TU BERGAKADEMIE FREIBERG

TUBAF
Die Ressourcenuniversität.
Seit 1765.

ZIRKON

Hochschule Zittau/Görlitz
UNIVERSITY OF APPLIED SCIENCES

“Characterization of Tire Wear Particles and the Occurrence of Tire Wear Compounds (6PPD-Q, DPG, 2-OHBT)”

28.11.2024

Faith Chebet Tumwet

Europäische Union

Europa fördert Sachsen.
ESF
Europäischer Sozialfonds

Freistaat Sachsen

Diese Maßnahme wird mitfinanziert durch Steuermittel auf der Grundlage des vom Sächsischen Landtag beschlossenen Haushaltes.

Introduction

"Roadside soils act as a sink for tire wear particles, co-transporting compounds (6PPD-Q, DPG, 2-OHBT) and enhancing their persistence."

- Tire wear particles (TWP) are a major source of microplastic pollution.
- Primary entry pathways are surface runoff and wind transport.

Introduction

"Roadside soils act as a sink for tire wear particles, co-transporting compounds (6PPD-Q, DPG, 2-OHBT) and enhancing their persistence."

- Tire wear particles (TWP) are a major source of microplastic pollution.
- Primary entry pathways are surface runoff and wind transport.

Tire Manufacturing	Transformation product
N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine (6PPD)	6PPD-quinone
N,N'-diphenylguanidine (DPG)	-
Benzothiazole (BT)	2-hydroxybenzothiazole (2-OHBT)

Introduction

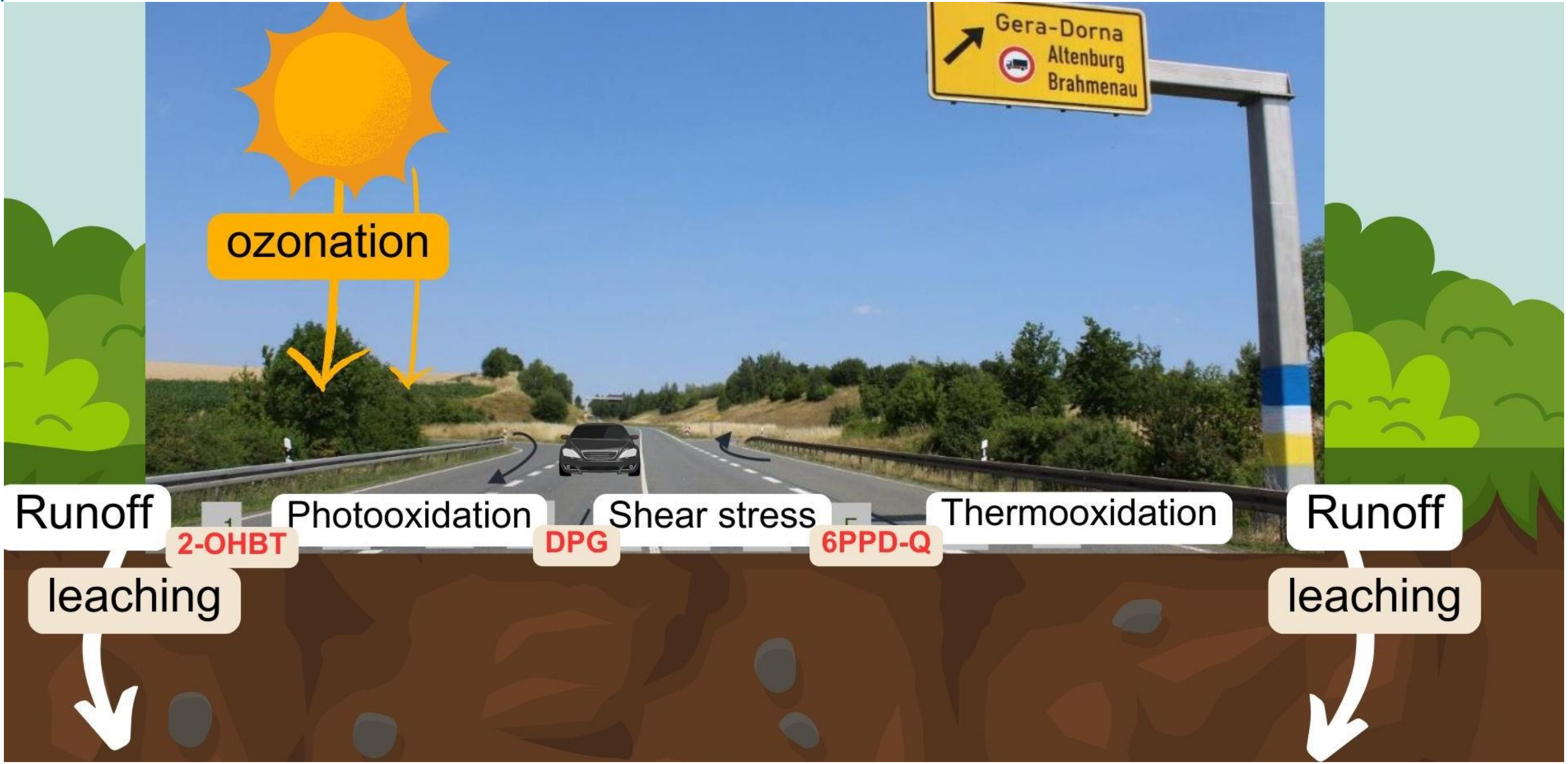


Fig. 1: Environmental pathways and transformation processes of TWPs and associated chemicals.

