Where the Rubber Meets the Road: Opportunities to Address Tire Wear Particles In Waterways

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INTRODUCTION

The mission of the US Environmental Protection Agency's (EPA's) Trash Free Waters program ("TFW") is to prevent trash from getting into our waterways and remove trash that is already in the environment. TFW works to improve the health of our nation's waterways and communities by fostering effective partnerships, providing informational resources, and facilitating shared learning. Microplastics, including tire wear particles, are part of the program's purview. Tire wear particles are small, plastic particles primarily generated by abrasion with pavement. They enter the aquatic environment in roadway runoff. Recent scientific studies suggest that tire wear particles, and contaminants associated with the particles, can potentially harm aquatic life (see, for example, Tian et al. 2021finding that 6PPD quinone, a tire rubber–derived chemical, induces acute mortality in coho salmon). The extent to which tire wear particles may impact human health via ingestion and other processes is unknown.

EPA's TFW Report on Priority Microplastics Research Needs: Update to the 2017 Microplastics Expert Workshop (2021) identified tire wear particles as an area of increasing focus in the research community. Tire wear particles as a pollutant in waterways is a relatively new field of study without standardized terminology, assessment methodologies, or established solutions. The emergence of tire wear particles as a specific microplastics concern prompted EPA to convene stakeholders in two roundtable discussions in Spring 2022 to facilitate shared learning about the challenges of addressing the problem of tire wear particle pollution. The roundtables focused on the issue of tire wear particles generated by vehicles driving on roadways.[1] Stakeholders represented diverse perspectives on the nature of the problem and how to effectively address it. Appendix A contains a list of participating organizations.

The roundtables provided a forum for discussion among participants without committing to a specific course of action. Participants discussed a set of questions aimed at understanding the barriers to and opportunities for managing tire wear particles in waterways. The questions included:

- Where are the barriers to managing tire wear particles in roadways and waterways?
- What specific opportunities could improve awareness and management of the problem?
- What information, data, or tools could help your organization better address this issue?
- What specific roles or products should EPA initiate to address tire wear particle issues?

This brief report summarizes the roundtable discussions. In producing it, EPA seeks to make public the challenges and potential solutions discussed during the roundtables, in order to broaden the community engaged in addressing tire wear particle pollution. The report begins with a short primer on tire wear particle pollution before introducing the challenges and potential solutions identified by the roundtable participants.

[1] The roundtable discussions did not address tire wear particles sourced from recycled tire crumb rubber, often used in applications such as sports fields or playgrounds.

TIRE WEAR PARTICLE POLLUTION: A PRIMER

Vehicle tires are made of a variety of components designed to support longevity and performance. The ability of a tire to grip the pavement is critical for the safety of vehicular travel. However, the contact between tires and road surfaces causes abrasion of both the tire and road surface, resulting in deposition of particles on or near roadways that then become part of stormwater runoff into local waterbodies, or are emitted into the atmosphere as dust that contains tire wear particles (see, for example, Brahney et al. 2021, Baensch-Baltruschat et al. 2020, Baensch-Baltruschat et al. 2021). Recent studies have found that tire wear particles comprise approximately 85% of the microplastics identified in waterways (Werbowski et al. 2021).

Kole et al (2017) estimated the global average tire wear particles emissions per capita at 0.81 kg/year, with per capita emissions in the USA estimated at 4.7 kg/year. According to the U.S. Tire Manufacturers Association, record tire shipments of more than 340 million units were predicted for the U.S. market for 2022, which is about 5 million more tires than in 2021 and 8 million more than in 2019.[2]

Researchers are unravelling the complexities of how particles are generated. For example, the number of particles generated depends on tire composition, driving speed and style, road surface type and condition, temperature, and other factors. Researchers report that the majority of tire wear particles are conglomerates of tire and road wear particles due to the interaction of tires with pavement and can vary in size from 1 nanometer to 5 millimeters (Kole et al. 2017, Wagner et al. 2018). The presence of recycled tire crumb rubber in certain pavement complicates source evaluation (i.e., from the roadway itself, tires, or a combination). Due to a lack of standardized detection, collection, and quantification methods for these small particles (primarily <100 μm), the quantity of tire wear particles is likely underestimated in aquatic environments.

