Tyre Particle Health, Environment and Safety Report

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TyreStewardship AUSTRALIA

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Acronyms

ECHA – European Chemicals Agency

EOLT – End-of-life tyres

ETRMA - European Tyre and Rubber Manufacturers Association

EU – European Union

NESP - National Environmental Science Program

PAH – Polycyclic aromatic hydrocarbon

RMM - Risk management measures

SVOCs – Semi-volatile organic compounds

TSA – Tyre Stewardship Australia

TDP - Tyre-derived products

TRWP – Tyre and road wear particles

VOC – Volatile organic compounds

Assessment of the potential community and environmental risks from tyre particles during vehicle use and in recycled applications.

1. Introduction

Tyre Stewardship Australia (TSA) is an industry program that was formed in 2014 to assist in the development of feasible markets and products for end-of-life tyres (EOLT). This is achieved by supporting recovery processes that reduce the number of tyres that end up in landfill, are dumped illegally, or are exported to overseas industries with poor environmental practices, as well as by creating and supporting opportunities to safely reutilise these resources.

State of play in Australia

In Australia, public concern regarding environmental sustainability has created a push to recycle and reuse resources. An increasing number of tyre recyclers and associations exist to reprocess EOLT and create new materials for various applications.

Conventional tyre recycling involves mechanically grinding tyres down into physically smaller pieces. Once reduced in size, these tyre materials can then be used either as a loose particle or bound into a product. These new materials are known as tyre-derived products (TDP), and are utilised in applications such as road surfaces, industry and commercial flooring, building insulation, artificial turf for sports fields, running tracks surfaces, playground surfaces and fuels.

To align with a vision to develop sustainable outcomes and solutions for the millions of EOLT that are produced each year, TSA has undertaken this research to review, understand and assess the potential health and environmental impacts of tyre particles. Furthermore, as greater awareness has been raised in recent years regarding tyre and road wear particles (TRWP) and their contribution to chemical and microplastic pollution in the environment, these particles have also been included in the scope of this review.

The work first presents an overview of international studies involving tyres 'in-use' (tyres on vehicles) and the potential risks related to TRWP and microplastics. Following this, a review of international studies involving TDP is presented, specifically TDP that interact closely with people and the environment. By identifying where TDP are similarly used in Australia, the findings of these studies have been contextualised for recycled tyre materials in Australia.

In Australia, TRWP, artificial turf, playground/running surfaces and crumb rubber-modified asphalt were identified as the main tyre particles that interact closely with the environment and the community. Each material application was considered individually during the literature review and risk assessment process.

2. Studies on tyre and road wear particles: Literature Review

The abrasion of tyres on a road surface produces micro sized rubber particles which are widely accepted to fit into the category of "microplastics".[1] The abrasion of tyres is caused by friction between the tyre and road surface and is an essential aspect to ensure safety during variable conditions and driving behaviour. The debris formed during tyre abrasion on the road consists of an approximate 50:50 mixture of tyre tread particles and road surface material, collectively termed *Tyre and Road Wear Particles*.[1,2]

TRWP have been identified in microplastic samples worldwide and road run-off is believed to account for approximately 44% of the microplastic pollution released into the oceans worldwide.[3] In fact, TRWP has been detected in all environmental compartments, specifically road dust, air, soil, freshwater and marine.[4] Since TRWP are reported to contribute to a significant proportion of global microplastic pollution, it is crucial to identify the individual role these particles play in ecotoxicity.

A major concern for these particles is not only their fate, but their transport life cycle. During transport processes there is the potential for particles to break down further, leach chemicals they contain, and absorb and re-release chemicals present in the surrounding environment. Furthermore, particulate matter has the potential to cause physical harm if ingested by aquatic life or humans, and subsequent toxicity if they can penetrate cell membranes or are retained in the gut.[1]

Thus, the literature review included studies that evaluated the ecological risks associated specifically with TRWP and rubber particles. Studies have primarily focused on the potential toxic effects of leaching of chemicals from tyre materials, with a few including physical effects, and have been summarised in Table 1.

