water quality criteria for 6PPDQ to protect aquatic life and apply the new criteria to water quality permits upon approval from EPA.

#### Lead agency
Department of Ecology

#### Proposed partners for implementation
U.S. EPA, municipalities

#### Justification
In February 2024 Washington State proposed 6PPDQ aquatic life criteria in an update to our water quality standards. A final decision on whether to adopt those criteria into rule will be made in Fall 2024. If they are adopted by the state, they will then be sent on to EPA for Clean Water Act review.

This standard could affect MS4, industrial stormwater permittees, and entities permitted to discharge to fresh waters. The 2024 draft Industrial Stormwater General Permit proposes that facilities in various sectors begin sampling and reporting 6PPDQ concentrations on a quarterly basis, without a numeric effluent limit or benchmark. The Municipal Stormwater Permits were reissued in 2024 and do not include this standard. However, the water quality criteria could be included when this permit is reissued in 2029. Through this recommendation, Ecology commits to working with the EPA, industry, and municipalities to identify any effects to permittees in the permit development process.

## Research Recommendations

### Fund research to assess hazard and performance of potential safer alternatives to 6PPD in tires.

#### Lead agency

Department of Ecology

#### Proposed partners for implementation

University of Washington, Washington State University, National Oceanic and Atmospheric Administration, United States Geological Survey, commercial rubber testing laboratories, rubber and tire manufacturers, non-governmental organizations

#### Justification

Ecology doesn't currently know whether:

- Potential alternatives meet the tire performance requirements to replace 6PPD.

- Potential alternatives meet the toxicological requirements (as defined in the 6PPD Alternatives Assessment Hazard Criteria)[26] to be safer to humans and the environment.

Funding would allow Ecology to use toxicity testing to assess the hazard of potential alternatives. It would also enable the agency to assess antiozonant performance using rubber testing. Ecology is contacted routinely by chemical manufacturers to assess chemicals that they feel could be a replacement for 6PPD in tires. In a few instances, there is lack of performance testing because the tire manufacturers are not currently considering the chemical. To provide reasons for the industry to consider these chemicals, Ecology may choose to fund initial rubber testing to confirm potential performance in a tire. The department may consult rubber and tire manufacturers for their expertise.

## Support primary research that investigates which species may be affected by 6PPD and 6PPDQ and how these chemicals exert toxicity.

### Lead agency

Department of Ecology, Department of Fish and Wildlife

### Proposed partners for implementation

Department of Health, United States Geological Survey, National Oceanic and Atmospheric Administration, Washington State University, Washington Stormwater Center, University of Washington, Tribal partners

### Environmental justice opportunities

Include native species that are of significance to subsistence fishers from vulnerable populations; include marine and freshwater aquatic species that are of significance to vulnerable populations.

### HEAL Act alignment

Service/budget equity

### Justification

Ecology and the Department of Fish and Wildlife (WDFW) identified several significant data gaps around which species 6PPD and 6PPDQ impact and how the chemicals cause toxicity. The research efforts outlined in this recommendation are designed to close some of those data gaps. These efforts currently focus on 6PPD and 6PPDQ but can be expanded to consider additional PPDs and viable alternatives as needed. Priority research topics, in no specific order, are as follows:

- **Mode of action of 6PPD and 6PPDQ on salmonid species.** The mode of action refers to how a chemical interacts with living organisms to cause toxicity or another effect.
- **Acute and chronic effects of 6PPD and 6PPDQ on non-salmonid species**. Focus on culturally, economically, and ecologically significant species living in the Pacific

[26] https://apps.ecology.wa.gov/publications/SummaryPages/2304036.html

Northwest. Acute toxicity refers to the immediate effect(s) of chemical exposure. Chronic toxicity refers to the effect(s) of repeated or continuous low-dose chemical exposure.

- **Sublethal exposure effects of 6PPD and 6PPDQ on aquatic life**. Sublethal exposure effects are any non-lethal impacts that may occur to an organism after exposure to a chemical, such as impaired growth or impaired motor function.

Closing important data gaps related to 6PPD and 6PPDQ ecotoxicology is a vital step in understanding the effects of these contaminants on environmental health. Results of the research efforts described below have the potential to impact several areas of 6PPD and 6PPDQ decision-making:

- Provide data to inform any future population studies of potentially affected fish, shellfish, and plant life.
- Identify additional species that may be impacted by 6PPD and 6PPDQ, especially harvested species that are identified by Health and other partners as important to communities that face disproportionate environmental impacts.
- Support toxicity testing on 6PPD and their transformation chemicals for potential alternatives to 6PPD in tires and other commercial products.

Ecology may support this research through funding or other routes. For example, Ecology has ongoing contracts and funding commitments with academic and government agencies to further 6PPD and 6PPDQ ecotoxicity research. Ecology is also committed to non-funding forms of support, which could include letters of support, outreach, and education.

**Research Topic 1: Mode of action of 6PPD and 6PPDQ on salmonid species**

**Lead agency: Department of Ecology**

Despite the high acute toxicity response of 6PPD-quinone on coho salmon, researchers do not yet understand the mode of action of 6PPD and 6PPDQ on salmonid species (Blair et al., 2021; Mahoney et al., 2022; Greer et al., 2023).

More research is needed to fully understand the toxic effect of these chemicals on coho salmon and other salmonids. Such research can help Ecology and WDFW determine what other species are similarly affected by 6PPD and 6PPDQ. Understanding the mode of action could help in designing alternatives that avoid this mechanism. Tests should include *in vivo* and *in vitro* laboratory studies that investigate $LC_{50}$, gene expression and function, and behavior. $LC_{50}$ is the concentration at which 50% of a test species dies when exposed to a toxic chemical.

**Research Topic 2: Acute and chronic effects of 6PPD and 6PPDQ on non-salmonid species**

**Lead agency: Department of Ecology, Department of Fish and Wildlife**

Washington State needs to understand risks to potential species of concern across different taxonomic groups and trophic levels. Organisms such as phytoplankton and zooplankton are important food sources for species of concern (Johnson and Ringler, 1980; NOAA, 2023; NWF, n.d.). Any detrimental effect to the populations of these and other lower trophic level organisms, like eelgrass, could have larger population effects for organisms up the food chain.

Information about the toxic effects of 6PPD and 6PPDQ across trophic levels is vital to understanding the full impact of 6PPD and 6PPDQ on the environment. Additionally, the Alternatives Assessment includes a requirement to investigate the effects of 6PPD and 6PPDQ across tropic levels. Once the Alternatives Assessment is completed, this recommendation can be expanded during Phase 2 of the 6PPD Action Plan to explore the toxic impact of potentially viable alternatives on species of concern in the Pacific Northwest.

**Research Topic 3: Sublethal exposure effects of 6PPD and 6PPDQ on aquatic life**

**Lead agency: Department of Ecology, Department of Fish and Wildlife**

To address the lack of data related to chronic and/or sublethal effects of 6PPD and 6PPDQ on aquatic plant and animal fitness, Washington state should support research initiatives investigating this topic. Ecology and WDFW can then use the results from such studies to inform and/or predict potential population-level effects. Studies supported by this recommendation should include both laboratory- and field-based experiments. Ecology and WDFW recommend laboratory studies use both *in vitro* and *in vivo* models when appropriate. Specific sublethal toxicity responses may include but are not limited to:

- Lethargy.
- Altered fin or brain development.
- Physical size changes.
- Altered reproductive development.
- Abnormal predator avoidance behaviors.
- Altered smoltification (the process – physical, morphological, and behavioral – by which juvenile salmon transition from freshwater to saltwater environments).

