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Binding Properties of Heavy Metals on Tire and Road Wear Particles in the Aquatic Environment

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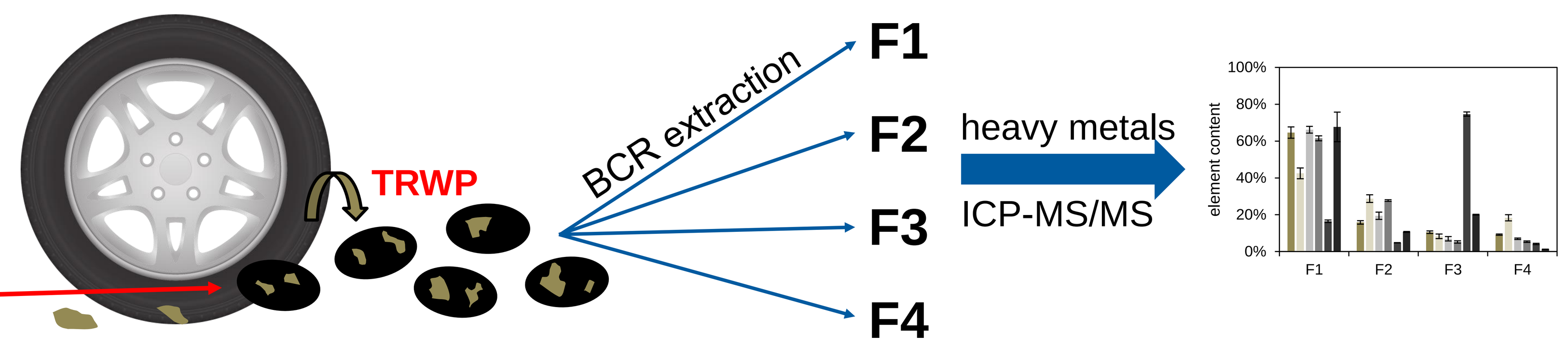
Motivation

- 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 incorporate other traffic-related particles,** becoming **TRWP** (*tire and road wear particles*) [2,3]
  - ➢ TRWP have higher amount of **heavy metals** due to attached traffic-related particles (brake lining, road wear particles) [4]
  - ➢ attached heavy metals can lead to a **deterioration of the chemical water quality** [5]

➔ **still unclear: bioavailability of heavy metals from TRWP in the aquatic environment**

Methods

- sequential extraction (F1–4) adapted from Ure et al. (1998) [6] (BCR extraction) for different **tire-related samples**



- additional incubation experiment adapted from Rocha Vogel et al. (2025) [7]
  - ➢ 350 mg tire-related sample incubated in 20 L pre-filtered (0.2 µm) water sample of the Freiberger Mulde (high in heavy metals) for 24 h
  - ➢ tire-related sample recovered through filtration
  - ➢ BCR extraction of dried tire-related sample