Introduction

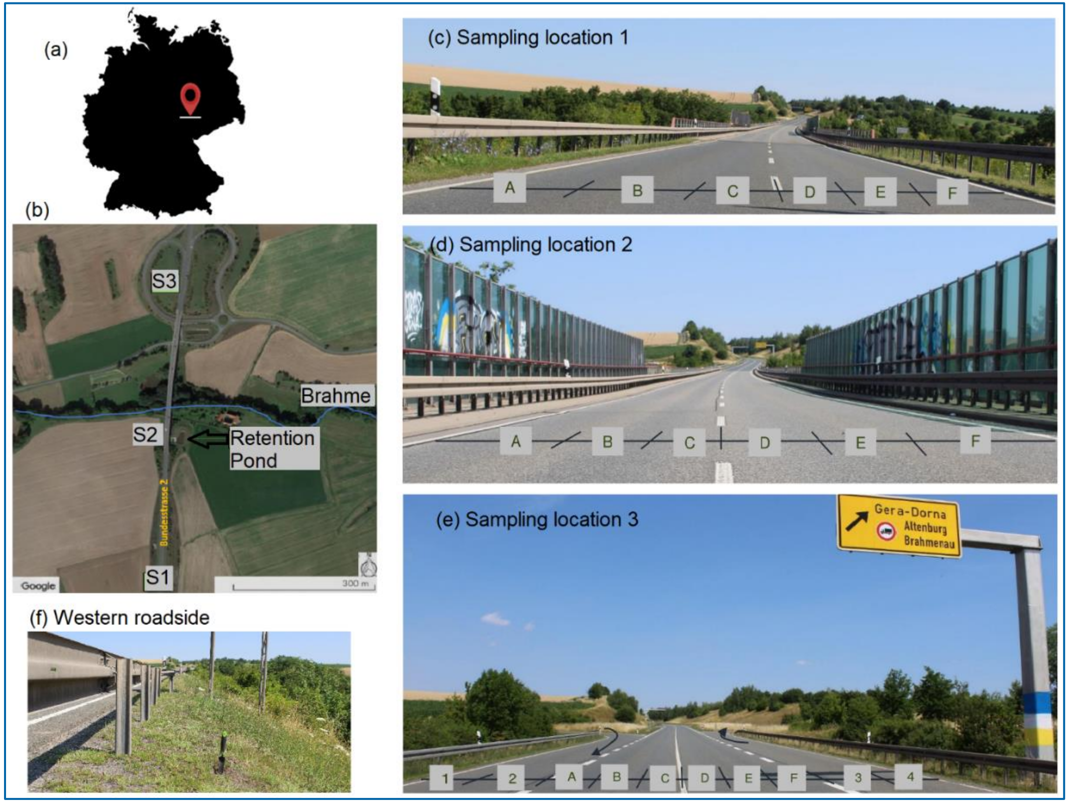
"Roadside soils act as a sink for tire wear particles, co-transporting compounds (6PPD-Q, DPG, 2-OHBT) and enhancing their persistence."

- Tire wear particles (TWP) are a major source of microplastic pollution.
- Primary entry pathways are surface runoff and wind transport.

Objective:

- Quantify the occurrence of 6PPD-Q, DPG, and 2-OHBT in road dust and roadside soils.
- Characterise individual TWPs in terms of morphology and chemical composition.

Study Area



- Gera
- Bundesstrasse 2
- 1.5 km off A4 (Direction Zeitz)
- 2.2 ° slope
- 400 m between each sampling point
- No speed limit

Fig. 2: Sampling locations.

Research Study

1. Sampling

Each sampling site approximately 2.4 m².

Fig. 3: Sampling with a vacuum system and a broom.

2. Sample preparation and Analysis

DRYING AND SIEVING → DENSITY SEPARATION → SINGLE PARTICLE ANALYSIS → EXTRACTION OF ORGANIC TWP COMPOUNDS

DRYING AND SIEVING
- Road dust particles < 1000 µm and soil fraction < 315 µm.

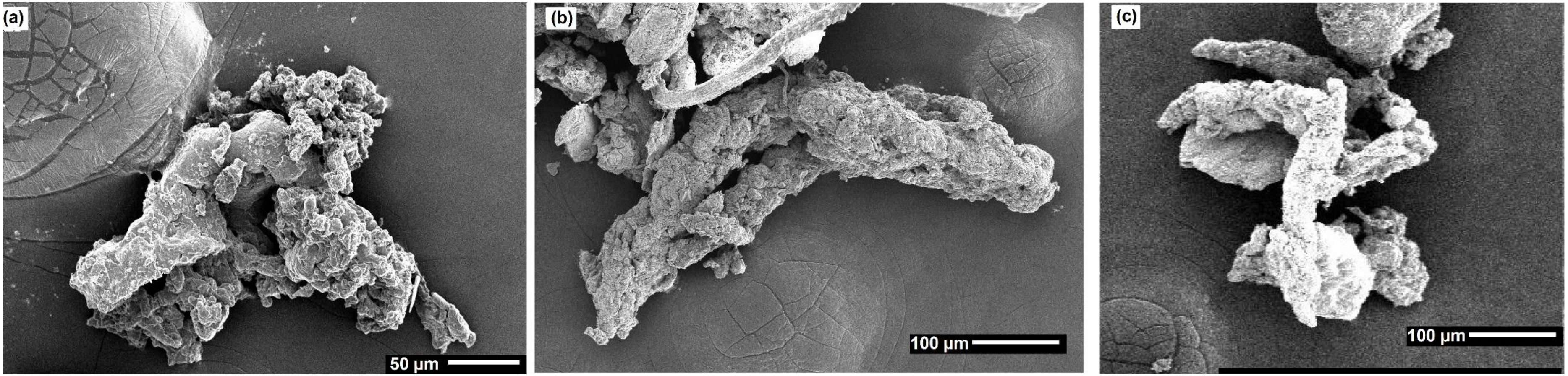
DENSITY SEPARATION
- Sodium polytungstate (1.2 – 1.9 g/cm³).

