UFZ HELMHOLTZ Centre for Environmental Research

Junge Umweltchemie & Ökotoxikologie

FRIEDRICH-SCHILLER-UNIVERSITÄT JENA

# Tire and Road Wear Particles in Water

*What happens at the particle surface?*


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Friedrich Schiller University Jena



sponsored by DBU Deutsche Bundesstiftung Umwelt


**28th November 2024**

Tire wear in the environment

(*HS Zittau Görlitz, online*)

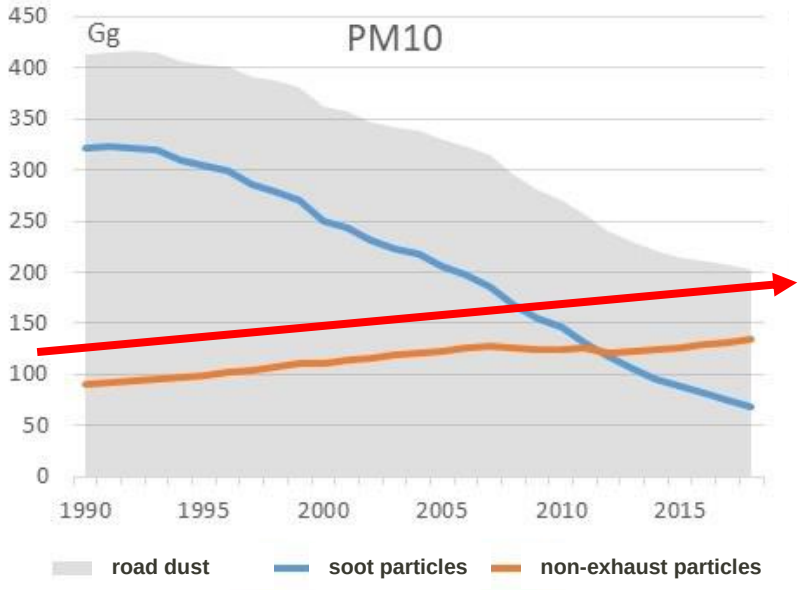
# Overview

- **Motivation**
  - Why are tire wear particles an **environmentally issue**?
  - What are potential **pathways** into the (aquatic) environment?
  - What are **relevant processes** that take place in the water with/on tire abrasion?
- **Adsorption of trace elements** on tire wear particles
  - Adsorption **kinetics**
  - Comparison of different **tire wear samples**
- **Separation of tire wear particles** from environmental samples
- **Conclusion & summary**
- **Outlook**

# Motivation

*Why are tire wear particles an environmentally issue?*

- 1327 kt/a tire wear in **EU**
  - 100–133 kt/a tire wear in **Germany**
  - **1–2 kg/a per capita**
  - **$\varepsilon_F \approx 100$ mg/vkm**
- approx. **30 % of microplastics emissions**
- legal regulation in EU
  - microplastics: **Directive (EU) 2019/904**
  - exhaust emissions: **Regulation (EG) 715/2007**
  - particulate matter: **Directive 2008/50/EG**
- **no EU regulations for tire wear particles!**
  - ➢ **Euro 7 standard** in legislative process