In addition to classic dose-response studies, endpoints to explore may include persistence and chemical half-life within organisms of concern. These endpoints are critical to addressing existing 6PPD in the environment and in seafood. Knowledge about the persistence of these chemicals in edible fish tissue would also help Health understand if eating these fish are a concern for human health.

## Related recommendations

- Provide long-term funding to continue research and monitoring of high priority tire-related compound threats to anadromous habitats.
  Link to recommendation.
- Continue tracking and engaging with ongoing federal 6PPD and 6PPDQ work to ensure Washington's work aligns with current federal knowledge, guidance, and initiatives.
  Link to recommendation.

## Expand research and monitoring of high priority tire-related compound threats to migratory, nearshore, and marine species.

### Lead agency

Department of Fish and Wildlife (WDFW)

### Proposed partners for implementation

Department of Ecology, Department of Health, Washington State University/Washington Stormwater Center, University of Washington, National Oceanic and Atmospheric Administration, United States Geological Survey, Tribal partners

### Justification

Tire-related compounds like 6PPD and 6PPDQ are just one of many contaminants in Puget Sound. Endangered Southern Resident killer whales, threatened Chinook salmon, forage fish, plankton, and other species are exposed to these chemicals when eating and residing in their habitats.

The Department of Fish and Wildlife's contaminant monitoring program, Toxics Biological Observation System (TBiOS), conducts ongoing biennial surveys of toxic contaminants in Pacific herring, English sole, and Chinook salmon. TBiOS also recently started monitoring contaminants in the nearshore using caged bay mussels. The department reports on these species and contaminants as part of Toxics in Aquatic Life Vital Sign.[27]

WDFW received funding from the Legislature to measure contaminants of emerging concern, including tire-related compounds, in historic indicator species. Preliminary monitoring results revealed detections of 6PPDQ in whole body tissue samples of juvenile Chinook salmon and caged bay mussels sampled from developed sites (Kuo et al., 2024). These results demonstrate that these species are excellent indicators for assessing the presence of tire wear compounds in estuarine and nearshore habitats.

Additional in-depth sampling (beyond what WDFW can accomplish with current funding) is needed to better understand the extent to which juvenile Chinook and coho salmon are exposed to tire-related compounds and where these compounds are entering waterways. Sampling is also needed for tire-related compounds in other marine and anadromous species that WDFW and Ecology do not currently monitor but that Health may use to determine potential for human exposure through fish consumption.

The information that TBiOS collects would advance our understanding of the occurrence and potential threat of tire-related compounds in Puget Sound fishes, invertebrates, and the food web. WDFW would collaborate with Ecology to identify high-priority remediation sites by conducting in-depth 6PPD and 6PPDQ tissue concentration monitoring at sites that Ecology's passive sampling network has flagged as contaminated. Targeted studies of juvenile salmon in high-risk river systems could provide additional exposure details for other threatened species. Additionally, WDFW would regularly assess 6PPDQ in caged mussels in nearshore marine

[27] https://vitalsigns.pugetsoundinfo.wa.gov/VitalSign/Detail/28

waters around the state to identify potential exposure sites for salmonids moving through the area.

Results will be used to guide clean-up and pollution prevention efforts in juvenile salmon habitats and aecelerate recovery and protection of species listed under the Endangered Species Act, including Chinook salmon, steelhead trout, and other Puget Sound species. Biomonitoring data will identify locations where species are exposed to tire-related chemicals, including 6PPD and 6PPDQ. This is critical to reducing threats to toxic chemicals in Puget Sound and recovery of the ecosystem.

TBiOS would share the tire-related compound data it collects from edible fish tissues with Health, as it has done with other legacy contaminants in the past. Once health-based guidance levels are available, Health could use these levels to create human health consumption advisories. WDFW may also expand its monitoring program to sample at new locations identified or to sample species not currently monitored by WDFW at Health's request.

### Related recommendations:

- Provide long-term funding to continue research and monitoring of high priority tire-related compound threats to anadromous habitats.
  Link to recommendation.
- Evaluate the potential for human health impacts of 6PPD due to consumption of aquatic species, including but not limited to salmonids.
  Link to recommendation.
- Develop a 6PPDQ field method training and outreach program to support standardized spatial and temporal occurrence sampling and surveys to inform treatment prioritization efforts.
  Link to recommendation.

## Provide long-term funding to continue research and monitoring of high priority tire-related compound threats to anadromous habitats.

### Lead agency

Department of Ecology

### Proposed partners for implementation

Washington Department of Fish and Wildlife, Washington Department of Transportation, Washington State Department of Health, and additional State and federal agencies, Tribal governments, academic scientists, and other entities as indicated

### Justification

Toxic exposures, including anti-ozonates like 6PPDQ, are a known cause of declining salmonid populations. However, exposure to toxic chemicals is often overlooked when planning urban development, restoration, and conservation actions. If salmonids and other impacted aquatic life face continued exposure to toxic chemicals, restoration efforts (such as stream restoration,

riparian revegetation, and fish passage improvement projects) could be undermined and fail to positively impact recovery without corresponding water quality improvement projects. Ecology and research partners lack the long-term resources to effectively address toxics in aquatic ecosystems. Flexible and consistent funding is needed to support ongoing Ecology research and engage in collaborative, multi-disciplinary partnerships to expand the toxics in fish and aquatic life research efforts across Washington State.

This work would provide long-term funding to continue research and monitoring of high priority tire-related compound threats to anadromous habitats by:

- Continuing to evaluate and employ field sampling methods for measuring 6PPDQ in water, sediments, biota, and periphyton.
- Continuing to develop laboratory methods for measuring 6PPDQ in sediments, biota, and periphyton.
- Supporting lab capacity for 6PPDQ monitoring and research.
- Identifying collaborative sampling opportunities with parallel monitoring efforts to characterize 6PPDQ across urban gradients.
- Conducting high resolution source ID monitoring when high levels of 6PPDQ are found.

Ecology could provide long-term funding to continue coordinating and standardizing 6PPD science and monitoring activities in Washington State by:

- Coordinating with agencies, tribes, federal partners, and academia through the Salmon Recovery Office, the Puget Sound Partnership workgroups, Puget Sound Stormwater and Transportation workgroup, and other groups across Puget Sound and the Columbia Basin.
- Coordinating sampling efforts across organizations and forming joint agency agreements between Ecology science staff and our research partners.
- Providing technical assistance to communities.
- Installing a platform of 20+ monitoring stations to monitor 6PPDQ across the urban gradient and conduct source ID monitoring when levels of 6PPDQ are found.
- Leveraging existing juvenile chinook monitoring work by adding sites and doing high resolution toxics and 6PPDQ analysis and identifying hotspots to focus mitigation efforts.
- Using 6PPDQ detection in receiving waters as a surrogate for point and non-point stormwater pollution to help focus water quality improvement needs.

This work would provide continued sampling of priority contaminants of concern, including 6PPDQ in water, sediments, and biota in natural waterways, with an initial focus on salmonid habitat. The program would also complement WDFW 's TBiOS' aquatic species tissue collections. The program would also participate in collaborative platforms for priority contaminant environmental research. This recommendation supports many of the recommendations that require 6PPDQ sampling, particularly: Expand research and monitoring of high priority tire-related compound threats to migratory, nearshore, and marine species.

