PFN

Plastic Footprint Network

Plastic Footprint Guidelines

Module on microplastic from tires

Version 1. November 2023

Convened by EA – Earth Action · www.plasticfootprint.earth

Introduction to the Plastic Footprint Network

Leading organizations have united within the Plastic Footprint Network to chart a new, more effective **path toward plastic pollution** mitigation.

The network's first priority was **unifying the framework** for measuring plastic leakage into a **single**, **science-based methodology** for organizations to accurately assess the environmental impact of their plastic use. Over **100 professionals** from **35 organizations** worked to establish the resulting **methodology**, which consists of **11 modules**, all optimized for usability and delivery of **actionable results**.

Objectives

Unifying the methodologies and perspectives of leading scientists, experts, and global practitioners, PFN enables organizations to understand the full impact, or footprint, from the use of plastic in their companies, products, and services.

1. Update and unify plastic footprinting methodologies
2. Ensure the methodology is used consistently by practitioners
3. Disseminate and scale the use of plastic footprinting
4. Explore link with plastic credit schemes, and how to prevent greenwashing claims

What are the objectives of this module?

The goal of this module is to establish a standardized approach for evaluating the impact of microplastics derived from tire particles within the broader context of a plastic footprint. To achieve this, we will address the following key questions:

1. What defines the significance of tire-derived microplastics within the overall plastic footprint?
2. How can an effective methodology be employed to quantify microplastics from tire particles accurately?
3. What specific data is crucial for precise calculations, and how can it be seamlessly integrated into the assessment process?

This module aims to offer a comprehensive and contemporary methodology, based on a meticulous analysis of existing approaches and real-world scenarios, while highlighting the necessity for users to gather primary data to ensure a thorough evaluation of the impact of tire-derived microplastics within their plastic footprint analyses.

At the end of this module, the users should know how to include tire dust particles in their plastic footprint assessment.

Where does this module fit in the PFN landscape?

Guidance

Strategic | Cross-cutting or specific issue

- Introduction to plastic footprinting
- Scopes and boundaries
  Alignment with environmental reporting standards
- new Data governance
- 2024 Target setting and mitigation

Technical

- Technical introduction to plastic leakage
- Glossary

Inventory: Macroplastics

- Packaging
- Textile
- new Fishing gears
- new Leakage from export
- new Release rates
- 2024 Automotive
- 2024 Construction

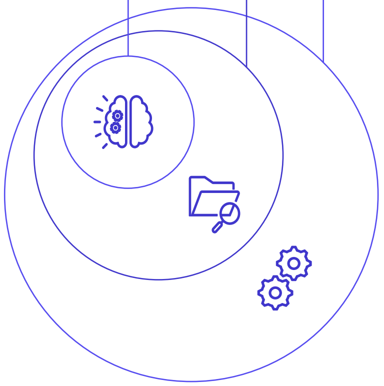
Inventory: Microplastics

- Current module Micro tire dust
- Micro textile fibres
- 2024 Micro pellets
- 2024 Micro paint
- 2024 Micro agriculture

Impact

- new Impact MariLCA

Structure of each technical module



1 Methodological choice

High level overview and different methodologies available at the moment, which one(s) to use and when.

Target audience: busy reader, scientific journalist

2 System map and calculation routes

- The different elements to take into account during a plastic footprint.
- How these elements interact.
- The calculation routes to follow.

Target audience: scientist, experts

3 Key data & background assumptions

The secondary data needed to perform the assessment and the main assumptions for the modeling.

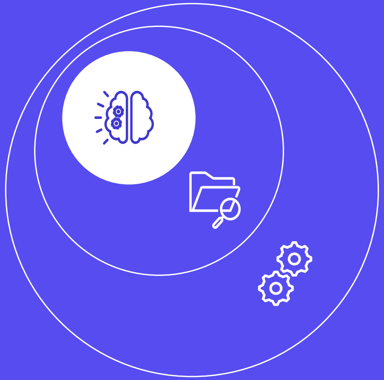
Target audience: scientist aiming at performing a plastic footprint.

Reading keys: Main take away Supporting information Key warning

Part. 1

Methodological choice

The different methodologies available at the moment, which one(s) to use and when.



