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ABSTRACTS

The abstracts of the oral presentations are ordered chronologically, according to the program.

The posters abstracts are ordered according to the numbered posters list in this booklet.

Microplastic issues as trigger of the re-design of polymers, exemplified by a case study on the generation and degradation of microplastic during biodegradation of food packaging in compost

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As part of the global reorientation towards sustainability, also polymers need to start transitioning to recycled and biobased feedstock and accomplish CO_2 emission neutrality. This is not only true for structural polymers, such as in packaging or engineering applications, but also for functional polymers in liquid formulations, such as adhesives, lubricants, thickeners or dispersants. At their end of life, polymers need to be either collected and recycled via a technical pathway, or be biodegradable if they are not collectable. Advances in polymer chemistry and applications, aided by computational material science, open the way to addressing these issues comprehensively by designing for recyclability and biodegradability. This talk will review the technological design options that may target the molecular architecture and/or the integration of material systems in products. The present occasion will not permit to discuss the political and societal frameworks that are however indipensible. Instead, this talk will delve into a detailed case study on polymers designed for compostable food packaging. However, their acceptance by consumers and industry necessitates evidence that they do not leave behind persistent microplastics, because there are ligitimate concerns that the loss of structural integrity during biodegradation produces micro- and nanoplastic fragments. We tracked a polyester blend (and LDPE control) through a series of standardised industrial composting tests. Methods were initially validated on micronised particles as worst-case, and were then applied to more realistic thin films and finally to certified compostable polymer-coated paper cups. Fragmentation did occur. The interim number of fragments per composted polymer ranked in the order 183,033/g (films), 63,661/g (particles), 4,007/g (coated paper cup). Intermittently, up to 0.0012% of the mass of polymer was in fragments below 25 µm, but less than 10^{-10} of the polymer mass remained in fragments at 90% CO_2. Particle counts dissipated with 2.5 days halftime for the realistic thin films, and could be correlated with structural degradation of the molar mass and copolymer identity. In summary of the case study, we found that the fragmentation hypothesis holds true for specific plastic shapes, but we also found that these fragments degrade to complete biomineralisation. Compostable plastics thus contribute to organic waste recollection and are indeed more sustainable than conventional alternatives. Similar studies on the fate and transformation of polymers throughout their use phase and recycling or biodegradation will be needed to validate the re-design of polymers for circularity.

The multi-dimensionality of microplastics – and how it affects their fate and effects in aquatic ecosystems

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Microplastic particles are unique from other contaminants in that they are a physical particle composed of a complex mixture of different chemicals (e.g., monomers, additives). In the environment, they are found in diverse shapes and sizes. These multidimensional characteristics affect their fate in the environment, and thus exposure in biota. Moreover, their different characteristics likely affect their impact on ecosystems. This presentation will share results from an in-lake mesocosm experiment conducted at the International Institute for Sustainable Development's Experimental Lakes Area (IISD-ELA) to discuss the fate of microplastics in aquatic ecosystems. Different concentrations of a mixture of polyethylene, polystyrene and polyethylene terephthalate were added to nine 10-m diameter x 2-m deep limnocorrals as part of a ten-week experiment to measure the fate and effects of microplastics. The fate of the microplastics influences exposure in biota – relevant to risk. In addition to discussing the work at IISD-ELA, this presentation will share results from meta-analyses, and field and lab experiments to discuss the fate of microplastics in food webs and the physical and chemical effects of different types of microplastics across multiple levels of biological organization. Over the last two decades, the field has matured and we are beginning to understand the contamination, fate and effects of microplastics. Still, there is a lot to learn about how their diverse characteristics affect their fate and interactions in ecosystems.

Dealing with the complexity of microplastic in risk assessment

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The multidimensionality of microplastics influences their fate, effects and risks in aquatic ecosystems. Tiered approaches are often used in both prospective and retrospective risk assessments. Tiered approaches provide a systematic way of determining what level of research is appropriate given the risk assessment problem at hand, minimizing unnecessary investigations and enabling more efficient use of resources. In recent years we have developed a series of tools to assess the risks of microplastic particles for endpoints at increasing levels of biological complexity, such as individual aquatic species, communities and dynamic food webs, tools that fully take into account the multidimensionality of the particles. These tools enable the quantification of microplastic effects and risks under environmentally realistic exposure scenarios, while taking into account, without simplifications, microplastic characteristics such as size, shape, density, polymer identity, co-occurring chemicals and particle abundance. Where necessary, uncertainty in parameters and diversity in microplastic particle properties and environmental conditions are covered using probabilistic approaches. This talk provides an overview of the framework and recent applications to combine physical and chemical effects of microplastics, and to probabilistically assess microplastic risks in the Laurentian Great Lakes as an example.

Challenges in the quantification of microplastics in the environment – clarity in reporting to improve the longevity of data

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Whilst a standard definition of microplastics has yet to be agreed, taking into consideration the definition of a nanomaterial under the recommendation of the European Commission, microplastics may be considered as plastic particles smaller than 5 mm, but greater in size than 100 nm. This presents an analytical challenge for the detection and quantification of microplastics in complex environmental samples that may vary so greatly in size. Here we present our experiences from the lab in sampling, extracting and quantifying microplastics from a range of environmental samples, representing the occurrence of microplastics at a number of stages during the (waste) water treatment process. Whilst the analytical tools may differ between microplastics and nanoparticles, the principles and challenges behind the sampling, extraction and interpretation of the data are mirrored by those faced by the nano-community over the past decade.

Principles of analytical chemistry are fundamental, but often neglected in reporting microplastic quantification in the environment. In this presentation, we cover some of the fundamental principles that should be considered when attempting to quantify microplastics in the natural environment; from representative sampling, to approaches to quality assurance and control that are increasingly recognised as pressing issues for which consensus is needed in the "microplastics community". As the field moves from exploratory to establishing standardised methods for more routine monitoring, the aims of these efforts should be clearly understood. No single method can identify and quantify this diverse contaminant across the whole range of polymers, sizes and forms that are encompassed within the "microplastic universe". Here, we demonstrate approaches to defining the analytical window within which a study is quantitative, in an effort to ensure that the data generated now will have longevity into the future.

Microplastic concentration varies with local and landscape scale factors in a large Canadian watershed

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Spatial and temporal analysis of microplastics was conducted in the Ottawa River watershed in Canada. Spatial analysis included sampling for microplastics at 105 main channel and tributary locations. Results suggest that microplastic concentrations do increase as you move downstream, however, regression analysis presented only a weak relationship demonstrating there are many other factors to consider that may influence microplastic concentration in large watersheds. Furthermore, urban versus non-urban, tributary versus main channel, distance from wastewater treatment plants and distance from dam structures did not provide any significant relationships further highlighting the complex spatial interaction of microplastics in rivers. However, a temporal analysis in the City of Ottawa downstream of a combined sewage overflow and in an urban stormwater creek produced highly correlated data in the flux of microplastics to various temporal events. These temporal events included heavy rain, snow and snowmelt. Each of these events presented large spikes of microplastics at both locations compared to background concentrations. Downstream of a combined sewage overflow, during an active overflow event, concentrations were observed to increase seven times with concentrations doubling during rainfall with a non-overflow event. The urban stormwater creek exhibited an increase of 50 times the microplastic concentration compared to ambient conditions. However, the largest temporal flux in microplastics at both locations was observed during the primary snowmelt of spring, with microplastic concentrations increasing 114 times in the urban stormwater creek and 11 times in the urban river. Furthermore, during spring snowfall, microplastic concentrations increased 34 times in the urban creek. These results demonstrate snowfall and snowmelt are potentially a major conduit of microplastics to river systems, especially in urban areas that receive winter snowfall. The spatial analysis has highlighted the complex interaction of microplastics in large watersheds with analysis of temporal events demonstrating they are extremely important to consider in the distribution of microplastics in rivers. This accentuates the importance of moving away from a presence or absence methodology at a singular (sometimes random) temporal point in time, towards a focus on monitoring or capturing microplastic data over larger temporal scales. This approach will enable researchers to be able to better assess the inputs, throughputs and sinks of microplastics in large watersheds.

Life on microplastics in a Swiss eutrophic lake (Lake Lugano)

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Microplastics (MPs) accumulate in lakes' water and sediments, where are quickly colonized by microorganism. The biofilm's growth, could increase the size and density of plastic particles, and decrease the surface hydrophobicity. Therefore, the biofilm's composition likely influence MP buoyancy and vertical dynamics. However, little is known about the biological community growing on MPs in lakes. The aim of this preliminary study was to analyse the community composition of biofilm growth on MPs in a Swiss lake highly polluted by MPs (Lake Lugano), and to understand the link with MP sinking process. We applied a combined approach based on a field study and in-situ experiments. MP-biofilm aggregates were analysed from samples collected on the surface and in the water column in spring, during the diatoms' bloom, using optical and fluorescent microscopy, and were compared with phytoplankton composition in the euphotic zone. In parallel, we incubated lab-made MPs at different depth to analyse biofilm's growth. Moreover, sediment traps were deployed below the metalimnion to quantify downward fluxes in spring and in summer. Our results showed that in the euphotic layer the biofilm was dominated by diatoms, especially pelagic large species. Diatoms were also observed on MPs in the hypolimnion, which suggest a possible effect of diatom colonization on MP settling, owing to the dense siliceous frustules. This hypothesis is supported by the higher MP sinking rate observed in spring, compared to summer. These preliminary results open also new questions regarding the effect of MPs on sedimentation fluxes of phytoplankton in lakes and the toxicological effect caused by MP-phytoplankton close interaction.

Influence of microplastics composition and algae aggregates on particle settling rates in freshwater

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To date, many studies have focused on the detection and quantification of microplastics (MPs) in natural waters, but only a few have been conducted to systematically understand the processes which drive MPs fate and transport in freshwater ecosystems. This includes heteroaggregation with suspended natural colloids and small biota, and how these interactions affect distribution and transport in freshwater (e.g., settling dynamics). Freshwater snow (FWS), a mixture of algae and natural particles, is responsible for most of the flux of organic matter from the water surface to the sediments and can potentially act as a vector for MPs through the water column. Here, we systematically analyzed the settling rates of particles of different sizes, densities and morphologies in a plexiglass column, illuminated by a laser, to track particles with a stereoscopic camera system. Image sequences were acquired and analyzed with a tracing software to determine settling rates of particles in three test system variants: 1) MPs of various polymer chemistry, size and morphology, 2) FWS alone and 3) MPs-FWS heteroaggregates. For each experimental set, our system allowed the tracking of up to 2×10^4 particles, which ensured statistical convergence of the results. The system was validated by measuring the settling velocity of model MPs beads of known size and density where the experimental settling rate matched the expected rate according to Stoke's law. FWS was created by mixing freshwater algae from different classes (*Asterionella*, *Mycrocistis*, *Kirchneriella*) on a roller table to simulate the formation of natural flocks over time. Our goal was to assess if the settling rates changed when plastic and FWS were aggregated together, compared to their settling dynamics individually. For those MPs whose density is higher than water (PET, PLA) unsurprisingly, the settling rate of MPs increased with increasing particle size, but MPs fibers had a significantly slower settling velocity than equivalently sized fragments. Depending on MPs size, the number of MPs fragments differed in MPs-FWS heteroaggregaes (as assessed by fluorescence microscopy). Nevertheless, in all cases these aggregates settled faster than the individual MPs and significantly faster than the FWS alone, except for the case of MPs fibers. Conversely, those MPs whose density ratio was less than 1 (PP, PS) did not influence the settling rate of FWS no matter the MPs size. Collectively, we provide further insights on the settling rates of MPs which can be used as input values for future fate models in freshwater systems, as well as an indication as to how the presence of MPs can impact the biogeochemical cycles through altering FWS settling in freshwater. In particular, when MPs are incorporated into FWS aggregates, this faster settling rate will impact the flux of carbon, nitrogen, and phosphorus contained in FWS to the sediment, potentially having implications on productivity throughout the water column.

Detection of microplastics in bottom waters of the Tennessee and Cumberland Rivers and their tributaries in Tennessee, USA

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Both the Tennessee and Cumberland Rivers in the state of Tennessee were sampled for microplastics (MP) occurring in the water column just above their beds at depths ranging from three to nine meters. Three water samples were collected along a 10-mile stretch of the Tennessee River adjacent to the city of Chattanooga and two samples were collected from Chattanooga Creek, a tributary of the Tennessee River that drains a portion of the city of Chattanooga. Five water samples were collected along a 20-mile stretch of the Cumberland River adjacent to Nashville, with a total of three samples taken from the tributaries of Mill Creek and Richland Creek, which drain a large portion of urban Nashville. Four-liter water samples were collected with a Wildco depth sampler and were then vacuum filtered through a 30-micron stainless steel filter disk. The filtrate on the disks was then visually inspected for MP with a reflected-light microscope and their positions on the disk noted with a sketch map. The MP particles were left on the disks and analyzed by Raman microscopy to determine the type of plastic present.

All water samples contained MP in the size range of 0.03 mm to 5mm. The highest concentration of particles (up to 6500 m^3) was in the tributaries draining the urban areas of Chattanooga and Nashville, with lower concentrations in the main channels of the Tennessee and Cumberland Rivers. MP particles were secondary and composed of both fibers and sub-equant particles. The majority were composed of PVC while PET was subordinate. Our preliminary findings suggest that tributaries draining large urban areas serve as significant sources of MP particles in larger rivers into which they flow. Furthermore, this technique represents an efficient way to sample MP particles at depth in rivers.

Open dumping and burning of solid waste in underserved communities: an overlooked source of microplastics in terrestrial ecosystems

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We assessed the distribution in sediments of microplastics generated by open dumping and burning of solid waste. Open dumping and burning are non-standardized waste management practices utilized throughout the globe, including rural and Native American communities of the United States. Open burning of solid waste generates partially combusted plastic pieces. These brittle plastics are potentially more prone to microplastic generation than their non-burned counterparts; furthermore, incomplete combustion likely modifies the chemical and physical features of microplastics, which may lead to the release of derivatives, constituent monomers, flame retardants, or other additives used during plastic fabrication. We sampled open burning sites located in rural Oklahoma and Native American land Montana, United States. Dumping sites were divided in quadrants and one to three 1 kg bulk samples were taken per quadrant depending on the size of the site. Bulk samples were taken from the surface to a 10cm depth from each quadrant to determine soil texture, pH, and total amount of microplastics. Core composite samples were also taken to determine the vertical distribution (0 to 16cm) of microplastics near the dumping site. Samples were elutriated, density separated, and digested to eliminate excess of organic matter and inorganic materials. The recovered material was analysed with stereomicroscopy and fluorescence microscopy to identify and quantify microplastic contamination. Fourier transformed infrared attenuated total reflectance (FTIR-ATR) spectroscopy and scanning electron microscopy (SEM) were used to evaluate microplastic surface chemistry and morphology. Initial fluorescence microscopy results indicate samples contain 260 to 2780 particles/kg. To confirm their chemical composition, 10% of the particles detected in each sample were analysed with micro-FTIR-ATR. The analyses indicate that the most common occurring plastics were polyethylene, polypropylene and alkyd resins with spectra matching to pure polymer spectra from 63-93%. High matches (>90%) and lack of functional groups associated to oxidation in some of the FTIR spectra indicate that combustion processes of burning sites are, as expected, inefficient. The IR spectrum of some oxidized particles better matched to organic substances (e.g., N.N'-bis(2-hydroxyethyl) stearyl amine, pentaerythritol Tetraricinoleate) instead of visually identifiable particles. These findings indicate the importance of comparing spectra of oxidized materials to oxidized reference materials. Plastics that have been severely combusted and that are visually identifiable are commonly not accounted as microplastics due to the lack of similarity to a pure polymer spectrum (<60%). This may change the actual amount of microplastics found in open burning sites. Currently, our efforts are focused on 1) evaluating the vertical distribution of microplastic near dump sites, 2) developing a FTIR spectra library that accounts for partially oxidized plastics, 3) investigate the microplastics generation rates from partially burnt meso- and macroplastics, and 4) investigate the reactivity of partially burnt microplastics in aqueous media. Our results will inform communities where these practices are prevalent and will broaden the knowledge of sources of microplastic contamination.

Modeling the flows and releases of micro- and macroplastics to the environment

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Detailed knowledge about polymer flows through the anthroposphere and into the environment is essential for a better management of plastics. Currently, release estimates are often based on simple assessments, focusing mostly on only a selected number of products and are generic for a large region. In addition, only limited knowledge about specific polymer flows is available although it is well known that different polymers are used in very different applications and may therefore have very different release potentials. By using a detailed material flow analysis (MFA) model of the flows of specific polymers through the anthroposphere based on nine product sectors and 35 product categories, we were able to track the flows of 12 major polymers from production to end of life. By coupling the MFA with a release model with 40 distinct release pathways for each polymer throughout the life cycle, we were able to quantify the release of the 12 polymers into various environmental compartments (e.g. surface water, urban or natural soil, roadside soil). The total microplastic release fraction for Switzerland as geographic region is between 0.02% for PUR and EPS and 0.12% for LDPE based on the total flow into the region. The macroplastic release is between 0.03% for ABS and 1.22% for PET. The release percentages therefore vary widely between different polymers and are determined by their specific uses in product categories from which they are more or less likely released. The release fractions reported in this work are smaller than many previous estimates and may be more representative for countries with well-functioning waste system than more general assessments.

Lowland rivers as sinks for plastic? A model-based case study relying on in situ observations for the Scheldt estuary in Belgium

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In this study the objective was to map plastic waste accumulation zones and to quantify the plastic flux from Flemish estuaries and ports to the southern North Sea. Over a period of 2 years and following a strict sampling design and protocol, 131 microplastic (100 µm – 5 mm) and 263 macroplastic samples have been collected in the water column and sediment at 20 sampling locations in the Yser estuary, the port of Ostend, the port of Antwerp, the Ghent-Terneuzen canal, and the Scheldt estuary in Belgium. The sampling strategy included three types of campaigns: (1) seasonal samples; (2) 13h tidal cycle samples; and (3) bimonthly spot samplings. All samples have been processed in line with state of the art laboratory procedures and quality assurance/quality control criteria, including replicates, positive controls, negative controls, micro-FTIR or ATR-FTIR confirmation. It was found that plastic is an abundant pollutant in riverine and estuarine ecosystems in Flanders. The plastic concentrations vary spatially, and the highest microplastic concentrations have been observed in the river Scheldt (42.9 ± 70.6 particles/m³). All sediment samples contained plastics, and the highest concentrations were found inside harbour areas in Wintam in the Scheldt river (4301.6 ± 4926.8 part kg DW^{-1}). Clear spatial differences have been detected in the most dominant polymers. A hydrodynamic plastic dispersion model in the open-source software TELEMAC was used to quantify the plastic flux towards the marine environment. This model consisted of an ensemble analysis, a flood-ebb cycle analysis, a flux analysis, and a residual mass flux analysis. The model was calibrated and validated and a general circulation pattern of the plastic transport was inferred. From this model and its simulations, three patterns were inferred. First, based on the residual plastic mass flux, the plastic transported towards the sea was mainly following ebb channels. Plastic moving into the estuary mainly used flood channels. In the estuary, there are small-scale circulation patterns which suggest that plastic particles can be trapped and do not leave the estuarine region. Secondly, sources of plastic upstream of the Dutch-Belgian border contributed little to the mass of plastic that reaches the North Sea. As such, the Flemish estuary of the river Scheldt is considered to function as a plastic reservoir, with a plastic plume that moves around the plastic injection points. A final observation was that a significant part of the net plastic flux reaching the estuary does not move upstream of the Dutch-Belgian border, and is thus trapped in the estuary. Overall, plastic particles are expected to move up and down with the tide in the estuary, but their travel does not extend beyond 20 km. The tested scenarios suggested that the Scheldt estuary is a major sink for plastics. Plastic particles had the tendency to accumulate in intertidal areas, suggesting that beaching is a very important process. As beaching is considered an important process, dedicated monitoring campaigns can be initiated to quantify the amount of plastic on the river bank, and further finetune the model.

Fate, exposure, and risk assessment for microplastics in rivers on a national scale

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Fate and exposure modelling is urgently needed to assess the risks that microplastics pose in the environment. Here, we model the exposure concentrations using a spatio-temporal transport model for the main river network in the Netherlands. Microplastic sources include waste water treatment plant effluents and trans-boundary inputs. The emission concentrations and compositions are based on high-quality data obtained with µFTIR and automated image analysis. Based on this data, we define the multidimensional diversity of microplastic through 360 classes, where each class is a unique combination of polymer type and particle size. The emissions, transport and fate of these 360 different microplastic classes are modelled for a year. Transport and fate processes include advection-diffusion, settling, resuspension, burial, aggregation and biofouling. The number and mass concentrations in both water and sediment are then compared with threshold effect concentrations for aquatic and benthic organisms, respectively. Both the exposure and effect data are scaled to be representative for the environmentally realistic diversity of microplastic, resulting in the first spatiotemporally explicit and fully aligned environmental risk characterization for microplastic as it occurs in nature.