The benefit of this work includes:

- Piloting new methods and tools to accelerate toxics pollution identification to support salmon recovery and sustainability.
- Evaluating impacts of 6PPD and 6PPDQ remediation efforts in aquatic environments.
- Participating and communicating research findings through peer-reviewed publications, science conferences, and community outreach events.
- Informing models that examine changes in toxics loading and transport resulting from loss of vegetation and increases in impervious surfaces on toxics loading transport causing greater risk to aquatic life (urban stream syndrome).
- Providing technical guidance to local communities and regional conservation groups that are planning monitoring studies.
- Providing data to high-resolution toxics models that identify locations for transportation-related pollution mitigation actions and infrastructure investments.

The following are consequences if we don't conduct 6PPDQ sampling in aquatic ecosystems:

1) Lacking data to geographically focus enhanced water quality improvement projects that maximize benefits and minimize cost.

2) Lacking data to measure and support how well our water quality improvement projects have helped waterways recover; and

### Related recommendations

- Expand research and monitoring of high priority tire-related compound threats to migratory, nearshore, and marine species recommendation.
  Link to recommendation.
- Assess the potential for 6PPD and transformation products to reach Washington drinking water sources.
  Link to recommendation.
- Support primary research that investigates which species may be affected by 6PPD and 6PPDQ and how these chemicals exert toxicity.
  Link to recommendation.
- Develop a 6PPDQ field method training and outreach program to support standardized spatial and temporal occurrence sampling and surveys to inform treatment prioritization efforts.
  Link to recommendation.
- Conduct two additional years of research and studies to identify how effective stormwater best management practices are for treating 6PPDQ, including completing laboratory studies currently underway and implementing and monitoring BMPs installed in the field.
  Link to recommendation.
- Evaluate the potential for human health impacts of 6PPD due to consumption of aquatic species, including but not limited to salmonids.
  Link to recommendation.

## Continue to assess emerging science and research on human exposure pathways and potential health hazards of 6PPD and its environmental transformation products, including 6PPDQ

### Lead agency

Department of Health

### Proposed partners for implementation

State and federal agencies, academic scientists, and other entities as indicated

### Environmental justice opportunities

Identify unique exposure pathways for vulnerable populations and prioritize research for those vulnerable populations.

### HEAL Act alignment

Service/budget equity

### Justification

Researchers are just beginning to study the potential for human health effects of exposure to 6PPDQ. While more is known about the health effects of the parent chemical 6PPD, due to its long-term industrial use in tires and other products, the potential for widespread exposure and possible health impacts as a result of continuous release of 6PPD to the environment has not been characterized. Both chemicals have been documented in people's body fluids, including urine, blood, breast milk, and cerebrospinal fluid, demonstrating that people are exposed. To date, most of the studies that demonstrate human exposure have been performed in China. No studies yet address how different groups of people in Washington are exposed to 6PPD and 6PPDQ, and no biomonitoring data is available on the levels of 6PPD and 6PPDQ in Washingtonians. Due to uncertainties about potential public health impacts of 6PPD use in tires and other products, and the possibility that other chemicals may be introduced as replacement antiozonants, we recommend that Health actively engage in tracking and responding to emerging information in the following ways:

- Evaluate and interpret emerging research on health effects and exposure patterns of 6PPD, 6PPDQ, and related chemicals.
- Work to characterize the dominant pathways of exposure for Washington state populations, with a focus on identifying groups who may experience higher exposure from specific pathways.
- Develop public health communications and educational materials to provide the best current information about possible health risks of 6PPD and 6PPDQ for Washingtonians as well as opportunities to reduce use and exposure.
- Prioritize identification and engagement with communities who are more vulnerable to exposure to or health effects from 6PPD and related chemicals.

During our initial research phase some exposure pathways and further research needs were selected for further investigation. As a result of our evaluation and discussions with the advisory committee, three further recommendations are proposed below that reflect public priorities as well as feasible actions that can be taken to further investigate (Link to recommendation). We prioritized efforts to better understand whether drinking waters could be at risk of contamination, possible exposure through consumption of aquatic biota, and a project on health impacts that would begin by engaging communities in Washington who consume aquatic biota, including interested Tribes, to identify health stressors that result from 6PPD and related chemicals in the environment.

It is important to note that the current understanding of environmental fate and transport of 6PPD and 6PPDQ is growing rapidly. Research priorities for human exposure pathways and impacts may shift as Health learns more about fate and transport, toxicity, and who might be vulnerable to toxic effects. There is ongoing research at the federal level, and in other states, that may further inform exposure pathways and levels. Clarifying the exposure pathways of greatest concern is a necessary step in preparing recommendations to reduce exposure.

### Related recommendations

- Form a statewide 6PPD communications collaborative group to support timely information sharing; identify and engage with overburdened communities; and implement reporting and hazard communication on 6PPD and 6PPDQ in overburdened, underserved community media outlets (i.e. radio, newspaper) recommendation. Link to recommendation.

## Assess the potential for 6PPD and transformation products to reach Washington drinking water sources.

### Lead agency

Department of Health

### Proposed partners for implementation

Department of Ecology, Washington State Department of Transportation (WSDOT)

### Environmental justice opportunities

Prioritize the mapping of source water that is critical to vulnerable populations; prioritize overburdened communities in stormwater retrofitting projects.

### HEAL Act alignment

Service/budget equity

### Justification

Researchers have identified 6PPD and 6PPDQ in surface waters that are impacted by stormwater runoff. The Department of Health does not currently know whether contamination could reach any of the source waters that are used for drinking water in Washington nor whether contamination could reach a level that poses a concern for human health. Members of the public have raised concerns about drinking water safety related to 6PPD. A report of 6PPD

and 6PPDQ in drinking water sources in South China adds plausibility that road runoff could affect drinking water sources (R. Zhang et al. 2023)). In the Chinese study, researchers found 6PPD and 6PPDQ in water sampled from a shallow aquifer that is permeable to the adjacent river and in a polluted area. Health's Office of Drinking Water (ODW) should track 6PPD as an emerging contaminant. ODW will work with other agencies to identify appropriate actions as more scientific information is gathered about human health impacts and risk of transmission to drinking water sources.

Three aims for this recommendation are:

- Use mapping tools, shallow well characteristic data, and collaboration with other agencies to identify public drinking water system sources in Washington that may be vulnerable to contamination by stormwater runoff. Prioritize the mapping of vulnerable source waters that are also important from an equity and environmental justice standpoint.
- Collaborate with Ecology's 6PPDQ sampling and analysis projects. Through collaborative planning, sampling efforts can also inform the likelihood of drinking water source impacts. As funding allows, Ecology will sample and analyze source water from locations that Health identifies.
- Provide ongoing consultation and input on health-related impacts and health equity considerations to prioritize stormwater retrofitting projects in WSDOT'S Move Ahead Washington program. Health should evaluate whether the current map adequately captures potential risks to drinking water and vulnerable populations. Health should serve as a resource for WSDOT on human health matters.

### Related recommendations

- Provide long-term funding to continue research and monitoring of high priority tire-related compound threats to anadromous habitats.
  Link to recommendation.

## Conduct two additional years of research and studies to identify how effective stormwater best management practices are for treating 6PPDQ, including completing laboratory studies currently underway and implementing and monitoring BMPs installed in the field.

### Lead agency

Department of Ecology

### Proposed partners for implementation

Tribal Nations, Washington State University/Washington Stormwater Center, Washington State Department of Transportation, consultant organizations, municipalities, Stormwater Work Group

## Justification

Ecology has received funding from the Washington State Legislature from 2022-2023 and 2023-2025 to support stormwater BMP effectiveness research. These funds have supported several pilot studies to assess BMP effectiveness at reducing 6PPD in stormwater. Pilot projects include:

- Testing bioretention soil media mixes.
- Street sweeping effectiveness.
- Treatment of decant water.
- Stormwater characterization for different land uses and geographies.
- Monitoring for 6PPDQ in stormwater runoff.