SINGLE PARTICLE ANALYSIS
- SEM/EDX
- FTIR

EXTRACTION OF ORGANIC TWP COMPOUNDS
- 60 – 110 mg in 10 mL of 2-propanol.
- Liquid chromatography high-resolution mass spectrometry.

Fig. 4: Workflow for quantifying tire and road wear particles generated on the road.

Characterisation of TWP



TWP1: Cryogenically milled	TWP2: Road surface sample	TWP3: Roadside soil sample
Aspect ratio: 1.38	Aspect ratio: 1.37	Aspect Ratio: 1.25
Moderate elongation.	Minimal post-formation weathering.	Weathered particles; considerable rounding.

Fig. 5: Scanning Electron Microscope (SEM) images of the morphological structure of tire wear particles.

Elemental Composition of TWP

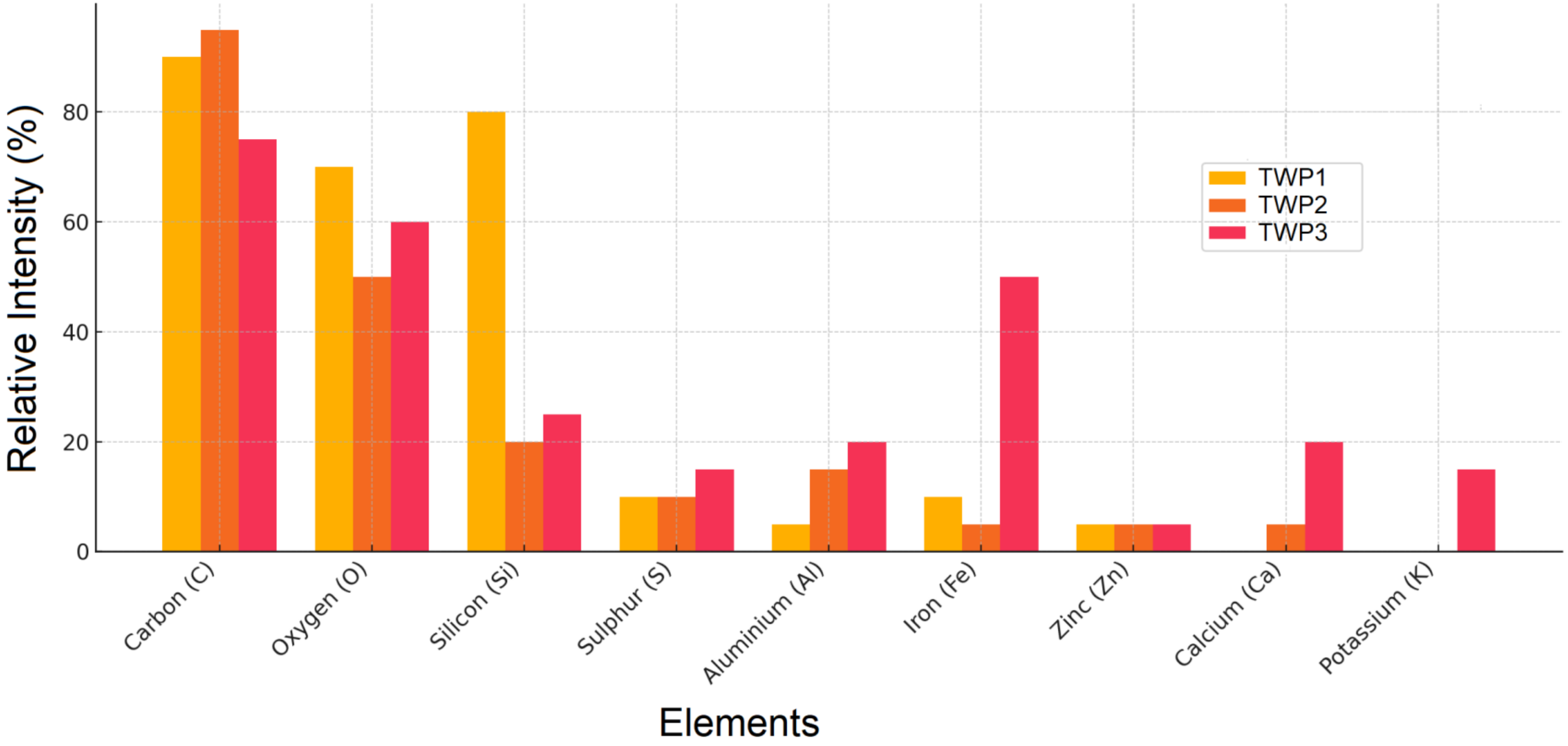


Fig. 6: Elemental composition of TWP samples analysed by energy-dispersive X-ray spectroscopy (EDX).

