Tire and road wear microplastics

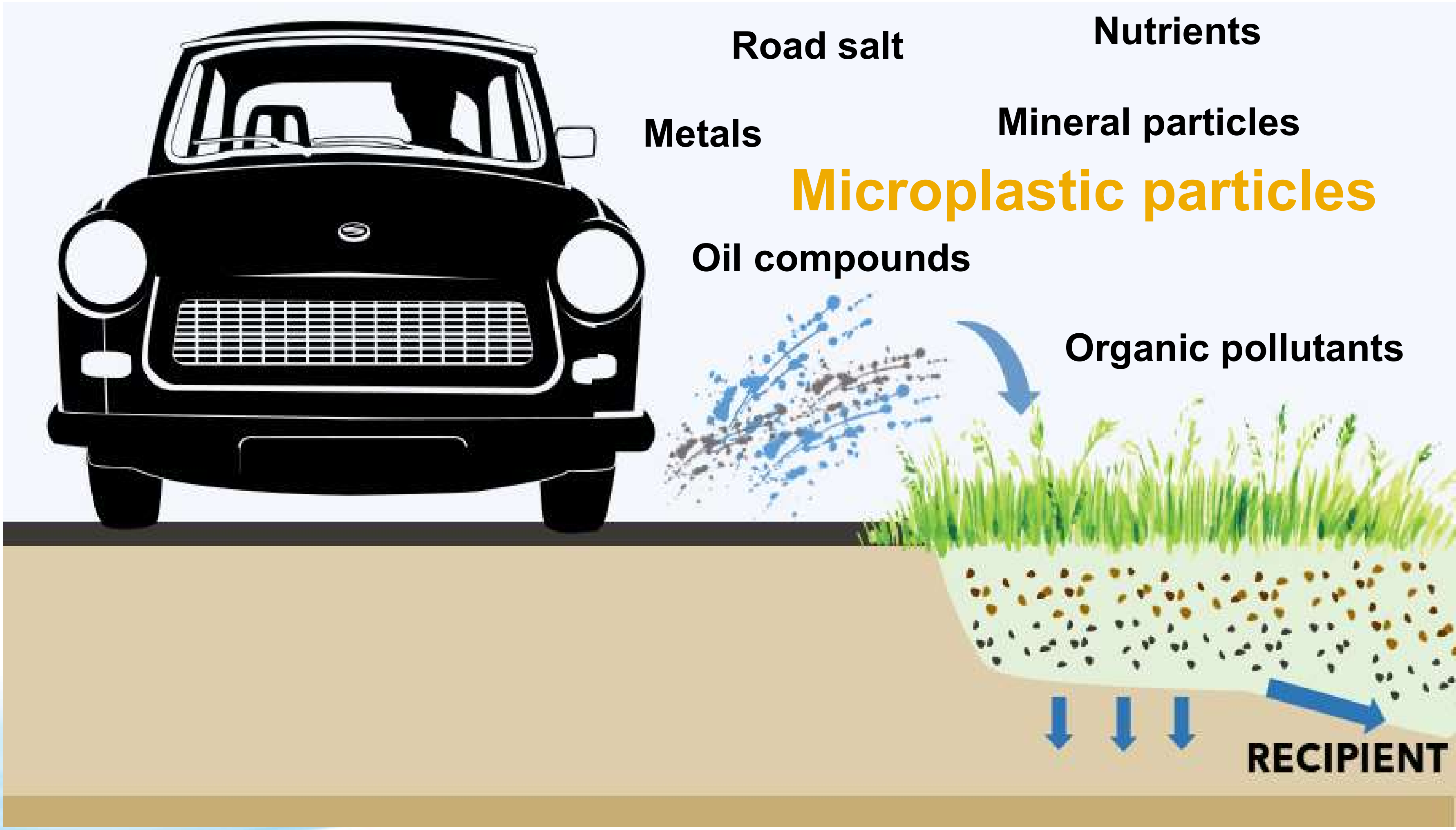
Elisabeth Rødland (elisabeth.rodland@niva.no)

Norwegian institute for water research (NIVA)

Overview of presentation

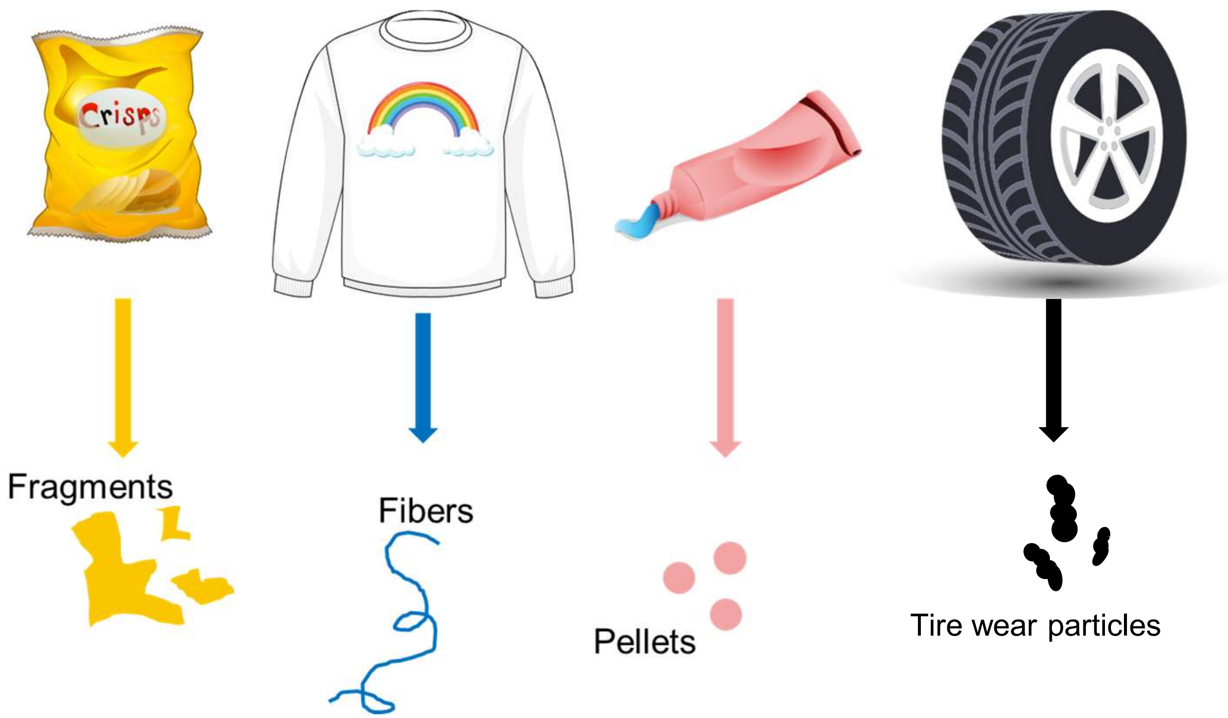
- **Road pollution**
- **Microplastics from roads**
- **Challenges with quantification**
- **Environmental concentrations**
- **Future needs**

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 1µm and less than 5000µm.



*Definition based on: *California Water Boards, 2020; SAPEA, 2019*

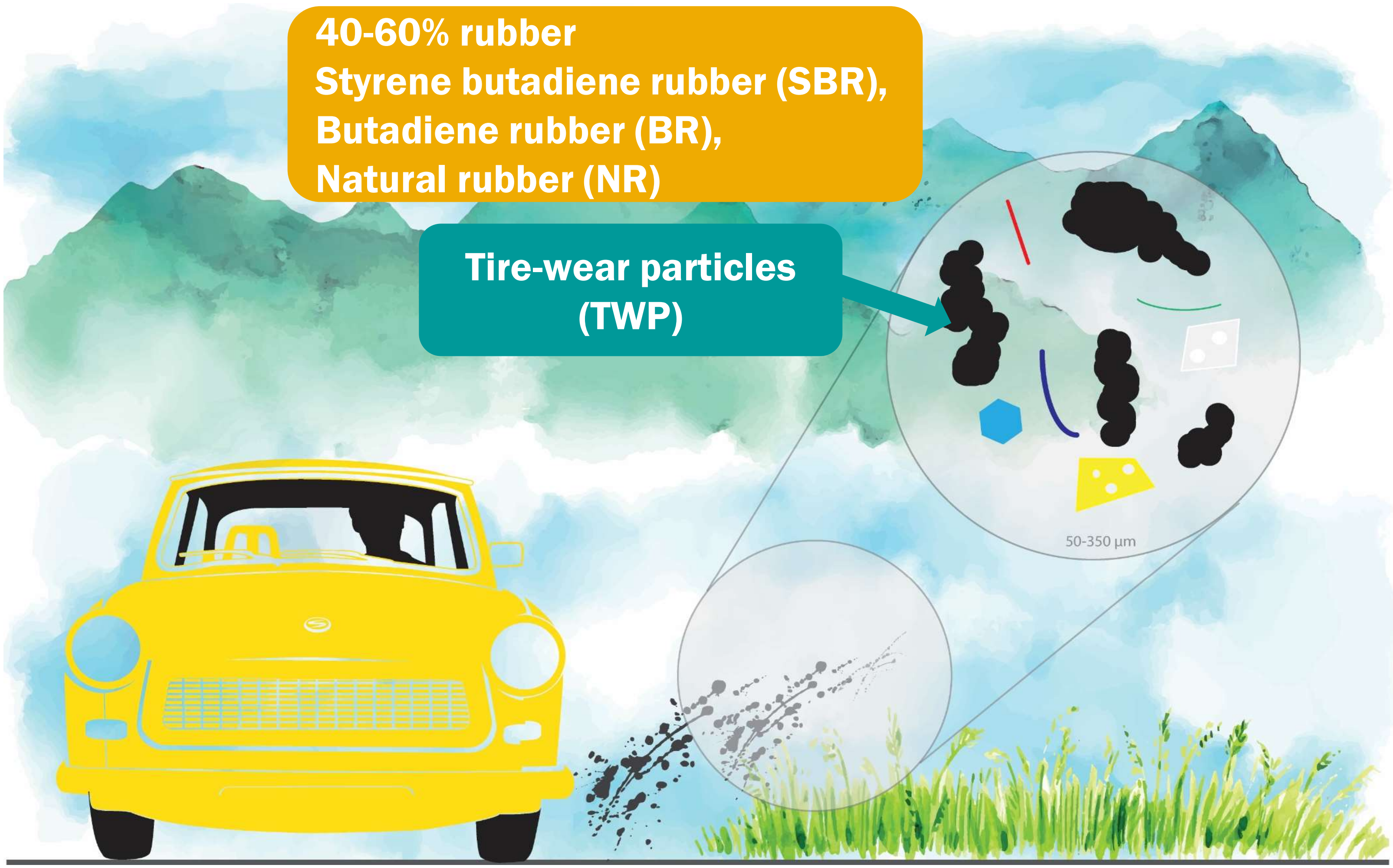
What are microplastics? **Environment**

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.

