Toxics in Aquatic Life Implementation Strategy Research Agenda Update 2024/2025: Microplastics

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1. INTRODUCTION

In 2019, the University of Washington Puget Sound Institute (PSI) supported development of a research and monitoring agenda to address key uncertainties in the Toxics in Aquatic Life (TIAL) Implementation Strategy (formerly Toxics in Fish (TIF)), a recovery plan in the Puget Sound National Estuary Program which aims to decrease chemical contamination in fish, as measured by the Puget Sound TIAL Vital Sign indicators. PSI asked regional toxics experts to identify priority knowledge gaps based on the extent to which they were barriers to management, planning, and activities for the Implementation Strategy. The resulting uncertainties comprised a regional research agenda on chemical pollution in Puget Sound (described in Chapter 7 of the TIAL Implementation Strategy).

PSI documented the 2019 toxics research agenda in its Grand Uncertainties Matrix (GUM), a database of regional research priorities for Implementation Strategies. In 2024, PSI and the Stormwater Strategic Initiative team recognized a need to update the toxics research agenda. Microplastics, which are broadly included as contaminants of emerging concern (CECs), were not previously addressed and so were a focus of this update.

This report describes the development of a microplastics research agenda for Puget Sound. The research agenda includes five top research priorities about topics such as microplastics distribution, sources, and fiber toxicology. A research agenda for contaminants other than microplastics is described in the TIAL Implementation Strategy Research Agenda Update 2024/2025 report.

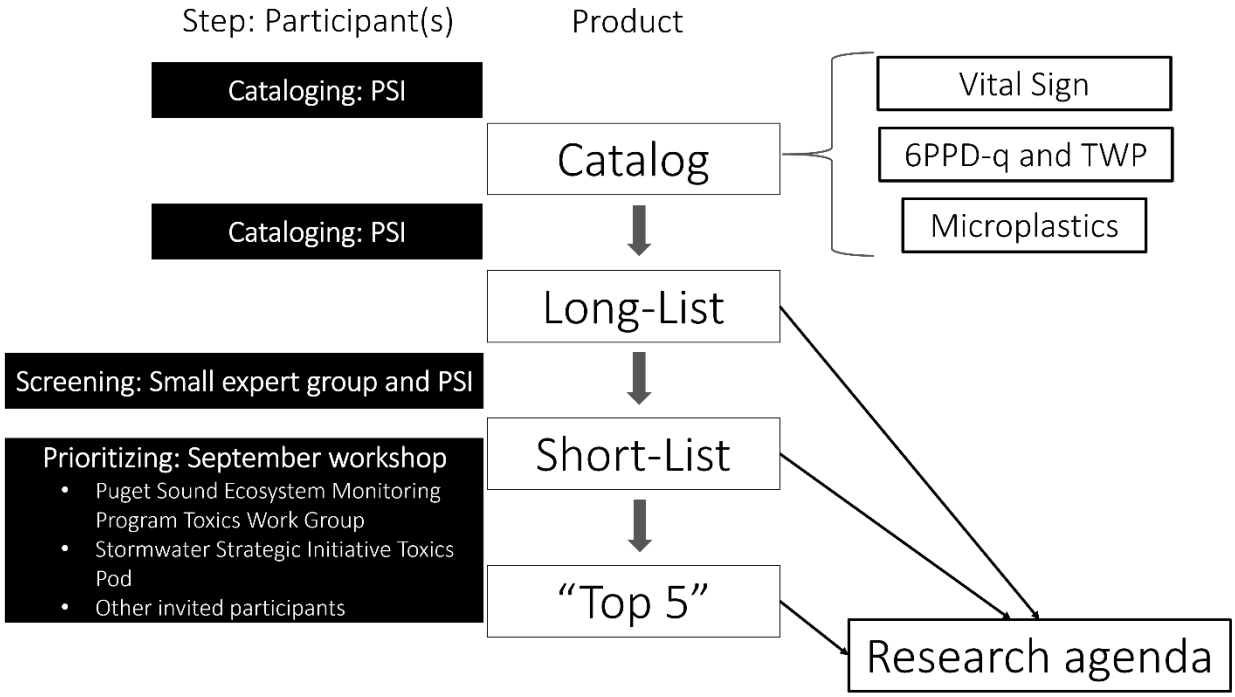
2. METHODOLOGY

2.1 IDENTIFYING TOP RESEARCH PRIORITIES

To produce the overall toxics research agenda, PSI generally utilized a multi-step process (Figure 1): PSI cataloged toxics uncertainties from various sources (Appendix Table A1), PSI and regional experts screened (some) uncertainties for relevance to the Implementation Strategy, and PSI asked additional experts and stakeholders to prioritize uncertainties based on

importance to the Implementation Strategy. These steps varied for three topical lists of uncertainties related to microplastics, 6PPD-Q and tire wear particles, and the TIAL Vital Sign (all other uncertainties relevant to the TIAL Implementation Strategy). PSI evaluated microplastics-related uncertainties separately from the other uncertainties in order to draw upon unique expertise specific to microplastics.

