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Information about the conference

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21-22 June 2016

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Germany

The objective of this conference is to exchange knowledge on plastics in European freshwater environments and to discuss its environmental and societal implications.

Stakeholders from regulation, non-governmental organisations, industry, water resources management, waste management and science will present lectures and posters.

Invited speakers will present lectures on various topics, including sources and sinks, environmental concern, risk perception and management options.

The conference is organised by the German Environment Agency (UBA) and the German Federal Institute of Hydrology (BfG) on behalf of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

Abstracts:
Oral Presentations

EU activities and plans to address plastics and microplastics in the aquatic environment

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Abstract

A broad and systematic approach at European Union level to addressing the issue of plastics – including microplastics – in the environment came with the adoption in 2013 of the Commission's Green Paper on a European Strategy on Plastic Waste in the Environment. This and the consultation on it fed into the development of the Circular Economy Package adopted by the Commission in 2015. This package includes a Circular Economy Action Plan foreseeing the adoption of a strategy on plastic in a circular economy, and including a target to reduce marine litter by 30 % by 2020, as well as proposals for revision of the waste legislation, i.e. a revised Landfill Directive, Waste Framework Directive and Packaging and Packaging Waste Directive, all with a role to play in reducing the quantity of plastic waste reaching the environment. A Directive aimed at reducing the consumption and disposal of lightweight plastic bags was agreed in 2015. In the context of the 2008 Marine Strategy Framework Directive, which requires that for Good Environmental Status the properties and quantities of marine litter do not cause harm to the coastal and marine environment, the Commission has sponsored research and commissioned studies looking at relevant sources of marine litter and at measures that could address them. The plastics that constitute a major proportion of the litter in European seas come mostly from land-based sources; meaning that freshwaters are of course also affected. The extent to which rivers are being polluted by plastics, and the measures being taken to tackle the problem, could soon become clearer as a result of information now being requested from Member States under the Water Framework Directive.

Plastics in Freshwater Environments: From monitoring to management options – how can we get there?

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1 Introduction – State of play

Plastics have become an integral part of modern society and everyday life. The first plastic polymers were commercially developed in the 1940s. Numerous new types have been invented over the last decades. The worldwide annual production of plastic polymers has increased exponentially from 1.5 million tons in 1950 to around 300 million tons today.

Researchers first reported detecting small pieces of plastic in the marine environment in the early 1970s, when worldwide plastic production was at 50 million tons per year (Carpenter et al., 1972). Since then plastics have been found globally, including remote regions and are now recognized as a serious issue of concern for marine ecosystems (UBA, 2013). In 2004, scientists identified microscopic plastic fragments and fibres in sediment samples from the UK (Thompson, 2004). These findings led to the distinction of large and small plastic particles according to their size. Today, plastic particles are categorised into nano- (<0.1 mm), micro- (0.1-5 mm), meso- (5-25 mm) and macroplastics (>25 mm).

Plastic has become an established issue in marine ecosystem health and is subject to scientific and regulatory interest. By comparison, monitoring efforts of plastics in freshwater environments were given less attention. First results were reported in 2012 (Faure, 2012) and since then several rivers and lakes have been investigated in eleven European countries (UBA, 2016). Most of the available data on the occurrence of freshwater plastic pollution is from Central Europe and Scandinavia whereas data are largely missing for Southern and Eastern Europe. In general, monitoring studies focused more on microplastics, and less data are present for meso- and macroplastic particles. There are no temporal trends available on plastics in freshwater environments. Samples from environmental specimen banks may be an option for retrospective trend analysis.

So far, there are only few effects data available on meso- and macroplastic items and freshwater species. In contrast, a range of studies have investigated the effects of large plastic particles on e.g. marine sea birds, mussels and coastal fish. At least 690 species were reported to have encountered marine debris and 92 % of the individual encounters with marine debris were related to plastic (Gall, 2015). Recently, the Marine Strategy Framework Directive established plastic particles in fulmars' stomachs as an environmental indicator to take account of their potential hazards (Galgani, 2013). There is likewise much more information available on the potential effects of microplastics in the marine environment than it is for freshwater ecosystems.

In addition to the lack of monitoring data, the data that are available are often not comparable because a standardisation is missing of collecting, processing, analysing and reporting of plastic particles of different sizes in environmental samples. At the moment, funding agencies are reluctant to support further investigations until harmonised approaches are available.

All macroplastic and all primary microplastics are produced onshore while fragmentation from larger to smaller secondary plastic particles may occur in all environmental compartments. It is estimated that up to 80 % of the plastic waste found in the marine environment originated from land sources (UNEP, 2005). Plastic waste inputs from coastal areas into the oceans were estimated to be close to 9.1 million metric tons in 2015 (Jambeck, 2015). The authors of the EU study 'Identification and Assessment of Riverine Input of (Marine) Litter' anticipate that in the absence of mitigation measures, any region with large rivers can be considered to substantially contribute to marine pollution (van der Wal, 2015). This assumption can be extended to lakes and sediment beds, as they are also sinks of riverine pollution. It is therefore surprising that only very few spatial and temporal data are available for micro-, meso- and macroplastics in freshwater environments and that only very little is known about the riverine input into the marine compartment.

To summarise the monitoring situation for micro-, meso- and macroplastics in European rivers and lakes:

- data quality is ambiguous since standards are missing for sampling, processing and analysis,
- consistent spatial data from representative sampling sites and temporal trends are missing,
- monitoring is mostly directed at microplastics, meso- and macroparticles are often ignored,
- very little is known on the effects of microplastics in freshwater organisms and no data are available for meso- and macroplastics,
- scale and size distribution of plastic riverine input is largely unknown.

2 What is the way forward?

The recent Special Eurobarometer (EU, 2014) showed that air pollution, water pollution, health impact of chemicals in products and the growing amount of waste ares primary concerns of European citizens. All of these concerns can be linked to plastics. It is therefore no surprise that plastics in freshwater environments quickly became an issue in the public and the media after scientists had published first results. Non-governmental organisations started discussing the plastic issue in their campaigns for clean rivers and lakes and initiated clean up campaigns including citizen science projects to quantify plastic pollution. Several water and environment agencies in European countries have initiated individual screening studies on plastics in selected freshwater bodies. It is encouraging to see these initiatives. However, so far a consistent approach is missing to give a complete picture of the situation in Europe.

Regulatory agencies have the potential to act jointly and provide consistency by making use of the existing water management infrastructure in Europe. Environment and Water agencies should work on a representative monitoring overview on the spatial and temporal plastic pollution in freshwater environments, identify the potential ecological risks and hazards, and initiate discussions on potential management options to reduce the plastic input.

3 How can we achieve a representative overview on plastics in European freshwater environments?

From a regulatory perspective, there are three main incentives to generate spatio-temporal monitoring data for plastics in freshwater environments.

1. Currently, there are not enough data in Europe to characterize the spatial situation for evaluating the potential risks and hazards of plastics in riverine and lake ecosystems. Data are missing at all scales: for the EU as a whole, for individual Member States as well as for transboundary and for national freshwater systems. The few available and the upcoming monitoring data are at risk to be flawed since standard operating procedures are missing. Within environment and water manage-

ment agencies there is a great potential to focus, prioritize and apply existing monitoring expertise. This expertise was established over the last decades in regulatory monitoring programmes for e.g. chemicals and nutrients (EU, 2000; EU, 2008a). A starting point may be to agree on size classes for plastic particles and protocols for sampling, processing and analysing these particles in a consistent manner. It would also be helpful to set up a centralised database for plastics in freshwater environments and provide templates for data collection. The existing infrastructure could then be used to prioritise further studies and gather a representative overview on plastic pollution in freshwater ecosystems.

2. The Marine Strategy Framework Directive (MSFD; EU, 2008b) requires the identification and quantification of sources of marine litter. Reporting of riverine input includes information on the pattern, sizes and amounts of plastic particles in rivers and lakes, in the river mouths and estuarine regions (EC, 2010). Extensive studies are needed to understand the seasonal differences in amounts and patterns of riverine plastic input. These investigations should cover micro-, meso- and macroplastics, including plastic litter. Most likely, more data will be needed from the upstream river basins to fully understand the processes in the river/sea connection. It is therefore crucial that the monitoring communities for freshwater and the marine compartment find common terms and definitions for plastics in the environment and agree on appropriate standards for monitoring and analysing plastic particles in environmental samples.
3. Monitoring plastics in the environment should be linked to the identification of relevant sources, exposure routes and transformation pathways. As an example, some data are available on plastic in effluents of sewage treatment plants (e.g. Gerdts, 2014) and of polymer processing industry (Lechner, 2014). Local authorities, water companies and plastic industry have started discussing potential measures and programmes to reduce the release of plastic particles into freshwater compartments, e.g. in Austria (BMLFUW, 2015a, b). Any resulting voluntary or regulatory action needs to be accompanied by monitoring programmes to control the efficiency of such measures. Likewise, any environmental standard or limit for plastics in freshwater bodies needs to be compared against sound monitoring results in compliance monitoring programmes. To be consistent and effective, such monitoring programmes should be framed in the regulatory concepts of European water management.

4 How can we identify potential risks and hazards?

At present, risk evaluation of plastics in the freshwater compartment is hampered by both, insufficient exposure and effects data. The problem for regulation is obvious, since the concept of simple risk characterisation, which is used in chemical and water management, depends on an exposure assessment with a modelled or measured environmental concentration for a chemical substance (EC, 2003). Then this number is compared against a concentration at which no effects are expected to occur and which has been derived for a set of representative organisms for the ecosystem of concern. Other approaches, like the hazard based concept for persistent, bioaccumulative and toxic (PBT) chemicals also rely on detailed information from laboratory tests on the fate, behaviour and effects of a substance in the environment substance.

A wealth of plastic polymers and their environmental transformation products can be expected in the environment. Discussions are needed in order to show how the potential toxic and bioaccumulative properties of these compounds can be adequately addressed. So far, effects data for risk assessment of plastics in rivers and lakes are missing. It has been questioned whether the standard test guidelines currently used in risk assessment are appropriate for micro-, meso- or macroplastic particles. A new toolbox of substance tailored tests may be needed for risk assessment since existing guidelines have been developed for the risk characterisation of inorganic and organic pollutants but not for plastic mono- and polymers (Duis, 2016).

At present, the broadly accepted environmental concern for plastics are the persistent properties of most polymers on the market. Plastic may mechanically be fragmented from larger into smaller particles. However, fragmentation only results in a larger amount of smaller particles and does not reduce the overall amount in the environment. Environmental degradation, i.e. mineralisation of plastic polymers to completely oxidized metabolites is a very long process from tens to hundreds of years which is still not fully understood. It has therefore been assumed that most plastic, which has entered the environment, is still present in the environment, either as unfragmented or as fragmented particles (Thompson, 2005).

Starting with a collaborative European activity it may well be possible to generate a representative overview on plastic freshwater pollution in the next years. However, it will remain a much bigger challenge to characterise the short and long term effects of plastics in the aquatic environment. The communities involved in effects assessment of plastics in the marine and freshwater compartment should work closely together. Discussions are needed on the relevant parameters and endpoints for toxicity testing and on the potential read across of effects data from marine to freshwater organisms, and vice versa.

5 How can we bridge the gap to management options?

To sum up the situation for plastics in the environment: Plastic consumption is growing at a global scale and the plastic enter the terrestrial, freshwater and marine environment, including remote regions. In addition, most plastic polymers are very persistent in the environment. Larger plastic particles can mechanically fragment to smaller plastic particles but complete biological degradation is expected to take many decades. We need to improve our understanding of the exposure situation significantly over the next few years by making use of existing monitoring infrastructure. However, it is expected to take much longer to sufficiently characterise the effects of plastics in the environment and its food webs. Currently, no established technology can remove plastics from the aquatic ecosystems once they have entered the environment. Consequently, plastic particles will continue to accumulate in marine and freshwater environments. Finally, the ecological consequences of plastics in the environment are uncertain.

The use of the precautionary principle promotes preventive action in the face of uncertainty. Commonsense aphorisms such as 'an ounce of prevention is worth a pound of cure' or 'better safe than sorry' capture the essence of the principle. The precautionary approach becomes particularly important when dealing with problems of large temporal or spatial scales, where uncertainties involved in prediction of risk are necessarily high and will remain so even with continuing research (Cairns, 2003). The Lisbon Treaty (EU, 2007) states that 'The Community policy on the environment . . . shall be based on the precautionary principle and on the principles that preventative action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay.' It recognizes that delaying action until there is compelling evidence of harm will often mean that it is then too costly or impossible to avert the threat.

Raffensperger (1999) listed four central components of the precautionary principle which may serve as the leitmotif for the management session in this conference:

1. Taking preventive action in the face of uncertainty;
2. Shifting the burden of proof to the proponents of the activity;
3. Exploring a wide range of alternatives …; and
4. Increasing public participation in decision-making.

In preparation of the conference on plastics in freshwater environments, a questionnaire was sent to European water agencies. Answers covered monitoring studies, risk awareness and management options. Overviews on the regulatory state of play will be presented at this conference. Professionals from outside the freshwater regulatory community will add experiences from environmental monitoring and risk assessment (including the marine compartment). Experts on risk communication and management will report from citizen science projects, environmental campaigning, waste disposal and plastic circular economy, and from standardisation. Discussions between the communities should become a springboard for future exchanges regarding appropriate measures for plastics in the environment.

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How concerned should we be about plastic litter in freshwater systems?

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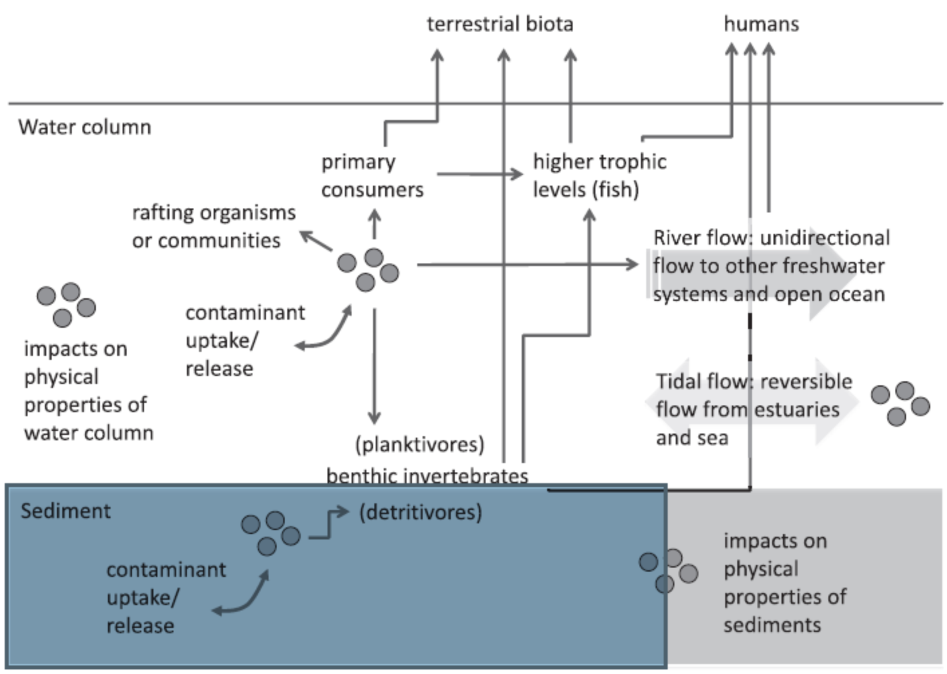
Plastic litter presents a global environmental problem with consequences for human health, the economy and wildlife. In the marine environment litter is pervasive throughout our oceans from the poles to the equator and from sea surface and shoreline to the deep sea. It is hazardous to seafarers resulting in unnecessary coastguard and rescue callouts and has substantial economic consequences for the local authorities responsible for clean-up. Perhaps most widely documented are encounters with wildlife which can result in direct harm and death. Well over 600 species of organisms are reported to encounter marine litter and the majority of these encounters are with plastic items. Freshwater systems are considered to represent important pathways for the input of debris to the oceans (Figure 1). Yet our understanding about the accumulation, transport and impacts of litter in freshwater systems lags behind that of the marine environment. This presentation will summarise current scientific understanding about the accumulation and potential environmental consequences of microplastic debris. Examples will be drawn from both marine and freshwater habitats.

Figure 1: Diagram showing potential transfer pathways of microplastics in freshwater. Source (with permission) Eerkes-Medrano et al., 2015



In the longer term the accumulation of litter in terrestrial, freshwater and marine habitats, is an environmental problem that can be solved. In the marine environment, the majority of the items that become litter are single use disposable items including packaging and sewage related debris. Such items can bring considerable societal benefit, for example in terms of food security and light weighting to reduce fuel usage, however these benefits can all be realised without the need for any emissions of litter to the ocean. Hence the long term solutions lie in recognising that if designed, used and disposed of appropriately, then end-of-life items that currently accumulate in waste management facilities and as litter in the natural environment can be used as a resource for production of new products. Working toward a circular economy of this kind will help reduce our reliance on non-renewable resources and simultaneously reduce the quantity of waste requiring disposal.

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Overview on plastics in European freshwater environments – Results of a survey

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1 Introduction

The accumulation of plastic in aquatic environments is one of the major challenges for risk assessment and management options. So far, risk awareness as well as research has been mainly focused on plastics in the marine environment. While numerous studies and reports on plastics in the marine environment have been published much less is known about occurrence and ecological risks of these materials in rivers and lakes.

However, the number of monitoring studies on plastics in European freshwater environments is gradually growing. Several scientific short-term studies were reported referring to the occurrence of microplastics in various European freshwaters. These studies covered among others freshwaters in Austria (Danube River), France (e.g. Rivers Marne and Seine), Germany (River Rhine and tributaries, Rivers Weser, Main, Elbe), Italy (e.g. Lake Garda), the Netherlands (e.g. Rivers Meuse and Rhine, and Lake Ijssel), Switzerland (e.g. Rhine River and Lake Geneva), and United Kingdom (e.g. River Thames)[1]. Measurements comprised various compartments like water surface and column, sediments and biota. The reported investigations differed in the applied methods of sampling, sample treatment and analysis.

In order to prepare an overview on monitoring and effect studies as well as on risk perception and management options referring to plastics in European freshwaters a survey on the current status of European activities was conducted.

2 Methods

The questionnaire, consisting of overall 11 questions, was sent to the representatives of the European countries in the Strategic Coordination Group (SCG). The SCG coordinates and gives advice to the Common Implementation Strategy (CIS) of the European Water Framework Directive. Besides the 28 EU members the representatives of six other European countries including Iceland, Montenegro, Norway, Serbia, Switzerland and Turkey were addressed. 41 % of these countries (total of 14) participated in the survey. The received responses and references were supplemented with a literature research. Initiated by the German Environment Agency (UBA), the German translation of the questionnaire was sent to all federal states of Germany in the scope of a separate national survey. The results were summarized in agreement with UBA to one representative response which was also considered in the present European survey. Apart from both surveys, a report was submitted by the Finnish non-profit organisation “Keep the Archipelago Tidy Association” (KAT). The outcomes of this report were also included into the results of the European survey.

[1] Hohenblum et al., 2015, Gasperi et al., 2014, Wagner et al, 2014, Klein et al., 2015, Laforsch et al., 2015, Imhof et al., 2013, Brandsma et al., 2015, Mani et al., 2015, Faure et al., 2012, Morritt et al., 2014

The questionnaire comprised ten content questions of which the first seven related to monitoring studies, riverine loads and riverine inputs into the marine compartment, main sources and pathways of plastics, and effect studies. Questions 8 to 10 referred to the issues of risk perception and management options. The corresponding answers are summarized in the abstract "European Overview on Management Options and measures in place for plastics in freshwater environments" by Hohenblum et al.

3 Results

The results of the survey as far as they touch questions 1 to 7 were assigned to the four topics: monitoring studies (3.1), riverine loads and riverine inputs into the marine compartment (3.2), main sources and pathways (3.3), and effect and biota monitoring studies (3.4).

3.1 Completed, ongoing and planned monitoring studies on plastics in freshwater environments

Question 1: Are investigations performed in your country on plastics in freshwater environments?

Question 2: Are details available on completed and ongoing monitoring studies?

Question 6: Are there further plans for monitoring activities on a national level for plastics in freshwater environments?

Completed studies

Completed studies were reported by the survey participants of **Austria** (River Danube), **Belgium** (River Leie), **Germany** (River Rhine and four tributaries, River Weser), and **the Netherlands** (River Rhine estuaries) (Hohenblum et al. (2015), Craenenbroeck et al. (2014), Laforsch (2015), Leslie et al. (2013). In addition, the Netherlands survey participant referred to various transboundary monitoring studies including Netherlands freshwaters like the Rivers Rhine and Meuse and the Lake Ijssel (Mani et al. (2015), Urgert (2015), Brandsma et al. (2015)). A study by van der Wal et al. (2014) covered rivers in the Netherlands (Rhine), Italy (Po), Romania (Danube) and Sweden (Dalålven). In **Finland** monitoring of litter in freshwaters was performed in a citizen science project.

Ongoing and planned studies

Beyond the already conducted studies, several further monitoring programmes on plastics in freshwater environments are ongoing, currently scheduled or under discussion. 57 % of the survey participants, who represented Austria, Belgium, Denmark, Germany, Lithuania, Luxembourg, the Netherlands and Portugal, stated further plans for monitoring studies.

3.2 Riverine loads of plastics and riverine inputs into the marine compartment

Question 4: Are there data on riverine loads of plastics?

Question 5: Are there data on riverine inputs into the marine compartment?

The availability of data on riverine loads of plastics in freshwater environments was reported by four of the 14 surveyed European countries including Austria, Belgium, Germany, and the Netherlands. The participants from Denmark, Germany, Latvia and the Netherlands stated that data exists on riverine inputs into the marine environment.

Hohenblum et al. (2015) estimated the riverine load of the Austrian **Danube** as less than 17 t/year for microplastics (< 5 mm) and less than 41 t/a for the total plastic load[1]. In the context of the microplastic

[1] No specification of size range for total plastic load in Hohenblum et al. (2015)

profile along the River **Rhine**, Mani et al. (2015) extrapolated a daily discharge of 192 Mio particles (at and beneath the surface) into the North Sea based on concentration measurements of a one-day sampling at Rees (Lower Rhine, Germany). The amount of riverine litter inputs of four selected European rivers discharged into the connecting seas was assessed by van der Wal et al. (2014). Table 1 shows the results of these estimations for the River **Dalålven** (Baltic Sea), River **Rhine** (North Sea), River **Po** (Mediterranean Sea), and River **Danube** (Black Sea).