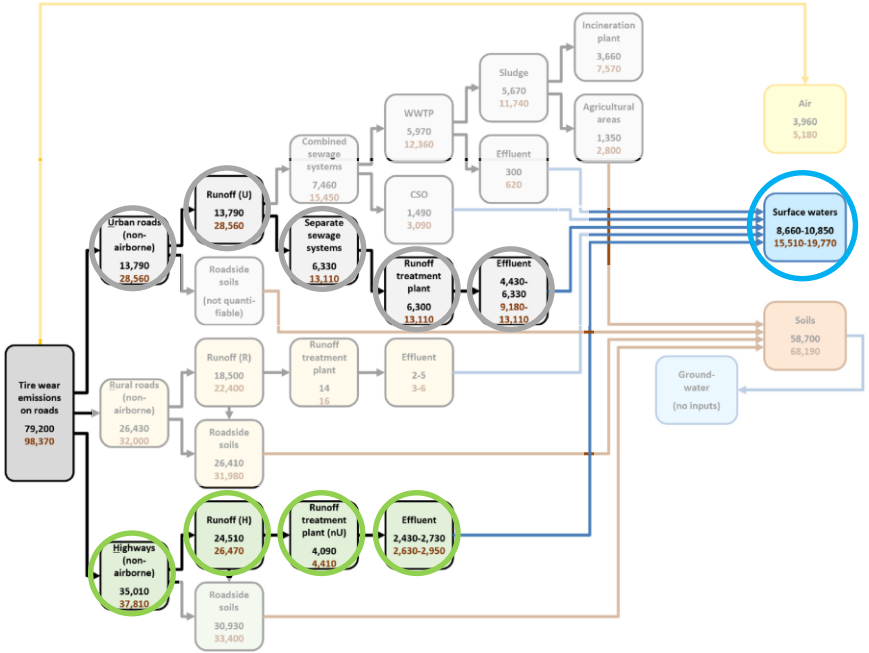


Bertling, J.; Bertling, R.; Hamann, L. Fraunhofer-Institut für Umwelt-, Sicherheits- und Energietechnik UMSICHT: Oberhausen, **2018**.
Hillenbrand, T.; Toussaint, D.; Böhm, E.; Fuchs, S.; Scherer, U.; Rudolphi, A.; Hoffmann; M. TEXTE 19/05; Dessau-Roßlau, **2005**.
Sommer, F.; Dietze, V.; Baum, A.; Sauer, J.; Gilge, S.; Maschowski; Gieré, R.; *Aerosol Air Qual. Res.* **2018**, *18*, 2014.
Wagner, S.; Hüffner, T.; Klöckner, P.; Wehrhahn, M.; Hofmann, T.; Reemtsma, T.; *Water Res.* **2018**, *138*, 83.
https://www.eea.europa.eu/data-and-maps/dashboards/air-pollutant-emissions-data-viewer-4

# Motivation

*What are potential pathways into the (aquatic) environment?*

- **≈ 100,000 t/a** in Germany





- pathways into **surface waters**:
  - **streets in the urban area**
    - ➢ separate sewerage system
  - **motorways**

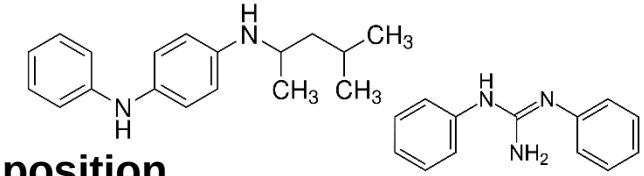
➢ **up to 20,000 t/a into surface waters**


Baensch-Baltruschat, B.; Kocher, B.; Kochleus, C.; Stock, F.; Reifferscheid; *Sci. Total Environ.* **2021**, *752*, 141939.
Hillenbrand, T.; Toussaint, D.; Böhm, E.; Fuchs, S.; Scherer, U.; Rudolphi, A.; Hoffmann; M. TEXTE 19/05; Dessau-Roßlau, **2005**.

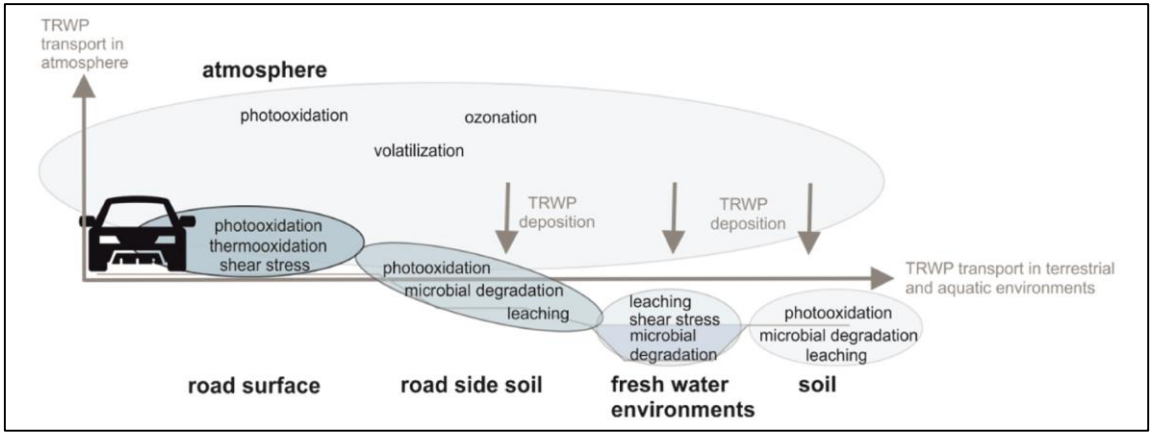
# Motivation

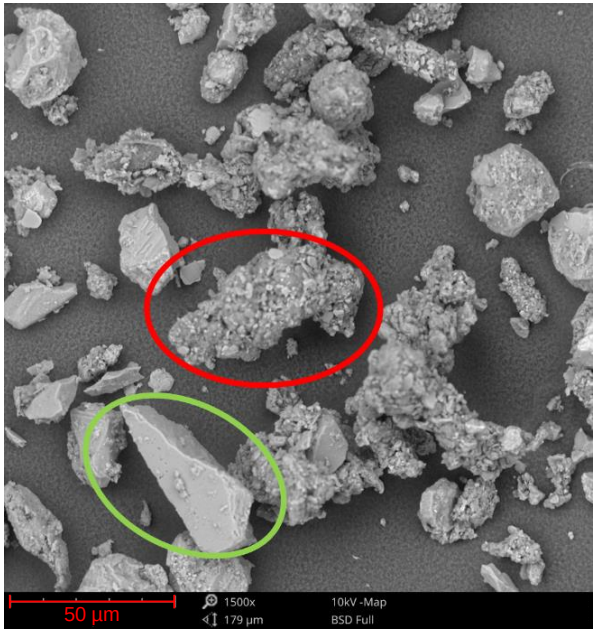
*What are relevant processes that take place in the water with/on tire abrasion?*

