7th Swiss Microplastics meeting (MP-CH-VII)

27. March 2026

University of Bern, UniTobler Areal

Lerchenweg 36

Room F023

Aims and Scope of the Meeting:

The main purpose of the meeting is to strengthen our network on all aspects of microplastics, to exchange ideas, challenges and results, find partners for new collaborations, and give early stage researchers the opportunity to present their work.

To stay informed about future events : https://microplastics.ch/

UNIVERSITÄT BERN

9.00-9.30		**Welcome Coffee**
9.30-9.35	Aurea Chiaia-Hernandez & Katrina Kremer	Welcome
Session: METHODS & ANALYTICS		**Chair: Aurea Chiaia-Hernandez**
09.40-09.50	Samuel Cusworth	Before You Measure: How Sampling Strategies Shape Microplastics Quantification in Soils
09.50-10.00	Florian Breider	Development of a Py-GC/MS Method to Quantify Tire and Road Wear Particles in Aquatic and Terrestrial Organisms
10.00-10.10	Thibault Masset	Combining laboratory and field experiments to explore bioaccumulation potential of tire-related additives in gammarids
10.10-10.20	Mike Rohling	Association of microplastics with water-stable aggregates formed under laboratory conditions
10.20-10.30	Moritz Häffner	Looking Closer: A Physicochemical Analysis of Test Nanoplastics
10.30-11.00		**Coffee break**
Session : ENVIRONMENT AND PROCESSES		**Chair : Loretta Müller**
11.00-11.10	Angélique Moraz	Quantification of Microplastics in Soils from the Swiss National Monitoring Network
11.10-11.20	Florian Storck	Towards microplastic monitoring in Swiss surface water
11.20-11.30	Merve Tunali	Vertical distribution of microplastics in soil affects plant response to microplastics
11.30-11.40	Elias Zimmermann	Release, Characterization, and Quantification of Natural, Biobased and Synthetic Fiber Fragments
11.40-11.50	Guillaume Crosset-Perrotin	Country-Wide Quantification of Microplastics Loads Discharged by Swiss Wastewater Treatment Plants
11.50-12.00	Frederica Rotta	Sediment traps reveal seasonal changes in microplastic settling in a deep stratified lake
12.00-12.10	Madushika Sewwandi	Impacts of subsurface microplastics pollution on deep-ocean carbon export
12.10-12.20	Antonia Kellner	Microplastic in Snow from Remote Alpine and Arctic Regions
12.20-12.30	Narain M. Ashta	Wet and dry atmospheric deposition of microplastics in Switzerland
12.30-13.40		**Lunch Break**
Session: BIODEGRADABLES		**Chair: Fabien Blank**
13.40-13.40	Gabriel Gerner	Biodegradable Plastics in the Environment
13.50-14.00	Arthur Groh	Biodegradation of Elastic Biocomposites for Abrasion-Sensitive Applications
14.00-14.10	Fanny Berset	Compostable plastic biodegradability and potential participation in microplastic pollution in industrial compost
Session: MODELLING		**Chair: Fabian Blank**
14.10-14.20	John Hader	Estimating natural versus synthetic microfiber emissions from European domestic laundry
14.20-14.30	Danyang Jiang	Advancing Plastic Release Modeling: Quantifying Macro- and Microplastic Emissions Across 30 European Countries
14.30-14.40	Mohamed Bey Zekkoub	A Fragmentation Model to Quantify Secondary Microplastics Generation from Environmental Macroplastics in Switzerland
14.40-15.00		**Coffee Break**
Session: HUMAN HEALTH		**Chair: Katrina Kremer**
15.00-15.25	Cezmi Akdis	Environmental Exposures and Epithelial Barrier Disruption: Role of Micro- and Nanoplastic
15.25-15.35	Veronika Rendlova	Functional effects of aerosolised polystyrene microplastics on human nasal epithelium
15.35-15.45	Myriam Borgatta	Human exposure to plasticizers – absorption of phthalates in controlled inhalation studies
15.45-15.55	Stephanie Eitner	Synthetic versus Biobased Textile Fibers: Investigating their Impact on Human Lung Health
15:55-16.05	Sina Ruhstaller	Investigating Placental Immune Responses to Micro-/Nanoplastics
16.05-16.15	Nathalie Jung	Single-cell Raman imaging reveals compartment-specific cellular responses to nanoplastic exposure in macrophages
16.15-16.25	Sena Ardicli	Multi-Omics Profiling Identifies Oxidative Stress, Epithelial Cell Activation, and Barrier Disruption Induced by PET Micro- and Nanoplastics
16.35-17.20	Ralf Kägi	Discussion Round & Closing
From 17.20		**Apéro**

Before You Measure: How Sampling Strategies Shape Microplastics Quantification in Soils

Samuel J. Cusworth[1*], Denise M. Mitrano[1]

[1]Department of Environmental Systems Science, ETH Zürich, Switzerland

*samuel.cusworth@usys.ethz.ch

Microplastics (MPs) in soils exhibit strong spatial heterogeneity driven by land use, source proximity and soil processes. The rapid pace at which terrestrial MPs research has developed outpaced the development of robust, standardized procedures along the entire analytical workflow, including sampling strategies. Without representative sampling, uncertainty introduced at the earliest stage of the analytical chain propagates through extraction, analysis and interpretation. As a result, many reported MPs distributions, including quantification, characterization and risk assessments, remain challenging to interpret, difficult to compare and lack reproducibility.

Here, we present a multi-step sampling framework designed to improve the accuracy, precision and comparability of MPs quantification in soils. Using laboratory-scale model systems representing different MPs contamination scenarios, we systematically evaluated the effects of different sampling strategies on sample representativeness (Figure 1). To enable high-throughput assessment, we used model metal-doped MPs synthesized in-house, where the metals acted as conservative tracers and were quantified by ICP-MS, circumventing the need for more lengthy traditional MPs analysis. We demonstrate that producing a representative analytical aliquot is highly dependent on the preceding homogenization and mass-reduction techniques. Post-homogenization, subsequent aliquots from experimental systems exhibited high sample-to-sample variability indicating incomplete homogenization (Figure 2). Representativeness is strongly dependent on MPs morphology (fragments vs. fibers), since fibers are likely entangled in soil and harder to homogenize. Amongst mass reduction techniques, riffle splitting was most effective, though when used alone was insufficient to ensure sample representativeness (Figure 3). This is likely due to de-mixing phenomena and segregation of the homogenized bulk, often unconsidered in sampling workflows.

While we used a specific soil and MPs combination here, these findings emphasize the need to pre-test sampling approaches, using reference materials to identify and account for segregation heterogeneity and other de-mixing phenomena in the given sampling conditions. Ongoing work

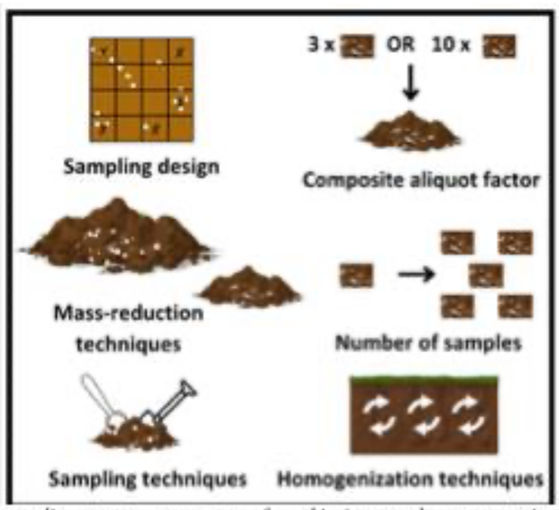


Figure 1. An overview of sampling strategy cornerstones for achieving sample representativeness. In this study, the effectiveness of different sampling designs, number of samples, composite-aliquot factors, homogenization and mass-reduction techniques, to produce representative samples were examined.

extends this framework to larger, more environmentally realistic systems to develop a reproducible framework for MPs sampling across different soil environments. Overall, this work provides a workflow for representative MPs sampling in soils and identifies critical bottlenecks that must be addressed to support harmonized monitoring and inter-study comparability.