Figure 1. Toxics research agenda development process



As part of this process, PSI compiled a catalog of uncertainties specifically about microplastics. PSI organized uncertainties by topic and combined similar or replicate uncertainties. PSI then cross-referenced the microplastics catalog with information in a 2024 presentation by Elise Granek (2024) and two recent microplastics reports (Iwanowicz et al., 2024; Paterson et al., 2024). PSI also identified uncertainties from Granek (2024) and Paterson et al. (2024) and categories of uncertainties from Iwanowicz et al. (2024) that were not in the microplastics catalog.

PSI developed the following microplastics research themes based on uncertainties from Granek (2024), Iwanowicz et al. (2024), Paterson et al. (2024), and the microplastics catalog:

- Field methods and protocols
- Analysis methods and protocols
- Microplastics levels (various media)
- Fate, pathways, and sources
- Ecotoxicity
- Dynamics between microplastics and CECs
- Management effectiveness
- Regulation options and necessary data
- Alternatives
- Other
- Particle and chemical characterization
- Interactions with organisms
- Transport (Environmental Protection Agency, 2024)

PSI assigned one or two of the above themes to each uncertainty in the microplastics catalog. After developing the research themes PSI did not further use the microplastics catalog, instead choosing to source microplastics uncertainties directly from experts.

PSI convened four microplastics experts (Table 1) on August 28, 2024 and asked them to share what they thought are important microplastics research topics for Puget Sound. PSI used the following modified subset of the microplastics research themes (from Granek (2024), Iwanowicz et al. (2024), Paterson et al. (2024), and the microplastics catalog) to prompt discussion:

- Sampling and analytical methods and protocols
- Fate, pathways, and sources

- Ecotoxicity (including particulates and plastic-associated contaminants)
- Management effectiveness
- Regulation options and necessary data
- Safer/green alternatives for additives
- Other

Experts generated a list of uncertainties about microplastics and then voted for the three uncertainties they thought were most important using the EasyRetro platform (https://easyretro.io/) and provided additional feedback.

Table 1. Microplastics experts involved in identifying microplastics research priorities for Puget Sound

Name	Affiliation
Elise Granek	Portland State University
Julie Masura	University of Washington Tacoma
Ezra Miller	San Francisco Estuary Institute
Andrew Spanjer	USGS

The five uncertainties with the most votes were also the only ones that received any votes, providing a clear top 5 list of microplastics priorities. Because PSI consulted microplastics experts directly to produce the top 5 list, PSI did not conduct a separate screening step (Figure 1) for microplastics uncertainties before this prioritization.

2.2 REFINING TOP RESEARCH PRIORITIES

In an in-person workshop on September 12, 2024, PSI solicited feedback on and prioritization of TIAL Vital Sign and 6PPD-Q uncertainties from 36[1] toxics experts, including members of the PSEMP Toxics Work Group and the Stormwater Strategic Initiative Toxics Pod. During this

[1] This includes three toxics experts who were discussion facilitators at workshop stations but also engaged in the activity.

workshop PSI also requested feedback on the top 5 priority microplastics uncertainties, at which time workshop participants suggested additional microplastics uncertainties.

After the workshop, PSI transcribed and reviewed input. PSI did not edit microplastics uncertainties in response to specific participant comments but instead either summarized those comments in notes (Appendix Table A2) or added new uncertainties to the list. Where applicable, in notes PSI also described the focus needed for an uncertainty to be relevant to the TIAL Implementation Strategy (e.g., species remit). PSI made minor edits to participant-suggested new microplastics uncertainties for clarity/formatting.

PSI added to the microplastics research agenda the top 5, other uncertainties generated by microplastics experts in the August meeting (except for those that were actions or value questions rather than uncertainties (Table 2)), and workshop participant-suggested new uncertainties. PSI added participant-suggested new uncertainties unless the uncertainties:

- Were duplicative (including with 2019 research agenda);
- Already have known answers (Appendix Table A3); or
- Were outside the scope of the TIAL Implementation Strategy (Appendix Table A3).

