

# Wastewater inflows into rivers can lead to mobilization of Cd and Zn from tire and road wear particles induced by dissolved organic matter

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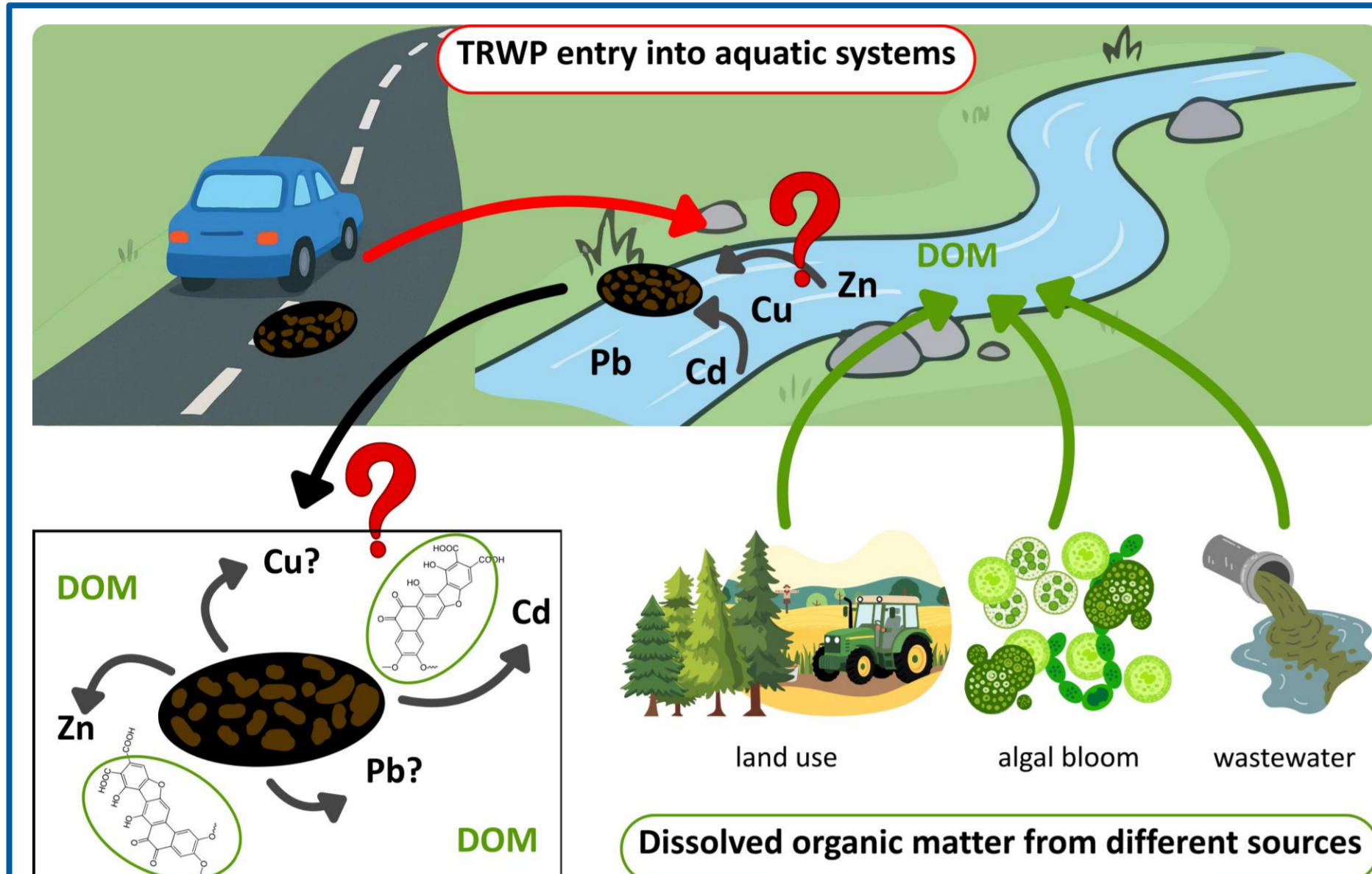
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## Motivation