Useful definitions

EmF = Emission factor

MP = Microplastic

PM = airborne particulate matter,
- PM_{10} = PM with aerodynamic diameter below 10 µm
- $PM_{2.5}$ = with aerodynamic diameter below 2.5 µm

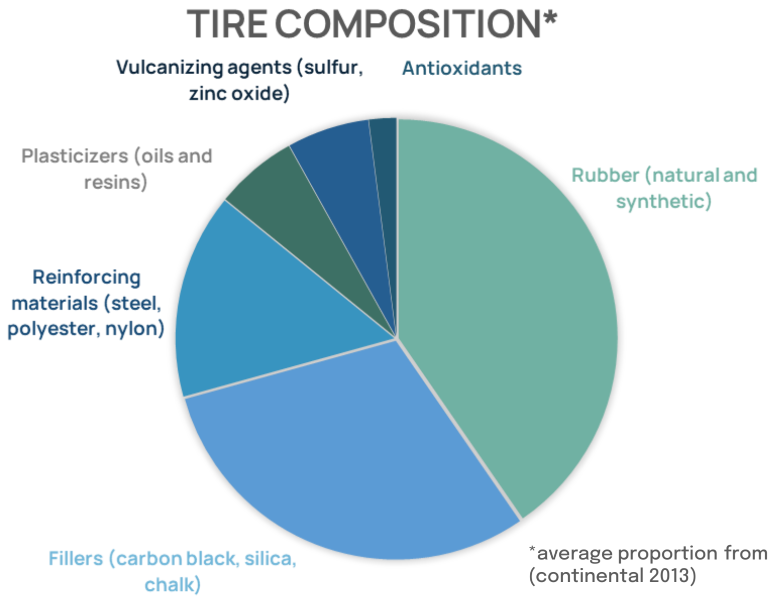
TRWP = Tire and Road Wear Particles, "a complex mixture of tire tread fragment, pavement released due to tire during use on the road surface and road surface elements such as minerals and road dust" (Jekel 2019) (Baensch-Baltruschat, Kocher et al. 2020)

WWTP = Wastewater Treatment Plant

An overview of micro tire particles

- Friction at the interface between the road pavement and the tyre tread provokes the abrasion of the latter.
- When rolling, temperature increases and the elastic and deformable rubber becomes sticky; thus minerals, road and other traffic-related particles may attach to it.
- With further wear and abrasion Tire and Road Wear Particles – a hetero-aggregate composed of particles from the tread and particles and dust from the road – are emitted to the environment.
- When abrasion of the tread mainly generates particles of coarse size (10 to 500 µm), volatilization of fine particulates (mainly PM_{10} and $PM_{2.5}$) is also possible on local hotspots on the tire.

The proportion of natural and synthetic rubber varies with the type of vehicle. For example, in truck tires 34% of the rubber is natural and 11% synthetic while in passenger cars, 19% is natural rubber and 24% is synthetic rubber (U.S. Tire Manufacturers Association 2020).



Source: Jekel 2019 and Baensch-Baltruschat, Kocher et al. 2020

What are TRWPs

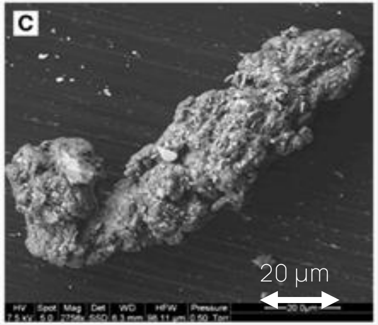
Properties of TRWPs:

- Cigar-shaped particles
- 90% of coarse particles (10 – 500 µm); 10% of particulate matter ($PM_{2.5}$ and PM_{10})
- Ratio of 50% tread wear – 50% road wear
- Density ~ 1.8 g/cm³
- Composed of synthetic and natural rubber residues but also chemical additives, heavy metals

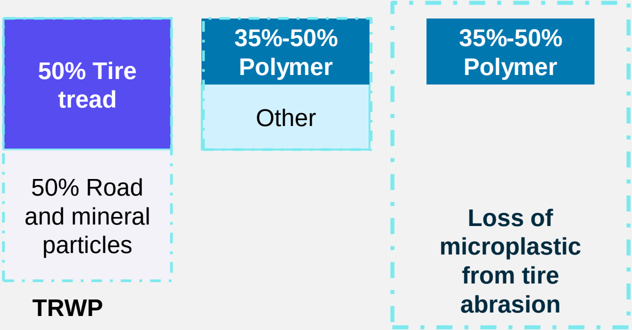
Are TRWPs microplastics?

- TRWP "*consists of tyre tread enriched with mineral encrustations from the roadway surface*." (ISO/TS, 2018).
- Microparticles with a polymer (rubber) matrix → **microplastics**

However, when assessing the microplastic leakage from tires, the focus is on the polymer share of the TRWPs (which represents 17.5 to 25% in mass of the TRWP) according to the assumed mass distribution.



Elongated "cigar-shaped" TRWP;
source: Kreider et al., 2010



Sources: Grigoratos and Martini 2014, Pohrt, 2019 and Hartmann, Hüffer et al. 2019

Source: Microplastic share in TRWPs; adapted from Peano, Kounina et al. 2020

How do microplastics from tires pollute the environment

Leakage of microparticles during rolling

- From the road where they are emitted, tire microparticles may disperse and distribute into environmental compartments through different pathways including road runoffs, precipitation and wind circulation.
- Although partly treated in the wastewater treatment plants within urban areas, a large proportion of particles ultimately end up in natural media, namely the soil near roads, other terrestrial environments, freshwater (and eventually groundwater), sediments and the ocean.
- Hence, TRWPs as microplastics are ubiquitous in the environment and potentially induce adverse effects on natural organisms. For that reason, they have to be properly accounted for and we have to consider their contribution to the total environmental pollution caused by plastic materials.

