



Tire and road wear microplastics

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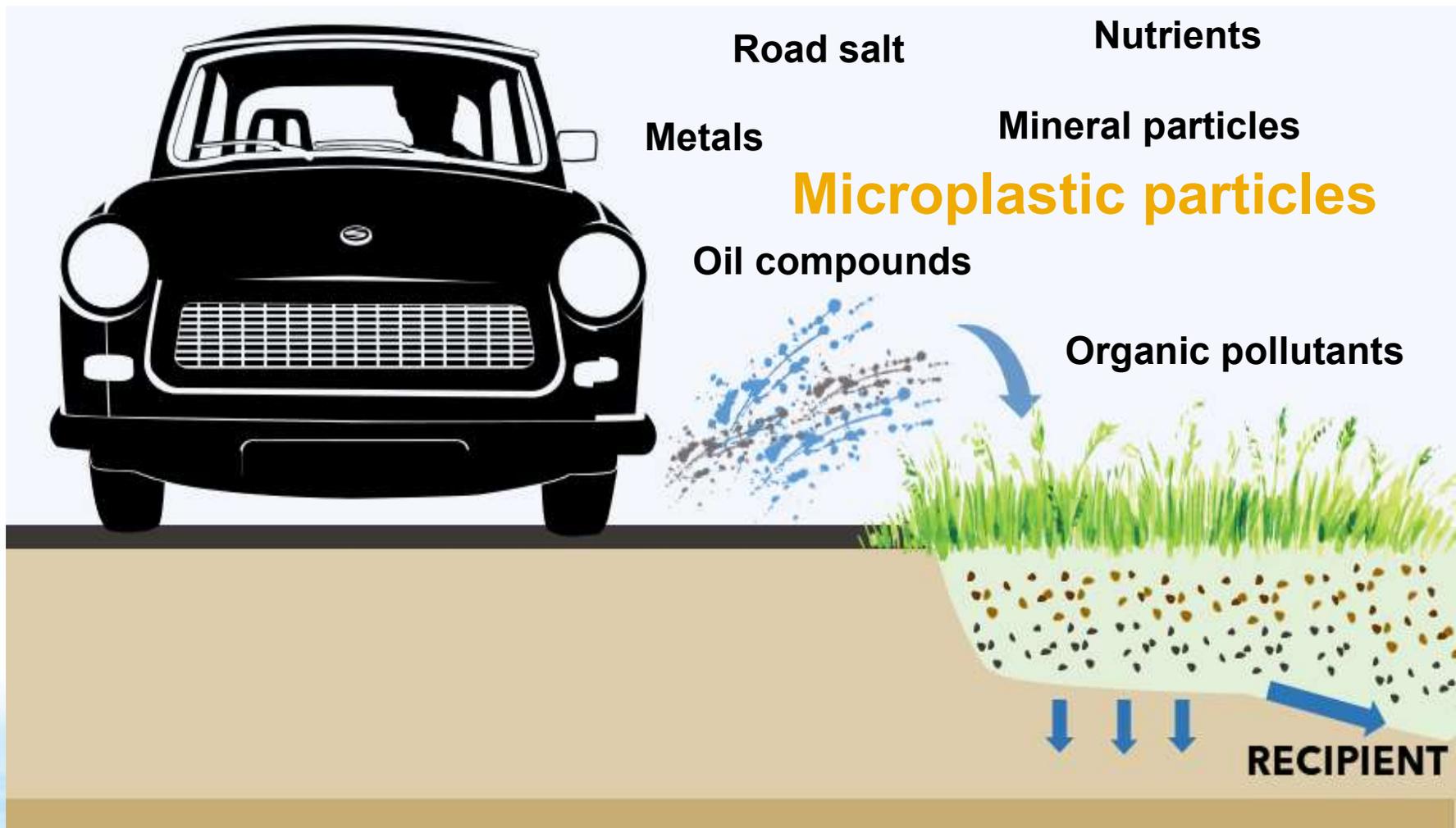
Norwegian institute for water research (NIVA)

Overview of presentation

- **Road pollution**
- **Microplastics from roads**
- **Challenges with quantification**
- **Environmental concentrations**
- **Future needs**

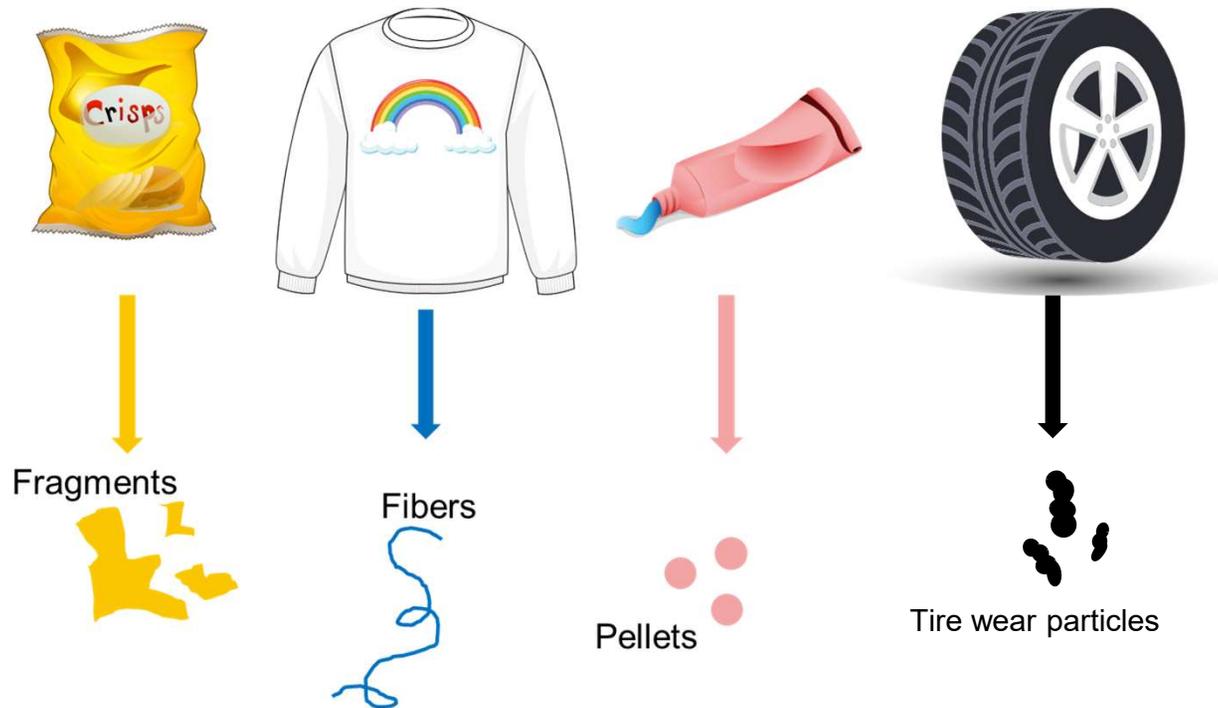


Traffic pollutants



What are microplastics?

Microplastics are defined* as particles made of (minimum 1% mass of) synthetic or semi-synthetic polymers with at least three dimensions greater than $1\mu\text{m}$ and less than $5000\mu\text{m}$.



What are microplastics? Environment

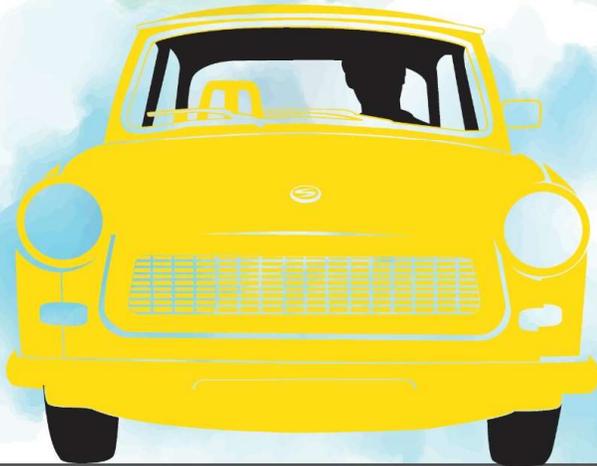
Microplastics are defined* as particles made of (minimum 1% mass of) synthetic or semi-synthetic polymers with at least three dimensions greater than 1µm and less than 5000µm.

- Low degradability in the environment (assumed persistent)
- Potentially breaks down into smaller sizes by wear, weathering
- Can potentially be taken up by organisms
- Can contain additives and chemicals that potentially leach out

Road-related microplastic particles

40-60% rubber
Styrene butadiene rubber (SBR),
Butadiene rubber (BR),
Natural rubber (NR)