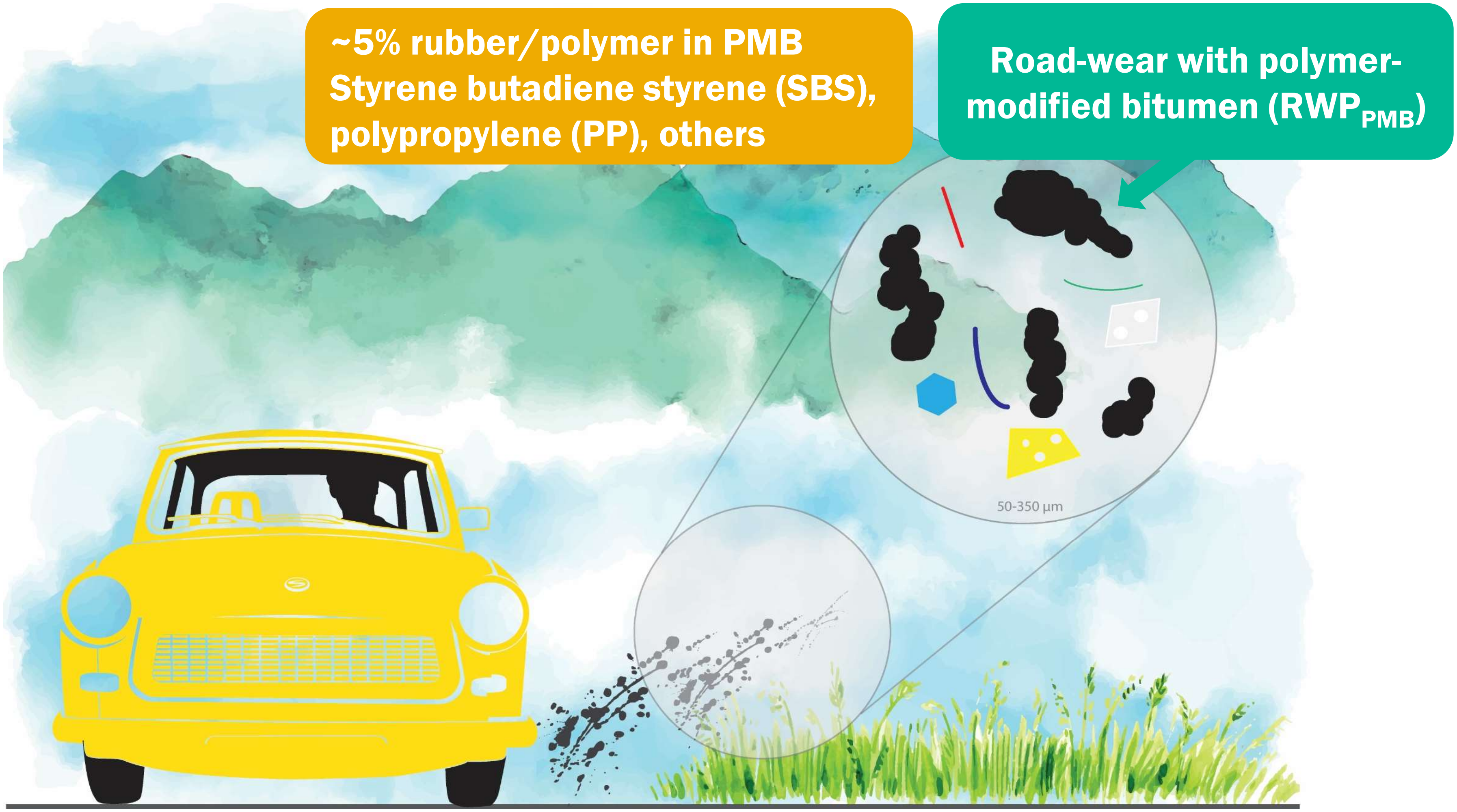
- Low degradability in the environment (assumed persistent)
- Potentially breaks down into smaller sizes by wear, weathering
- Can potentially be taken up by organisms
- Can contain additives and chemicals that potentially leach out