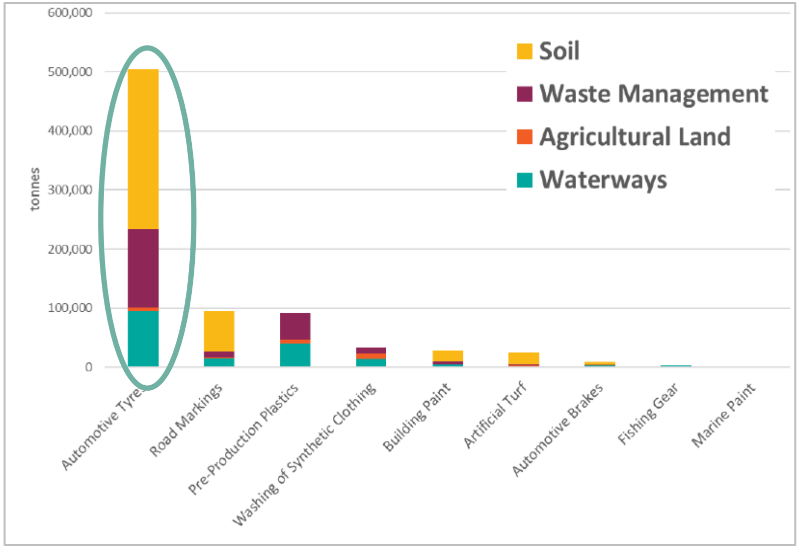
How big is the microplastic leakage from tires?

Among all the sources of microplastics in Europe, automotive tyres are the biggest contributor with more than 500 000 tonnes generated per year.

➢ Tire abrasion is a major source of MPs emitted to the environment

The assessment of the microplastic leakage from tire particles is relevant in the context of the environmental impact assessment of road transport, especially the:

- Transport of passengers
- Transport of goods



Source: Annual generation and fate of microplastics from automotive tires compared to other microplastic sources from wear and tear in EU28; from Eunomia report (2017)

Sources:: Hann, Sherrington et al. 2018 and Kole, Lohr et al. 2017

Useful definitions

Activity/Mass

We identify the quantity of plastic of interest through an activity or a mass.

- For microplastics from tires, the tire abrasion rate is the relevant indicator. It refers to the mass of tread lost (by abrasion or volatilization) during the tire use phase.
- The emission factor (EmF) is defined after this abrasion rate and is given in mg/km.
- The loss rate from tires is defined as the mass of the tire lost which is microplastic. It is therefore calculated by multiplying the EmF by the share of polymer in the tire.

Release

Fraction of the plastic transferred from the loss to the environmental compartment. In this case, fraction of lost tire microparticles that are not captured by a WWTP and end into the oceans, or tire microparticles that are captured but ultimately released to soil.

Loss

Fraction of the plastic leaving the well managed system. In this case fraction of tire tread lost during rolling (use phase).

Plastic leakage to the environment

Plastic leakage is defined as the plastic potentially leaving the technosphere (human environment) and accumulating in the natural environment.

The term "emission factor" is widely used to describe a vehicle's emission performance which includes the exhaust and non-exhaust emissions. Still, here we only refer to microparticle emissions due to tire abrasion.

Inspiration: Methodology from Plastic Leak Project

Inventory of emissions for transport of goods and passengers:

- Based on tire wear abrasion rate
- For several vehicle classes: Passenger cars and light trucks, Medium/heavy trucks, Bus/coach, Motorcycle, Aircraft
- Two calculation routes are proposed: for “tire-related studies” and for “non-tire-related studies”

The PLP model is based on four phases:

- Loss – first release (to initial environmental compartments) – redistribution – final release (to final release compartments)
- First release and redistribution rates are based on (Unice, Weeber et al. 2019) which represent the European context.