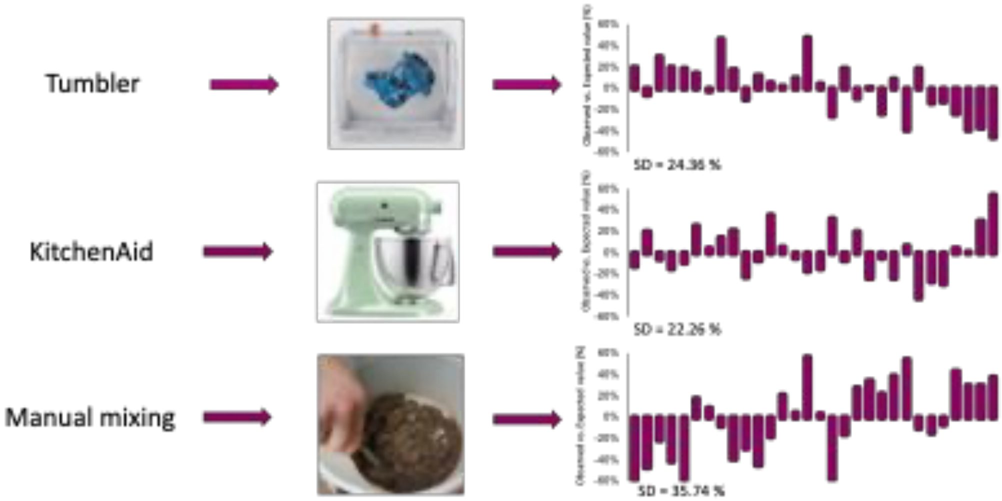


Figure 2. An example of the different homogenization techniques used to improve the representativeness of individual samples. Each bar represents one of 30 soil samples of equal volume, collected from each experimental system in the order as it was taken. The expected value holds the assumption that every sample collected from the system contains an equal amount of MPs. The observed value, i.e. what was measured, was expressed as a percentage of the expected value to examine the effectiveness of each technique in homogenizing the sample

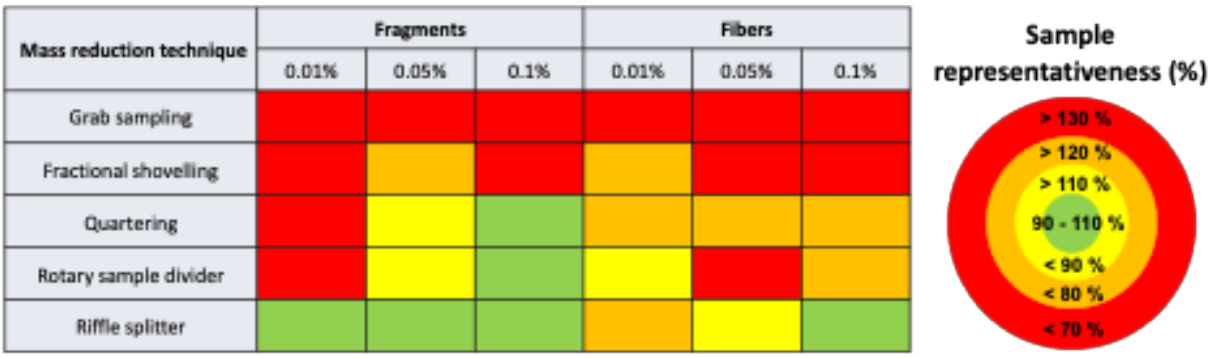


Figure 3. A heat-map representing the effectiveness of different mass-reduction techniques in producing a sub-sample representative of the bulk sample. MPs were spiked into model soil systems at concentrations of 0.01, 0.05, 0.1 w.w% and mixed. Each color grading equates to different thresholds of sample representativeness, which is expressed as the difference between observed and expected values of MPs, if split equally. Any deviation above or below 100% is an expression of an under- or overestimation of the bulk sample, according to the values of the sub-sample.

Acknowledgments
This research is funded by the Foundation for Chemistry Research & Initiatives under the American Chemistry Council (Developing a framework for micro- and nanoplastics sampling and extraction from soil (SAMPLEX). D.M.M. was additionally funded through the Swiss National Science Foundation (grant number PCEFP2_186856).

Development of a Py-GC/MS Method to Quantify Tire and Road Wear Particles in Aquatic and Terrestrial Organisms

Anaïs Denigot[1], T. Masset[1,2], B.J.D Ferrari[2] K. Schirmer[3,4] A.Toso[3], Sara Gonçalves[3], E. Vermeirssen[2], A. Bergmann[2], F. Breider[1]

[1] EPFL – Ecole Polytechnique Fédérale de Lausanne, Central Environmental Laboratory, Institute of Environmental Engineering, ENAC, station 2, CH-1015 Lausanne, Switzerland.

[1] Ecotox Centre - EPFL ENAC IIE, GE, Station 2, CH-1015 Lausanne, Switzerland and Überlandstrasse 133, 8600 Dübendorf, Switzerland

[3] Department Environmental Toxicology, Eawag – Swiss Federal Institute of Aquatic Science and Technology, Überlandstrasse 133, CH-8600 Dübendorf, Switzerland

[4] ETHZ, Institute of Biogeochemistry and Pollutant Dynamics, Zurich, 8092, Switzerland

florian.breider@epfl.ch

Tire and road wear particles (TRWPs) are ubiquitous contaminants detected across all environmental compartments, including aquatic, terrestrial, and atmospheric systems. As a result, organisms inhabiting these environments are continuously exposed to TRWPs and their associated chemical additives, which have been shown to induce toxic effects, notably in coho salmon. Moreover, TRWPs can be transferred through the trophic chain, raising concerns about their bioavailability and potential ecological impacts. Despite this, methods to reliably quantify TRWP exposure in living organisms remain limited. The present study aims to develop and validate a robust sample preparation and analytical method based on pyrolysis-gas chromatography-mass spectrometry (Py-GC/MS) for the quantification of TRWPs in complexe biological matrices. Three model organisms representing different environmental compartments were investigated: two aquatic species, *Gammarus fossarum* and *Chironomus riparius*, and one terrestrial species, *Eisenia fetida*. To account for increasing environmental matrix complexity, experiments were conducted on (*i*) lyophilized organisms spiked with cryomilled tire tread (CMTT) particles, (*ii*) organisms exposed to CMTTs under controlled laboratory conditions, and (*iii*) organisms collected directly from the environment. Various chemical (H_2O_2) and enzymatic (chitinase) digestion protocols were systematically evaluated to identify optimal conditions (i.e. temperature, incubation time, concentration) enabling maximal removal of organic matter while preserving the integrity of TRWPs. In parallel, several rubber-specific chemical markers (i.e. 4-vinlycyclohexene, 2,4-dimethyl-4-vinylcyclohexene, □-methylstyrene, dipentene and 4-phenylcyclohexene) were assessed to enhance detection specificity, minimize potential analytical interferences, and optimize method sensitivity. The resulting methodological framework provides essential tools for the accurate quantification of TRWPs in complex biological matrices and represents a critical step toward improving exposure assessment and ecological risk evaluation of TRWPs in aquatic and terrestrial ecosystems.

Combining laboratory and field experiments to explore bioaccumulation potential of tire-related additives in gammarids

T. Masset[1,2], F. Breider[2], K. Schirmer[3,4] A.Toso[3], Sara Gonçalves[3], D. Robert-Charrue[5], J.F Rubin[5], A. Rubin[5], E. Vermeirssen[1], A. Bergmann[1], R. Beauvais[1], N. Delorme[6], A. Chaumot[6], O. Geffard[6], and B.J.D Ferrari[1]

[1] Ecotox Centre - EPFL ENAC IIE, GE, Station 2, CH-1015 Lausanne, Switzerland and Überlandstrasse 133, 8600 Dübendorf, Switzerland

[2] EPFL – Ecole Polytechnique Fédérale de Lausanne, Central Environmental Laboratory, Institute of Environmental Engineering, ENAC, station 2, CH-1015 Lausanne, Switzerland.

[3] Department Environmental Toxicology, Eawag – Swiss Federal Institute of Aquatic Science and Technology, Überlandstrasse 133, CH-8600 Dübendorf, Switzerland

[4] ETHZ, Institute of Biogeochemistry and Pollutant Dynamics, Zurich, 8092, Switzerland

[5] Maison de la rivière - Ch. du Boiron 2, 1131 Tolochenaz

[6] INRAE, UR RiverLy, Ecotoxicology Team. Centre de Lyon-Grenoble Auvergne Rhône-Alpes, 5 rue de la Doua CS 20244, 69625 Villeurbanne, France

thibault.masset@epfl.ch

Tire and road wear particles (TRWP) are produced during abrasion of tires on road pavement. Tire abrasion is considered to be a major source of microplastic entering in Lake Geneva (Switzerland). Field measurements suggest that levels of TRWPs decrease between their emission source and the aquatic environment. Many chemicals are intensively used in tire formulations as vulcanization agents, antioxidants and antiozonants; they can represent several percent of the tire rubber mass. The distribution and fate of TRWPs and related chemicals in the aquatic environment are still poorly understood as are their potential impacts for aquatic biota.

This study aims to explore the potential for bioaccumulation of tire-related additives in a model aquatic invertebrate (gammarus fossarum). First, a laboratory experiment using sediment spiked with high concentrations (0.5% w/w) of cryogenically milled tire tread (CMTT) particles, as a proxy for TRWP, was performed under controlled conditions for 7 days. It enabled to investigate the bioaccumulation potential and the uptake kinetics of the tire-related additives for gammarus fossarum. Secondly, a ex-situ experiment using caged gammarids exposed to river water (Boiron river, maison de la rivière, Vaud canton) for 14 days was performed to assess the bioaccumulation of tire-related additives under environmentally relevant conditions. Uptake of some chemicals was observed in both experiments with lower internal concentrations and different uptake kinetics observed in the ex-situ experiment. The comparison between both experiments data will be presented and discussed. Our results provide important data for a better understanding of tire-related additives fate in freshwater ecosystems, as well as their potential for bioaccumulation in aquatic invertebrates and trophic transfer. The data could also be used for future risk assessment and mitigation studies.