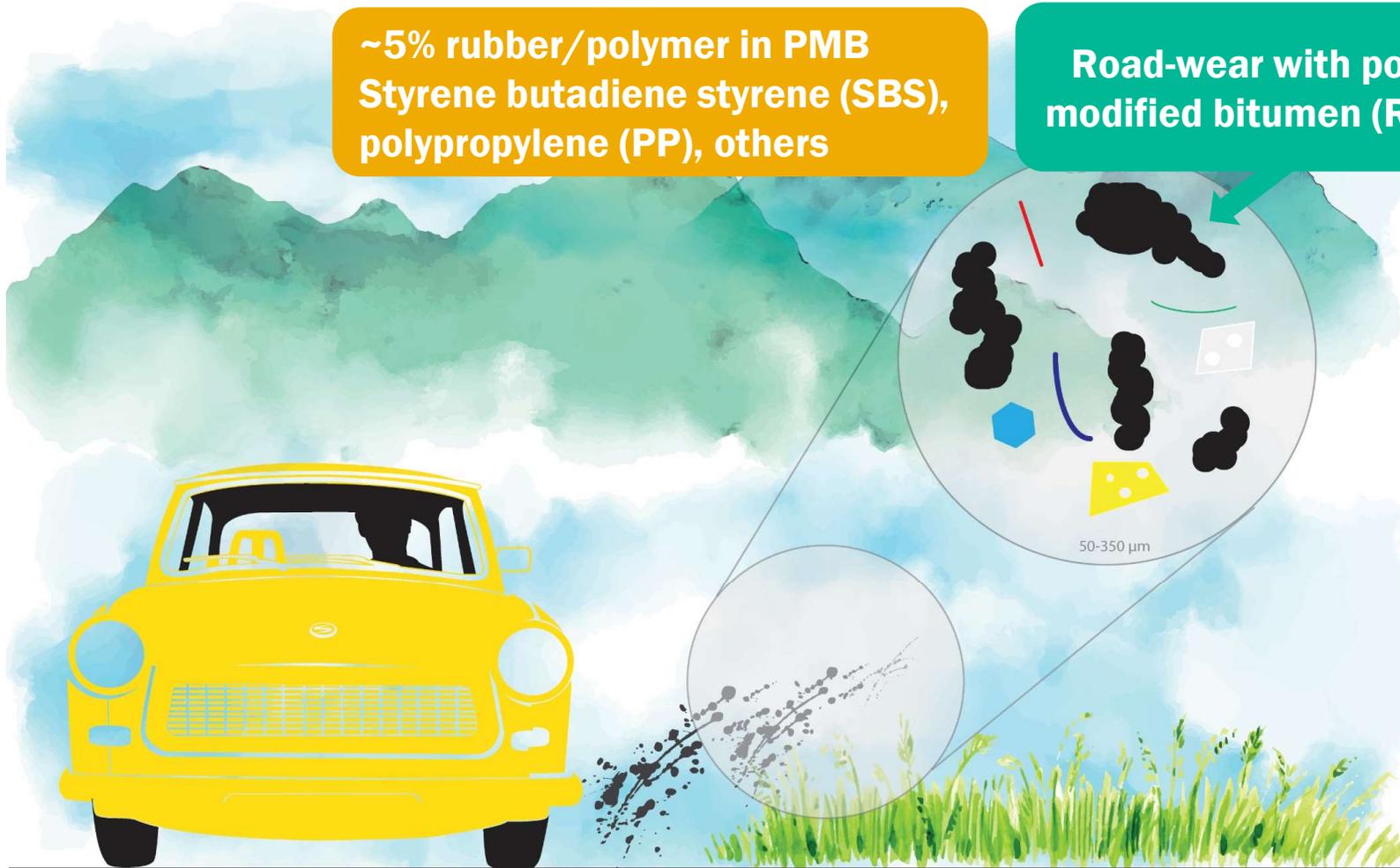
Tire-wear particles
(TWP)



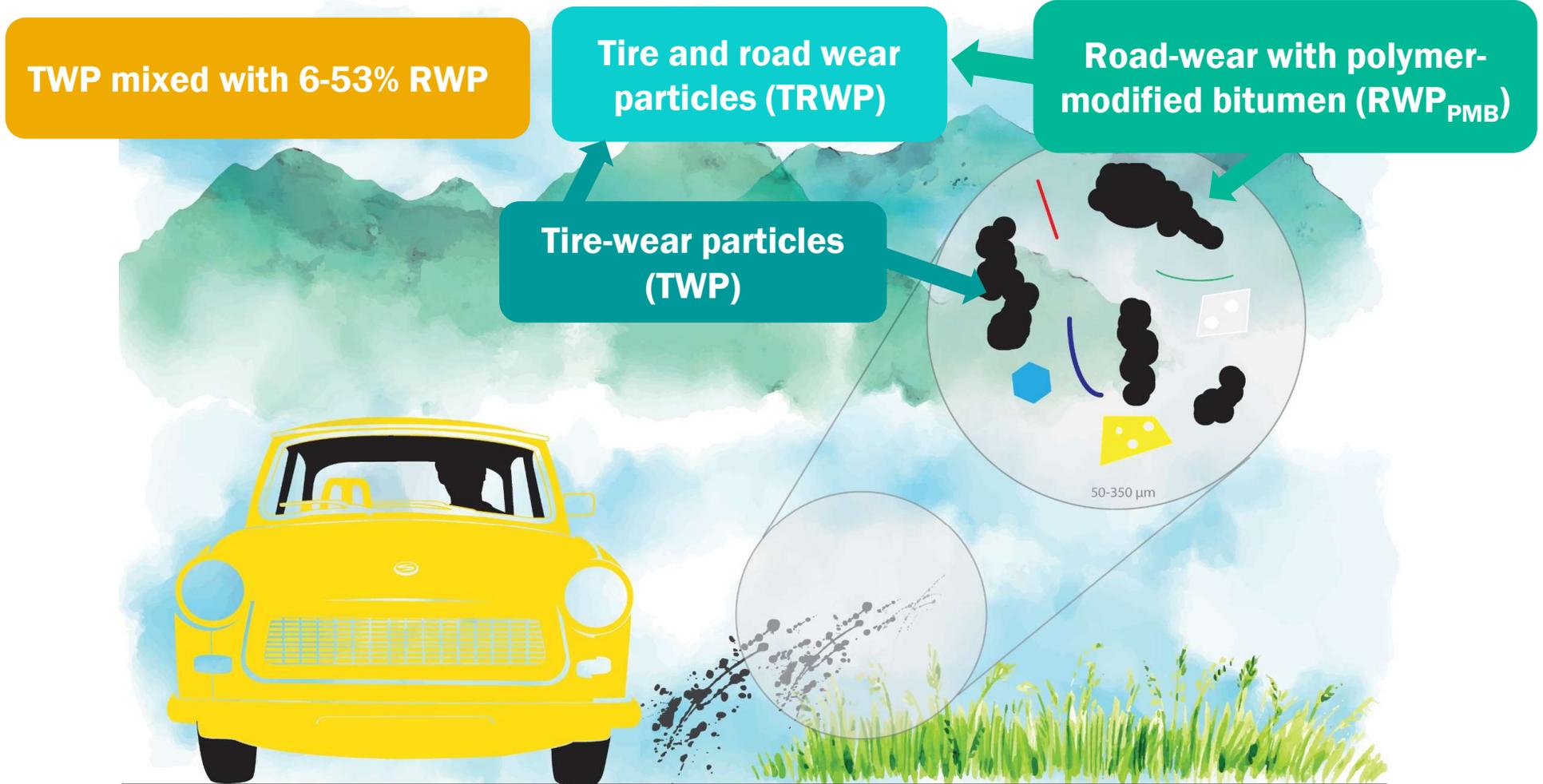
Road-related microplastic particles

~5% rubber/polymer in PMB
Styrene butadiene styrene (SBS),
polypropylene (PP), others

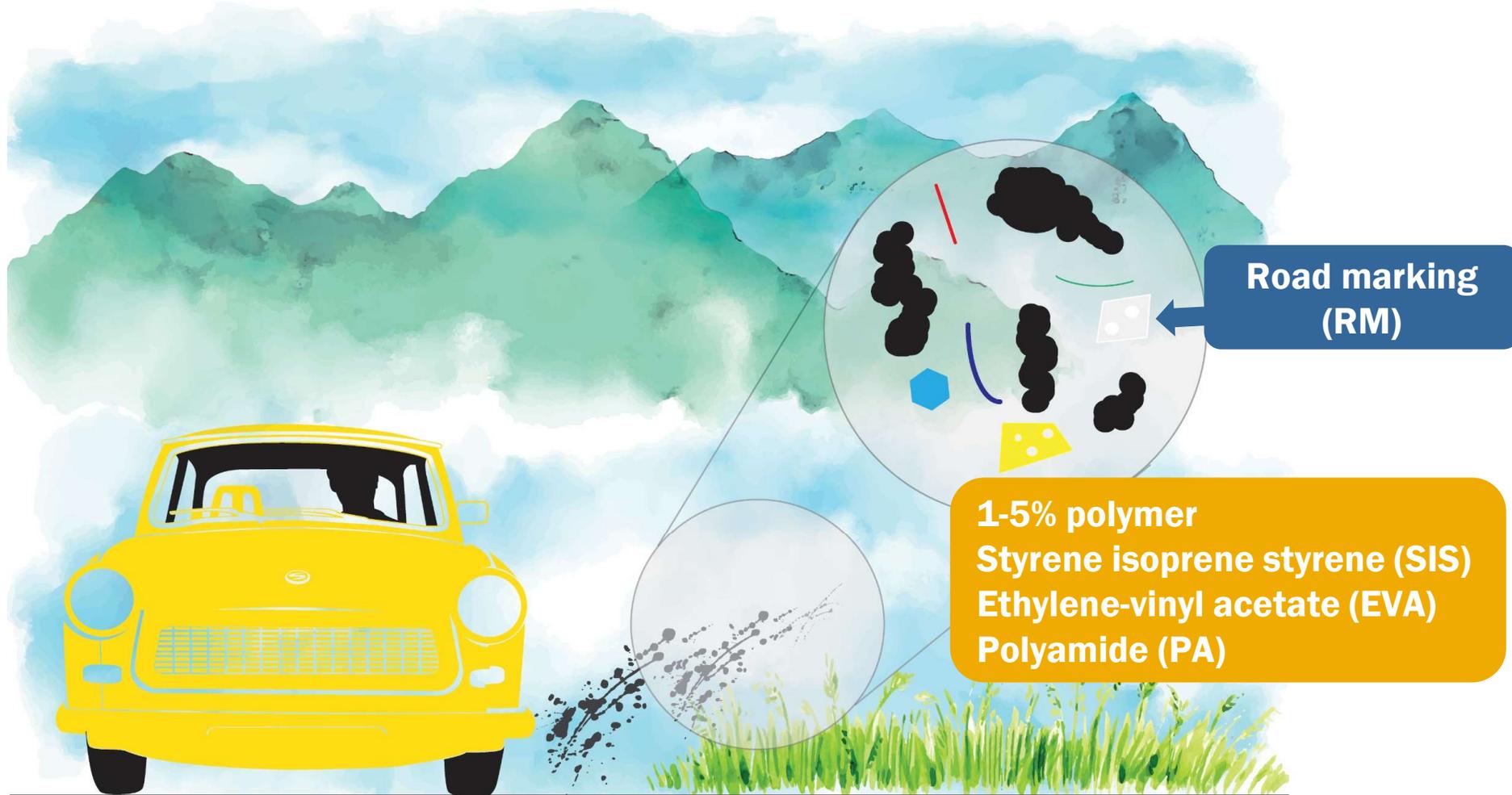
Road-wear with polymer-
modified bitumen (RWP_{PMB})