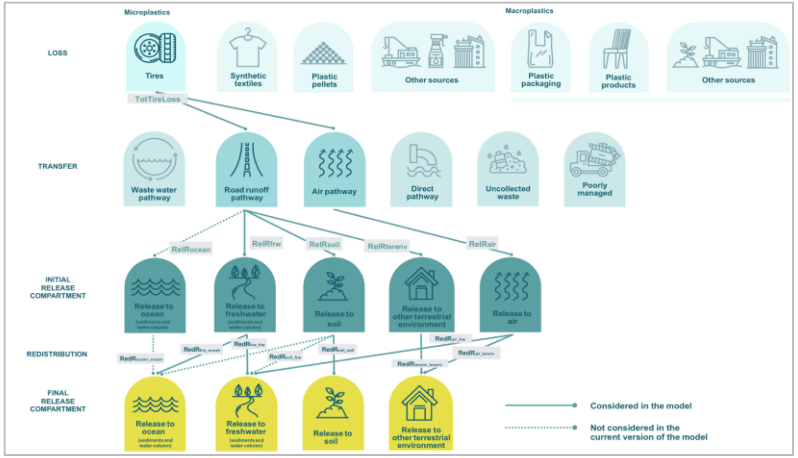
⊗ Redistribution: Because our compartments are already ocean and freshwater altogether, and soil and other terrestrial compartments altogether, we don’t model the redistribution and we give release rates directly to the final compartments.

Improvements:

✓ We update the data collection for tire abrasion rate by reviewing new data sources.

✓ We propose specific EmFs according to the type of road (urban, rural or highway), to take into account parameters that influence the tire abrasion rate (combination of the nature of the pavement, road profile and driving speed).

Source: Peano, Kounina et al. 2020



Source: PLP - Section 8 - Inventory of microplastic leakage from tire abrasion - page 113, 114

Simplified methodological approach

Simplified methodology to apply in case no information is available on the number of passenger and/or load of the vehicles

Primary data needed:

- Number of vehicles per type N_{type}
- Distance travelled per vehicle and type $D_{vehicle,type}$

Secondary data needed:

- Microplastic loss rate for each vehicle type $LR_{vehicle,type}$
- Release rates by compartment $RR_{compartment}$

Two calculation routes are proposed according to the desired level of detail: the first accounts for the traffic activity in terms of the number of vehicles and distances travelled while the second takes also into account the occupancy and load of vehicles for the transport of passengers or merchandise.

The category or type of vehicle can be a passenger car, light-duty vehicle, etc.

The loss rate represents the mass lost by the tire that is microplastic.

It is important to look both at ocean and land for a full comprehension of the leakage.

Steps:

1. Collect primary data: the number of vehicles per type, and the distance travelled per vehicle and type.
2. Compute activity: Calculate the activity rate (AR) for each vehicle type
3. Compute mass: Calculate the mass of microplastic lost by tires for each vehicle type
4. Compute release: Multiply the lost mass with the release rates for the compartments of interest, which can be found in the excel file.

STEP 2: $AR_{type}[vch * km] = N_{type}[\#vhc] * D_{vhc,type}[km]$

STEP 3: $TireLoss\ [kg\ of\ microplastics] = AR_{type}[vhc * km] * LR_{type}\left[\frac{kg}{vhc * km}\right]$

STEP 4: $Leak_{compartment} = \sum_{country} \sum_{vehicle\ type} \underbrace{(TireLoss_{type}^{passengers} + TireLoss_{type}^{goods})(kg)}_{\text{Mass loss}} * \underbrace{RR_{compartment}(\%)}_{\text{Release}}$

With compartment = ocean, land

Detailed methodological approach

Detailed methodology to apply in case information is available on the number of passenger and/or load of the vehicles

Primary data needed:

- Number of vehicles per type N_{type}
- Distance travelled per vehicle and type $D_{vehicle,type}$
- Actual number of passengers, $Nb_{pass,type}$, or transported load, $M_{good,type}$, per vehicle type

Secondary data needed:

- Microplastic loss rate for each vehicle type $LR_{vehicle,type}$
- Average number of passengers, $Pass_{av,type}$, or transported load, $Load_{av,type}$, per vehicle type
- Release rates by compartment $RR_{compartment}$

Two calculation routes are proposed according to the desired level of detail: the first accounts for the traffic activity in terms of the number of vehicles and distances travelled while the second takes also into account the occupancy and load of vehicles for the transport of passengers or merchandise.

The category or type of vehicle can be a passenger car, light-duty vehicle, etc

The loss rate represents the mass lost by the tire that is microplastic.

It is important to look both at ocean and land for a full comprehension of the leakage.

Steps:

1. Collect primary data: the number of vehicles per type, the distance travelled per vehicle and type and the number of passengers or loads of merchandise transported
2. Compute activity: Calculate the activity rate (AR) for each vehicle type
3. Calculate the occupancy or load parameter according to the type of transport and vehicle
4. Compute mass: Calculate the mass of microplastic lost by tires for each vehicle type

STEP 2: $AR_{type}[vch * km] = N_{type}[\#vhc] * D_{vhc,type}[km]$

STEP 3: $Occupancy_{type} = \frac{Nb_{pass,type}[\#pers]}{Pass_{av,type}[\#pers]}$ or $Load_{type} = \frac{M_{good,type}[kg]}{Load_{av,type}[kg]}$