Table 1: Estimates of riverine inputs of plastics to the marine environment

	Manta net (micro particles < 5 mm)	Waste Free Water Sampler (meso particles > 5 mm)	
	particles/year	t/year	particles/year
Dalålven	$5 * 10^{10}$		
Rhine I	$30 * 10^{10}$	20	$3 * 10^{8}$
Rhine II	$10 * 10^{10}$	31	$0.8 * 10^{8}$
Po	$70 * 10^{10}$	120	$7 * 10^{8}$
Danube	$200* 10^{10}$	530	$100 * 10^{8}$

Remark: For the River Dalålven no WFW samples were collected since the location was not suited for this equipment set up. Sampling at the Rhine River was conducted two times (Data source: van der Wal et al. (2014)).

3.3 Main sources and pathways for plastics in the freshwater environments

Question 3: What are the main sources and pathways for plastics in the freshwater environment of your country?

The results show a significant perception of landscape littering as the main source of plastic in freshwater environments, about 70 % of survey participants selected this option. Additionally, the option “Unknown” was chosen in 50 % of the answered questionnaires. The remaining selections of main sources and pathways were selected in fewer than 50 % of the questionnaires including ‘Storm Water’, ‘Tire Abrasions’, ‘Others’, ‘Waste Water’ and ‘Industrial Emissions’ (in that order).

For two countries, **Denmark** and the **Netherlands**, comprehensive inventories of the sources of primary and secondary microplastics released into the aquatic environment were estimated (Lassen et al. (2015), Verschoor et al. (2015)). In addition, Verschoor elaborated a prioritisation list of land based sources of microplastics which can facilitate future management options to reduce the inputs of plastics into the environment.

3.4 Effect and biota monitoring studies

Question 7: Are there studies on effects of plastics in freshwater environments?

Two studies on the microplastic contamination of fish from the River Danube were reported by the Austrian survey participant. In the study by Hohenblum et al. (2015) no findings of microplastics in the intestines of 30 organisms fish individuals (species: *Barbus barbus* and *Leuciscus cephalus*) were recorded. Lumesberger-Loisl and Gumpinger (2015) stated that in the digestive tracts of only two of 840 fish individuals microplastics were found (one particle in each individual). In Denmark, Germany, Ireland, and the Netherlands (research project TRAMP) studies on effects of microplastics on aquatic organisms are ongoing or planned, resp. Further studies were conducted in France and Switzerland, which did not participate in the European survey. In France 186 wild gudgeons from ten different streams were investigated. 12 % of the organisms contained microplastics (Sanchez et al. 2013). Faure et al. (2012) analysed 41 fish individuals and a black-necked grebe from the Lake Geneva. No evidence of contamination was found.

Strictly, these studies do not refer to effects of plastic contamination on freshwater organisms, but can be regarded as biota monitoring studies. Only few effect studies on freshwater species in the narrower sense have been performed so far. For instance, Oliveira et al. (2013) determined if microplastics modulate short-term toxicity of contaminants (pyrene) on *Pomatoschistus microps.* Several effect studies describe the toxicity of microplastics in marine organisms (Eerkes-Medrano et al. 2015). It is an open question whether the results of these studies can be transferred to the effects of microplastics on freshwater species.

4 Discussion

The results of the European survey and the literature research reveal that the knowledge of the distribution, abundance and risks of micro-, meso- and macroplastics in freshwater environments is far from complete and requires further evaluation. Differences exist in the size ranges of the microplastic particles detected. In most studies, particles with a size < 5 mm were investigated relating to the generally accepted definition of the upper size boundary of microplastics. However, no agreement has been found on a scientific definition of the lower size boundary so far. Therefore, the lower limit of the size range considered varies from study to study depending on the type of sampling methods and the sensitivity of the analytical methods applied. For instance, by use of a plankton net the mesh width determines the size of the particles that are collected. Visual inspection of purified samples is more subjective than identification by physico-chemical detection methods like FT-IR, Raman spectroscopy or pyrolysis GC-MS. Likewise monitoring results are reported in different metrics including data on the number of detected particles or mass concentrations which can refer to water surface area or water volume or unit of time if water samples are analysed. Due to the particle density the sampling location - water surface or water column – will influence the results of an investigation. Regarding these differences it is hardly possible to compare the data from different studies. Therefore, a quantitative evaluation how strongly European freshwaters are contaminated with plastics can currently not be made.

There are needs for harmonization and further investigations particularly with regard to the following issues:

- So far, a generally accepted definition of the lower boundary of the particle size is missing for microplastics. Therefore, the size range of particles, on which the various monitoring studies on freshwater refer, is quite different particularly depending on the lower limit of sampling and analytical methods.
- To enable the comparison of monitoring data standardized methods for sampling, sample treatment and particle identification have to be developed. Since especially the smallest microplastic particles are suspected to be of special interest in studies on organisms it is important to be capable of gathering and detecting particles much smaller than 300 µm.
- The completed and ongoing monitoring studies on rivers and lakes cover only a part of the European countries. Occurrence and loads of plastics in numerous freshwaters, among them major rivers probably contributing to relevant inputs into the connecting seas, have not been investigated so far.
- Furthermore, knowledge of accumulation, sources, sinks and environmental impacts of micro-, meso- and macroplastics in freshwater environments is currently limited. Further investigations are required to evaluate the potential physical and chemical impacts.
- In contrast to research on contamination of marine organisms and effects on these species only few studies have focused on the risks of micro-, meso- and macroplastics to freshwater organisms. Further research is required to answer the questions whether plastics are taken up by freshwater species to a considerable extent, whether the particles release chemicals, irritate or harm. Especially with regard to microplastics it should be investigated if the particles pass membranes and accumulate in tissues, and whether enrichment in aquatic food webs occurs.

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Monitoring activities for plastics in rivers and lakes in Germany

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1 Introduction

Plastics have become an indispensable part of our daily life due to its flexible material properties and diverse applications. In 2012, world production was around 288 million tonnes. This is compared to 1989 an almost threefold increase, and a further elevation of production rates is predicted. Germany is a large market for plastics. The annual demand of 13 million tons in Germany is equivalent to 23 % of the European market and 4 % of the global market, respectively (PlasticEurope, 2013).

It has been a concern for some two decades that due to improper handling or littering plastic waste can enter the marine environment where it remains for a long time due to its low degradability (Barnes et al., 2009). For marine ecosystems, the high load of plastic particles is well documented.

Most of marine plastic waste is considered to be of terrestrial origin (UNEP, 2009). Rivers and wastewater discharges contribute substantially to the plastic contamination of marine environments (Rech et al., 2014; Morrit et al., 2014). Although a causal relationship between plastic litter as well as microplastic load of inland waterways and marine ecosystems is obvious, only a few studies on the possible sources and the degree of microplastic contamination of rivers and lakes have been published so far. This also holds true for Germany.

Only recently, researchers began to investigate European rivers and streams for microplastic particles of various size, shape and polymer composition, e.g. the rivers Danube (Lechner et al., 2014), Elbe, Moselle, Neckar, Rhine (Wagner et al., 2014; Klein et al., 2015; Mani et al., 2015), as well as several Swiss lakes and the river Rhone (Faure et al., 2015). Investigation of the beach sediments of the subalpine Lake Garda (Imhof et al., 2013) revealed a microplastic contamination in the same order of magnitude as has been described für marine sediments. Also in Lake Geneva and other Swiss lakes, microplastic particles have been detected in samples of both, beach sediments and water surface (Faure et al., 2012; Faure et al., 2015).

However, study results for European inland waters are not always comparable with each other. In the first place, technical inconsistencies in particular with regard to sampling methods, sample preparation as well as the detection method itself hamper the interpretation of data (Dris et al., 2015; Eerkes-Medrano et al., 2015). Apart from methodological variations, also the choice of the relevant aquatic compartment for the detection of microplastic is under discussion. It is also important to note that until now only a few investigations have been conducted with regard to the potential impact of microplastic on fresh water species. There are no data available which enable a risk assessment of microplastic concentrations detected in fresh water ecosystems.

Plastics in rivers and lakes – a new issue in Germany

Germany is organised according to federal principles, and government tasks are split between the Federal Government and the states. Enforcement of the provisions relating to water, including water resources management falls under the control and administration of the states (UBA, 2014).

Germany is a densely populated country in the centre of Europe with a high level of industrialisation, much of which is concentrated in particular geographical regions. Over four fifths of the total area is farm- and woodland. 13.4 % of the area are used for settlements and traffic. Water accounts for only a small proportion of land (2.4 %).

Ten river basins are defined in Germany, i.e. the Danube, Rhine, Maas, Ems, Weser, Oder, Elbe, Eider, Warnow-Peene and Schlei-Trave. The rivers and streams have a combined length of more than 400,000 km and flow into the coastal regions. The Rhine, Elbe, Weser, Ems, Maas and Eider river basins drain into the North Sea; the Oder and the Schlei-Trave and Warnow-Peene river basins flow into the Baltic Sea; and the Danube flows into the Black Sea. Large natural lakes, which are partly interconnected areas are found in the North German Lowlands and the South German Alpine foothills.

Discussions on plastics in German freshwater environments took off around 2013. One of the starting points was the study by Imhof et al. (2013) at Lake Garda in the North of Italy, which raised considerable attention among the public and media. In the same year, a number of questions were raised in several State Parliaments regarding microplastics in freshwater environments, e.g.

- What are the dangers for flora, fauna and humans directly or indirectly arising from microplastic particles?
- What results have investigations provided so far and what repercussions can be concluded for humans and wildlife?
- Is there an increase of microplastic concentrations expected in rivers, groundwater, lakes and water reservoirs?
- What preventive possibilities are considered to be appropriate, necessary and proportionate to avoid risks caused by the entry of microplastic particles into the waters?

In June 2014, the Bavarian Environment Agency organised a first national workshop on microplastics in freshwater environments (Augsburg, June 2014). At the end of the conference a memorandum captured the state of knowledge:

- Accumulation of microplastic in the marine ecosystem has been demonstrated.
- Accumulation of microplastic in rivers and lakes is indicated by few investigations and has to be accepted as a nationwide phenomenon.

- There are no standardised analytical methods. Therefore, the results of the current studies are not mutually comparable.
- Microplastics are taken up by organisms - very little is known about their effects.
- Media reports on microplastic in food are not considered to be scientifically reliable.

Since then, projects have started at different scales in Bavaria, Baden-Wurttemberg, Hesse, Rhineland-Palatinate and North Rhine-Westphalia. In March 2016, the German Environment Agency and the Bavarian Environment Agency organised a formal discussion on the level of the Federal Government and federal states on plastics in freshwater environments to discuss the newest state of knowledge. The agenda covered discussions on the analytical methods and first analytical data provided by the federal states, the future coordination and harmonisation of different federal activities, the identification of knowledge gaps, and the possibilities for cooperation.

In preparation of the workshop, a questionnaire on research and water management activities related to plastics in rivers and lakes was send to all federal states. The results of the survey are summarised below. Furthermore, an overview on the current monitoring activities for microplastic performed by the federal states will be given.

2 Monitoring activities for plastics in rivers and lakes in Germany

2.1 Outcome of the nation-wide survey

A total of 14 out of 16 federal states have responded to the questionnaire. However, it has to be considered that not all questions have been answered consistently by the different states.

The results of the survey can briefly be summarised as follows:

Questions on Monitoring

- So far, only Bavaria, Baden-Wurttemberg, North Rhine-Westphalia, and to a smaller extent, Rhineland-Palatinate and Hesse investigate microplastic in freshwater environments. Hence, some information is available for the river basins Rhine and Danube but not for e.g. the Elbe.
- Currently, there is no reliable evidence on diffuse sources and pathways for plastics in inland water systems as well as on the riverine load of plastics.
- Two federal states (Lower Saxony and North Rhine-Westphalia) have funded investigations on potential microplastic discharge via sewage treatment plants, so far.
- There are no data on the riverine inputs into marine environments.
- Three federal states (Bavaria, North Rhine-Westphalia, Saarland) intend to carry out further studies on the occurrence of plastic in inland waters. Two of these states (Bavaria, North Rhine-Westphalia) are already active in investigating plastics in rivers, lakes, or sewage treatment plants, respectively.
- Only one state (Bavaria) performs systematic studies on the possible effects of microplastic in biota.

Questions on risk perception and management options

- Overall, the public perception of the issue "plastics in freshwater environment" varies considerably between the federal states with Schleswig-Holstein showing the highest attention.
- Possible measures to reduce plastics in inland waters are discussed in most of the states. This relates primarily to governmental authorities, media, and non-governmental organizations, but also in part to the public.
- Around 50 % of the federal states are planning or even implement measures in order to reduce the input of plastics into inland waters.
- Significantly less states are planning or have already implemented measures to remove plastic waste from inland waters.

2.2 Current monitoring activities in German inland waters – similarities and differences

Five federal states in Germany have initialised monitoring programmes to assess the microplastic load of inland water systems: Bavaria, Baden-Wurttemberg, North Rhine-Westphalia, Rhineland-Palatinate and Hesse (Figure 1). Even if the individual projects might have different regimes, the main requirements are given to compare the study results. The most important conformities of the studies refer to the methods applied. The Department of Animal Ecology I, University of Bayreuth, is the contract partner for all five state monitoring programmes and performs the environmental sampling, preparation of samples as well as microplastic analysis by means of FTIR-Spectroscopy. All monitoring programmes include the investigation of rivers while two states, Bavaria and Baden-Wurttemberg, also monitor microplastics in lakes.

Besides similarities, also differences are obvious with regard to the prioritization within the monitoring programmes. Some studies already considered emission aspects (e.g. possible influence of sewage treatment plant effluents) or potential "hot-spots" (e.g. plastics processing industry companies). In contrast, other studies focused on a first overview on the microplastic load in various rivers and lakes differing in size, land use, or wastewater percentage. All monitoring programmes include samples from the water surface but additionally each programme focused on individual further aquatic compartments (Table 1 and 2). Only the Bavarian project so far investigates the potential accumulation of microplastic in biota such as bivalves and fish under field as well as under standardized laboratory conditions. At a later stage of this project studies will be performed on the possible effects of microplastic on aquatic organisms.

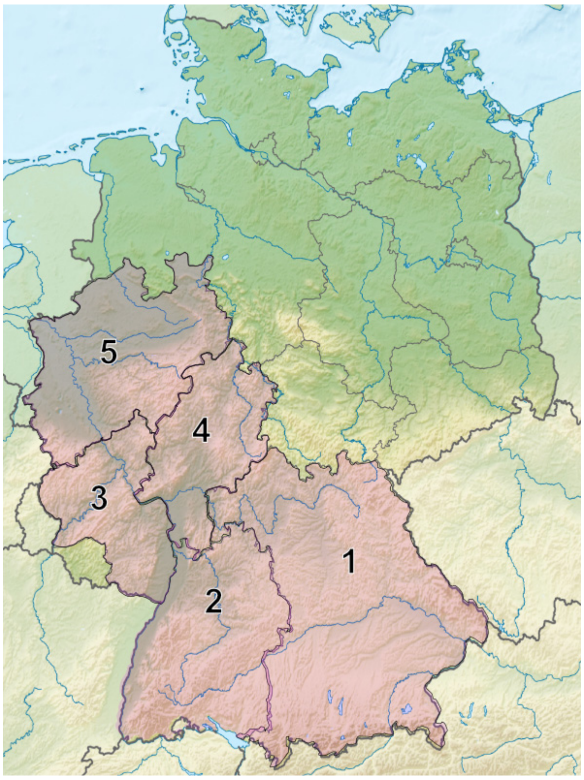
Table 1: Monitoring activities in rivers of Germany and aquatic compartments under investigation

Federal state	Number of rivers	Water surface	Water column	Shore sediment	Soil drift	STP Effluent
Bavaria	5	X		X	X	
Baden-Wurttemberg	11	X		(X) river sediment		
North Rhine-Westphalia	7	X	X			X
Rhineland-Palatinate	2	X		(X) river sediment		
Hesse	1	x		(X) river sediment		

Table 2: Monitoring activities in lakes of Germany and aquatic compartments under investigation

Federal state	Number of lakes	Water surface	Water column	Shore sediment	Ground Sediment
Bavaria	5	X	X	X	X
Baden-Wurttemberg	1	X		X	X

Figure 1: Monitoring activities for microplastics in rivers and lakes of Germany



Map of Germany with states highlighted, where regulatory agencies investigate plastics in freshwater environments: 1 - Bavaria, 2 - Baden Wurttemberg , 3 - Rhineland-Palatinate, 4 - Hesse, 5 - North Rhine-Westphalia

3 Summary and Outlook

One aim of the work presented was to get an overview on monitoring activities related to plastics in rivers and lakes in Germany. A nation-wide survey revealed a heterogeneous picture in relation to how the federal states are dealing with the issue of microplastic pollution. The public perception of the issue "plastics in freshwater environment" varies a lot within Germany. So far, only five federal states are actively involved in a monitoring for microplastic. Three states intend to carry out further investigations on the occurrence of plastic in inland waters. Only one state performs systematic studies on the possible effects of microplastic in biota.

It is important to get an overview on this new issue. We need to characterise the exposure of plastics in freshwater environments. The formal discussion on Federal Government and federal states level on plastics in freshwater environments led to the following results:

1. Analytical capabilities: are currently insufficient. Further optimisation and standardisation of sampling and analytical methods have highest priority. So far, only analytic results of spectroscopic investigations (FTIR and Raman spectroscopy) are considered. Development of complementary analytical approaches such as thermogravimetric analysis (Pyrolysis GC/MS) is still in an initial phase. However, both methods need to improve and to accelerate laboratory procedures to become reasonable tools for future studies.
2. Identification of relevant pathways (e.g. littering, treated wastewater, storm water, tire abrasion): is promising; 'hot spots' should be investigated more in detail. To some extend exposure may be related to emission from industrial companies, which produce or process primary plastic particles (pellets).
3. Modelling of plastics in freshwater environments: should be investigated regarding a possible adaptation of existing models to cover the fate of microplastic particles in freshwater systems and the demand on quality and quantity of input data.
4. Risk assessment of environmental data: studies on possible effects of microplastic particles on freshwater organisms are urgently required.

5. Waste management: The Freshwater community should initiate discussions on sources with colleagues responsible for plastic waste management and circular economy.
6. Further opportunities for cooperation and the possible use of synergies: should be checked and established.

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Quick scan and Prioritization of Microplastic Sources and Emissions

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1 Introduction

Nowadays, plastic has penetrated virtually every single aspect of everyday life: from clothing to electronics and from building materials to cleaning products. The development of plastic has skyrocketed since the 1950s. Global plastic production in 2014 reached 311 million tonnes and continues to increase by roughly 3 % every year. Plastic is cheap, durable (little to no decomposition), is chemically inert (rarely reacts with other substances) and is relatively lightweight and malleable, resulting in a practically unlimited number of possible applications [1].

However, the disadvantages of plastics are gradually becoming apparent [2]. Large quantities of plastic pollute the oceans, seas and rivers, and back on dry land, plastic litter is an everyday sight in our towns and cities [3-5]. There are concerns about the consequences of plastic for sea life such as fish, sea birds, seals and turtles. The most common problems of plastic for animals are obstruction (resulting in starvation), injury or suffocation [6-9]. These effects play out at the individual level.

The effects of smaller plastic particles are less clear, although they could well have far-reaching consequences. Smaller particles may be absorbed by the tissue of aquatic organisms such as mussels and fish, resulting in the plastics entering the food chain [10]. Via these plastic particles, animals can also be exposed to other agents added to the plastics such as plasticizers, which can cause amongst others hormone disruption [11]. Furthermore, many waterborne contaminants have a tendency to adhere to plastics. A number of studies indicate that exposure to these contaminants is enhanced due to intake via plastics [12], although there are also claims that contradict this [11]. Although the full impact of microplastics on humans and the environment is not yet known, the persistence of plastics is beyond dispute. For this reason, the reduction of plastic waste is one of the key issues of both Dutch and European environmental policy.

Our study [13] presents an inventory and prioritization of land-borne sources of microplastics to support the development of effective and efficient action plans by the government.

2 Methods

The plastics under consideration are limited to solid, polymeric materials of petrochemical origin. This report includes primary as well as secondary microplastics. For a systematic inventory of microplastic sources, the Dutch Pollutant Release and Transfer Register (www.prtr.nl), was used as a template. Sources were further supplemented with literature data and results of a previous expert-meeting.

A multicriteria analysis (MCA) was performed in order to assign a priority for microplastic sources. The MCA included relevance (volume of emission), feasibility of measures (alternatives, quick win) and perceived urgency (media attention, options for consumers choice or action perspective). A group of experts representing the National Institute for Public Health and the Environment (RIVM), Rijkswaterstaat and Deltares assigned qualitative scores to the criteria that reflect the volume, extent or likelihood of the criteria based on the Dutch situation. The scores were combined to a total score, which determines the priority.