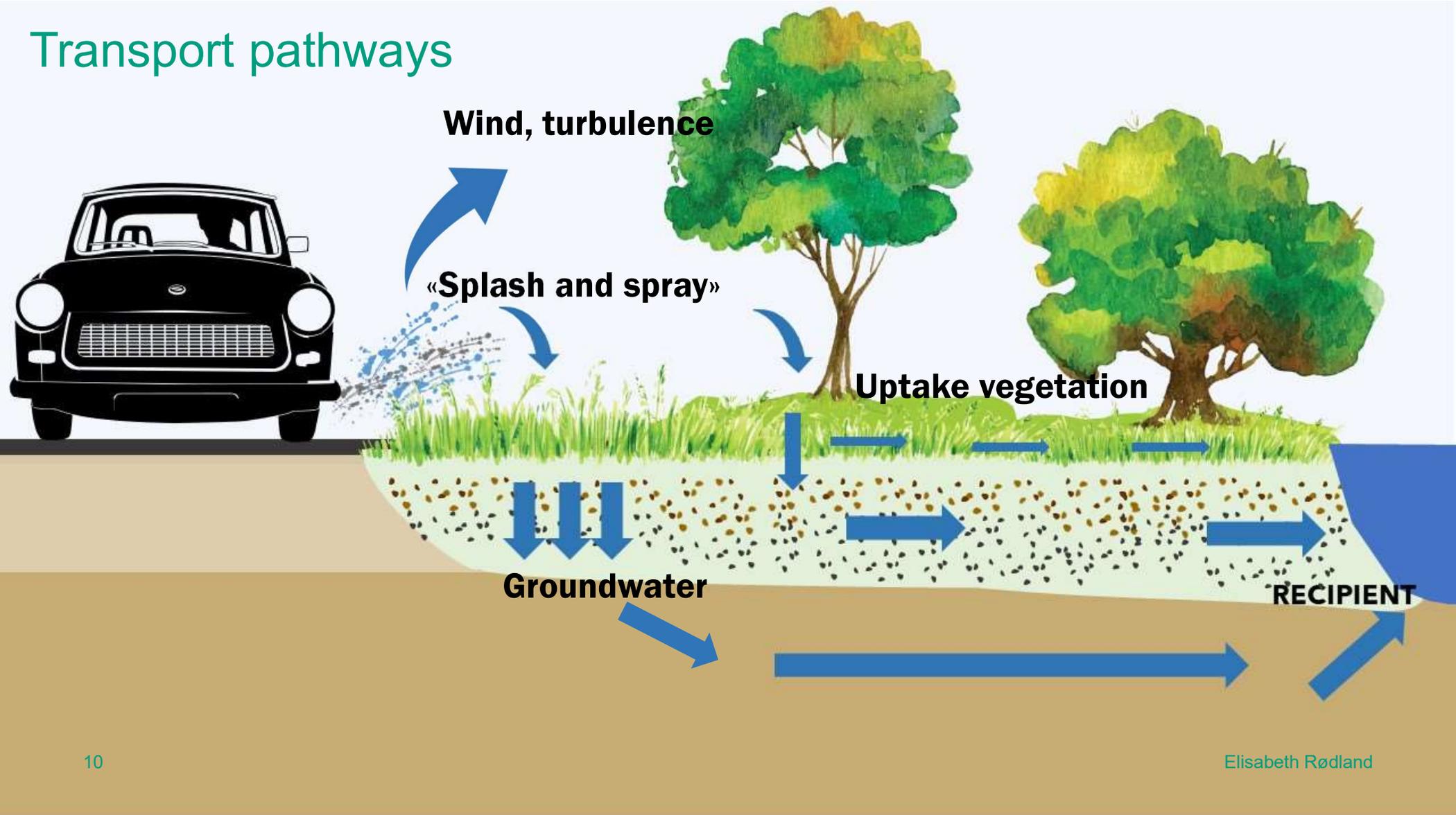
Road-related microplastic particles



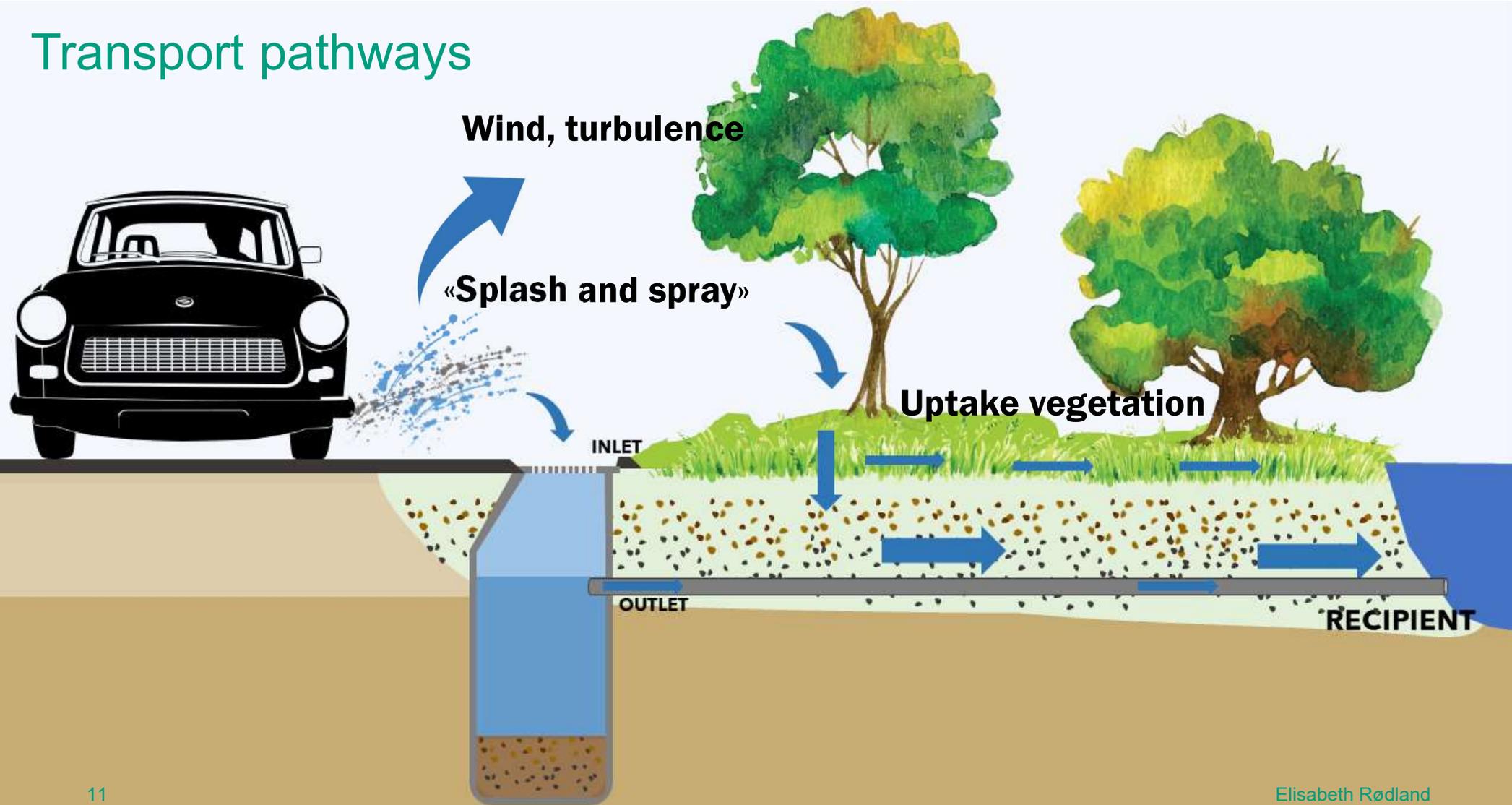
Road-related microplastic particles



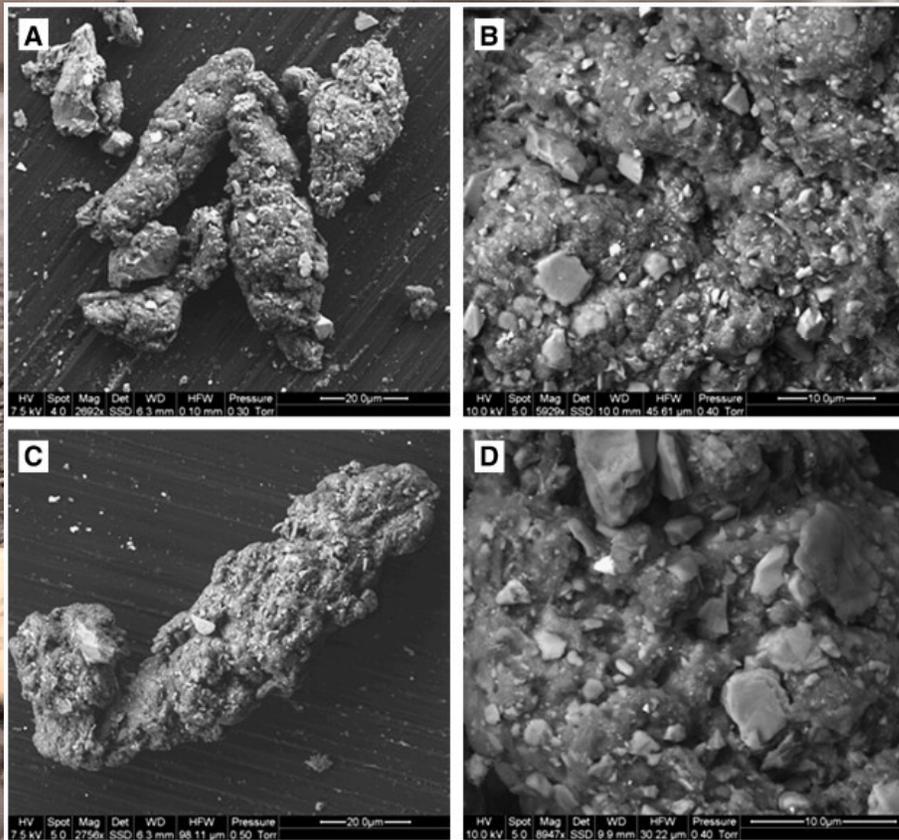
Transport pathways



Transport pathways

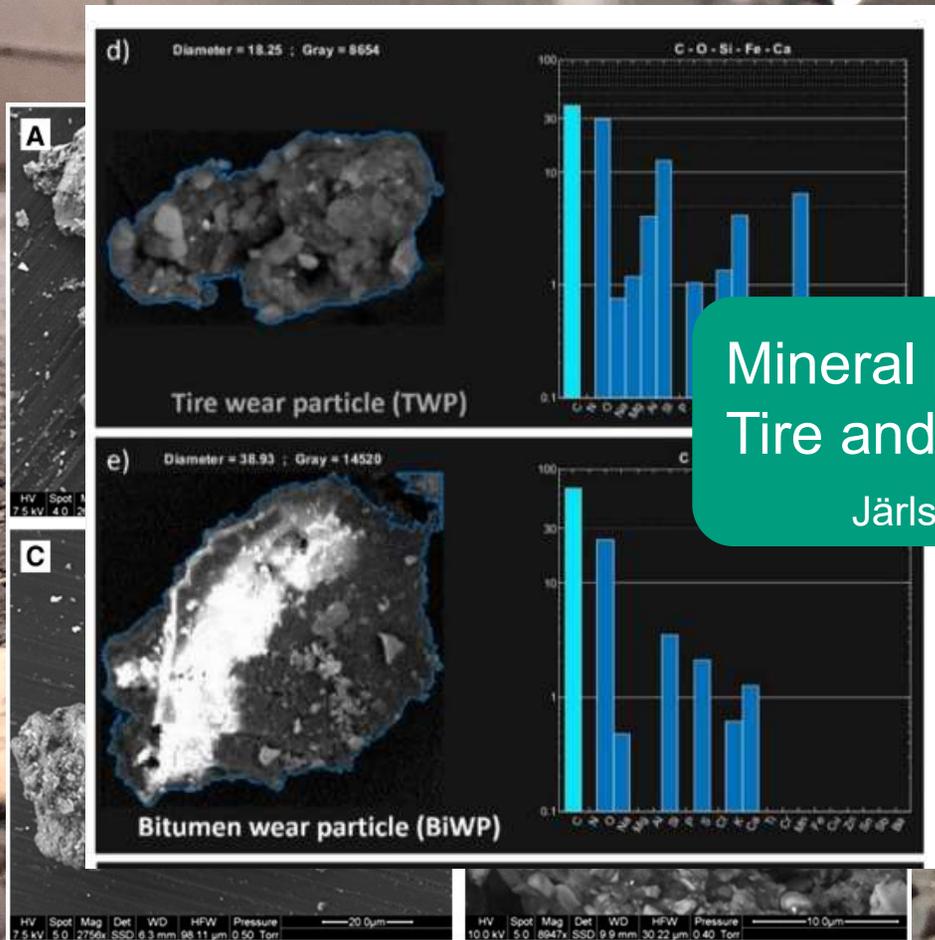


Analytical challenges



Scanning electron microscope images of RP (A, B) and TWP (C, D). Kreider et al. (2010)

Analytical challenges



Mineral particles ~75%
Tire and road particles ~ 20%
Järleskog et al., 2022



Scanning electron microscope images of RP (A, B) and TWP (C, D). Kreider et al. (2010)

Analytical challenges

Mass concentration of tire and road wear particles