PSI allocated the following priority levels to microplastics uncertainties:

- Top = five uncertainties that received the most votes from the microplastics experts in the August meeting (top 5)
- High = two additional uncertainties identified by the microplastics expert group in the August meeting
- No priority = uncertainties suggested by participants in the September workshop (since these were not officially voted upon for prioritization)

3. RESULTS

3.1 IDENTIFYING TOP RESEARCH PRIORITIES

The microplastics catalog contained 102 uncertainties. The full microplastics catalog, list of expert-identified uncertainties, and final research agenda are available in the 2025 TIAL Research Agenda spreadsheet for access using Microsoft Excel (link directly downloads Microsoft Excel file).

The microplastics uncertainties identified by the microplastics expert group, including the top 5 priorities, are listed in Table 2.

Table 2. Microplastics research priorities identified by microplastics expert group

Votes	Uncertainty	In final research agenda?
3	What is the relative distribution of microplastic sources (e.g., fishing gear, clothes, etc.) and the primary pathways (e.g., stormwater, aerial deposition, in water activity, etc.) of microplastics in Puget Sound?	Yes
3	What is the distribution of microplastics among different matrices (e.g., sediment, fish, water, etc.) in Puget Sound?	Yes
2	Develop/adopt a standard analytical method/protocol for microplastics in Washington state, including a focus on tire wear particles	Yes
1	What is the toxicology of microplastic fibers across a range of types, sizes, and species?	Yes
1	How effective are stormwater BMPs (e.g., trash capture devices) at removing microplastics?	Yes
0	What are non-regrettable substitutions for plastics, particularly plasticizers?	Yes
0	What products should no longer be allowed to be created with plastics?	No (action or value question)
0	Address the gap in public knowledge to support strong policy action	No (action or value question)
0	What is the ecotoxicity of microplastics (of various types, features, etc.) that are found in the environment?	Yes

3.2 REFINING TOP RESEARCH PRIORITIES

The final microplastics research agenda (Table 3) consists of 11 uncertainties: five top priorities, two high priorities, and four new uncertainties not assigned a priority level. Appendix Table A2 provides additional details about the microplastics research agenda, including summarized feedback from September 2024 workshop participants.

Table 3. Puget Sound microplastics research agenda

Uncertainty	Priority Level
What is the relative distribution of microplastic sources (e.g., fishing gear, clothes, etc.) and the primary pathways (e.g., stormwater, aerial deposition, in water activity, etc.) of microplastics in Puget Sound?	Top
What is the distribution of microplastics among different matrices (e.g., sediment, fish, water) in Puget Sound?	Top
Develop/adopt a standard analytical method/protocol for microplastics in Washington State, including a focus on tire wear particles.	Top
What is the toxicology of microplastic fibers across a range of types, sizes, and species?	Top
How effective are stormwater BMPs (e.g., trash capture devices) at removing microplastics?	Top
What are non-regrettable substitutions for plastics, particularly plasticizers?	High
What is the ecotoxicity of microplastics (of various types, features, etc.) that are found in the environment?	High
How can plastic use be reduced (e.g., via single-use bag bans, changes to food and packaging, reducing consumption, etc.)?	No priority
To what extent does PFAS connect/bind to microplastics?	No priority
What types of plastics are more likely to become nanoplastics?	No priority
How effective is wastewater treatment at removing microplastics?	No priority

In addition, September 2024 workshop participants suggested two other uncertainties which relate to microplastics:

- Are tire wear particles and microplastics continued sources of toxics?
- Tire wear particles are considered micro and nanoplastics. What are the environmentally relevant concentrations of TRWP, TWPs?

However, during analysis of workshop feedback it was unclear whether participants suggested these uncertainties for the microplastics agenda or the 6PPD-Q agenda. PSI conceptually grouped tire wear particles with 6PPD-Q so allocated these uncertainties to the 6PPD-Q research agenda, which will be documented in the GUM alongside the microplastics agenda. Both uncertainties are designated as low priorities in the 6PPD-Q research agenda (if participants suggested them for the 6PPD-Q research agenda, the uncertainties received zero votes for prioritization).