STEP 4: $TireLoss_{type}^{pass}[kg\ of\ microplastics] = AR_{type}[vhc * km] * LR_{type}\left[\frac{kg}{vhc*km}\right] * Occupancy_{type}$

Or $TireLoss_{type}^{goods}[kg\ of\ microplastics] = AR_{type}[vhc * km] * LR_{type}\left[\frac{kg}{vhc*km}\right] * Load_{type}$

STEP 5: $Leak_{compartment} = \underbrace{\sum_{country}(TireLoss_{type}^{passengers} + TireLoss_{type}^{goods})(kg)}_{\text{Mass loss}} * \underbrace{RR_{compartment}(\%)}_{\text{Release}}$

With compartment = ocean, land

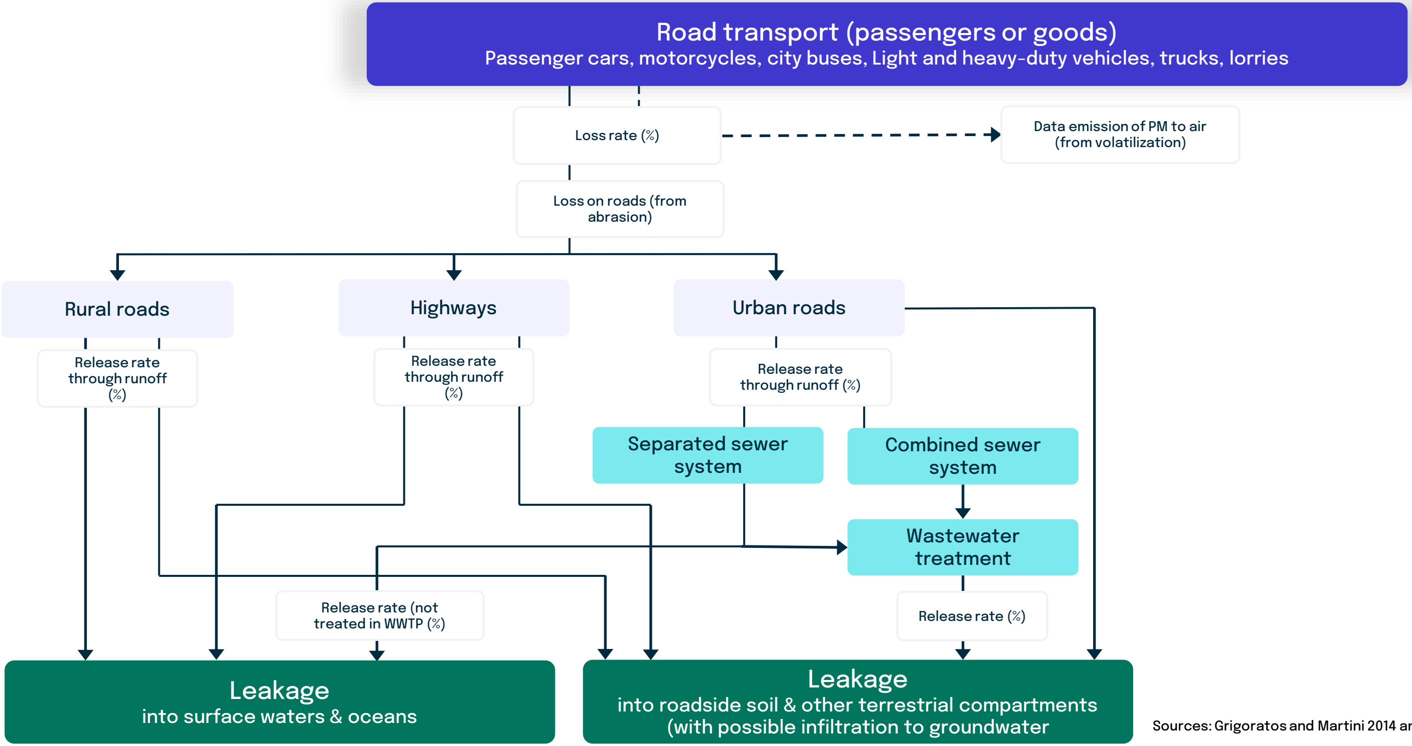
Part. 2

System map & calculation routes

The different elements to take into account during a plastic footprint. How these elements interact? Which calculation routes to follow?