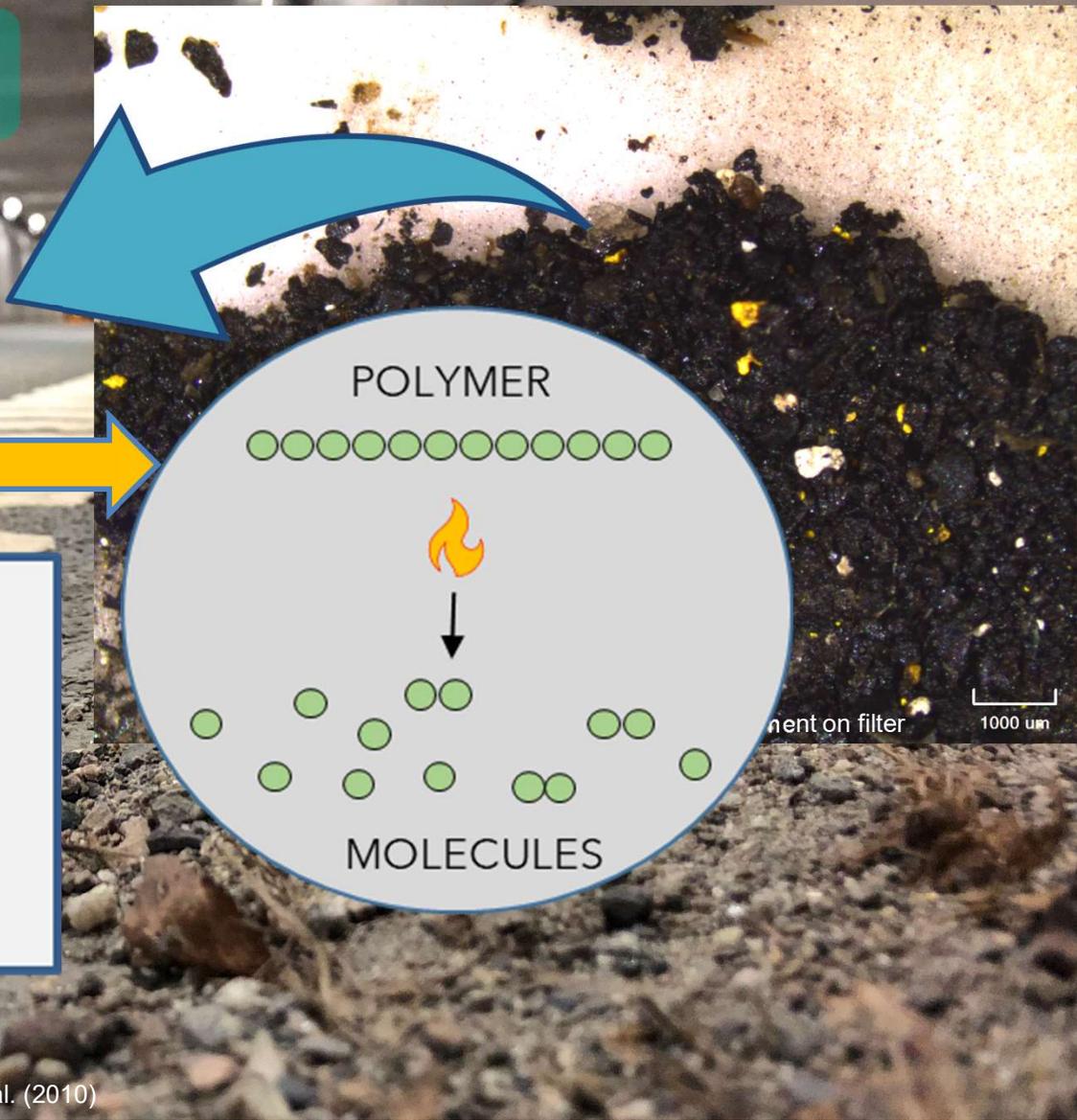
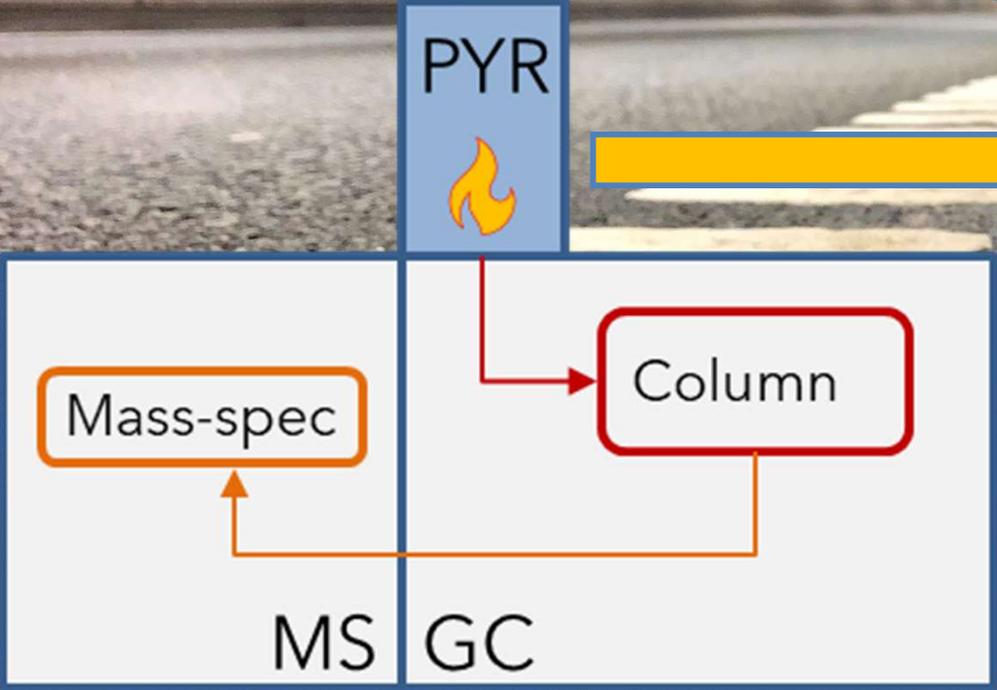
Where do they end up?

What treatments are effective?



Analytical challenges

Pyrolysis GC/MS



Scanning electron microscope images of RP (A, B) and TWP (C, D). Kreider et al. (2010)



**RWP CONTAINS SBS RUBBER
IDENTICAL TO TIRE RUBBER
(SBR) WITH PYR-GC/MS**

SEPARATE TIRE AND PMB

- Separation between SBR and SBS
- Environmental samples identified as mixtures
- BUT, model failed to predict pure tire particles
- In depth study of unused tires showed high complexity, different ratios of styrene to butadiene and isomers of butadiene