FTIR (Fourier Transform Infrared) Spectra of TWP

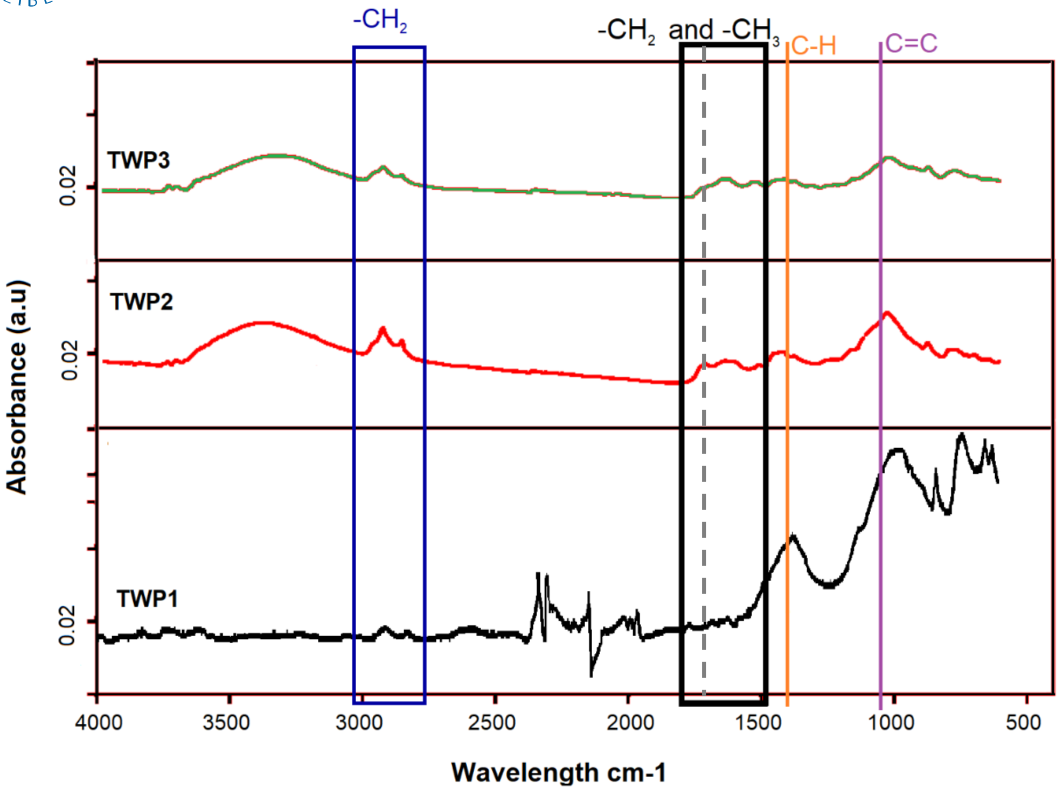


Fig. 7: Fourier-transform infrared (FTIR) spectra of tire wear particles.

TWP3: Reduction in peak intensity suggests lower polymer content due to environmental exposure.

TWP2: Retains more of its original tire polymer characteristics.

TWP1: Spectrum represents unaltered tire wear particles with minimal environmental influence.

6PPD-Q, DPG, and 2-OHBT concentrations at Sampling Location 1

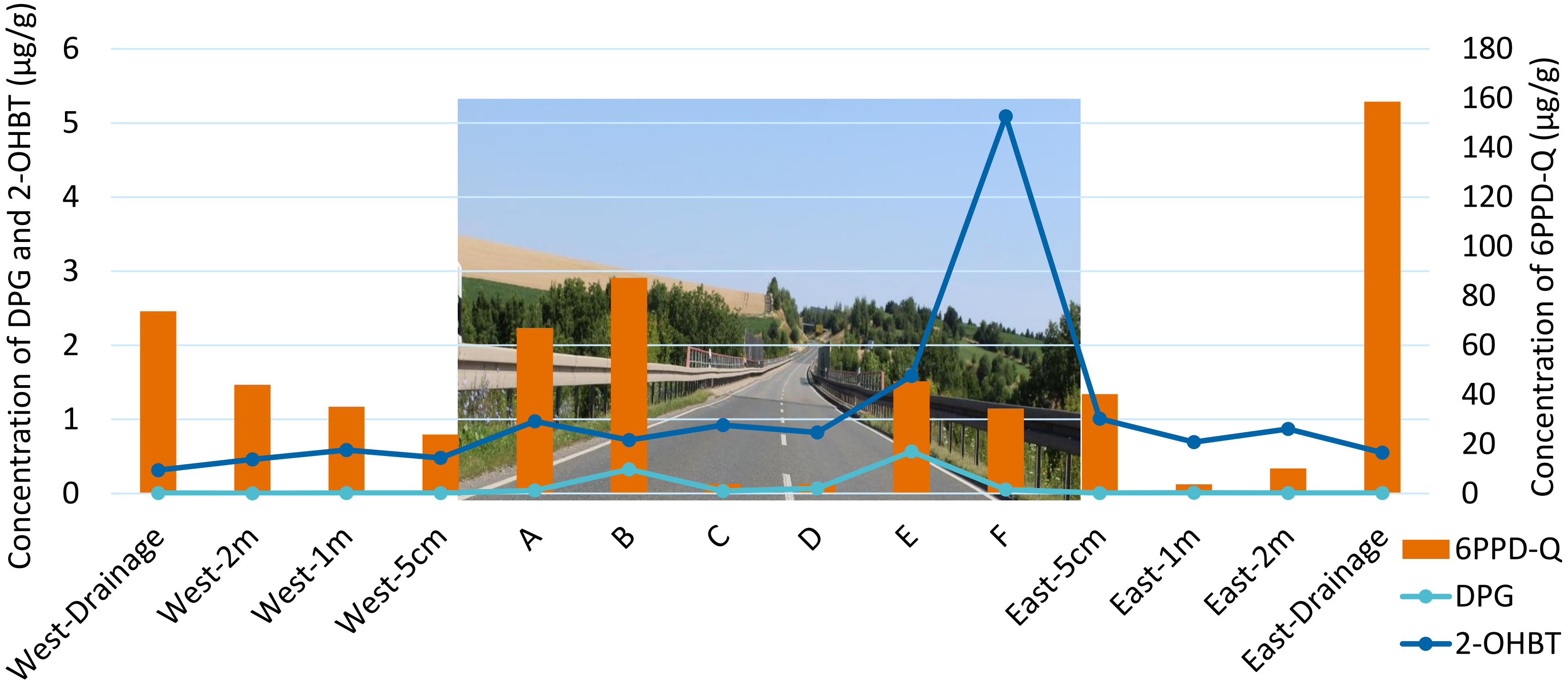


Fig. 8: Concentration of 6PPD-Q, DPG, and 2-OHBT at Sampling Location 1 from the drainage ditch in the west of the road, the road surface, to the drainage ditch in the east.