In addition to ecotoxicity, it is also important to address the potential impact of microplastics on human health. Microplastics and tyre particles have been detected in low levels in air, soil, drinking water, seafood, and other dietary sources.[5] Exposure may occur via ingestion, dermal contact, or inhalation. The preliminary studies identified that have assessed the health effects of TRWP towards humans have been summarised in Table 2.

Table 1: Ecotoxicity of tyre particles

Source	Organism	Ecotoxicity conclusions
Tyre particles from new rubber – (chemical leaching)	*R. subcapitata* (microscopic algae), *D. magna* (crustacean) and *X. laevis* (frog embryos).[6]	Zinc, low pH levels leading to mortality and deformation
Tyre particles – (chemical leaching)	*R. sylvatica* (frog larvae).[7]	Developmental delays from zinc levels
Tyre particles from worn tyres shredded - (chemical leaching)	*D. magna* and *C. dubia* (crustaceans), *P. subcapitata* (algae) and *D. rerio* (zebra fish eggs).[8–10]	Zinc and organic compounds – immobility, mortality, growth inhibition
Tyre wear particles from a road simulator- (chemical leaching)	*P. subcapitata* (algae), *D. magna* (crustacean), *P. promelas* (cyprinid) and *H. azteca* (crustacean).[11,12]	No acute toxicity and limited chronic toxicity observed (growth inhibition and larvae mortality). Overall low risk.
Tyre particles in sediment – (physical particle)	*G. pulex* (crustacean).[13]	Particles discovered in the gut, but no negative effects observed
Tyre particles – (chemical leaching) Tyre particles – (physical particle)	*H. azteca* (crustacean).[14]	(Chronic) Mortality, reproduction, growth inhibition after 21d exposure. Varying toxic effects between leaching and physical particle.
Tyre wear particles - (chemical leaching)	*Oncorhynchus kisutch* (salmon).[15]	Acute toxicity linked to 6PPD-quinone, an anti-ozonant transformation product present in some tyre mixtures.

Table 2: Human health risks of tyre particles

Source	Test subject	Conclusions on toxic effect
Airborne tyre particles	Latex-sensitive patients – inhalation pathway.[16]	No clear evidence that tyre particulates increase incidence of asthma or allergy.
TRWP from ambient particulate matter	Rat biological study –inhalation pathway[17]	A general no observable adverse effect level measurement.
Air particles from high vs low traffic areas	Rat biological study –inhalation pathway.[18]	A trend of slightly greater adverse effects in high traffic areas – cytotoxicity and inflammation.
Organic extracts from tyre particles	Human lung epithelial cells (A549) – inhalation pathway.[4]	Negative effects on cell morphology and inducing reactive oxygen species. NB only applicable if organic extracts become bioavailable.

3. Studies on tyre derived products: Literature Review

In Australia in 2020-21, around 459,000 tonnes of used tyres reached their end-of-life. Developing viable and sustainable solutions for EOLT is a priority for TSA. An increasing push to utilise recycled materials, and therefore TDP, introduces additional considerations regarding the risks towards humans and the environment. Materials like rubber crumb and rubber granules have been used in asphalt and artificial turf applications for over 50 years with no definitive health effects. However, increased knowledge on pollution has placed TDP in the spotlight and necessitate further consideration regarding their environmental and health impacts.

Studies involving the types of TDP that are currently used in Australia in significant volumes and interact closely with the environment and people were selected for inclusion in the risk assessment. The materials containing TDP that were identified as warranting investigation are artificial turf, playgrounds and running track surfaces, and crumb rubber modified asphalt.

Artificial turf fields are advantageous compared to natural grass surfaces due to lower maintenance requirements, and the flexibility to be used in different climates and seasons. Rubber granulates can both physically support the plastic fibre blades and provide cushioning and shock absorbance during sport activities.