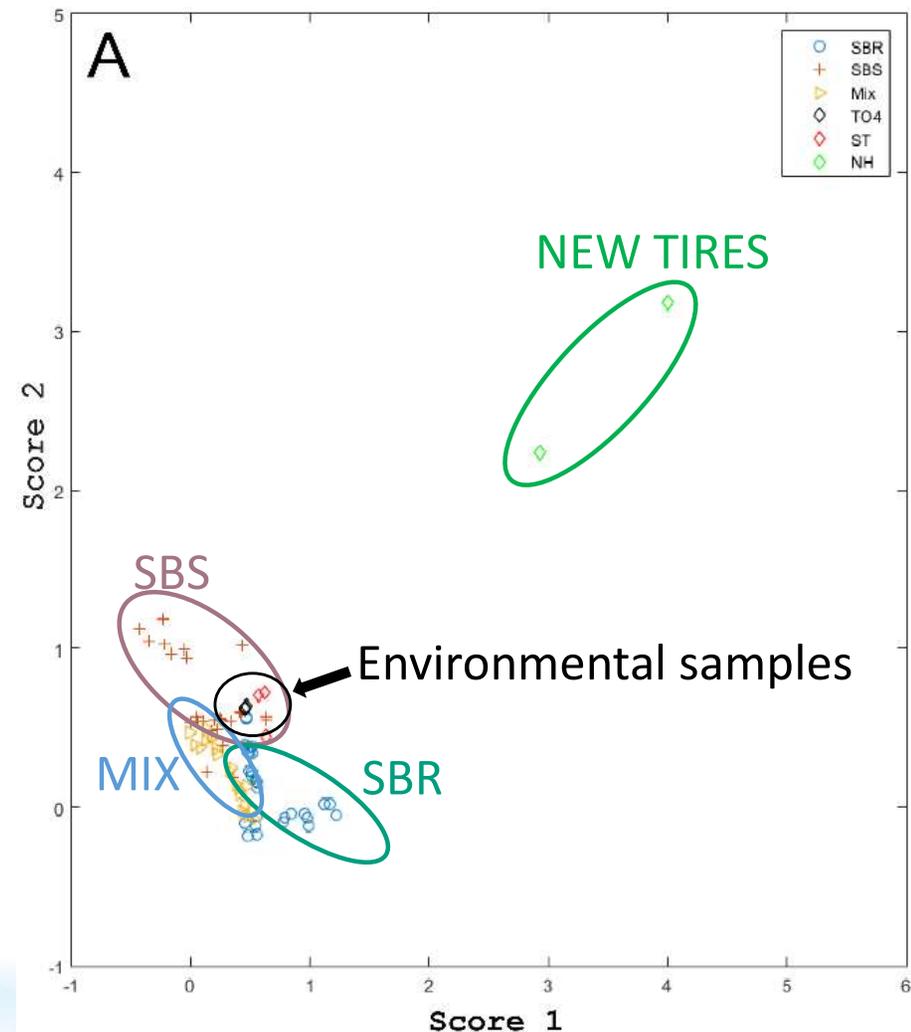
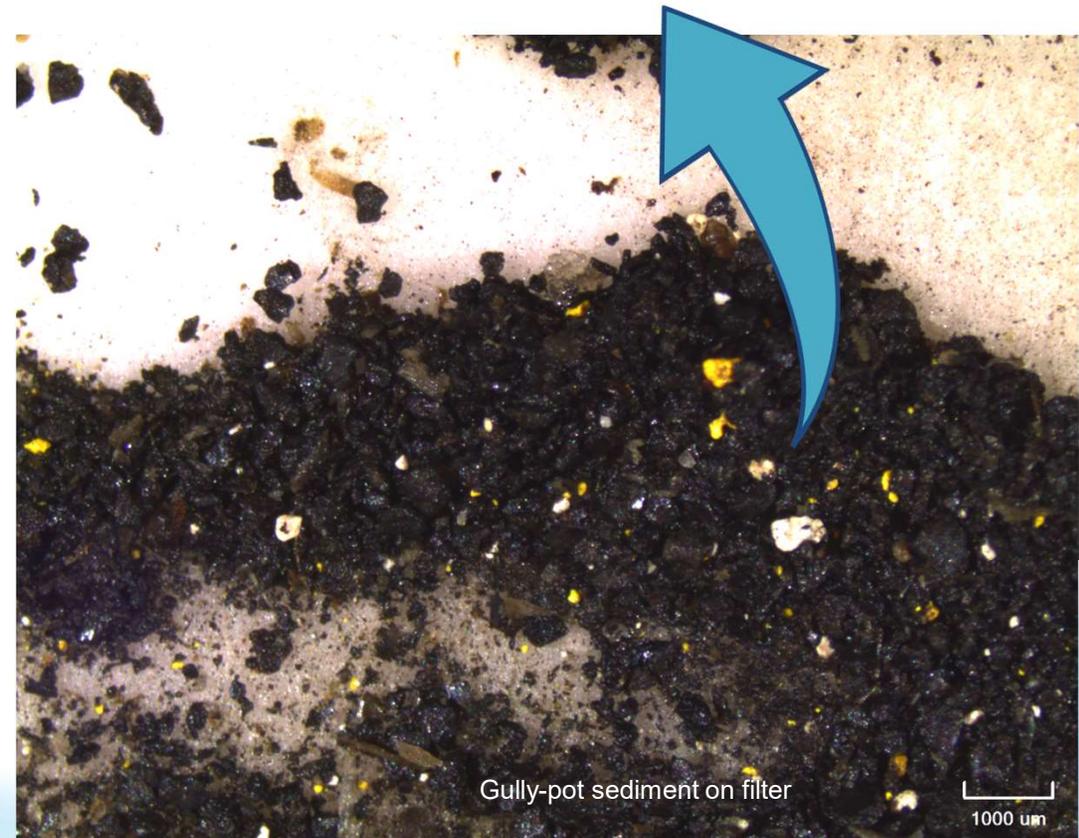


Figure S21. Separation of samples using PLS-DA model. A) between the first two latent variables

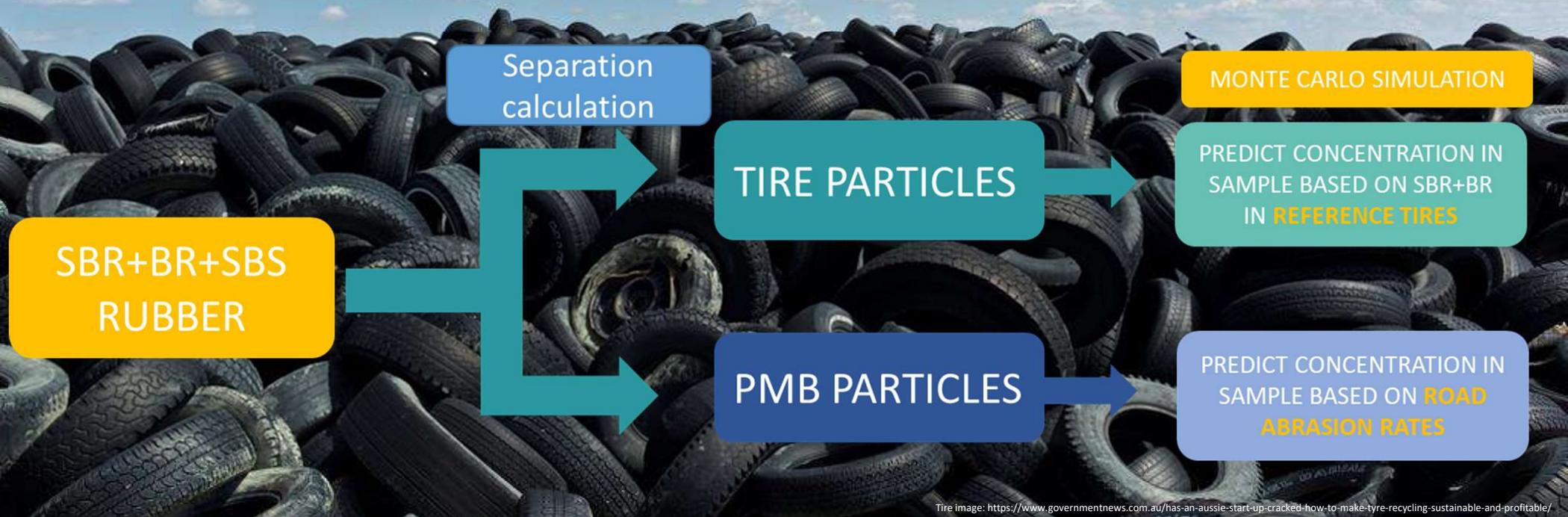
SEPARATE TIRE AND PMB

- The idea of separation by pyrolysis was abandoned
- Method focus on accurately measure mass of SBR+SBS in samples
- Calculate tire and PMB mass based on SBR+SBS

TOTAL SBR+SBS



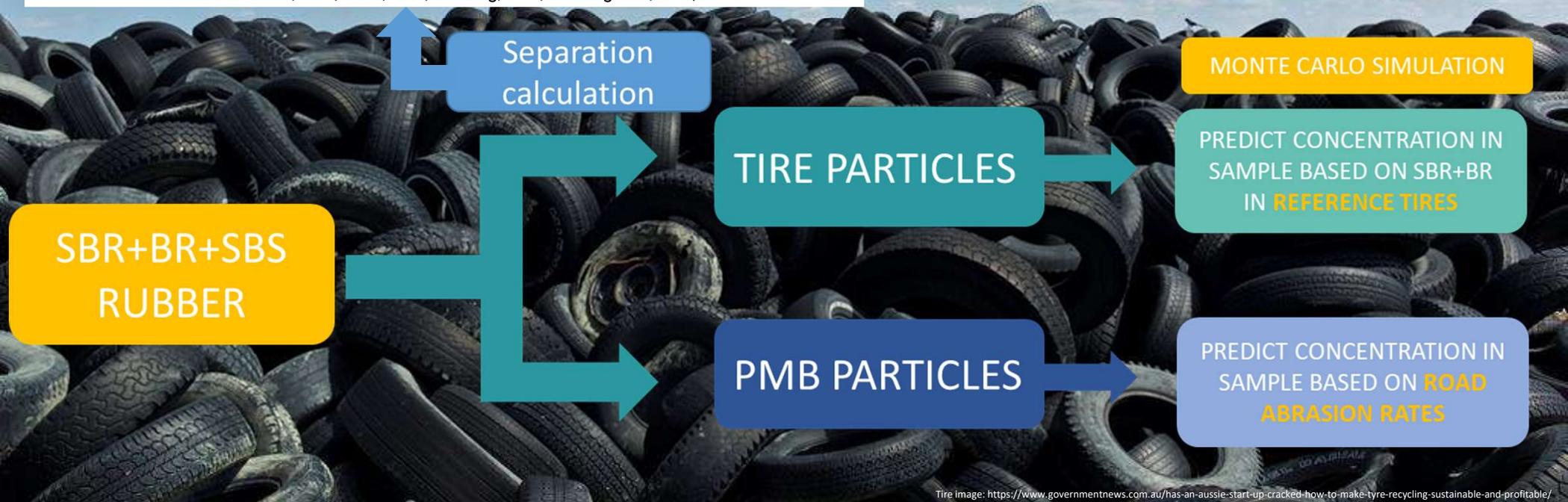
TWP and RWP-PMB calculation based on reference tires and traffic data



Emission factors (EFs)