Due to time constraints of previous Legislative funding, research has been limited to short-term pilot studies, mostly in laboratory settings. Ecology would like to continue this research for two more years in preparation for the 2029 municipal stormwater permit renewal. Research needs include:

- Test BMP effectiveness such as bioretention, road embankments, swales and other frequently prescribed BMPs in the field and over time at reducing 6PPD concentrations.
- Identify other potential sources of 6PPD such as artificial turf fields, ports, and industrial facilities, that may contribute to concentrations of 6PPD in stormwater.
- Stormwater characterization of different traffic densities and land uses to identify concentrations of 6PPD in stormwater.
- Review stormwater operations and maintenance practices such as cleaning catch basins to determine if they are effective at reducing 6PPD.
- Investigate the effectiveness of frequent street sweeping to reduce 6PPD from stormwater runoff.
- Identify proper sediment and street waste disposal guidelines.
- Understand geographic differences in the performance of BMPs (e.g., Western versus Eastern Washington).

Ecology's partners, including Tribal Nations and municipalities, have confirmed the need to test more BMPs in the field, particularly in locations where 6PPDQ may be of concern for salmon recovery. Many of these locations might not have BMPs installed yet due to development happening before Ecology required stormwater BMPs.

Ecology anticipates that many existing stormwater BMPs are not designed to be monitored. Challenges with monitoring existing stormwater BMPs include:

- Water might not flow the entire length of the BMP. Therefore, it is difficult to obtain influent and effluent samples.
- Access to BMPs might be limited, and sampling might be impossible given the location.

- It might not be possible to collect samples at BMP sites throughout an entire storm using methods other than grab samplers (i.e. autosamplers).

Stormwater characterization will help Ecology understand the impact of various land uses on stormwater quality. It will also help the department develop strategies for effective stormwater management. These projects explore variability in stormwater concentrations across different land uses and seasons. The results are used to inform and prioritize stormwater management actions and BMPs. Regional stormwater discharge data can help natural resource managers and stormwater managers reduce reliance on national studies that may not represent local climate or land uses. Ecology should also characterize stormwater to understand influent concentrations to BMPs that impact the treatment capability of the BMP.

Conducting ongoing research and monitoring BMPs implemented in the field will increase certainty about BMP effectiveness. This can speed up the inclusion of various BMPs in regulatory processes.

### Related recommendations

- Provide long-term funding to continue research and monitoring of high priority tire-related compound threats to anadromous habitats.
  Link to recommendation.
- Complete a fish toxicity study to determine whether wastes from recycled tire products need special handling or stormwater control measures.
  Link to recommendation.
- Assess proper storage, handling, and disposal methods of tires and post-consumer tire waste products.
  Link to recommendation.

## Evaluate the potential for human health impacts of 6PPD due to consumption of aquatic species, including but not limited to salmonids.

### Lead agency

Department of Health

### Proposed partners for implementation

Department of Fish and Wildlife, Ecology, Tribes, community leaders, King County, Northwest Indian Fisheries Commission, Columbia River Inter-Tribal Fish Commission

### Environmental justice opportunities

Identify aquatic species that are food sources for vulnerable populations.

### HEAL Act alignment

Community engagement; service/budget equity

## Justification

Members of the public and Tribes are concerned that animals and plants harvested for food could be sources of human exposure to 6PPD, 6PPDQ, and other chemical transformation products of 6PPD. Health does not know the levels of these compounds in fished and foraged foods or whether consumption could pose a human health hazard. This recommendation outlines the steps necessary to provide enough information for Health to evaluate the potential for human health impacts of 6PPD due to ingesting aquatic species.

The first step towards evaluating health impacts from fish consumption is obtaining data on the presence and levels of 6PPD and 6PPDQ in species and tissues that people consume. Currently, analytical testing of fish samples has centered on the gills and other organ tissues because the focus has been on understanding toxicity to the fish species. To date, only one study from China has reported the presence of 6PPD and 6PPDQ in muscle tissue of fish (Wei et al., 2024).

Researchers have not yet reported data on 6PPD and 6PPDQ levels in muscle or the whole body of fish caught in Washington. However, the National Oceanic and Atmospheric Administration's Northwest Fisheries Science Center is developing a method to test for the presence of 6PPDQ in tissues (Kuo et al., 2024). The Washington Department of Fish and Wildlife (WDFW) is using this method in its TBiOS monitoring program.

Health should collaborate with WDFW and Ecology to plan sampling studies. In these collaborations, Health should promote the testing of water samples and edible species at locations where Washingtonians frequently fish. Existing partnerships with local community groups and local health jurisdictions can be leveraged to identify:

- Locations used for fishing by high consumers and other groups who frequently fish.
- Fish species frequently consumed in the sampling area.
- Consumer fish preparation methods that may affect exposure to 6PPD and 6PPDQ.

WDFW's Toxics Biological Observation System (TBiOS) unit is already performing preliminary sampling of 6PPDQ in muscle and whole-body tissues via their existing monitoring program, with analysis of the tissue concentrations planned for the near future. Health routinely collaborates with TBiOS to ensure sampling efforts reference Health's Fish Sampling and Data Acceptance Guidance (DOH 334-529) framework. Expanded sampling through WDFW's TBiOS program would provide additional samples for Health to evaluate.

If the presence of 6PPD or 6PPDQ is confirmed in preliminary samples, Health should work with WDFW, Ecology, and other partners to develop integrated sampling and analysis plans for 6PPD and 6PPDQ in a broader range of aquatic biota and locations. This work can potentially take place through a related recommendation (Provide long-term funding to continue research and monitoring of high priority tire-related compound threats to anadromous habitats).

The development of formal fish advisories that provide guidance on safe consumption levels may occur as a later step, depending on the results of the initial studies. To develop advisories, exposure levels are combined with health guidance values known as "reference doses." Reference doses are generally developed at the federal level to define safe levels of intake for toxic chemicals. The federal government has not established reference doses for 6PPD or

6PPDQ yet. In the absence of federal toxicity thresholds, Health may develop an interim health-based reference dose for 6PPD when adequate toxicity data is available. Health may also develop an interim health-based reference dose for 6PPDQ. This will depend on the adequacy of published toxicity research at that time.

### Related recommendations

- Expand research and monitoring of high priority tire-related compound threats to migratory, nearshore, and marine species.
  Link to recommendation.
- Provide long-term funding to continue research and monitoring of high priority tire-related compound threats to anadromous habitats.
  Link to recommendation.

## Investigate holistic effects on people's health resulting from salmon decline due to 6PPD and 6PPDQ.

### Lead agency

Department of Health

### Proposed partners for implementation

Tribes and Tribal organizations, Tribal policy staff at Health, Ecology environmental justice staff, community advisory group of Washingtonians who frequently fish

### Environmental justice opportunities

Identify how salmon decline impacts the overall health of vulnerable populations.

### HEAL Act alignment

Community engagement

### Justification

Human health and ecosystem health are interconnected. Reduced species abundance has tangible and intangible effects on human health. This contributes to increased morbidity and mortality in sensitive and vulnerable populations. Indirect impacts of salmon loss on human wellness may include impacts to culture, identity, social relationships, economy, mental health, recreation, and connection to nature (Windward Environmental LLC, 2016; Donatuto et al., 2011).