Association of microplastics with water-stable aggregates formed under laboratory conditions

Mike Rohling[1], Iso Christl[1], Denise M. Mitrano[1]

[1] Department of Environmental Systems Sciences, ETH Zürich, Universitätstrasse 16, 8092 Zürich, Switzerland

Water-stable soil aggregates (WSAs) are a key to the structural stability of soils. The presence of microplastics (MPs) has been found to aTect WSA formation. Additionally, the association of MPs with WSAs may strongly alter the transport behavior of MPs in soils. However, the association of MPs with newly formed WSAs has not yet been investigated as a function of MP and soil properties. In this study, we assessed how polymer composition [polyethylene terephthalate (PET), polylactic acid (PLA)], particle size (small: nominally <63 µm; large: nominally >250 µm), MPs concentration in soil (0.2, 0.5, 1 wt.%) and soil texture (loam, loamy sand) impact WSA formation and MPs-WSA association over a two-week incubation under controlled laboratory conditions. Small PLA fragments reduced WSA formation more strongly and tended to be less associated with WSAs than small PET fragments, potentially due to the slightly greater hydrophobicity of PET. Across all incubations, coarse PLA fragments at 0.2 wt.% showed the largest share of unassociated fragments with approximately 35% of all MPs introduced into the system. The eTect of small PLA fragments on WSA formation was concentration-dependent, with reduced aggregation at low and intermediate concentrations but near-control levels at high concentration, despite a higher fraction of unassociated MPs. These non-monotonic eTects suggest that MPs aTect WSA formation through opposing mechanisms and monotonic concentration–response assumptions may be inappropriate for intra- or extrapolating MP eTects on WSA formation. Altering soil texture from loam to loamy sand did not impact the share of unassociated small PET fragments. Collectively, MPs polymer composition, size, and concentration in soil impacted WSA formation and their association with WSAs under the experimental circumstances, showing potential for reduced MPs transport in soils and altered soil structural stability.

Looking Closer: A Physicochemical Analysis of Test Nanoplastics

Moritz Haeffner,[1] Jessica Caldwell,[1] Laura Rodriguez-Lorenzo,[3] Barbara Rothen-Rutishauser,[1] Alke Petri-Fink,[1,2,*] and Patricia Taladriz-Blanco[1,*]

[1]Adolphe Merkle Institute, University of Fribourg, Chemin des Verdiers, 4, 1700 Fribourg, Switzerland
[2]Chemistry Department, University of Fribourg, Université de Fribourg, Chemin du Musée 9, 1700 Fribourg, Switzerland
[3]International Iberian Nanotechnology Laboratory (INL), Water Quality Group, Av. Mestre José Veiga s/n, 4715-330, Braga, Portugal.

Understanding the fate of nanoplastics in the environment is essential for quantifying exposure, evaluating hazards, and ultimately assessing risk. As the extraction of real nanoplastic particles from the environment remains not feasible in the near future, achieving this requires high-quality, well-characterized test and reference nanoparticles. To synthesize such particles, several methods are commonly used, including reprecipitation, ball milling, and emulsion polymerization. Prior to analytical or toxicological studies, particles are typically characterized depending on polymer type, size, and surface charge. However, we found that test nanoplastic preparation methods critically affect other particle properties beyond the scope of conventional characterization. Under the conditions applied in this work, we found differences in plastic particle properties depending on the manufacturing process. These method-dependent differences could affect spectroscopy-based detection and potentially toxicological studies. This highlights the urgent need for standardized production protocols to advance nanoplastic research.

Quantification of Microplastics in Soils from the Swiss National Monitoring Network

Angélique Moraz[a,b], G. Crosset-Perrotin[b], N. Ashta[b,c], M. Philipp[b], R. Kaegi[b], C. Hueglin[c] and T. D. Bucheli[a]

[a] Environmental Analytics, Agroscope, Zürich, Switzerland
[b] Process Engineering, Eawag, Dübendorf, Switzerland
[c]Laboratory for Air Pollution and Environmental Technology, Empa, Dübendorf, Switzerland

angelique.moraz@agroscope.admin.ch

While soils are hypothesized to be a substantial sink for microplastics (MP), terrestrial monitoring remains limited. Consequently, baseline concentrations of MPs in soil remain largely undefined, creating a critical gap in risk assessment. Indeed, in the absence of robust exposure data, ecotoxicological studies rely on predicted concentrations that may differ from real-world conditions.

This project presents the framework and preliminary insights from a nationwide monitoring campaign designed to establish an overview for soil MP contamination across Switzerland. The samples are archive soils from the Swiss soil monitoring network (NABO) established since the mid 1980s. Beyond quantification, this study aims to apportion MP source by correlating results with land-use types, intensity of human activity, and historical management practices, such as past sewage sludge application and compost amendment.

The MPs were extracted from soil by tetrasodium pyrophosphate and density separation using a solution of sodium polytungstate (1.5 g/ml), followed by a Fenton oxidation of the organic matter. The resulting particles were collected onto an aluminum oxide membrane, which was imaged using focal plane array µ-Fourier transform infrared spectroscopy (FPA-µ-FTIR). To ensure robust data quality, the analytical pipeline incorporated the spiking of surrogate standards, enabling sample-specific recoveries and rigorous quality control.

Initial results detailing the polymer types, particle size distributions and extrapolated mass found in a first set of Swiss soils are presented. Specifically, polystyrene (PS) mass estimates derived from particle size data are cross-validated with direct mass quantification by Pyrolysis-Gas Chromatography/Mass Spectrometry (Py-GC/MS).

The final dataset will be extrapolated to estimate MPs concentration in soils on a national scale and compared with the findings of probabilistic material flow analysis models. By comparing the soil measurements against loads estimates for wastewater treatment plants and atmospheric deposition, this work aims to provide a broad assessment of MP occurrence in Switzerland.

Towards microplastic monitoring in Swiss surface water

Storck, F.R.[1], Philipp, M.[2], Kägi, R.[2]

[1]: Florian Storck, Bundesamt für Umwelt, 3003 Bern, florian.storck@bafu.admin.ch
[2]: Ralf Kägi, Eawag, 8600 Dübendorf, ralf.kaegi@eawag.ch, Matthias.Philipp@eawag.ch

Aims of microplastic (MP) monitoring programs are a reduction of MP pollution and MP inputs. Although monitoring of MPs in surface water has been integrated into international agreements like the OSPAR-convention or ICPR programs, harmonized sampling protocols and analytical pipelines are still largely lacking. Recent progress in both, instrumental developments and sampling pipelines, however, enabled higher sample throughput and streamlined sample processing. These achievements make a robust MP monitoring in surface water feasible. In this talk, we present our most recent results from Swiss microplastic monitoring and describe our ideas for a future MP monitoring program in surface waters.

To assess the feasibility of a long-term MP monitoring program, we have compared different sampling strategies and evaluated different instrumental approaches. For that purpose, we have collected MP samples from 4 campaigns in 4 seasons at 3 Stations (Rhine: Weil and Diepoldsau and Rhone: Porte-du-Scex). We have collected samples in a 4 L glass bottle and in parallel, we have filtered between 4 and 70 L of surface waters using a 47 mm pressure filtration unit. Sample preparation pipelines largely consisted of a oxidative digestion followed by a density separation step.

Initial sampling campaigns resulted in a considerable spread of data, mostly related to challenges associated with sample collection and processing. The sampling campaigns conducted in 2025, however, resulted in a coherent dataset, suggesting a total MP particle count of around 10 #/L in the collected surface waters. MP number concentrations were comparable at all three sampling sites. Main polymer types included PE, PET and PMMA. The results on the PMMA number counts, however, have to be treated with care, as a new software algorithm, associated with IR laser instruments seems to overestimate the PMMA contents.

Although the current MP classifiers of the IR laser-based instruments of the latest generation still need to be validated and possibly improved, the measurement times for an entire filter (25mm diameter) dropped from between 10 and 20h (focal plane array based FT-IR instruments) to less than 30 minutes. Combined with a harmonized sample preparation protocol and QA/QC procedures, including the systematic use of surrogate standards, this will allow conducting MP monitoring programs at considerably higher frequencies and at drastically reduced costs.

Literature:

https://www.ospar.org/convention
https://www.iksr.org/en/topics/water-quality/targets-and-measures
https://www.iksr.org/fileadmin/user_upload/DKDM/Dokumente/Symposien-Workshop/DE/symp_De_Programm_WS_Plastik.pdf

Vertical distribution of microplastics in soil affects plant response to microplastics.

