Salt gradients in rivers change adsorption of Cd and Zn on tire and road wear particles – experimental approach

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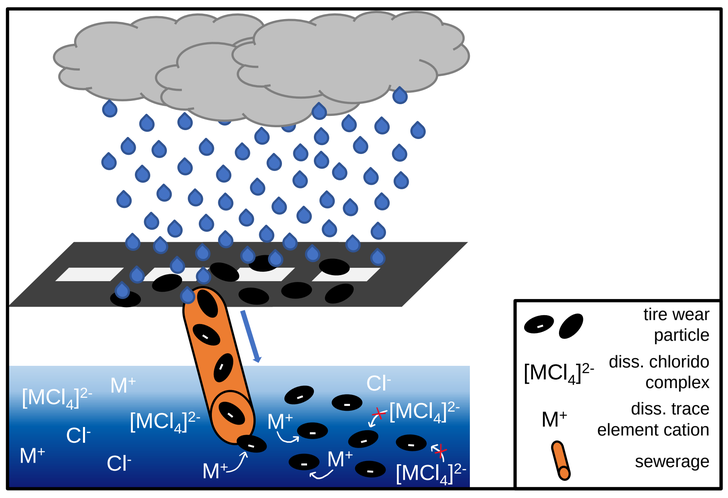

Fig. 1 Sketch of the emission of TWP into aquatic systems. Adsorption of trace elements, no adsorption of complexes.

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 TWP** emitted into German surface waters **per year** [2]
  - ➢ main entry paths: surface runoff and sewerage [2]
  - ➢ TWP-concentration up to 18 mg/L estimated in surface water [3]
- adsorption of trace elements on TWP under investigation and observed for Cr, Ni, Cd, Pb [4-6]
  - ➢ this adsorption could lead to a potential deterioration of the chemical water quality [6]
- all major rivers discharge into the sea experiencing a salt gradient influencing the adsorption
  - ➢ seasonal anthropogenic impacts like gritting roads with salt in winters

➔ **This study investigated influence of varying salt concentrations on the adsorption of trace elements**

Methods

- adapted from Glaubitz et al. (2023) [5] and Rocha Vogel et al. (2024) [6]
- 16.7 mg "**real world**" tire materials (TRWP+RS) weighed into glassware
- NaCl added to obtain the required salt concentrations
  - ➢ six samples ranging from 0.15 g/L Cl^- (Freiberger Mulde) to 15.2 g/L Cl^- (tidal Elbe, Northsea) (s. Fig. 2)
- 1 L filtered water samples (0.2 µm) from Freiberger Mulde added
- samples shaken for 24 h on a shaking device (150 min^{-1})
- 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

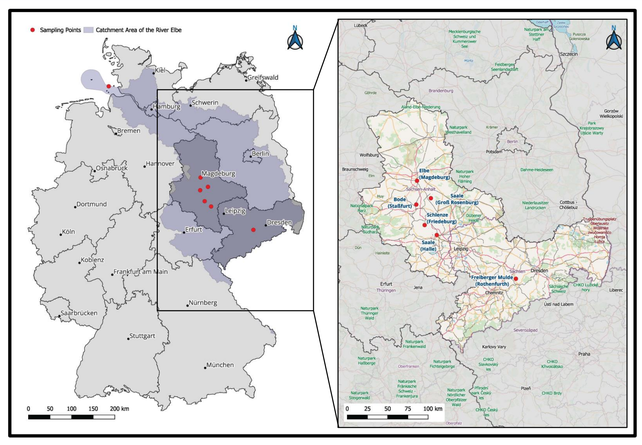

Fig. 2 Sampling sites along the Elbe catchment area. *QGIS. © GeoBasis-DE / BKG (2024)* [7].

Tab. 1 Theoretical classification of priority trace elements (Cr, Ni, Cu, Zn, Cd, Pb, As*) by the LAWA (*ARGE ELBE) system for suspended matter for TRWP+RS treated with water from the Freiberger Mulde resembling the salt concentration of both Freiberger Mulde and tital Elbe (Northsea). Comparison with the classification of suspended matter in the river Elbe [8].