3 Results

Table 1: Priority scores for sources of microplastics based on five criteria. C1: Scale of emissions, C2: Indispensability, C3: Opportunities for quick wins, C4: Risk perception, C5: Alternatives for the consumer

Activity/product	Sector/actor	Scale	Feasibility		Urgency		Priority
		C1	C2	C3	C4	C5	
Packaging material	Consumers	2	2	2	2	1	9
Litter (general)	Various sectors	2	2	1	2	1	8
Waste collection	Waste disposal	2	0	2	2	0	
Cosmetics	Chemical industry	1	1	2	2	1	
Cosmetics	Consumers	1	1	2	2	1	
Paint, lacquer, dyes	Consumers	2	1	1	1	1	7
Fibres and clothing	Consumers	2	1	1	1	1	
Loading, unloading, transfer	Services	2	0	1	1	2	
Runoff from paved surfaces	Traffic and transport	2	1	1	1	2	
Dust from construction sites	Construction	2	0	1	1	1	
Abrasive cleaning agents	Industry	1	1	2	1	1	
Abrasive cleaning agents	Consumers	1	1	2	1	1	
Agricultural plastics	Agriculture	1	1	2	1	1	
Compost, sewage sludge	Agriculture	1	1	1	1	2	6
Treated water	Sewage treatment plants	1	1	1	1	2	
Overflow and untreated water	Sewage treatment plants	1	1	1	1	2	
Tyre wear	Traffic and transport	2	0	0	1	2	
Inflow from abroad	Other	2	0	0	1	2	
Composting installations	Waste disposal	1	0	1	1	2	
Glues, paints	Construction	1	0	1	1	0	
Insulation	Construction	1	1	1	1	1	
Cast floors, carpeting	Construction	1	1	1	1	1	
Food	Consumers	1	1	1	1	1	
Household items	Consumers	2	0	1	1	0	5
Automotive businesses	Services	1	1	1	0	2	
Dry cleaners	Services	1	0	2	0	2	
Cleaning of tankers	Services	1	1	1	0	2	
Sports fields	Services	1	1	0	1	2	
Foodstuffs and snacks	Consumers	0	1	1	2	1	
Landfill sites	Waste disposal	1	0	0	1	2	
Fibres	Chemical industry	1	1	0	1	1	
Packaging	Chemical industry	1	1	0	1	1	4
Granular material (DIY)	Consumers	1	1	1	0	1	
Medical resources	Consumers	2	0	1	0	0	
Toys and party items	Consumers	2	0	1	0	0	
Combustion	Waste disposal	1	0	0	0	2	
Sandblasting	Construction	0	2	0	0	2	
Granular material	Chemical industry	1	0	0	0	2	
Foodstuffs and snacks	Chemical industry	0	1	1	1	1	
Glues and adhesives	Consumers	1	0	0	0	2	3
Shipyards	Services	1	0	0	0	2	
Rotary milling	Traffic and transport	1	0	0	0	2	
Atmospheric deposition	Other	1	0	0	0	2	
Preparation of recycling	Waste disposal	1	0	1	0	0	
Production of base chemicals	Chemical industry	0	0	0	0	2	
Paint and adhesives	Chemical industry	0	1	0	1	1	
Medical resources	Chemical industry	0	0	0	0	2	
Electronics, printers	Consumers	1	0	0	0	1	
Dental surgeries	Services	1	0	0	0	1	2
Corrosion of water mains	Services	0	1	0	0	1	
Extraction and distribution	Drinking water industry	0	1	0	1	1	
Cooling water	Energy	0	0	0	0	2	
Aviation	Traffic and transport	0	0	0	0	2	

4 Discussion

A total of 56 sources were identified and subjected to the multicriteria analysis. In Table 1 the scores and overall priority are shown. The largest source of plastic and secondary microplastic emissions is plastic debris, which consists largely of packaging materials and disposable products. This was confirmed by the high scores in this report (8-9 on a scale of 1-10). Other sources of secondary microplastics with a relatively high score (6-7) were fibres and textiles, roadway runoff (including tyre dust), dust from construction places, agricultural plastic and input from abroad via rivers. Waste water, sewage sludge and compost (score 6) contain primary as well as secondary microplastics, from sources with emissions to the sewer system, such as households that emit fibres through the washing machine and microbeads used for personal care and cosmetic purposes.

The estimation of microplastic quantities, technical possibilities for emission reduction and alternatives of microplastics had an exploratory nature. This study provides a prioritization that supports decisions about the continuation of a number of current policy measures and the eventual introduction of additional measures. Refinement and corroboration of technical details, costs and benefits are necessary before new measures can be enforced. Recently a follow-up study is finalized to quantify emissions from abrasive cleaning agents, paints and tyres and to identify potential measures and instruments [14]. Another study has been started to explore the costs and benefits of these measures.

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Conceptual considerations on the environmental risk assessment of microplastics

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1 Introduction

Although the occurrence of small plastic particles in the environment was already described more than 40 years ago (Carpenter et al. 1972), public attention has until recently largely focused on macroplastics. However, this has changed in the last few years and potential risks caused by microplastics in the environment are now controversially discussed. Microplastics found in the environment are a very heterogeneous group of particles. They differ in size, shape, surface texture, chemical composition (including polymer composition and additives such as plasticisers, stabilizers, flame retardants, pigments and antimicrobials) and specific density (Teuten et al. 2009, Andrady 2011, 2015). All these properties may influence fate and effects of microplastics in the environment. Disintegration and, especially, degradation of plastic materials in the environment is a very slow process (Shah et al. 2008, Andrady 2011).

Microplastics have been shown to be ingested by a variety of species (Hollman et al. 2013, Wright et al. 2013a). In laboratory experiments with marine organisms, high concentrations of microplastics cause physical effects, particularly a reduced food uptake due to the presence of plastic in the intestinal tract. This, in turn, leads to lower energy reserves and related effects on other physiological functions (Lee et al. 2013, Wright et al. 2013b, Cole et al. 2015, Duis & Coors 2016). Effects may also be caused by plastic additives (e.g. Oehlmann et al. 2009). Moreover, potential effects on sediment properties (Carson et al. 2011) and the function of microplastics as vectors for the transport of hydrophobic pollutants (Teuten et al. 2009), invasive species and pathogens are discussed (Barnes 2002, Goldstein et al. 2012, De Tender et al. 2015).

2 Current environmental risk assessment procedures

In current environmental risk assessment procedures for chemical substances, measured environmental concentrations (MECs) or, usually, predicted environmental concentrations (PECs) of a substance are compared to predicted no effect concentrations (PNECs) (van Leeuwen 2007, Traas & van Leeuwen 2007). Predicted environmental concentrations are estimated using models developed for the respective substance group and its most relevant entry route(s) into the environment. Predicted no effect concentrations are derived from laboratory toxicity tests by multiplying the highest substance concentration, which did not cause significant adverse effects in the most sensitive species, with an assessment factor. The latter shall account for intra- and inter-laboratory variation in toxicity data, interspecies variation in toxicity, as well as the extrapolation from short- to long-term toxicity (where relevant) and from the laboratory to the field (e.g. EC 2003, ECHA 2008, Celander et al. 2011). If the ratio of the PEC to the PNEC is below 1, the risk caused by the substance in the respective environmental compartment is deemed acceptable.

Since the environmental impact of substances that are persistent, bioaccumulative and toxic (PBT) or very persistent and very bioaccumulative (vPvB) may be underestimated using the approach described above (EC 2003, van Wijk et al. 2009, Moermond et al. 2012), PBT and vPvB substances are identified in a complementary approach. Their persistence, bioaccumulation potential and toxicity are compared to trigger values as defined in EC (2011). The consequences of a classification of a substance as PBT or vPvB (e.g. restriction or implementation of risk mitigation measures) depend on the regulatory framework.

The approaches mentioned in the previous two paragraphs are used to assess the environmental risk of industrial chemicals, pesticides, biocides, human and veterinary pharmaceuticals. In this context it is of note that within REACH, polymer molecules are – in view of their high molecular weight – considered as being of low concern. Therefore, they are exempted from registration and evaluation, unless their content of (unreacted) monomers exceeds certain limits or they contain certain additives triggering registration and evaluation (ECHA 2012).

3 Approaches to assess potential environmental risks caused by microplastics

To obtain a first impression of the possible impact of microplastics on the environment, we have reviewed and compared measured environmental concentrations of microplastics and the lowest microplastic levels causing significant physical effects in laboratory tests (LOECs; Duis & Coors 2016), i.e. applied a simple MEC/LOEC comparison without taking an assessment factor into account. Due to the much better data base available, we have used data for the marine environment and marine test organisms. The lowest microplastic concentrations found to cause adverse effects in marine organisms (Lee et al. 2013, Kaposi et al. 2014) are by a factor of about 10,000 higher than the upper range of microplastic concentrations in marine water (Hidalgo-Ruz et al. 2012, Desforges et al. 2014). The effect concentration obtained in a water/sediment test with lugworms (Wright et al. 2013b) is by a factor of about 500 higher than highest microplastic levels in marine sediments (Vianello et al. 2013). However, the highest microplastic levels detected in beach sediments (Carson et al. 2011, Baztan et al. 2014) are higher than the aforementioned effect concentration in the water/sediment test (the impact of microplastics on organisms inhabiting beach sediments or soils has so far not been investigated).

Given that estimates of the lifetime of plastics in the environment are much higher than thresholds for the classification of chemical substances as very persistent (half-life times of >60 days in water or >180 days in sediment or soil; EC 2011), microplastics can be considered as vP. Yet, so far there are to our knowledge no data providing clear evidence for their bioaccumulation (i.e. for an increase of internal concentrations in relation to concentrations in the environment) or biomagnification (i.e. an increase of concentrations at higher trophic level).

Furthermore, a number of other knowledge gaps have to be pointed out. With regard to the ecotoxicity of microplastics, data are scarce for freshwater organisms and lacking for terrestrial organisms. Even for marine organisms, the available database is relatively limited (Rillig 2012, Wagner et al. 2014, Duis & Coors 2016). So far, we know little on the influence of the characteristics of microplastics (e.g. size, shape, chemical composition) on their ecotoxicity (Syberg et al. 2015). Similarly, our knowledge on fate and occurrence of micro- and macroplastics in the environment is limited, for instance regarding fragmentation and degradation rates, and size distributions in the environment (Hidalgo-Ruz et al. 2011, GESAMP 2015, Syberg et al. 2015). To date, only few studies have addressed the occurrence of microplastics in the freshwater and, especially, terrestrial environment (Wagner et al. 2014, Rillig 2012, Duis & Coors 2016).

The environmental risk assessment procedures described in section 0 have been developed to evaluate fate, effects and resultant risks of chemical substances. Thus, they do not cover several aspects that are relevant when assessing the risks caused by microplastics (i.e. particles), such as the fragmentation in the environment that leads to an increase in particle abundance over time with possible implications on toxicity. Moreover, different types of effects have to be considered for microplastics including chemical effects of monomers and additives, physical effects of the particles, effects on sediment properties, and the function as a vector for pollutants, invasive species or pathogens. Assessment factors and trigger values used in the risk assessment of chemicals may not be appropriate for microplastics. For a sufficiently comprehensive assessment of potential environmental risks caused by microplastics, an approach is needed that covers all relevant aspects (Teuten et al. 2009, Wagner et al. 2014).

There are a number of similarities between nanomaterials and microplastics. For instance, their size and shape are likely to influence fate and effects, they can have physical effects on organisms in the environment, and they may act as vectors for sorbed contaminants (Baun et al. 2008, Crane et al. 2008, Syberg et al. 2015). Hence, insights obtained in the field of nanoecotoxicology and concepts discussed for the environmental risk assessment of nanomaterials might prove to be useful when developing an approach for the risk assessment of microplastics (Syberg et al. 2015). This includes strategies to study bioaccumulation and ecotoxicity (Kühnel & Nickel 2014, Oomen et al. 2014).

4 Conclusions

With regard to possible environmental risks of microplastics, it has to be emphasised that plastics are extremely persistent. Due to the fragmentation of macroplastics, concentrations of microplastics in the environment will continue to increase even if the release of plastics into the environment is stopped (Andrady 2011, GESAMP 2015). In view of these facts and the already considerable environmental concentrations recorded e.g. in some coastal sediments, development and effective implementation of strategies to reduce the release of macro- and microplastics into the environment are urgently required – despite the lack of a comprehensive regulatory framework to assess the environmental risks caused by microplastics.

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Monitoring of Riverine Litter – Options and Recommendations

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1 Introduction

Marine litter is an issue of global concern as recognized by the Marine Strategy Framework Directive (MSFD) (European Commission, 2008). The MSFD requires Member States (MS) to develop strategies that should lead to programmes of measures to achieve or maintain Good Environmental Status in (GES) in European Seas. Furthermore, marine litter has been identified as a high priority at the G7 Science Ministers Meeting (Berlin, 2015), highlighting the concern about plastics and related risks to marine life. In order to develop effective strategies for the establishment of programmes of measures aiming to reduce plastics and its possible impacts, it is necessary to identify and quantify sources of litter and their pathways to the marine environment.

Literature review indicates that knowledge of marine litter sources and quantities is still very limited. At EU scale, there is no comprehensive comparable information about the amount of litter being transported through rivers into the sea. It can be expected that riverine inputs to the sea are highly variable between different river catchment areas and periods. Therefore, it is the river-sea boundary where research efforts are needed in order to gather solid knowledge and data on riverine litter inputs.

Within the MSFD Implementation Strategy, and in agreement with the WFD chemicals working group, the MSFD Technical Group on Marine Litter has been mandated to prepare a report on the currently available techniques for the quantification of marine litter fluxes into the European Seas. A comprehensive overview is needed in order to prepare harmonization of approaches.

This technical report compiles the options for quantification of riverine litter fluxes, focusing on the monitoring of anthropogenic debris that enters the seas via rivers. It also presents the scientific and technical background regarding litter in river systems, their flow regime and basic properties. The purpose is to allow the building of data sets which enable the comparison of litter flows from different rivers into the marine environment. It also elaborates on the type of data which is needed with respect to the implementation of the MSFD. The main topic is: possible ways of sampling and methods to establish trends in the occurrence of riverine litter.

The scope is limited to monitoring of litter objects and fragments with positive buoyancy, i.e. those on the water surface and in the water column. This report does not allow final recommendations on the best methodology to be used, but presents best practices, as far as possible.

2 Methodologies for the quantification of riverine litter fluxes

An extensive literature review has been performed in order to identify the existing options for the monitoring of litter items in rivers. Monitoring of riverine litter can be based on observation and collection methods. Both approaches have been applied in river bank and river water monitoring. Methodologies are described and technical details are reported whenever available.

Observation methods (visual observations or acquisition of surface images) can be used on river banks and river water surface for monitoring of meso (0.5-2.5 cm) and macro (>2.5 cm) litter. Observation on river banks has been mainly used on mobility and transport studies, but it does not directly reflect riverine litter inputs to the sea. In contrast, observation on river water surface, combined with river flow measures, can provide estimates on floating litter fluxes to the sea.

Regarding collection methods, which involve physical collection of litter, there are different options that can be used in river bank and river water (surface/column). Collection methods can cover all litter size categories: micro (<0.5 cm), meso and macro. Collection in river banks can provide abundance and composition information; and have been used in accumulation/mobility studies. Unfortunately, as mentioned for the observation methods, river bank monitoring do not directly retrieve data on litter fluxes to the sea. On the other hand, collection methods for litter in river water can be targeted to all different sizes of floating (water surface) or suspended (water column) litter. Methodologies are mostly based on trapping items/particles by using nets or cage-like structures, although collection of floating meso and macro litter can also be done by means of skimming water surface (e.g. floating booms). Net mesh size will determine the fraction of litter collected. A particular case is collection of micro litter in river water, where dynamic and stationary sampling strategies are used by means of neuston nets (e.g. manta trawls or conical driftnets), following methodologies evolved from classic plankton sampling in the marine environment. With appropriate measurements of river flow data, results from collection of floating/suspended litter can be expressed as riverine litter fluxes to the sea.

Monitoring is expected to be performed in the river/sea boundary, meaning estuarine areas, in order to gather data on riverine inputs to the sea. River surface observation and river surface/column litter collection are feasible approaches for quantification of litter fluxes to the marine environment. Both floating and suspended litter compartments are recommended for monitoring in order to obtain complementary information, allowing better estimations of litter fluxes. River surface water speed and/or flow data are needed parameters to allow calculation of litter fluxes. Characteristics of rivers flow regime, seasonal variability and environmental factors (e.g. storm events, wind, tides and others) have to be taken into account in the design of monitoring programs for an adequate coverage of variability in litter quantities. Some important features are the selection of monitoring sites, sampling compartment, frequency, timing and sample size (surface and/or volume).

3 Literature

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Plastics and the Society

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Abstract

Plastics with a current world production of nearly 300 MMT, annually has enjoyed the fastest growth rate of any material, especially in sectors such as packaging, building construction and transportation. Its popularity and success as a material is attributed to a set of unique material properties coupled with low cost. Plastics deliver exceptional mechanical properties, ease of formability, bio-inertness, recyclability and given its relatively low density allows light-weight products making it a a unique material. Societal benefits of plastics, acheived at a low cost has ensured its growth as a material in diverse applications.

This presentation will discuss plastics and their role in the society in the context of three broad areas: energy, resources and externalities (or emissions.) In each area, the value to the society and any potential adverse impacts will be considered drawing examples from packaging, building and transportation applications. The discussion will focus on sustainability considerations and therefore also look at future societal benefits from the material.

In the broad area of energy the role of plastics in conservation as well as energy production will be described. Conservation of fossil-fuel based materials is a critical element in sustainability. An aspect of conservation is to decouple plastics from fossil-fuel raw materials to obtain bio-based plastics. Recovery of post-waste plastics to conserve energy and materials is therefore an important focus in moving the industry towards sustainability. A particularly salient area in recent discussions on plastics and society has been the potential adverse impacts of plastics in terms of contaminating the environment. Sustainable global growth of plastics in the future would require these to be minimized.

RIMMEL: the RIverine and Marine floating macro litter Monitoring and Modelling of Environmental Loading

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1 Introduction

The Marine Strategy Framework Directive (MSFD) (European Commission, 2008) is the key policy framework for the protection of the marine environment across Europe. It is aimed to achieve Good Environmental Status (GES) of the EU's marine waters by 2020. The MSFD is divided into 11 thematic descriptors, being Descriptor 10 the one dedicated to the assessment of Marine Litter: “Properties and quantities of marine litter do not cause harm to the coastal and marine environment”.

Marine litter is an issue at global level and it has been identified as a high priority at the G7 Science Ministers Meeting (Berlin, 2015), highlighting the concern about plastics and related risks to marine life. On the other hand, literature refers to riverine and freshwater inputs as main sources of litter to the seas, but little research has been done on this subject so far. This lack of scientific data and knowledge calls for initiatives that can build capacity for quantification and monitoring in European rivers for environmental assessment of litter inputs to the marine environment. In this regard, the JRC has launched an exploratory research project:

The RIMMEL project aims to quantify floating macro-litter loads through rivers to marine waters, by collecting existing data and developing a European observation network for acquisition of new data. Eventually, results will be used to build a statistical inverse model of litter loading based on the up-stream catchments characteristics. This is the first-ever European-scale attempt for quantification of loads of floating litter to the European seas.

Additionally, the project will develop the RiverLitterCam methodology for continuous recording of floating litter in rivers, providing a new tool for observation and assessment of litter in freshwater/ estuarine environments.

Results will bring a better understanding on litter dynamics from freshwater to marine environments, contributing to source identification and quantification, thus supporting policy makers for improvement of management options.

2 Join the RIMMEL network

RIMMEL launches a call for expression of interest to join the *Floating Litter Observation Monitoring Network*. The project will provide a monitoring protocol for observation of floating litter along with a tablet computer application based on MSFD litter category list (software developed by JRC), allowing harmonization of the approach at international level.

We will use Visual Observation as a simple method to monitor fluxes of floating litter from rivers to the sea. Our approach considers the following:

- Contribution from researchers, MS authorities, River Commissions, NGOs ...
- Visual observations of floating macro litter (>2.5 cm) on river water surface
- Monitoring at river/sea boundary (e.g. estuaries) from a elevated position (e.g. bridges)
- Harmonized approach using the JRC Floating Litter Monitoring App.
- Regular monitoring based short individual surveys (e.g. 1/2 hour survey per week)

Interested parties are encouraged to contact RIMMEL in order to receive further info: rimmel@jrc.ec.europa.eu.

3 Literature

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Citizen science for riverine monitoring

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1 Introduction

Because of the litter taken into account by the MSFD but not by the WFD in order to reach the GES, and because of the lack of protocol to assess the quantity and typology of litter in river (Rech et al., 2014. Lechner et al., 2014) we decided to launch the Riverine Input project in 2013. The main purpose of the project was to collect data about the quantity and typology of litter through setting up a protocol with the help of volunteers. Once collected we decided to set up a specific litter categorisation list dedicated to rivers. The database allowed us to have an overview of the problems, to identify the typologies of activities which are likely to be responsible of this pollution and later will allow us to prepare recommendations in order to stop litter entering into aquatic ecosystems.

2 Methods

We conducted monthly sampling on our 7 spots corresponding to the different pressures that can impact the river (urban, agricultural, industrial, touristic, sewage treatment plants). The same areas were collected from on the banks each time. Hydro-morphological and hydraulic parameters were measured in order to assess the influence of environmental parameters on litter accumulation. We conducted sampling every month on the banks of the river and tributaries. The first sampling was done in February 2014. Furthermore, the first impacted beach by the river's plume was monitored according to OSPAR methodology. Monitoring of macro-litter (more than 0.5 cm) was completed with volunteers under the Surfrider Foundation Europe's supervision. The total surface area of the river banks collected from was 1 683 m^2. We trained volunteers to execute the characterisation and counting of litter following the list we had set up. The list was established in order to obtain comparable data with the OSPAR monitoring. This list contains specific items which are more likely present in river banks and omits some other items which are not present in rivers.

3 Results

84 817 items were collected during the two years survey. 46 299 items were collected on the river banks. 37 918 items on the first impacted beach by the plume of the river (OSPAR monitoring). Plastics-Polystyrene represents 88.3 % of collected items the first year and 85.1 % for the second year. On the beach it represents 89.6 % of the amount of litter collected the first year and 90.9 % the second year. This proportion ranged from 62 % to 96.8 % according to the different spots in river.

Statistical analysis are ongoing and are not presented here, yet (May 6th, 2016). (We will conduct comparison analysis test of proportion of material between the different spots, influence of hydrologic parameters on litter accumulation, influence of rain fall on this accumulation…).

4 Discussion

Once statistical analysis will be conducted we will provide complete discussion.

5 Literature

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Trashbusters H_2O – Crash the Trash! A youth Project for Clean Waters

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1 Youth Association for the Protection of Nature

The NAJU (Youth Association for the Protection of Nature) is the independent youth division of the NABU (Nature And Biodiversity Conservation Union) and is Germany's largest young people's organization for the protection of nature and the environment. Founded in 1982, its goal is to protect and safeguard environmental integrity, biodiversity and thus to conserve the natural foundations of human life through a range of conservation measures.

The NAJU reaches out to its more than 80,000 members through extra-curricular environmental education, environmental protection projects and practical conservation work. NAJU is active throughout Germany based on its 16 state associations and over 1,000 local groups. NAJU also collaborates with numerous partners of an extensive network in Germany and abroad.

One of our more recent projects is the "Trashbusters H_2O" project, which is being supported by the German Environment Agency (UBA) on behalf of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

2 A worldwide challenge addressed on a local scale

Around 70 % of the world's surface is covered by water. The largest component of the global hydrosphere is comprised by the world oceans. Shockingly, more than 10 million tons of trash finds its way into the oceans, around 75 % of which is plastic waste. Scientists so far discovered five extensive surficial accumulations of plastic waste, some of which occupying an area as big as Germany, Austria and Switzerland together. The Pacific between California and Hawaii contains plastic waste amounting to more than six times the abundance of plankton. The impacts of this vast accumulation of waste on marine ecosystems are already clearly discernible and are expected to increase significantly in the foreseeable future.