Merve Tunali[1,2], Matthias C. Rillig [1, 3]

[1] Freie Universität Berlin, Institute of Biology, Plant Ecology, Berlin, Germany Berlin-Brandenburg Institute of Advanced Biodiversity Research (BBIB), Berlin, Germany

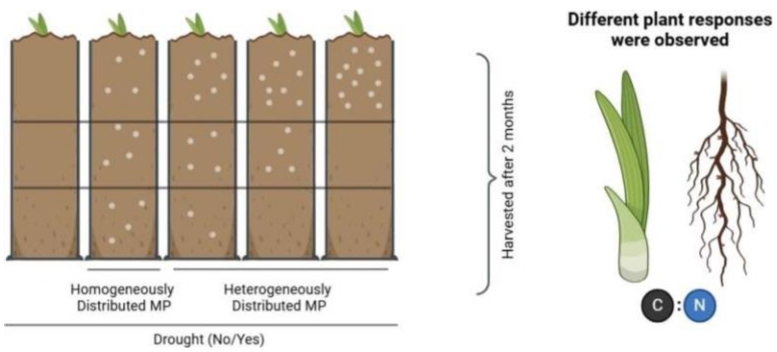
[2] Empa, Swiss Federal Laboratories for Materials Science and Technology, Technology and Society Laboratory, Lerchenfeldstrasse 5, 9014 Sankt Gallen, Switzerland

[3] Berlin-Brandenburg Institute of Advanced Biodiversity Research (BBIB), Altensteinstr. 6, 14195, Berlin, Germany

merve.tunali@empa.ch

The impacts of microplastics on plants have been extensively researched, yielding a variety of responses: promoting growth, limiting growth, or causing no change in plants. Experimental studies, following basic principles of ecotoxicology, typically use a homogeneous distribution of microplastics in soils, where soil and microplastic are well-mixed. However, in the environment, plastic is not homogeneously distributed. Therefore, we tested whether the distribution of microplastics in soils affects the impact observed on plants. For this purpose, we tested the effect of homogeneously distributed microplastics and heterogeneously distributed microplastics (at different levels) on the growth of spring onions. In addition, the presence of drought was also included in our greenhouse experiment. The results show that the distribution of microplastics (whether it is homogeneous or heterogeneous) affects the growth of spring onions differently, especially the shoot and root mass. First, differences of 21–22 % in shoot mass and 29–38 % in root mass were observed between heterogeneously distributed treatments and the homogeneous treatment. Second, under drought conditions, the effects -particularly on shoot mass and the C:N (carbon:nitrogen) ratio- may differ compared to non-drought. Differences of 30–37 % in shoot mass, and up to 16 % in the carbon/nitrogen ratio were observed between different heterogeneously distributed treatments and the homogeneous treatment in the drought case. In addition, shoot mass and the C:N ratio varied depending on drought conditions. Our results strongly suggest that future experiments on microplastic effects in soil should consider at least vertically heterogeneity of the pollutant to arrive at more realistic effect estimates.

Graphical abstract



Release, Characterization, and Quantification of Natural, Biobased and Synthetic Fiber Fragments

Elias J. Zimmermann[1], Stephanie Eitner[1,2], Tina Bürki-Thurnherr[2], Peter Wick[2], Bernd Nowack[1]

[1]Empa - Swiss Federal Laboratories for Materials Science and Technology, Technology and Society Laboratory, Lerchenfeldstrasse 5, St. Gallen
[2]Empa - Swiss Federal Laboratories for Materials Science and Technology, Nanomaterials in Health, Lerchenfeldstrasse 5, St. Gallen

elias.zimmermann@empa.ch

Released fibers, fibrils and microplastic fragments from textiles are an emerging concern for environmental and human health, yet most washing studies focus on synthetic materials and do not resolve different fragment morphologies. Natural and biobased fibers are often assumed to be less problematic, but they are frequently detected in environmental and indoor samples and may release different types of inhalable fragments.

In this study, we quantified and characterized fiber/particle release from textiles spanning natural, biobased, and synthetic fiber types during standardized washing. Released material was collected on membrane filters and analyzed by scanning electron microscopy (SEM), enabling high-resolution assessment of fiber/particle morphology (intact fibers, fibrils, ribbons, and particles) and size distributions. Elemental analysis using energy-dispersive X-ray spectroscopy (EDX) supported material specific identification of selected fibers/particles. To link release behavior to fiber properties, fiber widths in the original fabrics were measured, allowing detection of deviations between source textile and released material and identification of fibrils and irregular, production-related particles.

Natural textiles released the highest number of fibers/particles, followed by biobased and synthetic textiles, while mass release showed no corresponding trend and varied with morphology. Natural textiles released a larger proportion of intact fibers and particles, whereas synthetic textiles predominantly released fibrils or ribbon shaped fibers. Biobased textiles exhibited a mixed release profile, characterized by thin, elongated fibrils alongside intact fibers. These differences are environmentally and toxicologically relevant, as fragment size and aspect ratio influence transport, persistence, and respiratory deposition. Elongated microfibers and fibrils have been associated with impaired clearance and inflammatory responses in inhalation models and occupational settings. Beyond polymer class, yarn and fabric characteristics, such as staple vs filament fibers and knit vs weave constructions, strongly modulated shedding patterns. This indicates that manufacturing choices co-determine both the quantity and morphology of released fibers/particles. Overall, our findings demonstrate that natural and biobased textiles should not be excluded from fiber release assessments and highlight the need to consider polymer chemistry, fiber morphology and production related processes when evaluating the environmental and human health implications of textile design.

Country-Wide Quantification of Microplastics Loads Discharged by Swiss Wastewater Treatment Plants

Guillaume Crosset-Perrotin[1], Narain M. Ashta[2], Angélique Moraz[3], Matthias Philipp[1], Michael Sander[4], Eberhard Morgenroth[1,5], Thomas D. Bucheli[3], Christoph Hueglin[2], and Ralf Kaegi[1,*]

[1] Eawag, Department of Processing Engineering, Swiss Federal Institute of Aquatic Science and Technology, 8600 Duebendorf, Switzerland

[2] Empa, Laboratory for Air Pollution, Swiss Federal Laboratories for Materials Science and Technology, 8600 Duebendorf, Switzerland

[3] Agroscope, Environmental Analytics, 8046 Zürich, Switzerland

[4] ETH Zürich, Institute of Biogeochemistry and Pollutant Dynamics, 8092 Zürich, Switzerland

[5] ETH Zürich, Institute of Environmental Engineering, Zürich 8093, Switzerland

guillaume.crosset@eawag.ch

Wastewater treatment plants (WWTPs) are recognized pathways for microplastic particles (MPs) into surface waters. However, the absolute contribution of WWTPs to MPs pollution of surface waters in Switzerland remains unclear. During biological treatment of wastewater, MPs heteroagglomerate with sludge flocs, resulting in similar MP-to-total suspended solids (TSS) ratios in both activated sludge and treated wastewater. Consquently, measuring MPs in activated sludge offers a promising alternative to the direct quantification of MPs in WWTP effluents. In this study, we analyzed MP contents in activated sludge from 51 Swiss WWTPs (serving 44% of Swiss population) and estimated the loads of MPs emitted via WWTP effluents.

Activated sludge (~200 mg TSS) was treated with hydrogen peroxide to remove organic matter, followed by density separation with sodium polytungstate to remove inorganic particles. Processed samples were filtered onto aluminum oxide filters and analyzed using Focal Plane Array–μ–Fourier Transform Infrared spectroscopy to identify MP down to 20 μm. Robust QA/QC protocols were applied, and uncertainties along the analytical chain were quantified.

MP concentrations in the sludge ranged from 900 to 22,000 $\#_{MPs}$ $gTSS^{-1}$, while the estimated MP mass ranged from 0.01 to 1.7 mg_{MPs} $gTSS^{-1}$. The particle size distribution showed that 98.2% of the MPs were smaller than 100 μm. Using routinely measured TSS concentrations and volumetric flow rates from WWTP effluents, total MP discharge from WWTP effluents was estimated at $3.1 \cdot 10^{13}$ MPs $year^{-1}$ and 4.7 $tons_{MPs}$ $year^{-1}$ overall Switzerland. Normalizing these figures led to a per capita emission of $5.2 \cdot 10^{6}$ $\#_{MPs}$ $(year \cdot capita)^{-1}$ or 0.45 g_{MPs} $(year \cdot capita)^{-1}$. The findings of this study contribute to a better understanding of the inputs of MP in surface waters from WWTP effluents.

Sediment traps reveal seasonal changes in microplastic settling in a deep stratified lake

Federica Rotta [1,2] , Barbara Leoni [3], Fabio Lepori [4], Agnese Marchini [2], Camilla Capelli[1]

[1] Department of Environment Constructions and Design, University of Applied Sciences and Arts of Southern Switzerland, Switzerland

[2] Department of Earth and Environmental Sciences, University of Pavia, Italy

[3] Department of Earth and Environmental Sciences, University of Milano-Bicocca, Italy

[4] Direction générale de l'environnement, Direction de l'environnement industriel, urbain et rural, Epalinges, Switzerland

federica.rotta@supsi.ch

Laboratory simulations and modelling studies indicate that particle properties (i.e., shape, size and polymer) and hydrodynamics conditions (i.e., thermal stratification) are relevant factors driving microplastics vertical distribution and sedimentation in lakes. Yet, a substantial research gap remains regarding the sedimentation of microplastics under real environmental conditions.