Cultural groups that have a stronger connection to their environment more acutely feel the effects of ecosystem toxicity on their well-being. These groups include Tribes that rely on clean and healthy natural resources, like salmon, as a First Food keystone species.

In turn, stress related to the kinds of impacts listed above may result in effects on physical health. Cumulative stress may provoke or exacerbate health disparities in these populations (ATSDR, 2021).

People who frequently fish, including Immigrant communities and recreational fishers, may also be affected by declining salmon populations. Tribes and other communities who frequently fish can be considered sentinel populations to investigate the effects of salmon decline on the well-being of all Washingtonians.

Health will consider the utility of a One Health[28] framework in developing a better understanding of overall health impacts on vulnerable populations. One Health is a system that acknowledges the interconnectedness of the environment, plants, animals, and people such that wellness in one sector is dependent on overall ecosystem health. Health should partner with communities and Tribes who may be developing their own wellness indicators. Through partnership, communities and Tribes can identify the indicators they prioritize to better describe the holistic effects of 6PPD on people.

Health should leverage the communication structures with Tribes and other communities established by Ecology in other recommendations within this Action Plan, to support the work under this recommendation.

### Related recommendations

- Form a statewide 6PPD communications collaborative group to support timely information sharing; identify and engage with overburdened communities; and implement reporting and hazard communication on 6PPD and 6PPDQ in overburdened, underserved community media outlets (i.e. radio, newspaper).
  Link to recommendation.

## Management Recommendations

### Form a statewide 6PPD communications collaborative group to support timely information sharing; identify and engage with overburdened communities; and implement reporting and hazard communication on 6PPD and 6PPDQ in overburdened, underserved community media outlets (i.e. radio, newspaper).

### Lead agency

Department of Ecology

### Proposed partners for implementation

Department of Health, Tribes, local communities

### Environmental justice opportunities

Identify populations of concern; promote meaningful engagement with overburdened communities and vulnerable populations.

[28] https://doh.wa.gov/community-and-environment/one-health

### HEAL Act alignment

Community engagement

### Justification

A 6PPD communications collaborative group that represents overburdened communities should guide the overarching environmental justice work for the 6PPD Action Plan recommendations. The group can also help ensure 6PPD Action Plan compliance with the HEAL Act. The collaborative group should include individuals, community groups, non-governmental organizations, and media representatives from communities of color, low-income communities, workers, and others that face the cumulative effects of disproportionate environmental harms and adverse health effects. This group should act as an advisory and communications body to:

- Build relationships with overburdened communities.
- Educate their communities on the latest research and policies concerning 6PPD compounds.
- Identify ways the 6PPD Action Plan can benefit communities.

6PPD compounds may not yet be a priority of concern for all groups most impacted by 6PPD and 6PPD quinone. The communications collaborative can also provide guidance on effective, holistic approaches to engage communities that face compounding environmental and social harms. This approach can potentially shape:

- Research.
- Grant programs.
- Best management practices.
- Public communications
- Budget decision packages.

This work can effectively support the specific needs of overburdened communities while fulfilling the needs of the 6PPD Action Plan. Without the input of impacted community members and leaders, the 6PPD Action Plan may miss key opportunities for investment, including ways to efficiently allocate government resources. It may also fail to provide maximum co-benefits to the communities most in need.

6PPD and 6PPDQ are notable issues of concern to:

- Communities that face disproportionate exposures from environmental harms
- Communities that have historically been harmed by government action or inaction.

Reporters who are embedded in these communities can voice their communities' concerns, help investigate the issues, and bring awareness to the public. Funding for advertisements in community media or for community reporters to follow, report, and communicate the latest research on 6PPD and 6PPDQ could help inform and engage communities most impacted by 6PPD and 6PPDQ. Ecology should prioritize funding to media outlets embedded in

overburdened and vulnerable communities and communities where English is not the primary language.

The communications collaborative will work to identify populations of concern using a variety of methods, including but not limited to:

- Using census data to identify communities of color and low-income communities.
- Leveraging Health's Fish Advisories Program work and contacts for subsistence fishers from low income or communities of color.
- Identifying groups of workers who may be disproportionately exposed to 6PPD compounds.
- Identifying communities and groups that live, work, or play near areas potentially contaminated with 6PPD compounds from recycled and disposed tires.

Funding should support a statewide communications collaborative that will enable consistent messaging, risk communication support, and timely information sharing. The communications collaborative will provide a new approach to coordinate updates, issues, key messages, and community conversations.

## Continue tracking and engaging with ongoing federal 6PPD and 6PPDQ work to ensure Washington's work aligns with current federal knowledge, guidance, and initiatives.

### Lead agency

Department of Ecology

### Proposed partners for implementation

Department of Health, Department of Fish and Wildlife, and Department of Transportation

### Environmental justice opportunities

Align with federal environmental justice work regarding 6PPD and 6PPDQ.

### HEAL Act alignment

Not applicable

### Justification

Characterizing, mitigating, and eliminating impacts from 6PPDQ requires a coordinated effort across regions, organizations, and levels of government. Staying up to date and engaged with the federal government's 6PPD and 6PPDQ research programs, policy development, and cross-government initiatives is critical to maintaining this coordination. Regular engagement is also critical to ensure that Washington's programs and priorities are well-positioned in the national conversation. Washington State should continue to engage with federal partners, including participating in routine 6PPD federal-state meetings and tracking the following areas to identify appropriate engagement opportunities for Washington agencies:

- Advances in human exposure and toxicity research findings that can form the basis for evaluation of human health risks. The U.S. Environmental Protection Agency is evaluating 6PPD through the Toxic Substances Control Act. Washington State should track rulemaking, risk evaluations, and other Toxic Substances Control Act products.
- Ecotoxicity research, fate and transport of 6PPD and 6PPDQ in air and water; mitigation strategies (including green infrastructure solutions for stormwater contamination); and analytical method development research for multiple media (e.g., air and sediment).
- Opportunities to receive federal funding for 6PPD projects, especially to support long-term research needs and development of novel safer alternatives.
- Opportunities to provide feedback on federal policy or technical documents during public comment periods.
- Opportunities to coordinate with Federal agencies, such as the United States Environmental Protection Agency, to support the growth of programs and efforts that fund innovation research, particularly around safer chemistry.

## Implement Tire Pile Removal Program

### Lead agency

Washington State Department of Natural Resources

### Proposed partners for implementation

Department of Fish and Wildlife, Ecology, and Washington State Parks and Recreation Commission

### Justification

In the 1970s and 1980s, Washington State agencies used surplus automotive tires to build artificial habitat on the bottom of Puget Sound. The purpose of installing these artificial tire "reefs" was to increase the availability of native fish habitat and bolster recreational and sport fishing opportunities across the state. Years after installation, these "reefs" were deemed unsuccessful, having not provided the valuable habitat that was intended. It was determined these reefs posed a risk of becoming more harmful than beneficial.

Since then, the Washington State Department of Natural Resource's Aquatics Program has strived to better understand these derelict tires. The Department recognizes the need to prioritize tire removal from state-owned aquatic lands to continue to protect valuable subtidal and intertidal marine habitat. The Department of Natural Resources has since identified 14 tire pile sites as priority removal locations. Preliminary planning and coordination of a pilot removal effort is currently underway.

The Department of Natural Resources plans to develop a framework for tire pile removal. It also plans to establish best management practices to pursue the removal of all artificial tire-based structures on state-owned aquatic lands.

# Recommendations Under Consideration

The following recommendations were not included in 2025-27 budget packages. Ecology and Washington state partner agencies will continue to refine these recommendations as we better understand authority, feasibility, and implementation. We may include these recommendations in future action plan work.