6PPD-Q, DPG, and 2-OHBT concentrations at Sampling Location 2

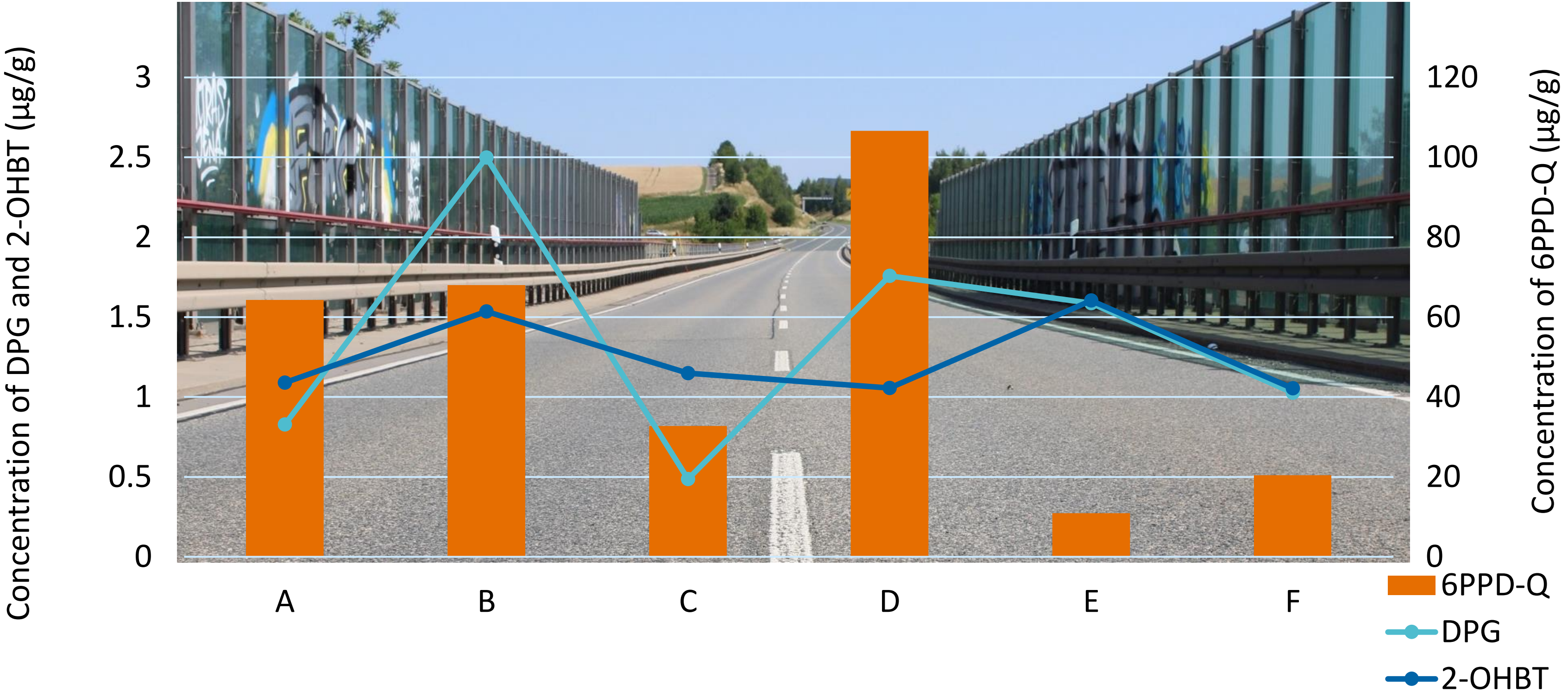


Fig. 9: Concentration of 6PPD-Q, DPG, and 2-OHBT at various sampled points within two lanes at Sampling Location 2 on a bridge with a 4 m high sound barrier and no adjacent roadsides.