Tires include components such as antioxidants, antiozonants, and curing systems to enable safe and effective performance.[3] Specific tire formulations vary across tire types, manufacturers, and countries. Therefore, tire wear particles have variable chemical compositions (Chibwe et al. 2021).

There is concern that degradation of tire wear particles can release chemicals from these components with the potential to pose ecological and health risks. In addition, tire wear particles may provide attachment surfaces for biotic and abiotic pollutants, and therefore become a source of these pollutants in roadway runoff to local water bodies (Luo et al. 2021, Wang et al. 2020). Many questions remain regarding the ecological risks of exposure to tire wear particles.

CHALLENGES AND OPPORTUNITIES

The roundtable participants shared the challenges they face in addressing the issue of tire wear particles in waterways and also brainstormed potential solutions and tools to address the identified challenges. Stakeholders made specific recommendations within the general categories of research, funding, education, and coordination. The participants also suggested engagement

[2] U.S. Tire Manufacturers Association, www.ustires.org/2022-tire-shipment-outlook
[3] U.S. Tire Manufacturers Association, http://www.ustires.org/innovation.

opportunities for EPA. Some participants shared information about ongoing research and related efforts. These are presented in Appendix B.

Table 1 provides a high-level summary of the challenges and potential solutions to addressing tire wear particles in waterways. The narrative following the table presents the substance of the discussions more fully, though no direct comments or attributions are included. The discussions reflected a range of organizational perspectives and geographic locations, which informed the approaches, tools, and research suggested as solutions.

TABLE 1. CHALLENGES AND OPPORTUNITIES TO ADDRESS TIRE WEAR PARTICLE POLLUTION

TOPIC	CHALLENGES TO ADDRESSING TIRE WEAR PARTICLE POLLUTION	OPPORTUNITIES TO ADDRESS CHALLENGES
Research: Measurement and Effects	• Lack of information on the physical and chemical characteristics of tire wear particles, and their transport, fate, and ecological and human health effects. • Lack of information on abrasion rates and influencing factors. • Lack of standardized methods for collecting, separating, and quantifying tire wear particle pollution, and studying the impact on waterways. • Access to necessary instrumentation for testing and analysis.	• Collaborate on studies that investigate the physical and chemical characteristics of tire wear particles, and transport, fate, and ecological and human health effects. • Collaborate on studies designed to further the understanding tire abrasion. • Develop and validate collection, separation, and quantification methodologies. • Create a clearinghouse of available data and research to encourage information sharing.
Research: Solutions	• Lack of information on alternative tire and pavement designs that meet safety requirements. • Lack of information on available stormwater treatment options and testing results on their effectiveness. • Identify land availability and locations to install stormwater treatment options.	• Coordinate research programs on alternative tire and pavement designs that meet safety requirements. • Develop EPA guidance to help states and municipalities manage tire wear particles (e.g., using stormwater best management practices) as an interim solution while long-term strategies are developed. • Compile information and case studies on tire wear particle reduction, capture, and treatment solutions, including information on cost and efficacy. • Could use existing tools to identify appropriate locations for stormwater treatment installation • Provide industry with incentives to develop and test alternative tire designs.

TOPIC	CHALLENGES TO ADDRESSING TIRE WEAR PARTICLE POLLUTION	OPPORTUNITIES TO ADDRESS CHALLENGES
Costs and Funding	• High cost of research to collect, test, and monitor particle shedding, and understand ecological and human health effects. • High cost of development and testing of treatment options and other solutions.	• Conduct cost-benefit analyses of various solution options. • Model the effectiveness of various solutions to inform priorities. • EPA could provide guidance on research, treatment, and other priorities to ensure that funding is used effectively. • Involve stormwater utilities in discussions about particle capture including green stormwater infrastructure solutions.
Education	• Lack of consumer education on the generation of tire wear particles, and their role in reducing or mitigating particle generation. • Lack of incentives for consumers to adopt best practices for reducing tire wear particles.	• Conduct national, state, Tribal, or local education. • Raise public awareness with messages about how tire abrasion generates tire wear particles. • Compile best practices for reducing tire wear particles and other information in a public clearinghouse.
Coordination	• Lack of government leadership and coordination undermines advances. • Lack of coordinated response disproportionately impacts Tribes.	• EPA and other governmental entities should provide leadership and coordinate mitigation and research efforts. • Include national, Tribal, state, and local governments in continued coordination. • Provide incentives for reducing miles traveled in coordination with other transportation programs.