4. DISCUSSION

4.1 MICROPLASTICS RESEARCH AGENDA

The microplastics research priorities are a subset of a larger list of toxics-related priorities that PSI co-developed to support the TIAL Implementation Strategy. Collectively the research and monitoring priorities for the TIAL Vital Sign, 6PPD-Q, and microplastics comprise an update to a regional toxics research agenda for Puget Sound. The microplastics research agenda highlights the need for fundamental research on this topic. By comparison, the only microplastics-related uncertainty in the 2019 TIAL research agenda was “What are toxics exposures related to presence/ingestion of microplastics?” (a medium priority). The updated research agenda reiterates the need for specific study of the microplastics exposure levels to which Puget Sound organisms are subject.

Some priority uncertainties on the microplastics research agenda are geographically specific to Puget Sound or Washington (e.g., learn where microplastics are found and originate in the region), while others are not (e.g., understand the utility of stormwater management tools for microplastics, and understand how microplastics affect organisms). Three of the five top priorities for Puget Sound relate (but are not identical) to “High Priority” (Paterson et al., 2024, p. 30) research topics about microplastics for San Francisco Bay in California. Microplastics sources and pathways are uncertain for both regions, but stormwater runoff is a particular research emphasis for San Francisco Bay (as are loadings and processes) (Paterson et al., 2024). For understanding the distribution of microplastics in water, sediment, and other matrices, the “High Priority” (p. 30) for San Francisco Bay is the distribution of microplastics that are sized

less than 335 µm in water and less than 45 µm in sediment (Paterson et al., 2024). In conjunction with microplastics distribution, San Francisco Bay "data gaps" (Paterson et al., 2024, p. 5) include microplastics risk, which is not specified in top priority microplastics uncertainties for Puget Sound. Standard methods are also needed in both San Francisco Bay and Puget Sound, though the top methodological issue for San Francisco Bay is measurement of smaller microplastics (Paterson et al., 2024). Experts involved in developing the Puget Sound microplastics agenda suggested Washington State develop a methodology to address tire wear particles because these are not addressed in California methodological development.

Furthermore, the toxicity of both microplastic fibers and microplastics generally, considering different microplastics characteristics, are also relevant research questions for San Francisco Bay but are not "High Priority" for that region (Paterson et al., 2024, p. 30). Five uncertainties on the Puget Sound research agenda are unique compared to San Francisco Bay (Paterson et al., 2024), including questions about wastewater and stormwater (top priority) treatment effectiveness, plastic substitutes, plastic reduction, and conversion to nanoplastics. However, several of these perhaps underpin one broad San Francisco Bay management question: "What are the anticipated impacts of management actions?" (Paterson et al., 2024, p. 9). Research from both within and beyond Puget Sound will contribute to answering top priority microplastics uncertainties.

To consider cross-topic prioritization in Puget Sound, in a short exercise at the September 2024 workshop PSI asked participants to express the relative priority of microplastics, 6PPD-Q, and the contaminants in the Vital Sign. Results indicated that microplastics merit some attention in Puget Sound, comprising a smaller proportion (~10% of overall funding) than Vital Sign and/or 6PPD-Q research. Research on the priority microplastics uncertainties will improve understanding of the threat microplastics pose to Puget Sound organisms and the level of further research necessary to inform effective management through the TIAL Implementation Strategy.

4.2 NEXT STEPS

September workshop participants pointed to existing research for two microplastics uncertainties. A future review of the scientific literature may determine if, and to what extent, uncertainties have been addressed. Another next step to resolve uncertainties is to scope questions into research projects.

PSI plans to communicate this microplastics research agenda to the Stormwater Strategic Initiative to inform their upcoming funding decisions related to the TIAL Implementation Strategy. PSI will add the 2025 research agenda (Appendix Table A2) to the GUM, to accompany the 2025 Vital Sign and 6PPD-Q research agendas and the 2019 research agenda. PSI also intends to communicate the research agenda to the broader Puget Sound science and recovery community to inform other research funding opportunities.

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APPENDIX

Appendix Table A1 contains the sources from which PSI collated scientific uncertainties related to microplastics, 6PPD-Q, and the Vital Sign to produce the initial catalog of toxics uncertainties. The microplastics catalog is a subset of this larger catalog. For 6PPD-Q, PSI subsequently adapted uncertainties from a preliminary version of ITRC (2024) instead of using the 6PPD-Q catalog that was produced from the sources below.

