Trace metal adsorption on tire and road wear particles (TRWP) in surface waters – A problem for water quality?

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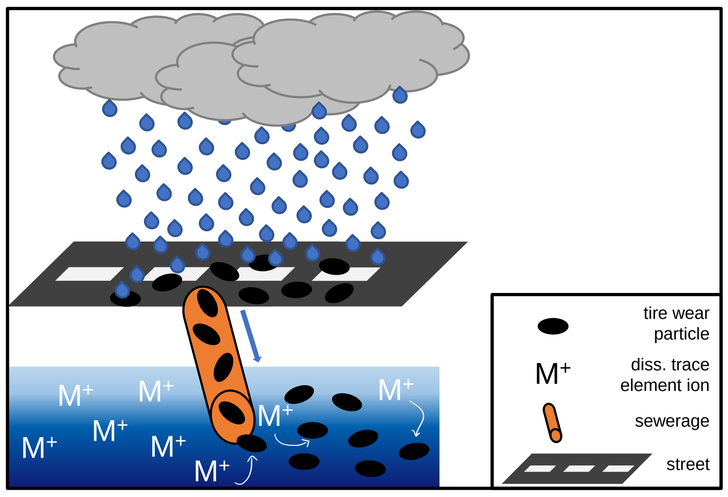

Fig. 1 Sketch of the emission of tire wear particles into the waters and adsorption of trace elements onto their surface.

Motivation

- tire wear particles (TWP) are a major source of microplastics (MP) in the environment
  - ➢ TWP estimated to make up to 30% of MP emissions[1]
- up to 20,000 t a^{-1} TWP emitted into German waters[2]
  - ➢ main entry paths: surface runoff and sewerage[2]
  - ➢ TWP-concentration up to 18 mg L^{-1} estimated in surface water[3]
- secondary effects e.g. due to **deposition of trace elements on the particles' surface in water samples are unknown** so far
- adsorption kinetics of Cd^{2+} and Pb^{2+} on artificial tire wear particles have been investigated[4,5]

➔ **close-to-nature experiments using environmental samples are necessary for risk assessments regarding the effects on the chemical water quality**

Methods

- 16.7 mg "**real world**" tire materials (TRWP+RS) weighed into glassware
- 1 L filtered water samples (0.2 µm) from Freiberger Mulde (Fig. 2) added
- shaken for 6 h, 24 h and 96 h on a shaking device (150 min^{-1}) + kinetics[5]
- filtration of the TRWP+RS samples (0.2 µm), subsequent drying
- digestion in microwave (*reverse aqua regia, V*(HNO_3):*V*(HCl) = 3:1) and trace element determination via ICP-MS/MS
- analogous experiments conducted using brake wear particles (BWP) and tire wear particles produced by filing (TWP/f)

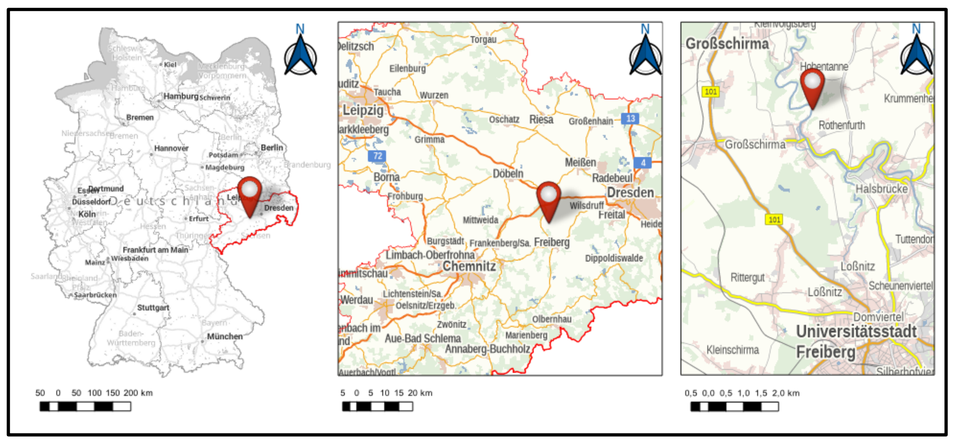

Fig. 2 Freiberger Mulde, Rothenfurth, Middle-Saxony, Germany. *QGIS. © BKG, GeoSn 2023.*

Tab. 1 Theoretical classification for heavy metals and arsenic on tire and road wear particles including road sediment (TRWP+RS I and II), tire wear particles produced by filing (TWP/f) and brake wear particles (BWP) by using the classification system of LAWA and ARGE ELBE* for suspended matter. Comparison of the "pure" material with the same material after adsorption experiments using filtered water samples of the Freiberger Mulde (particle concentration 16.7 mg L^{-1}). As a reference for the potential environmental impact of the different samples, the element classifications of the suspended matter in the River Elbe are given.

	TRWP+RS I traffic lane		TRWP+RS II tunnel		TWP/f laboratory		BWP brake test stand		Elbe	LAWA	
	"pure"	adsorption experiment	"pure"	adsorption experiment	"pure"	adsorption experiment	"pure"	adsorption experiment	suspended matter	quality class	explanation
Cr	I	III	III	III-IV	I	I	III-IV	III-IV	II-III	I	geogenic background
Ni	II	III	II-III	III	I	I-II	III	III	II	I-II	lightly polluted
Cu	III	III	IV	IV	I	I	IV	IV	II-III	II	moderately polluted
Zn	III-IV	IV	IV	IV	IV	IV	IV	IV	III-IV	II-III	critically polluted
As*	I-II	II-III	II	II	I	I	IV	IV	II-III	III	heavily polluted
Cd	I-II	IV	II	IV	I	II-III	I	II-III	III-IV	III-IV	very heavily polluted
Pb	I-II	I-II	II-III	II-III	I	I-II	II	II-III	II-III	IV	excessively polluted
TWP content	12%		22%		97%		---				

TRWP+RS I: tire and road wear particles including road sediment; *sample received from industrial partner,* ***traffic lane***
TRWP+RS II: tire and road wear particles including road sediment; *sample from A7* ***Neuer Elbtunnel****, Hamburg, Germany*
TWP/f: tire wear particles produced by filing; *sample self-produced in laboratory*
BWP: brake wear particles; *sample received from industrial partner, brake test stand*

Results

- **TRWP+RS I itself** is not more harmful than existing suspended matter in the River Elbe
- **TRWP+RS II** in general contains more priority trace elements than TRWP+RS I
  - ➢ accumulation of trace elements in tunnels?
- **TWP/f** potential source of **Zn**
- **BWP** potential source Cr, Cu, Zn, As, but especially **Cu** (regarding the element contents, *not shown*)
- **adsorption** of certain trace elements visible
  - ➢ TRWP+RS I: Cd >> **Cr** > Ni > As ≈ Pb > **Zn**
  - ➢ TRWP+RS II: Cd >> **Zn** > Ni > As ≈ Pb > **Cr** > Cu
  - ➢ TWP/f: Cr >> Ni > Cd > As > Pb > Cu
  - ➢ BWP: Pb > As
- **noticeable deterioration** of chemical water quality regarding suspended matter is expected
- fundamentally different kinds of adsorption of trace elements observed on TRWP+RS, TWP/f, BWP
  - ➢ TWP/f not suitable for answering environmentally relevant questions
  - ➢ binding properties of trace elements still unclear

Outlook

➔ investigations on the biogeochemical processes influencing the adsorption on trace elements of tire wear particles (biofilm, sedimentation, salinity)

Literature

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