- **leaching**
  - Zinc, 6-PPD, DPG, …



- **degradation and decomposition**



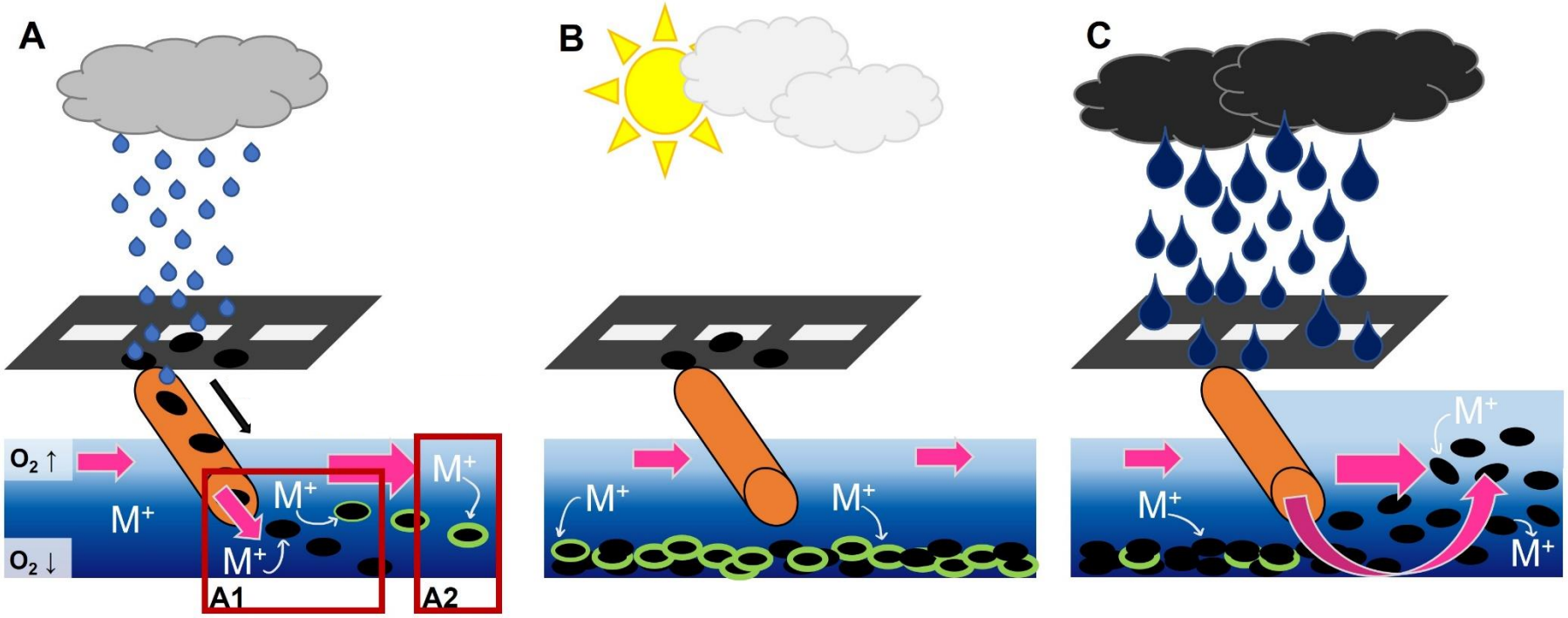

- interactions with **aquatic organisms**


Glaubitz, F.; **Rocha Vogel, A.**; Kolberg, Y.; von Tümpling, W.; Kahlert, H. *Environ. Pollut.* **2023**, *335*, 122293.
Müller, K.; Hübner, D.; Huppertsberg, S.; Knepper, T. P.; Zahn, D.; *Sci. Total Environ.* **2022**, *802*, 149799.
**Rocha Vogel, A.**; Kolberg, Y.; Schmidt, M.; Kahlert, H.; von Tümpling, W. *Environ. Pollut.* **2024**, *359*, 124571.
Wagner, S.; Klöckner, P.; Reemtsma, T.; *Chemosphere* **2022**, *288*, 132467.