RESEARCH: MEASUREMENT AND EFFECTS

Roundtable participants generally agreed there is a lack of information on the physical and chemical characteristics of tire wear particles and the impact of these particles on human and environmental health. For example, research is needed to determine which chemicals are released from tire wear particles into stormwater and receiving waterbodies, and what effects the particles and their associated chemicals have on aquatic life and human health.

Tires are complex and diverse in chemical composition and how they wear on the road. Participants identified data needs, including determining the percent of particles that fall into various size fractions, identifying the vehicle classes with the highest rates of tire wear particle emissions, and finding less ecologically impactful tire substitutions that meet performance, quality, and safety standards.

Because tire abrasion results from the grip between tires and the road, tire safety was described as a critical consideration before making a change to tire or road design and/or composition. Many factors influence abrasion rates, including tire design, vehicle weight, distribution of the vehicle load, location of the driving wheel, tire maintenance, road surfaces, and weather. Participants suggested focusing research on determining abrasion rates, which could inform future controls, surveillance, or regulation regarding tire wear particles.

Participants noted that many scientists do not have the instrumentation needed to characterize tire wear particles, particularly at the nano-scale. Scientific literature on the transport of tire wear particles and associated chemicals is sparse, but this information is necessary to effectively manage tire wear particles and minimize their impacts in waterways. Environmental monitoring of particles in air and surface water runoff would provide needed information. Indeed, much of the roundtable discussions focused on the importance of standardized tire wear particle collection, separation, and quantification methodologies and analytical approaches to studying the impacts of tire wear particles on waterways. Generally, participants agreed that a standardized methodology for collection, separation, and quantification of particles or validation of existing methods would better enable future tire wear particle research and mitigation efforts. Consistent methods and access to laboratory instrumentation will be critical for the successful collection and analysis of tire wear particles. In addition, there was agreement on the importance of understanding tire wear particle composition, fate, and transport, as well as awareness of how relevant factors (e.g., tire use and safety) impact decision-making about which solutions to pursue.

Participants suggested collaboration among scientists, industry, and state, Tribal, and federal agencies (both environmental and transportation) would be a helpful next step. Several participants proposed a clearinghouse of available data on tire wear particle size, composition, fate and transport, and impacts to encourage coordination and information sharing among research organizations.

RESEARCH: SOLUTIONS

A recurring theme was the lack of a one-size-fits-all approach to tire wear particle reduction, capture, and treatment. One participant described a framework developed by the San Francisco Estuary Institute that integrates a broad array of potential solutions that merit further investigation (Moran et al. 2021; Johannesson & Lithner 2022). The framework is structured as a continuum of solutions from prevention of tire wear particle formation to remediation of the resulting pollution. Examples of the solutions described in the framework include:

- Prevention actions by tire or vehicle manufacturers. These include product reformulation, voluntary tire ingredient review systems, or voluntary product ingredient controls.
- Reduction actions, including development and adoption of a reduced tire abrasion rate standard, production of airless tires, and/or inclusion of tire pressure monitors on all vehicles to reduce tire wear debris formation. Other ways to reduce debris could involve modifying road surfaces to reduce wear, reducing vehicle miles traveled, and changing driver behaviors.
- Remediation actions to treat the tire wear particle pollution. Techniques to remove tire wear particles and/or associated chemicals from surface water runoff include bioretention to treat runoff, infiltration (if safe), and diversion of "first flush" runoff to wastewater treatment plants.