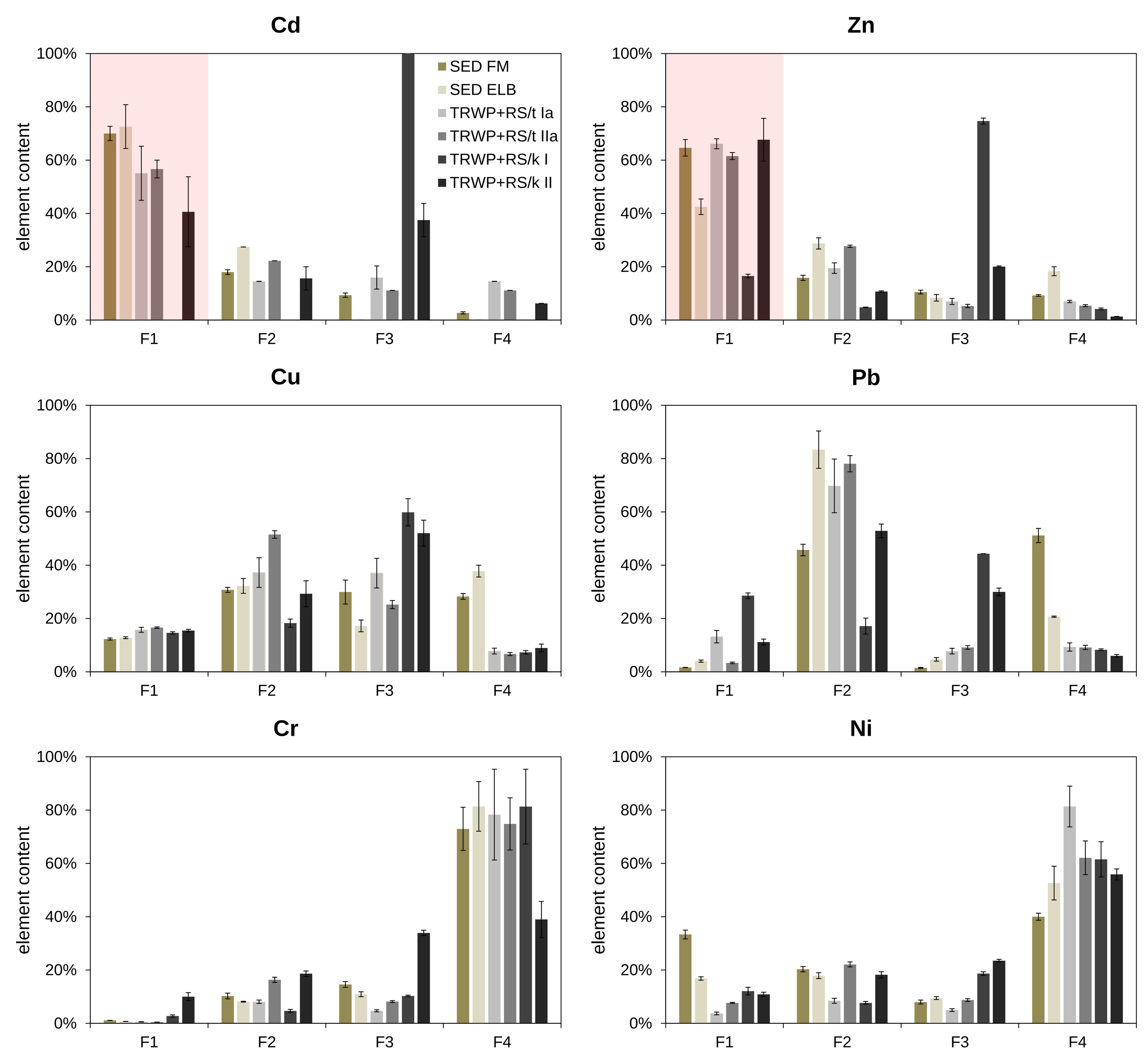


Fig. 1: Relative element distribution of Cr, Ni, Cu, Zn, Cd and Pb as derived from BCR extraction for sediment samples of the Freiberger Mulde (SED FM) and Elbe (SED ELB), as well as for TRWP+RS/t from the Elbtunnel (Ia = beginning, IIa = middle) and TRWP+RS/k from kart tracks (I & II). Standard deviation given as uncertainty.