# Motivation

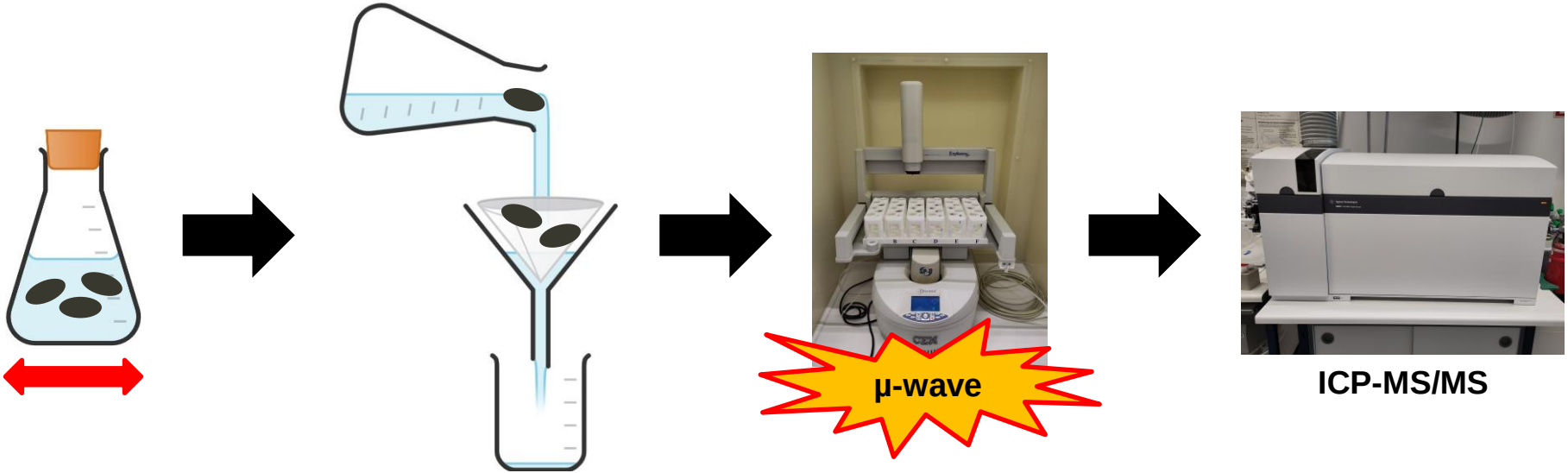
*What are relevant processes that take place in the water with/on tire abrasion?*

- **interactions with trace elements**



# Experimental approach

*Adsorption experiments*



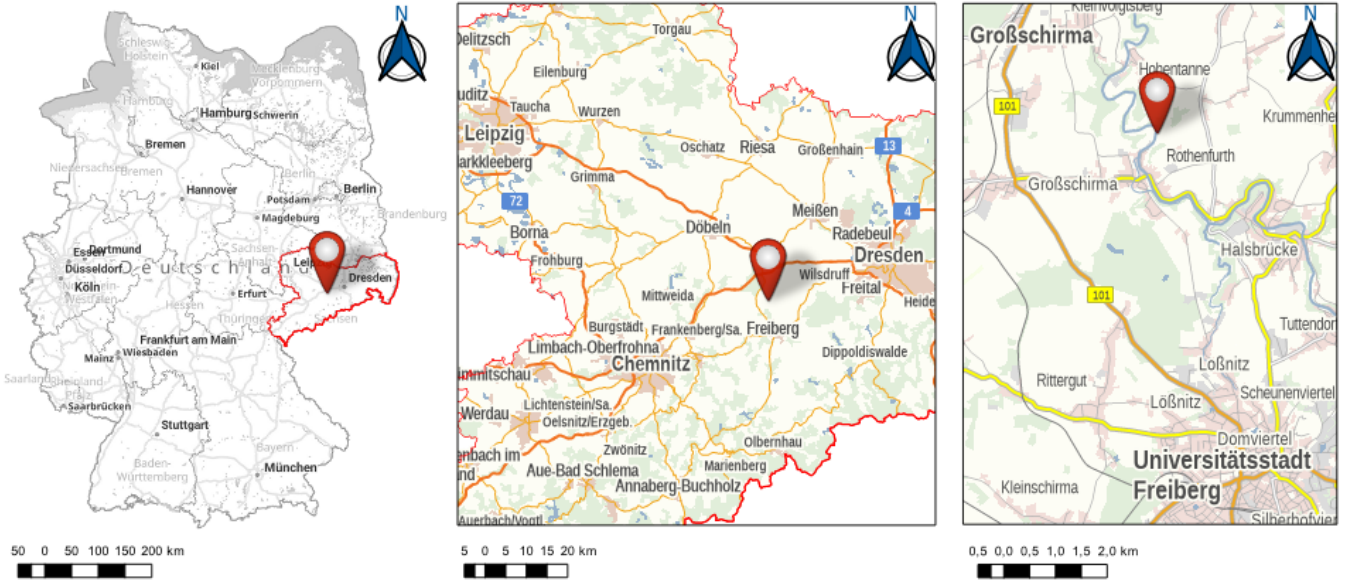

- filtered water sample (0,2 µm)
  - ➢ only **dissolved** trace elements
- particle concentration: approx. 16,7 mg/L