Road surface	EFA _{PV-st} (g/vkm)	EFA _{HV-st} (g/vkm)	EFA _{PV-nst} (g/vkm)	EFA _{HV-nst} (g/vkm)
Stone mastic asphalt (SMA)	5-10	25-50	0.125-0.25	0.625-1.25
Asphalt concrete (AC)	15-20	75-100	0.375-0.5	1.875-2.5
Topeca	<15	<75	<0.375	<1.875
Porpus asphalt	18-25	90-125	0.45-0.625	2.25-3.125
Asphalt concrete with more gravel	15-30	75-150	0.375-0.75	1.875-3.75

REF: Bakløkk et al., 1997; Horvli, 1996; Snilsberg, 2008; Snilsberg et al., 2016)



Road surface	EFA _{PV-st} (g/vkm)	EFA _{HV-st} (g/vkm)	EFA _{PV-nst} (g/vkm)	EFA _{HV-nst} (g/vkm)
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REF: Bakløkk et al., 1997; Horvli, 1996; Snilsberg, 2008; Snilsberg et al., 2016)

Emission factors (EFs)

Tire	PV	HV
EFT _H	0.104	0.668
EFT _U	0.132	0.850

REF: Klein J. et al., 2017

Separation calculation

MONTE CARLO SIMULATION

SBR+BR+SBS
RUBBER

TIRE PARTICLES

PREDICT CONCENTRATION IN SAMPLE BASED ON SBR+BR IN REFERENCE TIRES

PMB PARTICLES

PREDICT CONCENTRATION IN SAMPLE BASED ON ROAD ABRASION RATES

**Emission factors (EFs):
Calculate the ratio of tires and
PMB particles at each sample
location**

Separation
calculation

MONTE CARLO SIMULATION

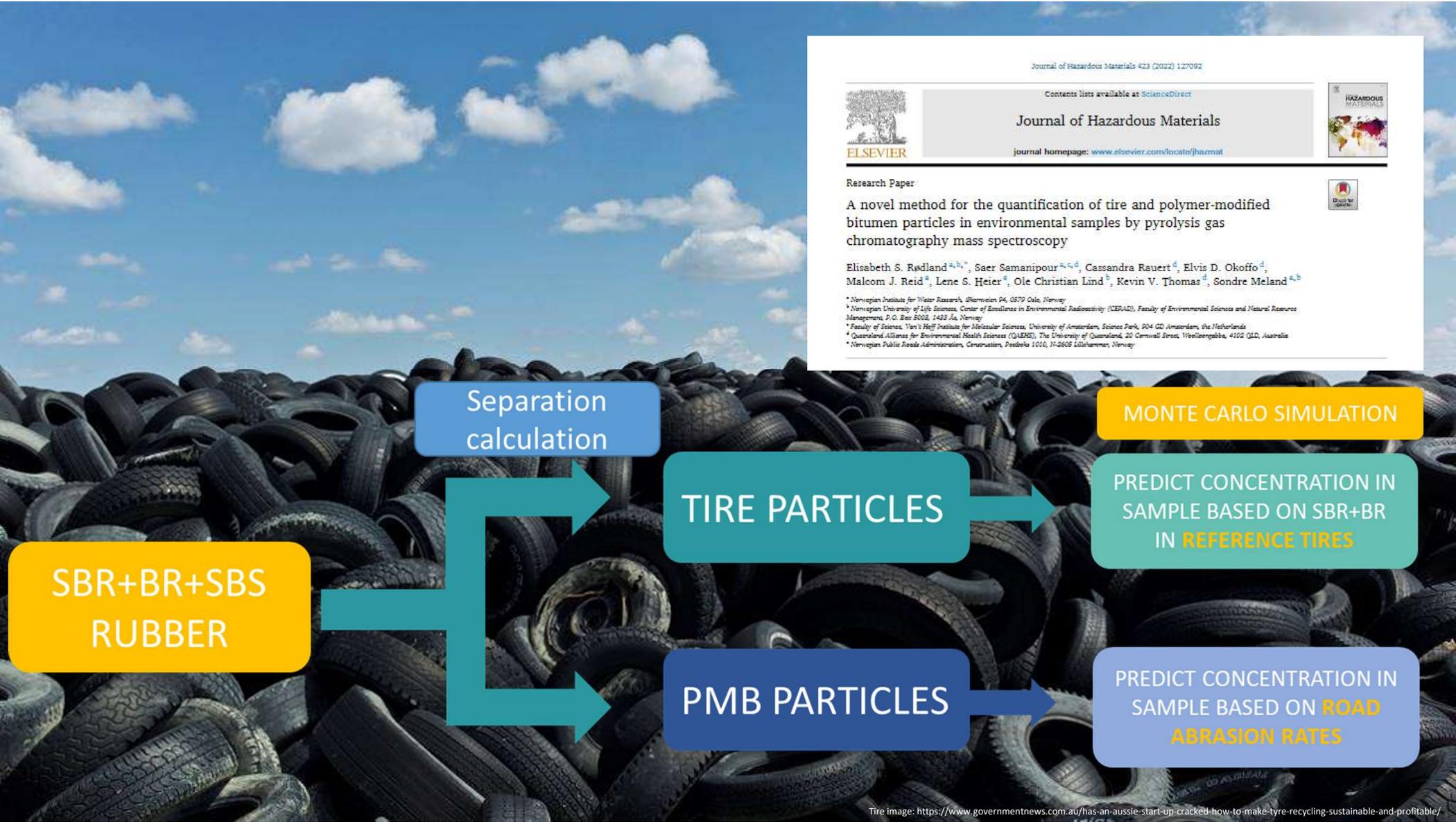
SBR+BR+SBS
RUBBER

TIRE PARTICLES

PREDICT CONCENTRATION IN
SAMPLE BASED ON SBR+BR
IN REFERENCE TIRES

PMB PARTICLES

PREDICT CONCENTRATION IN
SAMPLE BASED ON ROAD
ABRASION RATES



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journal homepage: www.elsevier.com/locate/jharmat

Research Paper

A novel method for the quantification of tire and polymer-modified bitumen particles in environmental samples by pyrolysis gas chromatography mass spectroscopy

Elisabeth S. Rødland^{a,b,*}, Saer Samanipour^{a,c,d}, Cassandra Rauer^d, Elvis D. Okoffo^d, Malcom J. Reid^e, Lene S. Heier^f, Ole Christian Lind^g, Kevin V. Thomas^d, Sondre Meland^{a,b}

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^b Norwegian University of Life Sciences, Center of Excellence in Environmental Radioactivity (CERAD), Faculty of Environmental Science and Natural Resource Management, P.O. Box 5002, 1483 Ås, Norway
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^e Norwegian Public Roads Administration, Construction, Postboks 1010, 17-2605 Lilleshammer, Norway

SBR+BR+SBS
RUBBER

Separation
calculation

TIRE PARTICLES

PMB PARTICLES

MONTE CARLO SIMULATION

PREDICT CONCENTRATION IN
SAMPLE BASED ON SBR+BR
IN REFERENCE TIRES

PREDICT CONCENTRATION IN
SAMPLE BASED ON ROAD
ABRASION RATES

Tire image: <https://www.governmentnews.com.au/has-an-aussie-start-up-cracked-how-to-make-tyre-recycling-sustainable-and-profitable/>

EXAMPLE

Site	Type of road	AADT (v/day)	PV (ratio)	HV (ratio)	Ratio of studded tires HV	Ratio of studded tires PV	Driving mode	EF_PV_tire (g/vkm)	EF_HV_tire (g/vkm)	EF_PV_road (g/vkm) ST	EF_HV_road (g/vkm) ST	EF_PV_road (g/vkm) NST	EF_HV_road (g/vkm) NST	SBS (g/day)	Ratio of SBR, winter tires	Mass_SBR (g/day)	% of SBS	Mean % of SBS at location
Bryn	SMA	36919	0.88	0.12	0.106	0.0316	Highway	0.104	0.668	5-10	25-50	0.125-0.25	0.625-1.25	6.75-15.7	0.3	190.1	3.4-7.6	5.37
Carl Berner	SMA	13000	0.94	0.06	0.106	0.0316	Urban	0.132	0.85	5-10	25-50	0.125-0.25	0.625-1.25	2.23-5.38	0.3	68.3	3.2-7.3	5.05
Frogner	SMA	6600	0.93	0.07	0.106	0.0316	Urban	0.132	0.85	5-10	25-50	0.125-0.25	0.625-1.25	1.15-2.74	0.3	36.1	3.1-7.1	4.90

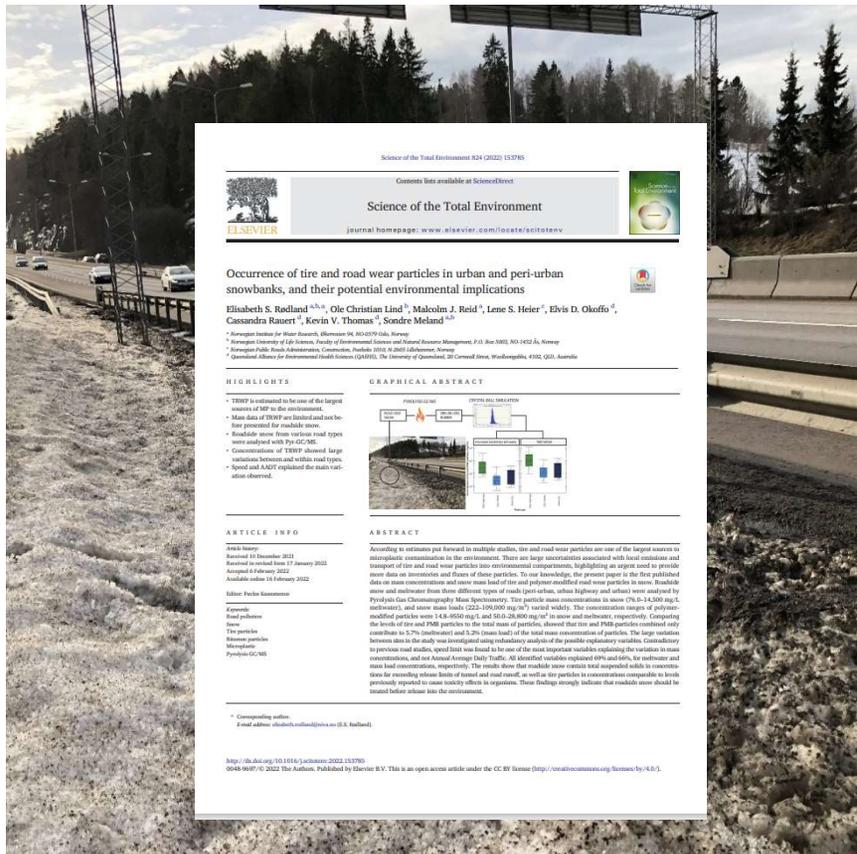


BRYN



FROGNER

Improved method applied to environmental samples



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Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Occurrence of tire and road wear particles in urban and peri-urban snowbanks, and their potential environmental implications

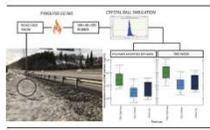
Elisabeth S. Rødland^{a,b,c}, Ole Christian Lind^b, Malcolm Reid^d, Lene S. Heier^e, Elvís D. Okoffo^f, Cassandra Rauer^g, Kevin V. Thomas^h, Sondre Meland^{i,j}

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^b Norwegian University of Life Sciences, Faculty of Environmental Science and Natural Resource Management, P.O. Box 8005, NO-1432 Ås, Norway
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HIGHLIGHTS

- TRWP is estimated to be one of the largest sources of MP in the environment.
- Mass data of TRWP are limited and are here presented for road-side snow.
- Roadside snow from various road types were analyzed with Py-GCMS.
- Concentrations of TRWP showed large variation between and within road types.
- Spread and AADT explained the large variation observed.