Appendix Table A1. Sources of potential new uncertainties cataloged

Source	Source Type	Source Date
Where the rubber meets the road: Emerging environmental impacts of tire wear particles and their chemical cocktails (Mayer et al., 2024)	Pre-proof journal article	2024
Conversation with Rhea Smith (Ecology) (R. Smith, personal communication, March 15, 2024)	Conversation with expert	2024
Stormwater Strategic Initiative (SIL) Toxics Pod 2024 Investment Recommendations (D. Bilhimer, personal communication, July 22, 2024)	Government/stakeholder spreadsheet	2024
Conversation with Maggie Taylor (Nooksack Indian Tribe) (M. Taylor, personal communication, July 23, 2024)	Conversation with expert	2024
Seattle Aquarium Microplastics and Marine Debris Workshop (Discussion of uPlastics in the Environment and Protocols for uPlastic ID (Q&A), 2023)	Workshop document	2023
Focus on: Monitoring 6PPD-q in the environment (Flores, 2023) (PSI reviewed this source but did not identify any uncertainties from this source for the catalog (for microplastics, Vital Sign, or 6PPD-Q uncertainties).)	Report	2023
What We Know: 6PPD and 6PPD-quinone (Interstate Technology Regulatory Council, 2023)	Report	2023
PNAMP Fish Monitoring Work Group Tech Talk by Nat Scholz: An update on NOAA-F stormwater science in Puget Sound (Pacific Northwest Aquatic Monitoring Partnership, 2023)	Research talk	2023
Salish Sea Marine Survival Project Transboundary Workshop 2023 (Salish Sea Marine Survival Project, 2023)	Workshop document	2023

Source	Source Type	Source Date
6PPD Washington State interagency webinar follow-up (State of Washington Department of Ecology et al., n.d.)	Report	2023
Collaborative Innovation Forum: Functional Substitutes to 6PPD in Tires Meeting Report (Sustainable Chemistry Catalyst (University of Massachusetts Lowell), 2023)	Meeting report	2023
NWIFC 2023 Annual Report (Treaty Tribes in Western Washington, 2023)	Report	2023
Stormwater Strategic Initiative Lead Fall 2023 Wastewater Treatment and Onsite Sewage Systems Workshops (F. Bothfeld, personal communication, January 29, 2024)	Workshop document	2023
6PPD Alternatives Assessment Hazard Criteria (Washington State Department of Ecology, 2023a) (PSI reviewed this source but did not identify any uncertainties from this source for the catalog (for microplastics, Vital Sign, or 6PPD-Q uncertainties).)	Report	2023
Focus on: Reducing Sources of 6PPD (Washington State Department of Ecology, 2023b)	Report	2023
Responsiveness Summary: 6PPD Hazard Criteria (Washington State Department of Ecology, 2023c)	Report	2023
Quality Assurance Project Plan: Monitoring of tire contaminants in coho salmon watersheds (Smith, 2023)	Report	2023
Focus on: Best Management Practices for 6PPD-q (Water Quality Program, 2023) (PSI reviewed this source but did not identify any uncertainties from this source for the catalog (for microplastics, Vital Sign, or 6PPD-Q uncertainties).)	Report	2023
6PPD in Road Runoff Assessment and Mitigation Strategies (Environmental Assessment Program & Water Quality Program, 2022)	Report	2022
Stormwater Treatment of Tire Contaminants Best Management Practices (BMP) Effectiveness (Navickis-Brasch et al., 2022)	Report	2022
Puget Sound Federal Task Force Action Plan 2022-2026 (Puget Sound Federal Task Force, 2022)	Report	2022

Source	Source Type	Source Date
Stormwater Strategic Initiative Lead 2021 Toxics Workshops (Stormwater Strategic Initiative (2021a) and documents contained therein (e.g., Day, 2021; Harper, 2021; King-Heiden, 2021; Kolodziej & McIntyre, 2021; McIntyre & Kolodziej, n.d.; Senter, 2021; Stormwater Strategic Initiative 2021b; 2021c; 2021d; West, 2021); Toxics in Aquatic Life – Key Messages 2021.04.26_FINAL document (internal SIL file) (C. A. James, personal communication, October 3, 2023))	Workshop documents	2021
Hazardous Waste and Toxics Reduction Program Technical Memo (Washington State Department of Ecology & Manahan, 2021)	Report	2021
2020 State of Our Watersheds (Treaty Tribes in Western Washington, 2020)	Report	2020
2019 Tribal Habitat Strategy (*gʷəd̓ᶻadad*) (Northwest Indian Fisheries Commission, 2019)	Report	2019
Recommended Priorities for Salmon Recovery and the Chinook Implementation Strategy (Tribes, 2017)	Report	2017

Appendix Table A2 contains the final microplastics research agenda, which is comprised of uncertainties identified by microplastics experts (in the August 2024 meeting) and uncertainties suggested by experts at the September 2024 workshop. Prioritization is based on votes by microplastics experts in the August 2024 meeting.