6PPD-Q, DPG, and 2-OHBT concentrations at Sampling Location 3

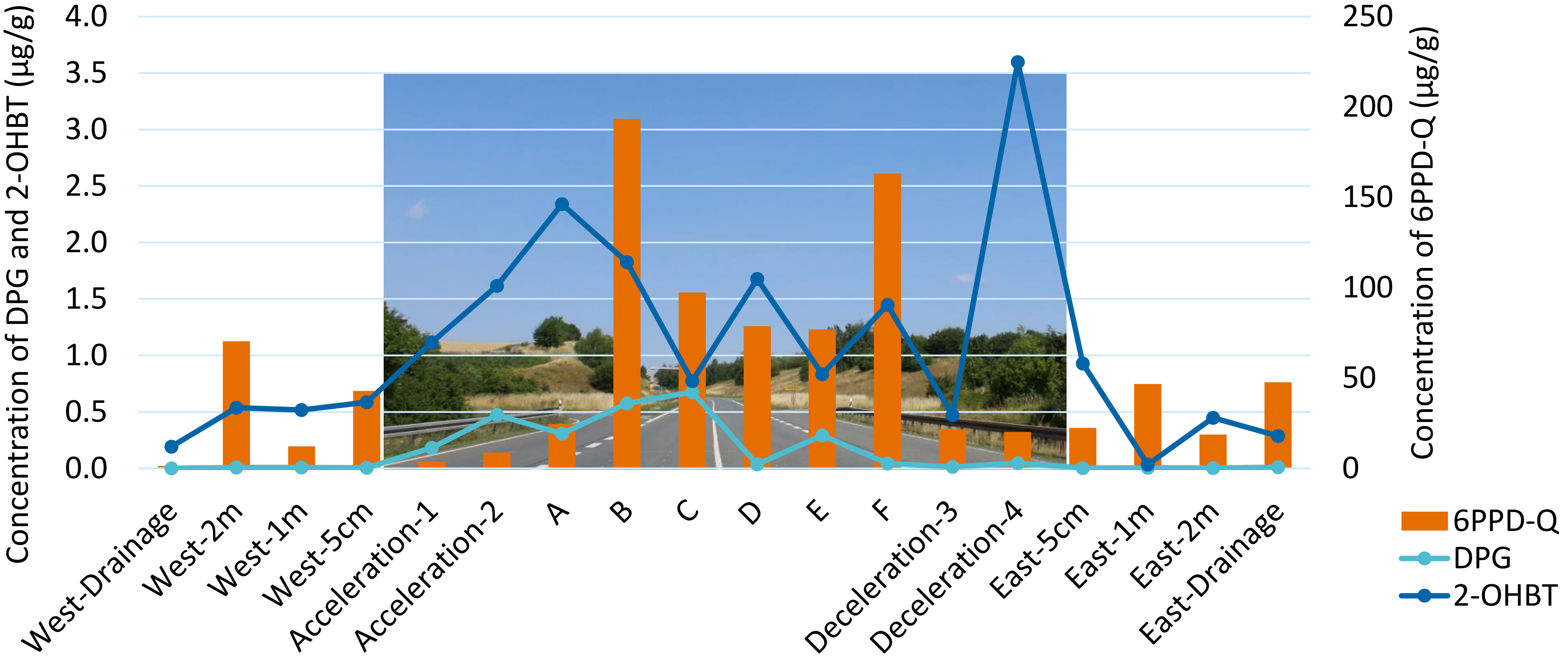


Fig. 10: Concentration of 6PPD-Q, DPG, and 2-OHBT at Sampling Location 3 from the drainage ditch in the west of the road, the acceleration lane, the road surface, the deceleration lane, to the drainage ditch in the east.

Outcome

- TWPs exhibit diverse morphologies and chemical compositions, influenced by abrasion during environmental transport and interaction with the soil.
- 6PPD-Q concentration higher due to its strong adsorption to TWP and organic-rich soils.
- DPG and its easy leachability is an indicator of contamination hotspots and the pathways of TWP.
- Occurrence of 2-OHBT confirms the presence of TWP in road dust and soils given its susceptibility to leach.

Faith Chebet Tumwet
Tel.: (+49) 3731393309
E-Mail: Faith_Chebet.Tumwet@hszg.de

Institute of Hydrogeology / Hydrochemistry
TU Bergakademie Freiberg
09599 Freiberg

Funded by:

Europäische Union

Europa fördert Sachsen.
ESF
Europäischer Sozialfonds

Freistaat Sachsen

Diese Maßnahme wird mitfinanziert durch Steuermittel auf der Grundlage des vom Sächsischen Landtag beschlossenen Haushaltes.