Recycled rubber particles are also used in various racing and running tracks, and as ground cover in playgrounds and schools. Rubber granules are combined with a polyurethane binding agent and poured into place on top of a hard surface such as concrete or asphalt.[19] The inclusion of rubber material is appealing as it has demonstrated improved shock-absorbing properties which improve performance and reduces the severity of potential injuries of children using the playground.[20]

Crumb rubber has been used in Australian roads in spray seals since the mid 1970's and has seen increasing usage in rubber modified asphalt and binder applications.[21] The recycling of rubber from tyres is economically beneficial due to reducing the amount of costly polymer and petroleum derived bitumen products in traditional asphalt additives.[22] During road construction, asphalt binders are heated to form a liquid, mixed with aggregates, laid on the road and then compacted. The temperature of materials during road and pavement construction often need to reach up to 160 °C to create the necessary liquid phase. Emission of volatile substances such as organic compounds and polycyclic aromatic hydrocarbons (PAHs) are known to increase as temperatures increase.[23]

Table 3 represents the literature studies that have examined the different environmental and health impacts of these tyre material applications.

Table 3: Human health and environmental risks of tyre-derived products

Application	Chemicals	Exposure routes	Conclusions
Artificial turf France 2007[24] -2 fields	Organic and metal concentrations	Percolate ecotoxicity	No ecotoxic effects in the lab study and outdoor artificial turf study were linked to the organisms tested.
	VOCs and aldehydes	Emission exposure	No health concerns towards users were found.
Artificial turf New York 2009[25] -2 fields	Heavy metals – including Zinc/Lead	Chemical leaching	No significant impact on both surface water and groundwater quality.
	VOCs and SVOCs	Ambient air testing, wipe, and vacuum	No observed health concerns towards users.
Artificial turf Review 2014[26]	VOCs, PAHs, heavy metals, and particulates	Chemical leaching and air quality	Low overall contamination in the aquatic environment, apart from zinc. No significant health risks associated with fields with rubber granulate.
Artificial turf US 2017[27] -soil study	PAHs, VOCs, metals	Earthworm and soil microbes	Soil microbial activity unaffected. Earthworm survivorship no different between soils, however worms did experience slower growth.
Artificial turf EU (ECHA) 2017[28] -100 fields	PAHs, metals, phthalates, benzothiazoles, VOCs, SVOCs	Airborne levels and migration	No elevated cancer risk from PAHs. Phthalates, benzothiazoles and metals was below levels considered a health risk. VOCs may cause eye and skin irritation indoors.
Artificial turf Netherlands 2018[29] -100 fields	PAHs, benzothiazoles, phthalates and heavy metals	Oral, dermal and inhalation migration experiments	Similar results to ECHA study - No evidence to suggest significant health risks.
Artificial turf EU 2020[30–32] 86 fields - 14 countries	PAHs, metals, benzothiazoles, phthalates, VOCs	Migration, air quality and evaluation studies	Calculated cancer risks for PAH exposure were less than 1 in 1 million and the evaluation for non-carcinogenic substances indicated no health concerns.
Playground ground cover Canada 2003[33]	Organic extract of tyre rubber	Leachate aquatic toxicity	Potential threat to marine organisms from undiluted runoff, but activity decreases rapidly through transport processes and over time.
		Genotoxicity	Does not pose a health hazard to children.
Playgrounds/ running tracks US 2007	Metals, PAHs, VOCs, allergens	Oral and inhalation migration scenarios	Low likelihood of negative health effects in children.
Playgrounds/ Artificial turf Spain 2021[34]	PAHs	Concentration levels	Average PAH concentrations were lowest in outdoor playgrounds, then indoor playgrounds, then artificial turf pitches. All recreational surfaces complied with relevant ECHA PAH limits.
Crumb rubber modified asphalt US 1995[35]	Trace metals, VOCs, SVOCs	Chemical leaching into surface and groundwater	Levels were too low to be considered environmentally hazardous, according to US guidelines.
Crumb rubber modified asphalt US 1998[36]	Water pollutants, PAHs, benzothiazoles.	Chemical leaching into surface and groundwater	Water quality did not indicate an increased risk toward the environment or human health. PAHs were not elevated levels. Benzothiazole levels were elevated, but unlikely to be harmful to the aquatic environment.