## Policy Recommendations

### When Ecology opens Chapter 173-350 WAC (Solid Waste Handling Standards) for revision, revise the current WAC 173-350-350 (Waste Tire Storage) using current studies to evaluate the waste tire permit threshold. Additionally, establish location standards similar to those required for inert waste landfills.

#### Lead agency

Department of Ecology

#### Proposed partners for implementation

To be determined

#### Justification

Revising Chapter 173-350 WAC would increase protection of impacted species, the environment, and human health. Below we suggest language for a location standard: "No permitted tire facilities may store tires in a manner that impacts surface waters, ground water, water sources, wetlands, flood plains, and any other areas with potential impacts to water." We could potentially establish specific distances from these areas based on the stationary tire pile research results.

### Revise requirements for using the statewide environmental vendor pool for 6PPDQ and contaminants of emerging concern.

#### Lead agency

Department of Enterprise

#### Proposed partners for implementation

Department of Ecology

#### Justification

In early 2024, the Department of Enterprise Services released the Environmental Consulting Services contract.[29] This contract requires state agencies to use a state-approved vendor pool for environmental contracts until February 2026 (or 2030, if extended). While this vendor pool

[29] https: https://apps.des.wa.gov/DESContracts/Home/ContractSummary/22222

expedites contracting processes, it limits which consultants can work with state agencies on environmental contracts.

Several members of the 6PPD Action Plan Advisory Committee have raised concerns over this vendor pool. This vendor pool might not represent the most qualified consulting organizations for addressing 6PPDQ; rather, it is a broad vending pool for environmental subjects. As a result, this contract could limit 6PPDQ data quality.

Additionally, science on contaminants of emerging concern (CECs), including 6PPDQ, is rapidly evolving. To produce usable data on CECs, the state needs flexibility in contracting to work with diverse firms who can produce high-quality data on CECs. Lastly, several of these firms do not address Tribal Treaty Rights and environmental justice, both of which are vital components of this issue. We require a larger pool of applicants to address 6PPD and 6PPDQ effectively and equitably.

This recommendation proposes revising requirements to use the statewide environmental vendor pool to allow flexibility for CEC research. Options for revisions include:

- Excluding 6PPDQ and/or CEC research from the vendor pool.
- Creating equitable and timely processes that would allow firms to join the vendor pool.

The Department of Enterprise Services should partner with Ecology to determine the best option forward, including defining parameters for whether CECs should or should not be exempt from the vendor pool.

## Assess the feasibility of a tire industry fee program to support funding for tire contaminant research.

### Lead agency

Department of Ecology

### Proposed partners for implementation

To be determined

### Justification

The expertise and money required to identify a safer alternative in products like tires is specific and extensive. Tire and chemical manufacturers should use their funding and expertise to research safer alternatives to 6PPD. Ecology will assess the feasibility of a tire industry fee program to support funding for hazard assessments and filling data gaps on alternatives.

## Expand lab capacity to support additional 6PPDQ monitoring and research.

### Lead agency

Department of Ecology

### Proposed partners for implementation

To be determined

## Justification

The Manchester Environmental Laboratory and research universities in Washington state require increased capacity to support monitoring and research around organic contaminants of emerging concern. There is a high demand for 6PPDQ analysis to fill data gaps surrounding the fate, transport, occurrence, and mitigation of this chemical. Additionally, more research is needed on the composition of chemicals of emerging concern and their fate in the environment.

The Manchester Environmental Lab is the only lab currently accredited to analyze 6PPDQ in water. Additionally, draft EPA method 1634[30] for water samples is out for review and being validated through a multi-laboratory validation study. The Manchester Environmental Lab is working to adopt current variations to the draft method and will adopt any new variations once method 1634 is finalized and ready for accreditation. The Manchester Environmental Lab is also currently developing a method to measure 6PPDQ in sediments. Further method development for biota and consumer products is still needed.

Ecology's lab accreditation program has taken many steps to streamline and keep up with increased demand for organic contaminant analytical capacity and the development of a new method for measuring 6PPDQ. Third-party labs will be seeking methods accreditation to support the demand for 6PPDQ and other related contaminants, both regionally and nationally. Ecology will continue to streamline the accreditation process. Other accredited third-party labs (under EPA draft method 1634) are necessary to support the demand for 6PPDQ analysis.

Ecology and partners need funding to support permanent staff, equipment maintenance, and continued development of the analytical method for sediment, biota, and consumer products.

## Related recommendations

- Provide long-term funding to continue research and monitoring of high priority tire-related compound threats to anadromous habitats.
  Link to recommendation.
- Conduct two additional years of research and studies to identify how effective stormwater best management practices are for treating 6PPDQ, including completing laboratory studies currently underway and implementing and monitoring BMPs installed in the field.
  Link to recommendation.
- Develop a 6PPDQ field method training and outreach program to support standardized spatial and temporal occurrence sampling and surveys to inform treatment prioritization efforts.
  Link to recommendation.

[30] https://www.epa.gov/cwa-methods/6ppd-q-using-liquid-chromatography-tandem-mass-spectroscopy-lcmsms-method-1634-not-yet

## Research recommendations

### Research the extent to which state programs that are intended to reduce vehicle miles traveled can reduce the volume of 6PPD and 6PPDQ released into highway stormwater.

#### Lead agency

Washington State Department of Transportation

#### Proposed partners for implementation

Department of Ecology, consultants, municipalities, Sound Transit

#### Justification

Source reduction, like developing and implementing a safer alternative for 6PPD in tires, directly addresses the root cause of pollution. Another form of source reduction could be through transportation planning and carbon reduction programs. Washington State Department of Transportation programs in Transportation Demand Management,[31] Transportation Carbon Reduction,[32] and other areas seek to reduce vehicle miles traveled[33] in Washington State. The department has not thoroughly investigated the co-benefits of corresponding 6PPD and 6PPDQ reduction, Transportation Carbon Reduction,[34] and other areas that seek to reduce vehicle miles traveled[35] in Washington State.

To offer helpful guidance to transportation planners, research should assess the relative per capita co-benefits between meeting the State's reduction targets around vehicle miles traveled and 6PPDQ reduction. Based on research findings, the Washington State Department of Transportation should provide transportation planners with guidance on incorporating 6PPDQ reduction as an element of larger reduction goals around vehicle miles traveled. This guidance should also address any needed changes to the Growth Management Act.

### Develop a 6PPDQ field method training and outreach program to support standardized spatial and temporal occurrence sampling and surveys to inform treatment prioritization efforts.

#### Lead agency

Department of Ecology

#### Proposed partners for implementation

United States Geological Survey, Trout Unlimited, Tribes, more to be determined

[31] https://wsdot.wa.gov/engineering-standards/planning-guidance/transportation-demand-management
[32] https://wsdot.wa.gov/construction-planning/statewide-plans/transportation-carbon-reduction-strategy
[33] https://wsdot.wa.gov/sites/default/files/2023-06/VMT-Targets-Final-Report-June2023.pdf
[34] https://wsdot.wa.gov/construction-planning/statewide-plans/transportation-carbon-reduction-strategy
[35] https://wsdot.wa.gov/sites/default/files/2023-06/VMT-Targets-Final-Report-June2023.pdf

### Justification

A reliable 6PPDQ sampling training program will promote prompt, standardized sampling efforts in areas of concern identified by State, Federal, and Tribal partners. State and Federal agencies should provide technical guidance to volunteers to support consistent, standardized field sample protocols across the state. Participants in this program could help us identify areas where salmonids are most at risk of exposure from 6PPDQ and thus need stormwater treatment. This program would help streamline and centralize data collection, promote resource sharing, and uphold quality assurance. Ecology could use data collected to provide updates for the Governor's Salmon Recovery Office statewide objectives.