	TRWP+RS *before ads. exp.*	TRWP+RS in *Freiberger Mulde*	TRWP+RS in *tidal Elbe* (Northsea)	Elbe[8]	LAWA	
β(Cl^-) / mg/L	---	146	15,200	suspended matter	quality class	explanation
Cr	III	III	III	II-III	I	geogenic background
Ni	II-III	III	III	II	I-II	lightly polluted
Cu	IV	IV	IV	II-III	II	moderately polluted
Zn □	IV	IV	IV	III-IV	II-III	critically polluted
As*	II	II	II	II-III	III	heavily polluted
Cd ▲	II	IV	II-III	III-IV	III-IV	very heavily polluted
Pb	II-III	II-III	II-III	II-III	IV	excessively polluted

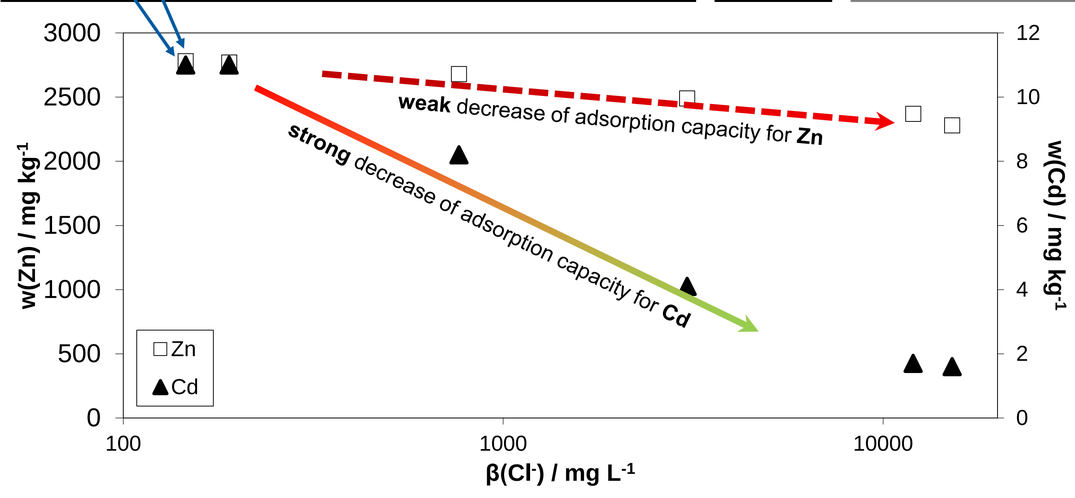

Fig. 3 Dependency of **Cd** and **Zn** content in and on TRWP+RS on the salt concentration.

Results

- **Cu** and **Zn** in **TRWP+RS** (before ads. exp.) could pose an endangering for suspended matter in rivers
- **after adsorption experiment** (*Freiberger Mulde*) significant adsorption of especially **Cr, Ni, (Zn)** and **Cd** on TRWP+RS was observed
  - ➢ this could lead to a **deterioration** **of the chemical water quality** of the suspended matter referring to **Cr, Ni, Zn** and especially **Cd**.
  - ➢ **Zn** is not likely to be adsorbed by the TWP in TRWP+RS but by other components (road or brake wear) in this TRWP+RS sample
- **increasing salt concentrations** change some adsorption properties
  - ➢ adsorption of **Cd** and **Zn** on TRWP+RS is weaker while increasing salt concentration (s. Tab. 1 and Fig. 3)
  - ➢ Cd and Zn can form $[MCl_4]^{2-}$-complexes [9], which do not readily bind to the negatively charged TRWP+RS surface [10]
  - ➢ adsorption of **Cr, Ni, Cu, As** and **Pb** on TRWP+RS is **not affected**

Conclusion and Outlook

- these findings are helpful assessing the **potential risks** posed by trace elements adsorbed onto TRWP(+RS), predicting the binding properties of trace elements on TRWP(+RS) in environmental relevant contexts
  - ➢ e. g. large river systems, water retention projects (sponge city)
- further investigations regarding other biogeochemical processes (biofilm, sedimentation) are needed

Literature

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Abbreviations

ads. exp. adsorption experiment
TRWP+RS: tire and road wear particles including road sediment
TRWP: tire and road wear particles
TWP: tire wear particles

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