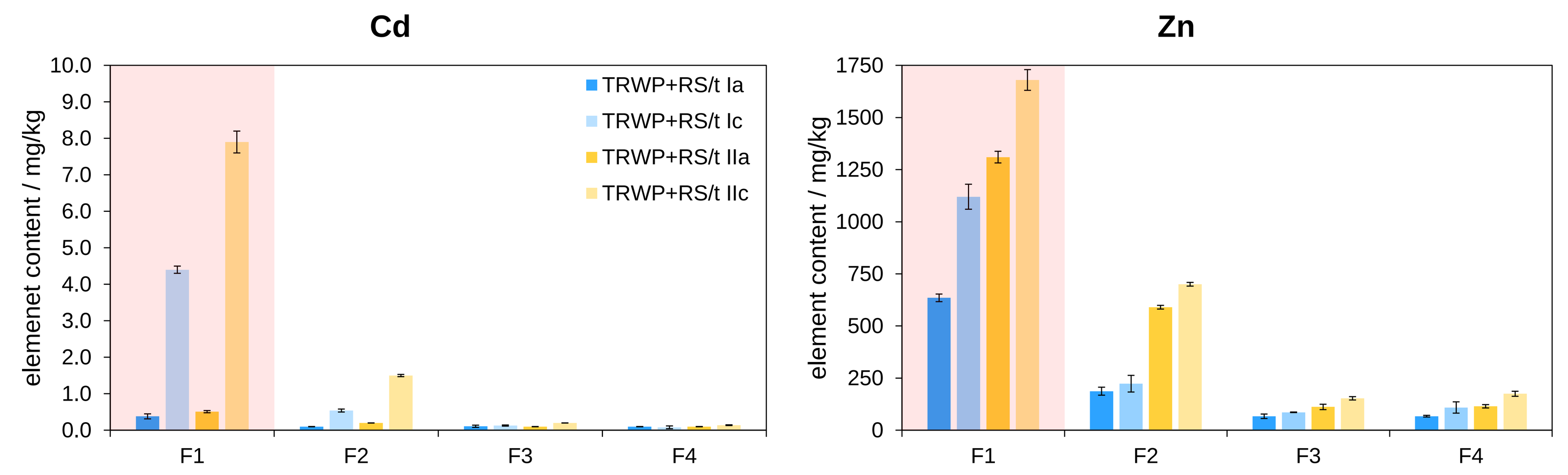


Fig. 2: Element distribution of Cd and Zn as derived from BCR extraction for TRWP+RS/t from the Elbtunnel (I = beginning, II = middle) before (a) and after (c) incubation experiments. The uncertainty is given by the first standard deviation. Standard deviation given as uncertainty.

Results

- F1 and F2 are considered to be bioavailable to organisms
  - ➢ F1 under aerobic, F2 under anaerobic conditions
- **in general** behavior of heavy metals from tire-related samples is **similar** to sediment samples (**Fig. 1**)
  - ➢ heavy predominantly from other particles than TWP (rubber)
  - ➢ tire-related samples have higher amounts of heavy metals compared to sediments from Elbe (**Tab. 1**)
- **Zn & Cd** easily bioavailable
- **Pb** mostly in F2, F3 pattern similar to Zn and Cd
- **Cu** evenly distributed among the fractions
- **Cr & Ni** mostly in residual fraction (F4)
- **freshly adsorbed Cd and Zn are highly bioavailable** (**Fig. 2**)
  - ➢ potential health risk for (micro-)organisms after uptake of TRWP+RS/t

Tab. 1: Element and approximate TWP content of different tire and road wear particles including road sediment (TRWP+RS) as well as of river sediment from Freiberger Mulde and Elbe. Theoretical classification of trace element contents by LAWA [8]. Values including first standard deviation.

size	TRWP+RS/t Ia 20–200 µm	TRWP+RS/t Ib 200–630 µm	TRWP+RS/t IIa 20–200 µm	TRWP+RS/t IIb 200–630 µm
Cr / mg kg^{-1}	237 ± 27	147 ± 4	381 ± 28	183 ± 13
Ni / mg kg^{-1}	105 ± 13	24 ± 6	115 ± 8	37 ± 7
Cu / mg kg^{-1}	541 ± 80	214 ± 40	1110 ± 60	637 ± 90
Zn / mg kg^{-1}	974 ± 60	666 ± 130	2220 ± 80	1350 ± 300
Cd / mg kg^{-1}	0.70 ± 0.08	0.33 ± 0.06	1.0 ± 0.1	2.0 ± 0.8
Pb / mg kg^{-1}	107 ± 11	48 ± 6	167 ± 13	101 ± 24
TWP content / %	9.4	6.4	21	13
size	TRWP+RS/k I 20–200 µm	TRWP+RS/k II 20–200 µm	Elbe 20–200 µm	Freiberger Mulde 20–200 µm
Cr / mg kg^{-1}	337 ± 110	82 ± 6	52 ± 12	41 ± 4
Ni / mg kg^{-1}	107 ± 15	36 ± 4	21 ± 1.2	32 ± 1.8
Cu / mg kg^{-1}	142 ± 12	119 ± 18	19 ± 1.5	241 ± 20
Zn / mg kg^{-1}	4500 ± 250	4550 ± 170	244 ± 30	4640 ± 300
Cd / mg kg^{-1}	0.27 ± 0.05	1.3 ± 0.07	0.88 ± 0.15	32 ± 3
Pb / mg kg^{-1}	57 ± 3	388 ± 29	33 ± 1.3	1880 ± 110
TWP content / %	69	71	n. a.	n. a.

I	geogenic background
I-II	lightly polluted
II	moderately polluted
II-III	critically polluted
III	heavily polluted
III-IV	very heavily polluted
IV	excessively polluted

Conclusion and Outlook

- the BCR extraction is a **suitable method** to describe the binding properties of heavy metals on tire-related materials
- risk assessment of heavy metals from tire-related samples possible
- important for water retention projects like **Blue-Green Cities**

Literature

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Abbreviations

TRWP+RS: tire and road wear particles including road sediment
TRWP: tire and road wear particles
TWP: tire wear particles
k: kart track
t: highway tunnel

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