GRAPHICAL ABSTRACT



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Article history:
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Keywords:
 Road pollution
 Snow
 The particles
 Microplastics
 Pyrolysis-GC/MS

ABSTRACT

According to estimates put forward in multiple studies, tire and road wear particles are one of the largest sources to microplastic contamination in the environment. There are large uncertainties associated with how consistent and transport of tire and road wear particles into environmental compartments, highlighting an urgent need to provide more data on occurrence and fluxes of these particles. To our knowledge, the present paper is the first published data on mass concentrations and snow mass load of tire and polymer modified road wear particles in snow. Roadside snow and meltwater from three different types of roads (peri-urban, urban highway and urban) were analyzed by Pyrolysis-Gas Chromatography-Mass Spectrometry. The particle mass concentrations in snow (79.2–14,000 ng/g meltwater) and snow mass loads (222–190,000 ng/m²) varied widely. The concentration ranges of poly-modified particles were 14.6–9500 ng/g, and 165.0–28,800 ng/m² in snow and meltwater, respectively. Comparing the levels of tire and PMB particles to the total mass of particles, showed that tire and PMB particles constituted only 0.003 and 0.01% of the total mass of particles, respectively. The large variation between sites in the study was investigated using redundancy analysis of the possible explanatory variables. Contradictory to previous road studies, speed limit was found to be one of the most important variables explaining the variation in mass concentration, and not Annual Average Daily Traffic. All classified variables explained 49% and 46% for meltwater and snow load concentrations, respectively. The results show that roadside snow contains total suspended solids in concentrations far exceeding release limits of treated and road runoff, as well as tire particles in concentrations comparable to levels previously reported to cause toxicity effects in organisms. These findings strongly indicate that results snow should be treated before release into the environment.

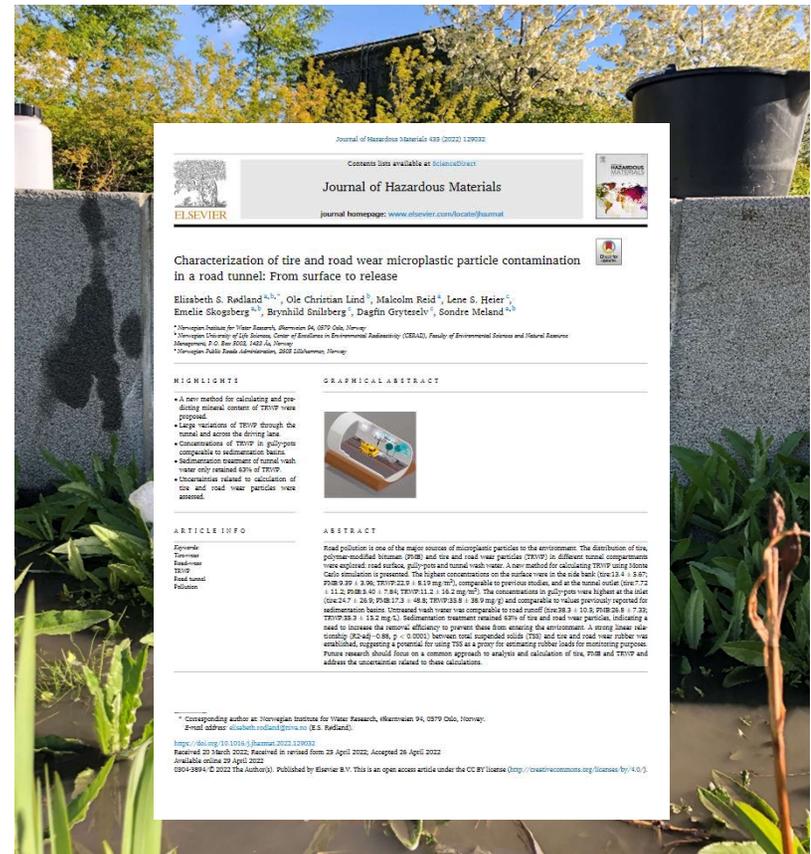
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Characterization of tire and road wear microplastic particle contamination in a road tunnel: From surface to release

Elisabeth S. Rødland^{a,b,c}, Ole Christian Lind^b, Malcolm Reid^d, Lene S. Heier^e, Emelie Skogseberg^{a,b}, Brynhild Snilberg^a, Dagfinn Grytsevåg^a, Sondre Meland^{a,b}

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^c Norwegian Public Health Administration, 2002 SØkkervei, Trondheim

HIGHLIGHTS

- A new method for calculating and predicting release content of TRWP was proposed.
- Large variations of TRWP through the tunnel and across the driving lane.
- Concentrations of TRWP in poly-pyrene compatible to sedimentation basins.
- Sedimentation treatment of tunnel wash water only retained 63% of TRWP.
- Characteristics related to calculation of tire and road wear particles were assessed.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
 Received 20 December 2021
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 Accepted 6 February 2022
 Available online 18 February 2022

Editor: Pankaj Karmantsev

Keywords:
 Road pollution
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 Microplastics
 Pyrolysis-GC/MS

ABSTRACT

Road pollution is one of the major sources of microplastic particles to the environment. The distribution of tire, polymer-modified bitumen (PMB) and tire and road wear particles (TRWP) in different tunnel compartments were explored: road surface, poly-pyrene and tunnel wash water. A new method for calculating TRWP using Monte Carlo simulation is presented. The highest concentrations on the surface were in the side bank (tire 13.4 ± 5.87; PMB 8.89 ± 3.36; TRWP 22.3 ± 8.12 mg/m²), comparable to previous studies, and in the tunnel inlet (tire 7.2 ± 11.2; PMB 3.40 ± 7.84; TRWP 11.2 ± 16.2 mg/m²). The concentrations in poly-pyrene were highest at the inlet (tire 24.7 ± 10.8; PMB 27.3 ± 18.8; TRWP 38.3 ± 18.9 mg/g) and comparable to values previously reported for sedimentation basins. Untreated wash water was comparable to road runoff (tire 38.3 ± 10.8; PMB 26.6 ± 7.39; TRWP 38.3 ± 13.2 mg/l). Sedimentation treatment retained 63% of tire and road wear particles, indicating a need to increase the removal efficiency to prevent these from entering the environment. A strong linear relationship (R² = 0.98, p < 0.0001) between time suspended solids (TSS) and tire and road wear particles was established, suggesting a potential for using TSS as a proxy for estimating rubber loads for dust-binding purposes. Future research should focus on a common approach to analysis and calculation of tire, PMB and TRWP and address the uncertainties related to these calculations.

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 E-mail address: elisabeth.rodland@niva.no (E.S. Rødland).

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Road-side snow

Hypothesis

- Higher levels close to the road side
- Traffic density is the most important

Mass concentrations in meltwater snow
Based on predicted mean values

TWP mg/L	PMB mg/L
786 ± 908	151 ± 170

TWP mg/L	PMB mg/L
370 ± 278	71.5 ± 52.4

TWP mg/L	PMB mg/L
210 ± 111	40.7 ± 21.1



Road-side snow

Hypothesis

- Higher levels close to the road side
- ~~Traffic density is the most important factor~~

RDA analysis of significant explanatory variables



Road tunnel - Smestad



Road tunnel

Hypothesis

- Road tunnels represent local “hot-spots”

Road surface

- Highest values in the bank area and in the outlet of the tunnel
- Higher than previous reported for tunnel dust (Klöckner et al., 2021)

TWP mg/m ²	PMB mg/m ²
890 ± 1210	710 ± 961



Road tunnel

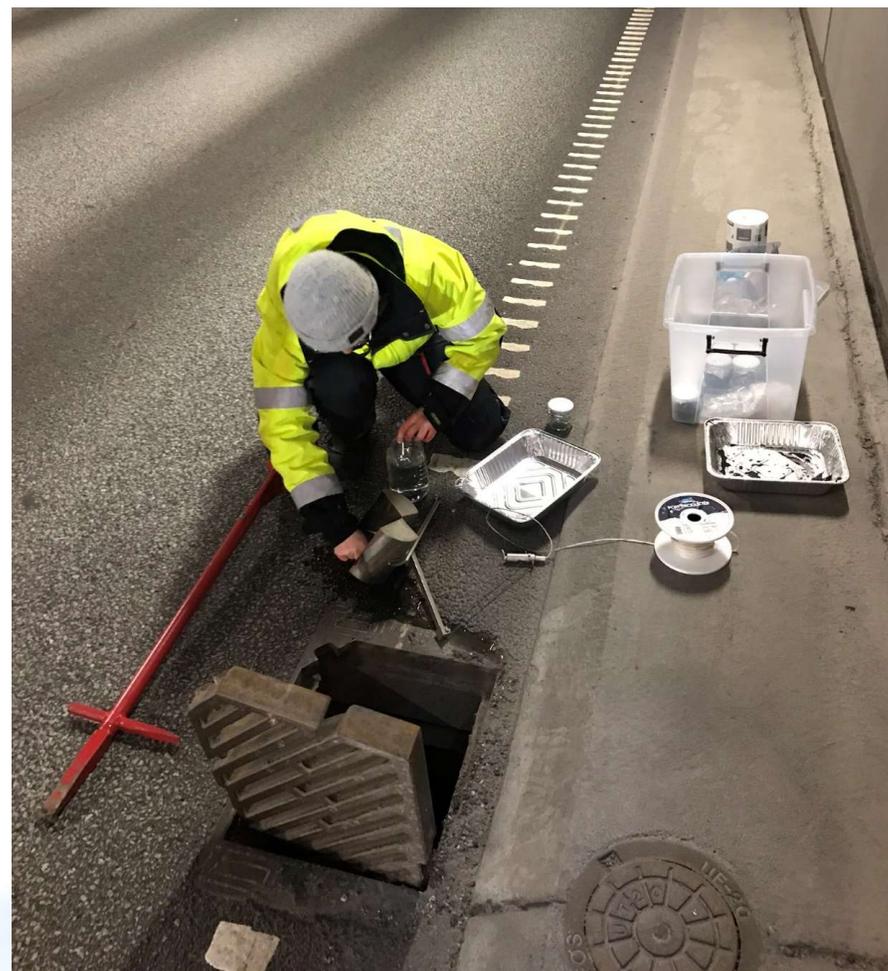
Hypothesis

- Road tunnels represent local “hot-spots”