These observations have been the major motivation for NAJU's Trashbusters H_2O project. The project aims to provide education to children and young adults about plastic waste in marine and inland waters. The project strives to motivate young people to start their own projects and actions and to avoid and remove littering in lakes, rivers and oceans. This includes possibly/preferably the modification of their own consumption behaviour and their use of resources. The project targets children and youths between the age of 6 to 19 years old and comprises either extra-curricular- or activities within schools. Thanks to a wide-ranging dissemination through nation-wide publications, news releases and social media campaigns, the youth's efforts and engagement are being recognized and publicized. In that way, their work attracts more attention and an increasing number of youngsters are being informed about the issues addressed.

3 Components of the project

3.1 Actions

Since the "International Coastal Clean Up Day" takes place once a year in September, this day has been picked to be the start of the Trashbusters H_2O Action Weeks that are carried out by youngsters dedicated to the project (Figure 2). All over the country, young people team up to clean up beaches and coastal environments during two weeks. To have their work included in the international statistics, participants are being asked to weigh the collected trash and report their results to the project coordinators. During the Action Weeks, an online map on trashbusters.de (Figure 1), the official project website and the Trashbusters H_2O app for mobile phones helps to raise interest in people to identify their own local clean-up area. Activities are not only restricted to water bodies. It is also useful to cleaning up the other areas in order to prevent trash finding its way into waters. To support groups, which are interested in organizing their own clean-up project, Trashbusters H_2O provides educational materials aimed to motivate and inform potential participants. In addition, there is the chance to win a competition, called the "Trashbusters Aqua Award", which is being given to a project that a committee of NAJU board members and experts of public relations of the NAJU office find extraordinarily creative and appealing.

Figure 1: Map of cleanups during the action weeks 2015 in Germany (www.trashbusters.de)

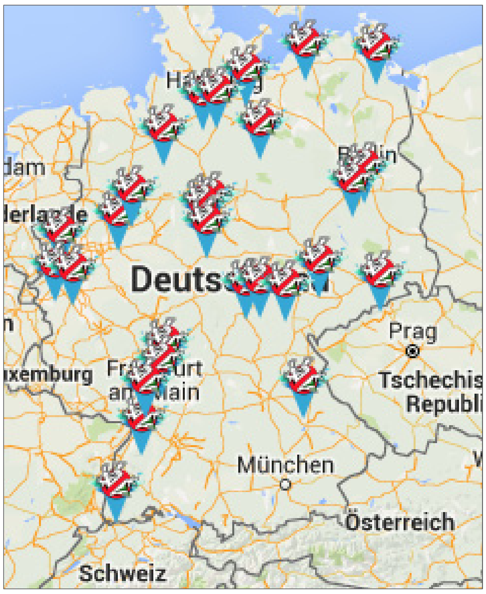

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Figure 2: Active youth group during the action weeks 2015

3.2 Educational materials

As part of the project, brochures (Figure 3) for two different ages (youth and kids) have been created to present information around the topic of plastic waste in marine and inland waters and to suggest ideas for self-organized projects.

The brochure for the youth is designed in an activating way. Groups of young people are called to use the brochure to learn about the topic and are being accompanied through the brochure on their way to organize their own project. The special design motivates the groups to paint, draw, cut and glue things onto the brochure and document their process of learning and planning.

Figure 3: Cover of the youth brochure

The brochure for kids provides ideas for learning stations about water and plastic pollution that have to be accomplished by environmental educators or teachers.

The concepts aim to not only provide a unique educational experience, but to encourage young people to become active. This is part of the United Nations program of Education for Sustainable Development (ESD).

3.3 Youth eco-festival

Figure 4: Logo of the youth eco-festival

Another part of the project is the environmental youth festival „Crash the Trash" (Figure 4). Youth festivals are organized by the NAJU bi-annually in summer. This year's festival is dedicated to the world's polluted waters and to promoting the goals of the Trashbusters H_2O project. Young adults above the age of 14 will take part in workshops on water- and resource-saving. They will also participate in hands-on environmental activities and will be encouraged to identify creative ways for the recycling and re-use of trash. The workshops will inspire group work in order to find solutions and to collect ideas for solving major environmental problems.

3.4 Educational approach

Plastic waste in waters represents a problem which results in economic and social impacts on the global scale that are caused by our own actions and behaviour. Through Trashbusters H2O, children and young adults are being guided to deal with these issues. By supplying educational materials, a website and an app for mobile phones, the project aims to help young people to develop a well-founded opinion, to enable advocacy for behavioural changes related to environmental issues and to participate actively. Aside of the educational value, the project also aims to convey a feeling of being part of a bigger movement. It is intended to unite young people who strive to enable environmental changes without yet knowing where to start from or who to turn to.

4 Resources

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Youth Association for the Protection of Nature (NAJU): Discover NAJU. www.naju.de/english. Access on 21.03.2016.

Plastics as a systemic risk of social-ecological supply systems

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1 Introduction

Plastic is an ambivalent material. It has become the ubiquitous material with multiple functional properties and a broad variety of applications like in packaging – the largest application – , building and construction, automotive, electronics or in the agriculture sector. Plastic is considered the workhorse of modern economy (WEF 2016). Its production has increased twentyfold in the last 50 years from 15 million tonnes in 1964 to 311 million tonnes in 2014 (WEF 2016, PlasticsEurope 2013). Though plastic is delivering many benefits, drawbacks are becoming more apparent. The single-use mentality especially of plastic packaging material contrasts with the durability of the material in the environment. While plastic has been known as a factor for environmental pollution – symbolized by the plastic bag – for a long time, recent scientific evidence on the massive accumulation in the oceans and the new risks associated with microplastics and chemical additives has led to an upswing of the debate on environmental impacts of plastic. There is a high insecurity concerning the adverse effects on human health and the environment (Oehlmann et al. 2009; Talsness et al. 2009). To understand the risks and their production associated with plastic a systemic approach is needed.

In our newly started junior research group PlastX, which is funded by the BMBF within the framework of Social-Ecological Research (SÖF), we are aiming to pursue such a systemic approach. According to our research program for the next five years we will analyze plastic as a systemic risk for social-ecological supply systems in an inter- and transdisciplinary manner. Therefore, our interdisciplinary research team comprises researchers from biology, chemistry, geography and sociology. In the following, our research program will be outlined.

2 Research approach

2.1 Systemic risk perspective

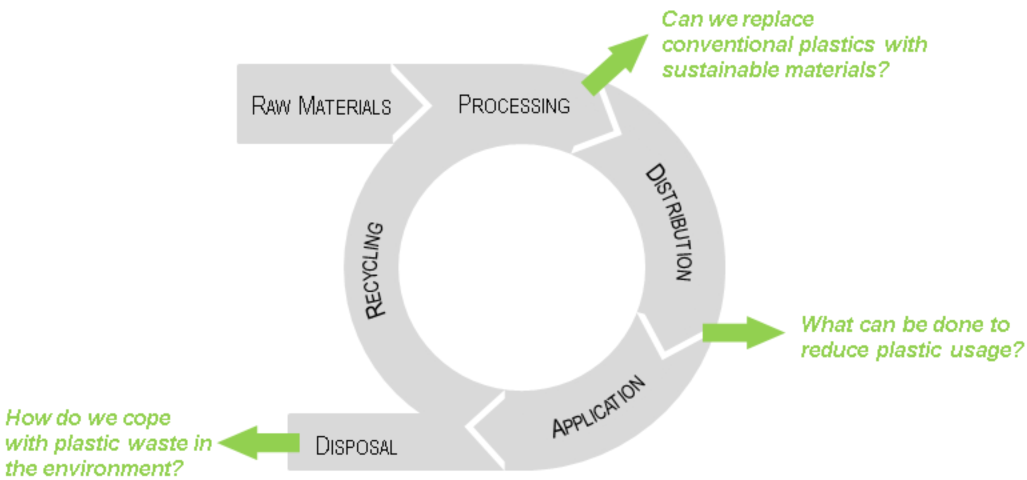
The production of plastic and its leakage in the ecosystem has so far been part of the normal mode of operation of the social-ecological supply system (Keil et al. 2008). The adverse effects on ecosystems such as the oceans may in turn have feedback effects on the social systems and human health (Bergmann, Gutow & Klages 2015). While classical risk analysis focus on hazardous events and their effects on a single sector, systemic risk analysis is broadening the perspective and takes into account that the risks might affect entire systems and their linked systems as it might for example be the case in a food supply system (Renn & Keil 2008). Thus, as Keil et al. (2008:357) put it "It is not just events such as constructional faults, operating errors, malfunctions of system components, or disastrous external events that must be taken into account, but also the processes of self-endangerment brought about by modern, highly interconnected societies." Plastic production and the consumption of plastic products is a global phenomenon, thus the risk production is equally global, ambiguous and complex as well.

Different constellations of actors from various systems are involved, who can be risk producing and risk affected at the same time. The concept of individual responsibility is important when it comes to waste disposal. Still, relying on the individual responsibility alone will not solve the problem as leakages into the environment will nonetheless most likely continue (Ocean Conservancy 2015). Thus, in order to tackle and govern systemic risks a systemic approach is needed. First approaches towards a systemic risk governance have been elaborated by Renn et al. (2007) or Beisheim, Rudloff & Ulmer (2012). They stress that in the case of scientific uncertainty the precautionary principle as a legal instrument to deal with possible hazardous situations comes into play. Further, the role of collective action and the inclusion of the different actors are emphasized with the aim to reorganize the system and so to minimize risks. Building on this, we will tackle issues like prevention, alternatives to the present situation and the management of plastic within different areas of the plastic life cycle (Fig. 1) which comprises consumption and packaging, plastic governance and ecotoxicological effects. Guiding questions are:

- Can we replace conventional plastic food packaging with sustainable materials?
- What can be done to reduce the usage of plastic?
- How do we cope with plastic waste in the environment?

While working on these questions we want to collaboratively analyze how risks associated with plastics are shared by different actors, which will be further outlined in section 3.

Figure 1: Plastic life cycle and research areas of PlastX



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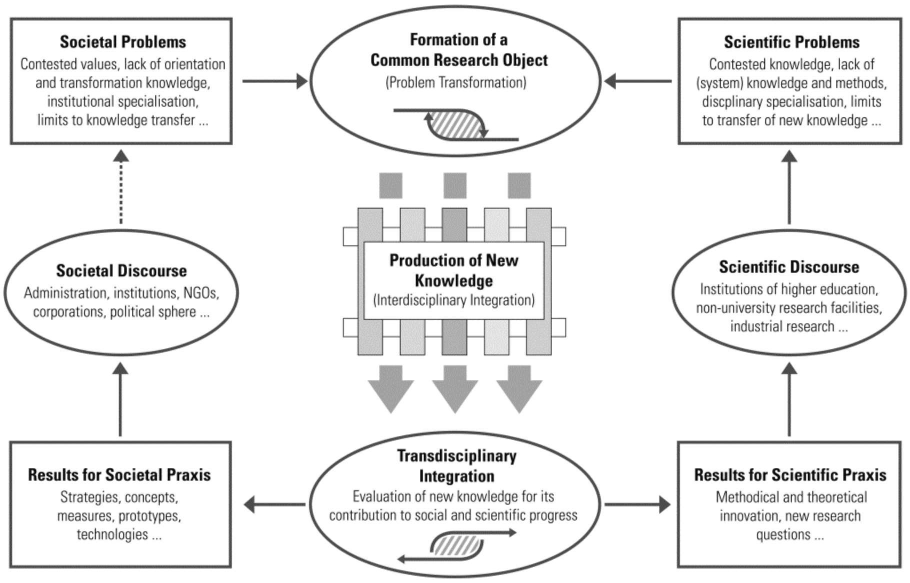
2.2 Transdisciplinary approach

The reasons we are following a transdisciplinary approach is that, we are dealing with "real world" problems and not solely scientifically oriented research questions. We are working with stakeholders from the food sector, public authorities and international organisations. The integration of knowledge from different disciplines and from societal stakeholders is central, but can easily fail if not designed and pursued properly. Therefore, we draw on the model conceptualised at the ISOE – Institute for Social-Ecological Research for the transdisciplinary research process (Figure 2) (Jahn, Bergmann & Keil 2012; Bergmann et al. 2012). A shared problem understanding is jointly established integrating societal knowledge. From this joint understanding, research questions for each of the disciplinary work packages (consumption and packaging, plastic governance and ecotoxicological effects of microplastic) are derived. Through social, communicative and cognitive integration of the disciplinary research and by taking the knowledge of societal stakeholders into account, we are aiming to develop adequate solutions and knowledge for change.

Figure 2: Transdisciplinary Research Process



© Jahn et al. (2012)

3 Research program

The identified research areas will be investigated by an interdisciplinary team and comprise the disciplinary working packages and an integrated module.

3.1 Disciplinary perspectives

- What can be done to reduce usage of plastic?

The largest application for plastic is packaging with increasing numbers in Germany (UBA 2015). At the same time there are trends of increased consumer awareness regarding environment-friendly packaging (consumer studies of pwc 2015, Ipsos 2009.). Against this background we seek to understand consumer and producer behavior and their linkages. Therefore, we will analyze everyday consumption practices, life-style specific valorization and (risk) perceptions of consumers regarding plastic packaging on the one hand and marketing and sustainability strategies of producers and distributors in the food sector on the other. On the basis of consumer and producer surveys, demands, trends and requirements profiles of packaging will be identified to support food retailers' strategies to reduce packaging material.

- Can we replace conventional plastic food packaging with sustainable materials?

We will further examine sustainable packaging alternatives such as bioplastics. Most of the currently produced bioplastics have to be optimized regarding their environmental benefits compared to conventional plastics (UBA 2012). Furthermore, there is a demand that future studies should focus on the practical implementation of bioplastics as packaging alternatives (Kumar et al. 2014). Therefore, sustainable biopolymers will be identified regarding their application potential as food packaging material in collaboration with partners from the food sector. We will consider the chemical properties required for packaging as well as the degradability under environmental conditions. We will further consider economic aspects regarding the production and application of the alternative material on a larger scale.

- How do we cope with plastic waste in the environment?

We will look at aspects of managing plastic waste in the environment in two different ways:

First, we are planning to develop an ecotoxicological risk assessment concept for microplastics in rivers since previous research on microplastics has dealt almost exclusively with effects on marine ecosystems (Cole et al. 2011, Wright et al. 2013). By examining how freshwater organisms are exposed to and affected by microplastics, we will contribute to a better understanding of the actual hazard microplastics pose to aquatic ecosystems. In collaboration with stakeholders from a federal agency responsible for waters, the risk assessment concept will support policy recommendations and solution strategies concerning the regulation of the release of microplastics into the environment.

Second, we will analyze the governance of plastic waste in the ocean. We are aiming to understand how global environmental risks are dealt with, which governing mechanisms and regulations are applied or developed. A multi-level perspective (Brunnengräber & Walker 2007) is taken to understand how global policies regarding the "plastic problem" are deployed and how they are implemented on the local level and at the same time shaped by local action. These scale interplays of the risk governance will be scrutinized in several case studies in close collaboration with stakeholders to identify and test management strategies and develop best practices.

3.2 Integrative perspective: Shared risks

In our integrative module we operationalise systemic risks as shared risks, which we will scrutinize via a stakeholder analysis. The idea of "shared risks" is promoted as a policy and management instrument in the water sector by WWF (WWF und HSBC 2009, WWF 2013) as well as by the CEO Water Mandate of the Global Compact of the United Nations. The approach starts with the disaggregation of risks into physical, regulatory and reputational risks that actors like a corporation or public authorities are facing. It then points to the fact that interdependencies exist and risks are shared, which to some degree calls for collective action (Comfort 2008). Taking all this into account and drawing on the systemic character of the risks, we will depict the interdependencies between the actors. Bringing inter- and transdisciplinary expertise from the different areas (consumption and packaging, plastic governance and ecotoxicological effects of microplastics) together allows to understand the underlying logics at work as well as perceptions and practices regarding these shared risks.

4 Conclusion

By the end of the project PlastX, the outcomes of the transdisciplinary work will contribute to both, societal as well as scientific issues related to plastics. The systemic approach aims to generate a comprehensive understanding of the associated risks and strengthens the awareness of the impacts of plastic usage. By integrating different disciplinary perspectives, the project team will develop practical solutions to manage, reduce, and substitute plastics.

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The New Plastics Economy – Rethinking the future of plastics

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1 Summary

The talk starts by presenting the main findings and conclusions of the report *The New Plastics Economy – Rethinking the future of plastics*, launched in January 2016 in Davos, by the World Economic Forum and the Ellen MacArthur Foundation, with analytical support from McKinsey & Company. After discussing the current, largely linear plastics system – with aquatic litter as just one symptom of the current ineffective system – a new vision, aligned with the principles of the circular economy, is presented – the *New Plastics Economy*. The talk continues by describing the systemic and collaborative approach required to capture the opportunities of this new plastics system, and ends by explaining how the Ellen MacArthur Foundation will mobilise the report's recommendations through their New Plastics Economy initiative – a concerted, global collaboration initiative that matches the scale of the challenge and the opportunity.

2 Findings and conclusions of *The New Plastics Economy – Rethinking the future of plastics*

2.1 The case for rethinking plastics, starting with packaging

Plastics have become the ubiquitous workhorse material of the modern economy – combining unrivalled functional properties with low cost. Their use has increased twenty-fold in the past half-century and is expected to double again in the next 20 years. Today nearly everyone, everywhere, every day comes into contact with plastics – especially plastic packaging, the focus of this talk.

While plastics and plastic packaging are an integral part of the global economy and deliver many benefits, their value chains currently entail significant drawbacks. Most plastic packaging is used only once; 95 % of the value of plastic packaging material, worth $80-120 billion annually, is lost to the economy. Additionally, plastic packaging generates significant negative externalities. A staggering 32 % of plastic packaging escapes collection systems, generating significant economic costs by reducing the productivity of vital natural systems such as aquatic environments and clogging urban infrastructure. The cost of such after-use externalities for plastic packaging, plus the cost associated with greenhouse gas emissions from its production, is conservatively estimated at USD 40 billion annually – exceeding the plastic packaging industry's profit pool. Given projected growth in consumption, in a business-as-usual scenario, by 2050 oceans could contain more plastics than fish (by weight), and the entire plastics industry could consume 20 % of total oil production, and 15 % of the annual carbon budget.

Figure 1: Plastic production increased twenty-fold over the last 50 years

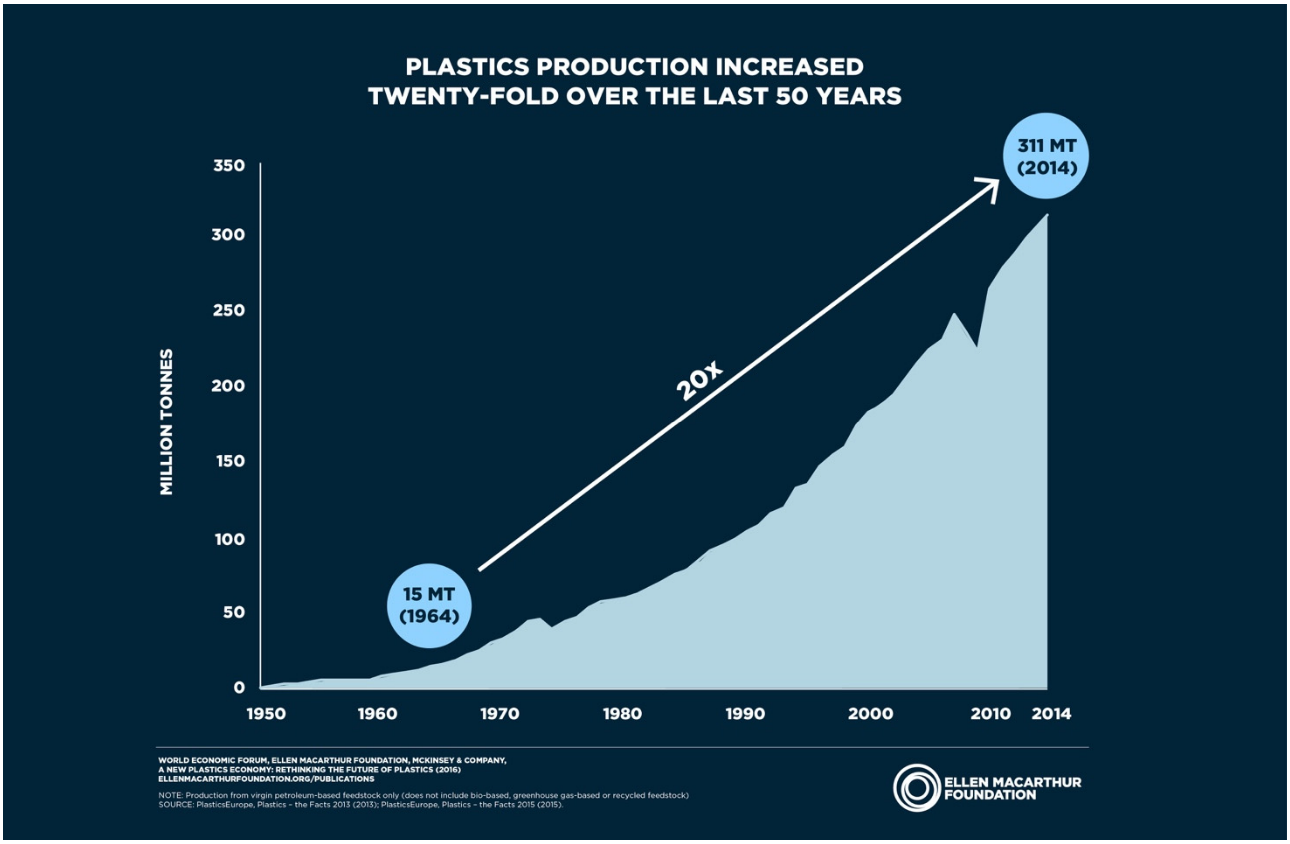
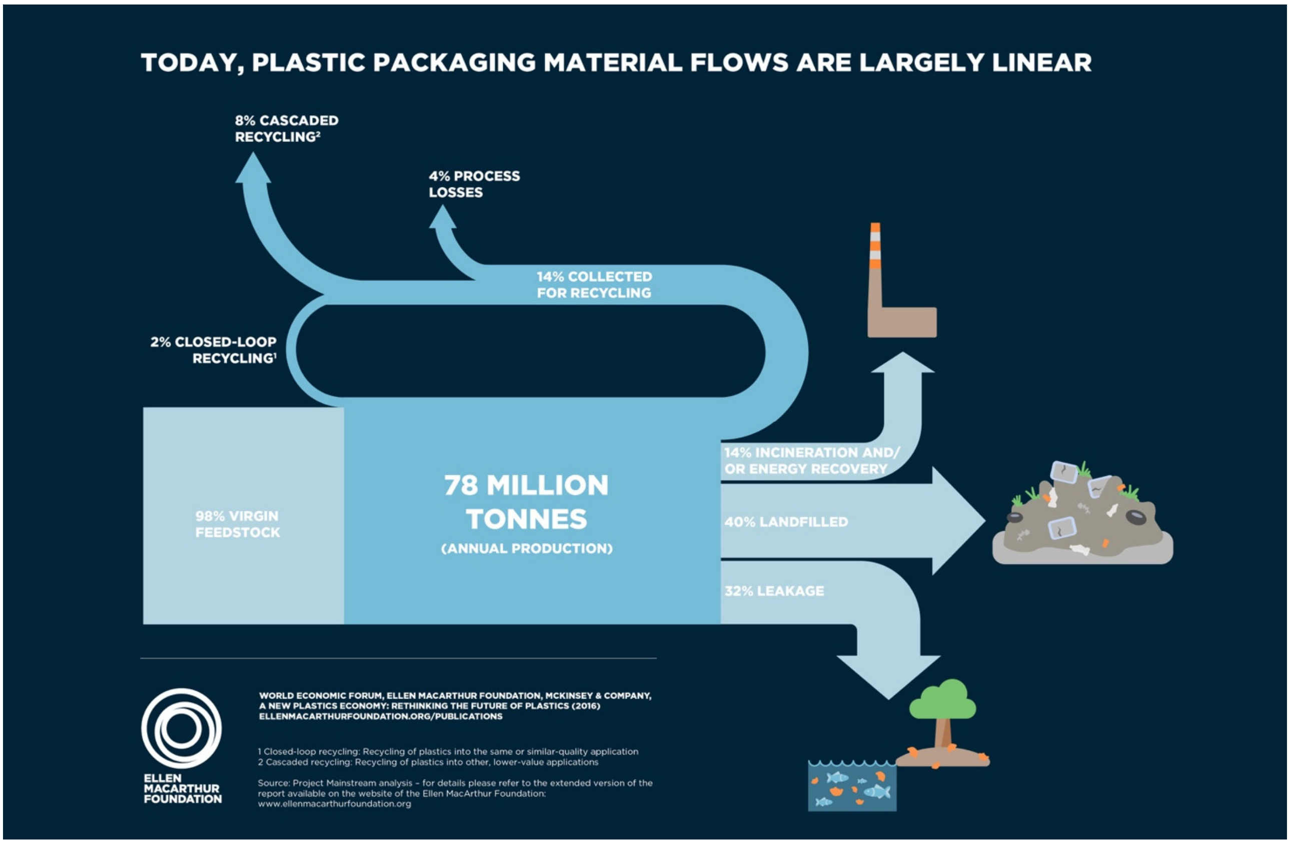