- shaking for 6 h, 24 h, 96 h
- **determination of trace elements** via ICP-MS/MS

Glaubitz, F.; **Rocha Vogel, A.**; Kolberg, Y.; von Tümpling, W.; Kahlert, H. *Environ. Pollut.* **2023**, *335*, 122293.
**Rocha Vogel, A.**; Kolberg, Y.; Schmidt, M.; Kahlert, H.; von Tümpling, W. *Environ. Pollut.* **2024**, *359*, 124571.

# Experimental approach

*Adsorption experiments*





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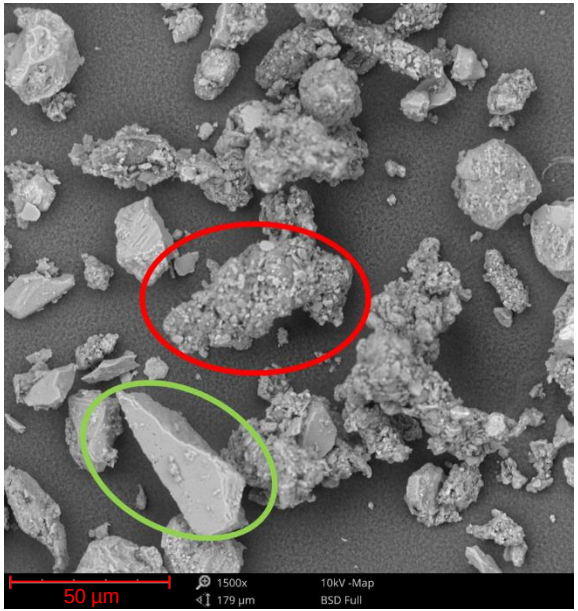
**Rocha Vogel, A.**; Kolberg, Y.; Schmidt, M.; Kahlert, H.; von Tümpling, W. *Environ. Pollut.* **2024**, *359*, 124571.

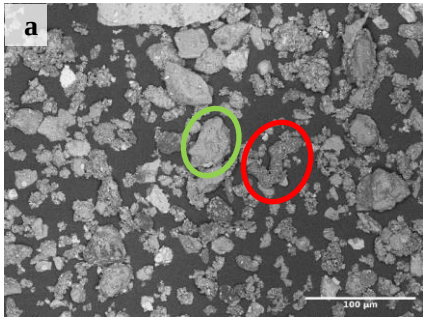
# Results I

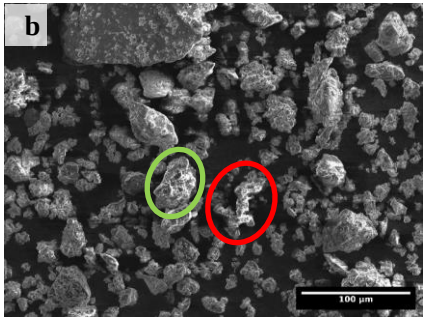
## *Surface observation and identification of TRWP+RS*