References

- Abbasi, Sajjad, Behnam Keshavarzi, Farid Moore, and Mohammad Reza Mahmoudi. 2018. “Fractionation, source identification and risk assessment of potentially toxic elements in street dust of the most important center for petrochemical products, Asaluyeh County, Iran.” Environmental Earth Sciences 77: 673. doi:10.1007/s12665-018-7854-z.
- Abbasi, Sajjad, Behnam Keshavarzi, Farid Moore, Andrew Turner, Frank J. Kelly, Ana Oliete Dominguez, and Neemat Jaafarzadeh. 2019. “Distribution and potential health impacts of microplastics and microrubbers in air and street dusts from Asaluyeh County, Iran.” Environmental Pollution 244: 153-164. doi:10.1016/j.envpol.2018.10.039.
- Adachi, Kouji, and Yoshiaki Tainosho. 2004. “Characterization of heavy metal particles embedded in tire dust.” Environment International 30 (8): 1009-1017. doi:10.1016/j.envint.2004.04.004.
- Amato, Fulvio, Flemming R. Cassee, Hugo A. C. Denier van der Gon, Robert Gehrig, Mats Gustafsson, Wolfgang Hafner, Roy M. Harrison, et al. 2014. “Urban air quality: The challenge of traffic non-exhaust emissions.” Journal of Hazardous Materials 275: 31-36. doi:10.1016/j.jhazmat.2014.04.053.
- Baensch-Baltruschat, Beate, Birgit Kocher, Christian Kochleus, Friederike Stock, and Georg Reifferscheid. 2021. “Tyre and road wear particles - A calculation of generation, transport and release to water and soil with special regard to German roads.” Science of The Total Environment 752: 141939. doi:10.1016/j.scitotenv.2020.141939.
- Baensch-Baltruschat, Beate, Birgit Kocher, Friederike Stock, and Georg Reifferscheid. 2020. “Tyre and road wear particles (TRWP) - A review of generation, properties, emissions, human health risk, ecotoxicity, and fate in the environment.” Science of The Total Environment 733: 137823. doi:10.1016/j.scitotenv.2020.137823.
- Besseling, Ellen, Joris T. K. Quik, Muzhi Sun, and Albert A. Koelmans. 2017. “Fate of nano- and microplastic in freshwater systems: A modeling study.” Environmental Pollution 220 (Part A): 540-548. doi:10.1016/j.envpol.2016.10.001.
- Boucher, Julien, Guillaume Billard, Eleonora Simeone, and Joao Sousa. 2020. The marine plastic footprint. Edited by Amy Sweeting. Switzerland: IUCN, Gland, Switzerland. doi:10.2305/IUCN.CH.2020.01.en.
- Chae, Eunji, Uiyeong Jung, and Sung-Seen Choi. 2021. “Quantification of tire tread wear particles in microparticles produced on the road using oleamide as a novel marker.” Environmental Pollution 288: 117811. doi:10.1016/j.envpol.2021.117811.
- Dehghani, Sharareh, Farid Moore, and Razegheh Akhbarizaheh. 2017. “Microplastic pollution in deposited urban dust, Tehran metropolis, Iran.” Environmental Science and Pollution Research 24: 20360–20371. doi:10.1007/s11356-017-9674-1.
- Eisentraut, Paul, Erik Dümichen, Aki Sebastian Ruhl, Martin Jekel, Mirko Albrecht, Michael Gehde, and Ulrike Braun. 2018. “Two Birds with One Stone—Fast and Simultaneous Analysis of Microplastics: Microparticles Derived from Thermoplastics and Tire Wear.” Environmental Science & Technology 5 (10): 608-613. doi:10.1021/acs.estlett.8b00446.
- ETRTO. (2023). Retrieved November 1, 2023, from European Tyre and Rim Technical Organisation: https://www.etrto.org/home
- Goßmann, Isabel, Maurits Halbach, and Barbara M. Scholz-Böttcher. 2021. “Car and truck tire wear particles in complex environmental samples – A quantitative comparison with “traditional” microplastic polymer mass loads.” Science of The Total Environment 773: 145667. doi:10.1016/j.scitotenv.2021.145667.
- Grigoratos, Theodoros, and Giorgio Martini. 2015. “Brake wear particle emissions: a review.” Environmental Science and Pollution Research 22: 2491-2504. doi:10.1007/s11356-014-3696-8.

References

- Halle, Louise L., Annemette Palmqvist, Kristoffer Kampmann, and Farhan R. Khan. 2020. “Ecotoxicology of micronized tire rubber: Past, present and future considerations.” Science of The Total Environment 706: 135694. doi:10.1016/j.scitotenv.2019.135694.
- Huber, Maximilian, Antje Welker, and Brigitte Helmreich. 2016. “Critical review of heavy metal pollution of traffic area runoff: Occurrence, influencing factors, and partitioning.” Science of the Total Environment 541: 895-919. doi:10.1016/j.scitotenv.2015.09.033.
- Hwang, Hyun-Min, Matthew J. Fiala, Dongjoo Park, and Terry L. Wade. 2016. “Review of pollutants in urban road dust and stormwater runoff: part 1. Heavy metals released from vehicles.” International Journal of Urban Sciences 20 (3): 334-360. doi:10.1080/12265934.2016.1193041.
- Klöckner, Philipp, Bettina Seiwert, Steffen Weyrauch, Beate I. Escher, Thorsten Reemtsma, and Stephan Wagner. 2021. “Comprehensive characterization of tire and road wear particles in highway tunnel road dust by use of size and density fractionation.” Chemosphere 279: 130530. doi:10.1016/j.chemosphere.2021.130530.
- Klöckner, Philipp, Thorsten Reemtsma, Paul Eisentraut, Ulrike Braun, and Aki Sebastian Ruhl. 2019. “Tire and road wear particles in road environment – Quantification and assessment of particle dynamics by Zn determination after density separation.” Chemosphere 222: 714-721. doi:10.1016/j.chemosphere.2019.01.176.
- Knight, Lydia J., Florence N. F. Parker-Jurd, Maya Al-Sid-Cheikh, and Richard C. Thompson. 2020. “Tyre wear particles: an abundant yet widely unreported microplastic?” Environmental Science and Pollution Research 27: 18345-18354. doi:10.1007/s11356-020-08187-4.
- Kole, Pieter Jan, Ansje J. Löhr, Frank G. A. J. Van Belleghem, and Ad M. J. Ragas. 2017. “Wear and Tear of Tyres: A Stealthy Source of Microplastics in the Environment.” International Journal of Environmental Research and Public Health 14 (10): 1265. doi:10.3390/ijerph14101265.
- Kreider, Marisa L., Julie M. Panko, Britt L. McAtee, Leonard I. Sweet, and Brent L. Finley. 2010. “Physical and chemical characterization of tire-related particles: Comparison of particles generated using different methodologies.” Science of The Total Environment 408 (3): 652-659. doi:10.1016/j.scitotenv.2009.10.016.
- Lee, S., J. Kwak, H. Him, and J. Lee. 2013. “Properties of roadway particles from interaction between the tire and road pavement.” International Journal of Automotive Technology volume 14: 163-173. doi:10.1007/s12239-013-0018-y.
- Müller, Alexandra, Heléne Österlund, Jiri Marsalek, and Maria Viklander. 2022. “Exploiting urban roadside snowbanks as passive samplers of organic micropollutants and metals generated by traffic.” Environmental Pollution 308: 119723. doi:10.1016/j.envpol.2022.119723.
- Müller, Axel, Birgit Kocher, Korinna Altmann, and Ulrike Braun. 2022. “Determination of tire wear markers in soil samples and their distribution in a roadside soil.” Chemosphere 294: 133653. doi:10.1016/j.chemosphere.2022.133653.
- Panko, Julie M., Jennifer Chu, Marisa L. Kreider, and Ken M. Unice. 2013. “Measurement of airborne concentrations of tire and road wear particles in urban and rural areas of France, Japan, and the United States.” Atmospheric Environment 72: 192-199. doi:10.1016/j.atmosenv.2013.01.040.
- Rauert, Cassandra, Elisabeth S. Rødland, Elvis D. Okoffo, Malcolm J. Reid, Sondre Meland, and Kevin V. Thomas. 2021. “Challenges with Quantifying Tire Road Wear Particles: Recognizing the Need for Further Refinement of the ISO Technical Specification.” Environmental Science & Technology Letters 8 (3): 231-236. doi:10.1021/acs.estlett.0c00949.
- Rochman, Chelsea M., Cole Brookson, Jacqueline Bikker, Natasha Djuric, Arielle Earn, Kennedy Bucci, Samantha Athey, et al. 2019. “Rethinking microplastics as a diverse contaminant suite.” Environmental Toxicology and Chemistry 38 (4): 703-711. doi:10.1002/etc.4371.