Crumb rubber modified asphalt US 2001[37]	Particulates, PAHs Organic sulphur compounds, VOCs, CO, H_2S, SO_2, O_3	Air emission samples and health questionnaires	Crumb rubber asphalt had slightly higher emissions and symptoms than conventional asphalt during construction activities, however safety recommendations were given for both types.
Crumb rubber modified asphalt US 2003[38]	Metals, benzothiazoles,	Chemical leachate	Contaminants were naturally removed during their transport through soil, rendered the leachate non-toxic to the aquatic organisms tested.
Crumb rubber modified asphalt Sweden 2018[39] Lab and field experiments	Benzothiazole and PAHs	Air emission exposures at two mixing temperatures for crumb rubber and conventional asphalt.	No overall evidence to suggest a higher risk when using crumb rubber asphalt compared to conventional asphalt in terms of asphalt worker exposure in any working area.
Crumb rubber modified asphalt US 2019[40] Lab and plant experiments	VOCs	Emission levels of VOCs at 120 °C, 140 °C and 160 °C.	VOCs are sometimes harmful to the environment and human health, there are no concluding results regarding the health hazards associated with the elevated VOCs in crumb rubber modified asphalt.
Crumb rubber modified asphalt Australia 2019[41]	VOCs, PAHs, suspended particles, benzothiazoles, bitumen fumes	Air emissions, exposures, and health questionnaires	Crumb rubber asphalt had higher benzothiazole levels, lower total suspended particles, lower bitumen fumes compared to conventional asphalt and no carcinogenic emissions in either asphalt type. All emissions were below Australian SafeWork emission standards– with no evidence regarding a greater risk of rubber asphalt compared to conventional asphalt.
Abbreviations: PAH – polycyclic aromatic hydrocarbon, VOC – volatile organic compounds, SVOCs – semi-volatile organic compounds, ECHA – European Chemical Agency.			

4. Results and discussion

The potential risks associated with different tyre particles were characterised based on exposure pathways towards humans and the environment, and the potential hazards related to this exposure. Based on potential hazards and consequences, the risks were rated according to both magnitude and likelihood and subsequently given a risk rating according to a relevant risk matrix. A risk matrix, created for the purpose of this work, and the detailed characterisation of each risks assessment can be found in the Appendix. A summary of key findings is presented here.

4.1 Tyre and road wear particles: The potential risks towards human health and the environment

There have been several toxicological studies regarding microplastics and the aquatic environment. Zinc accumulation was identified in several studies and was attributed as the cause of negative effects seen in marine organisms, particularly a slowing of growth trajectories. These studies generally exceeded average environmental concentrations and used lab produced tyre particles. Particles collected in a road simulator and at more relevant environmental concentrations demonstrated a low toxicity risk to aquatic systems. However, due to the unique and diverse components of tyre particles and the differences in concentrations used during testing, these studies do not provide consistent or conclusive evidence for TRWP aquatic ecotoxicity. A recent study has found a potential link between the toxicity to a salmon species in the US and an anti-ozonant chemical by-product, 6PPD-quinone. Importantly, these studies are currently being replicated in Australia, to better understand the local impact of TRWP to aquatic organisms.