*Definition based on: *California Water Boards, 2020; SAPEA, 2019*

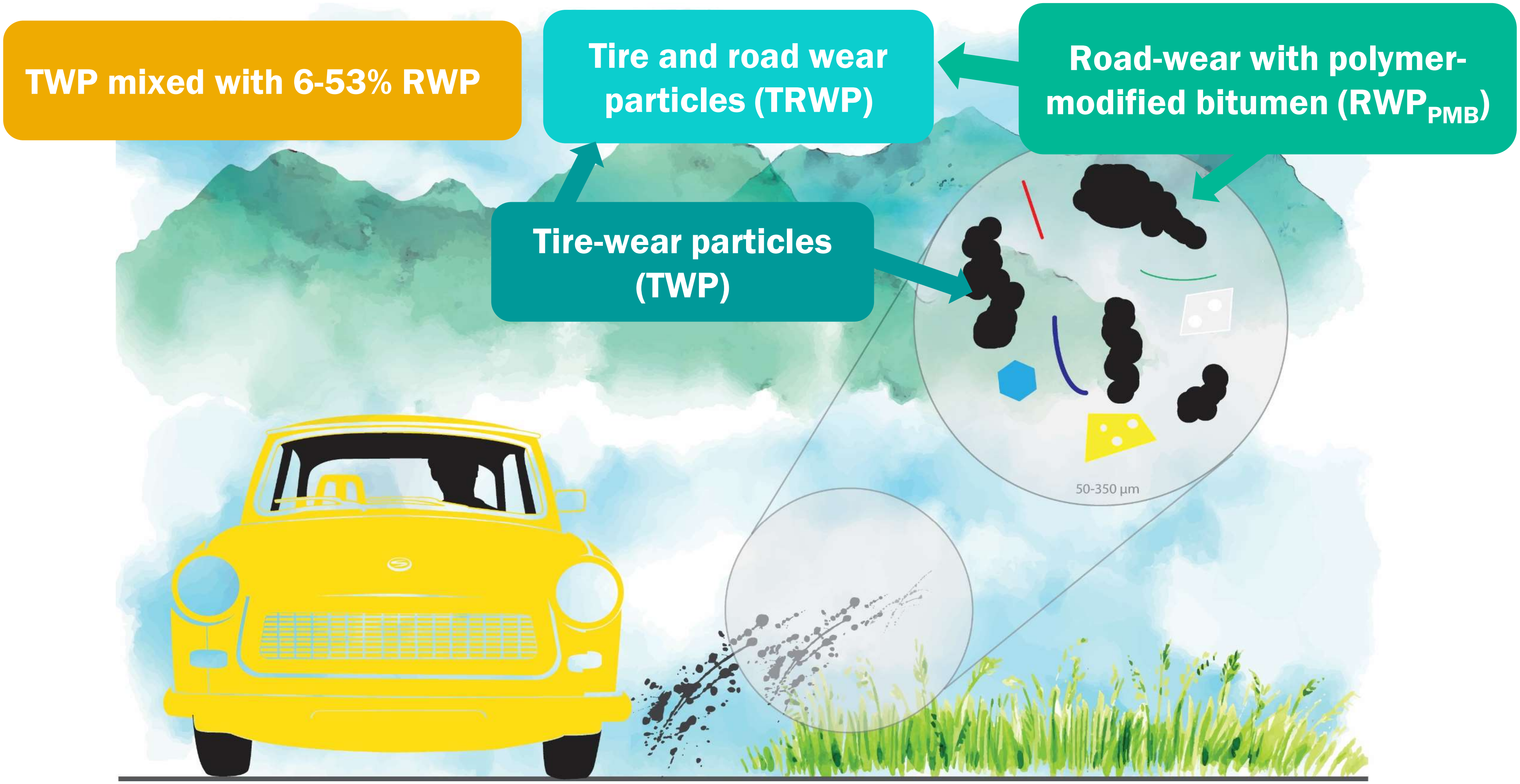
Road-related microplastic particles



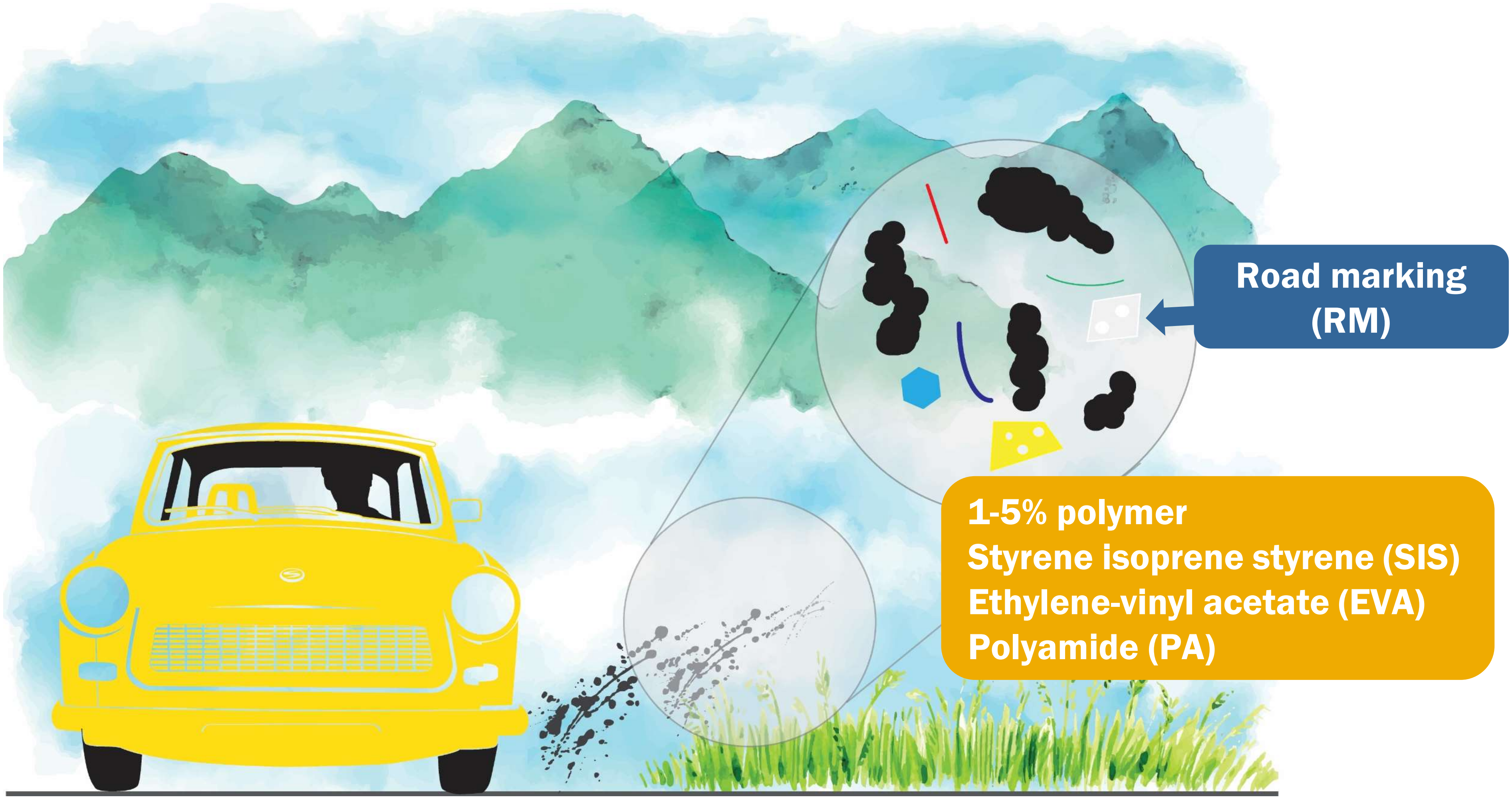
Road-related microplastic particles



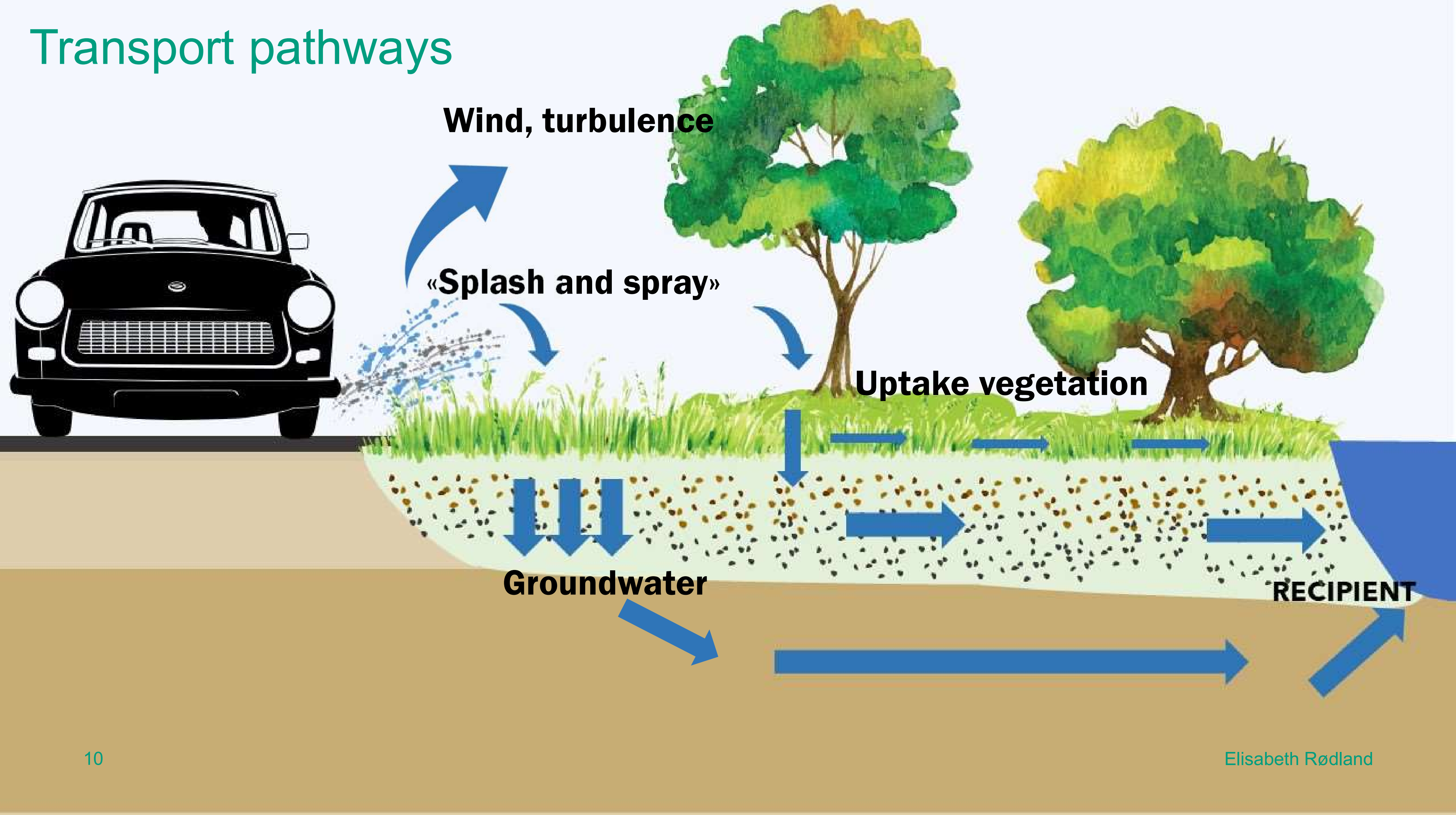
Road-related microplastic particles



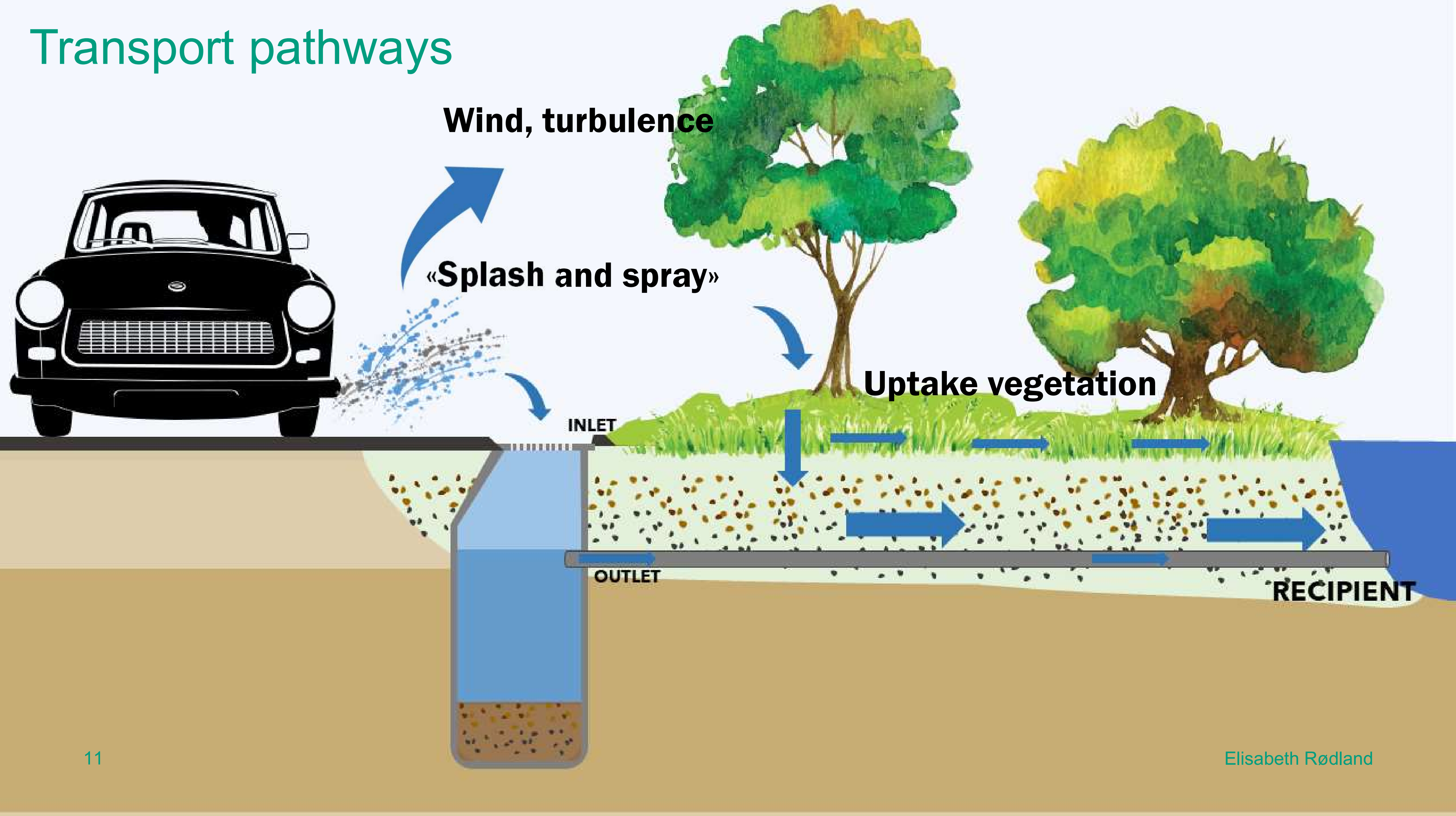
Road-related microplastic particles



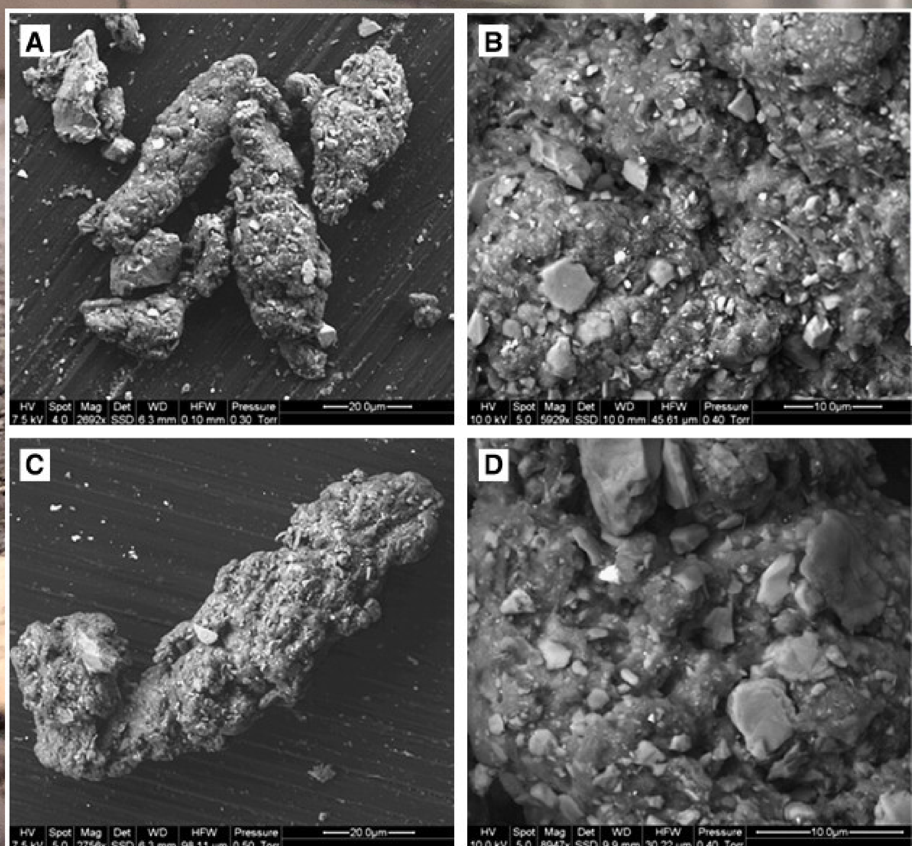
Transport pathways



Transport pathways