Here, we present results from a three-year (2023-2025) research study aimed at understanding microplastic sedimentation in Lake Lugano, a deep subalpine lake with high microplastic concentrations in surface and subsurface waters. Sediment traps were seasonally deployed for one month at 20 m depth, to obtain time series of microplastic vertical fluxes in stratified and turnover conditions.

Preliminary findings reveal pronounced seasonal variability in microplastic sinking rates. During summer stratification, sedimentation reached an average value of 33.3 microplastics m^{-2} day^{-1}, whereas during winter mixing the flux significantly increased to 107.5 microplastics m^{-2} day^{-1}. Particles shape and size also influence settling behaviour, with small fibres being more sensitive to changes in water columns density gradients, compared to larger fragments.

These results quantified for the first time the dynamic nature of microplastic transport in real environmental conditions, highlighting the central role of thermal stratification in regulating microplastics environmental pathway. In-depth particle characterisation, including polymer composition, will contribute to further explaining this process.

Impacts of subsurface microplastics pollution on deep-ocean carbon export

Madushika Sewwandi[1,2], Qing Sung[3,1,2], Alban Planchat[1,2], Charlotte Laufkötter[1,2]

[1] Climate and Environmental Physics, Physics Institute, University of Bern, Sidlerstrasse 5, 3012 Bern, Switzerland
[2] Oeschger Centre for Climate Change Research, University of Bern, Hochschulstrasse 4, 3012 Bern, Switzerland
[3] Wyss Academy for Nature, University of Bern, Bern, Switzerland, Kochergasse 4, 3012 Bern, Switzerland

Microplastics (MPs) have increasingly attracted attention in ocean biogeochemistry because they constitute a measurable fraction of particulate organic carbon (POC), which drives carbon transport to the deep ocean via the biological pump. However, our understanding of how present-day MP contributions to subsurface POC export influence carbon transport to depth remains limited. Using a 1D particle sinking model, we investigated how less dense polyethylene (PE; 0.94 g cm^{-3}) and denser polyethylene terephthalate (PET; 1.33 g cm^{-3}) MPs than POC (1.06 g cm^{-3}) affect particle sinking velocity and the efficiency of carbon transfer to the deep ocean. Loosely tied to upper-bound field observations, MP export flux at 100 m depth was prescribed as 4% of the total POC flux. At the global scale, POC export was simulated using calibrated small (20 µm) and large (250 µm) particle classes, representing regions where both particle sizes coexist, with MPs distributed between these classes following the model's POC routing scheme. Our results showed that ballasting minerals dominated sinking velocity, increasing it in mineral-ballasted aggregates by up to ~15-fold compared to organic-only aggregates. In contrast, the effect of MPs depended on MP type: PE consistently reduced sinking in both organic-only and mineral-ballasted aggregates, whereas PET accelerated organic-only aggregates but slightly decreased sinking in mineral-ballasted ones. PET MPs slightly enhanced the fraction of POC reaching 1000 m in organic-only aggregates (+0.07% to +3.25%), while changes remained minimal for mineral-ballasted aggregates (−0.35% to +0.12%). In contrast, PE MPs more consistently reduced transfer efficiency for both organic-only (−3% to ~0%) and mineral-ballasted aggregates (−3% to +0.3%). These findings suggest that MP density and natural variability in POC density combinedly influence carbon export by modifying particle sinking velocities. Nevertheless, even at the upper-bound carbon–MP contribution to POC flux, the overall impact on deep-ocean carbon export in regions where both small and large POC aggregates coexist remained negligible. Future studies are needed to assess the impact of MPs on carbon export in regions dominated by small/large POC aggregates.

Keywords: microplastics, biological pump, ballasting minerals, sinking velocity, ocean carbon export

Microplastic in Snow from Remote Alpine and Arctic Regions

Antonia Kellner [1,2,3,4], Ralf Kaegi[1], Christoph Hüglin[2], Katrin Vorkamp[3], and Thomas Bucheli[4]

[1]Eawag – Swiss Federal Institute of Aquatic Science and Technology, Duebendorf, 8600, Switzerland
[2]Empa – Swiss Federal Laboratories for Materials Science and Technology, Duebendorf, 8600, Switzerland
[3]Aarhus University, Department of Environmental Science, Roskilde, Denmark
[4]Agroscope, Reckenholzstrasse 191, 8046 Zurich, Switzerland

antonia.kellner@eawag.ch

Microplastic particles (MPs) are increasingly recognized as atmospheric contaminants capable of long-range transport. Several studies have reported atmospheric MPs deposited in both urbanized and rural areas. However, data from MP deposition in high-alpine regions and remote polar environments remain scarce.

Due to limited local anthropogenic activity, MPs detected in these areas are expected to predominantly originate from atmospheric transport. As snow acts as an efficient atmospheric particle scavenger, atmospherically transported MPs accumulate in freshly deposited surface snow. Therefore, sampling and analysing snow from remote regions can provide insights into atmospheric MP concentrations and potential long-range transport. Moreover, seasonal snowpack profiles collected over the winter may reflect cumulative MP deposition, potentially making snow an efficient natural passive sampler.

Given the expected low MP concentrations in remote alpine and Arctic environments, the development of reliable and contamination-controlled methods is essential to obtain representative data. This study aims to improve existing approaches for quantifying MPs in fresh surface snow and seasonal snowpacks from high-elevation regions in Switzerland (>2000 m above sea level) and Arctic environments. A key objective is to optimize (sub-) sampling design and processed snow volumes to ensure representative MP data while minimizing contamination during field collection and laboratory processing. The resulting protocol will be applied to the monitoring of MPs in alpine and remote polar environments.

Wet and dry atmospheric deposition of microplastics in Switzerland

Narain M. Ashta[1], Atiur Rahman[1], Guillaume-Crosset Perrotin[2], Angélique Moraz[3], Matthias Philipp[2], Thomas Bucheli[3], Ralf Kaegi[2] and Christoph Hueglin[1]

[1]Empa, Ueberlandstrasse 129, 8600 Duebendorf, Switzerland

[2]Eawag, Ueberlandstrasse 133, 8600 Duebendorf

[3]Agroscope, Reckenholzstrasse 191, 8046 Zurich, Switzerland

narain.ashta@empa.ch

The atmosphere may play an important role in the distribution of MPs in the environment. To understand more about this pathway, we monitored the wet and dry atmospheric deposition of MPs excluding tire-wear particles in urban, suburban and rural Switzerland on a four-weekly basis over a one-year period. We report on the results of this study, comparing the number- and mass-based wet and dry deposition rates measured at different sites. We put these deposition rates into context by comparing them with corresponding deposition rates of total aerosols and tire wear particles. Finally, we estimate the annual atmospheric inputs of MPs all over Switzerland, including to Swiss surface waters and agricultural soils. The inputs from the atmosphere to Swiss surface waters are compared to those arising from wastewater treatment plants, as estimated in a parallel study by colleagues at Eawag. The results indicate that MPs comprise a small yet quantifiable fraction of total aerosols and that the atmosphere plays an important role in the distribution of MPs in the Swiss environment.

Biodegradable Plastics in the Environment

Gabriel Gerner, Senior Researcher, Zurich University of Applied Sciences

Project: Einfluss und Nachweis von biologisch abbaubaren Werkstoffen in der Umwelt (BAWIU) | ZHAW Zürcher Hochschule für Angewandte Wissenschaften

The «Biodegradable Plastics in the Environment» (BAWIU) project provides a comprehensive picture of biodegradable materials (BM) regarding legal framework, usage and environmental impact. To address current knowledge gaps, we developed a new classification approach that captures both product characteristics and material behavior. Our literature review shows a persistent gap between theoretical biodegradability and actual degradation in real environments. Only PHA (PHB) consistently breaks down in soil, while PLA, PBAT, PBS and blends degrade slowly or inconsistently under environmental conditions in Switzerland. Ecotoxicological findings are still limited but indicate that BM are not automatically less harmful than conventional plastics.

We also tested analytical methods for detecting BM in environmental matrices (soil, compost and digestate). Solvent extraction combined with NMR proved promising, whereas FT-IR analysis was strongly hindered by organic material. These results underline the need for differentiated BM assessment and robust analytical tools to support sustainable decision-making.

Biodegradation of Elastic Biocomposites for Abrasion-Sensitive Applications

Oliver Weismantel[1], Arthur Groh [1] on behalf of KUORI, in collaboration with ZHAW LSFM – ICBT

[1]KUORI GmbH, Switzerland
ZHAW Zurich University of Applied Sciences, Life Sciences and Facility Management (LSFM),
Institute of Chemistry and Biotechnology (ICBT),

The increasing persistence of microplastics in terrestrial and aquatic environments highlights the need for polymeric materials that combine functional performance with controlled environmentally relevant degradability, particularly in abrasion-prone applications where particle release during use is unavoidable. At KUORI, bio-based polymer composites based on renewable biopolymers and food-industry byproducts are developed to reduce fossil carbon input and address the formation of persistent microplastics at the source.

This contribution presents ongoing joint research conducted by KUORI and the ZHAW LSFM – ICBT, Research Group Environmental Biotechnology & Bioenergy, investigating the biodegradation behavior of elastic biocomposites intended for mechanically demanding and abrasion-prone applications. The materials are engineered such that abrasion-generated particles remain biodegradable under environmentally relevant conditions rather than persisting as stable microplastic debris.