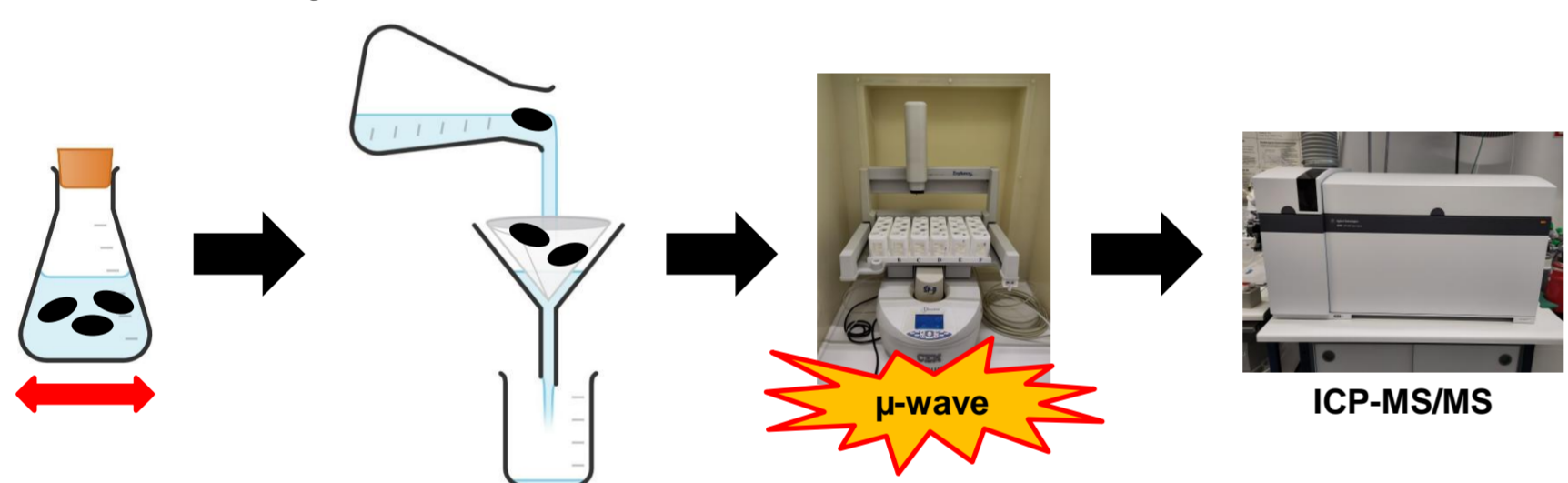
- tire and road wear particles (TRWP) are a major source of microplastics in the environment
  - TRWP estimated to make up to 30% of MP emissions [1]
- up to **20 % of TRWP** are emitted into German surface waters **per year** [2]
  - main entry paths: surface runoff and sewerage [2]
- adsorption of heavy metals on TRWP have been observed for Cr, Ni, Zn, Cd, Pb [3–5]
  - this adsorption could lead to a potential deterioration of the chemical water quality [5]
- all major rivers experience a change in composition and quality of dissolved organic matter [6]
  - dissolved organic matter (DOM) complexation of heavy metals is dependent on its quality [7]

→ This study investigated influence of different **DOM** on the adsorption of heavy metals

Fig. 1 Sketch of the emission of TRWP into aquatic systems. Adsorption of trace elements may be influenced by DOM.

## Materials and Methods

- 16.7 mg “real world” tire materials (TRWP+RS) weighed into glassware
- 1 L filtered water samples (0.2 μm) from different sources (s. Fig. 2)
- samples shaken for 24 h on a shaking device (150 min<sup>-1</sup>)
- filtration of the TRWP+RS samples (0.2 μm), subsequent drying, digestion in microwave (reverse aqua regia, V(HNO<sub>3</sub>):V(HCl) = 3:1) and heavy metal determination via ICP-MS/MS



- characteristics of **DOM** measured by 2D fluorescence
- DOM derived from household **wastewater** (treated and untreated), **forested streams** and **algal blooms**

## Results

Tab. 1 Relative change in heavy metal content (Cr, Ni, Cu, Zn, Cd, Pb) for TRWP+RS/t (highway tunnel) and TRWP+RS/k (kart track) after adsorption experiment (24 h) with water samples exhibiting different DOM characteristics. Getamej (upstream Yerevan), Yerevanyan Lake (algal bloom), Ghukasavan (downstream inflow WWTP Yerevan, protein-like substances), WWTP Gerwisch (Germany, treated wastewater), Rote Mulde (Germany, humic substances), Freiburger Mulde (Germany, elevated heavy metal concentrations). Light green: > 10 %; green > 20 %; light red: < -10 %; red: < -20 %.

