Vehicle tyres – A key source of microplastics to the environment:
An introduction to the fate, effects, and mitigation strategies

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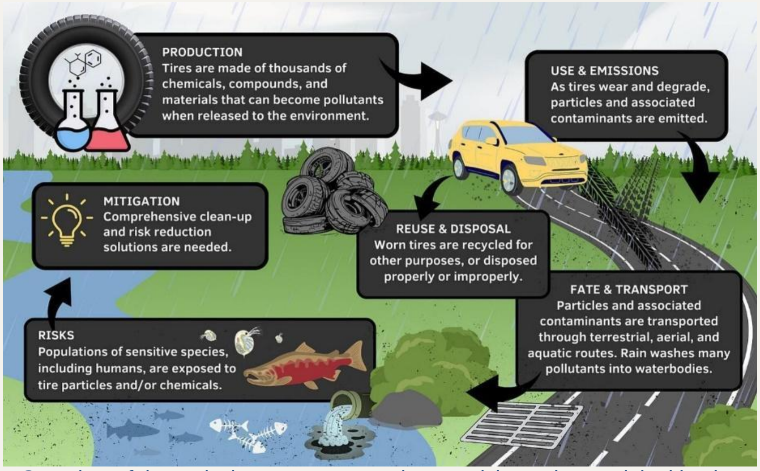
It is estimated 12.7 MT of plastic enter the environment as microplastics every year, the main sources being paint, tyre particles, pellets, textiles and personal care products[1]. There will also be substantial additional quantities from the fragmentation of larger items of plastic that have already entered the environment as debris. This document focuses on emissions from vehicle tyres which are estimated to account for an annual release of 3.6 MT of microplastic to the environment[1]. Every year, almost 2 billion new vehicle tyres are produced world-wide. At the same time >1 billion tyres reach their end-of-life. During use, tyre wear particles (TWPs) are formed through abrasion of the rubber material in contact with the road surface. By mass, tyres are one of the largest sources of secondary microplastics, but reported particulate emission volumes and environmental concentrations are highly variable, both spatially and temporally. The most commonly detected size ranges of TWPs are 0.05-100 µm, with most of the particles being below 2.5 µm[2-4]. Tyres and the emitted TWPs are known to contain a high level and diversity of chemicals of concern, many of which have been shown to leach into environmental matrices[5].

Source emissions: There is limited data on TWP emissions from direct measurements of environmental matrices[6]. Urban, highway and rural roads are considered the main point sources of TWP emissions, where higher emissions result from increasing traffic loads. Release per km per vehicle type typically decreases in the order lorry/18-wheeler > truck > bus > van > passenger car > motorcycle > moped (i.e., decreasing with decreasing vehicle weight)[2]. Braking, accelerating, and turning causes increased emissions for all vehicle types[7]. Emissions per km travelled are largest in urban areas (due to increased braking, accelerating and turning), followed by highways and rural areas. It is estimated that through its usable lifetime, a tyre loses between 10-30% of its initial mass. Considering an average initial mass of 8.2 kg for a passenger car tyre and of 70 kg for a truck tyre, around 1.2 kg (passenger car) and 12.6 kg (truck) of tread weight is lost to the environment during the working lifespan of the tyre[8,9]. However, not all tyres are fully worn before they should be replaced (ca. every 5 years). The amount of tyre wear may be higher for electric vehicles, which are heavier than those that are fuel-powered and are increasing in number [5].

Pathways: Road run-off,[10,11] atmospheric deposition of smaller TWPs, and re-distribution through wastewater treatment plants (WWTPs) may be considered the primary transport pathways for TWPs to reach the natural environment[12,13]. Re-purposing of roadside soils, and repurposing of end-of-life tyres as crumb in artificial sports pitches are potentially overlooked, additional pathways of TWPs to the natural environment.

Plastic chemicals in vehicle tyres: Tyres contain a complex mixture of chemicals, including organic chemicals and heavy metals[14]. Both unreactive chemicals (e.g., polymers, oils, fillers, wax, resins and antioxidants) and reactive chemicals (e.g., sulphur compounds, retardants, accelerators, activators and glue) are used in the composition of the tyre tread (where TWPs originate). Literature reviews have shown that ~800 chemicals are used and/or present in tyres and TWPs[15].

Chemical groups in descending order by number of known chemicals: vulcanisation accelerators, antioxidants and antiozonants, polymerisation agents, plasticiser, other protectants, adhesion agents, nitrosamine compounds, reaction products, mastication agents, blowing agents, vulcanisation agents, vulcanisation retarders, vulcanisation activators.



Overview of the emissions, transport pathways, risks and potential mitigation actions for car tyre pollutants [5]

Notably, decomposition products and 'other' chemicals represent some of the largest groups of chemicals.

As exact tyre formulations are subject to producer's intellectual properties rights, there is limited transparency of the volumes used in different tyres.

Importantly, many additives and non-intentionally added substances (NIAS) can leach out of vehicle tyres into the surrounding environment.

However, many additive chemicals associated with tyres have other uses, making it difficult to distinguish sources based on environmental concentration measurements[16-18]. Chemical emissions from tyres can occur when the vehicle is in motion and when stationary, but still in contact with the environment (especially under wet conditions).

TWP and chemical environmental transport routes and accumulation: Roadside soil is the primary recipient of TWPs[19,20], with an estimated 45-80% of TWP deposition occurring within the first few metres from the roadside. Small TWPs and mobile chemicals may wash-out from soils and transfer to groundwaters. Surface waters (lakes, rivers, seas) are the next largest recipient (6-26%) and can act as accumulation zones and transport mechanisms for TWPs and tyre chemicals to the marine environment when located close to main non-urban roads (e.g., highways)[21-23]. Coastal towns and cities may represent major points of emission and transport of TWPs and tyre chemicals to the marine environment via urban run-off or by passing through WWTP systems. Due to their variable encrustation of road wear materials the density and therefore buoyancy of TWPs is variable[24,25]. Furthermore, due to their small size (0.05-100 µm) their sinking rates can be quite long as drag processes become more dominant. Smaller TWPs (<100 µm) may remain airborne for longer and may be subject to long-range transport before deposition occurs[4].

Impacts of TWPs and their plastic chemicals: Additive and NIAS chemicals leaching from tyres have been demonstrated to be a source of significant toxicity to aquatic organisms, but he complexity of the mixture makes identifying the most toxic chemicals challenging[26,27]. For example, tyre leachates have been implicated in urban stormwater mortality syndrome in salmonids on the West coast of North America[11]. This syndrome, which causes 40-90% of returning salmon to die before spawning, threatening salmonid conservation, was associated with degraded water quality, urbanisation, and high traffic intensity. Recently, hybrid toxicity identification evaluation and effect-directed analysis was used to identify the chemical 6PPD quinone (a degradation product of the antiozonant 6PPD) as the primary cause. The physical presence of TWPs can also be toxic to organisms, causing food dilution and additional responses similar to other microplastic types[28,29], but further work is needed to separate chemical and physical particle effects. In addition to aquatic systems, there is increasing evidence that TWPs may lead to changes in essential ecosystem services and multifunctionality, and therefore represent an emerging threat to soil health[20]. Furthermore, human exposure to tyre wear and chemicals is highest near roads.

Potential Interventions:

- Simplification of tyre formulations to remove/replace the chemicals of highest concern
- Improved road runoff collection and processing
- Societal changes, including increased use of public transport, car sharing, changes in driving style, lower speed limits, reducing vehicle weight, ensuring correct tyre inflation
- Regulations on minimum tyre abrasion limits and transparent labelling to inform customer choice

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