References

- Rødland, Elisabeth S., Lene S. Heier, Ole Christian Lind, and Sondre Meland. 2023. “High levels of tire wear particles in soils along low traffic roads.” Science of The Total Environment 903: 166470. doi:10.1016/j.scitotenv.2023.166470.
- Rødland, Elisabeth S., Saer Samanipour, Cassandra Rauert, Elvis D. Okoffo, Malcom J. Reid, Lene S. Heier, Ole Christian Lind, Kevin V. Thomas, and Sondre Meland. 2022. “A novel method for the quantification of tire and polymer-modified bitumen particles in environmental samples by pyrolysis gas chromatography mass spectroscopy.” Journal of Hazardous Materials 423 (Part A): 127092. doi:10.1016/j.jhazmat.2021.127092.
- Sager, Manfred. 2020. “Urban Soils and Road Dust—Civilization Effects and Metal Pollution—A Review.” Environments 7 (11): 98. doi:10.3390/environments7110098.
- Sommer, Frank, Volker Dietze, Anja Baum, Jan Sauer, Stefan Gilge, Christoph Maschowski, and Reto Gieré. 2018. “Tire abrasion as a major source of microplastics in the environment.” Aerosol and Air Quality Research 18 (8): 2014-2028. doi:10.4209/aaqr.2018.03.0099.
- Stevenson, Keri, Bethan Stallwood, and Adam G. Hart. 2008. “Tire Rubber Recycling and Bioremediation: A Review.” Bioremediation Journal 12 (1): 1-11. doi:10.1080/10889860701866263.
- Unice, K. M., M. P. Weeber, M. M. Abramson, R. C. D. Reid, J. A. G. van Gils, A. A. Markus, A. D. Vethaak, and J. M. Panko. 2019. “Characterizing export of land-based microplastics to the estuary - Part I: Application of integrated geospatial microplastic transport models to assess tire and road wear particles in the Seine watershed.” Science of The Total Environment 646: 1639-1649. doi:10.1016/j.scitotenv.2018.07.368.
- Wagner, Stephan, Philipp Klöckner, and Thorsten Reemtsma. 2022. “Aging of tire and road wear particles in terrestrial and freshwater environments – A review on processes, testing, analysis and impact.” Chemosphere 288: 132467. doi:10.1016/j.chemosphere.2021.132467.
- Wagner, Stephan, Thorsten Hüffer, Philipp Klöckner, Maren Wehrhahn, Thilo Hofmann, and Thorsten Reemtsma. 2018. “Tire wear particles in the aquatic environment - A review on generation, analysis, occurrence, fate and effects.” Water Research 139: 83-100. doi:10.1016/j.watres.2018.03.051.
- Werkenthin, Moritz, Björn Kluge, and Gerd Wessolek. 2014. “Metals in European roadside soils and soil solution – A review.” Environmental Pollution 189: 98-110. doi:10.1016/j.envpol.2014.02.025.
- Wik, Anna, and Göran Dave. 2009. “Occurrence and effects of tire wear particles in the environment – A critical review and an initial risk assessment.” Environmental Pollution 157 (1): 1-11. doi:10.1016/j.envpol.2008.09.028.
- Xiao, Shuolin, Yuanfeng Cui, Janice Brahney, Natalie M. Mahowald, and Qi Li. 2023. “Long-distance atmospheric transport of microplastic fibres influenced by their shapes.” Nature Geoscience 16: 863-870. doi:10.1038/s41561-023-01264-6.
- Yukioka, Satoru, Shuhei Tanaka, Yoshiki Nabetani, Yuji Suzuki, Taishi Ushijima, Shigeo Fujii, Hideshige Takada, Quang Van Tran, and Sangeeta Singh. 2020. “Occurrence and characteristics of microplastics in surface road dust in Kusatsu (Japan), Da Nang (Vietnam), and Kathmandu (Nepal).” Environmental Pollution 256: 113447. doi:10.1016/j.envpol.2019.113447.
- Zehetner, Franz, Ulrike Rosenfellner, Axel Mentler, and Martin H. Gerzabek. 2009. “Distribution of Road Salt Residues, Heavy Metals and Polycyclic Aromatic Hydrocarbons across a Highway-Forest Interface.” Water, Air, and Soil Pollution 198: 125-132. doi:10.1007/s11270-008-9831-8.