From land to ocean: national-scale hydrological source tracking of microplastics in Danish coastal environment

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Land-based microplastics (MPs) are considered as the main contributing sources of the ocean. In urban systems, the spreading of MPs requires transport media: e.g., water, to mobilize the particles and transport them further to the adjacent environment. Such transport process has been widely documented but only remained in a theoretical level, and the method to track and identify the specific land-based sources is still unavailable.

In this study, we developed a GIS hydrological source tracking tool, which provides a backwards tracing procedure to identify all relevant land-based MPs sources based on the flow continuities, i.e., stream/river and coastal water. The development of this tool is based on the following assumptions: 1) the stream/river and urban sewer system are the main transport pathways of MPs from land to the ocean; 2) the main contributing sources from urban water system consist of three types of discharges: Combined Sewer Overflow (CSOs), wastewater effluent, and rainwater.

To test this method, we conducted a national survey on MPs in the Danish coastal environment by collecting marine sediments from 13 coastal water zones. The samples went through intensive biochemical and physical treatment steps to isolate MPs, and the extracted particles were identified by FPA-µFTIR imaging, then analysed by siMPle. Thereafter, the GIS hydrological source tracking tool was performed across the 13 stations to identify the relevant water discharges. Each of the discharge points was characterized by annual discharge volume (m^3), the number of discharges per year, and biochemical parameters (BOD, COD, nitrogen, and phosphorus). From a Danish national scale, we screened in total of 5918 discharge points relevant to the 13 coastal areas, consisting 765 CSOs, 2153 rainwater and 3000 wastewater effluent.

Our main findings are outlined as below: 1) The monitored coastal area were all polluted by MPs, and their abundance varies significantly between stations: particle number concentration ranges from 508 to 23,340 item/kg (dry weight), and 22 to 7,402 µg/kg for mass concentration; 2) the three types of discharge in urban water system significantly affect the MP concentration Danish coasts; 3) as opposed to CSO, discharge volumes of wastewater effluent (point-source) and rainwater outlet (non-point source) are more significantly co-related with the pollution load detected.

This study revealed an environmental-data based picture of the source and pathway of MPs from land to sea. This could provide useful information for both effective remediation strategies for land-based MPs, as well as optimized sampling and monitoring methods for marine environment.

Modelling plastic transport and accumulation in the environment on a country-wide scale

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Over the last years, more and more approaches were introduced to not only model plastic movement in oceans but also in freshwaters. Therefore, most microplastics models for freshwater base to certain extents on experiences from sedimentation modelling. Hence, input data and equations are partly similar to sedimentation modelling or are extracted from sedimentation experiments. The drawback for this model designs are the complexity and data requirements. Consequently, currently available plastic transport models for freshwater are either applied in "simple", "one stream only" river networks or do not consider the logical river flow through multiple river segments and lakes.

Our work, on the other hand, presents a model which addresses these challenges by considering a network of 600,000 river segments and over 200 lakes in Switzerland. Starting with an existing plastic emission model, we allow the plastics to flow through all river segments and lakes. In our modelling, we account for seven different polymers and micro- and macroplastics and address different properties such as density and size. Furthermore, we base our model on existing transport models but simplified the parameter input in order to create a country-wide model. Overall, we aim for a modelling approach that would be applicable in many countries around the world with mapped rivers / lakes plus few additional data such as average discharges or flow velocity.

As results, we clearly see the influence of lakes which retain plastics through sedimentation. However, for Switzerland many lakes are located upstream of the major cities which are considered hotspots of microplastic emissions in rivers through their waste water treatment plants. Thus, the effect of plastic retention in lakes is lower than expected. Through our work, we provide contamination data on the scale of each river section for an entire country which compared with so far available catchment scale model will provide an even closer look at local sources and sinks of plastics. Additionally, we differentiate between removed and accumulated plastics as well as plastics in the sediment or water column.

Our model is written in a way that parameters or plastic sizes can be easily adjusted. For instance, the current microplastic model will be extended to macroplastics by using other parameter sets in the near future. However, we are also aware that many parameters regarding micro- or macroplastic transport in natural rivers at a large scale are still unknown or hydrological parameters on a country scale are not available. Therefore, a compromise between data availability and implementation of physical processes in the model had to be found.

Nevertheless, we believe that our work can help to better understand the sources of the global plastic pollution but rises the need for experimental data on plastic transport in the environment. The large-scale understanding of plastic transport processes will provide policy makers with options were to tackle the spread of plastic pollution in the most efficient way.

A modelling approach for accumulation of plastics in the environment on a global scale

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Plastic material is rapidly accumulating in the environment. By applying a modelling approach to global plastic mass flows, improved insight in sources and fate of plastics in the environment can be obtained. Additionally, by including a future outlook, a perspective on plastic accumulation in the environment on a broad spatial scale can be acquired. In this study, a Material flow analysis (MFA) approach was used based on existing published MFAs, which includes potential losses from the full life cycle of the plastic product from multiple sectors and multiple polymers. The MFA was extended to a global model, and expanded to include; microplastic losses from packaging products, environmental transport to oceans, sludge application and rubber microplastic formation. Additionally, product lifetimes were included in the model to correct for stocks and elongated plastic lifetimes. As a final step, degradation of macroplastics was included to simulate global accumulation of plastics in the environment until 2050. Quantities of plastic production were modelled as 'business as usual' with a growth of 4% per year. The preliminary MFA results on plastic losses to the environment give multiple insight, as results can be given per sector, income class and environmental compartment. Globally, but especially In upper middle include and high income countries, the contribution of rubber microplastics from car tyres contribute over 60% of microplastics. These plastics accumulate mainly along roadsides and in subsurface waters. Most macroplastics in the environment originate from lower middle income countries, of which the packaging sector is the largest contributor. Most of the plastics end up on residential soils and in rivers (sunken or along the shorelines). According to the model, only limited micro and macroplastics lost on land will reach the oceanic environments. Future accumulation of microplastic in the environment is mainly caused by the packaging sector and rubber from car tyres. Quick degradation of macroplastics in specific environments and for specific polymers will significantly increase the number of microplastics, for example LDPE materials on land (a result of high UV exposure). For human and biota exposure, increased intake depends mostly on indoor air and surface water microplastic quantities. To conclude, the MFA and accumulation model give insight in quantities of micro and macro plastic losses to the environment on four different levels: polymer, country, sector, and environmental compartment. With the accumulation model, future scenarios can be modelled to assess potential impacts on the environment, on biota and human exposure.

You can't manage what you can't measure: from microplastic transport to representative monitoring

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It is undisputable that microplastics are widely distributed in the environment, as these anthropogenic contaminants have been detected even in the most remote areas. However, a closer look at their distribution shows that there are still many unanswered questions regarding the transport behaviour of microplastics in the environment. This presentation summarizes the current state of knowledge on the transport behaviour of microplastics in rivers, and identifies knowledge gaps that need to be addressed in the future. Special emphasis will be placed on the opportunity to learn from natural sediments to improve our knowledge on fluvial microplastic transport. This transfer from sediment research, which in contrast to microplastics research has been conducted for decades, provides important insights for our understanding of microplastics. However, some important aspects, such as the impact of particle properties on environmental behaviour, need to be considered when assessing the transferability of the fundamental transport processes from mineral sediment to microplastics. These aspects will be highlighted in the presentation. Additionally, based on our present knowledge of microplastic transport, and in particular the vertical distribution of microplastics in the water column, current measurement methods will be evaluated to provide a discussion basis for the development of standardized and representative measurement methods. This can be seen as an indispensable step towards the mitigation of plastic pollution, for what cannot be measured, cannot be managed. Or maybe it can?

Spectral flow cytometry, a new technique to identify and quantify small-scaled microplastics in natural waters

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The occurrence of microplastics in natural water is a general concern. Currently, for quantifying and characterizing microplastics in water, optical microscopy, FTIR and Raman spectroscopy are the most common analytical techniques used. In this study, we investigate a new technique based on spectral flow cytometry (SFC, Cytek, Aurora) coupled with a machine learning algorithm trained to recognise and quantify up to six different plastic polymers (e.g., PE, PET, PU, PP, PA, PVC) using custom-made and commercial standards. This technique allows the identification of small-sized (5-70 μm) microplastics in a volume less than 1L of unfiltered water. The SFC presents many advantages: (i) its sensitivity, (ii) its throughput with up to 18 samples processed and analysed daily, (iii) its easiness to perform sampling even in remote locations, (iv) its conveniency to identify a broad size range of microplastics. Analyses of samples collected 50 cm below the surface 3m away from Lake Geneva shoreline (Vengeron, Chambésy, GE, and Tropical Corner, Geneva, GE, May 2022) showed important microplastics concentration of 95 to 165 microplastics particles/L, representing 0.03-0.16 % of the total particles enumerated. The most abundant polymer in Lake Geneva was PE (87-95 %), PU (1-7 %), PET (2-5 %), and PC (1-2 %). 62-95 % of the PE detected was in the analytical size range 5-15 μm. To conclude, this investigation showed that Flow Cytometry is a promising technique to quantify microplastics in environmental waters and the addition of a machine learning algorithm extended its capacity to differentiate plastic polymers with good confidence. Results illustrated that technologies not able to go in small-size range (< 15 μm) significantly overlook microplastics pollution.

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Microplastics in the ice cover of a northern freshwater lake – a three-year monitoring

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Microplastics have been found from every environment studied. However, data is lacking about microplastic concentrations in freshwaters and especially in ice covers of freshwater lakes. Ice cover sampling could provide important information about seasonal variations of microplastic concentrations when comparing results from ice to water. Moreover, ice samples can enable tracking of sources of microplastics, because microplastics may accumulate to the bottom layer of the ice cover from water, or to the top layers from air fallout.

In this study, we analyzed ice samples from Lake Kallavesi, near city of Kuopio in Eastern Finland. Lake ice samples were collected in three consecutive winters 2020, 2021, and 2022. Ice samples were cut with an electric chainsaw and stored in metal containers. Thawed samples were treated with H_2O_2 and density separation to remove organic and inorganic non-plastic materials, and remaining microplastics were identified and counted using imaging Fourier-transform infrared spectroscopy (FTIR) equipped with a focal plane array detector (FPA). Spectral analysis was done using siMPle software, in which measured spectra was compared to reference spectra included in siMPle and to spectra measured at SIB Labs.

The microplastic concentrations in ice varied greatly between sites and years, being 3-26 MPs/liter (liquid water) in all the samples. Higher concentrations were found closer to the city center and settlements in general. Most of the particles were 50-150 μm in size. Moreover, the most common polymer types were polypropylene (PP), polyethylene (PE) and polyethylene terephthalate (PET), correlating with the most produced polymers. Other polymer types found were polystyrene (PS), acrylonitrile butadiene styrene (ABS), polyamide (PA), polyacrylonitrile (PAN), polyurethane (PU) and polymethyl methacrylate (PMMA).

The results indicate that microplastics accumulate to the ice cover of a freshwater lake, as the concentrations far exceed those found in water samples from same locations. Accumulation of plastics will also lead to a burst of microplastics entering the water when the ice melts. Furthermore, this microplastic burst might influence water biota every spring as the microplastic concentration in water could briefly rise to higher-than-normal levels.

Plastic particles in Arctic sea ice: pollution burdens in a changing climate

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Plastic debris is accumulating even in some of the most remote areas on Earth, such as the Arctic Ocean. For example, ocean circulation models and field sampling campaigns have shown that plastics accumulate in the Barents Sea in the same magnitude as in the North Atlantic gyre. Multiple studies have quantified microplastics (MPs, $1 – 5$ μm) throughout the Arctic Ocean, and nanoplastics (NPs, <1 μm) are suspected of being present as well. The accumulation of MPs and NPs in polar seawater is a cause for concern since this ecosystem provides essential services (e.g.: climate regulation, nutrient cycling) while being disproportionately vulnerable to global change (e.g.: climate change, accumulation of anthropogenic contaminants). Therefore, it is crucial to determine the fate of MPs and NPs in the Arctic Ocean to i) assess polar organisms' exposure rates, ii) resolve the global plastic budget and iii) determine whether these particles could modify sea ice properties and biogeochemical cycles. It is expected that the environmental fate of MPs and NPs in the Artic Ocean will be impacted by changing freezing dynamics. Indeed, the growth of sea ice strongly redistributes concentrations of dissolved and particulate species and now, due to climate change, the majority of the sea ice surface area freezes and thaws annually. The goal is to understand how freezing will affect the vertical transport of MPs and NPs into sea ice, accounting for plastic variables such as particle size and weathering state and environmental variables such as water chemistry and rate of freezing/thawing. By using a novel experimental approach which mimics the freezing of seawater, we systematically assessed at what rate and by which process MPs and NPs are accumulated into or expulsed from sea ice. This is achieved by measuring concentrations of different species (salts, organic matter and plastics) along the depth profile of ice and in the underlying water, and by linking this to sea ice structure, determined by micro-computed tomography. The use of model MPs and NPs with metal fingerprints offered the advantage of distinguishing them from organic matter and quantifying them at environmentally relevant concentrations by analyzing the metal as a proxy for plastics with ICP-MS. We hypothesise that particles' density and effective size (i.e. the size of a single particle if dispersed, or of the aggregates which can result in highly saline conditions) will govern their rate of enrichment in sea ice. We expect that buoyant particles and particle aggregates will be preferentially enriched in sea ice. This may be caused by scavenging by ice crystals during the initial ice growth and later by advancement of the freezing front in calmer conditions. By locating the particles in different structures of the ice, such as in the brine pockets and channels, for the first time we will be able to definitively demonstrate how MPs and NPs are incorporated into new sea ice. Finally, to define whether plastics behave differently compared to natural particles in this environment, we compared the behavior of MPs and NPs with that of a clay particle. This study significantly improves our understanding of plastic particles' source to sink dynamics in the Arctic, which is essential to better define polar species' exposure rate, and in turn, inform risk assessments.

Microplastics and their environmental impact – tire wear particles in surface runoff from highly frequented roads

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Tire wear particles are assumed to be the largest source for microplastics in the environment. Starting from roads, these particles are transported in the environmental media air, water and soil. Via surface runoff, tire wear particles can be carried not only to surrounding soils, but also into freshwater systems. Considering that surface runoff often enters the environment untreated, road runoff is of great importance in terms of environmental microplastic entry.

In the research project "RoadTox" surface runoff off from highly frequented roads is investigated and evaluated by sampling and following chemical-analytical quantifications of different pollutants to identify the overall ecotoxicological impact. Thereby, tire wear particles (microplastics) as well as heavy metals (chromium, lead, zinc, nickel, copper, cadmium, iron, titanium), polycyclic aromatic hydrocarbons (PAH) and petroleum hydrocarbons (PCOH) are investigated. To get an overall impression of the particle load, filterable solids (especially < 63 μm) are also measured. The considered roads that are sampled are highways, rural and urban roads to compare their loads and also their ecotoxicological effects. Therefore, comprehensive multi-endpoint bioassay battery is used and their results are contextualised with the chemical analyses and also hydrological influences.

The project's aim is to derive recommendations for dealing with surface runoff from roads based on the chemical analyses and the identification of the ecotoxicological impact. Results to date already indicate the need for treating roads' surface runoff prior to further environmental discharge.

Heteroaggregation of PS microplastic with ferrihydrite leads to rapid removal of microplastic particles from the water column

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Pollution with plastic materials has emerged as one of the most relevant current and future environmental problems. In the last few years, research focused predominantly on the occurrence and distribution of microplastics (MP) in the environment. Only recently, a more fundamental understanding of MP behaviour in the environment has started to attract attention. Transport and removal processes of MP in the water column are strongly controlled by interaction with environmental particles, such as ferric (oxy)hydroxides. However, our understanding of the mechanisms controlling aggregation and subsequent sedimentation of MP during interactions with multivalent oxides is still limited. Here, we analysed the heteroaggregation of 1 μm polystyrene (PS) particles and ferrihydrite, a common naturally occurring ferric (oxy)hydroxide. Furthermore, we performed sedimentation experiments in which PS and PS + ferrihydrite were analysed in settling columns after 1 day and 1 week of settling time. The presence of ferrihydrite increased sedimentation rates of PS at all pH values studied (pH 3-11). At pH 6 we found that almost all PS particles were removed from the water column after only one day of exposure time. For the same samples, SEM/EDS imaging and particle size measurements confirmed strong heteroaggregation between PS and ferrihydrite. At acidic pH values, zeta potential measurements indicated that the negatively charged PS surface was coated with positively charged ferrihydrite particles leading to charge reversal. Our results demonstrate for the first time that ferric (oxy)hydroxides drive heteroaggregation and subsequent removal of MP from the water column, especially at typical pH values found in natural lake environments. Given their abundance in aquatic systems, ferric (oxy)hydroxides need to be regarded as key scavengers of MP.

Microplastic pollution in long-term urban compost amended soils

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Microplastics, defined as solid polymer particles below 5 mm in size, threaten both terrestrial and aquatic ecosystems. In agricultural soils, microplastic contamination sources can be diverse, yet, at the present time, levels of contamination are largely unknown. In the context of a circular economy, urban waste compost use as soil amendment is promoted. It may be an important source of microplastics, depending on the quality of the biodegradable residue sorting. The aim of this study was to evaluate how long-term application of composts derived from different urban waste types impacts the microplastic nature and quantity in soils. We focused our work on two fractions of microplastics: coarse (2-5 mm) and fine (< 2 mm) microplastics.

Our approach was based on the use of a long-term field experiment, which has received urban waste composts derived from household waste, green waste and sewage sludge for 22 years. After soil and compost sampling, the coarse fraction of microplastics was recovered by hand-sorting while the fine fraction was studied following a soil physical fractionation or organic matter mineralization. We used pyrolysis coupled to gas chromatography and mass spectrometry (pyrolysis/GC/MS) and Fourier transformed infrared spectroscopy (FTIR) to characterize and quantify microplastics.

According to our results, polyethylene and polystyrene were the most abundant polymers in soil samples that received compost application. For the soil samples, we found that municipal solid-waste application in high quantity led to the highest microplastic concentration after 22 years. Similar results were obtained in the compost samples indicating that home-sorting was efficient to decrease the level of microplastics introduced in the field by compost application. We showed that organic amendments, even if they meet the French national standards, can introduce up to 27.6 million coarse microplastic particles per year, representing 65.1 kg per hectare.

Our results suggest a long-term accumulation of microplastics in soils and indicate a growing contamination of agroecosystem soils by this novel organic contaminant. Consequently, there is an urgent need to assess its fate in agricultural soils and its impact on biogeochemical cycling, environmental and human health.

Soil erosion a major source of microplastic entering inland waters?

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Agricultural soils play a key role as sink of microplastic (MP) coming from different sources, especially via the application of sewage sludge, compost, plastic mulch films, atmospheric deposition and tire ware. However, accepting (agricultural) soils as long-term sinks, steadily accumulating MP, also implies that soils are a long-term source of MP entering inland waters via the erosion pathway. While long-term as well as event-based soil erosion is studied for decades, allowing for reasonable estimates of sediment delivery into inland waters, little is known regarding the MP contamination of arable soils and the transport behaviour of this MP during overland flow and erosion processes. The aim of this study is to use a state-of-the-art soil redistribution model in combination with estimates of MP accumulation in arable soils since the 1960th to determine a reasonable range of possible MP delivery into the stream network of a meso-scale catchment in Southern Germany. Contamination estimates of arable soils in the approximately 500 km² Glonn Catchment are based on statistical data regarding sewage sludge and compost use, measured atmospheric MP deposition and tire ware inputs estimated from traffic census. The potential MP flux to the stream network is simulated with an adopted version of the spatially explicit soil redistribution model WaTEM-SEDEM. The modelling framework allows to account for the (large) uncertainties especially those associated to the MP accumulation over the last 50 years, and results in a range of reasonable/possible MP delivery into the stream network. The simulations indicate that even conservative estimates of the erosion-MP-pathway result in substantially higher MP inputs as compared to inputs from all water treatment plants in the catchment. Moreover, the model allows to estimate the effect of, for example a ban of sewage sludge application, for the MP delivery into the stream network. Overall, the study implies that the erosion pathway will be a substantial source of MP input into the stream network for decades to centuries even if MP input to soils could be stopped.

High resolution investigation of plastic aging in soil using scanning transmission x-ray microscopy (STXM)

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The micro- (MP) and nanoplastic (NP) contamination of soil is of great importance as huge amounts of plastic are released in the environment. Over time, MP/NP in soils can be affected by physical, chemical and biological factors, which change their chemical structure, size, shape and surface properties.

Most of the current methods of MP/NP identification rely on specific optical properties and chemical spectra. When the properties of plastic are altered by the aging of the material, these methods can fail to identify them properly, potentially leading to the underestimation of the environmental concentration of MP/NP in soils.