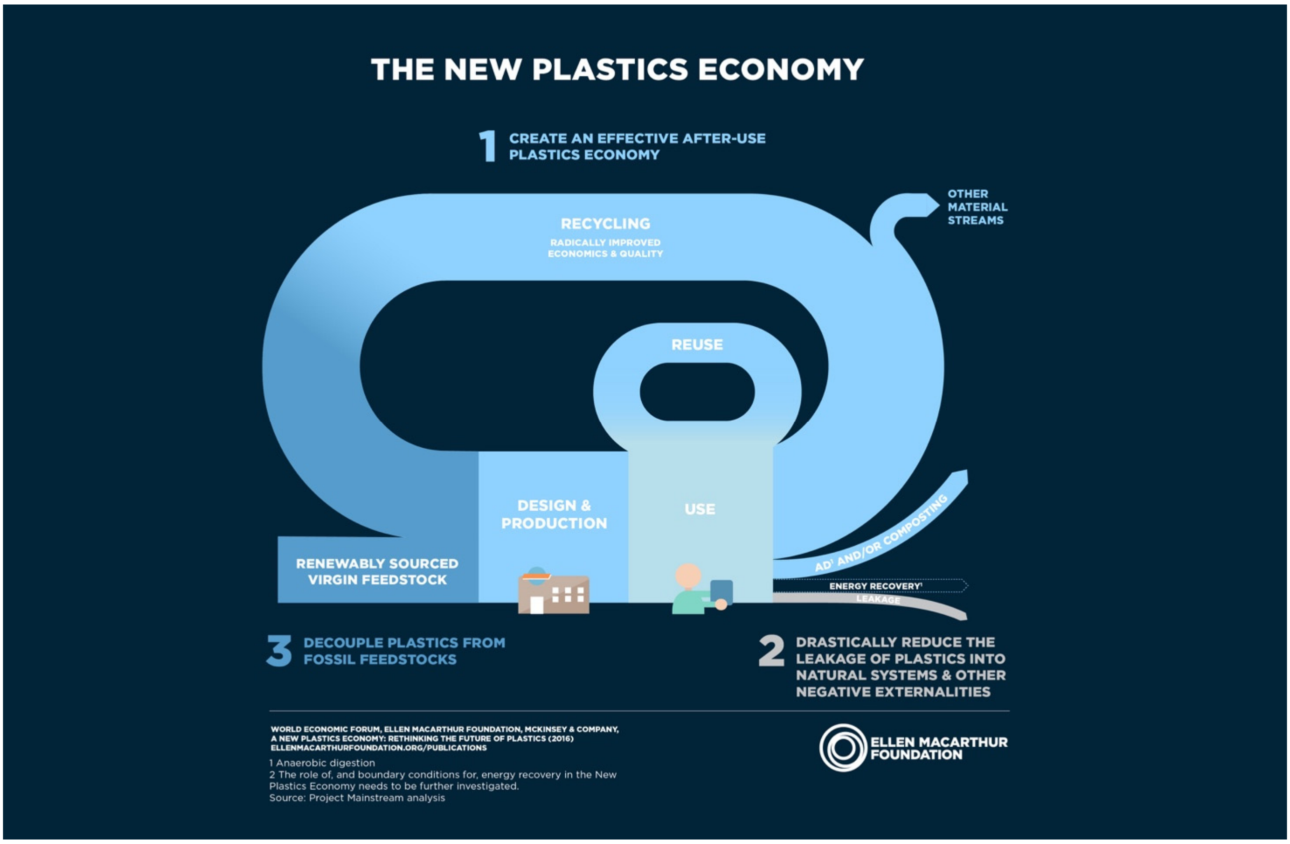
Figure 2: Today, plastic packaging material flows are largely linear



2.2 The New Plastics Economy: Capturing the opportunity

In overcoming the drawbacks of the current system, an opportunity beckons: enhancing system effectiveness to achieve better economic and environmental outcomes while continuing to harness the many benefits of plastic packaging. The 'New Plastics Economy' offers a new vision, aligned with the principles of the circular economy, to capture these opportunities.

Figure 3: The New Plastics Economy



2.3 The New Plastics Economy demands a new approach

With an explicitly systemic and collaborative approach, the New Plastics Economy aims to overcome the limitations of today's incremental improvements and fragmented initiatives, to create a shared sense of direction, to spark a wave of innovation and to move the plastics value chain into a positive spiral of value capture, stronger economics, and better environmental outcomes. The report outlines a fundamental rethink for plastic packaging and plastics in general; it offers a new approach with the potential to transform global plastic packaging materials flows and thereby usher in the New Plastics Economy.

3 The New Plastics Economy initiative

In January 2016, the World Economic Forum and the Ellen MacArthur Foundation, with analytical support from McKinsey & Company, launched the report "The New Plastics Economy – Rethinking the future of plastics" at the World Economic Forum in Davos, comprehensively laying out, for the very first time, the material flows in and drawbacks of today's plastics economy described above as well as the outline of a system with fundamentally better economic and environmental outcomes: the New Plastics Economy. The ground-breaking report became a global headline, reached a wide global audience, and is already shaping policymaker and business action.

Building on the success of the report, the Ellen MacArthur Foundation has launched in May the New Plastics Economy initiative, a bold, ambitious, 3-year initiative to mobilise the report's recommendations, working with stakeholders across the global plastics value chain, including consumer goods companies, retailers, plastic packaging producers and plastics manufacturers, businesses involved in collection, sorting and reprocessing, cities, policymakers and NGOs.

Initial areas of focus are:

1. Set up a global cross-value chain dialogue mechanism
2. Converge and re-design plastic packaging materials/formats and after-use systems through a Global Plastics Protocol
3. Mobilise targeted 'moon shot' innovations with the potential to scale globally
4. Develop insights and build a base of economic and scientific evidence
5. Engage policymakers

4 Literature

World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, *The New Plastics Economy – Rethinking the future of plastics* (2016, http://www.ellenmacarthurfoundation.org/publications)

European overview on management options and measures in place for plastics in freshwater environments

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1 Introduction

Beginning in the late 70s of last century reports emerged that oceans are a sink for plastic waste. Plastic pieces the sizes of less than 5 mm are referred to as microplastics, which reach high densities in water and sediments and interact with organisms and the environment in a variety of ways (Thompson 2015). They consist of synthetic polymer particles with low solubility in water and a low degradation rate. A great deal of microplastics is formed in the environment by weathering processes of larger particles (secondary microplastics) whereas primary microplastics are added to cosmetics and (cleaning) products or originate from industrial emissions during production, manufacturing or transport (Verschoor 2015). Once being dispersed in the environment, it is not feasible to remove them entirely due to their small size and continuous breakdown of larger items. Therefore, preventively tackling the problem at source is widely recognized as being the optimal approach, but microplastics are currently not subject to direct regulation.

Corresponding with a tremendous increase of the worldwide production of plastics since the seventies, scientific surveys describe the increase of plastics contamination in the marine environment (Andrady 2011, Moore 2008). Several investigations describe the amounts of plastics floating at sea and estimate that approx. 80 % of the input is of terrestrial sources (UNEP 2009). Rivers and freshwater systems have to be considered as contributors of plastics but sound studies in freshwater systems still are scarce (Faure 2014, Hohenblum 2015, Imhof 2013, Moore 2005, Zbyszewski 2011).

Those freshwater studies, however, which have been carried out in recent years, showed that plastic occurs in some parts in concentrations comparable to marine environments. A number of countries assigned freshwater studies to specifically address plastics in national rivers and lakes. Reports from Austria (Danube River), Switzerland (Lakes and Rhone River) as well as from non-coastal regions in Germany underline the importance of the topic. Results are barely comparable since a variety of methods is currently applied for sampling and analysis: some results relate to the surface of the sampled water body (and disregard spatial distribution of plastics within the water body), others relate to the sampled volume. At the same time, some studies investigate plastic concentrations while others examine particle numbers, especially of plastics in the lower µm range. Along with a binding definition of the overall problem, harmonization and standardisation of methods are needed to acquire knowledge on the environmental distribution of plastics. Only a harmonized approach will be able to identify relevant sources, to deduct appropriate measures and to monitor their efficacy.

2 Methods

2.2 Questionnaire survey on plastics in freshwater environments among EU countries

Currently, a systematic overview is missing on management options for plastics in freshwater environments. Similar to monitoring activities, freshwater management lags behind the marine community where concrete measures have been proposed and implemented to reduce plastic pollution in the seas, e.g. Regional Action Plan for Marine Litter in the Baltic Sea (HELCOM 2015).

The German Environmental Agency (UBA) and the Federal Institute of Hydrology (BfG) initiated a voluntary questionnaire to elaborate a coherent picture of activities and actions related to plastics in European freshwater environments. The questionnaire was informally mailed to the representatives of the European countries in the Strategic Coordination Group (SCG). The SCG coordinates and gives advice to the Common Implementation Strategy (CIS) of the European Water Framework Directive. In total, 28 member states of the European Union plus 6 non-EU countries were addressed and asked to complete the questionnaire.

The first seven questions of the questionnaire dealt with monitoring efforts for plastics in freshwater environments (see abstract Reifferscheid et al., 'Overview on plastics in European freshwater environments – Results of a survey'). Questions 8-10 sought for information and examples related to perception and management of plastics in rivers and lakes:

- Q8: How are plastics in freshwater environments perceived in your country?
- Q9: Are there discussions in your country on reduction measures for plastics in freshwater environments?
- Q10: Are there existing or planned actions in your country to reduce inputs of plastics and/or to remove existing litter from freshwater environments?

2.2 Specific examples from two EU countries

Two Member States, Austria and the Netherlands have investigated in detail exposure scenarios for plastics in freshwater environments. Discussions with stakeholders resulted in recommendations to control the pollution of freshwater systems with plastics. These management options will be analysed in relation to the outcome of the questionnaire survey among European countries.

3 Results

Questionnaire survey: feedback

14 countries (Austria, Belgium, Denmark, Germany, Iceland, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Slovakia, and United Kingdom) returned a completed questionnaire (41 %).

3.1 How are plastics in freshwater environments perceived in European countries?

Question 8 of the questionnaire survey addressed risk perception: "How are plastics in freshwater environments perceived in your country e.g., with regard to media reports, social networks, campaigns of non-governmental organisations?"

Public perception with regard to media reports, social networks or campaigns of non-governmental organisations rated in the majority of the responses (57 %) as average (3) on a scale between (1) and (5, indicating maximum attention). In three countries (21 %) public perception was rated low (1, 2) and in three countries (21 %) it was perceived as an increased (4) concern. No country evaluated public perception as high (5), whereas those countries, which carried out freshwater studies, often evaluated public perception of the topic in their country as increased (4).

The average value of positive responses was 2.9 within a range of 1-5. Higher than average ratings correlate with existing monitoring programs and undertaken measures in concerning countries (e.g. Austria, Belgium, Germany and the Netherlands).

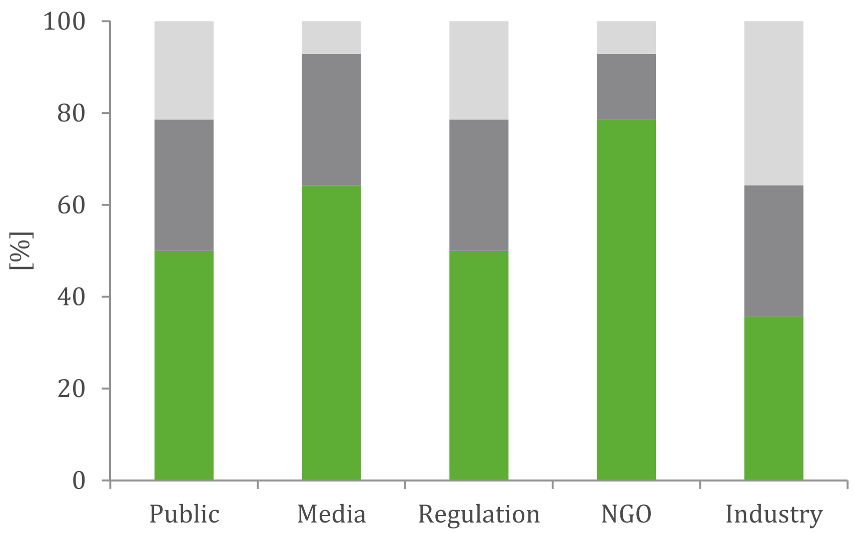
It is interesting to see that a lot of research on plastic in freshwater systems has been promoted by landlocked countries (Austria, Switzerland, landlocked regions in Germany and the Netherlands). In contrast, less attention to plastics in freshwater environments is apparently paid by countries with extended coastal regions.

3.2 Are reduction measures for plastics in freshwater environments discussed in European countries?

Question 9 of the questionnaire survey addressed water management: "Are there discussions in your country on reduction measures for plastics in freshwater environments?"

Overall, almost all participants of the survey stated on-going discussions on reduction measures in their countries. The survey revealed that NGOs (almost 80 %) and media (64 %) discuss reduction measures quite intensively, followed by discussions in the public and regulatory sectors (both 50 %). Almost 40 % of the questionnaires (36 %) mentioned discussions in the industrial sector.

Figure 1: Discussion on reduction measures in the surveyed European countries



The columns present the percentage of the selected answer option. Label of the stacked columns: green-yes; dark grey-no; light grey-not stated. Multiple answers were possible without specific ranking. Data source: Results of the European survey.

The use of microplastics in consumer products (especially cosmetics and detergents) is a hot topic. At present time, producers have already phased out the use of micro-plastics in some products on a voluntary basis. There are, however, still products on the market. At the EU Environment Council in December 2014, Austria, Belgium, the Netherlands, Luxembourg and Sweden jointly called on the EU Member States to ban microplastic added to products in order to protect the aquatic environment from pollution (2014).

Additional responses from other member state are summarized below:

Ireland envisaged the potential impact of river basin management plans under the Water Framework Directive, and also mentioned concrete actions in place, i.e. to reduce litter input from land based sources under the Marine Strategy Framework Directive Programme of Measures and the OSPAR Regional Action Plan for Marine litter.

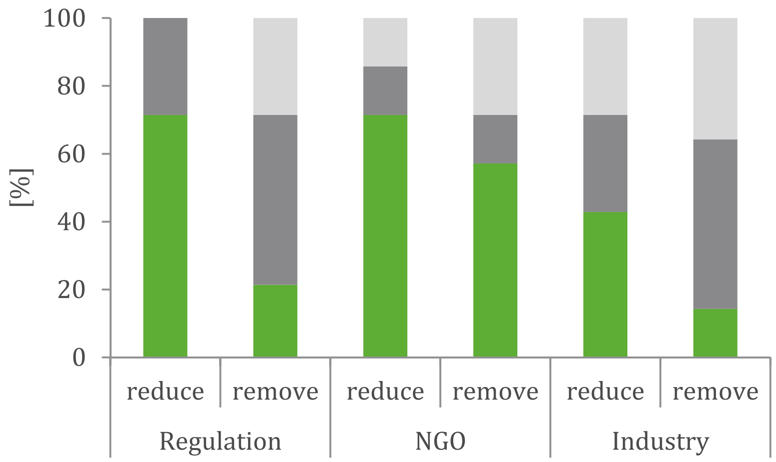
The **United Kingdom** consults two Scottish strategies that manage litter in terrestrial, coastal and marine environments. In a threefold approach, these programmes address the responsibility of individuals to act in an environmentally friendly manner (communication, education and support for business), infrastructure (providing/servicing bins, product design, guidance and future funding) and enforcement (improving the effectiveness of legislation and training). The overall objectives are monitoring plastics in the Scottish environment and subsequently reducing riverine plastic input into the marine compartment (Environmental Assessment Team Planning and Architecture Division Directorate for Local Government and Communities, 2013).

3.3 Do European countries reduce plastic inputs and/or remove plastic pollution from freshwater environments?

Question 10: “Are there existing or planned actions in your country to reduce inputs of plastics? - and/or to remove existing litter in freshwater environment?”

Planned and existing actions concerning the reduction of plastic-input and removal of existing litter in freshwater environments were assessed in relation to regulatory agencies, NGOs and industry. The summarized results are displayed in Figure 3. Overall, the majority of European countries, which responded, are planning or have already implemented measures to reduce the plastic waste from inland waters.

Figure 2: Existing and planned actions to reduce plastic inputs and to remove existing litter from freshwater environments



The columns present the percentage of the selected answer option. Label reduce: measures to reduce plastic inputs into freshwater environments; label remove: measures to remove existing litter from freshwater environments; label stacked column: green-yes; dark grey-no; light grey-not stated. Multiple answers were possible without specific ranking. Data source: Results of the European survey

What is the role of regulatory bodies?

71 % of the responses reported regulatory measures to reduce plastic input in European countries.

More general waste management schemes were mentioned by several countries. These programmes are operated by local authorities and municipalities to avoid littering *inter alia*. Additionally, national deposit and take back schemes have a share in reducing plastic-input into freshwater environments, e.g. the Dansk Retursystem A/S and "Repak" in Ireland collect disposed plastics followed by recycling and reuse as packaging material.

Specific regulations to prevent any kind of littering, were reported for the **Flemish Region of Belgium** (framework of the Flemish Waste Regulation) and in the **United Kingdom** (framework of "The Litter (Fixed Penalties) (Scotland) Order 2013"). The **Luxembourgish** Waste Management Plan (2010) introduced a quality certificate for business operators who support waste prevention, reuse and (if unavoidable) disposal of waste in an environmentally safe way.

Measures addressing the use of plastics bags have been reported from the following countries: **Iceland, Latvia, Portugal and Luxembourg**. With a consumption of about 18 lightweight carrier bags per person per year, Luxembourg nowadays already meets the reduction targets foreseen by the directive 2015/720/EU.

How do NGOs respond to plastic pollution in freshwater environments?

European NGOs work on strategies to reduce plastic-input into rivers and lakes. They are also actively removing existing litter from there. The responses to the questionnaire listed a number of examples ranging from campaigns on primary microplastics in cosmetics (and detergents) to monitoring of plastics in the environment and clean up campaigns in freshwater.

Austria and Portugal mentioned two specific NGO initiatives on primary microplastics in cosmetics: As **Austria** reports**,** the international "Plastic Soup Foundation" has initiated the international campaign "Beat the Microbead[1]". One of the outcomes is a smartphone application, which supports consumer decisions to purchase microplastic free products. Scanning the barcode of personal care products provides for a quick and easy information if the particular product is free of microplastics, or not.

The **Portuguese** Association on Marine Litter (Associação Portuguesa do Lixo Marinho: APLM) and the Aquamuseum of Vila Nova de Cerveira (Minho region, North of Portugal) organised the interactive exhibition "Litter from the River to the Sea" with a special focus on sanitary products (e.g. scrubs) and cosmetics as a source of pollution. As a first step, the exhibition discusses consumerism and citizens as waste makers. The activists are now planning a knowledge base to derive incentives for environmental education and to involve informed citizens as multipliers in the campaigns.

The replies to the questionnaire show that it is often NGOs who make efforts to remove existing litter from freshwater environments (57 %). Various cleaning-campaigns have been conducted in **Austria, Iceland, Latvia, United Kingdom (Northern Ireland, England and Wales) and the Slovak Republic**.

What is the role of plastic companies?

In six of the surveyed countries (43 %), actions on reduction of plastic-input are implemented by the industrial sector. Litter removal actions by industry are reported from two countries (Austria, Germany).