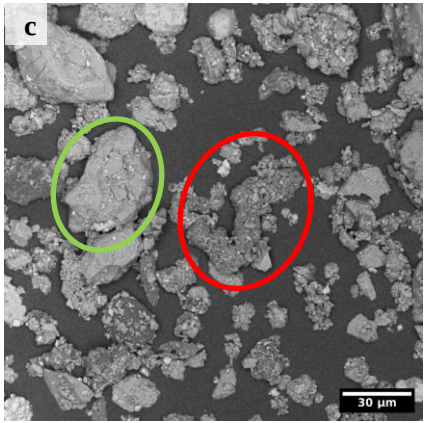
- **TRWP+RS I**

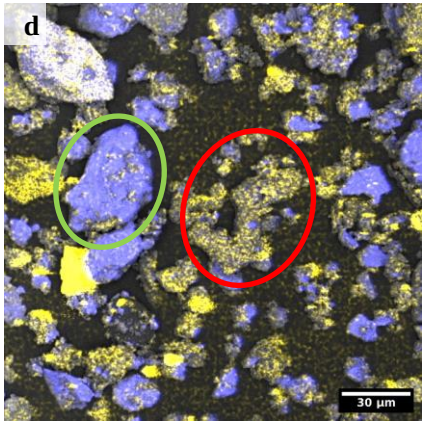



- **TRWP+RS III**
  - a: SEM (*SE*)
  - b: SEM (*BSE*)
  - c: SEM
  - d: SEM-EDX



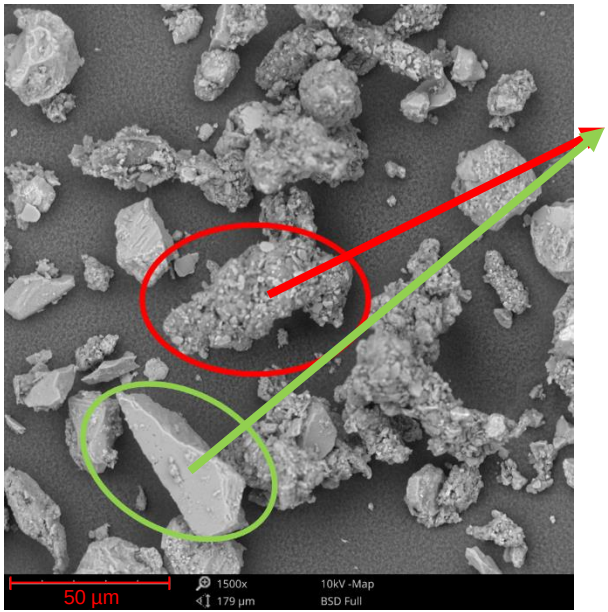




Glaubitz, F.; **Rocha Vogel, A.**; Kolberg, Y.; von Tümpling, W.; Kahlert, H. *Environ. Pollut.* **2023**, *335*, 122293.
**Rocha Vogel, A.**; Kolberg, Y.; Schmidt, M.; Kahlert, H.; von Tümpling, W. *Environ. Pollut.* **2024**, *359*, 124571.