In order to understand how plastic ages in soil, MP were collected from agricultural soils in Switzerland and homemade MP/NP particles of PE, PET, PA, PU and PC were incubated in two different soils for 3 months and 1 year. Additionally, MP of PS, PP, PET and PC were exposed to 168 hours of artificial sunlight in a SUNTEST chamber to assess the surface chemical alteration due to sunlight exposure of MP retrieved from agricultural fields. Samples were then microtomed into thin sections and the changes in chemical composition from the surface towards the bulk material of particles were analysed by STXM-NEXAFS. This method has a very high spatial resolution (15 nm) and is suitable to identify changes also in the uppermost surface layers. This high resolution implies a high sensitivity to changes, which is important as plastic aging is a very slow process. Furthermore, the depth resolved analysis might allow the assessment of the depth development of chemical aging. The particle surface was further investigated by acquiring SEM images in order to characterize possible physical changes.

MP particles of PET and PS collected in agricultural fields showed a chemical variation along the profile from the surface of the particles towards inside the bulk material. The transition between the surface structure to the bulk material occurred on a 0.1-1μm scale. Only the particles incubated for 3 months have been analysed so far and no significant effect of the incubation has been observed, indicating that 3-months is too short to cause any significant aging of MP surfaces. Results from the 1-year incubation and sunlight aging are yet to be analysed, but will be evaluated until the time of the conference. We expect changes of the surface of the particles to be visible after a 1-year incubation, with a dependence on the soil considered and the polymer incubated. Moreover, we expect that the comparison of MP from sunlight aging (only UV aging) with MP collected from agricultural soils (both UV and soil aging) and incubation experiments (mostly soil aging) will allow to assess possible differences of the aging processes. Finally, we aim to infer the lifetime of MP/NP of the tested polymers in soil from the observed changes of chemical alteration with time.

Microplastic water repellency reduced by ferrihydrite coating

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Pathways of Microplastic (MP) into ecosystems are manifold and range from agricultural mulching practices to atmospheric deposition with soil being considered the largest sink of MP in terrestrial ecosystems. Once deposited there, MP is posing a hydrophobic surface addition. Former experiments showed that pristine MP can cause lower water saturation of pore spaces and so change the liquid configuration within a porous network. If water cannot reach MP, biotic degradation might be hindered. However, in natural soil systems MP can be coated over time by soil abundant substances e.g., iron compounds with the potential effect of decreasing their hydrophobicity. We hypothesize that: 1) ferrihydrite pre-coated MP shows reduced hydrophobicity; 2) in-situ wetting and drying cycles with ferrihydrite leads to partial coating of MP.

We tested these hypotheses by applying hotspots of MP, pre-coated and pristine, to sand in rectangular columns and performed neutron imaging during capillary rise. Neutron imaging allowed for visualizing and quantifying liquid dynamics and configuration. Water was used for the pre-coated MP (n=6) variants and ferrihydrite suspension (100 mg L^{-1}) in three wetting and drying cycles for the pristine MP (n=6) variants. The utilized MP are polystyrene (PS, 20-75 μm) and polyethylene terephthalate (PET, 20-75 μm). The grain size of sand was 0.7-1.2 mm. Pre-coating was achieved by shaking the raw material for 3 h in a 100 mg L^{-1} ferrihydrite suspension and subsequent drying in a sieve supported by a vacuum pump.

Capillary rise of water into pristine MP variants exhibited zero water saturation at the hotspot and water movement around the MP aggregation was observed. Capillary rise of water into pre-coated MP variants differ in result by polymer type. While pre-coated PS is still hydrophobic, the pore space of pre-coated PET was completely water saturated. The rising water accelerated towards the hotspot due to its lower matric potential compared to sand.

Capillary rise of ferrihydrite suspension in wetting and drying cycles also showed varying results according to polymer type. While there is no effect on water saturation on PS in the hotspot after three wetting cycles, PET exhibits a slightly higher water saturation during the second wetting but stagnating in the third.

Our results suggest that ferrihydrite coating, being only one of numerous potential coating agents, can bond to MP and change its surface polarity. Differences in completeness of coating can be explained by inherent chemical and physical properties of different polymer types. But once hydrophilic, completely, or only part of the surface, water flow induced colonization and migration of microorganisms and their enzymes can proceed and biotic degradation can take place. The open question lies within the time frame necessary to overcome MP's inherent hydrophobicity.

Microplastics effects on soil porosity, oxygen distribution and greenhouse gas emissions

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Understanding the responses of soil ecosystems to the presence of microplastics (MPs) becomes increasingly important as multiple stressors can act together to negatively impact this environmental compartment, especially in the context of global warming. MPs (particularly fibers) impact soil structure and function, including aggregate stability, water holding capacity and microbial activity. Furthermore, recent studies suggest that the presence of MPs in soils affects the emissions of the greenhouse gases (GHG) carbon dioxide (CO_2) and nitrous oxide (N_2O). The mechanisms underpinning the direction and magnitude of MPs effects on GHG emissions from soils are uncertain, mainly due to the lack of knowledge of how the presence of MPs drives changes in soil structure and the subsequent linkages between soil structure and microbial activity. Here, we hypothesized that the presence of MPs affects soil structure by increasing porosity, leading to higher O_2 availability and consequently higher decomposition of soil organic matter (SOM). We also hypothesized that effect of MPs on soil porosity and O_2 availability will be higher for MPs fibers compared to MPs fragments. We spiked PET MPs fibers (0.05 mm length) and fragments (>250 µM) into a custom built rhizotron (4 x 4 x 1 cm) filled with a clay soil with a MPs treatment of 1 w/w%. Glucose dissolved in water (as a substrate source) in known concentrations were added at the beginning of the experiment to assess soil respiration over time. We determined the spatial distribution of microbial respiration by mapping O_2 concentrations using optode imaging, with a resolution of 1 image every 10 minutes over the course of 48 hours. Soil pore size, pore distribution and the pore connectivity network were determined by using X-ray micro-tomography (µCT). GHG emissions were measured by placing replicate set-ups in a Tedlar bag and collecting CO_2 and N_2O from the headspace in exetainers which were subsequently analyzed by gas chromatography. This approach allowed us to collect real-time O_2 distribution and compare this to X-ray micro-tomography (µCT) data from the same soil matrix to assess MPs impacts to the soil structure and link it to GHG emissions compared to the control (i.e. no MPs addition). Collectively, in this work we show the impacts of MPs addition to soil and their impacts on the linkages between soil structure, microbial activity and GHG emissions. This study can serve as a baseline for understanding the important impacts of MPs have on soil functioning, which is particularly relevant as plastics are increasingly used directly in agriculture and consequently have direct releases to the terrestrial ecosystem.

Do microplastics and nanoplastics enhance contaminant mobility in soils?

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Farmland soils are prone to contamination with micro- and nanoplastics (MNP) through a variety of agricultural practices. Concerns are recurrently raised that micro- and nanoplastics act as vector for organic contaminants to deeper soil layers and endanger groundwater resources. Whether and to what extent micro- and nanoplastics facilitate the transport of organic contaminants in soil remains unclear. Here we calculated the ratio between transport and desorption time scales using two diffusion models for micro- and nanoplastics between 100 nm and 1 mm. To identify micro- and nanoplastics bound contaminant transport we evaluated diffusion and partitioning coefficients of prominent agrochemicals and additives and of frequently used polymers e.g., polyethylene and tire material.

The use of plastic mulch or biosolids offers great benefits for agricultural producers in their effort to sustain a growing global population. To minimize the impact of agricultural practices on the environment and the consumers, the complete removal of plastic foils after use or their replacement by fully biodegradable materials should be advocated. The amount of plastics unintentionally entering farmland soils via biosolids and compost needs to be reduced and should be regulated. Good governance and targeted regulations are required to improve waste management and to promote a sustainable, effective circular economy Simultaneously, a thorough understanding of the risk associated with the presence of MNP in farmland soils is crucial to reduce the impact on the consumers' health. There is no doubt that the input of plastics contributes to the overall flux of potentially harmful organic contaminants to farmland soils. Although MNP carrying these contaminants may be physically worked into topsoil layers by physical and biological activities, the scenarios under which MNP play a relevant role for contaminant relocation into deeper soil layers are very limited. Our analysis shows that desorption from nanoplastics is fast for most polymer-contaminant combinations and nanoplastics bound contaminants will reach equilibrium with the soil matrix within the first meter of soil. Only larger microplastics with very slow contaminant desorption rates might add to the relocation of hydrophobic organic contaminants in addition to the plethora of natural mobile soil particles, provided that fast flow regimes and preferential flow paths prevail, and that the microplastic particles are mobile. However, in farmland soils, few preferential flow paths extend beyond 1 m in depth, and by the time microplastics reach deeper soil layers the organic contaminants will be desorbed.

Therefore, MNP are not expected to enhance the vertical mobility of most organic contaminants in farmland soils to an extent that endangers underlying groundwater resources. This conclusion stresses the need to focus further research activity on the potential risks associated with the presence of MNP derived organic contaminants in the root zone, plant uptake, or adverse effects on the soil microbiome.

Quality assurance and quality control in microplastic analysis in complex matrices: concepts, examples and recommendations

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Microplastics (MPs) are increasingly and almost ubiquitously present in the environment, where they may pose a risk to corresponding ecosystems and, in the longer run, even remain as prominent markers of the anthropocene. Assessing their exposure requires reliable and quantitative analytical methods at mostly trace concentrations. However, widely established quality assurance and quality control (QA/QC) measures in analytical chemistry are not yet regularly and fully implemented in MP analysis. Moreover, due to the different nature of particulate in comparison with elemental or molecular analytes, these measures may need adaption or even expansion when applied to MP analysis.

Here, we present a series of concepts, examples and recommendations how to translate and implement established QA/QC tools into MP analysis of complex matrices. These include among others the selection and use of different surrogate standards (e.g. coloured, isotope-labelled, fluorescent or metal doped) along different steps of the analytical chain to account for, e.g., extraction, pyrolysis or imaging efficiency, the development and use of controls such as fresh and aged MP standards and spiked reference materials, as well as inter-laboratory comparisons and ring trials. Whenever possible, one should resort to complementary analytical approaches based in orthogonal instrumentation and detection principles, and determine concentrations based on both on number and mass concentration, and in combination with size distribution. Figures of merits of any validated analytical method include method detection limits, blank levels, (linear) concentration ranges, repeatability and reproducibility, recoveries, matrix effects, etc. Their determination and reporting should (even) more regularly become good analytical practise among analytical chemists investigating MP in complex matrices.

Development of an online preconcentration method for nanoplastics analysis in environmental samples using representative standards of controlled size, shape, and composition by AF4-MALS

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The environmental fate and impact of nanoplastics (1 nm-1000 nm) has raised considerable and urgent concerns for several years. Nowadays, it is well accepted knowledge that plastics debris is degraded by different physical, chemical, and biological processes to break down into nano-sized fragments called nanoplastics. These nanoplastics can in view of their large surface to volume ratio even better sorb and desorb other (metallic or organic) contaminants present in the environment. Because of the longevity and colloidal behaviour of the nanoplastics, they can be transported together with the co-contaminants through the different environmental and biological compartments. This phenomenon is called "Trojan Horse Effect" and is governed by their physico-chemical properties, particularly by their size and shapes.

To develop analytical methods suitable for the characterization of nanoplastics in environmental samples, a range of representative nanoplastic standards beyond the commercially available ones (e.g., polymer latexes) are required. In our group, we generate nanoplastics with different characteristics (polymer composition and shape) and study them by asymmetrical-field flow fractionation coupled online with UV-vis and multi-angle light scattering detection (AF4-UV-MALS). For a more complete picture, dynamic light scattering (DLS), microscopy and zetametry are being conducted. We have compared three different shapes of nanoplastics (i.e., sphere, flake, and fibers) as well as several polymer types (e.g., polystyrene, polyurethane, nylon).

Until now, most studies use filtration techniques (e.g., ultrafiltration, ultracentrifugation, solvent evaporation) as preconcentration techniques prior analysis. These methods are laborious and not applicable to environmental samples with complex matrices. To tackle this and overcome the expected relatively low concentrations of nanoplastics in environmental samples, we have developed an online AF4 preconcentration method which also allows matrice removal during the AF4 run. To achieve this, we have modified a commercial system which enabled us to inject up to 50 mL of samples. With this technique we could characterize nanoplastics in environmental samples (surface water and sediments) from different regions in The Netherlands. The identity of the plastics present was revealed using py-GC-MS.

Cleaning waste water with Microplastics

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Without a dramatic increase of the worldwide recycling ratio of plastic products, the negative effects on aquatic life and human health will be ongoing and increasing. Microplastics transferred from plastic trash have the potential to attract pollutants from the chemical cocktail in rivers or marine waters. In addition to the ingredients of the debris, itself the adsorbed pollutants can transfer via debris to fish, bivalves, shellfish etc. upon ingestion. But the attractive properties of microplastics can be used in a positive way in order to to clean water and air. Microparticles made out of plastic litter show a way how artificial polymers can be introduced back into the loop of use. This contribution to recycling has additional environmental side effects like carbon dioxide reduction, when the filter material is used as an active carbon subtitution in municipal waste water treatments plants in a fourth cleaning step. In this context polyamide waste is transfered into effective filter material for organic pollutents, and polystyrene containing plastic scrap is functionalized as an ion exchange material.

The microplastic filters are generated in a simple way. Dissolved Macroplastic litter is precipitating in a second solvent. Applying this low cost process microplastic particles with very high surface areas can be produced (figure 1).
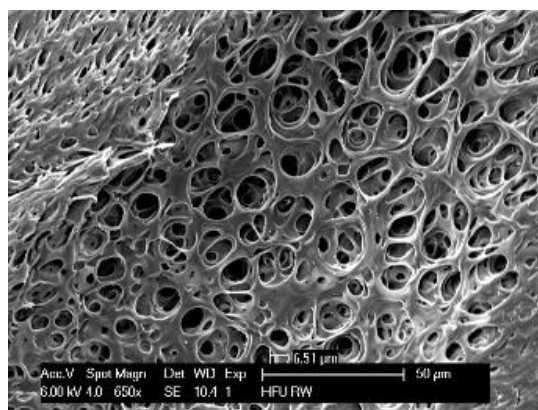

Figure 1. SEM Image of a PA12 Micorplasticparticle

The low energy input in these processes are considered as a central economic criteria when it comes to recycling. As long as it is cheaper to produce petrol based , instead of recycling plastic, there will be no increase of the recycling rate without legal regulations. Economic incentives are needed and presented.

Keywords | Microplastic, plastic recycling, wastewater treatment, adsorption of pollutants

The QCL based LDIR 8700 Imaging System for the Rapid and Automated Analysis of Microplastics in various matrices

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The analysis of microplastics has played an increasingly important role in recent years and has become one of the most important environmental analysis topics. Special efforts are made to find techniques that involve a high degree of automation and produce results as quickly as possible. The QCL based LDIR 8700 is a system that combines exactly these properties.

The LDIR 8700 is a new powerful infrared chemical imaging system that eliminates much of the problems associated with other system. By coupling the bright quantum cascade laser (QCL) with rapidly scanning optics and using a thermoelectrically cooled MCT detector, LDIR provides a new approach to chemical imaging and spectral analysis at an unprecedented speed without coherence artifacts. Because of the use of tunable laser, LDIR can rapidly acquire an image over a large area with diffraction limited spatial resolution by simply using some diagnostics wavelengths that are necessary for analysis. This dramatically improves the speed of analysis and allows to probe bigger area to obtain statistically relevant data without using any complicated chemometric analysis. As a result, this technological breakthrough makes it possible to scan large areas (25 mm × 75 mm) with varying pixel size resolution of as small as 1 μ m in a few minutes. The high spatial resolution combined with the rapid acquisition of data makes this technology very interesting for analysis of particles and contaminations in various matrices.

A related topic is the detection and analysis of Microplastics in aqueous and other more solid matrices. Researchers wish to measure the size, shape, and chemical identity of every plastic particle. Because smaller particles are thought to be the most biologically relevant, this analysis must extend to particles on the micron scale. Unfortunately, traditional techniques such as visual inspection are slow, manually intensive, and prone to operator bias. As a result, investigators have turned to chemically specific vibrational spectroscopy, which can be used in a microscope format for particle analysis at greater speeds.

But also, classical vibrational spectroscopy techniques have disadvantages. Raman microscopes struggle to identify fluorescent particles, while array based FTIR (Fourier transform infrared) microscopes generate a large number of spectra which are redundant or taken in the empty space between particles. Finally, the massive datasets generated by these microscopes introduce processing and storage challenges and makes these techniques quite slow. A Quantum Cascade Laser (QCL) is a tunable semiconductor laser than generates light in the mid-Infrared regions. Such a light source allows tight focusing of the bright infrared light at the precise center of each particle and this can facilitate rapid and accurate identification of micron-scale particles. The LDIR 8700 furthermore does the full analysis very fast and fully automated. Some examples will be presented in this study.

Improved chlorinated microplastics detection using a solid phase sorbent and Thermoextraction-desorption coupled with gas chromatography/mass spectrometry (TED-GC-MS)

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One of the analytical methods that is offering the most promising results for the analysis of microplastics in water are thermal technics such as Pyrolysis coupled to gas chromatography/mass spectrometry (Pyr-GC-MS) or Thermal Extraction-Desorption coupled to gas chromatography/mass spectrometry (TED-GC-MS).

Different studies have used TED-GC-MS to study microplastics, where water samples are first filtered to isolate microplastics. A part of this filter is placed in a thermogravimetric (TG) crucible and pyrolyzed in an inert atmosphere, trapping the thermodecomposition products in a solid sorbent, generally based on polydimethylsiloxane (PDMS). Once the decomposition products are trapped on the sorbent, they are thermally desorbed and analysed by gas chromatography/mass spectrometry.

The main objective of this study is to improve the retention of microplastic thermodecomposition products by seeking an alternative sorbent to PDMS, considering that carbon materials are good candidates.

To test the retention capacity of carbon materials, the activity of PDMS was compared with thermal desorption tubes filled with a triple bed of carbon (Carbopack C+B y Carbosieve S-III) when analysing 6 of the most found polymers in environment (PP, PS, PET, PA, PE and PVC).

When we compare the different sorbents, it can be seen how PDMS and carbon have a very similar behaviour. It can be seen how the carbon can retain all the microplastic thermodecomposition products besides of the chlorinated characteristic compounds of PVC, while they are not retained in the PDMS.

After comparing and analysing different materials and strategies for the retention of the thermodecomposition compounds of the studied polymers, it can be concluded that the results of the test carried out for the characterization of the materials show that all of them are materials without functional groups on their surface. In addition, it has been proven that PDMS is a non-porous material, confirming that the mechanism by which it retains the compounds is through absorption, as shown in the literature, while, in the case of carbon materials, these are packed in a thermodesorption tube forming three consecutive beds, thus achieving three adsorption zones and being able to retain compounds with three different molecular size ranges.

The use of carbon materials has shown to have optimal behaviour for this application, highlighting two main advantages; on the one hand, they present optimal slit-type pores to retain the aromatic compounds that many polymers present, and, on the other hand, carbon materials can retain the chlorinated compounds from PVC despite not having functional groups, while the absorption mechanism by which they are retained in the PDMS is not effective in retaining these compounds.

Classification of (micro)plastics using cathodoluminescence and machine learning; possible application for nanoplastics?

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In recent years microplastics have become of growing concern, having been found in the remotest locations of the earth and inside animals and the human body. Yet, the scale of the problem is not fully understood as the smallest micro- and nanoplastics (MNPs) cannot be accurately measured. This is due to limitations in measurement and detection techniques for the smallest plastics; the nanoplastics.

Chemical composition of the smallest fraction of microplastics (the nanoplastics) can be obtained through various methods, with thermal analytical based techniques being the most promising. However, as this is a bulk-based technique, it doesn't allow for single particle analysis which is needed in order to understand how these plastics are formed and distributed in the environment.

Single particle analysis of MNPs is achieved though the combination of microscopic and spectroscopic techniques such as Fourier Transform Infrared spectroscopy (FTIR) or Raman (or both). However, the detection limit of these techniques is approximately around 20 μm and 1 μm for μ-FTIR and μ-Raman respectively, and are therefore unsuitable for the detection of nanoplastics. Both techniques also suffer from problems due to the presence of additives and colourants in the plastics, especially with black samples as it absorbs all the light which is needed for analysis.

In our work, we show a novel approach by combining the nanoscale resolution of Scanning Electron Microscopy (SEM) with the spectroscopic power of cathodoluminescence (CL) to show that six of the most common plastics – HDPE, LDPE, PP, PA, PS and PET – have unique CL spectra that could help identifying the smallest MNPs. We have built a spectral database using reference and real world plastics with varying colours, sizes and shapes. Using this database, we trained a two-step Artificial Neural Network (ANN) classification model. With this model we were able to classify the six plastics based on their CL spectra with an accuracy of 97%. As measurements were performed in the submicron size range (data input is average of 121 spectra from a 7 x 7 μm area, pixel size = 636 nm), the SEM-CL technique in combination with the developed ANN model seems promising for the identification and classification of plastics that are too small for other conventional measurement techniques such as μ-FTIR and μ-Raman.

With this work we show a "proof of concept" for the SEM-CL technique for application in MNPs research. We hope that this approach can be further developed and demonstrated for nanoplastics to enable a greater understanding of the sources and distribution of micro- and nanoplastics.