1 http://www.beatthemicrobead.org/; international website

In 2012, the Austrian economy started the national initiative “Reinwerfen statt Wegwerfen[1]” (“throw-in, don’t throw away”). Voluntary commitments support various measures, e.g. reducing plastic waste and littering in general, waste separation for packaging, increasing waste recycling rates. Furthermore, awareness raising and environmental education go along with clean-up campaigns in freshwater environments and promoting “Reinwerfen statt Wegwerfen" at environmental events and festivals across Austria (Reinwerfen statt Wegwerfen, 2016).

3.4 Concrete examples of management options for plastics

In two countries, Austria and the Netherlands, extensive discussions on plastics in freshwater environments have led to specific recommendations by national regulatory agencies.

Austria

The topic of plastics and microplastics in freshwater systems emerged in Austria when scientists investigated fish larvae in the Austrian section of the Danube River and reported an appreciable amount of plastic particles in their drift nets. This secondary result was published and enjoyed high media attention (Lechner 2014). Consequently, a consortium led by the Environment Agency Austria[2] was assigned by the Austrian Ministry for the Environment together with three Federal Provinces to carry out measurements specifically focussing on plastics transport and plastic load in the Danube River. Although results suggest a significantly lower load of plastics than assumed in the preceding study, the Danube River still transports a noticeable amount of plastics is (Hohenblum et al. 2015).

In response to the study results, the Federal Minister for the Environment initiated a 10-point action plan to combat plastics in the aquatic environment. This initiative aims at addressing both, the national and European level to reduce plastics input into rivers (see Table 1).

Table 1: 10-Points of Measures for the quality of the Danube River, Austria

European Level
Uniform methods and measurement standards for plastic particles in rivers
Regulation of EU thresholds
Voluntary withdraw of the European cosmetic industry
Conference on microplastics in Brussels and inclusion in the environmental report 2020 of the European Environment Agency
Implementation of the Plastic Bag Directive
National Level
Stakeholder dialogue on the study of the Danube river
Implementation of the 10 Point Programme “Zero Pellet-Pact” with the association of the Austrian chemical industry
Continuation of the monitoring study on the Danube river and other selected rivers in cooperation with the Austrian federal states
Awareness-raising-measures in cooperation with the federal states and waste manage-ment and waste water associations
Raising awareness in the environmental department by e.g. supporting Green Events like the Eurovision Songcontest 2015[3]

10-Points of Measures fort the quality of the Danube River in Austria on European and national level (Translation of original document in German (original source: BMLFUW 2015a))

[1] http://www.reinwerfen.at; website in German language

[2] Environment Agency Austria (lead), University of Natural Resources and Life Sciences Vienna, ViaDonau

[3] https://www.eurovision.tv/upload/press-downloads/2015/SC15_Folder_GreenEvent_E.pdf

In 2015, Austria initiated a dialogue with relevant stakeholders to discuss the results of the Danube River study. The conference "Eliminating Plastic and Microplastic Pollution - an urgent need" encouraged European stakeholders including the network of the European Environment Agencies (EPA Network) to cooperate. In the same year the Austrian Minister for Agriculture, Forestry, Environment and Water Management and the Association of the Austrian Chemicals Industry (FCIO) adopted the "Zero Pellet Loss" initiative. This initiative aims at reducing plastic pellet losses into the environment during production and conversion. It was developed by international plastic companies and also became part of the 10-Point-Programme-of-Measures for the Austrian section of the Danube River (see Table 2). Austria subjected the phase out of micro beads in cosmetics in the European Council (Council 2014).

Table 2: Zero Pellet Loss: 10-Point-Plan-of-Measurement

No.	Measures
1	Securing that all loading stations are provided with collecting baskets
2	Strategic positioning of pellet containers for on-site disposal
3	Inspection of all drains regarding correctly installed screens
4	Safe sealing of bulk containers pre-shipment
5	Inspection of bulk containers regarding clean emptying
6	Assurance that the roofs of silo trucks are free of granulates after loading
7	Installation of central extraction systems, where practicable
8	Careful disposal of loose granulates
9	Training employees
10	Information of logistics partners

Austrian industrial initiative - Zero Pellet Loss (Translation of the original document prepared in German (original source: BMLFUW 2015b))

Netherlands

Management options for three sources, The Netherlands, (RIVM 2016)

Car tyre wear, paints and abrasive cleaning agents were selected for a study to microplastic emissions and mitigating measures after a quick scan of potential microplastic sources (RIVM 2014). The priorities following from the quick scan took into account the extent of the emissions, the feasibility of measures and the lack of action perspectives of consumers. This was done in a qualitative way. Other relevant sources were not included in the current study because they are studied in other projects (i.e. laundry fibers), or because some voluntary measures were already initiated (e.g. cosmetics, pellets). The aim of the follow-up study was 1) to quantify the release of microplastics from these sources, 2) determine the distribution pathways to soil, water and air and 3) indicate potential measures to reduce the exposure of the aquatic environment to microplastics coming from these sources.

Tyres, paints and abrasive cleaning agents can release microplastic particles, which are distributed in soil, water and air. Tyre wear is the largest of these three sources, with a total emission in the Netherlands of 17,300 tons per year, followed by paint particles at approximately 690 tons per year. The abrasive cleaning agents are a much smaller source, at approximately 3 tons per year.

The most likely measures to reduce emissions of primary microplastics, such as in abrasive cleaning agents and cosmetics, is substitution of microplastic. This can be achieved by legal, financial or persuasive instruments. The reduction of secondary microplastics such as particles from the wear of tyres and painted surfaces is more complicated. For each source, it is essential to create awareness amongst consumers and professionals in order to induce a change in behaviour. In addition to this, the release of microplastics could be reduced through innovation. Another option is to take measures that prevent the distribution of wear particles to the environment.

A generic measure could be the improvement of sewage treatment plant. In general, this end-of-pipe measure is less favourable than preventive source measures and measures that address the producer's responsibility. Furthermore, the current distribution of microplastics towards sewage treatment plants and removal efficiency of these plants are highly uncertain. These uncertainties must be reduced by specific research before end-of-pipe measures are introduced.

The measures proposed in this study are currently subjected to further socio-economic analysis to determine the effectiveness, viability, sustainability and the costs and benefits of the measures.

4 Discussion

A number of studies have demonstrated the relevance of freshwater systems as contributors to the marine plastic pollution. This goes along with the likely exposure at full scale of rivers and lakes to plastics and potential harmful consequences for limnic ecosystems.

So far, we do not fully understand the distribution of plastics and microplastics in environmental compartments and many data are either missing or are not comparable. It is generally accepted that a holistic understanding of environmental processes and distribution is an inevitable prerequisite to respond appropriately to plastics in the environments, including rivers and lakes. So far, specific lighthouse initiatives have been established that demonstrate how monitoring and mitigating activities can act together.

Until now, those countries have a greater awareness for plastics in freshwater environments that have conducted respective monitoring studies. Furthermore, until now landlocked countries/regions are promoting more research on plastic in freshwater systems than countries with large coastal regions. All countries, which participated in the survey reported on-going discussions on reduction measures in their country. These discussions involve NGOs, media, public and they are closely interrelating regulatory processes. Specific actions to reduce or to remove plastics from freshwater environments are triggered by NGOs or legislation and less by industry.

Specific practical examples of management options are inter alia reported from Austria and the Netherlands. Austria developed a 10-point measure plan to improve the quality of the Danube River. Moreover, a 10-point plan signed by the Austrian Minister for the Environment and the Association of the Austrian Chemicals Industry aims at reducing industrial plastic emissions. These actions advocate the existing dialogue between the stakeholders. In the Netherlands, management options were suggested for three specific plastic sources: tyres, paints and abrasive cleaning agents. Both countries addressed reduction measures at the pollution source. As a second pillar, Austria and the Netherlands created awareness amongst consumers and professionals to stimulate behavioural changes. A third pillar is material innovation, which is also regarded as a promising measure, e.g. to reduce wear and tear of products by innovative design.

A questionnaire survey showed that European countries are aware of plastics in freshwater environments. Measures are discussed to reduce the exposure of rivers and lakes to plastics from waste and production. There is a variety of measures in place at local, regional and also the national level. There is little knowledge about the efficiency of the measures since spatial and temporal monitoring data is still scarce. We recommend to rework and refine the questionnaire based on the results of this survey and to come back to the European countries in due time to collate more information on this issue.

Under the umbrella of the European Environment Agency EEA and in close cooperation with the European Commission, an Interest Group on Plastic is going to link technical issues with the political level by addressing gaps, needs and by keeping the present momentum. The Interest Group is chaired by Germany and supported by an increasing number of interested EPAs. The Interest Group also demonstrates that the European Union is a driving force in this issue and best practice in terms of eliminating plastic pollution.

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Regional Action Plans to combat marine litter including inputs from rivers

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Assessments of the pervasive pollution of the world`s oceans with litter show that plastics dominate the findings almost everywhere. According to scientific estimates six to ten percent of the global annual production of plastics of currently around 310 million tons sooner or later end up in the marine environment. The Convention of Biological Diversity recorded frequent negative interactions with marine litter for around 800 marine species. In more than half of these reports ingestion of or entanglement in marine litter were documented.

The Marine Strategy Framework Directive (MSFD) came into force in 2008 constituting the environmental pillar of the Integrated Maritime Policy of the European Union. In Annex I of the Directive eleven descriptors to determine a so-called good environmental status are listed. Descriptor 10 demands that "Properties and quantities of marine litter do not cause harm to the coastal and marine environment." Both, the final declaration of the Rio+20 United Nations Conference on Sustainable Development in 2012 as well as the United Nations Sustainable Development Goal 14.1 of 2015 call for a significant reduction of marine litter until 2025.

Knowledge about the major sea- and land-based sources and pathways is essential to define efficient measures to prevent further inputs of litter into the marine environment. To fulfill the requirements of the MSDF and to gain a better understanding about the status quo European Member States had to set up comprehensive monitoring approaches. While for litter on beaches and ingestion of litter items by sea birds datasets were already available at least regionally, corresponding results for other marine compartments namely the sea surface and the seafloor, for micro particles and the second main biological impact of entanglement are currently being derived and validated.

In 2011 the United Nations Environment Programme (UNEP) and the National Oceanic and Atmospheric Administration (NOAA) initiated the fifth "International Marine Debris Conference" which led to the thematic breakthrough. The so-called Honolulu-Strategy can be regarded as the first step towards a global Action Plan to combat marine litter. The Regional Seas Conventions for the protection of the Mediterranean (UNEP/MAP), the North-East-Atlantic (OSPAR) and the Baltic Sea (HELCOM) meanwhile developed Regional Action Plans on Marine Litter (RAPs ML), the latter two under the lead of Germany. The setup of actions within these plans follow a similar structure addressing major sea- and land-based sources, removal as well as education and outreach measures. The OSPAR RAP ML follows a lead country approach. The RAP ML action 41 aims at exchanging experience on best practice to prevent litter entering into water systems and highlight these to River and River basin Commission. Belgium, Germany and the Netherlands lead on this action. The task manager of these Contracting Parties attempt to connect the marine and riverine communities concerning the issue of litter and facilitate a learning process especially concerning best practices. As a first step a questionnaire was send to the river basin commissions to establish an inventory concerning the state of knowledge, data collection and examples of inspirational projects and best practices to prevent litter entering the water systems. Other actions with special relevance for riverine inputs concern e.g. the reduction of sewage and storm water related waste or the development of environmental friendly technologies and methods for the cleaning of riverbanks.

Chances and limitations of standardisation for managing plastics in the environment

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1 Introduction

Plastics are the important material of the 21st century. Meanwhile, they can be found in almost every product area and in very different application domains. This is due to the fact that plastics are universally applicable and, thanks to their specific material properties, can be easily targeted for a specific use.

A sustainable management and exploitation of products does not only include a safe and efficient manufacturing process and an environmental-friendly use and handling of the latter, but also the high-quality recycling and disposal of end-of-live products.

The use of plastics, however, has also had the adverse effect of end-of-life products gaining entry into the environment. Inappropriate handling of products or their waste or the inadequate or inefficient wastewater disposal or the degradation and fragmentation of litter items are some of the possible entry paths. Thus, plastic particles are released into rivers, oceans and can be found in the coastal zones. Oceans are the major sink where these particles can accumulate.

Already today it is apparent that the entry of plastic products and their waste into the environment is influenced by a number of factors. It depends, among others, on the consumer behaviour, the respective region or the existing infrastructure. There are various types of entries and their composition is diverse. They may consist of different kinds of waste or products such as bottles, plastic films, nets and textiles, timber, tyres, rubber etc. This is why entries cannot exclusively be attributed to one specific material or product.

For these reasons, it is of utmost importance to prepare standards which provide a basis for a reliable and verifiable evaluation of the impact of plastics in the environment. In order to achieve this goal, it is necessary to collect suitable data, to identify the cause for and the origins of such entries and then to identify suitable and efficient measures for prevention. Validated standards that are quality assured, such as the standards prepared by the International Organization of Standardization (ISO), form an indispensable prerequisite in this context.

2 Methods – where Standardisation can help

Standardisation is an effective instrument of self-regulation that serves the interests of society as a whole, and not the economic interests of individual parties. The national, European and global standardisation bodies ensure that all stakeholders have access to standards work. Standards help relieve the legislative burden on the States and international organisations: Legislators can concentrate on overall issues and protection objectives, referring to standards for technical details.

The following approaches for standardisation regarding plastics in the environment have been identified:

- The terms "plastic microparticles", "microplastics" or "solid micro particle" are not defined in a consistent way and are, especially in an international context, being used differently.

- Not only qualitative but especially quantitative statements based on reliable data are needed to determine the relevance for the environment. In principle, there is a number of test methods available for the determination of plastics. However, standardised and harmonised methods for the detection, analysis and assessment of small particles present in the environment, such as marine litter, are not yet available. This includes, in particular, the sampling and preparation of samples. At the moment, only qualitative statements can be made. However, only with a standardised and, above all, reproducible and verifiable sampling and sampling preparation method and an analysis which will have to be developed especially for different environmental compartments and materials, it will be possible to produce valid data by using the different detection methods.

- Not only sampling but also sample preparation and detection of (micro-) plastics in aqueous media are to be defined in standards. Simple visual tests, in particular, have proved insufficient in this context. Therefore, the harmonisation of existing and scientifically recognized methods of sampling, sample preparation and detection is paramount.

- Moreover, there is a statistical particularity with regard to marine litter: Its distribution is highly variable with hot spots forming where the litter accumulates. Marine litter distribution and density is therefore to be considered a strongly variable heterogeneous system. For this reason, harmonisation is needed with regard to the evaluation of results, especially for the statistical estimations of measured results. Numerous research activities have already been initiated which would highly profit from a harmonised measurement technology and measurement evaluation system.

3 Results – DIN and ISO Activities

Based on the assessment above the German plastics standardisation committee within DIN (FNK) has started to develop an activity around microplastics. First step was the organisation of a stakeholder workshop with representatives from industry, academia, NGOs and authorities to compile different experiences and expectations regarding a future handling of that topic in a standardisation process.

Next step was to bring the learnings from the workshop into a format that fulfills the requirements of an international standardisation process. Therefor a resolution on the platform of ISO TC 61 "Plastics" had been prepared for the meeting in New Delhi with the intention on creation of an ad-hoc group to develop a scope of a potential working group in the field of microplastics. First rapporteur will be Dr Bannick from German UBA; first secretary will be Dr Stoelzel from German DIN. This development will be part of a reorganisation of ISO TC 61 structure with the aim to establish a new subcommittee that covers all environmental topic regarding plastics (e.g. bioplastics, LCA, recycling, microplastics, carbon footprint, etc.). Next crucial step will be to set all these preparatory steps on track during the ISO TC 61 meeting in September 2016 in Berlin.

4 Discussion

With that concept microplastics would be covered in the context of other environmental issues in a holistic approach and from the very beginning on a global level. All interested stakeholders are invited to join and to support.

Plastics industry and other interested parties within the German standardisation body DIN developed and implemented this concept as one activity – amongst others – to cover questions around plastics in the marine environment.

PlasticsEurope is convinced that only a bunch of different measures will help to overcome the critical situation regarding Marine Litter:

- Proper waste management
- Contributions and collaboration of different stakeholders on global level
- Increase awareness and better education locally
- Research for evidence based solution

Standardisation can help to make some of these measures more effective and efficient.

5 Literature

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Abstracts:
Panel discussion on monitoring

Monitoring of plastics in freshwater environments in the Netherlands

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1 What methods have you applied?

Deltares is involved in both marine and freshwater monitoring of plastic litter. We focus mainly on the smaller items, the microplastic fraction.

Sampling methods that we are familiar with are the use of the Manta trawl, but also other types of plastic capturing devices such as the Waste Free Water sampler and pumps. We are aware of methods related to sediment grabs (marine), but also nets, volume samples in containers (suspended matter) and sampling of biota (marine) but have not personally applied them yet.

Together with partners, we are also involved in the analysis of (micro)plastics in field samples. Furthermore, in a more experimental stage, we have gained experience on monitoring of plastics with hyperspectral sensors.

Table 1: Overview on applied methods

Sampling				
Type of samples	Water x	Suspended matter x	Sediment x	Biota x Which type of biota: Marine: mussels, brittle stars, shrimp. Freshwater: mussels and other invertebrates
Sampling site e.g. water surface, water column, riverbank etc.	Water surface (freshwater & marine), water column (freshwater & marine), sea floor (marine), beach (marine)			
Methods of sampling e.g. manta trawl, plankton net, grab etc.	Manta trawl (freshwater & marine), pump (freshwater & marine), samplers (designed by a Dutch NGO, freshwater), Van Veen grab (marine), shrimp net (marine), manual collection (marine).			

Sample preparation	
e.g. enzymatic digestion, acid digestion etc.	This work is not lead by Deltares itself, but we do work together with other institutes (i.e. IVM-VU), are aware of methods used by partners (density separation, enzymatic digestion), and advice the Dutch government on suitable methods for microplastics to be implemented in the MSFD and freshwater environment.
Analytical methods	
e.g. visual inspection, FTIR, RAMAN, pyrolysis GCMS etc.	This work is not lead by Deltares itself, but we do work together with other institutes (i.e. IVM-VU), are aware of methods used by partners (visual inspection, Raman, gas chromatography) and advice the Dutch government on suitable methods for microplastics to be implemented in the MSFD and freshwater environment.

Table caption, e.g. for sources and remarks

2 What are your results and experiences regarding monitoring of plastics in freshwaters?

- We suggest that monitoring should take place in a cross-section of rivers to have a complete overview of variances in different areas of the river. Therefore, a mobile platform for sampling is more suitable than a stationary platform.
- Fine meshed nets, such as the Manta trawl, are easily clogged in freshwater environments due to the high concentration of suspended matter.
- Riverine transport of plastics from inundated floodplains towards the sea increases remarkably during periods of high discharges.
- Many Dutch voluntary initiatives and individuals are involved in litter picking river banks but there is no dataset nor (meta-) data standard to report these findings.
- It is essential to link the freshwater monitoring of plastic litter to that already in place for the marine environment (OSPAR, MSFD) as much as possible to cover the complete pathway from source to sink.

3 What current challenges and needs do you see for future monitoring?

- There is a need for calibrated, standardized methods for sampling of plastics in freshwaters. Since plastics are not included in the European Water Framework Directive, there is lack of a policy instrument to stimulate this harmonization. This should thus be done through other instruments. Furthermore, there is need for a standardized manner of reporting the findings.
- Contamination of samples is a big challenge. Once samples are in the laboratory, there is the opportunity to work from a clean bench, however, in the field the risk of contamination is high.
- There is a need for more insights in mass balances and transport processes of plastics from freshwater environments to seas and oceans, but also to identify plastics hotspots in the water system and the main sources. In the Netherlands, we still lack knowledge about fate and transport of plastics in freshwater environments, especially in lakes.

4 What lessons can we learn from the monitoring studies on microplastics and plastic litter performed up to now?

It seems that monitoring instruments and methods from the marine environment cannot be applied one-to-one in the freshwater environment. Furthermore, from literature it is known that there are several processes responsible for the transport of plastics along rivers, which go beyond the visible transport via the water surface. These matrices should be taken into account and investigated. Plastic litter can be found even in the most pristine looking rivers.

5 Literature

Van der Wal, M., van der Meulen, M.D., Tweehuijsen, G., Peterlin, M., Palatinus, A., Kovac Virsek, M., Coscia, L. and Krzan, A. (2015) SFRA0025: Identification and Assessment of Riverine Input of (Marine) litter, p. 208

Monitoring of plastics in freshwater environments in German federal states

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1 What methods have you applied?

We sampled macro- and microplastic from beach sediments of rivers and lakes using a combined approach using transects and sediment cores. Additionally we sampled fine sediment from the lake bottom but also from accumulation zones in rivers. Water surface samples were taken with an adopted "MiniManta"-Trawl (300 µm) equipped with a flowmeter in lakes and rivers.

Sediment samples were processed using density separation based on zinc chloride (1.6 – 1.8 kg/L) using the MPSS. Both sediment and water surface samples were purified using an enzymatic digestion protocol.

Particles >500µm were identified using ATR-FTIR and particles 500 – 50 µm are identified using micro FT-IR equipped with a Focal Plane Detector. Particles <50 µm were identified using Raman Microspectroscopy. In the study of Imhof et al. 2016 all plastic particles were identified using Raman Microspectroscopy.

2 What are your results and experiences regarding monitoring of plastics in freshwaters?

Microplastic particles are ubiquitous also in freshwater environments. Contamination in river surface samples is higher than in water surface samples of lakes. Fine sediment accumulation sites are "long-term sampler" for MP also in low contaminated areas. This includes not only highly dense polymers but also polymers which are expected to float on the water surface. Freshwater samples are more difficult to process than marine samples due to a high load of organic materials (leave parts, algae, organsims etc.)

Contamination hot spots exist, while other rivers are not or less contaminated.

3 What current challenges and needs do you see for future monitoring?

Monitoring approaches work well to a certain size (~300 – 500 µm) although still a high effort is necessary. If smaller size classes are of interest, the development of improved methods is necessary, especially for the development of routine monitoring protocols.

A visual characterization of MP is not possible and should not be performed. Visual sorting can be applied down to a size of ~500 µm but the effort is very high.

Development of methods for sampling, processing and identification of particles down to 1 µm and below.

4 What lessons can we learn from the monitoring studies on microplastics and plastic litter performed up to now?

Microplastic particles are ubiquitous but studies cannot be compared due to different methods used.