System map

The path of tire microparticles, from emission to final release:



Sources: Grigoratos and Martini 2014 and Peano, Kounina et al. 2020

Calculation routes for tire microplastics – simplified approach

$$Leak_{compartment} = \sum_{country} \sum_{vehicle\ type} \underbrace{\left(N_{type}[\#vhc] * D_{vhc,type}[km] * LR_{type}\left[\frac{kg}{vhc * km}\right]\right)}_{\text{Mass loss}} * \underbrace{RR_{compartment}(\%)}_{\text{Release}}$$

With compartment = ocean, land

MICRO

Symbol	Description	Unit	Value	Reference	Additional comments
N_{type}	Number of vehicle of a given category	# vhc	From primary data	n/a	
$D_{vhc,type}$	Distance travelled on the road by a vehicle of a given category	km / vhc	From primary data	n/a	
LR_{type}	Loss of microplastic from a tire of the vehicle type	mg / (vhc*km)	From secondary data	n/a	The loss rates were calculated for each vehicle category from emission factors and share of polymer in tires data from the literature
$RR_{compartment}$	Release rate to environmental compartments	%	From secondary data	Values from the PLP Guidelines results	

Calculation routes for tire microplastics – detailed approach

$$Leak_{compartment} = \sum_{country} \sum_{vehicle\ type} \Bigg(\underbrace{N_{type}[\#vhc] * D_{vhc,type}[km] * Occupancy/Load_{type}}_{\text{Mass loss}} * \underbrace{LR_{type}\left[\frac{kg}{vhc * km}\right]\Bigg) * RR_{compartment}}_{\text{Release}}(\%)$$

With compartment = ocean, land

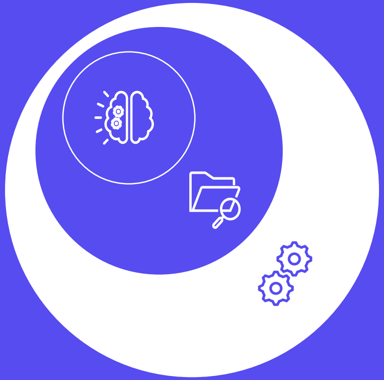
MICRO

Symbol	Description	Unit	Value	Reference	Additional comments
N_{type}	Number of vehicle of a given category	# vhc	From primary data	n/a	
$D_{vhc,type}$	Distance travelled on the road by a vehicle of a given category	km / vhc	From primary data	n/a	
$Occupancy_{type}$	Occupancy of the vehicle according to the number of passengers	n/a	To be calculated	n/a	
$Load_{type}$	Load of the vehicle according to the transportation of goods	n/a	To be calculated	n/a	
LR_{type}	Loss of microplastic from a tire of the vehicle type	mg / (vhc*km)	From secondary data	n/a	The loss rates were calculated for each vehicle category from emission factors and share of polymer in tires data from the literature
$RR_{compartment}$	Release rate to environmental compartments	%	From secondary data	Values from the PLP Guidelines results	
$Nb_{pass,type}$	Number of passenger transported over the distance $D_{vhc,type}$	# pers	From primary data (good to have)	n/a	
$Pass_{av,type}$	Average number of passengers for the vehicle type	Pers/vhc	From secondary data	Values from the PLP Guidelines (Table 8-7)	From Ecoinvent or expert judgement
$M_{good,type}$	Mass of product transported over the distance $D_{vhc,type}$	Kg	From primary data (good to have)	n/a	
$Load_{av,type}$	Average transported load by the vehicle category	Kg	From secondary data	Values from the PLP Guidelines	Medium and heavy trucks: 12'000; Light trucks: 3'500 (from expert judgement)

Part. 3

Data

The secondary data needed to perform the assessment.



Release rates – PLP and aggregation

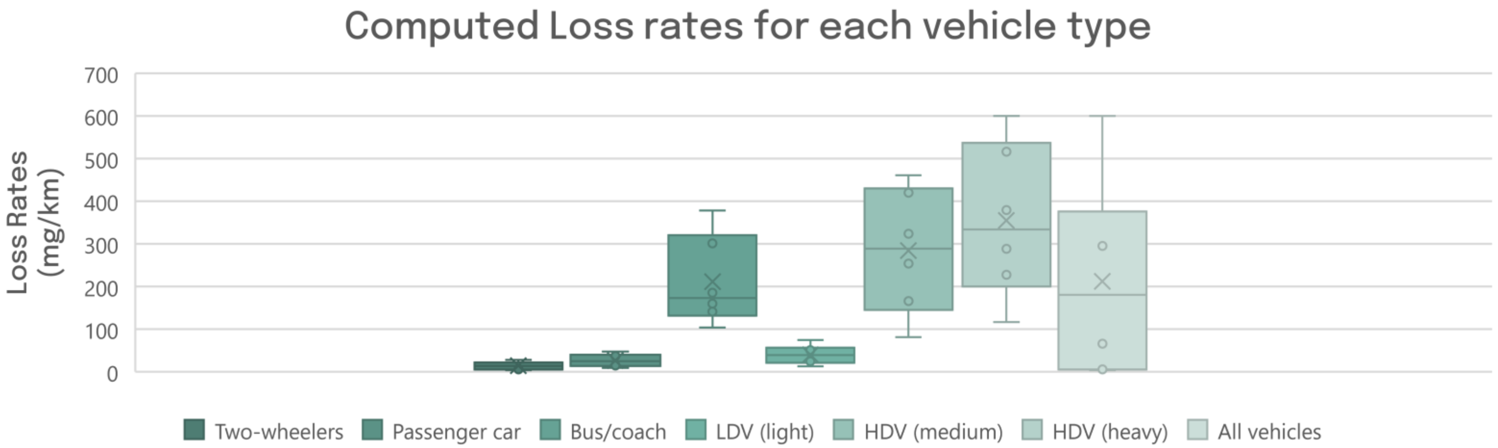
Final release rates from PLP (2020) based on the results provided by Unice et al. (2019): still used in the current PFN methodology