Leveraging established conservation networks to conduct expansive occurrence sampling of 6PPDQ in salmonid habitats would support ongoing toxics studies by providing many dedicated boots in the field. Many of the volunteers of regional conservation NGOs are compassionate, dedicated volunteers with technical backgrounds that are interested in helping conduct observation surveys of impacted salmonids and 6PPDQ sampling. This would allow Ecology to conduct orchestrated sampling over an expansive geographic area.

This work would promote prompt, standardized sampling by:

- Expanding 6PPD monitoring by installing a platform of 20+ monitoring stations to monitor 6PPDQ across the urban gradient and conduct source ID monitoring when levels of 6PPDQ are found.
- Leveraging existing juvenile chinook monitoring work by adding sites and doing high resolution toxics and 6PPDQ analysis and identifying hotspots to focus mitigation efforts.

## Management Recommendations

### Develop a Washington State Tribal Leaders Advisory Board to support continuous engagement and participation in projects related to 6PPD and salmon recovery.

*Ecology has been in close communication with the Governor's Office of Indian Affairs to determine authority and steps for implementation. The Governor's Office of Indian Affairs will carry this work moving forward.*

#### Lead agency

Governor's Office of Indian Affairs

#### Proposed partners for implementation

Department of Ecology, Department of Health, Department of Fish and Wildlife, Department of Transportation, Governor's Salmon Recovery Office, Recreation and Conservation Office, Puget Sound Partnership, Washington Stormwater Center, Northwest Indian Fisheries Commission, Upper Columbia United Tribes, Columbia River Inter-Tribal Fisheries Commission, Federal Puget Sound Task Force

### Justification

Washington's Tribes are co-managers of our lands and resources and thus critical decision-making partners to Washington State's environmental agencies. We need dedicated funding to support the time and resources we are requesting of our Tribal partners. Providing funding to a Tribal Leaders Advisory Board would facilitate prompt and effective decisions, regular communication, and strong collaboration with federally recognized Tribes located in Washington. The Tribal Advisory Board can provide guidance to help agencies and communities invest in the following actions that will protect salmon and the environment:

- Improved stormwater infrastructure.
- Identification and prioritization of salmon recovery project locations.
- Community engagement.
- Source control.
- Pollution prevention strategies.
- Solid waste handling.
- Communications and outreach.

## Provide capacity to review Ecology's Environmental Information Monitoring database (EIM) to determine optimization needs for storing 6PPD data.

### Lead agency

Department of Ecology

### Proposed partners for implementation

Department of Fish and Wildlife, Washington State Department of Transportation, Department of Health, Center for Urban Waters – University of Washington Tacoma, Tribes, counties, and cities

### Justification

Ecology's Environmental Information Monitoring database contains environmental monitoring data collected by departmental scientists and partners. While the Environmental Information Monitoring database is robust, researchers often collect additional data for contaminants of emerging concern to further understand data results. Currently, the system does not contain any additional fields to characterize contaminants of emerging concern.

Project partners should work with Ecology to review the system's data structure and reporting system. Ecology and partners should then identify what enhancements are needed to effectively manage data for contaminants of emerging concern. Environmental Information Management System staff should assist in this effort.

### Related recommendations:

- Provide long-term funding to continue research and monitoring of high priority tire-related compound threats to anadromous habitats.
  Link to recommendation.

- Develop a 6PPDQ field method training and outreach program to support standardized spatial and temporal occurrence sampling and surveys to inform treatment prioritization efforts.
  Link to recommendation.

## Create incentives and invest in initiatives to identify sustainable chemistry and materials for use in tires and other products that use PPDs.

### Lead agency

Department of Ecology

### Proposed partners for implementation

Department of Commerce

### Justification

There is limited publicly available information about tire research and development within the industry. Ecology should work with Commerce to invest in research for more sustainable material development.

If no safer alternatives are identified in Ecology's 6PPD Alternatives Assessment, Ecology should work to develop a grant program that encourages research for a rationally designed, potentially bio-based, 6PPD substitute. Rational molecular design is an approach that uses information from empirical, mechanistic, and computational methods to inform design. Researchers and manufacturers can use this type of approach to develop molecules that meet their intended function while minimizing adverse impacts to human health and the environment.

This approach allows for the development of alternatives that reduce hazards while keeping performance as a key driver. Rational molecular design is frequently used in the pharmaceutical industry but is much less common in other sectors. Encouraging efforts that increase support and funding for rational design and sustainable chemistry initiatives could advance the adoption of these approaches in a range of sectors.

## Support Tribes exercising their Tribal Treaty Rights and sovereign rights when managing toxics in stormwater, including prioritizing salmon recovery in Usual and Accustomed Areas and maximizing the health and abundance of salmon at a watershed scale.

### Lead agency

Department of Ecology

### Proposed partners for implementation

Tribal Nations, Northwest Indian Fisheries Commission, Washington State Department of Transportation, municipalities, Washington Department of Fish and Wildlife, National Ocean and Atmospheric Administration, Department of Natural Resources, all state resource agencies

### Justification

Washington State has a co-management responsibility to Tribal Nations to ensure the health and abundance of salmonids. Therefore, we must support Tribes exercising their Tribal Treaty Rights and sovereign rights and the inherent right of Tribal Nations to fish within stormwater management. Tribal Treaty Rights should be integrated and prioritized in 6PPD planning and implementation processes, particularly to support salmon recovery.

Additionally, Washington State should help produce best practices for municipalities and permittees when engaging with Tribes on managing 6PPD. Washington State should also facilitate watershed-scale planning processes to ensure that salmon recovery occurs on a watershed-by-watershed basis.

Through this recommendation, Ecology will help facilitate stormwater planning activities throughout the state (including with permittees, municipalities, and other stormwater managers) to ensure the principles of this recommendation are implemented.

## Create a dedicated funding pool for creating community co-benefits and addressing environmental injustices through the installation, operation, monitoring, and maintenance of stormwater BMPs.

### Lead agency

Department of Ecology, Washington State Department of Transportation, Washington State Parks

### Proposed partners for implementation

Department of Health, community-based organizations, non-profits, municipalities, parks, and recreation agencies

### Justification

Municipalities have limited budgets for stormwater BMP installations. Often, a budget only covers the costs of labor and infrastructure installation. Community engagement activities should be included in the budget for stormwater projects to respond to community needs and address environmental justice concerns. However, stormwater funds often are limited, and don't allow time or funding for community engagement activities. Providing co-benefits to communities and addressing environmental injustices warrants additional investments.

Installing stormwater BMPs that provide co-benefits requires additional design considerations and expenses that exceed the typical budget for BMP installation. Providing distinct funding sources for BMPs and co-benefits could help achieve both water quality and environmental justice goals. This recommendation could also make progress on the Healthy Environment for All (HEAL) Act's directive for state agencies to invest 40% of their funds in underserved and overburdened communities. Lastly, if 6PPDQ is determined to have an air pathway through inhalation or deposition, stormwater infrastructure could be designed with air quality co-benefits to reduce further negative impacts to overburdened communities.

To achieve co-benefits, stormwater BMPs should enhance community well-being beyond providing water quality benefits. For example, stormwater park designs have the potential to:

- Provide increased green space and recreational access to communities.
- Enhance wildlife.
- Represent local cultures through art and design.
- Create educational opportunities.
- Honor Tribal Treaty Rights.
- Build local climate resilience (Puget Sound Regional Council, 2022).