Microplastic sampling, processing and identification from environmental samples is not trivial and many aspects have to be included in monitoring strategies.

Water surface samples especially in rivers are only a snapshots in time.

Further method development is needed. Performing “real” monitoring with inefficient methods is not recommended.

Monitoring of plastics in freshwater environments in Switzerland

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1 What methods have you applied?

A first stage of the study aimed at obtaining a first picture of microplastic pollution in various environmental compartments in a few lakes around Switzerland (water surface, bank sediments, biota). The investigations then focused on the microplastics pathways in and out of Lake Geneva, trying to get as close as possible to the sources.

Table 2: Overview on applied methods

Sampling				
Type of samples	Water ☒	Suspended matter ☐	Sediment ☒	Biota ☒ Which type of biota: Birds, fish, mussels
Sampling site e.g. water surface, water column, riverbank etc.	Lakes and rivers water surface + bank sediments Lake benthic sediments Rivers water column Urban runoff water, WWTP outflows Others (e.g. composts, construction or industrial sites, etc.)			
Methods of sampling e.g. manta trawl, plankton net, grab etc.	Manta trawl for water surface Cod end for smaller flows Van Veen grab for benthic sediments			
Sample preparation				
e.g. enzymatic digestion, acid digestion etc.	Sieving (> 5 mm, 1 mm < < 5mm, 0.3 mm < < 1 mm) Sediments: gravity separation in water saturated with NaCl (banks) or NaI (benthic) Biota: dissection, drying and enzymatic digestion followed by filtration (.45 µm or larger) – except for rejection pellets H_2O_2 oxidation after drying, for smaller fractions (< 1 mm) in the first stage of the study			

Analytical methods	
e.g. visual inspection, FTIR, RAMAN, pyrolysis GCMS etc.	Mostly visual identification and sorting in types according to probable source FTIR for representative part of the particles, mostly > 1 mm GC-MS/MS and LC-MS/MS for quantification of additives and sorbed pollutants

Most of the method details can be found in (Faure et al. 2015)

2 What are your results and experiences regarding monitoring of plastics in freshwaters?

Microplastics were found in significant concentrations in all the sampled lakes and rivers, both on the water surface, beach sediments and benthic sediments, as well as in biota. They were shown to contain potentially toxic additives, as well as adsorbing hydrophobic contaminants from the water. All tested suspected sources were confirmed, their respective contribution yet needing to be more precisely defined, and not excluding other potential sources. Results overall show high variability even within the same sites, suggesting selected methods could lack robustness. Data is scarce so far, therefore even such exploratory results are valuable, but the methods should be adapted for more repeatability and easier analysis of the samples. Sampling as well as sample preparation and analysis is still too manual and time-consuming, not allowing for enough repetitions and reliability. We ourselves tried to tackle various environmental compartments and matrices, requesting a continuous adaptation of the sampling and analysis methods depending on the samples types and the desired results.

3 What current challenges and needs do you see for future monitoring?

More comprehensive data for various sites and in time need to be obtained including the assessment of sources and fluxes. Impacts on freshwater organisms need to be assessed but not only in-vitro, as there is still a great gap between lab trials and environmental conditions (this is also the case for marine organisms). For studies to come, priorities should be set as to which matrices need the more attention, as well as to which particle size or type need to be focused on. Harmonization of the studied particle size is critical, as well as the detection/identification methods. These need to be comparable between studies, as well as more efficient and moreover much easier and lighter to apply. Finally, the link between the different size classes, i.e. from plastic particles bigger than 5 mm towards micro- or even nano-plastics need to be clarified as degradation processes are not yet well understood or transposable in the environment. Overall, the main challenges mostly include coordination between research programs and financial support from public institutions.

4 What lessons can we learn from the monitoring studies on microplastics and plastic litter performed up to now?

It has been shown that microplastics are ubiquitous, and that biota is exposed to these particles as well as to the associated potentially toxic additives and adsorbed hydrophobic contaminants. The fluxes of plastics between compartments are not quantified so far, and data is too fragmentary regarding the sources, pathways and sinks of plastic litter and microplastics. Most of the studies are exploratory, and need developments to become systematic and more representative with holistic approaches. So far, modelling approaches have been irrelevant due to the shortage of environmental data as to the nature and extent of this pollution - more monitoring studies are probably necessary. Although these are not likely to bring a full understanding of the problem, especially regarding the plastic flows into and within the environment, they are critical to feed material flow models. Monitoring studies on plastic in freshwater environments have shown this topic is still misunderstood and need to be developed and continued.

5 Literature

Faure, Florian, Colin Demars, Olivier Wieser, Manuel Kunz, and Luiz Felippe de Alencastro. 2015. "Plastic Pollution in Swiss Surface Waters: Nature and Concentrations, Interaction with Pollutants." Environmental Chemistry 12 (5): 582–91.

Monitoring of plastics in German federal waterways

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1 What methods have you applied?

The BfG research project "Microplastics in inland and coastal waterways – origin, fate, and impact" aims at establishing a scientific basis for assessment, monitoring and regulation of microplastics in the aquatic environment. Therefore data on the occurrence of microplastics (MP) and the characterization of its quantitative and qualitative input into inland waterways and coastal waters is essential. A preliminary survey in 2014 (sediment) as well as two sampling campaigns at the rivers Elbe and Saar in 2015 (sediment and water) have been conducted so far. Additionally, initial field investigations on biota have been carried out. A general overview on the applied methods is shown in table 1.

Table 3: Overview on applied methods

<table>
<tr><th colspan="5">Sampling</th></tr>
<tr><td>Type of samples</td><td>Water
x</td><td>Suspended matter
x</td><td>Sediment
x</td><td>Biota
x
(Mussels, Crustacean, Fish)</td></tr>
<tr><td>Sampling site</td><td colspan="4"><u>Water samples (incl. suspended matter (SM)):</u> approx. 20 cm to 50 cm below the water surface; <u>sediment and biota samples:</u> river bed</td></tr>
<tr><td>Methods of sampling</td><td colspan="4"><u>Water samples (incl. SM):</u> plankton net acc. to Apstein (mesh size 150 µm), continuously working centrifuge; <u>Sediment samples:</u> Van-Veen-grab; <u>biota samples:</u> collecting, electrofishing</td></tr>
<tr><th colspan="5">Sample preparation</th></tr>
<tr><td></td><td colspan="4"><u>Water samples (incl. SM):</u> freeze-drying, electro-separation, acidic digestion with HCl, density separation with sodium poly tungstate, pressure filtration
<u>Sediment samples:</u> wet sieving, density separation ($ZnCl_2$) in Munich Plastic Sediment Separator (MPSS) (Imhof et al. 2012), removal of organic material with enzymatic or hydrolytic digestion
<u>Biota samples:</u> digestion (acidic or enzymatic)</td></tr>
<tr><th colspan="5">Analytical methods</th></tr>
<tr><td></td><td colspan="4">particles > 500 µm => visual inspection, ATR-FTIR
particles < 500 µm => Py-GC-MS, µFTIR (planned)</td></tr>
</table>

2 What are your results and experiences regarding monitoring of plastics in freshwaters?

Results:

The preliminary survey in 2014 showed that sediments of the rivers Elbe, Moselle, Neckar, and Rhine contained 32 to 64 MP particles per kg. Hence, the amount of MP in freshwater sediments is comparable to marine sediments, where (acc. to literature data) 0.3-165 MP particles per kg have been found. The sediment and water samples from the rivers Elbe and Saar (sampling campaign 2015) as well as biota samples are currently being investigated.

Experiences:

It became apparent that current methods are restrictedly suitable to monitor MP in freshwater environments. Often only one compartment is investigated, either the water surface or sediments. By using a net for sampling it has to be noted that the size range of the particles is limited by the mesh size.

Current methods of sample treatment have its limits. One major difficulty is caused by organic matter which may interfere with MP during processing and identification. Own validation experiments concerning density separation in the MPSS revealed that the recovery in sandy sediments is 96-100 % depending on particle size. But with an increase of organic material, the recovery of smaller particles (100-500 µm) decreased rapidly to only 13 %. Hence, a removal of organic material during sample processing is advisable. Therefore many methods require the use of either enzymes or hydrogen peroxide. While enzymatic digestion includes up to several weeks of shaking, which is potentially capable of damaging porous particles, some types of plastics can be oxidized by H_2O_2. Therefore, different acids and oxidizing agents were tested. HCl proved as the best agent for organic degradation.

At present no method, which can easily be handled, meets all requirements for a complete separation of MP from any other material. Recovery experiments repeatedly showed that high losses as well as contaminations have to be expected. Without a standardized method capable of detecting all sizes and types of MP discussions on monitoring results are impeded.

3 What current challenges and needs do you see for future monitoring?

All monitoring studies described in literature so far differed in the applied methods of sampling, sample treatment and analysis. Differences also exist in the size ranges of the MP particles detected. In most studies, particles with a size < 5 mm were investigated relating to the generally accepted definition of the upper size boundary of MP. However, no agreement has been found on a scientific definition of the lower size boundary so far. Therefore, the lower limit of the size range considered varies from study to study depending on the type of sampling methods and the sensitivity of the analytical methods applied. Likewise monitoring results are reported in different metrics including data on the number of detected particles or mass concentrations which can refer to water surface area or water volume if water samples are analysed. Due to the particle density the sampling location – water surface or water column – and also the hydrological situation will influence the results of an investigation. Due to these differences it is hardly possible to compare the data from different studies. To enable the comparison of monitoring data standardized methods for sampling, sample treatment and particle identification have to be developed. Since especially the smallest MP particles are suspected to be of special interest in studies on organisms, it is very important to be capable of gathering, detecting, and identifying particles much smaller than 300 µm.

4 What lessons can we learn from the monitoring studies on microplastics and plastic litter performed up to now?

The results of the monitoring studies performed up to now reveal that the knowledge of the distribution, abundance and risks of MP in freshwater environments is far from complete and requires further evaluation. There are urgent needs for method development, method harmonization, consistent risk assessment and further investigations. The previous monitoring studies on rivers and lakes cover only a part of the European countries. Occurrence and loads of plastics and MP in numerous freshwaters, among them major rivers probably contributing to relevant inputs into the connecting seas, have not been investigated so far. Furthermore, the knowledge of accumulation, sources, pathways, persistency and environmental impacts of MP in freshwater environments are currently limited. Up to now, only few studies have focused on the risks of MP to freshwater organisms. Further research is required to answer the questions whether MP are taken up by limnic species to a considerable extent, whether the particles pass membranes and accumulate in tissues, and whether enrichment in aquatic food webs occurs. Therefore this problem should also be addressed in future monitoring studies.

5 Literature

Imhof, H. K., Schmid, J., Niessner, R., Ivleva, N. P., Laforsch C. (2012): A novel, highly efficient method for the separation and quantification of plastic particles in sediments of aquatic environments. Limnology and Oceanography Methods, 10, 524-537

Abstracts: Poster

Monitoring

Microplastics in an urban environment: sources and receiving water

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Microplastics are particles with a size smaller than 5 mm. They have been widely reported in marine environments. While their occurrence in both marine and continental environments have been studied, their inputs are still very poorly identified and only few works focused on their sources. Moreover only few studies concentrated on the occurrence and spatiotemproal distribution of microplastics on rivers. This work aims at assessing the microplastic contamination in different compartments of the urban water cycle and estimating the spatiotemporal variability of microplastics in a river.

The atmospheric fallout of microplastics was collected during one year on an urban site and 6 months on a suburban site. Throughout the monitoring, an average atmospheric fallout of 110 ± 96 particles/m2/day (mean ± SD) was encountered in the urban site while it was around 53 ± 38 particles/m2/day on the suburban site. A significant difference between the urban and the sub-urban site was found. Greywater and wastewater were also studied. In washing machine effluents, concentrations between 8,850,000 and 18,700,000 particles/m3 were encountered, confirming the large contribution of the clothes as a source of fibers. Microplastics in a waste water treatment plant were also analyzed exhibiting high levels of fibrous plastics the in the influents (260,000 – 320,000 particles/m3) while the concentrations in the effluents are in the 14,000 – 50,000 particles/m3 range. A microplastic removal rate between 83 and 95% has been estimated.

The Marne river was also considered. During short-term temporal variability tests, concentrations ranged between 38 and 102 particles/m3 in the first campaign with a coefficient of variation around 45% and between 19 and 39 particles/m3 during the second with a coefficient of variation of 26%. A yearly monitoring was also carried out. Concentrations through the year oscillated in the Marne River from 6 particles/m3 to 398 particles/m3 corresponding to a mean concentration of 104 ± 128 particles/m3. The coefficient of variation is of 122% which is superior to the short term variability. The variations through the year are probably due to changes in the input of microplastics, either punctual sources like the wastewater treatment plants, or diffusive sources like the runoff, the atmospheric fallout or the resuspension of the microplastics from the sediments.

Qualitative and quantitative analysis of microplastic and pigment particles in freshwater

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Plastic became a ubiquitous material with applications in many fields in the last decades. Especially properties like the inertness, formability and low costs contributed to the increased use. One large disadvantage of plastic is that it decades slowly, therefore an enrichment in not only marine systems but also in freshwater bodies has to be expected. The risks for humans and environment provoked especially small plastic particles, so called microplastics (MP) attracted notice in the scientific community as well as the public media. MP is currently not clearly defined, but it is generally applied for particles and fibers from 1 µm to 5 mm. [1, 2]

In recent broad studies [3,4] we characterized microplastic particles from sediment samples in the subalpine Lake Garda, Italy. We separated and identified about 450 microplastic particles with a diameter down to 9 µm by means of the Munich Plastic Sediment Separator (MPSS) [5] and Raman microspectroscopy. Most common found plastic types were polystyrene, polyethylene and polypropylene. We found a relation between plastic type and particle sizes. For very small microplastics (defined as 1 µm - 50 µm) [6] mostly polyamides were found. Additionally, to plastic particles a high number of pigmented (non)plastic particles were identified. We show with inductively coupled plasma mass spectrometric analysis that pigmented particles can contain high levels of (toxic) heavy metals. The size distribution of these particles shows an increase with decreasing size, which suggest that even smaller pigment particles might be present (down to the nm-range).

Literature:

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[5] H. K. Imhof, J. Schmid, R. Niessner, N. P. Ivleva & C. Laforsch, *Limnol. Oceanog.* **2012**, 10, 524-537.

[6] N. P. Ivleva, R. Nießner, *Nachrichten aus der Chemie* **2015**, 63, 46- 50.

A ’living laboratory’ for the microplastic pollution research in the Finnish Lake District: Lake Kallavesi and the City of Kuopio

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There are 187 888 lakes in Finland. The majority of lakes in Finland are located in the Finnish Lake District in the eastern part of Finland, where the terminal moraines trap networks of thousands of lakes separated by hills and forested countryside. With an area of 473 km^2, Lake Kallavesi is the tenth largest lake in Finland, located in the region of Northern Savo in Eastern Finland. It belongs to the Finland’s largest freshwater drainage basin called the Vuoksi main drainage basin, which covers an area of 16 270 km^2. Lake Kallavesi surrounds the City of Kuopio, which is the eight biggest city in Finland with population of 112 000. The main aim of this research is to turn the City of Kuopio into a ‘living laboratory’, focusing on how plastic litter and microplastics in drainage waters affect freshwater ecosystems such as Lake Kallavesi. The ’Living Laboratory of Kuopio’ together with the state-of-the-art analytical laboratories at the University of Eastern Finland provides opportunities to carry out on-site research of sources, transport, fate and effects of macro- and microplastics in freshwater ecosystems in Lake Kallavesi. Furthermore, the research aims to assess the effect of the stark contrasts of four seasons on the abundance and distribution of microplastic in Lake Kallavesi. For almost five months the Lake Kallavesi is covered with ice which could retain the otherwise floating particles on the surface. Our preliminary results of the ice samples confirm the presence of microplastic in Lake Kallavesi with a substantial amount of fibres.

Monitoring and interventions for riverine litter (case the Lys, Flanders)

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In 2014 the Public Waste Agency of Flanders commissioned an assessment study on plastic debris in the river De Leie. The report entitled 'Monitoring and interventions for riverine litter (case De Leie)' contains quantitative and qualitative data of floating plastic debris, as well as plastic debris from the upper part of the watercolumn. The study focused on the touristic part of the Lys river and takes into account occurring currents, interfering hydrological influences and seasonal variations. It also includes microplastic analyses from samples taken along the watercolumn and sediment. Sampled microplastics are categorized in spherical beads, amorphous fragments and fibres as a preliminary indication of the source of the microplastics. Management measures are suggested.

Microplastics in inland waterways and coastal waters – origin, fate, and impact

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The accumulation of plastic debris in aquatic environments is one of the major but least studied human pressures on aquatic ecosystems. Under environmental conditions, larger plastic items degrade into smaller particles, so-called microplastics (MP) (< 5 mm in diameter). MP resulting from degradation processes are classified as secondary MP, while primary MP are produced as such for industrial purposes. MP particles represent freshwater contaminants of emerging concern. However, to assess the environmental risks associated with MP particles in freshwater ecosystems, comprehensive data on their abundance, fate, sources, and biological effects are needed.

Therefore the research project "Microplastics in inland waterways and coastal waters – origin, fate, impact" by the Federal Institute of Hydrology (BfG) aims at establishing scientific principles for assessment, monitoring and regulation of MP in freshwater aquatic environments (water and sediment). Within this project the following tasks will be addressed: (1) occurrence (quality and quantity) of MP in inland waterways, (2) characterization of quantitative and qualitative input in waterways and coastal waters (mass balance study), (3) bioaccumulation potential of MP, (4) investigation of biological effects of MP on aquatic organisms, and (5) risk assessment for aquatic organisms and aquatic environments. On this account the research project consists of 5 work packages: (I) sample preparation and qualitative description, (II) development and validation of quantification methods, (III) biological effects, (IV) modeling and monitoring, and (V) leaching, impact, and risk assessment; of these the first results will be presented here.

Waste in German rivers

Input- and Output-pathways, Amount, Key Figures and Avoidance Measures

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Introduction: Littering of seas and oceans in particular caused by plastic waste is a growing problem with substantial environmental impacts. Global land-based sources for entry of waste are coastal areas with tourism or disorderly landfills as well as rivers, which are carrying waste from inland areas. It is expected that German rivers are also sources for entry of waste into seas and oceans.

Aim: The purpose of this study is to determine waste types, input and output pathways and the amount for both macro waste (> 5 mm) and micro waste (1 - 5 mm) in German rivers. On basis of this information avoidance measures will be developed.

Research methods: Waste types, input and output pathways and mass-based amount as well as quantities of waste are determined by sampling screenings of hydroelectric power plants, flotsam in the water and in riparian zones as well as collecting waste at riverbanks and the surrounding areas. The collected waste will be classified into product, material and size classes by means of sorting-analyzes. To identify input and output pathways site-inspections and a comparison of waste products in all analyzed areas are done.

Results: It was generated that Littering is the major input pathway for macro waste. The entry of primary micro waste takes place by discharges from Drain and Sewer Systems. The removal of screenings of hydroelectric power plants is the major output pathway for macro waste and due to adhesions for micro waste as well.

Taking the example of the Saale River the amount of macro waste has been detected with an annual freight of approx. 673 kg or approx. 269,000 waste particles. Micro waste was found in the Werra River with a total annual amount of approx. 25.6 kg and approx. 10 million particles. Additionally the specific pollution of micro waste at the riparian zones of the Werra River was determined with specific loads of approx. 1,400 pcs./km and approx. 20 g/km.

The mass-based waste composition of macro waste is dominated by packaging materials (52% Saale). Based on the quantities the product class "foils, bags and sacks" is the most common waste fraction due to a rapid fragmentation (51% Saale). The dominating waste types among micro waste are plastic pellets considering mass percentage (64% Werra) and plastic foil fragments based on quantities (62% Werra).

Conclusion: German rivers are contaminated with macro- and micro-waste that ultimately enter the seas and oceans. Thus, Germany contributes to littering of seas and oceans. Considering that Germany is a highly developed country with a functional waste disposal infrastructure, water pollution by waste cannot be acceptable. On basis of the acquired knowledge about typical waste products and their pathways, several avoidance measures are derived.

An initial study of microplastics in Irish freshwater and wastewaters

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Microplastics in the marine environment have been recognized as an issue of concern in recent decades, due to their ingestion by, and potential harmful effects on, aquatic organisms. Microplastics can also release toxic materials such as plasticizers and other additives by leaching and due to further breakdown of the microplastic particles. Until recently however, there has been relatively little focus on microplastics in freshwater systems, despite their obvious importance as inputs to the marine environment, as well as their potential to negatively impact freshwater ecosystems. In this preliminary study we have validated methods for the detection, characterization and quantification of microplastics in water and sediment samples from the midlands region of Ireland. Samples were collected from lake and riverine locations and the microplastics content was analyzed using various physico-chemical tests and by FTIR spectroscopy. Samples from wastewater treatment plants were also collected and analyzed in order to assess the significance of these plants as inputs of microplastic contamination.

While no microplastics were recovered from the majority of freshwater samples examined, there is sufficient evidence of microplastics contamination to suggest that further work is justified in order to obtain a more representative picture of microplastics pollution in Irish rivers and lakes. Polystyrene and polyethylene were the predominant polymers detected in freshwater samples. Significant numbers of microplastic particles were detected in samples collected from three wastewater treatment plants. Analysis of samples taken from different points in the wastewater treatment processes indicated that the majority of microplastics were removed during treatment; however there is clear evidence that there is a significant microplastics content in Irish municipal wastewaters. Further investigation of the sources and fate of these materials is suggested.

Monitoring beach macro litter utilizing MARLIN beach litter monitoring method and crowdsourcing

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The Association participated in the **Baltic Marine Litter (MARLIN)** project in 2011-2013. MARLIN was an EU funded project with partners from Sweden, Estonia and Latvia. The aim of MARLIN was to increase awareness among the public and policymakers in regard to marine litter in the Baltic Sea by introducing a monitoring method in combination with opinion building activities.

The monitoring method is based on UNEP/IOC monitoring guidelines that have been adapted for the Baltic Sea. The method has a few ground rules. There must be at least three different beach types: urban, peri-urban and rural. Beaches have to be monitored three times per year: spring, summer and autumn. The monitored area must fall within the minimum and maximum size. Litter is calculated per item.