Abreviation	Description	Generic value [% of TRWP emitted], or [% of microplastic from tire abrasion]	Detailed description
FinalRelRocean	Final release rate of TRWP in ocean (sediments and water column) compartment	2%	TRWP emitted in freshwater initial compartment and not deposited into sediments
FinalRelRair	Final release rate of TRWP in air compartment	0%	TRWP redistributed to freshwater and other terrestrial environment compartments
FinalRelRfrw	Final release rate of TRWP in freshwater (sediments and water column) compartment	15%	TRWP deposited in freshwater sediments, coming from: • TRWP in runoff water going though separated system and directly released in freshwater • TRWP in runoff water going through CSO of combined system • TRWP in runoff water going through combined system but not retentate in wastewater treatment plant
FinalRelRsoil	Final release rate of TRWP in soil compartment	66%	TRWP captured in soil, coming from: • TRWP deposited near road deposition • TRWP in runoff water going through combined system, retentate in wastewater treatment plant and which sludge is spread on fields • TRWP retentate in ditches
FinalRelRterenv	Final release rate of TRWP in other terrestrial compartments	4%	• Mismanaged waste from TRWP retentate in WWTP sludge not spread ; Mismanaged waste from TRWP retentate in stormwater management sludge • TRWP initially released into air redistributed between freshwater and other terrestrial compartments
Well managed waste	Part of TRWP that is removed from the environment	14%	• TRWP retentate in WWTP sludge not spread that is landfilled or incinerated • TRWP retentate in stormwater management sludge that is landfilled or incinerated

Aggregated release rates used in the current PFN methodology

Final release to land	Sum of release to soil and to terrestrial environment	**69%**	These final release are built using the share of rural/urban/highway in the French context. For a more precise assessment these release rates need to be recalculated based on the geography of interest.
Final release to ocean	Sum of release to freshwater and to ocean	**17%**	

Loss rates – synthesis of the literature analysis



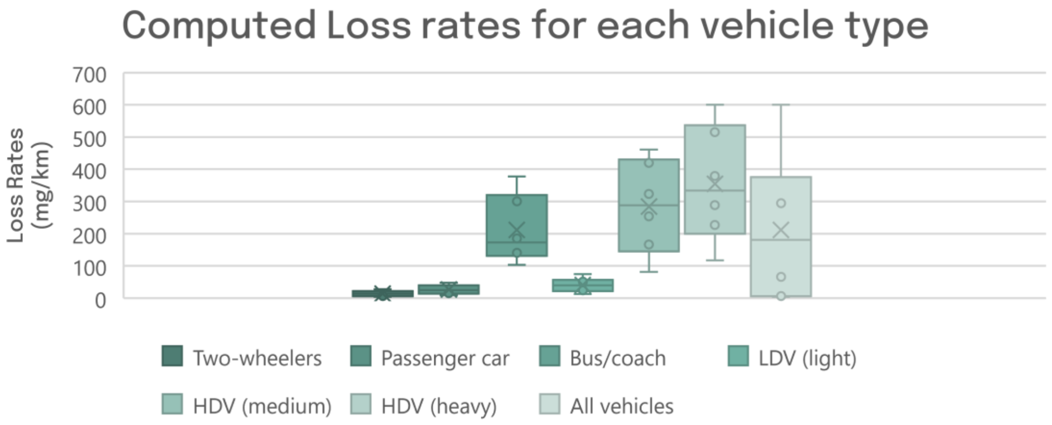
The loss rates were obtained by multiplying the emission factors of each vehicle type by their respective share of polymer in tires.
For each vehicle category lower, central and upper values of LR are given to the user who can choose the most adapted one according to his own context.

The loss rates are communicated in terms of mg/(vhc*km) for ease of reading (regarding the orders of magnitude), however, we must apply a 10-3 when calculating the Tire microplastic loss and the Leak to compartments in kg.