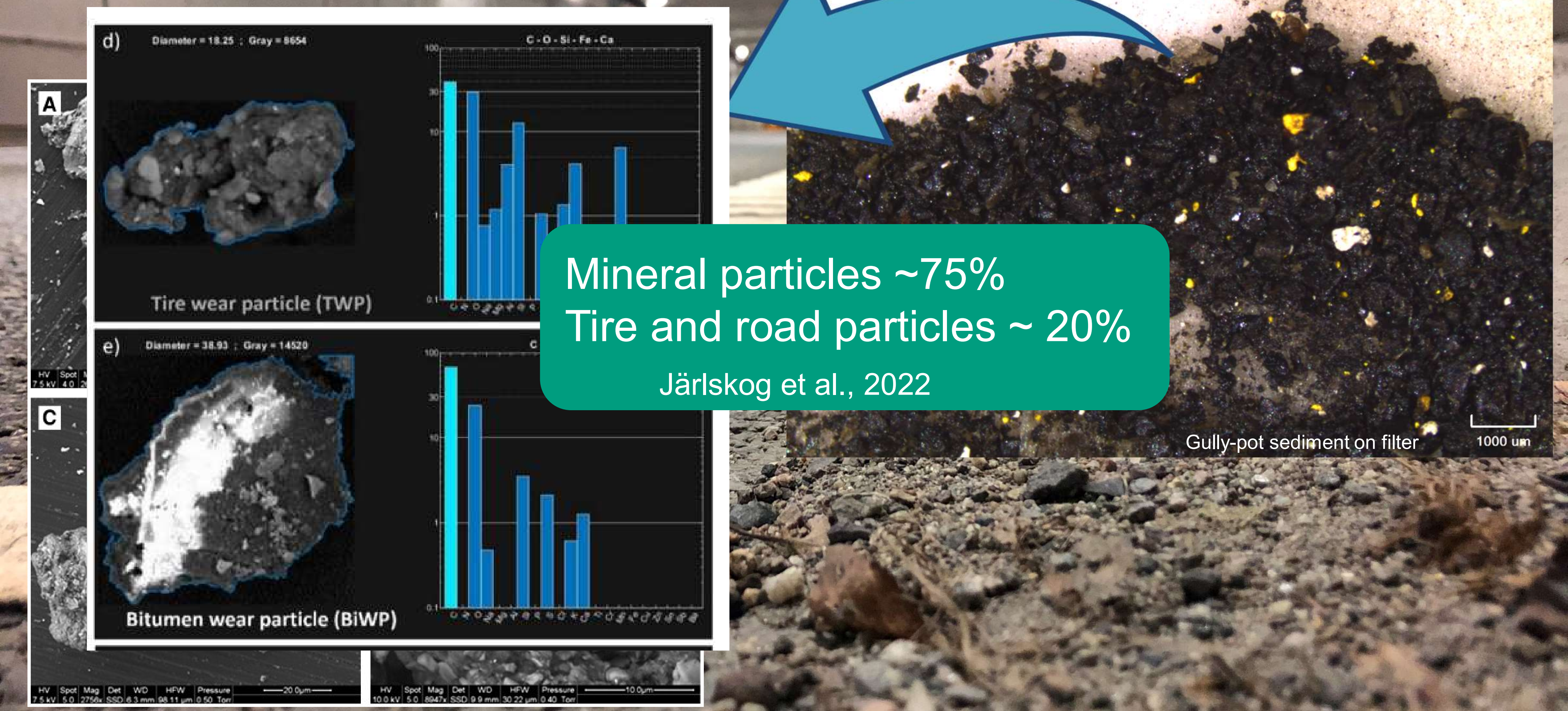
Analytical challenges



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

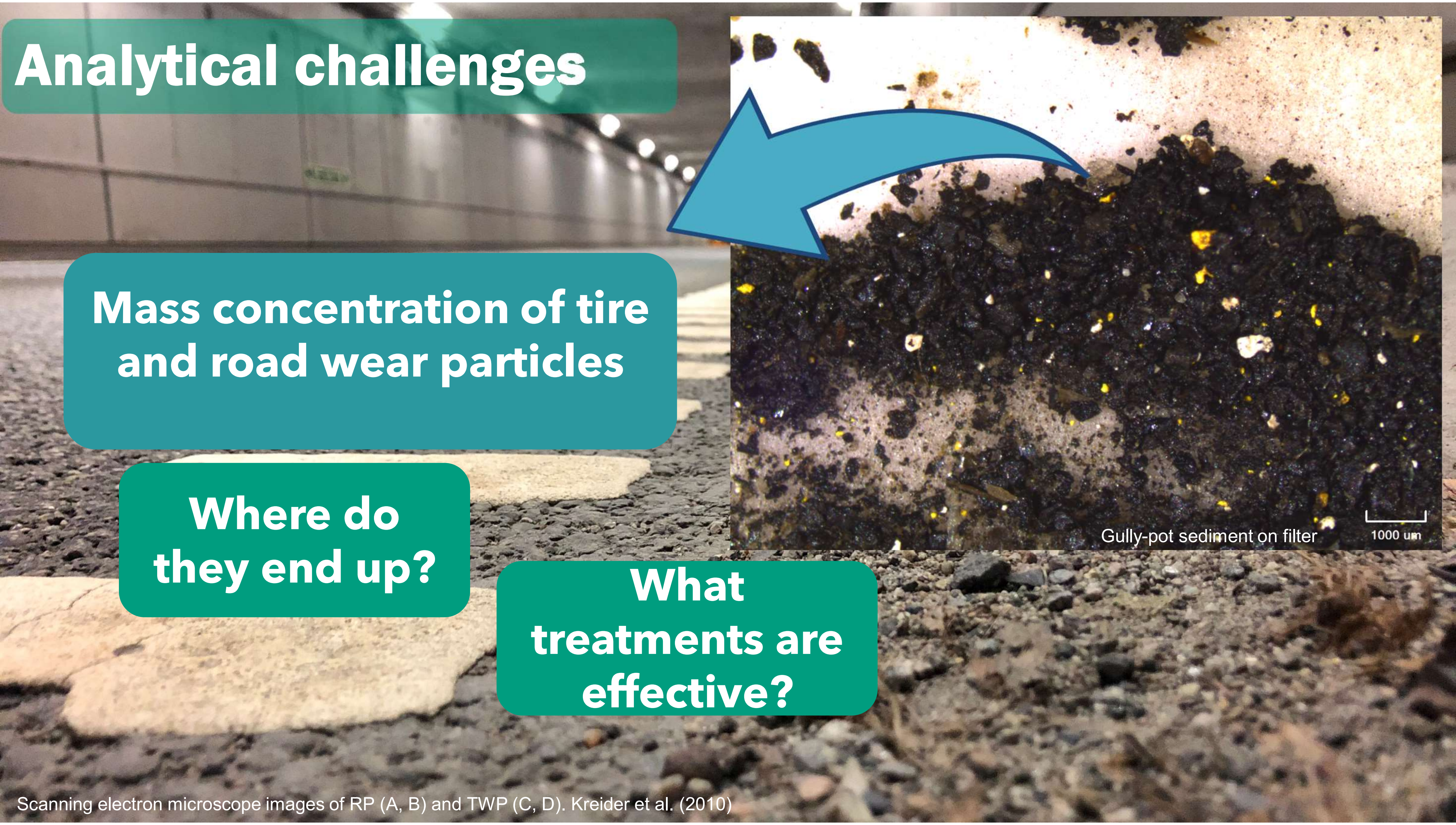
Gully-pot sediment on filter

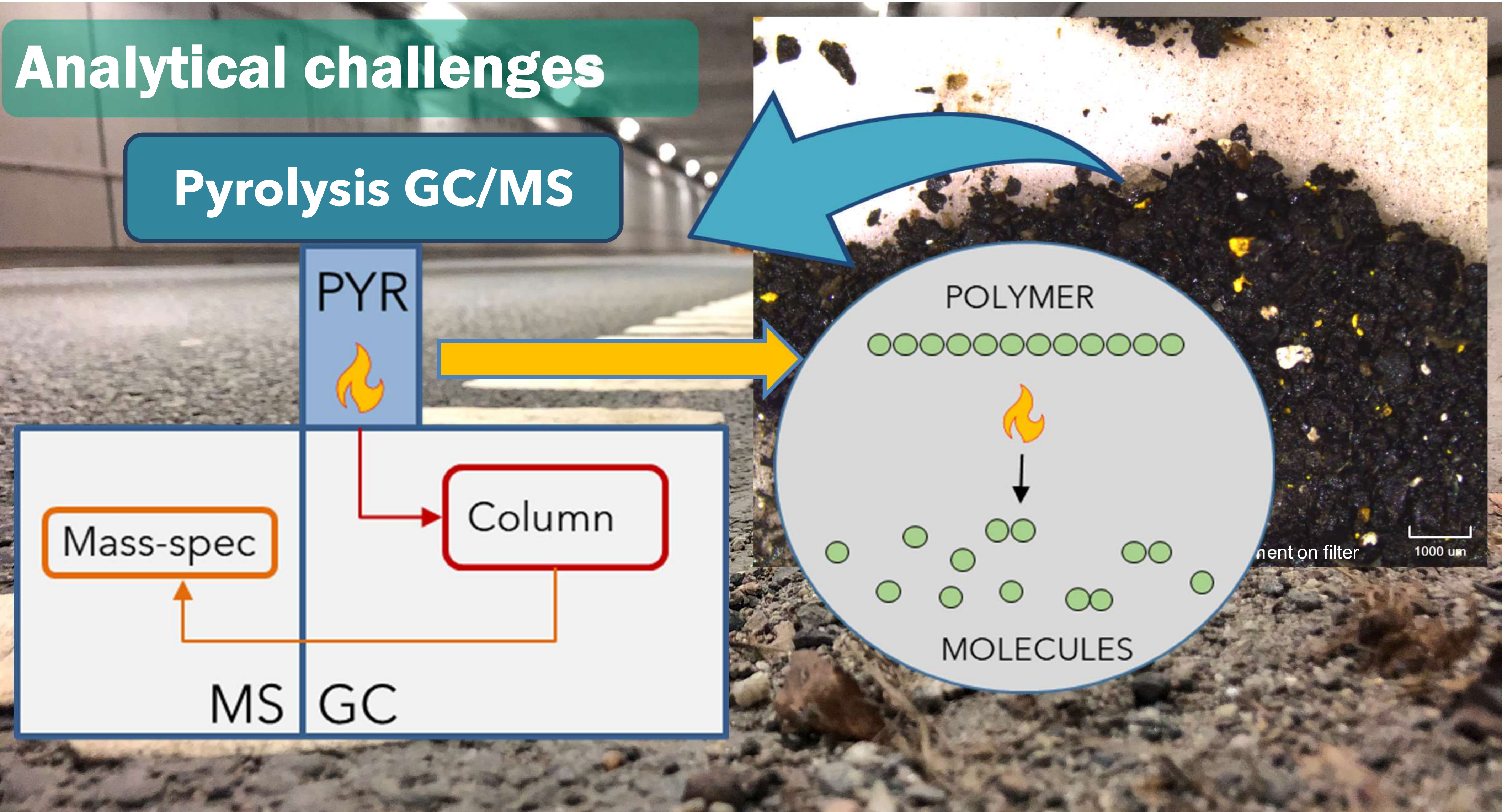
Analytical challenges



Mineral particles ~75%
Tire and road particles ~ 20%
Järlskog 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?
Gully-pot sediment on filter
1000 um
Scanning electron microscope images of RP (A, B) and TWP (C, D). Kreider et al. (2010)