# Results I

## *Adsorption kinetics of trace elements*

- **TRWP+RS I characteristics**




spec. surface area of *TRWP+RS I*
**0,75 ± 0,11 m²/g**

zeta potential
**–37,9 ± 6 mV**

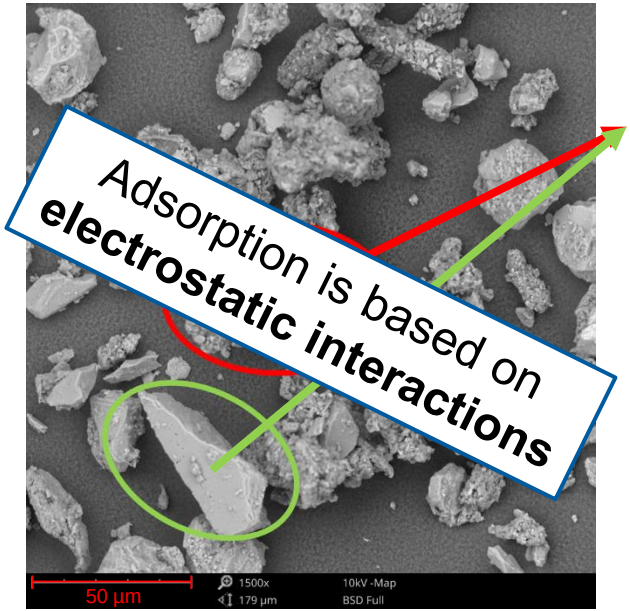
Zn proportion in *TRWP+RS I*
**1,3‰**

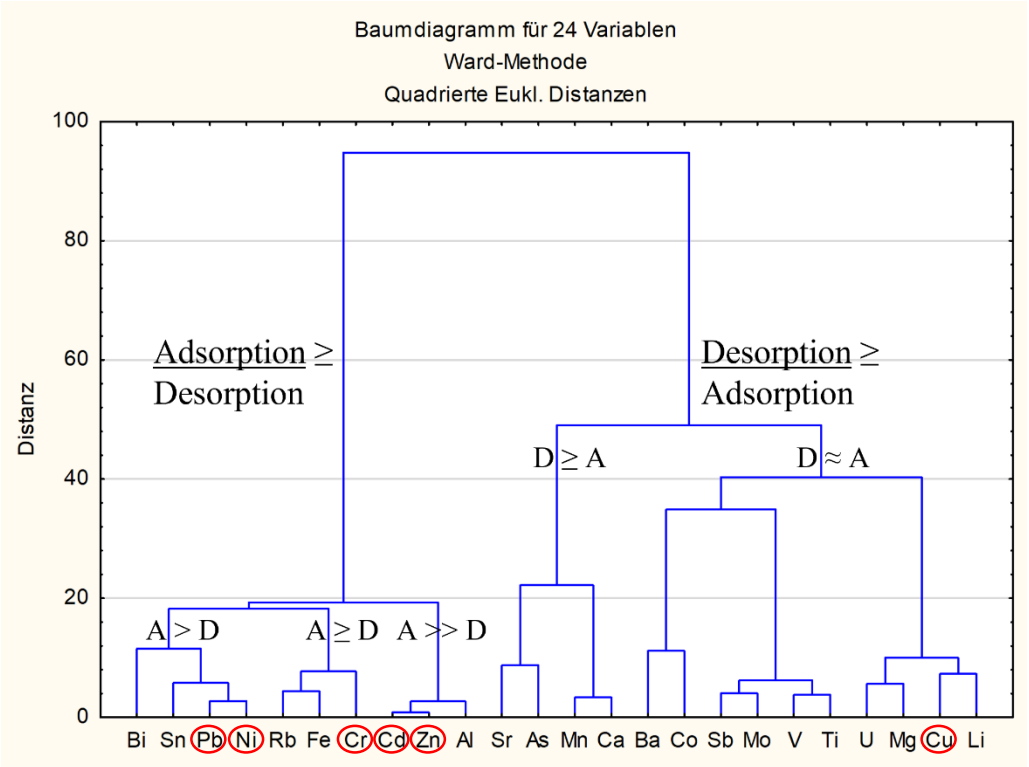
**12% TWP in TRWP+RS I**

# Results I

## *Adsorption kinetics of trace elements*

- **TRWP+RS I characteristics**



# Results II

## *Adsorption of trace elements on tire wear samples*

| Material | TRWP+RS I *traffic lane* | | TRWP+RS II *tunnel (entry)* | | TRWP+RS III *tunnel (centre)* | | TWP-f *laboratory* | | BWP *test stand* | | Elbe SM | LAWA Klassifikation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | before | after | before | after | before | after | before | after | before | after | | |
| **Cr** | I | III | III | III | III | III-IV | I | I | III-IV | III-IV | II-III | I |
| **Ni** | II | III | III | III | II-III | III | I | I-II | III | III | II | I-II |
| **Cu** | III | III | IV | III-IV | IV | IV | I | I | IV | IV | II-III | II |
| **Zn** | III-IV | IV | III-IV | IV | IV | IV | IV | IV | IV | IV | III-IV | II-III |
| **As** | I-II | II-III | II | I-II | II | II | I | I | IV | IV | II-III | III |
| **Cd** | I-II | IV | II | IV | II | IV | I | II-III | I | I | III-IV | III-IV |
| **Pb** | I-II | II | II-III | II-III | II-III | II-III | I | I-II | II | II | II-III | IV |
| TWP share | 12 % | | 9,4 % | | 22 % | | 97 % | | --- | | | |

**Rocha Vogel, A.**; Kolberg, Y.; Schmidt, M.; Kahlert, H.; von Tümpling, W. *Environ. Pollut.* **2024**, *359*, 124571.

# Results II

## *Adsorption of trace elements on tire wear samples*

| Material | TRWP+RS I *traffic lane* | | TRWP+RS III *tunnel (centre)* | |
|---|---|---|---|---|
| | before | after | before | after |
| Cr | I | III | III | III-IV |
| Ni | II | III | II-III | III |
| Cu | III | III | IV | IV |
| Zn | III-IV | IV | IV | IV |
| As | I-II | II-III | II | II |
| Cd | I-II | IV | II | IV |
| Pb | I-II | II | II-III | II-III |
| TWP share | 12 % | | 22 % | |

- **TWP** endangerment regarding **Zn**
- **TRWP+RS** endangerment regarding **Zn + Cu**
- generally, **tunnel samples** have higher trace element contents
- **Hazard potential** due to the **adsorption** of trace elements
- **BWP** irrelevant for adsorption