	LR (example for passenger cars	Unit
Low value	22	mg/(vhc*km)
Central value	28	mg/(vhc*km)
High value	37	mg/(vhc*km)

Loss rates for tires – detailed results

LR [mg/(vhc*km)]	Transport of passengers			Transport of goods			
	Two-wheelers	Passenger car	Bus/coach	LDV (light)	HDV (medium)	HDV (heavy)	All vehicles
MIN	4	9	104	24	82	117	4
Q1	6	22	160	38	254	288	6
MEDIAN	**13**	**28**	**186**	**40**	**323**	**380**	**66**
Q3	20	37	301	51	420	516	301
MAX	28,1	47,5	378,0	74	461	600	600
AVERAGE	14	15	141	13	166	228	295
Sample size	**14**	**29**	**227**	**45**	**311**	**383**	**163**



Emission factors for tires can vary depending on parameters like road type, driving speed, use of winter tires, and specific tire characteristics. However, there is no clear and direct correlation between these parameters and the EmFs, and subsequently, the loss rates.

To account for this variability, we offer average values of LR. These averages were calculated based on the emission factor values obtained from various sources in the literature.

Limitations to the current methodology (1/2)

- The proposed quantification method exclusively considers the polymer component from the tire fraction of tire and road wear particles (TRWPs). It's important to note that if we were to include the mineral and road-based components of these particles, the total mass released into the environment would significantly increase. For instance, assuming TRWPs comprise an equal mix of 50% minerals from the road and 50% tire tread, the total particle mass would effectively double. As a result, the fate of the particles in the environment and the final release to land and ocean would be different as well.

- Consideration of **parameters that influence the loss rate**:
    - Several key factors affect tire wear and, consequently, the release of microplastic particles. These factors relate to tire characteristics (such as design, pressure, and geometry), vehicle characteristics (including weight, load, and driving behavior), road surface conditions (like material and roughness), and environmental factors (e.g., weather and road topology).
    - However, the relationships (and possible correlations) between those parameters and the wear rate are not established yet, except for vehicle type, where noticeable differences exist and which we can clearly distinguish.
    - The lack of experimental data and correlations is mainly due to the challenge of disentangling the effects of various parameters and environmental conditions. As a result, these parameters are currently not considered in the emission inventory.

- Aircraft are not considered in the current methodology as the focus is mostly on road transport which is considered to be the major contributor to microplastic pollution from tire abrasion.

- Emissions to **air compartment**: Within the system map, a direct emission flow to the air signifies the production of tire and road wear particles falling within the size range of airborne particulates, specifically below 10μm. These airborne particles make up roughly 10% of the total particles generated. These particles are anticipated to be transported through the atmosphere and eventually settle in the road, land, or water compartments, where they follow the same pathways as larger, coarse particles.
    - It's worth noting that these airborne particles, while part of tire and road wear, do not contain a polymeric component and consist of organic materials and heavy metals. As a result, they are not considered into the calculation of microplastic leakage.

Limitations to the current methodology (2/2)

- Scope and **application of the methodology**: We present a methodology for calculating microplastic emissions from vehicle tires that is designed to be versatile and applicable to various geographic settings. To demonstrate the calculation process and ensure its comprehensiveness, we have included data from a study conducted in the Seine watershed by Unice et al. in 2019. It's important to note that while the provided data originates from a French context, which includes specific information about the distribution of road types and water treatment systems, the results in terms of release rates can serve as valuable proxies for a European context. This assumption is based on the expectation that the proportion of road types and the nature of water treatment systems in Europe will exhibit similarities to those in the French context. Nevertheless, it's advisable to exercise caution when applying these values to other contexts.

- As a result:
    - The category of the road (urban, rural, or highway) is important in considering the systems used to treat water runoff and the effectiveness of these treatments, which, in turn, impacts the release rates of tire microplastic particles.
    - In the current methodology, we did not gather or review data regarding the distribution of road types in various contexts and regions. Instead, we relied on data from the PLP guidelines, which itself is based on a single instance of release into freshwater.
    - It is important to note that the percentages representing the distribution of these road types are general averages and can be adjusted to match the specific geographical conditions of the area.

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Our commitment to continuous improvement

The Plastic Footprint Network's successful collaboration is built on pillars of:

- Open
- Non-competitive and productive dialog
- Leveraging science and supporting ongoing research
- Broadly empowering global stakeholders (product manufactuers, brand owners, treaty negotiators, regulators, consultants, NGOs, etc) to effectively do their part to address the plastic pollution crisis.

Given corresponding commitments to transparency and continuous improvement, we welcome and encourage your feedback and input on this document so that the methodology can continue to be enhanced and refined.

Thank you for supporting the work of the Plastic Footprint Network.

Contact us at: contact@plasticfootprint.earth

PFN

Our mission is to continuously advance Plastic Footprint Methodology, ensuring it remains at the forefront of sustainable practices and promoting its widespread adoption. By empowering companies to rigorously assess, enhance, and transparently report their plastic footprints, we aim to make significant strides in mitigating the plastic pollution crisis.

Plastic Footprint Network

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With the participation from:

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