Gully-pots

- Highest concentration close to inlet, lowest at outlet
- Comparable levels to previous reports for sedimentation basin (Klöckner et al., 2019)

TWP mg/kg	PMB mg/kg
22 ± 24	17 ± 19



Inside the Smestad tunnel

Road tunnel

Hypothesis

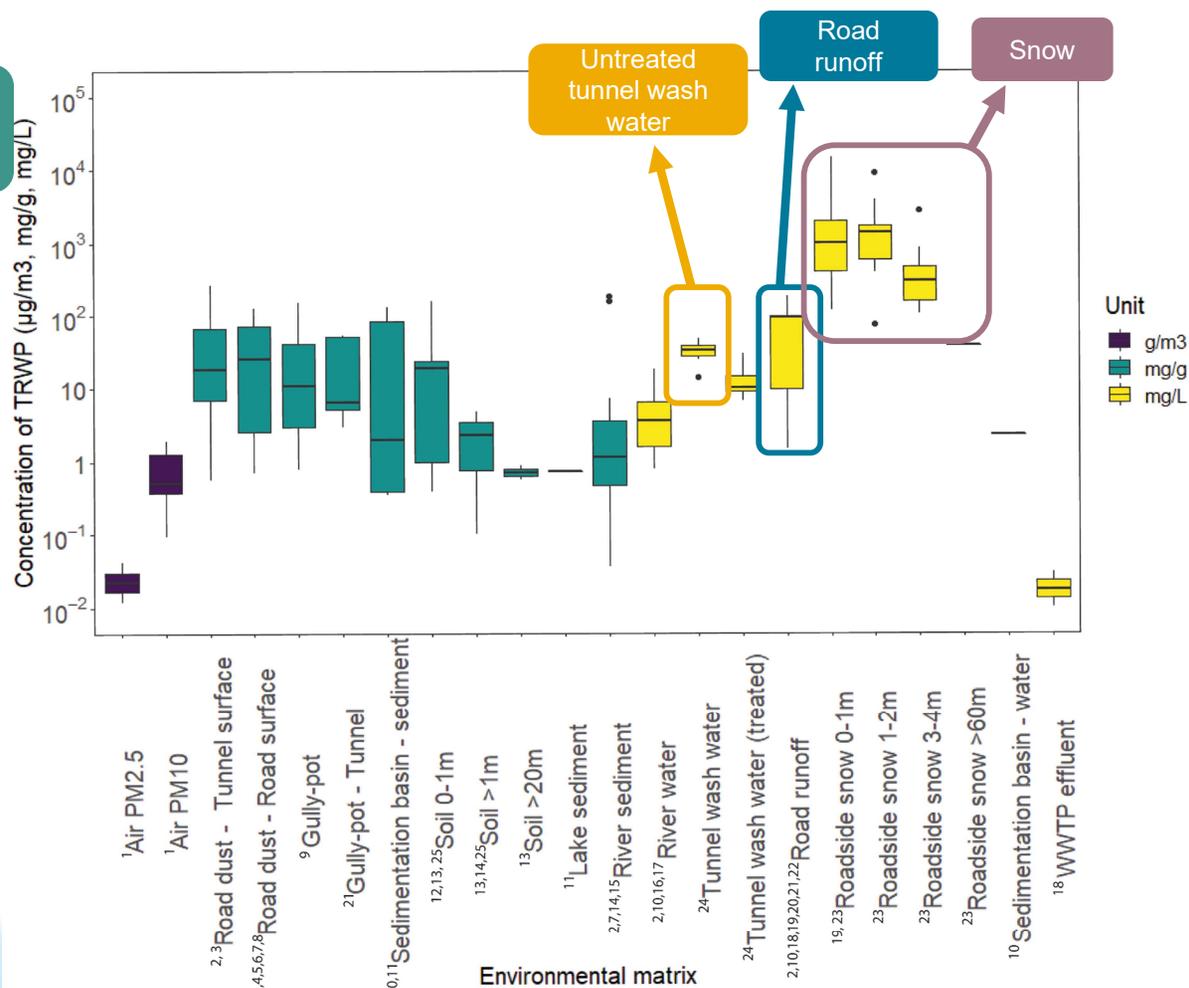
- Road tunnels represent local “hot-spots”

Tunnel wash water

- The untreated TWW had comparable levels to road runoff, but lower compared to roadside snow in Oslo (Paper III)

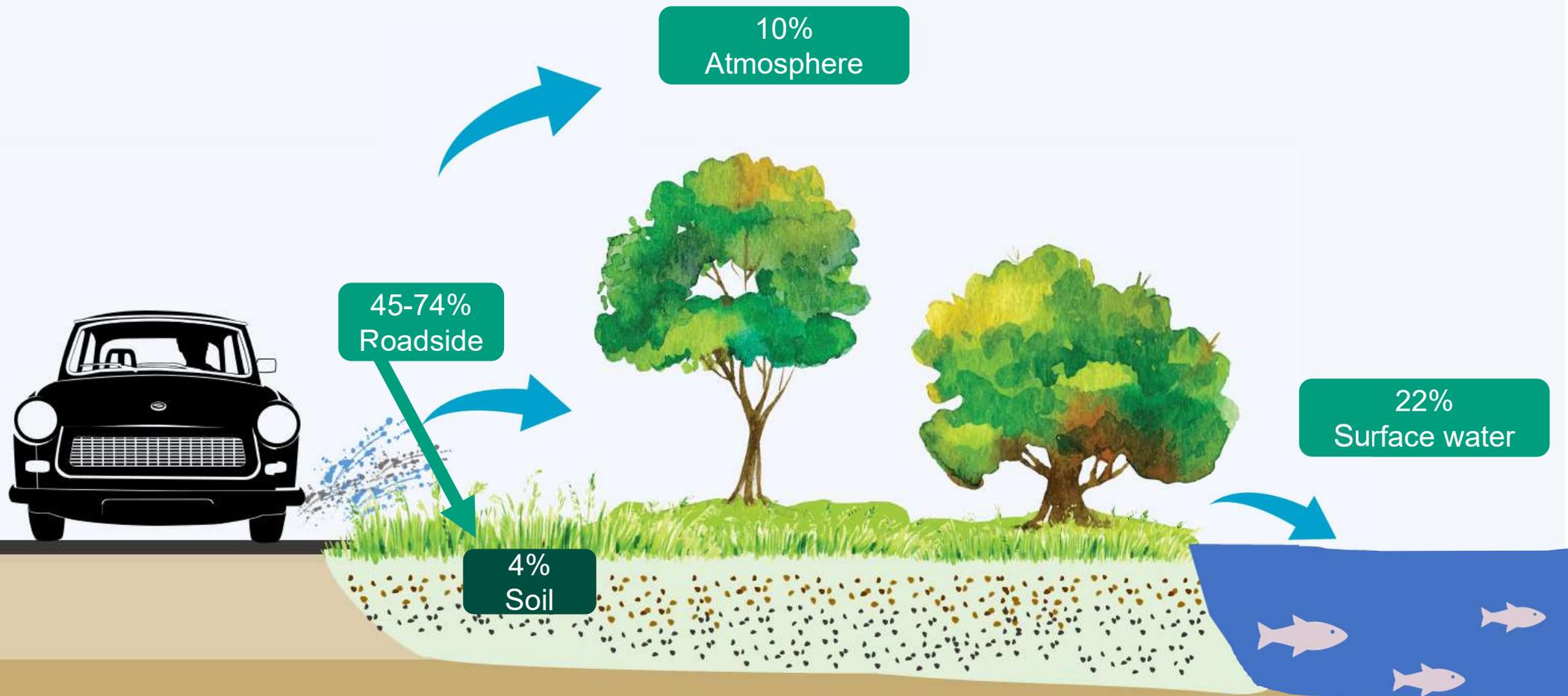
TWP mg/L	PMB mg/L
34 ± 9.20	27 ± 7.3

- The sedimentation basin removed 63% of the rubber-particles (tire, PMB, TRWP)



1) Panko et al. (2019), 2) Kumata et al. (2000), 3) Klöckner et al. (2021b), 4) Hopke et al. (1980), 5) Rogge et al. (1993), 6) Kumata et al. (2002), 7) Zakaria et al. (2002), 8) Eisentraut et al. (2018), 9) Mengistu et al. (2021b), 10) Reddy and Quinn (1997), 11) Klöckner et al. (2019), 12) Kocher et al. (2008), 13) Müller et al. (2022a), 14) Unice et al. (2013), 15) Spies et al. (1987), 16) Ni et al. (2008), 17) Rauert et al. (2022), 18) Parker-Jurd et al. (2021), 19) Baumann and Ismeier (1998), 20) Kumata et al. (1997), 21) Kumata et al. (2002), 22) Zeng et al. (2004), 23) Rødland et al. (2022a), 24) Rødland et al. (2022b), 25) Rødland et al., (2022c)

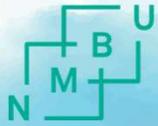
Tire wear particles ...what about RWP particles?



Conclusions

- **Microplastics can contribute to negative impacts on the environment**
- **Road microplastics include tire wear, road wear and road markings**
- **The knowledge of road wear particles with polymer-modified bitumen is so far limited**
- **We need more data on the abrasion of PMB road surfaces to improve the calculation and separation of tire and PMB particles**
- **High levels of tire and road wear particles are present in road-side snow and road tunnels**

NIVA is interested in collaboration to increase knowledge on road wear particles and PMB



Norwegian University
of Life Sciences



Vegvesen



Thank you! Contact me for questions and collaborations

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