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


Gully-pot sediment on filter
1000 um
RWP CONTAINS SBS RUBBER IDENTICAL TO TIRE RUBBER (SBR) WITH PYR-GC/MS
PMB image: https://www.mrpavement.com/about-us/blog/general-information/how-pavement-reacts-temperature-changes/

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

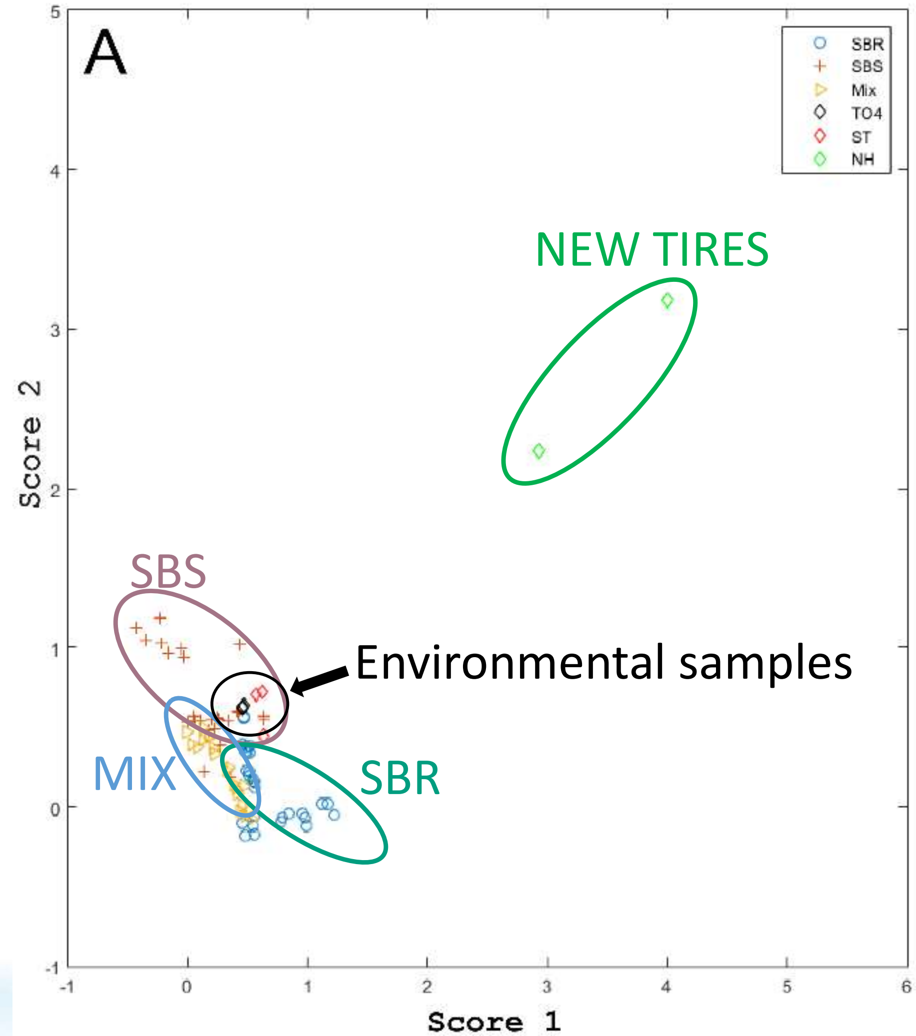
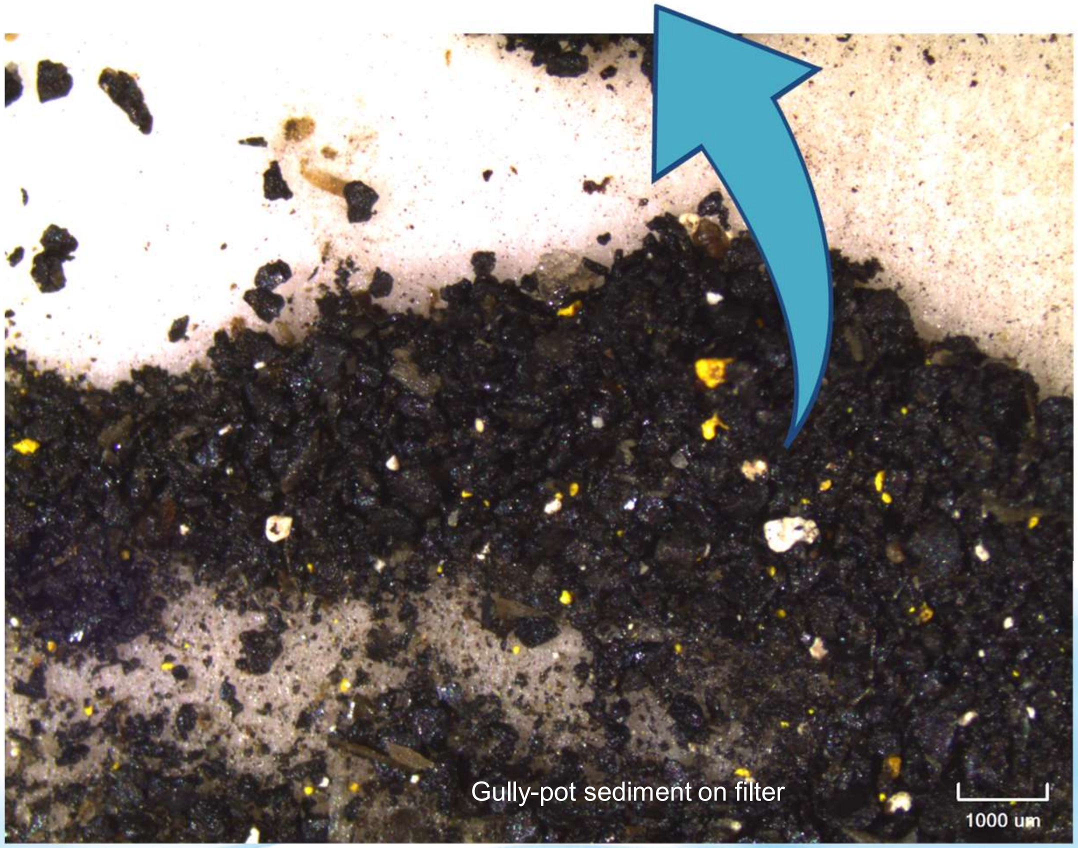


Figure S21. Separation of samples using PLS-DA model. A) between the first two latent variables