The framework prompted discussions about prevention actions, including tire modification and development of new vehicle designs. Some participants suggested that research focus on technology and innovation to reimagine tires to use different materials and fewer toxic chemicals, or to design tire wear particle capture systems for use on vehicles. A participant mentioned that efforts are underway to develop tire wear particle collection systems for

installation on vehicles. Research on alternative tire design, such as airless tires that wear less than traditional tires, is ongoing. However, more research is needed to ensure that any alternative designs maintain the safety, durability, and other critical factors that traditional tires provide to meet regulatory requirements on safety. In addition, future vehicle designs should also consider the impact on tire wear particle generation and how vehicle improvements may be able to address the issue. For example, electric vehicles are hailed for their ability to reduce air pollution and emissions but may generate more tire wear particles than traditional gasoline-powered vehicles due to their increased weight. In the case of self-driving vehicles, they could be programmed to reduce tire wear with appropriate braking. Participants encouraged the development of incentives for industry to research and develop tires that are less prone to abrasion or vehicles that reduce tire wear or even vehicles without tires.

Participants also discussed approaches for reducing the generation of tire wear particles. One topic to explore is the availability of pavement alternatives that may reduce tire abrasion. In addition, a participant suggested investigating whether recycled tire materials used in asphalt resurfacing contribute to tire wear particles in waterways. Participants suggested coordination among research programs on alternative tire and pavement designs that meet safety requirements.

In the area of remediation of tire wear particle pollution, the participants requested EPA guidance to help states and municipalities manage tire wear particles while long-term solutions are developed. Such guidance might include stormwater best management practices and green infrastructure designs to capture tire wear particle pollution. Advancements in particle capture technology, such as catch basin inserts or filters to stop trash from moving from roads into stormwater conveyances, could be amended to address tire wear particles. One participant suggested the small size of tire wear particles is a barrier to collecting them, and that filter technologies deployed to collect tire wear particles from roadways could be developed. Certain green infrastructure techniques, such as bioretention areas, have potential for capturing tire wear particles before they reach waterways. Participants noted that further examination of stormwater management practices to evaluate efficacy and feasibility for collecting tire wear particles is needed. Solution design and selection should consider both the relevant tire particle size (e.g., nanoparticles to about 100 μm) and surface area.

There was consensus that communities could not just "treat their way out of" the tire wear particle problem. Land availability is another barrier noted. Most green infrastructure and stormwater management practices require space, which might not be available near roadways or adjacent to downstream waterways. Participants advocated that stakeholders compile information on the testing, feasibility, and practicality of tire wear particle capture solutions to help decision-makers understand the efficacy and applicability of stormwater remediation options.

COSTS AND FUNDING

When discussing the barriers to understand tire wear particle toxicity and treatment options, roundtable participants identified costs as a major issue. Costs are associated with research to collect, test, and monitor particles shed from tires, to understand the ecological and human health effects of exposure to tire wear particles, and to develop and test treatment options and alternatives. Future discussions involving prevention through particle capture should involve entities administering local stormwater utilities and consider funding green infrastructure solutions where such practices are not already eligible for funding.

Participants also noted that not addressing the problem could lead to significant costs. The "downstream" costs of what happens to the environment and human health could be considered in a cost-benefit analysis, including costs to indigenous and at-risk communities. It was noted that Tribes are discussing the legal ramifications of the loss of food sources (such as salmon or other fish) resulting from the effects of tire wear particle pollution on ecosystems. Without meaningful improvements in mitigating tire wear particle generation and impacts to water-bodies, this could result in litigation costs to the Tribes and potential defendants (e.g., states).

To ensure that funding is used effectively, participants suggested it would be helpful for EPA to develop guidance on research, treatment, and other priorities. For example, participants discussed that modeling potential solutions may determine their effectiveness, which could then inform a roadmap for future mitigation. Modeling the relative effectiveness of various interventions (e.g., reduction in miles driven, substitution of low abrasion tires, green infrastructure, etc.) could help decision-makers prioritize interventions with the potential for the greatest reductions in tire wear particle pollution.