Machine learning automated data analysis of microplastics measurements and its implications on advancing microplastics analysis to routine analysis

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To gain a better understanding of the occurrence and origin of microplastics in our environment, a reliable and scalable measurement method is needed. Promising methods for analysis are based on micro-spectroscopy since it allows for a determination of both the particle shape as well as the chemical structure. Raman and micro-FTIR (imaging) are widely used. However, the enormous amounts of complex data generated during the measurement process pose a challenge:

The conventional approach for analysing spectral data is by using spectral library searches. However, studies and experiences in recent years show that this approach has limitations in the context of microplastic analyses. The many manual interventions and various parameter settings (reference spectra, similarity measures, operator, thresholds…) to obtain results of sufficient quality, lead to reduced reproducibility and comparability. Furthermore, the limited amount of reference spectra in a library can lead to results of questionable quality (false positives and false negatives). Meanwhile the analysis is time-consuming and, thus, costly.

These problems already led to new developments in the use of spectral library search and finding alternative solutions, such as the introduction of machine learning technology. Machine learning models are ultimately mathematical models which were created from training data. To solve the microplastics classification problem, a model was trained to decide which pixel in a hyperspectral image is a polymer and which one is not. It was also taught to distinguish between different types of polymers.

Machine learning technology brings several advantages. In contrast, library-based analysis solutions often have a couple of hundred IR spectra in their library. The cross-checking of each pixel to the library is therefore quite slow and gets even slower as the library gets bigger. A more robust classification requires a bigger library which will slow down the process of the classification even further. With machine learning, however, this trade-off between analytical quality and speed of the analysis does not exist. The broad applicability of only one model and the reduction of manual intervention increases reproducibility and comparability. Furthermore, models trained by experts can be used by personnel with less experience, making robust microplastics analysis more accessible.

These characteristics imply that machine learning based automation is an innovative method that can advance microplastics analysis, thus, having the potential of becoming the new state-of-the-art and enabling microplastics analysis to become a routine analysis.

This presentation will focus on the importance of scalable microplastics analysis methods to enable a supply that will meet demand in the future. It will highlight machine learning-automated data analysis by outlining the difference with spectral library approaches, the advantages as well as limitations. Moreover, the implications of an automated data analysis with respect to advancing microplastics analysis to routine analysis will be discussed.

Investigating tire tread particle toxicity to fish using Rainbow Trout cell lines

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Tire and road wear particles (TRWP) are generated during the abrasion of tires while driving, and are composed of rubber and tire additives, but also road minerals, bitumen and brake particles embedded during generation. Recently, questions were raised about their potential contribution to microplastics released into the aquatic environment and their potential toxicological impacts. Our study aimed to assess the toxicity of TRWP and associated chemicals to fish using two Rainbow Trout (*Oncorhynchus mykiss*) cell lines representing the gill (RTgill-W1) and the intestinal (RTgutGC) epithelium. The toxicity of cryogenically milled tire tread (CMTT) particles, used as a proxy for TRWP, was assessed considering several potential exposure pathways: 1) exposure to CMTT with direct contact in order to quantify a combined particle/leachate effect, 2) exposure to CMTT leachate only, to assess the toxicity of the leaching chemicals, 3) exposure to CMTT digestate, to investigate if fish gastro-intestinal conditions could result in a different chemical profile and change the toxicity and 4) exposure to thermooxidised CMTT, to determine the effect of aging on the induced toxicity. In accordance with OECD TG249, cell viability was assessed after 24 hours acute exposure using a multiple-endpoint assay indicative of cell metabolic activity, membrane integrity and lysosome integrity. Chemical composition of the exposure medium was analyzed to assess which chemicals could be responsible for the observed acute effects. The determined fish cell line in vitro EC50 values were 2.02 g/L and 4.65 g/L for RTgill-W1 and RTgutGC cell lines, respectively, and in the same range as what was previously reported *in vivo*, and far above tire and road wear particle environmental concentrations reported in river water (4 mg/L). However, road runoff concentrations were found to exceed 100 mg/L and our results showed that the non-toxic concentration was in the range of 40 to 130 mg/L, hence more research into long-term effects of such high exposure is required. Moreover, our results showed that the presence of the particles was greatly contributing to the overall observed toxicity, as the leachate alone induced lower toxicity. Aging of the particles also resulted in a lower toxicity, due to less chemicals leaching out in the medium. On the opposite, *in vitro* digestion of the CMTT resulted in a higher toxicity in comparison to water leachates, due to higher concentrations of metals and organic compounds leaching in the digestive fluids, among which were Zn, 2-mercaptobenzothiazole, 1,3-Diphenylguanidine (DPG), and N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine (6PPD). Although traces of 6PPD-quinone were also measured, further cytotoxicity assays using RTgill-W1 and RTgutGC cell lines showed no toxicity of this compound up to 3 mg/L, while several studies reported toxicity *in vivo* at far lower concentrations. This lack of toxicity when exposing the gill and intestinal cell lines could be due to a specific mode of action of this chemical compound, such as neurotoxicity, which we will investigate further using a Rainbow Trout brain cell line.

Bioaccessibility, bioaccumulation and effects of tire-associated chemicals for aquatic and soil-dwelling organisms

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Tire and road wear particles (TRWP) are produced by the friction between the tires and road and consist of polymer-containing tread with pavement encrustations. There are many data gaps remaining regarding their fate and potential toxicological impact on the aquatic and terrestrial environment. This study aimed to (i) investigate the solubilization and bioaccessibility of 11 tire-associated chemicals into fish gastric and intestinal fluids using an *in vitro* digestion model. The effect of food co-ingestion on the bioaccessibility of the chemicals was also assessed by introducing ground *Gammarus pulex* as a food surrogate in the digestion vessels. We also (ii) explored the effects of tire particles at environmentally relevant soil concentrations on survival, growth and reproductive output of an earthworm species, *Eisenia fetida*. The bioaccumulation potential of several commonly used tire-related chemicals was established and their bioaccumulation kinetics were determined.

Our results show that the targeted compounds were rapidly solubilized into fish simulated digestive fluids within an average gut transit time of 3h in gastric fluid and 24h in intestinal fluid. Only a small percentage (0.06%) of hydrophobic tire-associated chemicals was found to be solubilized in the simulated fluids compared to more hydrophilic chemicals for which up to 44% of the total concentration in tire particles was solubilized. The effects of food co-ingestion on the solubilization of tire-associated chemicals was compound-specific and either lowered or stimulated their solubilization into the gut fluids. Our experiments also indicate that tire-associated chemicals were bioavailable to earthworms in natural soil spiked with tire particles albeit with a significant chemical increase in the organisms only in a highly contaminated soil (5% tire particles). The chemicals investigated did not show strong bioaccumulation potential: the Biota-Soil Accumulation Factor was <1 except for some apolar Polycyclic Aromatic Hydrocarbons. All chemicals were rapidly eliminated from earthworms during the depuration phase of our bioaccumulation test. No mortality or impact on growth in the adult earthworm population was observed in either treatment tested (control, 0.05% tire particles and 5% tire particles) after 4 weeks of exposure. A slight decrease in weight of the juveniles exposed to tire particles was observed in the reproduction test. More research will aim to confirm these results and reveal the underlying physiological mechanisms involved.

Genotoxic and estrogenic effects of cryo-milled tire tread particles detected with high performance thin-layer chromatography (HPTLC) bioassays

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Vehicle tires abrade during use, generating particles that can be transported to aquatic environments. Chemicals in the tire rubber can then leach into aquatic matrices or be ingested by organisms, possibly resulting in adverse outcomes through endocrine disruption or genetic damage. This work aimed to (1) characterize the comprehensive profiles of potential estrogenic and genotoxic activity in tire particles including, when possible, attributing effects to specific chemicals, and (2) evaluate realistic exposure scenarios of tire particle ingestion by fish and leaching into sediment overlying water. For (1), organic chemicals were extracted from cryogenically milled tire tread (CMTT) with Soxhlet extraction. For (2), we approximated a fish digestion scenario with successive incubation of CMTT particles in simulated gastric and intestinal fluids. In these samples, we first identified and quantified eleven organic chemicals suspected of being associated with tire wear particles with LC-MS/MS. We evaluated estrogenicity and genotoxicity of the individual chemicals and CMTT samples with a yeast estrogen screen (YES) and umuC test for DNA damage (umuC) without metabolic activation, respectively, directly on HPTLC plates after chromatographic separation. Two individual chemicals were active in HPTLC-YES: N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine (6PPD) and 2-2'-dithiobisbenzothiazole. Three chemicals were active in HPTLC-umuC: N-cyclohexyl-2-benzothiazolesulfenamide, cyclohexylamine, and 1,3-diphenylguanidine (DPG). Following application of CMTT extract (equivalent to up to 1 mg CMTT) multiple estrogenic and genotoxic signals were detected. Among the eleven chemicals measured in CMTT, DPG is one that was likely responsible for umuC genotoxicity in CMTT extracts. It was measured in CMTT at levels above the biological detection limit of umuC and the individual compound shared the chromatographic position of genotoxicity observed in CMTT extracts. However, simulated digestates of CMTT did not induce a response in either HPTLC-YES or HPTLC-umuC assay. Accordingly, DPG was also measured in CMTT digestates, although below the lowest effect level of DPG alone. In summary, genotoxic and estrogenic hazards were (1) detected in comprehensively extracted tire particles, but were (2) below biological detection in simulated digestates, suggesting low concern in such a scenario. Future efforts will work to identify the remaining unknown toxicants to allow risk evaluation of these hazards and determine effects of environmentally representative tire and road wear particles.

The effect of microplastic particles on cells of the adaptive and innate immune system

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Plastic waste is a growing problem globally due to increasing plastic manufacture, disposal, and anthropogenic activities. Microplastics (plastic particles <5 mm) are highly dispersive and known to geographically spread, accumulate, and cause persistent contamination. For this reason, human exposure to such particles is inevitable and may occur by ingestion, inhalation, and dermal contact. Yet, the effects of microplastics in human health still need to be investigated, especially in terms of effects on human immune cells.

In this project, the effects of polystyrene (PS) and poly(methyl methacrylate) (PMMA) particles in the size of 50-1100 nm on human cells of the adaptive and innate immune system were investigated. As a positive control, amine-modified PS particles (size: 55 nm) were utilized. The immune cells were isolated from peripheral blood mononuclear cells (PBMCs) from whole blood donations. After 24 h incubation with the microplastic particles, the toxicity and the effect on activation markers of T-lymphocytes were determined. Regarding the toxicity, only the amine-modified particles decreased the cell viability of CD8 positive (CD8+) cytotoxic T-cells and CD4+ helper T-cells. The effect on their activation markers (e.g., CD69 and CD25) depended on the donor rather than the treatment. Similar results were found for 72h exposure of the particles to the leucoagglutinin (PHA-L) activated T-cells. Cytotoxic effects of the non-modified microplastic particles could barely be observed. Likewise, the expression of the activation markers was mostly donor-dependent. In contrast to T-lymphocytes, dendritic cells (DCs) are classified as professional phagocytes as they engulf large particles. Consequently, non-modified PMMA and PS particles in higher concentrations (100 µg/ml) also displayed toxic effects in DCs. Moreover, a negative correlation between cell viability and the maturation markers CD25 and CD197 was observed. For the activation marker CD40 and CD80, which are required for triggering T-cell activation, a positive correlation was found.

Our results suggest that microplastic particles could affect the function of specific immune cell subpopulations, particularly phagocytes. Future studies need to clarify the biological consequences of such alterations in living hosts.

What if you eat nanoplastic? Simulation of gastrointestinal digestion of biodegradable vs polystyrene nanoplastics and their interactions with food components

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With the growing plastic pollution and accumulation in the environment, nanoscaled plastic particles (nanoplastics) have been found in various environmental compartments including human blood stream. It is presumed that they may be absorbed by humans, with oral ingestion being one of the most prevalent exposure routes. Research on animals has shown that nanoplastics have hazardous impact on living organisms. However, the behaviour of plastic particles in conditions of human digestive tract has not yet been scrutinized, leaving a knowledge gap regarding the fate of nanoplastics between ingestion and absorption to human cells. Moreover, the influence of food matrix, with which particles are most probably ingested, on the risk of being absorbed, has not been investigated either.

In this light, we conducted research with the aim of assessing the fate of nanoplastics in the human digestive tract. For the experiments, polystyrene standard nanoparticles of well-defined size (60 nm and 400 nm) and morphology (spherical shape) were used. For comparison and to study the effect of polymer composition, the procedure was also applied on nanoparticles containing a biodegradable polymer. The digestive tract was simulated by two phases of incubation, imitating the conditions (temperature, acidity, shaking, presence of specific enzymes) in human stomach and small intestine, respectively. As analytical tool, asymmetrical-flow field flow fractionation (AF4) with UV and multi-angle light scattering (MALS) detection (AF4-MALS) was used. This technique was chosen as it allows the separation of particles of different sizes, giving information about their size and shape distributions, which are crucial for the absorption of nanoplastics within the digestive tract. To investigate the potential interactions of plastic particles with food, the most common food components were included, thus simulating the ingestion of NPs together with the food matrix. For this, the influence of each component type (i.e. sugars, proteins and fats) on the size and shape distributions was assessed. As food matrix model selected component-rich products were used, e.g. protein supplement and edible plant oil. The amounts of food components used in the study were selected based on the dietary reference intakes, which state that an average meal consists of sugars (45-65%), lipids (20-35%) and proteins (10-35%).The result is an overview of changes which NPs undergo in the human gastrointestinal system, leading to preliminary conclusions about the possibility of NPs being absorbed via the oral exposure route which will allow to further assess the potential human health risks posed.

Biodegradation dynamics of biodegradable mulch foils in agricultural soils: analytical advancements and comparative analysis across incubation scales

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Conventional mulch films composed of persistent polyethylene are widely used in agriculture to improved crop yields while decreasing water consumption and pesticide use. Thin mulch films are, however, difficult to completely recollect from the field after use, leading to a fraction of the films entering soils. The resulting accumulation of residual polyethylene film pieces negatively impacts soil productivity and turns agricultural soils into sources of plastics to surrounding environments. Mulch films certified as soil biodegradable promise to help overcome this pollution problem. However, certification relies exclusively on laboratory soil incubations under controlled conditions coupled to respirometric analysis of mulch film mineralization to CO_2. A thorough assessment of the biodegradation dynamics of biodegradable mulch film products *in situ* in the field with highly variable conditions is lacking, in part reflecting the absence of analytical methods to accurately quantify residual mulch film polymers in soils over time. This study aims at following mulch film biodegradation directly in the field over two years and to compare the biodegradation dynamics in the field with the dynamics of the same films in the same soils but incubated in soil mesocosms in the greenhouse and in soils in the laboratory. To reach the aim, we first advance a methodology to extract and quantify the main synthetic polymeric components of mulch films, poly(butylene adipate-co-terephthalate) (PBAT) and polylactic acid (PLA), from soil. The methodology is based on exhaustive Soxhlet extraction of PBAT and PLA from soil followed by quantitative proton NMR of the extracted PBAT and PLA. The analytical method was optimized to provide a high sample throughput (extraction time of 1.5 hours) and to account for interferences caused by co-extracted soil organic matter in the NMR spectra. In a second part, we then use this analytical approach to follow the biodegradation of two commercially available biodegradable mulch films in three Swiss agricultural soils in a two-year incubation study. Polyethylene and a poly-hydroxyalkanoate were included as negative and positive biodegradation controls. All polymers were deployed in mesh bags and incubated in the selected soils in the laboratory, greenhouse mesocosms and the fields. We statistically compare biodegradation rates and extents between three soils and two tested films across the three incubation scales. This comparison provides a first reliable assessment of the transferability of biodegradation results from laboratory incubations to the field. Our results highlight strong variations in biodegradation dynamics between soils and between PBAT, PLA and the positive control. Furthermore, the results call for caution when using laboratory incubation studies, exhibiting comparatively high biodegradation rates and extents, to predict biodegradation of the same mulch film products in the field.

Study on nanoplastic degradation under environmental-like conditions

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Microplastics and nanoplastics (NPs) in the environment undergo weathering, induced by mechanical abrasion, oxidation, UV radiation or microbiological activity. Oxidation and photo-oxidation becomes an important chemical degradation pathway when the size of plastic particles decreases, (i.e. <2 μm in size), because reactivity is proportional to the surface to volume ratio. NPs have size lower than 1 μm and, due to their density, they are expected to float at the surface of the oceans and interact with both atmosphere and bulk water. Therefore, NPs can absorb sunlight and react with oxidants in the gas and in the liquid phase.

In this work we studied the degradation of polystyrene (PS) nanoparticles as proxy of nanoplastics. We exposed PS nanoplastics dispersed in water to light (UV-B light and/or sunlight), oxidants in the gas phase (i.e. ozone) and oxidants in the liquid phase (i.e. hydroxyl radicals). We characterized the degradation products released in the liquid phase through mass spectrometry using an electrospray ionization differential mobility analyser coupled with an atmospheric pressure interface time of flight (ESI-DMA-APi-TOF) and the chemical changes on nanoplastics, in terms of carbon and oxygen functionality, were investigated with scanning transmission X-ray microscopy coupled to near-edge X-ray absorption fine structure spectroscopy (STXM/NEXAFS). PS degradation leads to the formation of formate and acetate and other compounds, with molecular mass up to 200 Da that are released in liquid phase. The STXM analysis highlights also the presence of oxygenated functions in the particles, showing that these plastic particles dispersed in water can react with light and oxidants leading to particle oxidation and organic compounds release in water.

We also studied the interaction between PS and iron(II) under UV light irradiation with the aim of understanding the possible effects of nanoplastics on the natural photochemical cycle of Fe(II)/Fe(III) in water. PS nanoparticles suspensions in water were irradiated with and without the presence of Fe(II). The degradation kinetics of Fe(II) and the changes of total iron in solution were determined through spectroscopic methods; the iron oxidation state on nanoplastics was investigated STXM/NEXAFS. Under our experimental conditions, we observed a rapid degradation of Fe(II) and a loss of total iron from the solution, indicating that it was adsorbed on PS particles as Fe(III), as highlighted by STXM/NEXAFS analysis.

These experiments show that NPs could perturb the natural water photochemical equilibria, interacting with naturally occurring species (i.e. iron) and that the degradation of NPs can be induced by light and/or oxidants both in the gas and in the liquid phase. The degradation leads to a change in the C/O ration in the particles and to the release organic matter to water, with potential consequences on carbon cycle.

Pathways to micro- and nanoplastic:
results from accelerated weathering studies

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The main source of microplastic (MP) in the environment is fragmentation of macroplastic, resulting from weathering. However, degradation does not stop, when MP-size is reached. For the degradation of MP particles, knowledge on degradation mechanisms, time-scales, fragmentation rates and nanoplastic particle production is limited and largely based on estimations. To fill this knowledge gap, we performed accelerated weathering experiments on Polystyrene (PS), low-density Polyethylene (LDPE) and Polypropylene (PP) polymer particles of 125-200 µm size. Degradation and fragmentation were monitored using a variety of analytical tools, such as Gel-Permeation-Chromatography, Differential Scanning Calorimetry, Scanning Electron Microscopy and Particle Size Analysis.

We identified two stages of weathering for amorphous, and three stages of weathering for semi-crystalline particles: stage I is dominated by photooxidation in a near-surface layer; in stage II fragmentation is enhanced via microcrack-formation and particle rupturing; in stage III, for semi-crystalline polymers, crystalline domains degrade as well, leading to nanoparticle-formation and particle aggregation.

Degradation and fragmentation proceeds from the surface into the bulk. With increasing weathering, the particle size decreases rapidly and small secondary daughter MP particles (DMP) are abraded from the highly weathered surface and released into the environment. Fragmentation rates largely depend on the polymer: for PS, 600 DMP are released from one 160 µm pristine particle, whereas for LDPE the value is much higher, with 14 000 secondary DMP being produced from one 190 µm pristine particle. PP even exceeds this number, one 190 µm particle produces 100 000 secondary DMP. These micro- and nanoplastic particles are highly weathered and chemically modified and do not resemble the original polymer in their chemical composition and physical properties.

Advancing our understanding of plastic fragmentation in the environment through a mechanistic model of micro- and nanoplastic fragmentation

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The potential for plastics to degrade and fragment towards nano-sized particles in the environment is raising concerns about the divergent fate, hazard and risk of different sized plastic particles. For example, nanoplastics may more easily permeate biological membranes, and follow different fate pathways enabled by their tendency to aggregate to natural environmental particles. However, there is limited understanding of the fragmentation process and the influence of different environmental stresses in altering the susceptibility of plastics to fragmentation. We are addressing this by developing an open-source mechanistic model of Micro and NanoPlastic degradation and FRAGMentation in the ENvironmenT – FRAGMENT-MNP.

The rate at which a given polymer breaks apart (fragments) in the environment depends on the polymer material, its size and the environmental compartment it resides in. The environmental compartment determines the degradation stresses (such as photolysis, hydrolysis, biodegradation and temperature) that might alter the susceptibility of the polymer to fragmentation, and the mechanical power input that ultimately causes the polymer to break apart. We use this conceptualisation to model fragmentation, whereby we define a *fragmentation rate* that is a function of the degradation state, polymer type, particle size and mechanical power input.