Co-benefits could also allow stormwater managers to access multiple sources of funding beyond stormwater funds. For example, stormwater projects with co-benefits could use funds aimed to improve recreational access, build climate resilience, etc. Traditional stormwater projects are not eligible for these kinds of funds, and thus this proposal could help diversify funding sources.

To implement this recommendation, lead agencies should use the Environmental Health Disparities Map and host outreach and engagement activities. This information can help identify where to implement BMPs and how those BMPs could enhance community well-being. Lead agencies should also partner with Health to coordinate with existing community-based organizations and groups. Direct outreach and engagement with these groups would help identify community needs and co-benefits that serve community interests.

### Related recommendations:

- Investigate holistic effects on people's health resulting from salmon decline due to 6PPD and 6PPDQ.
  Link to recommendation.

## Dedicate funding toward evaluating and implementing stormwater operations and maintenance best practices to ensure the long-term effectiveness of BMPs that address 6PPD.

### Lead agency

Department of Ecology

### Proposed partners for implementation

Washington State Department of Transportation, municipalities

### Justification

Research on stormwater BMPs suggests that several BMPs might be moderately to very effective at managing 6PPD. However, an important effectiveness criterion is the longevity of the BMP (how effective that BMP continues to be over time). Permittees face challenges with the long-term operations and maintenance of BMPs. Additionally, operations and maintenance practices need to be identified and applied to address 6PPDQ specifically. High-quality monitoring equipment and practices are also necessary to monitor effectiveness over time.

Funding should support the operation, maintenance, labor, and replacement costs of BMPs that help manage 6PPD, 6PPDQ, and tire wear particles. Additionally, funding should support further research into operations and maintenance practices that ensure the long-term effectiveness of BMPs. Funders should also expand local capacity grants to ensure funding for operations and maintenance.

### Related recommendations:

- Provide long-term funding to continue research and monitoring of high priority tire-related compound threats to anadromous habitats.
  Link to recommendation.

## Support local efforts to implement the Retrofit Prioritization Framework developed by the Puget Sound Stormwater and Transportation Charter Group.

### Lead agency

Department of Ecology

### Proposed partners for implementation

Tribal Nations, Washington State Department of Transportation, National Oceanic and Atmospheric Administration, U.S. EPA, municipalities

### Justification

We recommend providing resources to state, local and Tribal salmon recovery organizations to develop watershed-by-watershed prioritizations for transportation-related runoff. These prioritizations should be based on a framework developed by the Federal Puget Sound Task Force charter group. The charter group should determine the mechanism to update the framework as new scientific information is published. This prioritization would inform, not replace, the retrofit prioritization plan required in municipal stormwater permits. This recommendation includes prioritizing salmon recovery in Usual and Accustomed Areas.

Recovery lead entities and municipalities should work together to use existing data, tools, and models and compare loading and risk assessments with knowledge held by state, local and Tribal salmon recovery experts. These biologists represent the best professional judgment necessary to identify the salmon restoration potential of sites within a watershed. By using a consistent framework, prioritization objectives, and data, this work would provide a statewide picture of restoration priorities focused on stormwater retrofit needs. State and local entities could use this information to prioritize transportation retrofits.

### Related recommendations:

- Implement the low-risk, high-reward stormwater treatment demonstration projects identified by the Federal Puget Sound Leadership Task Force Stormwater and Transportation Charter Group.
  Link to recommendation.

- Support Tribes exercising their Tribal Treaty Rights and sovereign rights when managing toxics in stormwater, including prioritizing salmon recovery in Usual and Accustomed Areas, and maximizing the health and abundance of salmon at a watershed scale. Link to recommendation.

## Conduct a barriers analysis of factors that inhibit installation of stormwater BMPs for municipalities and permittees.

### Lead agency

Department of Ecology

### Proposed partners for implementation

Washington State Department of Transportation, municipalities

### Justification

Several barriers could inhibit the prompt implementation of 6PPD stormwater BMPs to address 6PPD. These barriers include, but are not limited to:

- Planning.
- Property acquisition costs, especially in rural/suburban areas.
- Contracting policies.
- Construction.
- Funding sources.
- Access to materials.
- Federal and State permitting.

We have noted and addressed many barriers in other recommendations in this document. Additional work is still needed to:

1. Identify significant barriers that local governments face when installing stormwater BMPs through new development, redevelopment, or retrofits; and
2. Identify ways to remove barriers and expedite 6PPD solutions.

Ecology should lead a collaborative process with state and local agencies to make progress on these two criteria. Then, Ecology should summarize findings in a published report. These findings could directly inform future Legislative funding requests.

## Investigate alternative methods of funding stormwater BMP installation to reduce impacts to overburdened communities and permittees.

### Lead agency

Department of Ecology

### Proposed partners for implementation

Washington State Department of Transportation, U.S. Environmental Protection Agency, municipalities

### Justification

Rapid and expansive stormwater best management practice implementation is critical to managing 6PPD; however, the cost of implementation is extensive. For example, different blends of bioretention soil mix cost between $7,000 to $11,000 per acre of impervious surface treated. If communities installed bioretention along driving surfaces within ¼ of a mile from streams across Washington State, an advisory committee member estimated the total cost of 6PPD stormwater treatment would be at least $1.8 billion.

Ecology should assess existing funding structures to ensure the cost of BMPs is distributed equitably. Additionally, alternative funding sources should be made available based on assessment findings. For example, taxing or implementing fees on the tire industry could shift the burden of funding to 6PPD producers.

Federal and state governments could expand their funding programs to avoid increasing local taxes or stormwater utility rates. Local governments could also modify tax structures to increase taxes or stormwater utility rates in higher-income communities and distribute benefits to overburdened communities (i.e. installing BMPs with co-benefits in overburdened communities).

### Related recommendations:

- Assess the feasibility of a tire industry fee program to support funding for tire contaminant research.
  Link to recommendation.

## Implement the low-risk, high-reward stormwater treatment demonstration projects identified by the Federal Puget Sound Leadership Task Force Stormwater and Transportation Charter Group.

### Lead agency

Washington State Department of Transportation

### Proposed partners for implementation

Department of Ecology, U.S. Environmental Protection Agency, National Oceanic and Atmosphere Administration, United States Geological Survey, Tribes

### Justification

Several stormwater management technologies are potentially effective at treating tire and road wear particles, including 6PPD and 6PPDQ. The Federal Puget Sound Stormwater and Transportation Charter Group identified locations for the installation of low-risk, high reward BMPs. These locations could showcase stormwater remediation efficacy. These new BMPs may include monitoring equipment to assess BMP effectiveness.

Federal partners are interested in using the data collected at these locations to evaluate models for management applications (for example, the capacity to predict chemical loading reductions as a consequence of specific mitigation actions). Therefore, demonstration projects should

inform the development of a toolbox of retrofits. Stormwater managers could use this toolbox to identify which BMPs might be the most appropriate given location characteristics.

### Related recommendations

- Conduct two additional years of research and studies to identify how effective stormwater best management practices are for treating 6PPDQ, including completing laboratory studies currently underway and implementing and monitoring BMPs installed in the field.
  Link to recommendation.
- Provide a toolbox for 6PPDQ municipal and industrial stormwater management and retrofit planning by regularly updating Ecology's stormwater manuals, technical guidance documents, and communications materials. Facilitate implementation of new best management practices through comprehensive project management of the Stormwater Work Group.
  Link to recommendation.

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