**Rocha Vogel, A.**; Kolberg, Y.; Schmidt, M.; Kahlert, H.; von Tümpling, W. *Environ. Pollut.* **2024**, *359*, 124571.

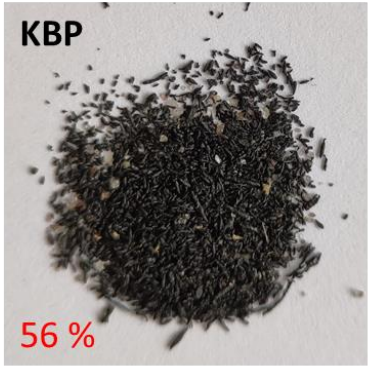
# Results III

## *Separation of tire wear particles from environmental samples*

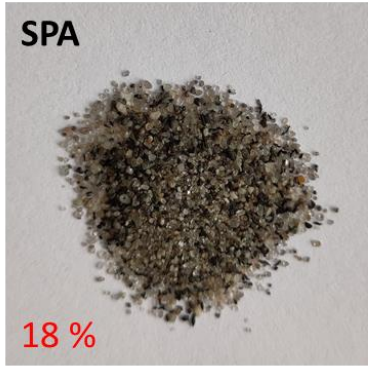
KBP

density separation

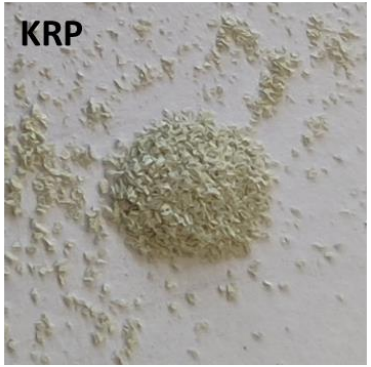
SPA + APA

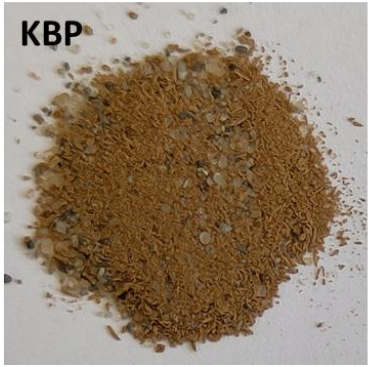





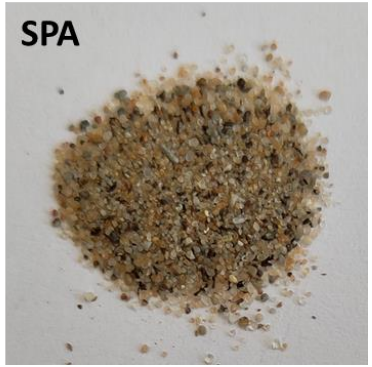



- **NaI sol.**
- ρ = 1,8 g/cm³
- quantitative



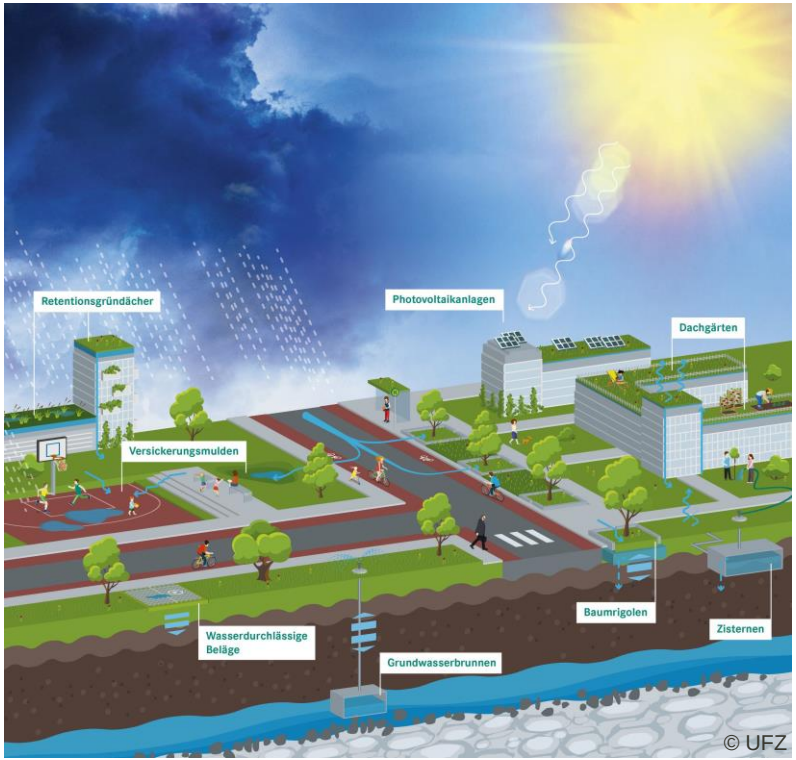




# Conclusion

*For whom are these works of interest?*

- results provide the basis for estimating tire wear regarding the **trace element binding** in a **river basin**
- **public authorities:** BfG, FGG, IKSE
- tire manufacturers
- **sponge cities** (rain water retention) water quality assessment
- fine filtration systems/ drainage systems
- tire wear/ rubber as secondary raw material?



# Summary

## Adsorption of trace elements on tire and road wear particles

- Bonding is of an **electrostatic nature**
- **TWP** endangerment regarding **Zn**
- **TRWP+RS** endangerment regarding **Zn + Cu**
- generally, **tunnel samples** have **higher** trace element contents
- **Hazard potential** due to the **adsorption** of trace elements

adsorption kinetcs

Risk assessment

separation of tire wear particles

## Separation of tire wear particles from samples

- quantitative separation using NaI sol possible
- limitation: other particles $\rho > 1{,}8$ g cm$^{-3}$
- suitable for kart lane samples

# Thank you for your kind attention!

PD Dr. Wolf von Tümpling
Yannik Kolberg
Maximilian Reisch

Andrea Hoff
Nils Ribbe

Colleagues at UFZ

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