Biodegradation tests are being established, with a focus on soil-based experiments conducted under natural conditions at room temperature to better reflect realistic environmental exposure scenarios. These ongoing efforts are complemented by exploratory, small-scale screening approaches intended to enable rapid comparison of formulations during early-stage material development. The methods under development aim to capture early degradation kinetics and structural changes, allowing first-order evaluations of biodegradability under environmentally relevant, non-standardized conditions.

In addition, simplified conceptual models are introduced to describe degradation behavior as a function of polymer matrix composition, filler content, and interfacial morphology. By linking experimentally observable parameters to degradation kinetics, these models support qualitative prediction of formulation effects and guide the design of abrasion-resistant yet environmentally degradable biocomposites.

This work demonstrates how industrial material development, in close collaboration with applied environmental biotechnology research, can address microplastic generation already at the material design stage, particularly for abrasion-prone applications.

Compostable plastic biodegradability and potential participation in microplastic pollution in industrial compost

Fanny C. D. Berset[a], Wei Liu[b], Serge Stoll[a]

[a]Department F.-A. Forel for environmental and aquatic sciences, Section of Earth and Environmental Sciences, Environmental Physical Chemistry, University of Geneva, Switzerland.
[b]Université Claude Bernard Lyon 1, Laboratoire d'Ecologie Microbienne, UMR CNRS 5557, UMR INRAE 1418, Villeurbanne, France.

fanny.berset@unige.ch

In agricultural soils, microplastics (MPs) concentrations usually reach 1,000 – 4,000 items / kg, posing a threat to environmental and human health depending on their chemical types. Compost amendment is a major pathway, and compostable plastics (CPs) have been proposed as a solution to face this issue, despite some studies noticing non fully biodegraded CPs in composts and soils. Since there is a need to investigate actual baseline pollution of both noncompostable and compostable MPs into composts, this study focused on observing CPs potential participation in MPs pollution in industrial compost.

A biodegradability test ISO 148552 was performed on a compostable plastic bag (CPb). The remaining composts - control (Blank), reference (Cellulose), and amendment with CPb (BA) - were sieved from >5 mm down to 0.5 mm to recover MPs. Those were identified through Fourier-transform infrared detection (ATR-FTIR) and sorted according to form, size and chemical type.

The CPb reached 87.2 ± 2.5 % biodegradability and was still visually recognizable and identifiable by ATR-FTIR at the end of the experiment. CPb concentration reached 4,357 ± 436 particles/kg, almost exclusively as films and in all size ranges. CPb particles represented 28 % of the total MPs in BA (15,799 ± 4,889 MPs/kg), significantly increasing it compared to Blank (8,991 ± 5,682 MPs/kg). Globally, most MPs were found in the 0.5 – 1.25 mm size range, mainly polyethylene terephthalate and polypropylene fibers in Blank, and CPb, polyethylene high density and polyvinyl chloride films in BA.

This work allowed to confirm the potential participation of CPs to the actual MPs pollution in industrial composts.

Estimating natural versus synthetic microfiber emissions from European domestic laundry

John D. Hader & Bernd Nowack

Empa – Swiss Federal Laboratories for Materials Science and Technology, St. Gallen, Switzerland

John.Hader@empa.ch

Microplastic fibers are a subset of the overall microfibers released from textiles, which comprises both synthetic plastic microfibers as well natural microfibers – such as those from cotton or wool textiles. Despite their "natural" origin, natural microfibers emitted from human laundry activities may still pose an environmental hazard – either from the microfibers themselves or from leaching of associated chemicals – and have been shown in various studies to contribute substantially to environmental concentrations of microfibers. However, much of the scientific literature focuses on microplastic fibers, while not considering microfibers of natural origin. For example, while many studies exist simulating geospatially resolved emissions of microplastic fibers to the environment from laundry activities, few studies have assessed such emissions of natural microfibers, highlighting a key gap in understanding of this potentially important source of anthropogenic pollution. To help fill this gap, we present results of a modelling study on the emissions of natural as well as synthetic microfibers from European domestic laundry practices. We combine data on the fraction of natural versus synthetic textiles consumed by Europeans with data on the release rates of these different types of microfibers during laundering, as well as the frequency of laundering practices as a function of country. Furthermore, we pair these resulting estimates of wastewater emissions of microfibers with wastewater treatment plant connectivity rates per country and the varying presence of the different treatment stages to estimate the mass of microfibers emitted to surface water. By using country-specific data on sludge application to soils, we also derive mass flows of microfibers emitted to soil. Results of our study could form the basis for environmental risk assessments of both synthetic as well as natural microfibers in both water and soil, and furthermore inform policy recommendations for the management of the full spectrum of microfiber pollution.

Advancing Plastic Release Modeling: Quantifying Macro- and Microplastic Emissions Across 30 European Countries

Danyang Jiang[1], Bernd Nowack[1]

[1]Empa – Swiss Federal Laboratories for Materials Science and Technology, Technology and Society Laboratory, Lerchenfeldstrasse 5, 9014 St. Gallen, Switzerland

danyang.jiang@empa.ch

Systematic understanding of plastic emissions is essential for developing effective mitigation strategies. Combining material flow analysis (MFA) with release assessments enables quantification of plastic releases across the entire product life cycle. In this study, we developed a plastic release model based on MFA for the EU27, Switzerland, Norway, and the United Kingdom, comprehensively quantifying macro- and microplastic emissions of LDPE, HDPE, PP, PS, EPS, PVC, and PET for 2020. The model consists of ten aggregated product sectors, 45 product categories, 12 waste collection systems, and six recycling systems, accounting for 456 emission flows across all life stages.

Our results show that, in Europe, macroplastic emissions mainly arise from post-consumer collection, littering, and fishing-gear loss, while microplastics are dominated by agricultural films, recycling, pellet loss, and fiber shedding. For Europe as a whole, the emission factor was 0.187 ± 0.018% for macroplastics and 0.0404 ± 0.0030% for microplastics. Emission factors vary widely between countries and are linked to consumer behavior and waste management practices. Microplastics are released mainly to soil, with emission factors ranging from 0.019 ± 0.003% in Belgium to 0.047 ± 0.010% in Latvia. Subsurface soil receives microplastics mainly from sewage leakage and construction pipe use, with Romania showing the highest emission factor (0.008 ± 0.003%). Macroplastic emission factors are higher overall than microplastic, with soil as the main receiving compartment, ranging from 0.04 ± 0.01% in Lithuania to 0.52 ± 0.18% in Greece. Our model provides a solid basis for identifying key plastic emission pathways and guiding policies to mitigate plastic pollution in Europe.

A Fragmentation Model to Quantify Secondary Microplastics Generation from Environmental Macroplastics in Switzerland

Mohamed Bey Zekkoub[1], Bernd Nowack[1]

1 Empa – Swiss Federal Laboratories for Materials Science and Technology,
Technology and Society Laboratory, St. Gallen, Switzerland

Understanding the sources and pathways of microplastics in the environment is crucial for assessing their ecological risks and developing effective mitigation strategies. While primary microplastics have received considerable attention, secondary microplastics formed from the fragmentation of larger plastic items remain poorly quantified, particularly at regional scales. Here, we address this critical knowledge gap by developing a model to estimate secondary microplastic generation from macroplastic released to the environment in Switzerland.

We focus on seven major commodity polymers that dominate plastic consumption: Low- and HighDensity Polyethylene (LDPE, HDPE), Polypropylene (PP), Polystyrene (PS), Expanded Polystyrene (EPS), Polyvinyl Chloride (PVC), and Polyethylene Terephthalate (PET). Our methodological approach consists of two interconnected steps. First, we derive polymer-specific fragmentation rates by synthesizing and analyzing empirical data on material fragmentation under various environmental stressors such as UV radiation, mechanical abrasion, and hydrodynamic conditions. Second, we implement these rates within a mathematical framework that quantifies the generated microplastic mass from the released macorplastic mass across three distinct environmental compartments: terrestrial surface soil, subsurface soil (via burial processes), and riverine systems.

Our results provide insights into the fragmentation dynamics of different plastic items and polymers, which have remained poorly quantified until now. We identify significant differences in fragmentation rates between polymer types and environmental compartments. Notably, our model reveals specific environmental conditions and polymer combinations that accelerate fragmentation processes, highlighting key pathways for microplastic generation in the Swiss environment.

This study represents a first step forward for quantitative fate and exposure assessments of microplastics in Switzerland, providing a robust basis for environmental risk assessment.

Keywords: Secondary Microplastics, Fragmentation Modelling, Polymer Degradation, Environmental Fate.