Whilst the information regarding the ecological risks of microplastics is limited, and there is a significant contribution from TRWP to global microplastics, the general literature on microplastic pollution suggests that exposure levels are, on average, lower than the predicted no-effect level and it is unlikely that ecological effects will be widespread.[5]

Preliminary studies have been conducted to examine the health effects of microplastics and TRWP towards humans, with minimal health hazards identified. Whilst this is an ongoing area of study, several working groups have concluded that there is currently no evidence to suggest a widespread risk towards human health caused by microplastic and TRWP pollution, instead suggesting that precautionary measures be taken to address public concerns, such as waste treatment, particle capture and removal systems and particle reduction strategies.[41]

A thorough risk assessment was conducted based on what is currently known in the literature regarding TRWP and can be found in the Appendix (Table 4 and Table 5). The review of this literature was assessed in detail and deemed that at current concentrations, there is a minor risk towards the environment. With the continuing increasing concentration of TRWP in the environment, this may change in the future, due to possible chemical risks. Current studies regarding the health effects of TRWP towards humans, in particular the inhalation of particles, was deemed to have a minor risk.

4.2 Tyre derived products: The potential risks towards human health and the environment

Rubber granulate is used as an infill material in artificial turf fields and the health and environmental risks have been examined in several international studies. Studies involving human health risks were frequent, covered broad locations and thoroughly examined different exposures routes. Importantly, the oral, dermal and inhalation exposure of both the physical granulate particle and the chemicals released were examined. The studies agree that there is no increased risk of cancer or other negative health effects from playing on fields with rubber infill. Similarly, the environmental risk assessments identified generally agree there is minimal risk to surrounding environment, although zinc levels were flagged as a potential ecological hazard to consider in the future.

The close interaction of people, in particular children, to rubber materials from recycled tyres and the substances they contain has led to several international studies included in this assessment. The results from the studies that investigated the health and environmental effects of these surfaces produced no evidence to suggest an increased risk from exposure. As the studies pertained to a limited number of locations, additional studies in more widespread locations would provide a more conclusive assessment.

A selection of studies have been conducted to address whether the inclusion of crumb rubber modified asphalt in construction applications creates a greater risk of toxic emissions to personnel working onsite. The identified literature generally agrees that both conventional asphalt and crumb rubber modified asphalt produces toxic emissions in varying levels, but whether there is an increased health risk from asphalt containing crumb rubber requires more investigation. Importantly, the recent study in Victoria, Australia comparing crumb rubber-modified asphalt and conventional asphalt found the fumes and airborne particles are not above SafeWork Australia standards, are not carcinogenic and the inclusion of crumb rubber does not appear to increase negative symptoms for asphalt construction workers. One study also assessed the environmental risks of leachates from crumb rubber modified asphalt and agree that soil sorption and biodegradations readily remove toxic chemicals and prevent distribution in waterways.

A risk assessment based on these literature studies regarding TDP can be found in the Appendix (Table 4 and Table 5). The literature generally agrees there is a minor risk towards the environment and human health from using artificial turf fields. The literature studies on bound surfaces, such as playgrounds and sports tracks were assessed to have a minor risk towards the environment and a negligible risk towards human health. An assessment of crumb rubber modified asphalt studies suggests there is a minor risk to the surrounding environment and a moderate/minor fuming risk towards construction workers during asphalt construction, similar to conventional asphalt and depending on personal protective equipment usage.

5. Knowledge Gaps

A few knowledge gaps still exist regarding microplastic and TRWP pollution. There is limited evidence relating to TRWP production and concentration in the environment. There is also a lack of studies regarding TRWP and microplastic exposure pathways and the potential human health effects. To fully understand the negative effects of microplastics and TRWP and create more accurate risk assessments and solutions, these knowledge gaps need to be addressed.

The European Tyre and Rubber Manufacturers Association (ETRMA) have launched a collaborative body, the European TRWP Platform, to share knowledge and develop potential solutions and methods to address concerns regarding TRWP. A recent action from the ETRMA was a released statement saying that the tyre industry intends to review the findings of study relating to the toxicity of 6PPD-quinone towards aquatic organisms.[15] The Tire Industry Project is another initiative to provide a global forum to discuss tyre sustainability issues and includes TRWP as a key focus area. On a local scale, the Marine Biodiversity Hub, with a collaborative partnership with the Australian Government's National Environmental Science Program (NESP), have undertaken a research project to assess primary microplastics in the marine environment. A component of the project investigated TRWP, their sources, release and pathways into the environment, and potential options to address the TRWP contributions to microplastic pollution.