To parameterise our model, we are performing degradation and fragmentation tests to produce an experimental database of fragmentation rates and size distributions for a broad range of polymers that have undergone photolysis, hydrolysis and biodegradation at different temperatures, followed by mechanical disruption. To validate model results, we are subjecting polymers to single and combined stresses, including sand abrasion of degraded polymers and soil microcosms to simulate the abrasive action of plant roots.

In this presentation, we will present the initial version of the FRAGMENT-MNP model, including indicative results based on preliminary data, highlighting the importance of certain parameters in determining plastic fragmentation. This work will help us gain mechanistic insights into fragmentation rates and resulting size distributions of various polymers under realistic environmental conditions, providing a significant step forward in our understanding of plastic fragmentation and plastic pollution in the environment.

Investigating Protein Corona composition in different environmentally relevant plastic particles

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In recent years, research has suggested that microplastics may represent a significant health hazard to humans, particularly as humans consume significant quantities of microplastics each year. *In vivo* studies have demonstrated that microplastics are damaging to cells, while animal studies have identified passage of microparticles to major organs, including the brain, liver, kidneys and stomach. These data suggest that microplastics in humans could lead to a range of health conditions. Microplastics can also bind biomolecules following ingestion, such as lipids and proteins, forming a corona. In case of proteins, a hard corona, which is comprised of proteins tightly bound to the surface of the particles and a soft corona, proteins that bind more weakly to the hard corona, is formed. The protein coronas may yield a disguise that once established, facilitates the penetration of epithelia, leading to unwanted physiological effects.

In the present study, 1 μm and 50 nm polystyrene (PS) particles (pristine, COOH and $-NH_2$ modified), and laser-ablated PP particels ($\approx$ 200 nm) were incubated in 0.1% foetal calf serum to generate protein corona. Hard and soft corona were separated by centrifugation. The proteins were then extracted and separated from the particles using 5% SDS, 20 mM DTT and 40 mM IAA. Proteins were then loaded on an S-trap column for enzymatic digestion via trypsin. Peptides were eluted from the column and analysed by liquid chromatography high-resolution tandem mass spectrometry (LC-HR-MS/MS). Raw files were processed using Proteome discoverer (Thermo Scientific) and the label-free quantification data was used to determine the composition and abundance of the hard and soft corona of each PS particle.

A total of 422 and 392 proteins were identified in all protein corona of the 1 μM and 50 nm PS particles, respectively. $PS-NH_2$ hard corona had the most bound protein of all the corona in both 1 μM and 50 nm particles. This is likely due to the role of the surface charge of the particles and the net charge of the proteins. Perhaps unsurprisingly, serum albumin was among the most abundant bound protein, particularly among the $PS-NH_2$ hard and soft corona as well as the PS-COOH soft corona. However, $PS-NH_2$ has higher abundance across numerous proteins compared to all other corona. When looking at protein numbers there is little difference between the various coronas, with the hard coronas binding slightly higher numbers of proteins. Gene ontology analysis of the corona proteins reveal the most common biological processes of the bound proteins are biological regulation, metabolic processes and response to stimulus. Due to the commonness of these proteins, the surface of the corona-cladded microparticle can actively integrate in physiological processes, especially transport (of drugs) or transport across cell membranes and subsequently could have effects on health.

Protein corona formation and characterization of environmentally relevant microplastics generated by sonication

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The presence of microplastics (MPs) in the environment is a cause of concern since potentially harmful effects in biological systems including men cannot be excluded. The lack of appropriate methods for collecting microplastics from environmental matrices forces the use of engineered model nanoparticles. Such synthetic particles have fewer defects, a homogeneous chemical composition, and a surface chemistry, which differs significantly from MPs distributed in the environment, which have irregular shapes and complex surface chemistry due to experienced degradation. These differences influence their interactions with biological systems. In this work, a sonication method was used to generate polyethylene terephthalate (PET) microplastics to mimic environmental MPs. To generate the particels, randomly cut PET film pieces were sonicated in hydrolytic conditions. Scanning electron microscopy (SEM) images showed that the PET film became cloudy after sonication and holes and structures appeared on the surface. The surface chemistry of the PET particles was investigated by X-ray photoelectron spectrometry (XPS). The results showed that the percentages of binding in C1s remained unchanged after sonication (63% C-C/C h_{arom}, 20% C-O, 16% COO), whereas binding in O 1s changed after sonication (53% C-O in the PET film decreased to 47% in the MPs and 46% C=O in the PET film increased to 53% in the MPs). The size distribution and surface charge of the fabricated PET-MPs were investigated using dynamic light scattering (DLS). The DLS spectrums showed the presence of PET-MPs with the average size of 781 ± 1 nm with the polydispersity index (PDI) of 0.5, indicating the successful preparation of submicron PET particles but with different size populations. In addition, zeta potential studies showed the negative charge on the surface of the particles (-62 mV), which is in agreement with the XPS results. After complete study on size and surface chemistry of PET particles, the protein corona on PET particles were formed by incubation with fetal calf serum (FCS) for 1 hour. The successful formation of a protein corona was confirmed by a particle size increase from 781 to 2250 nm and an increase of the surface charge from -62 to -36 mV. High-resolution mass spectrometry was used to characterize the soft and hard protein corona bound to the PET-MPs. Proteomics results showed 160 and 192 proteins in the hard and soft corona, respectively, with 16 unique proteins in the hard corona, while 50 unique proteins were characterized in the soft corona. In addition, the post-translational modifications (PTMs) of the protein corona were investigated. The results indicated a higher number of PTMs such as oxidation, dioxidation, quinone, and quinone+O in the hard corona compared with the soft corona, confirming that the direct interaction of MPs with proteins can cause oxidative damage to the proteins in hard corona. In conclusion, this study demonstrates the suitability of the sonication method to form environmentally relevant MPs and shows how the interaction of proteins with MPs can change the size and surface charge of particles and cause oxidative damage to proteins, which could affect their interaction with biological systems such as cell membranes.

Microplastics and society: How concerned is the public, and does this matter for policy and industry?

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Microplastic risk is assessed, and regulation is planned, based on an evidence base from the natural and technical sciences, e.g., ecotoxicology, marine biology, plant ecology, modelling and many other disciplines and approaches. This evidence is communicated to society and policy makers via the media, and via more or less structured science advice processes, at national, regional and global levels. Crucially, regulatory initiatives can be fuelled by societal demand, for example where citizen have high concern and demand change from policy makers. On the other hand, regulation may fail, or fail to reach its predicted effect, due to opposition by the public or other stakeholders. This presentation will give an overview of social and behavioural sciences approaches to risk perception, risk communication and policy support, focusing on key theoretical and empirical perspectives. I will review large-scale social data on plastic concern for human health or environmental reasons. I will review key insights from an evidence review report on microplastics we wrote for the European Commission (SAPEA 2019), including its subsequent reception, posing the question of how much evidence is needed to justify action. I will also provide preliminary findings from recent work with the European Food Standards Authority on risk perception in the context of food and drink, and from projects set in the Global South, specifically Indonesia and the Philippines. I will end the presentation by discussing some gaps and challenges (e.g., how can we integrate different approaches), setting this in the context of current science-to-policy activities (e.g., GESAMP WG-40, the "plastics treaty") and plastics as a system.

Effects of different polymers of microplastics on soil-plant system

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Agricultural microplastic pollution has been gaining increasing attention, to alleviate the environmental burden, biodegradable materials were introduced to agricultural fields. However, neither the effects of microplastics from traditional agricultural materials on soil plant systems, nor from the biodegradable materials have been sufficiently reported. In this current presentation, we introduce an experiment that was conducted in Wageningen University by adding two types of microplastics in a soil-plant system, common bean (Phaseolus vulgaris L.;) as model plant. We measured the plant growth parameters, include root and shoot biomass, root characteristics and nodules, soil labile organic carbon fractions, and available nitrogen and rhizosphere bacterial communities. The results showed as compared to traditional low-density polyethylene (LDPE), microplastics from biodegradable materials posed more severe effects on soil-plant health.

Tire materials in agricultural soils – From additives release to plant uptake

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Tire wear particles, which have gained attention in recent years due to the toxicity of additives that leach from them are ubiquitously present in urban stormwater. Many cities combine stormwater with municipal wastewater and treat it in conventional wastewater treatment plants, where, like thermo-microplastics, tire wear particles are expected to settle to sludge. Wastewater sludge, containing tire wear particles, is then often applied to agricultural fields as fertilizer. We expect that tire wear particles leach most of their additives once on the field, due to their relatively short residence times in wastewater treatment plants, and their comparatively slow additive release rates. This could pose a serious health risk to humans if edible plants take up and accumulate these additives from soil, a phenomenon which is well established for other classes of organic micropollutants. Therefore, in this study we evaluate lettuce uptake of 5 commonly detected tire additives: diphenylguanadine, hexa(methoxymethyl)melamine, benzothiazole, N(1,3-dimethyl-butyl)-N'-phenyl-p-phenylenediamine (6PPD), and 6PPD-quinone. Under hydroponic conditions, we expose lettuce in one scenario directly to additives, and in another scenario, to tire particles themselves. We monitor the resulting concentrations of additives in lettuce roots and leaves, as well as in hydroponic nutrient solution, using a modified QuEChERS extraction method16 followed by measurement via liquid chromatography coupled with triple quadrupole mass spectrometry. After exposure, we remove lettuce plants to clean nutrient solution, and monitor degradation of the compounds in the plants over time. We also measure sorption of additives to root material, since high affinity to root material can impede translocation to leaves, which limits the amounts of compounds reaching the edible part of the plant. Preliminary results indicate that all five additives are taken up by lettuce roots and are translocated to leaves. On the other hand, initial experiments indicate that stability in leaves is compound dependent. When looking at uptake results from a mass balance perspective, we find that less than 0.01% of compounds added to nutrient solution are taken up by plants, leading us to assume that except under very high concentrations, tire wear particles in agricultural sludge do not pose a serious health risk to humans.

Polyvinyl chloride microplastics leach phthalates to the aquatic environment over decades

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Plastics are widespread pollutants and a source of organic contaminants to the aquatic environment. This includes contaminants sorbed from adjacent media and intentionally added substances (additives). Additives can transfer to the surrounding environment within the lifespan of the plastics. Phthalates are commonly used plasticizers, especially for polyvinyl chloride. Leaching of phthalates from plastics changes the mechanical properties of the plastics and results in embrittlement and fragmentation of larger plastic items to microplastics. Phthalates like bis(2-ethylhexyl) phthalate (DEHP) pose a risk to the environment due to their endocrine disrupting effect. For the environmental risk assessment and modelling of the fluxes of plastics and its associated additives in-depth knowledge of leaching kinetics of additives from (micro-) plastics into aqueous environments is required. The release of additives and non-additives from microplastics is controlled by internal and external diffusion, i.e., intraparticle diffusion (IPD) and aqueous boundary layer diffusion (ABLD), respectively. The diffusion process of some organic contaminants like polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) from microplastics to aqueous systems has been identified. Yet data on leaching kinetics of phthalates to the aqueous environment are not available. In this work, we used an infinite sink method using activated carbon powder to investigate the leaching of phthalates from PVC microplastics into aqueous environments. Batch leaching experiments were conducted over a time span of 120 days with six different microplastics containing ~23% to ~39% of di(2-ethylhexyl) phthalate (DEHP), di(2-ethylhexyl) terephthalate (DOTP) or diisononyl phthalate (DINP). Thereby, time dependent leaching curves for each phthalate could be obtained. These leaching curves were evaluated using models for IPD and ABLD. The aqueous boundary layer diffusion model could well match the experimental data and could be identified as the governing diffusion process. Elucidating the governing diffusion process allowed us to calculate specific desorption times (e.g., desorption half-lives) of phthalates in aqueous environments. Our findings contribute to better understand the fate and behavior of microplastics and phthalates in the aqueous environment.

Modeling additive release from fragmenting plastics

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Of the approximately 4.8 to 12.7 million metric tons of plastic annually emitted to the ocean, larger plastic materials are likely to fragment into smaller millimeter-sized particles or even smaller colloidal fractions that are not entirely accounted for based on oceanic circulation models. The plastic pollution on land and in freshwaters can be many times greater than the ocean inputs and little is known regarding the levels of colloidal plastics in these environmental compartments. Nanoplastics are the smaller nano-scale fraction of these colloids and are most likely incidentally produced from the fragmentation of larger plastic debris. Although complete breakdown of larger plastic debris can take up to hundreds of years, it is likely that mechanical wear, heat, UV degradation and, in some cases, biological factors, lead to relatively rapid fragmentation of plastic debris down to micron- and potentially nano-scales.

Plastics often contain a wide variety of chemical additives as well as non-intentionally added substances such as degradation products, reaction by-products and/or impurities. Since these other chemicals are not generally covalently bound to the polymer matrix, they may leach out of the plastic. These leached chemicals include bisphenol A, phthalates, nonylphenols, brominated flame retardants, to name a few. Also, nanomaterials are sometimes incorporated as nanofillers into polymer formulations to enhance existing properties or to add new properties of interest in the products made from these plastic composites. For example, multiwalled carbon nanotubes (MWCNTs) are known for their unique and diverse properties (mechanical, electrical, thermal, electrochemical, optical and hydrophobic properties) and have many applications in the polymer industry, especially in improving a polymer's mechanical properties when added to the polymer matrix. Even though there are many advantages to using MWCNTs in polymers, the potential release of manufactured nanomaterials (MNMs), such as MWCNTs during the product life cycle and resultant probabilities of exposure for manufacturing workers, product users, and the environment, has raised concerns.

This presentation presents a modeling framework for describing additive release from plastics that considers the role of plastic fragmentation in increasing surface area and release rates over time and methods for parameterizing the models from plastic abrasion and additive leaching experiments. Derivations of mechanical stresses on plastics as a function of power input are related to rate constants in a population balance on plastic particle number distributions. The leaching of additives from homogeneous plastic spheres is estimated as function of fragment size and environmental conditions and the implications for exposure to additives are discussed.

Micro- and nanoplastics from intended use of food packaging

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Food packaging plays a critical part in the modern food supply. It enables food transportation, marketing, and storage. As such, food packaging, and especially plastic food packaging, has become an enabler of today's globalized food systems. But food packaging is a known source of micro- and nanoplastics (MNPs) exposure. Normal use, e.g. opening a glass bottle with a plastic gasket, leads to abrasion and the transfer of small particles into the food. As humans ingest MNPs with food, there is an urgent need to get a better overview of MNPs in foodstuffs and identify their sources (e.g., a certain type of food packaging) to reduce exposure.

Therefore, we compiled a systematic evidence map on MNPs that are generated by normal and intended use of (plastic) food packaging and thereby are released into foodstuffs or food simulants. We searched the scientific literature for relevant studies published until mid-2022 and extracted data on detected MNPs (e.g., size, quantity), the food or food simulant type, the food packaging (e.g., polymer type, single-use vs. repeat use, bottle vs. container), as well as on the origin of the MNPs (e.g., food packaging, food processing equipment, other sources, unclear) amongst others.

With this mini review, we aim to provide an overview of the current knowledge base for food packaging as a source of MNPs in foodstuffs, identify pertinent knowledge gaps, and propose a methodology for investigating food packaging as source of MNPs that researchers can use in future studies. Since MNPs are a novel type of contaminant originating from (plastic) food packaging, our methodological approach is inspired by the common, legally required practice to assess the migration of chemicals from food contact materials. Moreover, we hope to provide first industry and policy recommendations to reduce MNP exposure via the normal, intended use of (plastic) food packaging. This is especially relevant in the context of necessary changes for achieving more sustainable food systems, where packaging, including made of plastics, plays a critical role.

Secondary nanoplastics released from food packaging: quantification and formation mechanisms.

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Since nanoplastics are currently considered potentially hazardous to the environment and human health, reliability of studies on nanoplastic exposure becomes crucial. However, analytical challenges limit our understanding of their formation and detection, thus hampering their biological interactions assessment, an essential step for a proper assessment of their potential health hazards and an enhancement in consumer products design. In particular, there is concern about the release of secondary nanoplastics from the degradation of plastic packaging during their use in every-day life. So far, a validated and harmonized strategy to tackle this ambitious issue is not available.

Here we provide a combined approach to quantitatively and qualitatively detect the release of nanoplastics in water matrixes and to estimate direct consumer exposure during common use of different food packaging. We demonstrate that plastic breakdown to micro and nanoplastic can occur during the normal use of polyethylene (PE) sealing of drinking water bottles, rice cooking bags and ice-cube bags as well as of nylon teabags. A multi-instrumental approach based on Raman microscopy, Single Particle Extinction and Scattering (SPES), and scanning electron microscopy (SEM) is applied to evaluate the chemical nature of the released material, its morphology and its size distribution. In particular, we demonstrate that the polyethylene sealing of the bottles released particles with a size distribution ranging from few hundreds nanometers up to about one micron and we estimated a mass release in the order of few tenths of nanograms per opening/closing cycle. We additionally observe that the mechanical stress alters the physical-chemical characteristics of the generated secondary nanoplastics and degrades the material properties compared to the original bulk source, thus complicating their spectroscopic chemical identification. Additionally, we highlight the importance in the use of spectral databases that include not plastic materials, since released micro and nanoplastics from ice bags and rice cooking bags are contaminated with dyes and food residues. Finally, in the case of nylon teabags, classical Fourier transform infrared (FT-IR) spectroscopy is used to measure the mass concentration of released material. Here, temperature is shown to have a strong impact on the morphology and aggregation status of the released particles, posing to scientists and legislators a challenging question: should we consider keeping the heat-released material after cooling as being "oligomeric" or should we take into account the possible formation of nanoplastics?

Our findings demonstrate that understanding material degradation processes is crucial for identifying and quantifying nanoplastics in real samples. Moreover, an approach that combine information coming from different instruments is fundamental for a complete characterization and a global understanding of the undergoing processes.

POSTERS

Quantifying the wet and dry atmospheric deposition of microplastics in Switzerland using analytical methods harmonized across environmental matrices

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Microplastics (MPs) are found virtually everywhere – in the atmosphere, waterbodies, landmasses, mountaintops and at the poles. Organisms of all forms, including humans, are exposed to these MPs. Exposure to airborne MPs may affect human health as MPs < 2.5 µm can enter the lungs and may cause inflammatory responses. Moreover, atmospheric MPs are transported to locations far from their emission sources and contaminate pristine ecosystems. However, an accurate quantification and reliable comparison of MP concentrations across different environmental compartments is currently hampered by the lack of harmonized analytical methods. We will therefore work towards a harmonized analytical method that is adaptable to different matrices. The method will use optical microscopy complemented by focal plane array Fourier transform infrared imaging to determine the number of MPs in atmospheric deposition samples and to identify their shapes and sizes. The results obtained on an individual particle level will be compared to the results of total masses of MPs gained from Pyrolysis-Gas Chromatography/Mass Spectrometry analyses. Surrogate standards will be spiked to the individual samples as a measure for quality assurance and quality control. This work will be conducted in close collaboration with two other research projects that focus on MP contents in soil and sewage sludge and will eventually allow a harmonization of the method across different environmental media. The method will be used to determine the amounts and types of MPs in wet and dry atmospheric deposition samples collected at regular intervals over a one-year period in urban, sub-urban, rural and remote locations across Switzerland. Through this approach, we seek to identify major emission sources of different types of atmospheric MPs and their relative importance. Gathering this information will be useful for environmental authorities to gain a better understanding of the role of the atmosphere for the distribution of MPs in the environment and also to define appropriate policy measures to prevent or mitigate the effects of MP contamination.

Modelling Microplastics Release from Laundry Wash and Personal Care Products Relevant to Wastewater in Major Estonian Cities

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Microplastics (MPs) research still at the budding stage in Estonia. A theoretical model build on substance flow analysis principles was developed. The goal of this study is to broaden understanding of MPs-types in wastewater and their contribution from known sources, quantify their presence based on model prediction and in-situ measurements. The authors evaluate two sources (laundry wash (LW) and personal care products (PCPs)) as known MPs contributor to wastewater in Estonia. We estimate the release of microplastics from LW and PCPs to wastewater treatment plants (WWTPs) and the concentrations in the effluent stream reaching water bodies. The total estimated MPs load from two main sources PCPs and LW in Estonia was between 4.25 – 12 tons/year, 3.52 – 11.24 tons / year respectively. Under three scenarios (low-medium-high), total estimated MPs concentrations 0.49 µg/L, 4.64 µg/L and 25.97 µg/L in WWTPs effluent stream, respectively. MPs concentration detected in the effluent of selected four WWTPs were compared with modelled effluent concentrations. Based on MPs chemical characterization under stereomicroscope and µFTIR, measured MPs concentration were within the predicted range in all investigated WWTPs. Microfibers release during LW remain most significant contributor. The model avail us broader overview about the theoretical concentrations of MPs discharge to the environment and gain valuable insight into developing process methods that prevent MPs accumulation in sewage sludge for safe applications in agriculture.