Appendix Table A2. Puget Sound Microplastics Research Agenda

Uncertainty	GUM ID	Notes	8/28/2024 Votes	Source of Uncertainty (and Prioritization)	Priority Level
What is the relative distribution of microplastic sources (e.g., fishing gear, clothes, etc.) and the primary pathways (e.g., stormwater, aerial deposition, in water activity, etc.) of microplastics in Puget Sound?	TIF 151		3	8/28/2024 Microplastics meeting	Top
What is the distribution of microplastics among different matrices (e.g., sediment, fish, water) in Puget Sound?	TIF 152	A prioritization workshop participant (September 2024) suggested that research on uncertainties TIF 153 and TIF 154 should take place before research on this uncertainty (TIF 152).	3	8/28/2024 Microplastics meeting	Top
Develop/adopt a standard analytical method/protocol for microplastics in Washington State, including a focus on tire wear particles.	TIF 153		2	8/28/2024 Microplastics meeting	Top
What is the toxicology of microplastic fibers across a range of types, sizes, and species?	TIF 154	Prioritization workshop participants (September 2024) indicated the importance of focusing on benthic species. For TIAL Implementation Strategy purposes, research on this uncertainty should focus on species in Puget Sound. A workshop participant pointed to OSU and USGS for work related to this uncertainty. PSI will soon summarize this research (and how it addresses the uncertainty) in a GUM Research Note.	1	8/28/2024 Microplastics meeting	Top

Uncertainty	GUM ID	Notes	8/28/2024 Votes	Source of Uncertainty (and Prioritization)	Priority Level
How effective are stormwater BMPs (e.g., trash capture devices) at removing microplastics?	TIF 155	Prioritization workshop participants (September 2024) expressed expectation that microplastics are comparable to TSS, so this isn't an uncertainty; indicated that the answer to this uncertainty varies; and pointed to OSU (Brander and Harper) and EPA Trash Free Waters as relevant resources. PSI will soon summarize this work (and how it addresses the uncertainty) in a GUM Research Note.	1	8/28/2024 Microplastics meeting	Top
What are non-regrettable substitutions for plastics, particularly plasticizers?	TIF 156		0	8/28/2024 Microplastics meeting	High
What is the ecotoxicity of microplastics (of various types, features, etc.) that are found in the environment?	TIF 157		0	8/28/2024 Microplastics meeting	High
How can plastic use be reduced (e.g., via single-use bag bans, changes to food and packaging, reducing consumption, etc.)?	TIF 158	A prioritization workshop participant (September 2024) noted the importance of "environmentally preferable purchasing" and "pollution prevention".	n/a	9/12/2024 Toxics Workshop	No priority
To what extent does PFAS connect/bind to microplastics?	TIF 159	A prioritization workshop participant (September 2024) noted that this uncertainty was interesting.	n/a	9/12/2024 Toxics Workshop	No priority
What types of plastics are more likely to become nanoplastics?	TIF 160		n/a	9/12/2024 Toxics Workshop	No priority
How effective is wastewater treatment at removing microplastics?	TIF 161		n/a	9/12/2024 Toxics Workshop	No priority

Appendix Table A3 contains uncertainties that experts suggested in the September 2024 workshop and which are not included in the microplastics research agenda because they do not align with the scope of the TIAL Implementation Strategy. Some other participant-suggested uncertainties were not added to the toxics research agenda and are not listed in this table; these uncertainties (none of which were microplastics uncertainties) were either duplicates with other uncertainties (including those in the 2019 research agenda), or were related enough to other uncertainties that PSI incorporated them into the summary notes for those uncertainties.

Appendix Table A3. Other uncertainties (not included in research agenda)

List	Uncertainty	Notes	9/12/2024 Votes	Uncertainty Source
Vital Sign	When do we have enough information about new contaminants to require sampling via permits?	Not added to research agenda because this question is presumably known by those in charge of permits, and is therefore not a research question.	0	9/12/2024 Toxics Workshop
Vital Sign	Is the Salish Sea model already working on understanding to what extent toxics in Puget Sound come from the region?	Not added to research agenda because this question is known; the model can do this but such work is not underway.	1	9/12/2024 Toxics Workshop
Microplastics	What are the human health impacts?	This uncertainty is not included in the microplastics research agenda because human health is outside the scope of the TIAL Implementation Strategy (the Implementation Strategy focuses on humans via consumption of aquatic life).	0	9/12/2024 Toxics Workshop