Whilst the above knowledge gaps remain, recommendations from studies, microplastics forums and organisations generally agree on adopting precautionary measures. These include strategies such as particle capture and removal systems, encouraging reusable plastics alternatives, technology, and innovation to modify car, tyre and road designs and driving behaviour education.

There is prevalent research regarding TDP and the risks towards the environment and human health, however, there are still a few knowledge gaps to be addressed. There are limited long-term environmental impact studies of TDP applications and few broader scale studies of TDP applications that conduct analysis at multiple locations. The risk assessment performed above was generalised to Australian applications, under the assumption that products use analogous tyre materials in similar applications, which would ideally be supported by future studies.

Future research should be directed at filling these knowledge gaps and adding to the current body of research. As more information and knowledge gaps are filled, the risk assessments from this review will need to be updated.

In many examples of TDP use, precautionary measures exist, such as ensuring safe work practices and personal protective equipment is used during road construction, regardless of asphalt type, to ensure the safety of workers. Risk management measures (RMMs), in the sporting industry, are aimed at reducing the loss of particles to the environment in surfacing applications.[43] This includes strategies such as drain filters, containment barriers, correct storage and installation practices, machine and boot cleaners, and regular maintenance and repair to damaged surfaces. These RMMs are particularly relevant with an upcoming decision to be made by the EU Commission on whether to ban rubber infill in artificial turf applications.[44]

6. Conclusions

The information gathered and summarised in this report is a literature review conducted regarding TRWP and TDP health and environmental safety. The findings from various studies have been reviewed and contextualised for tyre particle safety in Australia. A general assessment of each tyre material was conducted, and a summary of the risks findings from the current research is outlined below:

1. **TRWP -** A review of this literature was assessed in detail and deemed that at current concentrations, there is a minor risk towards the environment. Studies regarding the health effects of TRWP towards humans, in particular the inhalation of particles, was also deemed to be a minor risk.
2. **Artificial turf -** Has been studied in great depth and despite ongoing contention related to environmental transport of particles from the EU commissions microplastics initiative, the literature generally agrees there is a minor risk towards the environment and human health.
3. **Playgrounds and running tracks -** Has been examined by researchers internationally across a number of surfaces and assessed to have a minor risk towards the environment and a negligible risk towards human health.
4. **Crumb rubber-modified asphalt -** An assessment of these studies suggests there is a minor risk to the surrounding environment and a minor/moderate fuming risk towards construction workers during asphalt construction. Importantly, recent studies comparing crumb rubber-modified asphalt and conventional asphalt have found the fumes and airborne particles are not above SafeWork Australia standards, are not carcinogenic and the inclusion of crumb rubber does not appear to increase negative symptoms for asphalt construction workers.

The recycling of rubber from EOLT has great environmental benefits due to the repurposing of an otherwise waste product, as well as additional benefits due to the improved performance features of many tyre-derived materials. However, TSA also acknowledges that any utilisation of recycled tyre material must be done so in a manner that is safe to the community and environment. The purpose of this research was to better understand and characterise these risks. The risks assessments conducted in this report are only a guide. They rely on the most current research and will require updating when new information and research is published. It is recommended that precautionary measures are maintained to eliminate any potential hazards created by mismanagement practices or identified knowledge gaps. As such, TSA will continue to remain vigilant in monitoring new information and research as it becomes available. TSA will also undertake research where appropriate and beneficial.