ROUNDTABLE PARTICIPANTS AGREED THAT FUNDING COULD ADVANCE STUDIES TO ADDRESS TIRE WEAR PARTICLES IN WATERWAYS AND PROVIDE INCENTIVES FOR INNOVATION TO SPUR TECHNOLOGY. PRIORITIES SHOULD INCLUDE:

- **UNDERSTANDING** TIRE WEAR PARTICLE COMPOSITION, FATE AND TRANSPORT, AND IMPACT ON WATER BODIES;
- **STUDYING** THE HEALTH EFFECTS OF CONSUMING FISH AFFECTED BY TIRE WEAR PARTICLE POLLUTION, WITH A FOCUS ON INDIGENOUS AND SUBSISTENCE POPULATIONS;
- **DEVELOPING** ALTERNATIVES TO TIRES OR IMPROVEMENTS THAT COULD REDUCE TIRE ABRASION; AND
- **SHARING** INFORMATION ON THE COSTS AND EFFECTIVENESS OF INTERVENTIONS, INCLUDING RESPONSIBLE DISPOSAL OF CAPTURED TIRE WEAR PARTICLES.

EDUCATION

Participants acknowledged that consumers could play a role in reducing tire wear by changing the ways they operate their vehicles. However, most consumers are not aware of how their driving habits affect the generation of tire wear particles, or even that tire wear particle pollution is an environmental issue. Educational materials should include clear definitions of terms such as abrasion and microplastics, as well as explanations for how driving behavior influences the generation of tire wear particles. For example, both tire inflation and driving style (e.g., hard stops and starts) are something that drivers control, but consumers will need to understand not only how to change their behavior, but why such changes would be helpful in reducing tire wear particle pollution. By eliminating unnecessary trips to reduce vehicle miles traveled, consumers could be part of the solution. As with any suggested change in consumer behavior, providing educational resources and incentives for modifying habits will be necessary to support public adoption of best practices for reducing tire wear particles.

Raising awareness about the factors that cause tire abrasion and what happens when tire wear particles reach waterbodies was identified as the first step in educating the public. Participants recommended providing the public with information on the proper inflation of their tires and how their driving techniques can reduce tire abrasion. A participant noted that some education efforts are already underway, such as a regional stormwater outreach group in the Seattle area that focused on auto maintenance, eco-driving practices, and a study on 6PPD-quinone in street sweeping waste. Awareness and education could take place at the national, Tribal, state, and

local level, and participants noted that national coordination or tools would help create a consistent message.

Education was also mentioned as a way to help stakeholders across the country understand if, and to what extent, pollution from tire wear particles is a locally important issue, including on Tribal lands and in communities with environmental justice concerns. Digital compilations of research, alternatives, best practices, and other critical information in one easy-to-access public clearinghouse was a common request during the roundtables.

COORDINATION

Because tire wear particle pollution is an issue at the local, state, and national scales, participants acknowledged that it would take leadership, coordination, and political will to comprehensively address and mitigate the generation of tire wear particles and their effects on waterways. Consistent definitions, methods, thresholds, incentives, and requirements are necessary to ensure the success of all remediation and mitigation efforts, as is clear leadership. Roundtable participants sought leadership from EPA on scientific methodologies, measurement, research funding, prioritization, information gathering, best management practices, and education. In addition, they suggested the U.S. Department of Transportation (DOT), state agencies with authorities relevant to any aspect of the tire wear particle issue, and local stormwater utilities also have roles to play. State agencies sought a more developed understanding of the types of efforts their communities plan to pursue, so they can seek funding for such projects. State DOTs, regional transportation authorities, and municipal governments could also provide incentives and alternatives to decrease vehicle miles traveled and increase walkability to reduce the generation of tire wear particles on busy roads. Intergovernmental coordination related to tire wear particle remediation and mitigation must include Tribal governments, as Tribal communities are guaranteed fishing access in many waterbodies that may be impacted by tire wear particles.

NEXT STEPS

Participants acknowledged that the roundtables were a first step to share knowledge on tire wear particles in waterways. They affirmed an interest in continued collaboration among Federal agencies, Tribes, states, utilities, industry, transportation departments, and other interested stakeholders. Participants suggested convening stakeholders in a consistent and holistic way to build and connect a community of practitioners interested in developing long-term solutions for tire wear particle pollution.