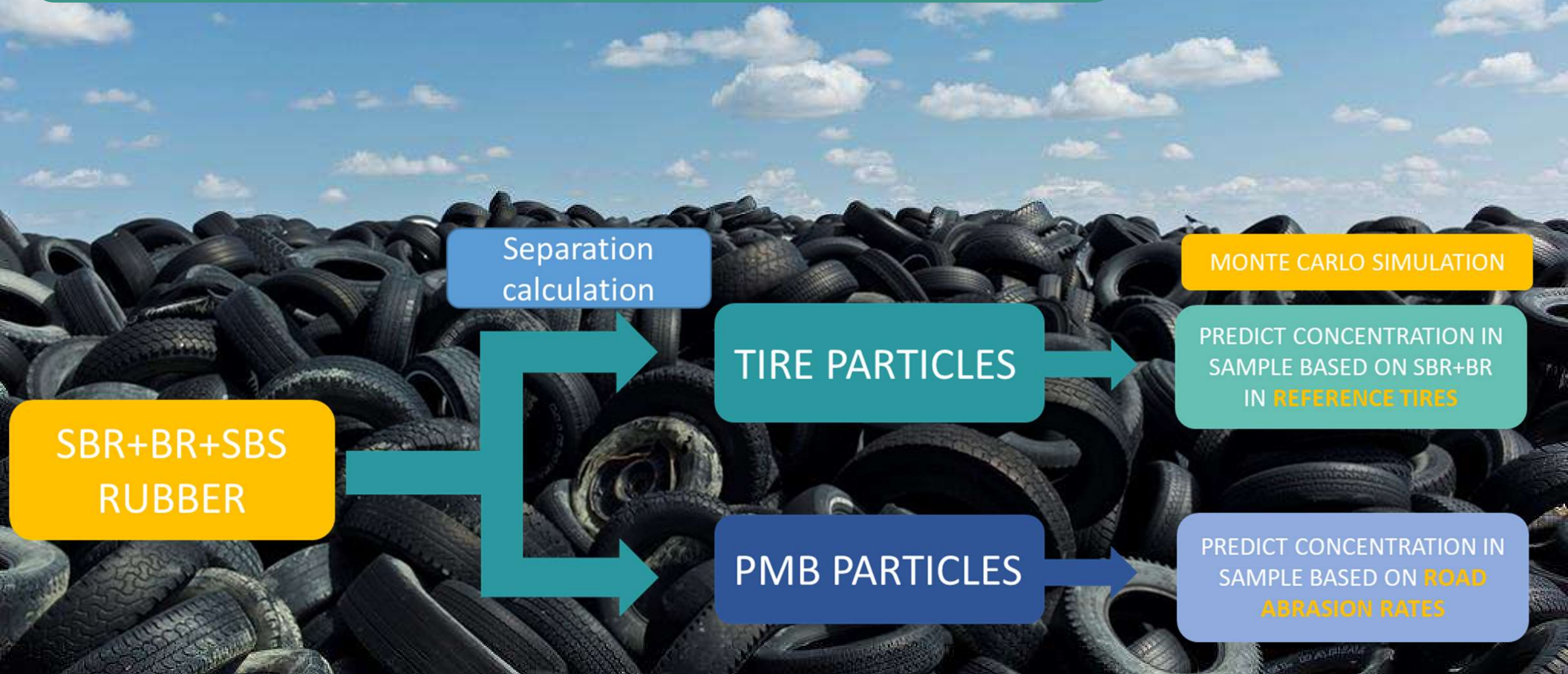
SEPARATE TIRE AND PMB

- 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

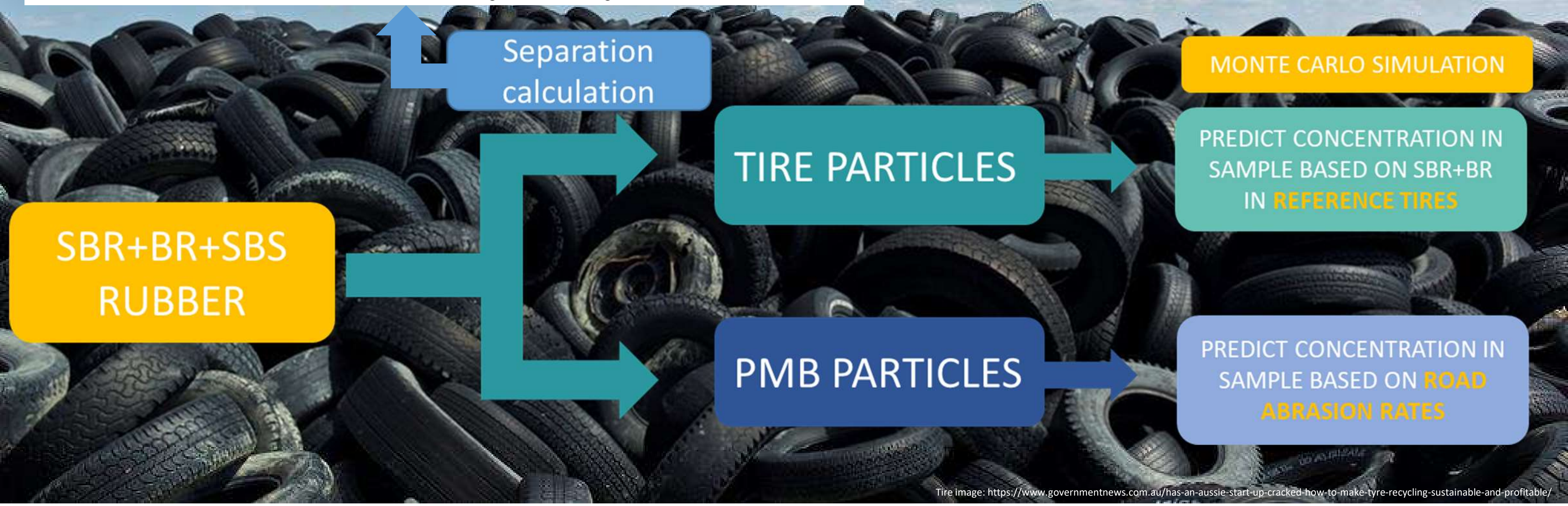


Tire image: https://www.governmentnews.com.au/has-an-aussie-start-up-cracked-how-to-make-tyre-recycling-sustainable-and-profitable/

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)



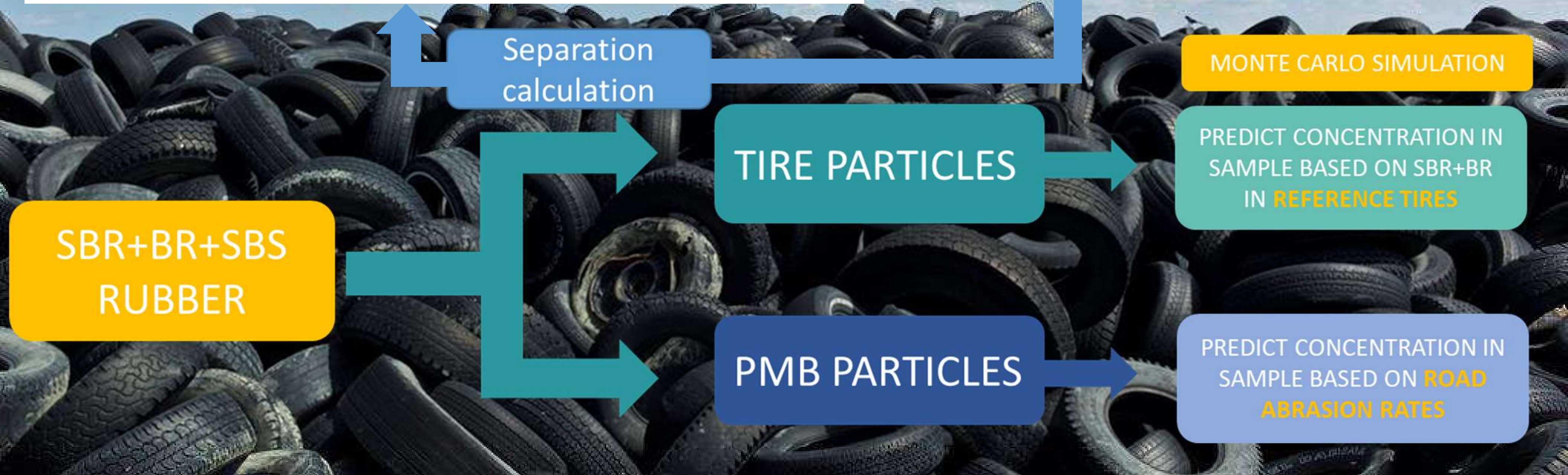
Emission factors (EFs)

Road surface	$EFA_{PV\text{-}st}$ (g/vkm)	$EFA_{HV\text{-}st}$ (g/vkm)	$EFA_{PV\text{-}nst}$ (g/vkm)	$EFA_{HV\text{-}nst}$ (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

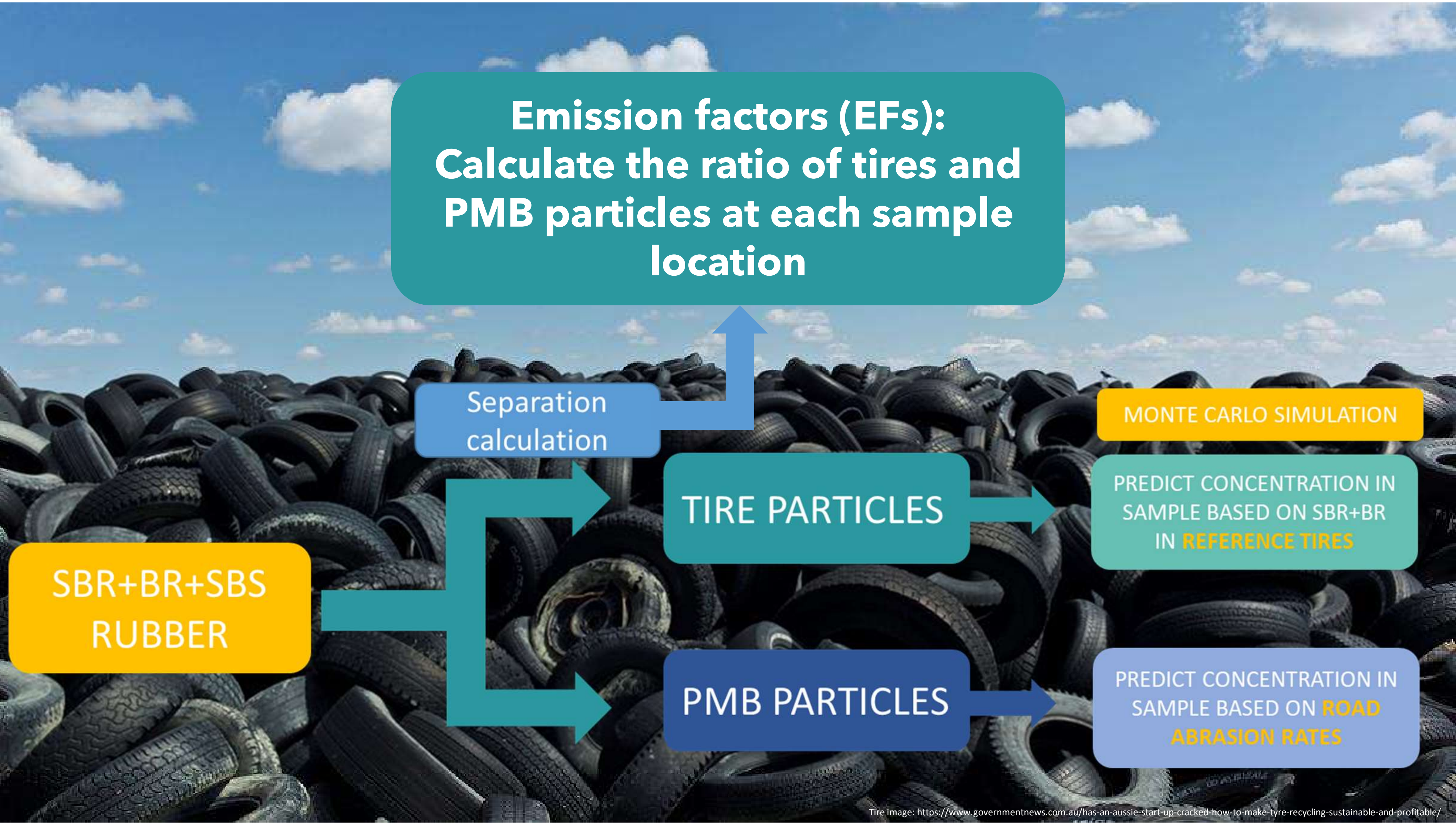
REF: Bakløkk et al., 1997; Horvli, 1996; Snilsberg, 2008; Snilsberg et al., 2016)

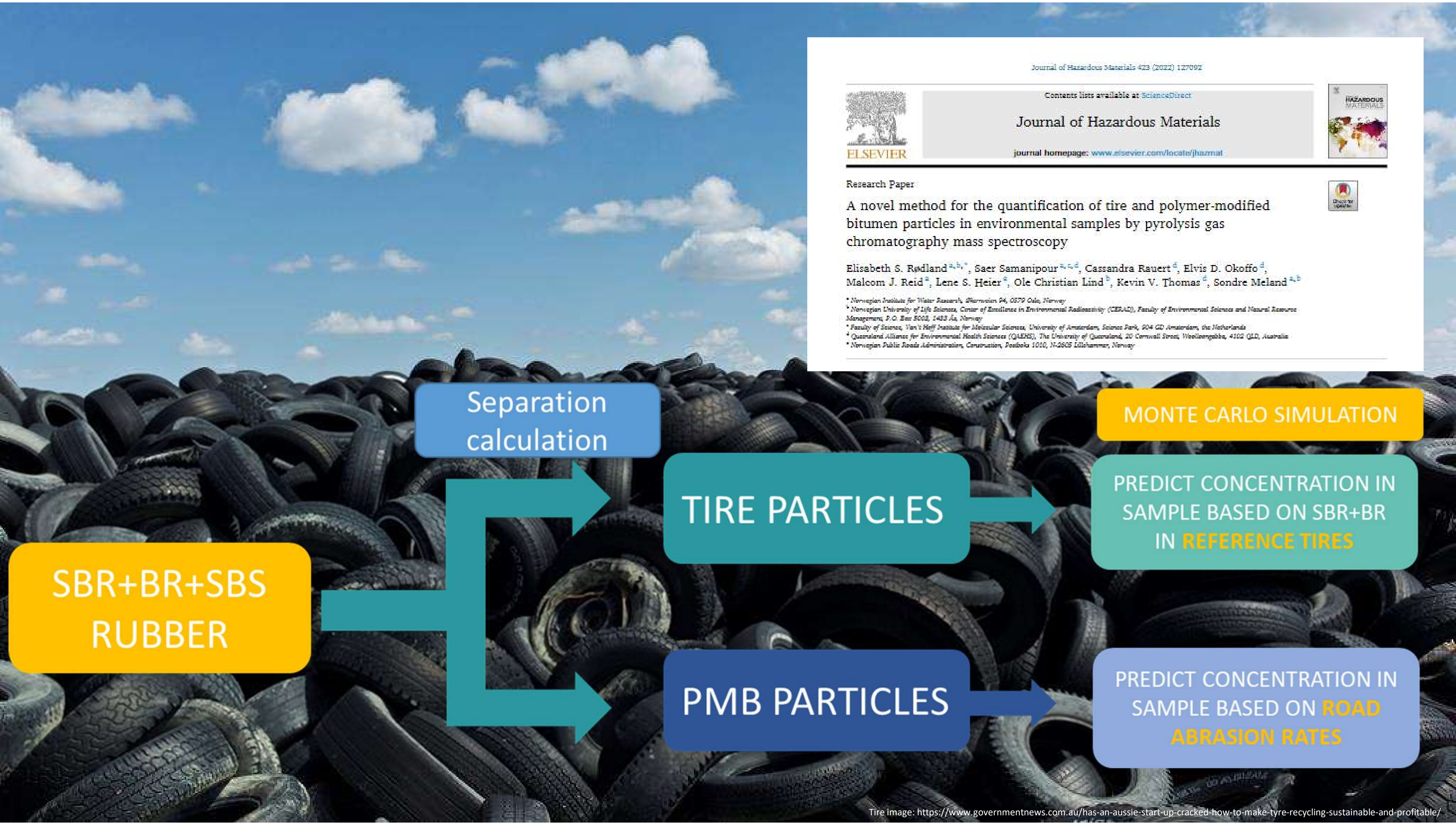
Tire	PV	HV
EFT_H	0.104	0.668
EFT_U	0.132	0.850