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Appendix

Figure 1: Risk Matrix and Risk Assessment

Consequences

	Human Health	Environment
Severe	-Fatality due to injury or illness caused by exposure	-Irreversible environmental damage -Remediation clean-up for more than 1 year -Local community outrage
Large	-Permanent disabling injury or illness caused by exposure	-Long-term environmental damage or pollution -Clean up and rehabilitation more than 1 year
Medium	-Medical treatment required, loss of work time, illness caused by exposure	-Medium-term environmental harm or pollution -Clean up and rehabilitation requires less than 1 year
Small	-No long-term health effects, exposure may require first aid treatment	-Short term environmental harm or pollution -Clean up and rehabilitation requires less than 1 month
Insignificant	-No short or long-term health effects	-Minor environmental harm and pollution -Clean up requires less than 1 day

Likelihood

Very High	-Almost certain to occur in identified situations with no controls in place -A trend in incidents, with near certainty it will occur again
High	-Likely to occur in identified situations without any controls -A trend in incidents but without certainty
Medium	-May occur in identified situations with no controls in place -Infrequent incidents
Low	-Could occur in identified situations with no controls in place -Small number of recorded incidents
Very Low	-Very unlikely to occur in identified situations with no controls in place -No evidence of incidents

Risk Matrix		Consequences				
		Insignificant	Small	Medium	Large	Severe
Likelihood	Very High					
	High					
	Medium					
	Low					
	Very Low					

Risk Rating
Critical
Significant
Moderate
Minor
Negligible

Table 4: Risk assessment of tyre particle sources towards the environment

Source	Potential Hazards	Potential Consequences	Risk rating		
			Magnitude	Likelihood	Risk Rating
Tyre and Road Wear Particles*	Ingestion of particles by organisms	-Toxic effects on survival, growth and feeding	Medium	Low	Minor
	Chemical leaching causing toxicity in organisms	-Zinc accumulation leading to mortality, developmental delays, immobility	Medium	Low	Minor
Artificial Turf Fields*	-Ingestion of particles by organisms	-Toxic effects on survival, growth and feeding	Medium	Very Low/Low (depending on RMMs)	Negligible Minor
	-Chemical leaching causing toxicity in organisms	-Zinc accumulation leading to mortality, developmental delays, immobility	Medium	Low	Minor
Playgrounds and Running Tracks**	-Chemical leaching causing toxicity in organisms	-Zinc accumulation leading to mortality, developmental delays, immobility	Medium	Low	Minor
Crumb Rubber-Modified Asphalt**	Chemical leaching causing toxicity in organisms	-Zinc accumulation leading to mortality, developmental delays, immobility	Medium	Low	Minor

*Assumption: TRWP and artificial turf are loose rubber particles, and the environmental transport of both the physical particles and the chemical leachate present was considered during the assessment.

**Assumption: Playgrounds and running tracks and crumb rubber-modified asphalt products are a polymer bound product, with no loose rubber particles, and only the environmental transport of chemical leachate was considered during the assessment.

Table 5: Risk assessment of different tyre particles towards the human health

Source	**Potential hazards**	**Potential Consequences**	**Risks rating**		
			Magnitude	**Likelihood**	**Risk Rating**
Tyre and Road Wear Particles	-Inhalation of particles	-Respiratory symptoms, inflammation, lung diseases	Medium	Low	Minor
Artificial Turf Fields (acute and lifelong exposure)	-Inhalation of toxic fumes	-Respiratory symptoms, inflammation, lung diseases	Insignificant	Low	Negligible
	-Inhalation/ ingestion of particles	-Respiratory symptoms, inflammation, cancer risks	Insignificant	Very Low	Negligible
Playgrounds and Running Tracks (acute and lifelong exposure)	-Ingestion of particles	-Inflammation, physical damage, cancer risks	Insignificant	Low	Negligible
	-Dermal contact with particles	-Inflammation, physical damage, cancer risks	Insignificant	Medium	Minor
Crumb Rubber-Modified Asphalt (acute and lifelong exposure)	-Inhalation of toxic fumes	Respiratory symptoms, inflammation, lung diseases, cancer risk	Medium	Medium (Low if PPE in place)	Moderate Minor if PPE in place
	-Inhalation of particles	-Respiratory symptoms, inflammation, lung diseases	Medium	Low	Minor

Tyre Particle Health, Environment and Safety Report

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