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APPENDIX A: PARTICIPATING ORGANIZATIONS

Alliance for Automotive Innovation

Bay Area Clean Water Agencies

Bellingham, Washington, and Washington State 6PPD-quinone Subgroup

Brown & Caldwell

California Association of Sanitation Agencies

California Stormwater Quality Association

Central Contra Costa Sanitary District

City of Seattle

College of Charleston

Goodyear Tire & Rubber Company

Hoopa Valley Tribe

National Asphalt Paving Association

National Association of Clean Water Agencies

New England Interstate Water Pollution Control Commission

New Jersey Department of Environmental Protection

North Carolina Department of Transportation's Highway Stormwater Program

Ocean Conservancy

Oregon Department of Transportation

Oregon State University

Pew Charitable Trusts

Puget Sound Partnership

San Francisco Bay Regional Water Quality Control Board

San Francisco Estuary Institute

Talk Strategies

Texas Commission of Environmental Quality

U.S. Environmental Protection Agency (Office of Wetlands, Oceans and Watersheds, Office of Wastewater Management, Office of Research and Development, regional offices and laboratories)

U.S. Tire Manufacturers Association

Virginia Department of Transportation

Washington State Department of Ecology

Zero Waste Washington

APPENDIX B: RESOURCES SHARED BY ROUNDTABLE PARTICIPANTS

San Francisco Estuary Institute (SFEI) has a fact sheet on microplastics from tire wear particles in the San Francisco Bay and a *Synthesis of Microplastic Sources and Pathways to Urban Runoff* that includes an outline of potential tire wear particle mitigation options:

- https://www.sfei.org/documents/microplastics-tire-particles-san-francisco-bay-factsheet-0
- https://www.sfei.org/documents/synthesis-microplastic-sources-and-pathways-urban-runoff

European Review of Mitigation Options from the Swedish National Road and Transport Research Institute, 2022

- https://www.vti.se/en/archives/news/archives/2022-03-02-how-microplastic-pollution-caused-by-tyre-wear-can-be-reduced---new-research-study

EPA's Trash Free Waters program published and recently updated a Report on Priority Microplastics Research Needs:

- https://www.epa.gov/system/files/documents/2021-12/tfw-report-on-priority-microplastics-research-needs_0.pdf

The EPA laboratory in Corvallis, Oregon, and EPA Region 10 in Seattle are creating an ecohydrological model to assess the effectiveness of green and gray infrastructure improvements meant to reduce stormwater contaminant loads to Seattle's Longfellow Creek. The creek experiences high rates of coho salmon pre-spawn mortality associated with lethal concentrations of 6PPD-quinone associated with tire wear particles.

- https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=352990&Lab=CPHEA

The Tire Industry Project (TIP) is a forum supported by U.S. Tire Manufacturers Association (USTMA) and the World Business Council for Sustainable Development (WBCSD):

- https://www.wbcsd.org/Sector-Projects/Tire-Industry-Project

TIP has a web page on tire and road wear particles and other material research:

- https://www.wbcsd.org/Sector-Projects/Tire-Industry-Project/Resources/Tire-and-Road-Wear-Particles-TRWP-and-other-Material-Research

Cryo-milled tire tread samples are also available for researchers from TIP:

- https://www.ustires.org/cmtt

Studies were shared regarding tire wear particles and environmental effects:

- https://azdot.gov/sites/default/files/2019/05/tire-wear-emissions-for-asphalt-rubber-portland-cement-concrete-April2006.pdf
- https://www.researchgate.net/publication/357980339_Toxicity_of_Micro_and_Nano_Tire_Particles_and_Leachate_for_Model_Freshwater_Organisms
- https://environment.transportation.org/teri-idea/stormwater-management-to-address-highway-runoff-toxicity-associated-with-tire-wear/

Washington State Department of Ecology assessed potential hazards of 6PPD-quinone and alternatives:

- https://www.ezview.wa.gov/Portals/_1962/Documents/6ppd/6PPD%20Alternatives%20Technical%20Memo.pdf#:~:text=In%202021%2C%20the%20Washington%20State%20Legislature%20passed%20an,tires.%E2%80%9D%201%20This%20technical%20memo%20fulfills%20that%20assignment.?msclkid=a1d1a7c3af9111ec88cfbf3ce5027ab0

Oregon Department of Transportation has a Stormwater Technology Testing Center:

- https://sttcoregon.com/

The Watershed Game, created by the University of Minnesota-Duluth, helps participants learn how land use affects water quality and natural resources:

- https://seagrant.umn.edu/watershed-game?msclkid=5bc28553af8f11ecb02a569716ecb2f8