TRWP+RS/t (highway tunnel, 22 % rubber content)	Cr	Ni	Cu	Zn	Cd	Pb	DOC / mg/L
Getamej (upstream Yerevan, Armenia)	0.3 %	-17 %	-9.5 %	-22 %	-10 %	2.4 %	4.16
Yerevanyan Lake (Yerevan, Armenia)	4.5 %	-18 %	-15 %	-20 %	10 %	0.0 %	10.4
Ghukasavan (downstream WWTP Yerevan, Armenia)	12 %	-1.6 %	-18 %	-28 %	0.0 %	14 %	29.7
WWTP Gerwisch (Magdeburg, Germany)	10 %	-4.9 %	-10 %	-21 %	-10 %	-1.8 %	14.5
Rote Mulde (Grünbach, Germany)	33 %	17 %	-33 %	-65 %	-20 %	-35 %	21.9
WWTP Gerwisch + heavy metal standard	6.6 %	-5.0 %	-18 %	-11 %	490 %	29 %	14.5
Rote Mulde + heavy metal standard	34 %	33 %	-13 %	-33 %	30 %	9.0 %	21.9
Freiburger Mulde	9.4 %	0.5 %	-13 %	20 %	1100 %	3.6 %	5.01
TRWP+RS/k (kart track, 72 % rubber content)	Cr	Ni	Cu	Zn	Cd	Pb	DOC / mg/L
Getamej (upstream Yerevan, Armenia)	26 %	-8.3 %	9.1 %	-6.4 %	-15 %	-26 %	4.16
Yerevanyan Lake (Yerevan, Armenia)	21 %	2.8 %	3.6 %	-1.3 %	15 %	-36 %	10.4
Ghukasavan (downstream WWTP Yerevan, Armenia)	56 %	25 %	16 %	-10 %	0.0 %	-10 %	29.7
WWTP Gerwisch (Magdeburg, Germany)	4.9 %	-8.3 %	0.9 %	-16 %	-31 %	-35 %	14.5
Rote Mulde (Grünbach, Germany)	74 %	64 %	1.8 %	-10 %	-7.7 %	-28 %	21.9
WWTP Gerwisch + heavy metal standard	66 %	86 %	11 %	-7.0 %	100 %	-10 %	14.5
Rote Mulde + heavy metal standard	63 %	67 %	-12 %	-5.5 %	7.7 %	-28 %	21.9
Freiburger Mulde	63 %	41 %	-6.7 %	-2.0 %	220 %	-17 %	5.01