Evaluation of subsampling variability for microplastics in sediments

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The occurrence, abundance and distribution of microplastics (MPs) in marine sediments have gained notable attention, as knowledge hereof provides the background to further assess whether the MP content is at a level that could harm the coastal and marine environment. However, little research has focused on the variability in subsampling sea bottom sediments, particularly the methodological basis for a representative subsampling method and the comparability of sample purification in this matrix.

One of the challenges in achieving a representative subsampling from a complex environmental matrix, e.g., sediments, is to overcome the vertical and horizontal heterogeneity within the matrix, caused by time and space dependent processes such as preferential deposition, resuspension, and bioturbation. Another variation between the subsamples can originate from the extraction of MPs, with its combination of biochemical and physical treatments. Therefore, a reliable subsampling method is critical to ensure that the reported abundance of MPs in a complex environmental matrix is statistically representative, a prerequisite to provide reliable results for risk assessment and monitoring programs.

In order to answer "how much sample is needed to obtain a statistically representative result for MP-content", we collected a large amount of sediments from 4 distinct Danish marine environments (13 kg each), and assessed the variation within each sample. This was done by inserting 11 custom-made stainless-steel sampling corers (Ø:37 mm, L:30 cm) into each bucket holding a sample as collected at sea. All subsamples went through the exact same MP extraction steps. To evaluate the variation originated from the extraction steps, we performed recovery test using standard microbeads, which covered two size classes (45-63 µm, 90-106 µm), and two densities (> 1 g/cm3, < 1 g/cm3). In total, 4 types of beads were selected and each subsample was spiked with a known number of beads. Following that, samples were processed by a multistep enzymatic-oxidative and physical protocol for MP extraction. The extracted particles were analysed by FPA-µFTIR hyperspectral imaging, followed by data analysis using siMPle for MP identification and quantification, while the recovered beads were identified by stereomicroscopy.

Our study attempts to quantify how the degree of statistical reliability depends on the amount of sample being processed. It also casts light on how much MP is recovered from a complex matrix like marine sediments and how variable such recovery is. Preliminary results show that although the recovery of microbeads remained at 50%-60%, there were no significant differences among subsamples. I.e., the recovery was quite constant. The results also illustrate the suitability of microbeads for these kinds of recovery tests. Furthermore, we provide the correlation between properties of sediments and variability, including parameters such as heavy metals, water content, and organic matter content, as well as grain size distribution, and propose how these can be used as side indicators to assess the degree of homogeneity when subsampling.

Development of Reference Materials for Spectroscopic and Thermal Analysis of Microplastics

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Microplastics having become critical environment issue as an emerging anthropogenic pollutants, research on microplastics is actively conducted to establish standardized methods for sample collection/pretreatment and qualititive and quantitative analysis on various sites (ocean, household chemicals, freshwater, river sediment, water purification plant, sewage, etc.).

Reference materials are important substances that are indicators of whether the test or analysis results represent accurate values, and serve as evidence of the accuracy and reliability of the results. Thus, reference materials must be used to standardize analysis methods, but there is no standard for microplastics.

We developed various reference materials for microplastics analysis in this study. We designed process of manufacturing microplastics reference materials in 6 types and 3 sections of particle sizes. Considering the usage of each plastic types and amounts of microplastics detected in the existing study, we determined the types of plastics to be produced as microplastics reference materials (HDPE, LDPE, PS, PET, PP, PVC). The sizes of particles were divided into three sections (20 µm or less, 20 to 100 µm, and 100 to 500 µm) according to behavioral characteristics of microplastics depending on particle sizes. Because the reference materials are produced by cryo-crushing methods, those can represent the environmental samples having various shapes(Spherical, needle-shaped, fibrous, plate-shaped, thin-walled). We checked the characteristic values and uncertainties by conducting assessment of stability and homogeneity according to international standard (ISO Guide 35).

The reference materials developed in this study are currently provided for various research and development about microplastics analysis. Furthermore, we are progressing another project to develop reference materials of mixture polymer that could be used for microplastics quantitative thermal analysis by Py-GC/MS. It is thought that these would serve as an important data for future method development research on microplastics analysis.

Open Specy 1.0: An open-source online tool for Raman and FTIR spectral analysis of microplastics and beyond

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Open Specy is used by over 100 microplastic labs around the world to identify microplastic particles with FTIR or Raman. Open Specy is open source and provides open data so that the community can maximally benefit from using it. Since Open Specy debuted in 2020, the field of microplastic spectroscopy has grown substantially. New devices like hyperspectral imagers (Raman & IR) have brought automated analysis of microplastic samples almost within reach for most labs. However, data analysis routines remain slow, inaccurate, and highly subjective. We are now building Open Specy 1.0 to alleviate these strains. Open Specy 1.0 will allow batch upload or hyperspectral map upload. Analysis routines will be optimized for speed with a goal to analyse 1 million spectra in under 10 minutes on a standard machine. Spectral classification will be leveraged on machine learning approaches to maximize the accuracy and ease of use of the tool. The entire Open Specy workflow will work with a single click with a high accuracy to avoid user errors and maximize throughput. We are looking for collaborators to join our team to make these visions come true.

Surrogate standards as a proxy for microplastics extraction efficiency from sewage sludge

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Wastewater treatment plants (WWTPs) act as hubs for anthropogenic pollutants to enter freshwater ecosystems. Such pollutants, for example, include microplastic particles (MPs), which have been detected in WWTPs sewage sludge and water effluent, as well as in downstream surface waters. However, relevance of WWTPs as MPs sources remains unclear despite a considerable number of studies. Overall comparability of the results is hampered by the lack of suitable analytical methods and quality controls measures. In our previous study, blue and red polyethylene (PE) spheres (50-60 μm) were spiked as surrogate standards in sewage sludge matrices. By quantifying the surrogates spiked to sludge samples using automated visible light microscopy before and after the MPs extraction protocol, sample specific recovery rates can be assessed. These recovery rates are used as a decision-making tool whether or not to subject a given sample to further, more elaborate and time consuming analyses using focal plane array μ-Fourier transform - infrared imaging. Results showed high recovery rates (>80%) for the PE spheres, demonstrating low particles losses throughout the whole sample processing. We now aim to consolidate and extend this method to MPs of different shapes (films, fragments, spheres), sizes (from 25 to 100 μm), types (polymethyl methylacrylate, polystyrene), and extents of weathering (pristine or artificially-aged under realistic environmental conditions e.g. UV-light). Spiking of these plastics in a pilot WWTP will enable the validation of our extraction procedure under real world conditions. Our work aims at establishing a robust, yet timesaving and efficient approach to generate reliable and inter-comparable data of MPs in wastewater systems. The approach established for sludge can easily be adapted to other matrices and will thus allow a comparison of data across different technical systems and natural environments.

Uptake and toxicity of different microplastics polymer types, sizes, and concentrations in three different cell lines

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The ubiquitous nature of microplastic particles (MP) is a growing environmental and ecological concern due to their impact on aquatic systems and potentially on human health. Previous in vitro and in vivo studies have described inflammation, oxidative stress, and metabolic disruption upon plastic exposure, depending on several variables such as particle size, polymer type, shape, charge, and concentration, albeit the effect of such parameters is not fully unraveled. To this end, this study aimed to investigate the effects of acute exposure (within 72 h) to different polymer types, sizes, and concentrations in three different human cell lines. Specifically, A549, HEK293, and HeLa cells were exposed to polystyrene (PS) or polymethylmethacrylate (PMMA) MP in three concentrations (1 µg/ml, 10 µg/ml, and 100 µg/ml). PS MP (non-fluorescent) with 50, 200, and 1000 nm diameter size and flash red PS (FRPS) MP (fluorescent) with 44, 190, and 1040 nm diameter size were used. In addition, PMMA MP (non-fluorescent) with 70, 400, and 1100 nm diameter sizes were used, and amine-modified PS (PS-NH$_2$; fluorescent) with 55 nm diameter size was selected as positive control for plastic uptake and cytotoxicity assessment. Each cell line was exposed to MP with a single dose for 24 h and 72 h, and MP uptake and cytotoxicity were assessed. PS-NH$_2$ dose-response was determined, and values around IC$_{25}$ were selected for each cell line. MP exposure increased the granularity of cells, suggesting particle uptake or attachment on cellular membranes. Using fluorescence labeling of cell membranes and multi-z-stack microscopy, high-content imaging showed an efficient uptake of particles, and an algorithm-based analysis was performed to quantify cellular uptake of all sizes of FRPS in all cell lines. No differences were observed in cellular metabolic activity and cell cycle after MP exposure, except for PS-NH$_2$ MP. As expected, PS-NH$_2$ MP increased apoptosis of cells, although other MP showed slight effects on the viability of human cell lines. Moreover, the very subtle reduction in cell line viability after PS MP exposure (fluorescent and non-fluorescent) was more pronounced at higher concentrations and bigger sizes. In addition, MP exposure increased thiol levels in all cell lines, although neither dose-dependence nor size-dependence was observed. Nevertheless, increased thiol levels suggest a role in oxidative stress response after MP exposure. Thus, we conclude that MP was internalized by human cell lines independent of polymer size and type analyzed. After MP uptake, oxidative stress was induced and slightly reduced viability, mainly at higher concentrations and for larger PS MP. However, the induction of oxidative stress response did not contribute to other cellular consequences, such as metabolism and cell cycle alterations.

Investigation of the Transport Behavior of Microplastics in Riverbed Sediments

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Unmanaged plastics and its shredded or weathered debris result in Microplastics (MPs) pollutions in the environment. These MPs (d ≤ 5mm) are transported through rivers, which might be a risk to water quality. This study aims to predict the spatial distribution of MPs in river sediments by running lab experiments with flumes and testing HEC-RAS to simulate the transport behavior of MPs and the sedimentation of sediment particles and MPs in/on the bedload in open channels. With this, hot spots of MPs monitoring can be identified.

In this study, 64 test runs of four types of MPs were conducted to study the transport of MPs. A small and a large flume were used to examine MPs size and density effects using sand, gravel and mixed sediment and different placement techniques. The small flume was 1.7 m in length, and the large flume was 4.6 m long. The flow velocity ranged from 0.01 to 0.25 m/s. Polyamide (PA) and Polyoxymethylene (POM) MPs were used in both flumes. PA was 2 mm in size with a density of 1.14 g/cm^3. POM was 1, 2 and 3 mm in size with a density of 1.41 g/cm^3. During the experiments, MPs were placed either statically or dynamically in the flume. Based on the experimental data, a simulation of MPs transport on mixed sediment was used to reflect MPs transport behavior in HEC-RAS.

The settling velocity and shear stress of MPs based on Waldschläger's concept showed that denser and larger MPs settled faster than others. In the small flume, the peak accumulation of 3 mm dynamically placed POM was 30 cm further than that of 1 mm POM. Comparing different placement techniques, POMs which were placed statically have been transported a shorter distance (30 - 60 cm) than dynamically placed POM particles due to the lack of initial velocity. This pattern was magnified for PA because of its low density. For MPs of the same size, the denser MPs have a shorter travel distance as compared to less dense MPs on the same sediment (gravel and mixed sediment). The size of MPs (2 mm POM) which was similar to the sediment mean grain size (d_{50} =1.4 mm) tended to remain at the point source as compared to POM of other sizes. This indicates a hiding-exposed effect in sedimentology.

The experiment results revealed that density plays a greater role than size of MPs in the transport of MPs with the same placement on the same sediment. This is consistent with findings of Nizzetto et al. (2016). The result from the large flume was used to simulate the sediment load in the simulation. Even though many concepts were assumed applicable from sediment to MPs, for the bedload transport simulation conducted here, MPs cannot be treated as same as sediment particles in Thomas-Wilcock sediment transport analysis in HEC-RAS. This is because MPs had very low mass and portion of e.g. 0.0004% compared to sediments in the sediment load.

The transport of MPs was found to be hindered by high density and high settling velocity. MPs whose size were close to the grain size also had shorter travel distance. These findings suggest that denser or similar to grain-sized MPs are less mobile, thus they can be sampled near the point source in environmental monitoring programs. The result of simulation was unexpected due to very low portion of MPs in the sediment load. A possible solution to simulate MPs transport would be to use a particle tracking module. Even though the simulation was not successful, it is still feasible to apply sedimentology concepts for the description of transport of MPs. Future research should consider the size ratio of MPs to sediment particles and test particle tracking concepts of MPs' transport

Formation and dynamics of lipid coronas on model plastic particles and their influence on cellular transport processes

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Plastic waste pollution in the environment has increased drastically in the past decades. A plentitude of plastic types can be found in soils or water bodies. Due to environmental impacts, such as UV-radiation and shearing forces, the waste breaks down into micro- and nanoplastic particles. Their numbers increase, especially in water and air, raising a threat to (aquatic) ecosystems and even to the human food chain.

To date, little is known about the effects of small plastic particles after ingestion or inhalation by humans. It appears that crossing of epithelial barriers cannot be excluded, alongside with the risk of disorders. To evaluate this, the dynamics of the interaction between particle and biomolecules must be studied, with a special focus on human body fluids like saliva. Besides the formation of protein coronas around ingested nanoparticles, we also expect interactions of environmentally relevant nanoparticles with lipids and subsequently a modulation of their cell entry pathways. Lipid corona formation might also result in (local) lipid oxidation, further increasing the physiologic impact.

In our studies, we aim to understand the formation, dynamics and lipid corona alterations around model plastic particles. To examine the lipid – nanoparticle interactions, we incorporated a well-established liposome model, which was incubated with polystyrene (PS) nanoparticles, using differently composed liposomes, PS surface chemistries and particle sizes. Changes in hydrodynamic size and zetapotential after incubation were determined by dynamic light scattering (DLS). Observations are indicating the interaction between liposomes prepared from phospholipids (i.e. 1-palmitoyl-2-oleoyl-glycero-3-phosphocholine, POPC) and the PS nanoparticles in dependence on their size. In contrast, incubation of PS nanoparticles with liposomes prepared from 1-palmitoyl-2-oleoyl-sn-glycero-3-phospho-L-serine (POPS) did not show any change in hydrodynamic size or zetapotential, independent of the nanoparticle surface chemistry. Surface plasmon resonance (SPR) studies verified the DLS observations. Sensor surfaces coated with POPC, demonstrated interactions with PS nanoparticles. In contrast, sensor surfaces coated with a combination POPC and POPS did not show attachments of PS nanoparticles. In a second step, the incorporation of lipid-coated PS particles into a human cell line (A549) was studied, revealing a modulation of the uptake dynamics when the lipid corona is present. In future studies, polymethyl methacrylate (PMMA), polyethylene terephthalate (PET), and polypropylene (PP) particles in the sub-micron range will be studied and for PS model particles, both dynamics and lipid oxidation will be investigated via high-resolution mass spectrometry.

Temperature-induced modifications in sugarcane bagasse derived biochar: A sustainable solution for nanoplastic remediation

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Plastic pollution is a global concern and a challenge to the society and scientific community. What's more serious is the degradation of large plastics into micro (MPs) and nanoplastics (NPs). MPs and NPs are emerging contaminants, which have been proved to be toxic to living organisms. Not only this, but most recent studies have indicated their role to act as potential vectors for other contaminants in the environment. Hence the remediation of MPs and NPs from the environment is the need of the hour. In this study, a common agricultural waste sugarcane bagasse has been converted into biochar by pyrolyzing at different temperatures i.e., 350, 550 and 750^{0}C (BC-350, BC-550 and BC-750 respectively) and utilized for the remediation of NPs from aqueous environment. BC-750 showed >98% removal of NPs unlike other two composites BC-550 and BC-350, which showed <45% and <25% removal, respectively. The highest removal in case of BC-750 was attributed to its high surface area, increased pore volume and least number of negatively charged carbonyl functional groups. The kinetic studies showed instantaneous removal of NPs with an equilibration time of <5 minutes. Isotherm studies showed a maximum sorption capacity of 44.9 mg/g for BC-750. A better fit of pseudo 1st order removal kinetic model was obtained from non-linear-kinetic modelling while isotherm and thermodynamic modelling confirmed- sorption spontaneity and monolayer nature of NPs sorption. From the results that were obtained from the study of the effect of pH, humic acid and complex aqueous matrices on NPs sorption, it was concluded that enhanced electrostatic repulsion resulted in a decrease in NPs sorption at alkaline conditions, whereas at higher humic acid concentrations, steric hindrances caused limited removal. BC-750 also showed the minimal impact of competing ions on NPs sorption with complete removal in synthetic groundwater. From this study, we were able to conclude that pyrolysis temperature had a significant effect on the physicochemical properties of biochar which affected the sorption capacity of all the biochar types. Biochar can be a promising solution for the remediation of emerging contaminants like NPs.

Instrument development for automated water-sampling and microplastics composition analysis

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Sampling microplastics (MPs) from surface waters and analyzing their composition requires manpower, extensive field and lab operations, expensive equipment and expertise of specialists. This limits the potential of achieving automated monitoring of microplastics contamination in surface waters.

Here, we present the technical approaches and some first results in our development process for an automatized MP monitoring device*. Water sample collection for MP analysis will be carried out automatically by the instrument. Samples will then be filtered to remove constituents larger than 1 mm. Hydrophobic MPs will be separated from sediments by floatation. Separated MPs will be entrapped by an only-water-permeable specimen carrier and desiccated with dry air. Afterwards, hyperspectral images of samples placed on the carrier will be taken by a near-infrared camera system with high optical resolution (< 5 μm) and steering precision (< 500 nm). Deep learning algorithms based on random decision forests method will be applied for analyzing spectra information of measured MPs in comparison to data from our self-generated reference library. This enables an efficient identification and accurate classification of MPs. Chemometric tools like spectral descriptors, focusing on chemistry details at specific regions of a spectrum, will further be employed to support the deep learning algorithms, to avoid false-positive classifications and further increase the accuracy. Information about the size distribution and the total number of MPs will be extracted from the clusters of identified pixels. Here, we demonstrate the first results of our hyperspectral imaging technique for the analysis of styrene-butadiene-copolymers, high-density PE, PET and other MP particles. The entire process from sampling to obtaining analytical results will only take a few hours.

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Influence of COVID-19 pandemic on the distribution and distinctive source of MPs from the riverine system of central west coast of India: A comparative approach

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Plastic waste has become one of the global emerging threats to severe transboundary and the COVID-19 pandemic has an enormous effect on its production, consumption and disposal. This study was achieved to comprehend the relative difference in the abundance and source of Microplastics (MPs), just after the COVID-19 pandemic. For that surface water and sediment samples were collected during both the dry (April) and the wet (September) seasons from the most primitive rivers of Goa i.e. Mandovi and Zuari. In order to get the impression of the COVID-19 pandemic, a comparative assessment of MPs was also addressed which were observed during 2019, i.e., pre-pandemic (both dry and the wet seasons) in the same study region. Interestingly, a sharp decrease in the concentration of MPs was found during the post-pandemic (2021) as compared to the pre-pandemic (2019). The wet season showed a higher number of MPs in surface water ($0.070 MPs/m^3$) and in sediments (2183MPs/kg d.w.) as a contrast to the dry season ($0.010 MPs/m^3$, 1516MPs/kg d.w.), respectively. Fragments found the most abundant shape in surface waters in both seasons followed by fibres and films. While in sediments, fibres are detected as a profound shape followed by fragments and films. Smaller-sized i.e. less than 1mm MPs distributed more in the riverine system followed by 1-5mm. The micro-FTIR analysis highlighted polyvinyl alcohol (PVAL), polyamide (PA), polyvinyl chloride (PVC) and ethyl vinyl alcohol (EVOH) as the most dominant polymers. This data clearly shows the impression of the COVID-19 pandemic which affected several rivers of Goa, India. The decrease in the concentration of MPs might be due to the minimization of plastic wastes generated because of restrictions on tourist inflow, maritime traffic and fishing-related activities during the post-pandemic. However, the increase of MPs during the wet season as compared to the dry season is probably due to the effect of monsoonal input as well as the enhanced activity of a variety of domestic and industrial wastes. Notwithstanding various impacts, the pandemic has ameliorated the quality of the environment and thereby exhibited a golden fortuity to restore the deteriorated ecosystems. Hence the present study acquaints the distribution of MPs and their possible sources in the Mandovi-Zuari riverine system during post-pandemic and thus suggests how regulated anthropic activities can reduce the risk of plastics in freshwater ecosystems.