Environmental Exposures and Epithelial Barrier Disruption: Role of Micro- and Nanoplastic

Cezmi A. Akdis, MD
Swiss Institute of Allergy and Asthma Research (SIAF), University Zurich, Davos

Humans are exposed to a variety of toxins and chemicals every day. It is estimated that more than 350'000 new chemicals have been introduced to our lives after the chemistry revolution in 1950s, mostly without any reasonable control of their health effects. Many studies are now pointing to the rapid rise of exposure to many of these harmful substances during the last six decades with their implications on skin and mucosal epithelial barrier function. Major substances that damage epithelial barriers have been demonstrated as detergents and cleaning substances, dishwasher rinse aids, toothpastes; substances that cause air pollution, particulate matter, ozone, micro and nanoplastic, various processed food additives and emulsifiers, artificial sweeteners and taste enhancers. According to the epithelial barrier theory (www.epithelialbarriertheory.com), exposure to many of these above listed substances damage the epithelium on the surface of our skin, lungs and intestine. A defective epithelial barrier has been demonstrated in more than 80 chronic noncommunicable diseases such as asthma, atopic dermatitis, allergic rhinitis, chronic rhinosinusitis, eosinophilic esophagitis, celiac disease, and inflammatory bowel disease. The "epithelial barrier theory" proposes that the rise in epithelial barrier damaging agents linked to industrialization, urbanization and modern life underlies the rise in allergic, autoimmune and other chronic conditions. After breaking of the epithelial barriers by various environmental agents, microbiome, which normally floats above the skin and mucosas translocates deeper between and beneath the epithelial barrier. Microbial dysbiosis and decreased biodiversity develop following the colonization of opportunistic pathogens. An "epithelitis" with the activation of inflammasome, release of alarmins and multiple chemokines initiates the immune response and inflammation inside and beneath the epithelium with the aim of an "expulsion response" against the deep translocating opportunistic pathogens, pollutants and toxic substances to clear them in deeper tissues. In our two recent studies on micro and nanoplastic analysing the epithelial cell effects of different doses of polystyrene and polyethylene terephthalate demonstrated oxidative stress, inflammation, epithelial barrier defects, endoplasmic reticulum stress, lipid metabolism changes and cell death. The biotoxicity of polystyrene was not only associated with the exposure concentrations but also predominantly regulated by particle size. Anti-inflammation using an NF-κB inhibitor or prednisone, and blocking reactive oxygen species appeared as a potential strategies to alleviate polystyrene-induced toxicities. In general, because of these epithelial barrier damaging effects cells and cytokines leak to the circulation from the barrier defective tissues, migrate and cause inflammation in target tissues in distant organs. The loss of the capacity to heal the disturbed epithelial barrier, because of microbial dysbiosis, chronic tissue inflammation and epigenetic mechanisms lead to the continuum of the local tissue inflammation as well as the chronicity of the disease. Pets and domestic animals are also substantially affected with the burden of epithelial barrier damaging diseases.

Functional effects of aerosolised polystyrene microplastics on human nasal epithelium

Veronika Rendlova[1, 2], Martina Dzepic[1, 2], Thomas Geiser[1, 2], Emilie Seydoux[1, 3], Fabian Blank[1,2]

[1]Lung Precision Medicine, Department for BioMedical Research, University of Bern, Bern, Switzerland
[2]Department of Pulmonary Medicine, Allergology and Clinical Immunology, Inselspital, Bern University Hospital, University of Bern, Bern, Switzerland
[3]Division of Pediatric Respiratory Medicine and Allergology, Bern University Hospital, Bern, Switzerland

Airborne microplastics are increasingly recognised components of particulate air pollution, especially in the indoor environment. The respiratory tract provides a large and continuously exposed surface for particle deposition, yet interactions between airborne microplastics and the airway epithelium remain poorly understood. Here, we present a physiologically relevant *in vitro* model to investigate the effects of aerosolised polystyrene microplastic particles on primary human nasal epithelial cells.

Differentiated primary human nasal epithelial cell cultures grown at the air–liquid interface were exposed to thoroughly characterised, fluorescent spherical polystyrene microplastic particles (~700 nm in diameter) at three doses (1.2, 3.4, and 8.8 μg/cm²) using the Vitrocell Cloud Alpha 12 nebulisation system to mimic real-world aerosol exposure. The system is equipped with a quartz crystal microbalance, enabling control of the deposited particle dose. Fluorescent labelling allowed visualisation and localisation of particles at the epithelial surface. Functional effects were assessed by measurements of cytotoxicity (lactate dehydrogenase (LDH) release), transepithelial electrical resistance (TEER), and ciliary beating frequency (CBF) at 1, 3, and 7 days post-exposure.

The cells exhibited dose-dependent functional responses, with evidence of cytotoxicity observed at the highest microplastic dose. High-dose exposure (8.8 μg/cm²) was associated with a decrease in TEER and a transient reduction in CBF. Moderate-dose exposure (3.4 μg/cm²) also decreased TEER in some cultures, although these effects were more variable than those observed at the high dose. Unexpectedly, moderate-dose exposure consistently increased CBF, with effects persisting for up to three days post-exposure. Low-dose exposure (1.2 μg/cm²) produced no consistent effects and appeared comparable to the negative control.

The data demonstrates that aerosolised microplastic particles deposited at the airway epithelial surface induce dose-dependent functional responses in primary human nasal epithelial cells, supporting their consideration as biologically active components of particulate air pollution. This physiologically relevant model provides a basis for comparative studies investigating the effects of particle size and polymer composition.

Human exposure to plasticizers – absorption of phthalates in controlled inhalation studies

Myriam Borgatta[1], Jennifer Pache[1], Maria Serena Merli[1], Florian Breider[2], Nicole Charrière[1], Nancy B. Hopf[1]

[1]Department of occupational and environmental health (DSTE) Center for primary care and public health (Unisanté), Lausanne University, Lausanne.
[2]Central Environmental Laboratory, EPFL - Swiss Federal Institute of Technology, Lausanne.

The general population is chronically exposed to plastics and related additives via the inhalation route. Phthalates are plasticizers of significant health concern, as they have been associated with delayed male reproductive development and altered semen quality in humans. Since these chemicals are not covalently bound to the polymer matrix, they can migrate to the surface and contaminate indoor environments, both in the gas phase and adsorbed onto airborne particles. Human toxicokinetics of phthalates is lacking, leaving unresolved whether phthalates can enter the bloodstream following inhalation. The internal dose (blood concentration) of phthalates represents the inhaled fraction over time that is distributed to target organs and may potentially induce an effect. Toxicokinetic parameters such as the rate and extend of absorption, internal dose, and elimination rate are essential to understand phthalate toxicity. Most toxicokinetic studies are performed in animal following high-dose oral exposures, and human data are limited to single low oral-dose. Consequently, we aim to introduce controlled human inhalation studies performed in the exposure science sector at Unisanté, a Center for Primary Care and Public Health of the University of Lausanne. Following Swissethics approval, we exposed healthy volunteers to low dose of labelled phthalates using a portable aerosol delivery system or an exposure chamber that is unique in Switzerland, among a few available worldwide. Blood and urine samples are regularly collected to characterize the exposure-dose relationship. A preliminary test with the long-chain phthalate bis(2-ethylhexyl) phthalate (DEHP) has already been performed with 4 healthy participants, demonstrating the presence of metabolites in urine following inhalation exposure. A full toxicokinetic study with diethyl phthalate (DEP), a short-chain phthalate was subsequently undertaken with 7 participants. DEP was almost immediately bioavailable in blood and rapidly metabolized following the start of exposure. These findings are directly applicable to humans and provide critical support to regulatory authorities in risk-assessment processes for volatile chemicals and in the establishment of exposure limits. The human toxicokinetics of phthalates obtained under controlled exposure conditions will be presented, together with results from blood and urine analyses.

Synthetic versus Biobased Textile Fibers: Investigating their Impact on Human Lung Health

Stephanie Eitner[1,2], Elias J. Zimmermann[2], Tina Bürki-Thurnherr[1], Bernd Nowack[2], Peter Wick[1]

[1]Empa (Swiss Federal Laboratories for Materials Science and Technology), Nanomaterial in Health, Lerchenfeldstrasse 5, St. Gallen, CH
[2]Empa (Swiss Federal Laboratories for Materials Science and Technology), Environmental Risk Assessment and Management, Lerchenfeldstrasse 5, St. Gallen, CH

stephanie.eitner@empa.ch

Microplastic pollution poses environmental and human health concerns, with the lungs being particularly vulnerable to airborne particles[1]. Smaller fibrils and fiber debris below 5 µm may present great health risks, as they can penetrate deep into the respiratory tract, potentially affecting lung function and clearance mechanisms[2]. Despite growing research on microplastic behavior and distribution, there is still limited knowledge about the health effects of inhaled textile-derived polymeric fibers. In particular, chronic and repeated low-dose exposures are insufficiently studied. This project therefore aims to investigate the long-term impact of airborne synthetic, biobased, and natural textile fibers, fibrils and debris on respiratory health using advanced 3D lung cell culture models and environmentally relevant exposure settings. To achieve this, we are assembling a material repository of freshly produced and aged fabrics that vary in textile type, composition, and finish. Fibers, fibrils, and debris are extracted using a sterile, water-based method and subsequently characterized by FTIR, Raman, and SEM. Maintaining sterility of the fibers is crucial to ensure downstream cellular responses are not confounded by any microbial contaminants. Furthermore, we will perform an in-depth toxicological analysis in 3D lung models to determine textile- and fiber-specific modes of action and to evaluate potential contributions of material additives to toxicity.
Initial findings demonstrate successful sterile fiber extraction while preserving textile integrity and surface chemistry. SEM-based quantification of fibers, fibrils, and debris reveals distinct release patterns for each material, while preliminary cell culture data indicate no acute toxicity across synthetic, biobased, and natural fibers. Together, these preliminary results provide a solid foundation for further toxicological studies.