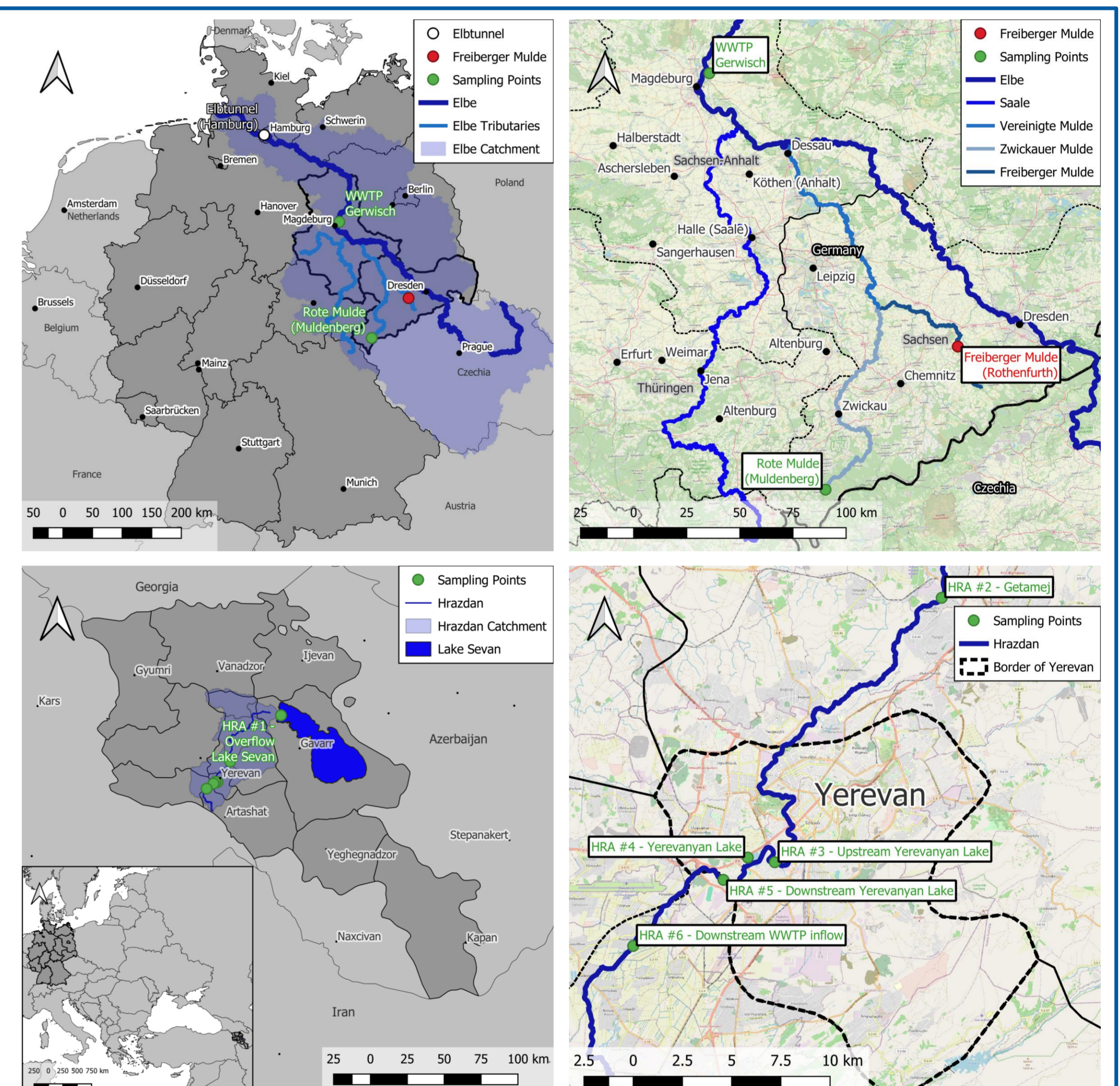


Fig. 2 Sampling sites in Germany and Armenia. Maps created using QGIS.

## Conclusion

- wastewater inflow into River Hrazdan mobilized **Zn** and **Cu** from TRWP samples
  - adsorption of **Cd** and **Zn** to TRWP is hindered by **DOM** originating from **treated wastewater**
  - mobilization** of **Cd** and **Zn** from TRWP is possible, when the amount of **wastewater** exceeds 25 % in rivers
  - water samples rich in **humic acids** show greater mobilization potential than **wastewater**
  - no significant effects were observed for **DOM** from **algal blooms** in the Yerevanyan Lake
- In summer or during droughts, **mobilization** of **Cd** and **Zn** may be more pronounced

## Literature

- [1] J. Bertling, R. Bertling, L. Hamann, *Kurzfassung der Konsortialstudie*, Fraunhofer UMSICHT, Oberhausen, 2018.  
 [2] B. Baensch-Baltruschat, B. Kocher, C. Kochleus, F. Stock, G. Reifferscheid, *Sci. Total Environ.*, 2021, 752, 141939.  
 [3] X. Fan, Z. Ma, Y. Zou, J. Liu, J. Hou, *Environ. Res.*, 2021, 195, 110858.  
 [4] F. Glaubitz, A. Rocha Vogel, Y. Kolberg, W. von Tümpling, H. Kahlert, *Environ. Pollut.*, 2023, 335, 122293.  
 [5] A. Rocha Vogel, Y. Kolberg, M. Schmidt, H. Kahlert, W. von Tümpling, *Environ. Pollut.*, 2024, 359, 124571.  
 [6] N. Kamjunke, N. Hertkorn, M. Harir, P. Schmitt-Kopplin, C. Griebler, M. Brauns, W. von Tümpling, M. Weitere, *Water Res.*, 2019, 164, 114919.  
 [7] S. Baken, F. Degryse, L. Verheyen, R. Merckx, E. Smolders, *Environ. Sci. Technol.*, 2011, 45, 2584.

## Abbreviations

- DOC:** dissolved organic carbon  
**DOM:** dissolved organic matter  
**TRWP:** tire and road wear particles  
**TRWP+RS:** tire and road wear particles including road sediment  
**WWTP:** wastewater treatment plant