Preparation of synthetic microplastics for method validation studies

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Microplastics are still not well understood both in their environmental and health impacts. Thus, reliable detection and quantification of microplastics from environmental samples is a very important field of study. Several methods exist for qualitative and quantitative microplastic analysis, such as Fourier-transform infrared spectroscopy and Raman spectroscopy. Typically, the validation of these methods is done with standard-shaped fluorescent polymer beads, which are not representative for environmental samples by size and shape. In this study, several polymer types were grinded into microplastic particles via cryogenic milling to provide representative particles for method validation. Commercially available polypropylene, polystyrene, polyethylene terephthalate, linear low density and high-density polyethylene, plasticized and unplasticized polyvinyl chloride, polyamide, styrene butadiene rubber, as well as beads from recycled plastics (polypropylene and polyethylene) were ground in this study. The milling process was optimized and adjusted for each polymer, based on their physical properties and potential occupational safety and health hazards, to achieve reproducibly generated microplastics. The resulting powders were analysed under scanning electron microscope to confirm particle sizes. Generated sizes of plastics were from 200µm down to 25µm when using the 250µm grinding sieve and even down to 50nm when using the 80µm grinding sieve. Therefore, these particles could be used in for determining size detection limits and recovery rates in quantification of microplastics and studies on nanoplastics in the future. Recycled plastics resulted in even smaller particles, possibly due to brittleness by material aging and presence of numerous different additives. Compared to standard-shaped beads, the generated microplastics better represent real microplastics in environmental samples, due to their irregular shapes, wide size range and, in the case of virgin microplastics, lack of other additives. They are already used for method validation purposes, including validation studies of novel optical detection methods, recovery testing of pre-treatment methods, membrane filtration recovery and suitability studies and Raman spectroscopy.

Microplastics in the sediments and selected marine organisms of the Gulf of Trieste

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Due to geomorphological and hydrological characteristics of the Gulf of Trieste, the accumulation of pollutants and microplastics is more intense. There are relatively few results on the microplastic pollution in the Gulf of Trieste, mostly in the Slovenian part of the Gulf of Trieste, in seawater, beach sediments and in marine organisms. Although these results show that microplastic particles are present in the Slovenian part of the Gulf of Trieste, the distribution of plastics and microplastics in marine sediments and marine organisms is still completely unexplored.

This work aims to investigate the presence of microplastics in sediments and selected marine species of the Slovenian Sea and to compare the results with those for the northern Adriatic. The study includes analyses of sediment and selected marine organisms. The microplastic particles were initially identified and classified by optical microscopy. Infrared spectroscopy and scanning electron microscopy (SEM) were used to identify and characterize the microplastic chemical composition and surface.

The highest concentrations of microplastic particles in sediment samples are present in municipal harbors and marinas, where higher accumulations were also expected. Fragments of polyethylene and polypropylene were the most common microplastic particles. SEM images of microplastics from the Gulf of Trieste show that microplastic particles serve as a vector for the transport of algae and diatoms. Preliminary results show that microplastic particles are present also in selected species of fish and ascidians.

The results obtained will contribute to a better knowledge of the distribution and possible sources of plastics and microplastics in the investigated part of the Gulf of Trieste. Investigating long-term changes in the accumulation of microplastics in the sediment will be essential to understanding the historical trend of this pollution and the response to human activities.

Do freeze - thaw cycles induce plastic fragmentation?

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The production and use of plastic materials has grown exponentially over the last decades. This led to an increase of ill-managed plastic, which eventually reaches all areas of the planet. Plastic waste in the environment is subject to weathering that can degrade the materials morphologically (e.g., by fragmenting into micro- and possibly nano- plastic particles) and chemically (e.g., by photo-oxidation) with still poorly understood consequences for ecosystems. In this experimental study, we investigate to what extent plastic materials are fragmented by freeze-thaw cycles. Different types of plastic foils (50 - 200 μm: polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinylchloride (PVC) and polyethylene terephthalate (PET)) and plastic spheres and fragments (50 – 300 μm: PE, PS, PVC, PET) were exposed to UV light (Suntester CPS+, AMETEK) with an irradiance of 700 W/m^2 over up to 1000 hours with flipping over the foils every 3 days. This is roughly equivalent to 25–50% of the solar radiation received annually in Switzerland from unobstructed sky. Subsequently, freeze-thaw cycles were imposed on the differently aged plastic foils, spheres and fragments. For this purpose, the samples were transferred into sealable aluminium (Al) containers which afterwards were filled with tap water. The Al containers were placed into two identical computer-controlled cooling baths and exposed to two different freeze-thaw regimes while submerged in the circulating water-glycol mix. In bath 1, the temperature remained constant at -5°C over 9 days followed by 9 days of +5°C. In bath 2, the temperature was cycled between -5°C and +5°C every 2 hours over 18 days resulting in 108 freeze-thaw cycles. Both conditions thus have nearly identical time at each temperature, but with different numbers of freeze-thaw cycles.

Results from visible light microscopy measurements (VHX 7000, Keyence) demonstrated a yellowing of the PVC and to a lesser extent of the PS foils and spheres over time, which was consistent with respective UV-vis absorption spectra (Cary 60, Agilent) showing increased absorptions in the visible range. These changes were paralleled with the appearance of a broad peak abound 1700 cm^{-1} in attenuated total reflectance - μ-Fourier transform-infrared spectroscopy measurements (Cary 670 FTIR instrument, Cary 610 IR microscope, Agilent), reflecting carbonyl groups formed upon the photo-oxidation of the polymers. The peak related to carbonyl groups were most obvious for the PS samples, but an increase in the carbonyl region was also observed for PP, PET and PVC. In addition to these changes, the materials in general became increasingly brittle over time, to an extent, where handling the materials became challenging. This was especially the case for PE and PS films, which we expect will be most susceptible to fragmentation by the imposed freeze-thaw cycles.

Our initial screening experiments will help assessing whether freeze-thaw cycles in combination with UV exposure contribute to the formation of microplastic particles and will help to identify key parameters controlling the fragmentation processes during freeze-thaw cycles. In additional experiments, salinity gradients and different total solids contents will be addressed to also cover marine and terrestrial environments.

Microplastics weathering affecting recovery rates of oil separation during microplastics extraction from soils

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In recent years, the focus of public awareness on microplastics contamination in the environment has increased noticeably. Therefore, research on the evaluation of precise analytical methods for determining the present microplastic pollution is intensified. Lately, soil as a crucial sink for microplastics has gained more attention.

Amongst other methods, oil extraction as a separation method for microplastics from soil matrices is currently investigated as a necessary preparatory step for a precise quantification. Due to its greater hydrophobicity compared to the soil matrix, microplastics tend to accumulate in the oil phase during the extraction process. However, numerous publications on this method use unweathered microplastics as the analyte to determine the effectiveness of said method.

In this publication, we are presenting the effects of weathering on the oil separation recovery rates of microplastic particles extracted from artificial, spiked soils. For this purpose, a loamy-silty soil was cleared from all pre-existing microplastics as well as interfering soil organic matter and then subsequently spiked with a defined number of LDPE particles. Microplastics, obtained from foils that had aged for approximately 20 years either covered by soil or exposed to the air, was used in this experiment. The determined extraction recovery rates were compared to those achieved by using unweathered LDPE. The particles were identified based on their visual appearance, using light microscopy. Accompanying this, FTIR spectra, static contact angles and superficial characteristics of all used LDPE-samples were recorded.

During our researches, we discovered a significant reduction of the oil separation recovery rates down to 30% as well as an significant increase of hydrophilicity when LDPE, weathered exposed to air, was extracted.

Conclusively, this increased hydrophobicity of air-exposed weathered LDPE would lead to incorrectly low concentrations of said polymer, extracted by oil separation from environmental samples.

Fluorescence microscopy versus Raman spectroscopy for direct identification of small (< 2 μm) microplastics in soils

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Research on microplastics (MP) in soils is much complicated due to the lack of dedicated (extraction) methodologies and the strong matrix interferences for MP detection, and there is almost no research on the dynamics of the smallest MP in soil (< 20 μm). In our research we compared the possible detection of the smallest MP fraction (1-2 μm) by μ-Raman spectroscopy and fluorescence microscopy in matrices of highly varying complexity. Samples of pure quartz sand, soil with removal of native soil organic matter (SOM), and soil with native SOM still present were amended with fluorescent polystyrene (PS) microparticles (diameter 1.65±0.04 μm) in different concentrations ranging from 0.1 to 0.001%, and after mixing and compaction both the Raman spectra and fluorescence microscopy images were obtained. Characteristic PS Raman peaks (main peak at 1009 cm^{-1}) were visible in quartz sand (all concentrations) and soil without SOM (highest concentration only), but not in the other situations, whereas fluorescence microscopy clearly visualized the MP at all concentrations in all matrices. The possibility of direct and unambiguous fluorescent MP detection in real soil also circumvents the need for lengthy extraction procedures, and opens up new avenues for studying mechanistic aspects of the smallest MP fractions in soil.

Spatial and temporal variability of plastics in lake sediments (Lake Hallwil, Switzerland)

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Lake sediments provide an excellent archive of our past and thus can help to reproduce human influence on aquatic freshwater environments. Since the 1950s, plastics consumption has strongly increased across the globe and large amounts of this plastic is not recycled and is disposed into the environment. Through fluvial systems, plastics are transported and are deposited in sediment sinks such as lakes and oceans where the plastics accumulate. Thus, sediments which contain these plastic fragments can be used to assess their fate pathways, mass loads and accumulation rates in different environmental systems. This study aims to assess the plastics contamination in lake sediments, particularly for the microplastics size fraction (< 1mm) within Lake Hallwil, Switzerland. We aim to understand plastics temporal deposition and accumulation areas. For this purpose, we retrieved short sediment cores to study the temporal deposition history of plastics. To establish the chronology, sediments are dated through varve counting and ^{137}Cs radioisotope dating. In addition, surface sediment samples have been taken from different locations within the lake basin to study the geographical distribution of plastics. We separated the plastic particles from the sediments before identification and characterization.

In this contribution, we present first data of the temporal evolution and the spatial distribution of the microplastics contamination recorded in lake sediments.

Based on the initial results obtained, we plan to further expand the study to better understand the pathways of microplastics into lakes to assess specific release scenarios and mass concentrations of plastics from urban to natural areas surrounding Lake Hallwil, and finally compare these results to other lake systems.

Additive release from plastics in environmental and biological fluids

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To match exponential increases in plastic manufacturing and the expanding diversity of material applications, production of performance-enhancing polymer additives has also greatly increased. Many polymer-associated chemicals (PAC) are not covalently bound to the polymer and may leach out of the material to the surrounding environment. And now, plastic debris is ubiquitously present in aquatic environments and organisms. Defining polymer additives and their fate in environmental media after plastic particle release is crucial to predicting exposure in comprehensive risk assessments of PACs. Research concerning the consequences of ecological exposure to plastic particles has yet to holistically consider the vastness of known PAC space, in concert with the leaching behavior of individual polymer additives under relevant environmental and biological conditions of exposure. The wide array of PACs includes intentionally added chemicals for enhancement of material properties or polymer protection in its intended application. Generally, PACs include synthetic organic chemicals (e.g., dyes, flame retardants, plasticizers, lubricants, antioxidants, and UV inhibitors), inorganic or organic particulate additives (e.g., nanoclays, carbon nanotubes, and inorganic pigments in polyolefin plastics), and surface coatings such as polyfluorinated alkyl substances (PFAS) which confer water/stain repellency. Additionally, incomplete polymerization or polymer degradation may result in residual or regenerated monomers, oligomers, and transformation products, which may also pose an exposure risk to ecological receptors. Well-informed models are needed to assess leaching of PAC from plastics into simulated sweat, lung fluid, ambient waters, and digestive environments encountered by nano-/microplastics ingested by various organisms. Chemical and physical properties of more than 40 common polymers, nearly 7,000 PACs, and the above leaching environments were systematically parameterized by incorporating existing (experimental and predicted) data available for these properties and data generated through laboratory experimentation.

This presentation presents highlights from a comprehensive review of PAC space and leaching behavior —via existing literature, experimental data, and curated polymer additive databases— with the intention of informing model design for describing polymer additive release into susceptible ecological receptors.

Transport of Polyethylene Microplastics in Natural Sediments

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Safe water supply is one of the sustainable development goals (SDG 6) by the United Nations. Many countries rely on groundwater as water supply resources for many purposes. Soil, as a natural filter for groundwater protection, has been identified as the main sink of released plastic products. Moreover, plastics in both tap water and bottled water from groundwater sources have been detected in low numbers (Mintenig et al. 2019). So far, there is no clear evidence of the potential leaching risk from the microplastics in soil to the aquifer systems. Therefore, it's significant to understand the transport mechanism of microplastics in soil media. Although research interests in MPs in soil have been increased in recent years, the current studies still don't provide a comprehensive understanding of the vertical movement of microplastics in complex soil systems. To investigate the impact of grain size and particle size on the mobility of MPs, we tested the downward transport of different sized fluorescent polyethylene microsphere (from 10 up to 150 μm) in natural sediments under saturated conditions. Soil column experiments were conducted with gravel (2-4mm), coarse sand (0.63-2mm), medium sand (0.63-0.02mm), fine sand (0.02-0.063mm) at a constant flow rate (0.05 cm/min). Leachate was collected every 10 minutes and further analyzed with fluorescent microscopy after filtration. Sediments have been sampled at different depths to get the soil retention profile. The results from the plastic-soil experiment correspond with the tracer experiment with deuterated water. From the breakthrough curves, the grain size of sediments affects the maximum concentration time and peak concentration, with earlier arrivals at coarser sediments. Based on the preliminary evaluation of our samples, the mobility of MPs increased with increasing grain size of sediments, whereas negatively correlated with MPs size. This study focusing on the transport of polyethylene MPs with variable size ranges in different natural sediments, provides more insight into the transport behavior of MPs in different porous media.

Infiltration and transport of microplastic particles in riverbed sediments

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The investigation of microplastic particles (MP) as a new pollutant in the environment with a high persistence is currently subject of many research projects. Rivers have already been identified as important pathways for MP input into oceans. However, little is known about the transport behaviour of MP at the interface between surface water (SW), groundwater (GW) and the hyporheic zone as a porous medium.

The SW-GW interaction is controlled on the one hand by hydrological boundary conditions and on the other hand by the geomorphological and hydrogeological properties of the river bed. In particular, a possible decrease in the permeability of the bed sediments due to colmation processes is considered as a key variable of the SW-GW interaction. The persistence of MP opens up also the possibility of using MP as an ubiquitous tracer for the hydromorphological characterisation of river bed sediments.

In order to increase the understanding of these processes we conducted column experiments in the laboratory to get a basic knowledge about the infiltration behaviour of fluorescent polystyrene particles. Furthermore, we investigated the vertical MP distribution within river bed samples. Therefore, we used a freeze-core methodology further developed by the BAW which allows depth oriented undisturbed sampling of structurally intact and water saturated river bed sediments. For the analysis of the MP in the river bed samples the SWIR spectroscopy is used, enabling a cost-effective and relatively rapid detection.

First results of the column tests show a decreasing number of particles with depth and that more spherical and smaller particles can infiltrate to greater depths. In addition, the results indicate that higher flow rates lead to greater infiltration depths of MP.

The aim of investigation the distribution of microplastics in river beds is to find out whether it is possible to draw conclusions about the hydrodynamics in the riverbed and thus to better predict the effects of hydraulic engineering measures in federal waterways on the adjacent groundwater body. Exemplary results of MP distribution in river beds will be shown.

PRIORITY: connecting communities working on micro- and nanoplastics

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The COST Action CA20101 "Plastics monitoRIng detectiOn RemedIaTion recoverY" (https://ca-priority.eu/ and https://www.cost.eu/actions/CA20101/) – acronym PRIORITY – is a science and technology research network focused on developing, implementing, and consolidating strategies to tackle the global challenges of micro- and nanoplastics in the environment.

COST (European Cooperation in Science and Technology) funds the four years PRIORITY (start 19/10/2021 - end 18/10/2025) to enable scientists to grow their ideas by sharing them with their peers, boosting their research, career and innovation.

Environmental plastic pollution is nowadays a great concern. The extremely wide usage of plastic in almost every human activity has led to a progressive accumulation of plastic waste in the environment. Once plastic enters the environment it undergoes degradation processes, resulting in fragmentation into smaller pieces, generating micro- and nanoscale particles. PRIORITY supports the harmonization of European regulation associated with micro- and nanoplastics, assisting the European Commission in critical aspects of environmental and ecosystems protection, food safety and life science.

This COST Action combines expertise in chemistry, physics, life science, engineering, regulatory standards, economy, and law on issues related to micro- and nanoplastics, with specific targets of health and environmental concerns. The network is meant as a robust infrastructure for scientific communication, exchange, and collaboration to foster new research activities and citizen science. The topics of interest include, but are not limited to, hazard assessment, measurement procedures, mitigation strategies, metrology, and regulatory science.

The Management Committee (MC) is the committee responsible for the management of the Action, reflecting the intergovernmental character of COST. Nominations to the Action MC are based on national rules and procedures (up to two representatives for each State admitted to the COST Association). In October 2022, the PRIORITY MC was composed of 62 members from 35 COST countries. Working Groups (WGs) are groups of individuals participating in the Action on the long-term whose activity, composition and leadership are defined by the MC to achieve the Action aims and objectives. PRIORITY is organised in seven specific, while highly interconnected WGs; in October 2022 PRIORITY had a total of 335 WG members from 40 countries.

Method development for the characterisation of micro- and nanoplastic particles occurring in infant feeding bottles

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Polypropylene based infant feeding bottles (baby bottles) are known to release microplastics which have the potential to cause health related issues. To the best of our knowledge, nanoplastic particles are thought to be even more hazardous for both our environment and the human health. Characterising particles on the sub-micrometre scale is challenging already for inorganic particles. In the case of nanoplastic particles additional challenges arise, making the use of conventional characterisation techniques virtually impossible. In cooperation with the start-up company "Brave Analytics", opto-fluidic force induction characterisation (OF2i) was used to analyse the particle concentration of nanoplastic particles generated during the use of baby bottles. Additionally, the influence of heat and general handling of the bottle on the amount of released particles is qualitatively described. Depending on the size fraction a maximum of $8*10^8$ particles per litre at 50 – 100 nm were counted.

For analysing microplastic particles we could draw on more established characterisation methods, like µRaman spectroscopy. Following the recommendation of the WHO PP baby bottles made were sterilised using 95 °C hot ultrapure water, subsequently filled with 70 °C hot ultrapure water and shaken. Afterwards the contents of the baby bottles were filtered. The loaded filters were then analysed using light microscopy and Raman spectroscopy. An average microplastic particle concentration of $3.2*10^7$ particles per litre per baby bottle was determined. Electron microscopy images show alterations to the inner surface of the infant feeding bottle over the time of use. After sterilising the bottle, scales were found on the inner surface. These scales decreased in both size and number over the time of use. One can assume, that the thermal stress on the bottle during the sterilisation step is strong enough to damage the surface and particles make their way into the infant formula. Based on these findings, recommendations on the handling of baby bottles are developed to reduce the release of micro- and nanoplastic particles.

MIcro- and NAno-Plastics in AGRIricultural Soils: sources, environmental fate and impacts on ecosystem services and overall sustainability

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MINAGRIS is a H2020 project aiming to develop a better understanding of any potentially harmful impacts of plastic debris to soil biodiversity, soil functions, related ecosystem services and agricultural productivity at the field level and related socio-economic consequences at farm level.

MINAGRIS is based on a multi-actor approach to engage stakeholders and identify needs, improving farmer and citizen awareness, joint development of novel strategies for reducing plastic contamination.

The overall aim of MINAGRIS is to contribute to healthy soils in Europe by providing a deeper understanding and tools to assess the impact of MP and NP in agricultural soils on biodiversity, plant productivity and ecosystem services and their disaggregation fate in the environment and provide recommendations for sustainable use of plastic in agriculture at the farm and field levels for ensuring safe and economically viable food systems in Europe.

The poster will present the MINAGRIS project and focus on the first monitoring phase: the sampling in 11 CSS across Europe, 220 fields representing diverse agricultural managements. Four different methods are used to assess the plastic content in soil : Quadrant method in the field for Macroplastics, sieving for mesoplastics, density extractions for microplastic and nanoplastics. The sample collection happens from march to June 2022. We will show the preliminary results

Quantity and composition of microplastic released by macroscopic plastic

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The global plastic waste generation annually exceeds an amount of 300 Mio. tons since 2015. If current production and waste management trends continue, roughly 12 billion tons of plastic waste are assumed to accumulate in natural environments and landfills by 2050. Once in the environment, polymers undergo abiotic and biotic impact, leading to stepwise degradation, fragmentation, and eventually the formation of microplastic. However, knowledge about degradation mechanisms, changes in the chemical composition, morphology, and the mechanisms of microplastic particle release by macroplastic is still limited.

In a long-term accelerated weathering study, we exposed macroscopic test specimen of amorphous Polystyrene (PS) and semi-crystalline Polyethylene (PE) to simulated solar radiation. The stepwise degradation and embrittlement were monitored by a multitude of analytical techniques and mechanical testing. Based on the polymer structure we developed different phenomenological degradation models with a focus on the changes in chemical and physical properties. We expect our proposed degradation models to be valid for predicting the abiotic degradation of other commodity plastics with a carbon-carbon backbone. In addition, we forced the release of microplastic particles from embrittled surfaces under mechanical impact by mimicking a realistic scenario on the beachside. This enables us to calculate the specific surface degradation rate and to quantify the amount of secondary microplastic particles released by macroplastic in dependence of their exposition time. The artificial pathway simulates the typical fate of macroplastic litter from terrestrial environments eventually ending up in the ocean.