1. Ningrum, P. T. et al. A systematic review of the effects of airborne microplastic contamination on human lungs. Afr. J. Reprod. Health 28, 430–448 (2024).
2. Guo, C. et al. Effect of long-term exposure to fine particulate matter on lung function decline and risk of chronic obstructive pulmonary disease in Taiwan: a longitudinal, cohort study. Lancet Planet. Health 2, e114–e125 (2018).

Investigating Placental Immune Responses to Micro-/Nanoplastics

Ruhstaller, S. (presenting author), Gupta, G., Buerki-Thurnherr, T.

Nanomaterials in Health Lab, Empa, Swiss Federal Laboratories for Materials Science and Technology, St. Gallen, Switzerland

sina.ruhstaller@empa.ch

Prenatal exposure to environmental pollutants, including bio persistent micro-/nanoplastics (MNPs), is increasingly considered as a potential risk factor for adverse pregnancy outcomes and later-life diseases. Emerging evidence suggests that allergic diseases may originate *in utero* through maternal environmental exposures, with exposure timing defining the type of allergy the child develops. However, the effects of MNPs on the placenta and the mechanisms involved remain largely unknown. Given the placenta's essential immunological and barrier functions, MNP exposure may disrupt key processes with consequences for fetal development.

Therefore, we investigate the potential health hazards of environmentally relevant MNPs at the maternal-fetal interface, with a particular focus on their immunomodulatory effects. Specifically, our work examines (i) the accumulation and translocation of MNP across the human placenta, (ii) their ability to bind allergens and act as a "Trojan Horse" shuttle, and (iii) the immunological and endocrine responses of placental tissues and fetal immune cells to MNP and MNP- allergen complexes. To better reflect real-world exposure, we generated and characterized a diverse panel of secondary MNPs produced from everyday plastic products (PE, PP, PET, PS) using mechanical fragmentation (abrasion and milling) and sieving to get placenta relevant sizes (<63 μm). Physicochemical characterization revealed broad size distributions, including nanoscale fractions of relevance for translocation studies. Initial toxicity screening using a BeWo trophoblast monolayer showed no acute cytotoxicity and no immediate effects on energy metabolism, oxidative stress or pro-inflammatory cytokine (IL-6) release. Our current work focuses on allergen - MNP binding dynamics, and assesses uptake, translocation and immunomodulatory effects in placental tissues and fetal immune cells.

Our findings aim to clarify the immunological risks of prenatal MNP exposure, support sustainable plastic design and use, and contribute to improved risk assessment strategies to protect pregnant women and their developing children.

Funding:

This project receives financial support from Eduard Aeberhardt Stiftung, the European Union (EU) URPISE project (grant agreement number – 101156622) and the Swiss State Secretariat for Education, Research and Innovation (SERI).

Single-cell Raman imaging reveals compartment-specific cellular responses to nanoplastic exposure in macrophages

Nathalie Jung[1], Alke Petri-Fink[1], Barbara Rothen-Rutishauser[1]

[1]BioNanomaterials group, Adolphe Merkle Institute, University of Fribourg, Fribourg, Switzerland

Micro- and nanoplastics are increasingly recognised as environmental contaminants of potential relevance for human health, yet their cellular effects remain challenging to characterise using standard *in vitro* assays alone. Conventional toxicological readouts focus on predefined endpoints and bulk responses, which may overlook early, spatially localised molecular alterations or be prone to artefacts in the presence of particulate materials. Label-free, untargeted analytical approaches can therefore provide valuable complementary insight.

Here, we apply confocal Raman microspectroscopy to investigate cellular responses of THP-1derived macrophages following exposure to polystyrene nanoparticles. Raman hyperspectral imaging was employed to map the molecular composition of individual cells with subcellular resolution, enabling compartment-specific analysis of the nucleus, cytosol, and vesicular structures. Multivariate analysis of Raman maps revealed consistent exposure-associated molecular alterations that were specific to subcellular compartments. These included changes related to protein structure and chromatin organisation, as well as alterations in lipid-related spectral features across cellular regions.

Raman imaging demonstrates clear value as an untargeted and spatially resolved approach for probing cell–material interactions by providing quantitative, compartment-resolved molecular readouts.

Multi-Omics Profiling Identifies Oxidative Stress, Epithelial Cell Activation, and Barrier Disruption Induced by PET Micro- and Nanoplastics

Sena Ardicli[1,2], Huseyn Babayev[1], Lihong Chang[1], Ozge Ardicli[1,3], Can Zeyneloglu[1], Yagiz Pat[1], Duygu Yazici[1], Xiaoqing Liu[1], Ezgi Irem Bektas[4], Carina Beha[1], Halil I. Akyildiz[5], Nazrin Babayeva[6], Muhammed Emin Sari[7], Beate Rückert1, Raja Dhir[8], Ismail Ogulur1, Kari C. Nadeau[9], Mubeccel Akdis[1], Cezmi A. Akdis[1]

[1]Swiss Institute of Allergy and Asthma Research (SIAF), University of Zurich, Davos, Switzerland

[2]Department of Genetics, Faculty of Veterinary Medicine, Bursa Uludag University, Bursa, Turkiye

[3]Division of Food Processing, Milk and Dairy Products Technology Program, Karacabey Vocational School, Bursa Uludag University, Bursa, Turkiye

[4]AO Research Institute, Davos, Switzerland

[5]Department of Textile Engineering, Faculty of Engineering, Bursa Uludag University, Bursa, Turkiye

[6]Department of Physics, Faculty of Science, Selcuk University, Konya, Turkiye

[7]Department of Medical Biology, Faculty of Medicine, Necmettin Erbakan University, Konya, Turkiye

[8]SEED Inc. Co., Los Angeles, California, USA

[9]Department of Environmental Health, Harvard T.H. Chan School of Public Health, Boston, Massachusetts, USA

Plastic pollution has emerged as a pervasive global environmental challenge with potential implications for ecosystem integrity, animal welfare, and human health. However, the biological consequences of exposure to micro- and nanoplastics at physiologically relevant concentrations remain insufficiently characterized. Among synthetic polymers, polyethylene terephthalate (PET) is one of the most widely produced and used plastics, particularly in food packaging, bottled water, and a wide range of consumer products, leading to continuous, unavoidable daily exposure across populations. In this study, we investigated the impact of PET micro- and nanoplastics on epithelial barrier integrity and cellular homeostasis using a human gut-on-a-chip and nasal organoids combined with integrated transcriptomic and proteomic analyses. Well-characterized PET particles (containing a polydisperse micro- and nanoplastic fraction) were confirmed by Raman spectroscopy and scanning electron microscopy and applied across a wide concentration range, including levels relevant to daily human exposure. Intestinal barrier function was assessed by transepithelial electrical resistance (TEER), while cellular viability, oxidative stress, and molecular responses were evaluated using MTT assays, reactive oxygen species measurements, RNA sequencing, and targeted proteomics. PET exposure induced a clear dose- and time-dependent disruption of epithelial barrier integrity, with significant reductions in TEER observed at concentrations that did not yet cause overt cytotoxicity. Barrier impairment preceded cell death and was accompanied by rapid and sustained intracellular oxidative stress. Proteomic profiling of epithelial secretomes revealed pronounced, dose-dependent alterations, including

downregulation of antioxidant and junction-associated proteins and upregulation of inflammatory mediators and danger-associated molecular signals, even at low exposure levels. Transcriptomic analysis demonstrated extensive transcriptional reprogramming at higher PET doses, with distinct clustering by exposure levels and significant enrichment of pathways related to oxidative stress, endoplasmic reticulum stress, apoptosis, and metabolic dysregulation. In contrast, low-dose exposure elicited limited transcriptional changes, whereas higher doses triggered widespread pathway activation indicative of cellular stress and loss of homeostasis. Beyond the intestinal model, the effects of PET were also evaluated using human nasal epithelial organoids as a complementary airway barrier system. Increasing PET concentrations induced dose-dependent morphological alterations in nasal organoids, including changes in size, structural integrity, and epithelial organization. Significant differences were observed at concentrations overlapping with those that impaired intestinal barrier function, indicating that PET-induced toxicity is not restricted to the gastrointestinal tract. These findings suggest that environmentally relevant PET exposure can compromise epithelial barrier structures across distinct mucosal surfaces. These results demonstrate that PET micro- and nanoplastics weaken epithelial barrier integrity through interconnected oxidative stress, endoplasmic reticulum stress, and inflammatory signaling pathways. This study provides mechanistic insight into how pervasive plastic exposure may broadly undermine epithelial defenses and highlights the need to reassess exposure thresholds and regulatory frameworks.