REF: Klein J. et al., 2017



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

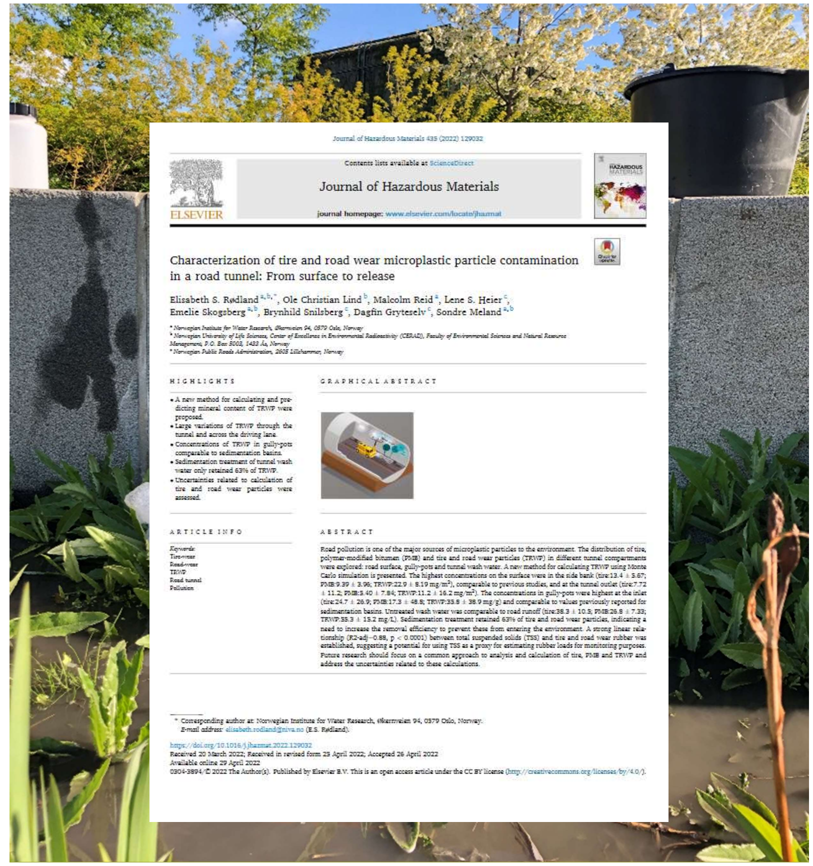

Emission factors (EFs):
Calculate the ratio of tires and PMB particles at each sample location
Separation calculation
MONTE CARLO SIMULATION
TIRE PARTICLES
PREDICT CONCENTRATION IN SAMPLE BASED ON SBR+BR IN REFERENCE TIRES
SBR+BR+SBS RUBBER
PMB PARTICLES
PREDICT CONCENTRATION IN SAMPLE BASED ON ROAD ABRASION RATES
Tire image: https://www.governmentnews.com.au/has-an-aussie-start-up-cracked-how-to-make-tyre-recycling-sustainable-and-profitable/


Journal of Hazardous Materials 423 (2022) 127092
Contents lists available at ScienceDirect
Journal of Hazardous Materials
journal homepage: www.elsevier.com/locate/jhazmat
ELSEVIER
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 Rauert d, Elvis D. Okoffo d, Malcom J. Reid a, Lene S. Heier e, Ole Christian Lind b, Kevin V. Thomas d, Sondre Meland a,b
a Norwegian Institute for Water Research, Økernveien 94, 0579 Oslo, Norway
b Norwegian University of Life Sciences, Center of Excellence in Environmental Radioactivity (CERAD), Faculty of Environmental Sciences and Natural Resource Management, P.O. Box 5003, 1433 Ås, Norway
c Faculty of Science, Van't Hoff Institute for Molecular Sciences, University of Amsterdam, Science Park, 904 GD Amsterdam, the Netherlands
d Queensland Alliance for Environmental Health Sciences (QAEHS), The University of Queensland, 20 Cornwall Street, Woolloongabba, 4102 QLD, Australia
e Norwegian Public Roads Administration, Construction, Postboks 1010, N-2605 Lillehammer, Norway
Separation calculation
SBR+BR+SBS RUBBER
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	AÅDT (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

Improved method applied to environmental samples



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

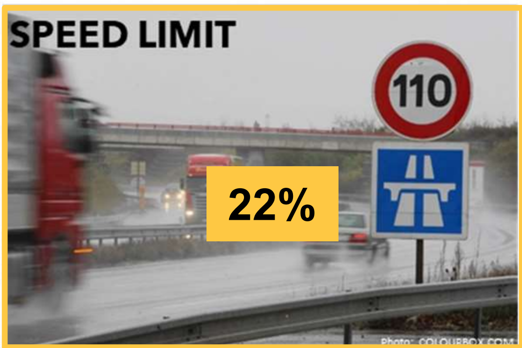
TWP mg/L	PMB mg/L
210 ± 111	40.7 ± 21.1

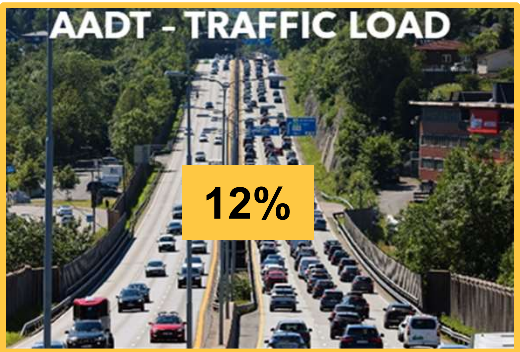
Road-side snow

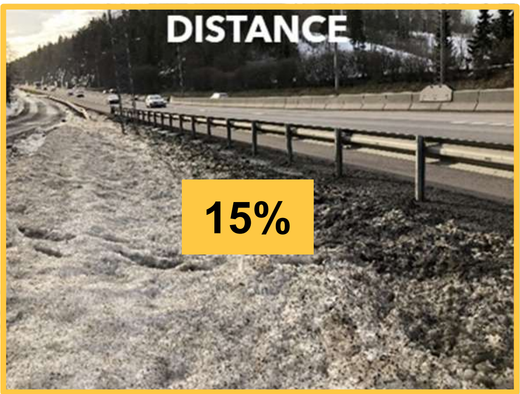
Hypothesis

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

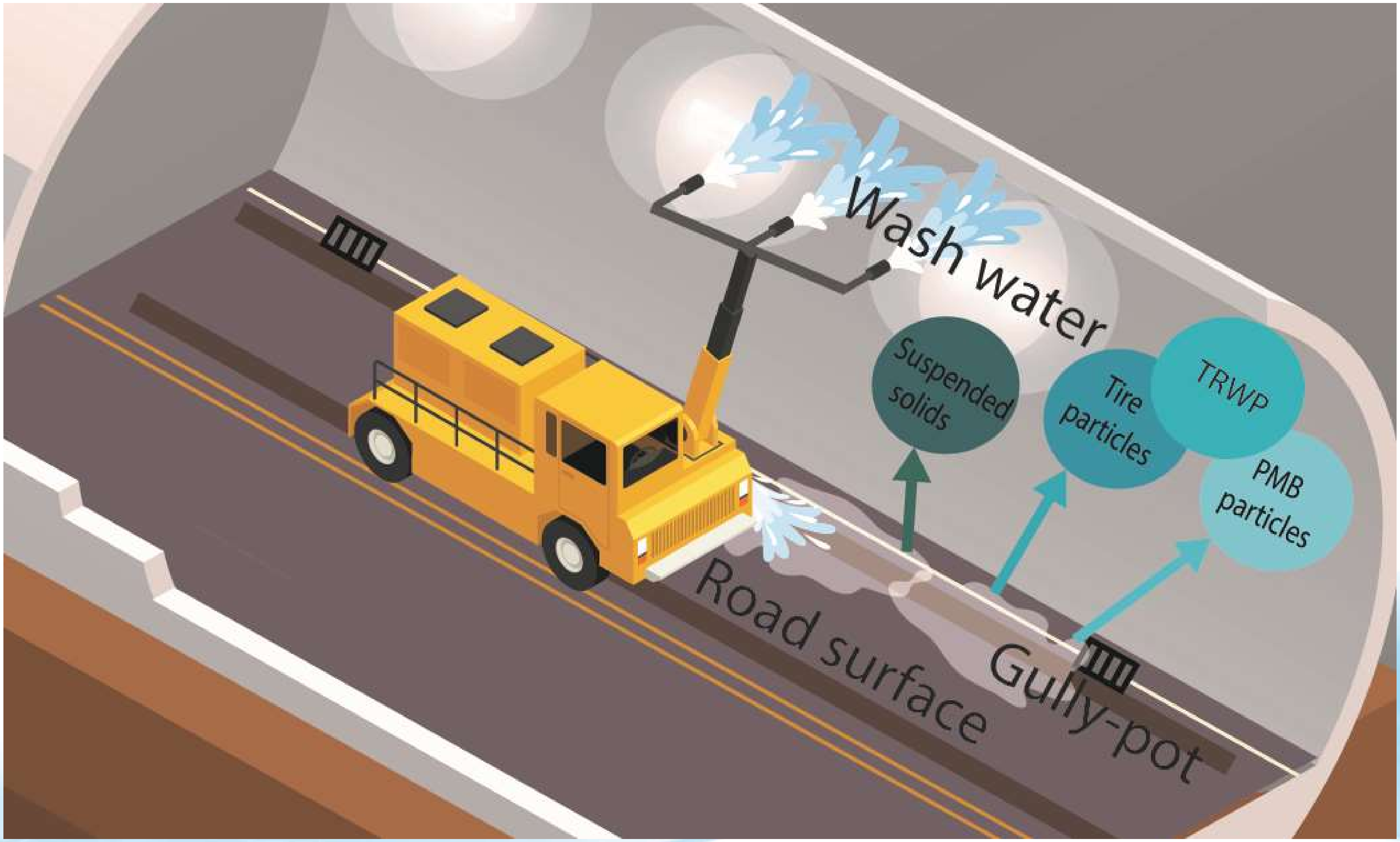
RDA analysis of significant explanatory variables