Microplastics occurrence in Swiss ground- and surface water

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Microplastics (MP) monitoring studies in groundwater are rare due to analytical challenges for quantifying particles at environmentally relevant concentrations and size. In view of this, groundwater has historically been perceived as a secure source of freshwater for drinking water supply given the capability of porous aquifers to filter anthropogenic contaminants. However, some recent studies show the presence of MP in non-fractured, porous aquifers. Those results suggest that plastics have the potential to reach groundwater systems, thus potentially poses a risk for underlying aquifers and drinking water supplies that rely on groundwater resources. It also demonstrates that improved regulatory measures are necessary regarding the general usage of plastics to protect aquifers and drinking water supplies. The surface water feeds alluvial aquifers, which are used for drinking water production. In this contribution, we will show preliminary results on the occurrence of MP in surface water, the interface between the river and the aquifer, along the flow path from the river to the drinking water well as well as in the pumped groundwater before and after treatment.

Towards an optimized and reliable analytical protocol to quantify microplastics in Swiss soils

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Microplastics (MPs) are recognized as emerging pollutants and have been observed in different environmental compartments. Soils are major recipients and sinks for MPs. To unravel to which extent MPs represent a threat for terrestrial ecosystems, robust data about MP properties and concentration in the respective compartments are needed. The lack of standardized analytical techniques to identify and quantify MPs is repeatedly highlighted in the literature as an obstacle for reliable comparisons between field studies. With our work, we focus on the optimization and harmonization of protocols for micro-Fourier-transform infrared spectroscopy (μ-FT-IR) and pyrolysis gas chromatography-mass spectrometry (Py-GC-MS) to identify and quantify MPs in soil matrices. The protocols will be designed to facilitate routine analyses and will include quality controls. Whereas the type of polymer can be identified by both instruments, each technique provides different yet complementary information in terms of the shape, size, number (μ-FT-IR), and mass (Py-GC-MS) of the MPs. The established method will be used to conduct a first MPs screening campaign in soil samples from the Swiss National Soil Monitoring Network (NABO). A second level of harmonization over different ecosystems such as wastewater / sewage sludge and the atmosphere will allow studying the distribution and fluxes of MPs in and between these ecosystems in Switzerland.

LAMPO – A.Low-cost Aquatic MicroPlastic Observation system for automatic ocean monitoring

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Microplastic pollution has been found in the most remote parts of the ocean and constitutes a serious environmental problem for marine wildlife. Most microplastic is not bio-degradable and accumulates in the marine food chain, thereby also posing a risk to human health.

The systematic study of microplastic contamination in the ocean remains a difficult endeavour and requires regular monitoring to collect a high density of data samples both spatially (to map origin and the effect of marine currents) and in time (to understand long-term trends). Ideally, the data obtained includes microplastic composition information: particle count, size fractions and plastic type. So far, most studies on microplastics have relied on samples collected on a single ship trip, which are subsequently analysed in a research lab by optical microscopy or Raman/FTIR spectroscopy. This method gives very good insight into the microplastic composition of the samples, however only limited information on its spatial and temporal distribution.

The Horizon 2020 project NAUTILOS aims to develop low-cost sensors for autonomous continuous in-situ monitoring of ocean parameters. Herein, we are developing an in-line microplastic sensor, capable of analysing marine microplastic in real time in an automated manner. A sampler unit mounted onboard a ship filters the microplastic of size 300 um and smaller from the marine water. After sampling, the microplastic sample is oxidised to remove biomaterials and stained with Nile Red, a fluorescent dye that helps differentiate polar from non-polar plastic. Finally, the treated microplastic sample is run through an optical fluorescence detector capable of measuring blue and UV fluorescence intensity for multiple colour channels. By aggregation of time-series data from several sensors on a Raspberry Pi, we plan to measure and identify marine microplastic on-site and in real time.

The microplastic sensor is planned to be deployed onboard a FerryBox on cruise ships and ferries, to automatically generate repeated microplastic datasets along the same shipping route, for long-term studies and monitoring purposes. The microplastic data will be matched with GPS position and other sensor data from the FerryBox and uploaded via satellite internet to the NIVA servers.

AURORA – studying early-life health impacts of micro-and nanoplastics

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Micro- and nanoplastics (MNPs) are ubiquitous and there is an urgent need for generating empirical data to assess human health risks. Recently, MNPs were shown to cross the placental barrier *in vitro* and *in vivo*, but their impact on reproductive and early-life health is not understood. Therefore, the AURORA research project investigates the impacts of MNPs on early life in humans (pre- and postnatal).

To this aim, the project measures MNPs and associated chemicals in tissues relevant for early-life development (placenta, cord blood, amniotic fluid, meconium, fetal tissue) and in different cohorts. We use qualitative and quantitative methods for both detailed and large-scale toxicological and exposure assessments, and also for epidemiological studies. These divergent approaches will be combined to provide the first extensive evaluation of maternal and fetal MNP exposures and related health perturbations, including placental function, immune-inflammatory responses, oxidative stress, accelerated aging, endocrine disruption, and child development. Using these data and methods, we will create a risk assessment framework specific to MNPs and also identify remaining knowledge gaps that hinder the evaluation of early-life health impacts.

In this presentation, we will provide an overview of AURORA (Actionable European roadmap for early-life health risk assessment of micro- and nanoplastics), a five-year EU Horizon 2020 project that started in April 2021 and involves 11 organizations across nine countries. We will clarify the project's objectives and the work planned across the seven work packages.

Towards representative sampling designs: small-scale distribution of microplastics in Lahn River sediments in Gießen, Germany

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Rivers are important transporters, but also short- and long-term sinks for plastic contaminants. While it is known that microplastics occur in riverine sediments worldwide, data on their spatio-temporal distribution on different scales is scarce and – due to different sampling and analysis approaches – badly comparable. An open question is how heterogeneously microplastics disperse in sediments on a small spatial scale, which has implications for representative sampling designs. The present study investigated submerged near-shore surface sediments of the German Lahn River in the urban centre of Gießen. Sediments were extracted with a Van Veen grab sampler from two adjacent sediment bars (distance: 40 m), along a straight river section between two weirs, in October 2021. Five samples were taken at the two locations each, with an inter-sample distance of 80–310 cm, below a water column of 10–60 cm, and with a distance to the river bank of 50–250 cm. Samples were dried and subjected to density separation (MPSS, sodium chloride with a density $\rho \approx 1.2$ g cm^{-3}) as well as size fractionation (>5000 µm, >1000 µm, >500 µm, >300 µm). Potential microplastics were detected under a stereo microscope with reflected and transmitted light, counted, and normalized to a kilogram of dry sediment weight. Dry sediments had an estimated mass of 484–1171 g with a mean of 747 g. As a result, 790 particles with obvious plastic appearance, excluding transparent or thin fibres, were detected. Additionally, 33 particles with unclear origin were verified by µATR-FTIR spectroscopy, whereof 18 particles were confirmed as plastics. The preliminary analysis suggests a concentration range from 50 to 211 particles per kilogram of dry weight, with a mean of 111 (± 55). Microplastics appeared in all ten samples, but concentrations seem to be more heterogeneously distributed between than within the locations (mean ± standard deviation at location 1 and 2 respectively: 148 ± 55 and 73 ± 19). To conclude on sources, subsequent ongoing analysis addresses polymer type, particle size and morphology as well as sediment grain size distributions. Future sampling designs could account for the small-scale heterogeneity by reducing inter-location distances and increasing the sample number per location.

Microplastic pollution in Lake Lugano's watershed: A look beyond the surface

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Freshwaters are key components of environmental pathways of plastic pollution, but their role is still poorly understood. For example, streams can be heavily contaminated due to their proximity to potential sources (e.g. wastewater treatment plants), while lakes could act as sinks and accumulate plastic concentrations as high as those observed in marine ecosystems. However, so far, microplastic research in freshwater environments has focused on surface waters. Only a few studies have investigated microplastic concentrations in subsurface waters or sediments, even though this information is necessary to assess the risk of exposure for freshwater organisms.

To fill this gap, we started a comprehensive watershed-scale research program. The main objective of our study is to quantify the distribution of microplastics in different environmental matrices (streams, lake's surface, lake's water column and sediment). In addition, we tested emerging analytical methods, e.g. microplastic staining with fluorescent dye, to assess their application in microplastic detection from environmental samples. The research was conducted in the watershed of Lake Lugano (Switzerland and Italy). Monitoring data from 2020 indicated that in this lake the mean surface concentration was 270'000 microplastic km^{-2}, a value approximately twice the average of other Swiss lakes and six time higher than the worldwide median.

In this work we present analytical methods and preliminary results from ongoing microplastic research in Lake Lugano. Samples were collected seasonally from surface and subsurface waters with nets of 100 μm mesh size. The water column was divided in three distinct layers (0 - 10 m, 10 - 20 m, 20 - 90 m depth) to evaluate differences in the vertical distribution of microplastics. Preliminary results show the ubiquitous presence of microplastic debris at each sampling depth, with fibres representing the most abundant morphological class. The number of microplastics tend to decrease with increasing depth, but the highest concentrations were detected in the 10 - 20 m layer depending e.g. on lake's environmental condition and microplastic shape and dimension.

The results of our project will provide a basis to understand the ecological risks connected to microplastic pollution in different environmental compartment and improve strategies to manage contamination across the lake's watershed.

Microplastic toxicity in chicken embryos and genotoxicity using cytokinesis-block micronucleus assay and high content imaging

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The potential risks of plastic micro-particles (MP) and nanoparticles (NP) on human health is an emerging problem. The principal focus of the present study was to investigate the toxicity and genotoxicity induced by polystyrene (PS), poly(Methyl Methacrylate) PMMA, and polypropylene particles on human epidermal keratinocyte and chicken embryos. We aimed to determine MP and NP's genotoxic and cytotoxic effects by using the cytokinesis-block micronucleus assay and automated evaluation using high content imaging and algorithm-driven quantitative image analysis. Micronucleation (MN) and cytokinesis-block proliferation index (CBPI) were investigated to calculate chromosome mis-segregation events and cytotoxicity in cultured cells treated with different particles size and concentrations. Furthermore, we assessed the cytotoxic potential of MP and NP by using the in-ovo model in chicken embryos. Based on our preliminary data, we found that amino-functionalized (PS-NH_2) polystyrene nanoparticles (50 nm) treatment significantly induced toxicity in vitro in a dose-dependent manner, which was not observed for PS and PMMA particles. We observed that even the treatment of the PS-NH_2 increased toxicity in chicken embryos compared to the untreated groups. One of the main results is that small PS and PMMA particles caused toxicity in-ovo model at day 10 injection, which indicates that probably small particles easily penetrate the blood vessels and cell membrane and increase the mortality rate. Furthermore, an in-ovo evaluation showed that an injection of plastic particles on day 4 in 3 different sizes increased mortality. However, there is a need for more investigation. In the following, MN and CBPI were measured after MP and NP exposure, and it was observed that even higher concentrations of these particles did not induce any genomic instability and cell proliferation index.

Asymmetric Flow-field Fractionation combined to polymer-specific binding peptides as biosensors to nanoplastics tagging and detection

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The detection and tracking of unmodified nanoplastics is technically very difficult due to the lack of analytical methods which can reliably distinguish polymeric particulates from other non-polymeric particulates. An often-cited solution is to dope or stain the nanoplastics with optical markers prior to analysis but this can a source of artefacts if marker molecules leach from the plastic particles or if the interaction is not sufficiently specific towards the polymeric materials. Furthermore, this marking strategy adds the complication of having to separate the free marker molecules from the polymer without further disrupting their binding to the nanoparticles.

For the latter issue, separation of free marker and particles, Flow Field Fractionation (FFF) techniques allow efficient separation of the particle analyte(s) from free molecular species while also permitting size-fractionation across the range from a few nanometers to micrometers. Furthermore, since FFF methods can use simple aqueous dispersions as the mobile phase, including those mimicking the physiological conditions, the size separation methodology is minimally invasive and compatible with any biomolecular species such as peptides and proteins which may be associated with the polymer particles. These capability of FFF have been exploited in this study which has examined for the first time the novel approach of marking nanoplastics with an optically detectable polymer-specific biomolecular species.

In this work, Asymmetric Flow-field Fractionation (AF4), coupled to different on-line detectors (UV-vis, fluorescent and dynamic light scattering), was investigated as a means to size-separate and detect nanoscale plastic particles which have been incubated and tagged with polymer-specific biomolecular species fused with a fluorescent protein. Results evaluating the binding specificity obtained using single polymer or mixtures of polymer/non-polymer are presented and discussed.

Aged nanoplastics for laboratory testing

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Reference particle models are essential to obtain an accurate perspective of how environmental nanoplastics behave in natural systems and to generate data on their environmental fate and impact on living organisms. However, although the current available models are particularly important for filling the initial knowledge gaps on nanoplastics, they do not demonstrate enough diversity and/or accuracy to represent the actual heterogeneity of the physical and chemical properties of environmental nanoplastics.

In this framework, the Joint Research Centre (JRC) and the National Institute of Standards and Technology (NIST) are collaborating on a challenging project, which aims to identify a novel strategy for the production of aged nanoplastics. These new test materials are designed to become environmentally relevant models made by the combination of mechanical abrasion and artificial UV exposure for ageing. The objective is to obtain nanoplastics, which mimic naturally weathered ones in size distribution and surface chemistry.

The scalable production of these nanoplastics is investigated to make them available to stakeholders. This test material will have applications for the development of new analytical methodology to detect nanoplastics, to better understand their role in carrying other pollutants and increase knowledge related to their behaviour and fate in the environment.

Microplastics' analysis in water: Easy handling of samples by a new Thermal Extraction Desorption-Gas Chromatography-Mass Spectrometry (TED-GC/MS) methodology

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Thermal Extraction-Desorption (TED) using a thermogravimetric analysis (TGA) equipment coupled to a gas chromatograph (GC) with mass spectrometer (MS) detector is an extended method for polymers identification in complex matrixes.

Extraction is the key part of this methodology.

Traditionally, a TGA has been used to pyrolyze samples and break down polymers. As an alternative proposal to this equipment, we propose the use of a tubular furnace in which the complete sample can be pyrolyzed after a usual filtering system.

To verify the differences between both devices, different analyses (qualitative and quantitative) have been carried out with each of them.

Pyrolyzing the whole filter in a tubular furnace has advantages with respect to using a TG with a small crucible in TED-GC/MS, being the main ones:

- Easy manipulation of the sample since the filter does not have to be manipulated to extract the sample or cut some portions, avoiding sample losses.

- No limitations on the weight of the sample, so high-intensity signals can be obtained in order to avoid confusing signals with noise, false negatives or values so close to the LQ.

- The furnace significantly increases the sensitivity with regard to TGA, represented by a greater slope of the line when comparing samples with different polymer masses, obtaining signals between 2 and 10 times more intense.

- After filtering the samples containing microplastics, these particles are not distributed homogeneously on the surface of the filter, so when taking a portion of the filter the result is less representative, proven by observing lower linearity in the results of known masses.

Microplastics in surface waterbodies in agroecosystems in the central United States

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As research to understand the prevalence and persistence of microplastics has become more prominent, considerable work has been done to identify potential sources of microplastics and their movement in the environment. Comparison of microplastic inputs from specific sources, such as urban centres and wastewater treatment plants, over different geographic areas and countries is an important step to quantifying the impact these sources may contribute to microplastic pollution. However, it is also important to gain context of microplastic levels contributed by different land uses in a closely related geographic area to better understand regional variations in environmental microplastic concentrations.

Water and sediment samples were collected from four waterways spanning an agricultural to urban land use gradient in eastern Nebraska. Each waterway and sampling location was chosen with respect to the surrounding and up-stream land use. Land use types included agricultural, urban, and wastewater discharge in order to provide comparison of how microplastic concentrations in the area could fluctuate. Waterways were sampled with four litre grab samples and corresponding sediments were sampled by collecting sediment from the top three cm. All samples were collected in glass containers. Water samples were processed through a series of sieves with the lowest mesh size at 63 μm and then density separation with NaCl was used to separate microplastics from environmental media. Sediment samples were oxidized before going through density separation steps with NaCl and $ZnBr_2$.

Preliminary investigation during the summer of 2021 found trends showing an increase of microplastics in both the waterway and sediment downstream of the wastewater treatment plant. Comparison between waterways with surrounding urban land use and wastewater treatment plant inputs with agricultural land use show that agricultural land use had a slightly higher concentration of microplastics than all other sampling locations except for the sampling site at the wastewater treatment plant outfall. Average microplastic concentration in sediments was generally consistent over all sampling sites, only showing an increase in microplastic concentration downstream of the wastewater treatment plant. Further sampling at established sites as well as additional sampling sites to be added during the summer of 2022 will explore these trends in microplastic concentration in relation to land use as well as look for connections between microplastic concentration and other water quality parameters such as total suspended solids and conductivity.

Improved detection and identification of microplastics in soils through the combination of nile red staining and FTIR-analysis

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Microplastics are ubiquitously found in all environmental compartments. Given the complex nature of organic matrices in soils, the purification and identification of microplastics is analytically challenging. Most purification protocols remove inorganic particles through density separation and mitigate organic particles via oxidation before analysis by Fourier transform infrared (FTIR) spectroscopy. However, chemical oxidation of lignified biomass is not possible without degradation of common plastic polymers (*e.g.* PE, PS). Thus, high numbers of non-plastic particles persist in purified samples. To identify the presence of microplastics all remaining particles are measured resulting in increased analytical time and efforts.

This study presents an efficient method to automatically analyse solely microplastic particles by FTIR. Particles were purified from soil using Fenton's reagent and density separation before filtration onto FTIR-filters. Loaded filters were then stained with the fluorescent dye nile red, which adsorbs to microplastics but not to lignified biomass. Stained particles fluoresce under blue-turquoise light (480-490 nm), making it facile to identify them as plastic. To identify the polymer types of the fluorescent particles, a ring light using 16 high-power LEDs with a wavelength of 480 nm and a longpass filter with a cut-on wavelength of 525 nm was designed and manufactured for the Nicolet™ iN™10 Infrared Microscope (Thermo Scientific™, USA). Fluorescent particles could then be automatically detected and measured with the FTIR-microscope, resulting in significantly shorter measurement durations. This protocol and improvement of the FTIR-microscope reduces the particle number to be automatically analysed and, hence, is a step toward a high-throughput method appropriate for private environmental laboratories.

Effect of fragmentation on the transport of polyvinyl chloride and low-density polyethylene in saturated quartz sand

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Since microplastics are an obstinate pollutant in terrestrial environments, posing a risk to the subsurface soil matrix and potentially to groundwater, it is necessary to understand their transport behaviours. This study explores the transport and retention behaviour of two major plastic polymers, 125 – 300 µm Polyvinyl chloride (PVC) plastic fragments, and 300 µm Low-density polyethylene (LDPE) spherical particles in saturated quartz sand (1.6 – 2.0 mm) columns. The PVC used in this study represented secondary microplastics, while the LDPE represented primary microplastics. Retention profiles at different ultrapure water flow rates (2.0 – 3.5 ml/min) were compared and analysed. At the beginning and end of each column test, the microplastic particles were scrutinized, identified, and quantified by light microscopy. The results showed that the transport distance of microplastic particles increased with decreasing diameter of the microplastic particles. Small-sized PVC microplastic particles, whose morphology was more 1-dimensional, were more susceptible to fragmentation within the column, promoting migration. Spherical LDPE remained at their initial position without fragmenting. Microplastic degradation into fragments appeared to play an important role in improving the movement of particles. This study offers initial indications of infiltration depths and shape-dependent fragmentation of secondary microplastics in coarse sand based on the lab experiments.

The Nanoplastic Release Mechanism during Washing of Polyester Textiles: a Systematic Study on the Origin

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Synthetic textiles are a significant source of microplastic fiber (MPF) pollution. Although the MPF release mechanism during the washing/laundry of synthetic textiles is well understood, little is known about the origin and release of nanoplastics during this process. This study aims to 1) establish a test protocol for extracting and analyzing nanoplastics released during washing. 2) use a representative set of 12 different polyester textiles to understand the nanoplastic release mechanism and the origin. A combination of the analytical tools is used to characterize nanoplastics, including nanoparticle tracking analysis (NTA), scanning electron microscopy (SEM), and scanning transmissive electron microscope coupled with energy-dispersive X-ray spectroscopy (STEM-EDS). Our result shows that one gram polyester textile sample released $4.6 \times 10^{10} \sim 8.9 \times 10^{11}$ nanoplastics during washing. The number of released nanoplastics is not significantly (p-value=0.1) influenced by different textile structures, while the number released (reported by NTA) is positively correlated (slope=1.9, p-value< 0.01) with the number of nanoplastics on the surface of polyester fibers estimated by SEM image analysis. This correlation, together with the fast decrease trend of the release during repeated washes, suggests that washing is not a formation mechanism but just a release mechanism for nanoplastics in polyester textiles. Therefore, our results suggest synthetic textile is the primary source of nanoplastic pollution due to the large surface area of synthetic fibers compared with other plastic products. Moreover, the fiber production process is the key to mitigating nanoplastic pollution from the synthetic textile industry.