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/m²	PMB mg/m²
890 ± 1210	710 ± 961

Road tunnel

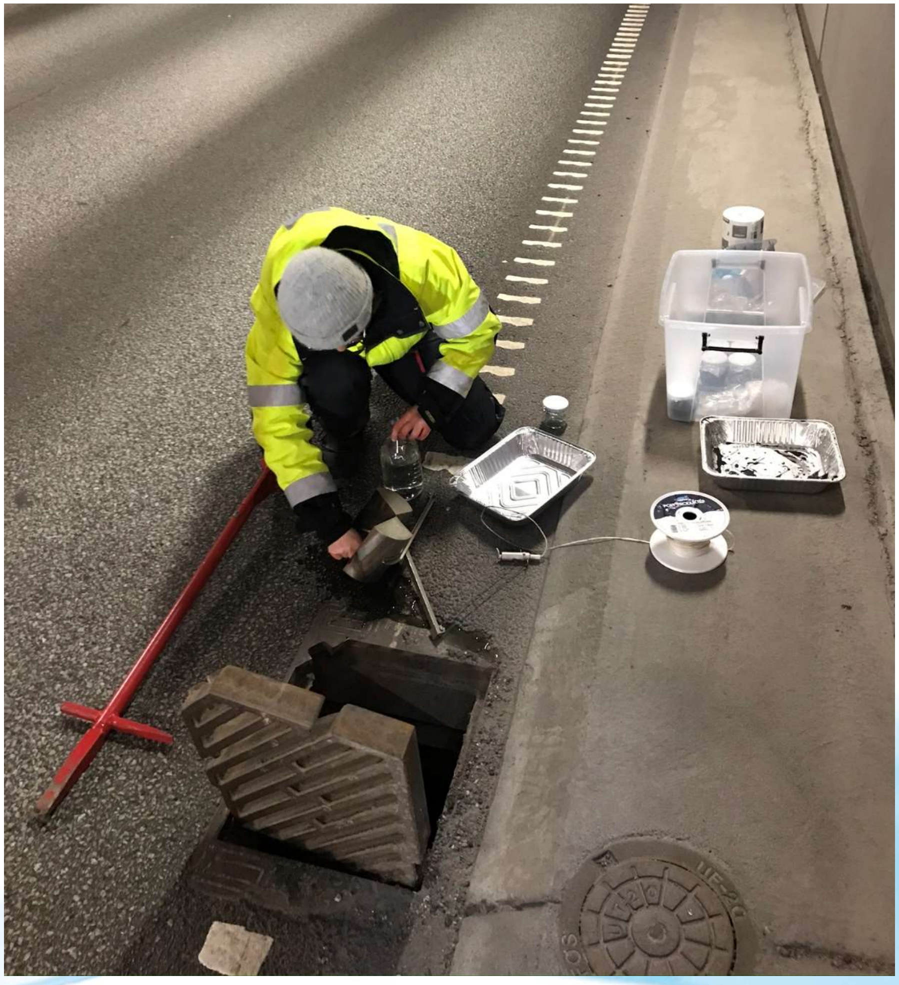
Hypothesis

- *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

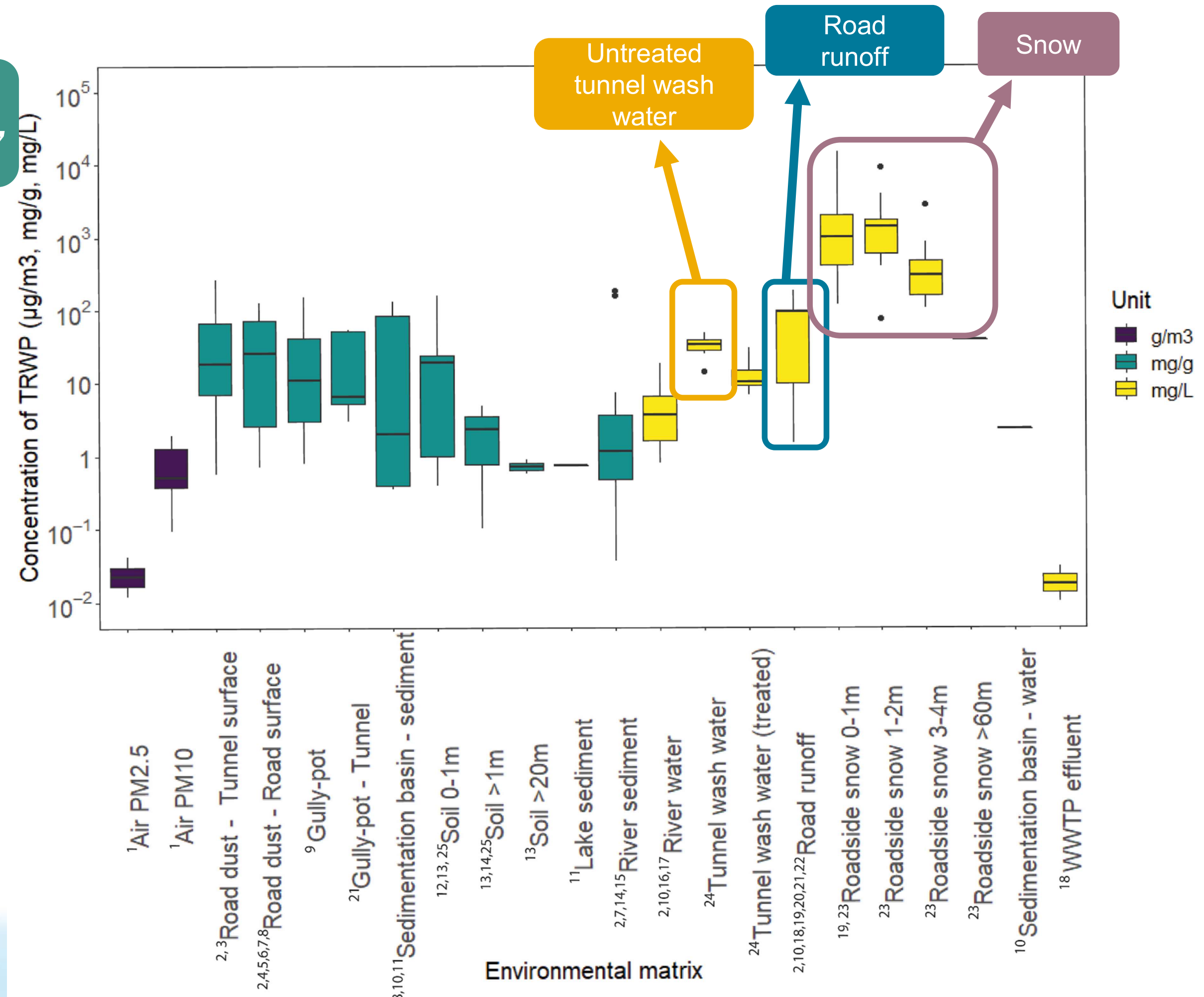
Hypothesis
- ***Road tunnels represent local "hot-spots"***

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

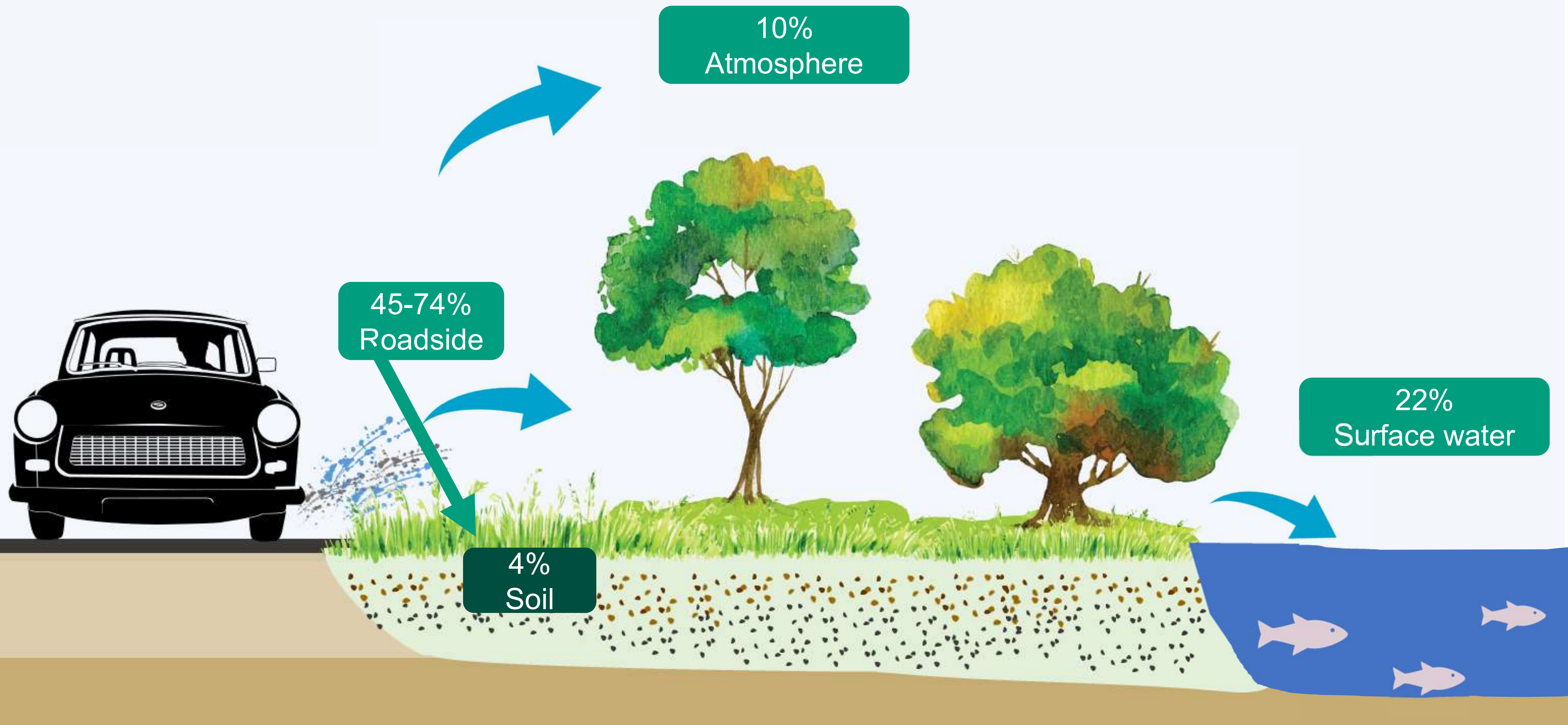
- **The sedimentation basin removed 63% of the rubber-particles (tire, PMB, TRWP)**



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)

NIVA

Tire wear particles …what about RWP particles?



REF: Sieber et al., 2020; Wagner et al., 2018

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

Norwegian Institute for Water Research

Statens vegvesen

NordFoU

Thank you!
Contact me for questions and collaborations

elisabeth.rodland@niva.no