At the first monitoring the rural beaches had more litter than urbans or peri-urban beaches. The following monitoring showed that the rural beaches litter amount decreased and then the most littered beaches were urban ones. The litter categories amount 2012-2013 were 75 % plastic, foamed plastic and cigarette butts, 7 % metal, 5 % paper and cardboard, 5 % wood, 4% glass and ceramics, 2 % cloth, 1 % organic and 1 % rubber.

The **Clean Beach campaign** is a beach clean-up campaign coordinated by the Keep the Archipelago Tidy Association (KAT). The aim is to clean the beaches during spring time, but also to raise awareness and collect data about marine litter.

Clean Beach was inspired by the MARLIN project. Anyone can create their own clean-up event at a beach along the Baltic Sea, a lake or a river.

The first campaign was held in 2014. In 2014 and 2015, clean-up groups reported all marine litter collected to KAT. The report form is more basic than the MARLIN or UNEP forms. The idea is to gain general information about different materials. The litter categories include plastic, paper and cardboard, metal, glass and ceramics, cloth, wood, organic waste, hazardous waste, rubber, cigarette butts and other.

Beaches are only caterogised by its location by waterbody type: a lake, a river or a sea beach. In years 2014-2015, most of the found litter in all beaches is plastic, foamed plastic and cigarette butts. Beaches of sea and lakes had plastic litter nearly 70 %. Noticeably the river banks had only 49,8 % plastic and more paper and cardboard and glass and ceramics than sea or lake beaches. Otherwise lake and sea beach litter amounts were in the line with the MARLIN results.

Abstracts: Poster

Sources and risk characterization

From Land to Sea – a model for recording land-based plastic waste

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What are the relevant input paths contributing to Marine Litter? Up to now there are no approaches known describing these pathways in a general context.

A quantitative model for the estimation of total amounts of land-sourced plastics litter entering the sea has been developed.

The total amounts are broken down by input paths (rivers, river navigation, coastlines, ports and landfills) as well as by particle size (micro versus macro plastics). The model serves to improve estimates of the origins, quantities and composition of the plastic waste entering the North Sea. It presents in detail the possible input paths of plastic waste (micro- and macroplastics) ending up in the sea. In the first instance, only the land-based input of synthetics (land-sourced litter) into the North Sea[1] is considered. The model does not include waste from maritime shipping, cruise ships and the fishing industry (sea-sourced litter), nor inputs into other seas.

In the first step, the input paths were identified and a data model set up. A database was created on the basis of this model. Initially, the representation of the input paths was intended to take place independently of the current data availability; when structuring the characteristics, however, attention was already paid to the subsequent data generation.

In the second step, the input quantities were analysed on the basis of primary and secondary data. To begin with, data selection was limited to the publications of OSPAR[2] and the Berlin Conference on Marine Litter[3]. Subsequently, primary data in the form of expert discussions were also generated.

The model can be applied to any sea or region worldwide. The model is currently being validated with stakeholders.

The poster would present and describe the model and its main results, additionally an outlook regarding the further proceedings.

[1] Geographic definition of the North Sea according to OSPAR: *"The Greater North Sea is situated on the continental shelf of north-west Europe. It opens into the Atlantic Ocean to the north, via the English Channel to the south-west, and into the Baltic sea to the east."* [Source: http://www.ospar.org/convention/the-north-east-atlantic/ii]

[2] Issue Paper to the OSPAR Workshop "Development of a Regional Action Plan on Marine Litter", October 2013.

[3] Issue Paper to the "International Conference on Prevention and Management of Marine Litter in European Seas", May 2013.

Growing threat in a throwaway society

Pathways and physico-chemical properties of river-relevant plastics and microplastics

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Since we are living in the age of plastic and since there are almost no opportunities anymore to evade the use of plastics in our everyday life, we urgently need to know the pathways, impacts and behavior of plastic in terrestrial and water environment. The growing threat due to microplastic is heavily related with its size and almost invisibility. Therefore - and because no plastic that has been produced in the last century has mineralized so far, we are currently focusing on their origin and degradation process. By doing so, we want to find new ways to avoid the spreading of microplastic particles to freshwater environments and finally into marine environment.

The form and type of microplastic degraded from packaging and other application areas do differ a lot, as shown by recent studies from freshwater environments. When Plastic products are littered, they are usually exposed to a mix of mechanical abrasion, UV-Sunlight-Radiation, Oxo-thermal influences and hydrolysis. These impacts slowly decrease the size of the former macro- or meso-plastics into micro- or nano magnitude. Mechanical abrasion and UV-degradation play the most important role of environmental factors, nevertheless there are some other factors:

By looking at the degradation processes, it is obvious that the range of plastic types get smaller in a different way and rate. There is a lack of knowledge about the different plastic types degradation processes. As the density of plastic is obviously significant, there are some other important properties, such as crystallinity, specific heat, light transmission and moisture absorption, which all have an important influence on the degradation process of microplastic.

Understanding the fragmentation pattern of micro-plastics from the North Atlantic Gyre

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More than 260 million tonnes of plastic are used each year. Based on population density and economic status of costal countries, the mass of land based plastic waste entering the ocean was recently estimated between 4.8 to 12.7 million metric tons per year1. Most striking is the estimation for 2025: this amount will increase by an order of magnitude if waste management infrastructures are not improved [1].

Plastic debris is abundant and widespread in the environment. Marine plastic pollution has been recently recognized as a global environmental threat [2, 3]. There is a need for better estimating the global scale of plastic inputs, better understanding fate of plastic debris in the environment and better studying the biological responses to plastic exposure in a variety of organisms.

In this context, the present study aimed at giving a detailed physicochemical characterization of microplastics (300 µm – 5 mm) collected at the surface of the North Atlantic accumulation zone. The characterization of the microplastics is given in terms of size, width, density, weight together with a microscopic, microtomographic and infrared spectroscopy analysis. A fragmentation mechanism based on a mathematical model and on the physicochemical data gathered is proposed.

There are still fundamental knowledge gaps in the transformation and fate of plastic debris in the aquatic environment. Understanding the fragmentation pattern of microplastics is an essential step in order to understand to what extent smaller particles are formed (micrometric and nanometric). The results presented suggest that smaller fragments are formed and underline the need to develop reliable sampling and detection methods for small plastic particles in environmental samples.

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Marine plastic litter: the missing nano-fraction

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We are not aware of any studies reporting the occurrence of nano-plastics in marine water, and only millimeter scale materials are referenced [1, 2]. This lack of evidence is due to (i) the dilution of nano-plastics on the ocean surface and (ii) the lack of appropriate methodologies for characterizing nanoscale materials in the environment [3, 4]. In a recent review, some authors reported that there is a doubt that nanoscale particles could be produced by the weathering of plastic debris and indicated a lack of analytical methods for quantifying these particles [3, 5, 6]. Cózar et al. identified a deficiency of marine plastic particles at the lower end of the size distribution (<1 mm) in the abundance diagram and argued that fast nano-fragmentation from millimeter scale debris might be a plausible explanation for this deficiency [7].

In our recent work, published in Environmental Science nano [8], we present for the first time undeniable evidence of nano-plastic occurrence due to solar light degradation of marine micro-plastics under controlled and environmentally representative conditions. As observed during our recent expedition (Expedition 7th Continent), plastic pollution will be one of the most challenging ecological threats for the next generation.

We developed for the first time a new solar reactor equipped with a nanoparticle detector to investigate the possibility of the formation of nano-plastics from millimeter scale plastics. With this system, correlated with electronic microscopy observations, we identified for the first time the presence of plastics at the nanoscale in water due to UV degradation. Based on our observations, large fractal nano-plastic particles (i.e., >100 nm) are produced by UV light after the initial formation of the smallest nano-plastic particles (i.e., <100 nm). These new results show the potential hazards of plastic waste at the nanoscale, which had not been taken into account previously.

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Microbial colonization of microplastics and other particles from commercial cosmetic products

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Microplastic particles from cosmetic peelings may enter rivers and lakes via wastewater if they are not removed in treatment plants. A significant fraction of those particles will finally end up in the sea, but transport and retention processes are not well understood so far. Microbial colonization which might influence the specific density of the particles and their uptake by organisms is believed to be an important factor. As an example we chose particles from a commercial shower peeling (polyethylene and jojoba ester beads) and a foot peeling (pumice and polyethylene). Particles were isolated from the matrix and cleaned by washing with ethanol and water. They varied in size and had an irregular shape which impaired microscopic quantification of biofilms. Particles were incubated with water from the river Bode in glass bottles on a rolling incubator for 4 weeks in the dark at room temperature. Biofilm structure was then studied by Syto 9 nucleic acid stain and confocal laser scanning microscopy. In addition, viable biomass in the biofilms was quantified after extracting phospholipid phosphate, a proxy for intact cell membranes. Particles from both peelings were colonized by microcolonies of coccal prokaryotes and some filamentous microbes. Foot peeling particles possessed lower biomass concentrations, and biofilm-covered pumice and polyethylene could no longer be distinguished with the available microscopic methods. Regarding the shower peeling, the blue jojoba ester beads were more intensely colonized compared to the colourless polyethylene particles. Pre-tests with rinsed particles showed that estimation of viable microbial biomass as phospholipid phosphate was possible without background signals. This method therefore appears to be suitable for routine biomass quantification from a variety of anthropogenic particles collected from aquatic environments. Incubations of anthropogenic particles in more natural settings or directly in a river or lake will help to improve our understanding of biofilm formation and subsequent fate of the material in aquatic ecosystems.

Biofilm on plastic is a low-quality food resource for the grazer *Radix balthica* (Gastropoda)

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Plastic contamination of running waters and lakes pose a potential threat to freshwater organisms. The effects of plastic on food chains in freshwaters are of particular interest concerning environmental functions and stability. But, investigations of plastic affecting more than one trophic level have not been carried out so far.

In this study effects of plastic on primary production, i.e. biofilms, and primary consumers, i.e. an invertebrate grazer, covering two trophic levels of the aquatic food web were investigated. Two plastic types, Perspex (PMMA) and Polycarbonate (PC), and glass (control) were used as substratum for natural biofilm establishment. These biofilms were fed to the freshwater gastropod *Radix balthica* in a laboratory grazing experiment. Biofilm structure and composition were observed with confocal laser scanning microscopy. Sub lethal effects on *R. balthica* were observed measuring consumption of biofilm (as faeces dry mass) and growth rates.

Biofilm structure and composition were similar on control and PC substratum, but biofilm on PMMA substratum showed significant differences. After the grazing experiment patches of remained biofilm were found on both plastic substrata. On control substratum, the entire biofilm was consumed by *R. balthica*. The consumption of biofilm was significantly lower in the PC treatment, compared to the control and the PMMA treatment. Growth rates were significantly lower in both plastic treatments, compared to the control treatment.

The low growth rates in the PC treatment may result from the lower consumption of biofilm in this treatment. In the PMMA treatment, the altered composition of biofilm could have reduced growth rates. Furthermore, both plastics might have leached or carried adhered pollutants, which may have reduced growth rates directly, or indirectly through lower grazing activity.

Concluding, it was shown that plastic as a substratum affects the composition of freshwater biofilms resulting in lower growth rates of a grazing benthic invertebrate. Thus, plastic in freshwaters has a direct effect on the primary production and an indirect effect on higher trophic levels.

Analysis of microplastic particles in bivalves samples

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The accumulation of microplastic (MP, 1 µm – 5 mm) in marine ecosystems is of increasing scientific and public concern [1-6]. Recently, MP has also been found in freshwater ecosystems [2-5]. The impact of MP on aquatic ecosystems is not yet fully understood, but there is an increasing number of studies reporting that MP particles are hazardous to aquatic organisms [6].

We investigate the accumulation of MP by fresh water organisms, e.g. indigenous bivalves (*Unio sp.*). The bivalves were exposed to MP either in the field or under standardized laboratory conditions. In the latter, organisms were exposed to various concentrations and particle sizes of polyvinylchloride (PVC) under flow through conditions. For the analysis of MP in bivalves we established a method including sample processing, as well as identification and quantification of MP down to 1 µm by means of Raman microspectroscopy (RM).

The stability of the most abundant plastics (polyethylene; PE, polypropylene; PP, PVC, polystyrene; PS, polyethylene terephthalate; PET) in this treatment was verified. Further RM studies will focus on the MP accumulation in fish exposed to MP containing food (e.g. PVC) under laboratory conditions. In parallel, possible adverse effects on fish health due to MP exposure will be investigated.

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Uptake and elimination of HD-PE microplastics in the digestive system of *M. edulis*

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The data base on the potential ingestion of microplastics (MP) by several species is growing continuously, while information on particles fate in tissues and cells is sparse. However, this information is crucial for the evaluation of the toxicological impact on organism health, bioaccumulation and food safety.

Many filter feeding species developed strategies to separate valueless materials from valuable nutritious particulate matter after ingestion. The mollusk M. edulis separates particles i.a. by means of density. Dense particles fall into rejection grooves whereas light particles, such as microalgae, are directed into the digestive gland, the main site of intracellular digestion. The aim of the present study was to identify how M. edulis deals with the exposure to MP as these particles are light but indigestible and valueless.

As the model plastic we used HD-PE (0.96 g/cm^3, irregular shaped, 0-80 µm), one of the most important consumer plastics and prevalently found in the environment. To analyze uptake processes, mussels were experimentally exposed to a particle concentration of 2000 p/ml for 3 h, 6 h, 12 h. To follow up a potential elimination, mussels were exposed for 12 h and thereafter transferred to plastic-free water where they remained for 3 h, 6 h, 12 h, 48 h, 96 h, 7d and 14 d until sampling. The digestive system was dissected and processed for histopathological analysis.

The particle load in four compartments of mussels' digestive system was visualized by a novel approach combining polarized light microscopy and quantification by means of digital image analysis. Particles presents in tissues was further verified by IR-spectroscopy.

Our study indicates that mussels are unable to identify MP as material of low value during post-ingestion particle selection. Mussels ingested MP and transferred large amounts into their digestive gland. Especially during times of strong gut passages large quantities of MP were found in the connective-storage tissue (CST) of the digestive gland around the stomach and intestine. Particles persisted notably long in the tubules and the CST of the digestive gland. Finally, all particles were eliminated from the digestive system after 96 h in plastic-free water.

To investigate if the exposure to MP exerted harmful effects, the digestive gland will be diagnosed for cell pathological changes including indicators for scar tissue formation.

Delicious plastic? Do freshwater mussels ingest microplastic under field conditions?

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A large amount of microplastic (plastic particles < 5 mm) can be found in marine and freshwater systems. Apart from indirect effects, organisms can be directly injured due to ingestion. Microplastic ingestion is already verified for several species, but only for a few freshwater species. Furthermore most of these studies were performed under laboratory conditions with a relatively high microplastic concentration compared to “natural” concentrations in freshwater systems.

This raises the question of whether species, for example the mussel *Corbicula fluminea*, ingest microplastic particles under field conditions. We exposed 90 individuals of *C. fluminea* for three weeks to different amounts of in situ microplastic in the River Lippe, a lowland river in northwest Germany. Forty-five individuals were placed into the outlet of a waste water treatment plant (expecting high concentrations of microplastic in the water), the other 45 individuals upstream of the wastewater treatment plant (expecting lower microplastic concentrations). Microplastic concentrations were detected in both reaches with driftnets. Results showed that, mussels exposed to higher concentrations of floating microplastic (12.7 ± 8.3 microplastic particles per m^3 floating in the outlet of the waste water treatment plant versus 7.1 ± 6.2 microplastic particles per m^3 floating in the water upstream the outlet) ingested significantly more microplastic particles (0.61 ± 0.30 particles per mg mussel dry mass versus 0.27 ± 0.14 particles per mg mussel dry mass). Hence, also freshwater mussels ingest microplastic particles and the amount of ingested particles increases with increasing plastic concentrations in the water.

PET microplastics have no long-term effects on the freshwater amphipod *Gammarus pulex*

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Microplastics (MP) are abundant in most of the global marine and freshwater ecosystems and can interfere with its biota. Potential adverse effects have already been studied *in situ* as well as in laboratory studies for several marine species while effects on freshwater organisms remain so far largely unstudied.

The present study provides first results on the short-term uptake and the long-term effects of PET MP on the freshwater amphipod *Gammarus pulex*. As part of an uptake study (24 hours) as well as an effect study (48 days) juvenile (6-8 mm) and adult (12-17 mm) individuals were exposed to fluorescent PET MP with a size range of 10-150 µm. Both studies covered MP concentrations from 0.4-4,000 particles mL^{-1}. The rate of MP uptake throughout 24 hours was determined by enzymatically lysing the exposed individuals and analyzing the ingested particles with a fluorescent microscope. Feeding activity, energy reserves (glycogen, lipids), molt period length and mortality were investigated as endpoints in the 48-days chronic toxicity study.

The results of the short-term uptake study indicate that MP ingestion by *G. pulex* is not size-selective and increases with particle concentration. Comparing the particle uptake of adults and juveniles at same particle exposure concentrations, juveniles ingested more particles than adult individuals. In the chronic toxicity study no significant changes in feeding activity, energy reserves, molt period duration and mortality were observed in any of the treatment groups.

In conclusion, this study demonstrates that a common freshwater amphipod readily ingests MP. However, the uptake does not result in adverse effects on behavioral, physiological and developmental parameters. The absence of long-term effects might be the result of the main feeding strategy of amphipods. *G. pulex* shredders detritus and plant materials and is adapted to a frequent uptake and egestion of non-digestible particles. Future studies will provide insight on whether MP adversely affect freshwater species with other feeding strategies (e.g. filter feeders).

Effects of pristine microplastic particles on the water flea *Daphnia magna*: A laboratory approach as basis for more complex scenarios

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Plastic pollution has already been observed in marine environments for several decades. Nevertheless, our understanding of both extent and consequences for our ecosystems is still very limited. This also includes fate and effects of especially small plastic particles (microplastics), which have been overlooked in the past. Recent studies focus on their abundance, distribution and fate in general and in freshwaters in particular but also on their potential effects on organisms with focus on laboratory studies (e.g. Cole et al. 2015, Imhof et al. 2016). Assessing the risks of microplastics in the environment is challenging especially because of the simultaneous presence of other stressors like chemical substances that sorb to the plastic matrix. Although some studies already showed that microplastics can be a vector for pollutants to aquatic animals (e.g. Rochman et al. 2013), the relevance of microplastics to the overall pollution is still under discussion. Separating and testing single effect factors systematically in a first step can help to understand risks of microplastics and their underlying processes. Therefore, we analysed in lab experiments, if pristine plastic material itself can induce negative effects on aquatic organisms before addressing research questions including more complex interactions with other stressors. Following established ecotoxicological methods we aimed at identifying threshold concentrations of 1-µm and 100-µm PE particles for immobilisation effects on the waterflea *Daphnia magna* at high concentrations (25-400 mg L^{-1}). While 100-µm particles were not ingested and did not cause immobilisation, 1-µm particles were ingested and caused immobilisation increasing with dose (up to 200 mg L^{-1}) and time (up to 96 h) with EC_{50} of 57.43 mg L^{-1} after 96 h. Preliminary results on PA-particles with an average diameter of 25-30 µm indicate, that these particles just cause immobilisation at the highest tested concentrations between 200-400 mg L^{-1}. In conclusion not only size and concentration of microplastics, but also exposure time and the type of polymer can influence negative effects on limnic zooplankton. Our results can be a first basis for studies including combined effects of microplastics and pollutants and future risk assessment.

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Size-dependent uptake of microplastics in *Daphnia magna*

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Aquatic ecosystems worldwide are polluted by plastic waste. This also includes the presence of microplastics that, due to their small size (< 5 mm), have the potential to affect a wide variety of aquatic organisms. The number of aquatic species, for which active or passive ingestion of microplastics has been observed, is steadily increasing. Although microplastic pollution occurs in marine as well as freshwater ecosystems, most studies on microplastic uptake so far focused on marine biota. Additionally, current approaches are mostly qualitative since quantitative measures of ingested particles are analytically challenging. The aim of this study was therefore to use a quantitative approach for determining the microplastics body burden of the freshwater crustacean *Daphnia magna* during a short term (48 h) uptake and depuration test. The experiments were conducted with two different sizes of fluorescently labelled polystyrene beads (0.01 µm and 2 µm), based on the underlying hypothesis that uptake mechanisms are particle size-dependent. Animals were exposed to a particle suspension (2 mg/l) for 24 hours (uptake phase), after which they were transferred to clean medium for another 24 hours (depuration phase). During uptake and depuration, animals were sampled at different time points (0.5 h, 1 h, 2 h, 4 h, 8 h and 24 h respectively), the tissues were enzymatically digested and the fluorescence was measured to determine the particle load of the animals. Additionally the fluorescence of the exposure medium was monitored during the uptake phase. Both particle sizes were readily taken up by the animals and body burdens increased with exposure time. Size-dependent differences in uptake are discussed as well as the potential competition between food (algae) and particle uptake.

Abstracts: Poster

Management options

Innovative approaches to reduce fibres discharged in textile washing processes

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Contamination of the aquatic ecosystems by plastic debris, so called microplastic, is a growing worldwide problem. The abundance in the freshwater and marine habitats as well as the sources and pathways of microplastics are not fully known to date, however sewage wastewater from textile laundry processes appears to be one origin of synthetic fragments. Examinations demonstrate that washing cloths and textiles is most likely to contribute to the microplastic problem [1]. Nowadays, synthetic polymers like polyester, polyamide or polypropylene dominate the fibre industry and are preferably used in textiles due to their durability and low price. In cleaning processes the garments are exposed to different strains e.g. mechanical strain, detergents and temperature which may cause damages to the fibres and textile surfaces. These damages can lead to the loss of particles and fibres with different sizes and shapes.

To date, there are no information about the impact of domestic and industrial laundry to the microplastic pollution. The aim of the research project is to characterize and quantify the amount of discharged particles and fibres from garments for different laundry processes (domestic and industrial laundry) and different conditions. First experiments indicated a release of fibres from polyester textiles in tumble dry processes [2].

In the scope of this study the washing processes are optimized to reduce the abrasion of particles and fibres on the one hand and abrasion-resistant textile treatments are tested on the other hand. This research work underscores the relevance of textile washing processes to the microplastic accumulation in aquatic environments and provides approaches towards preventative measures.

[1] M. A. Browne, P. Crump, S. J. Niven, et al., "Accumulation of Microplastic on Shorelines Woldwide: Sources and Sinks", Environmental Science & Technology 2011

[2] E. Claßen, J. Beringer, "BMBF-Project (03X0091B), UMSICHT", final report Hohenstein Institute for Textile Innovation gGmbH, 2012.

Test to assess and prevent the emission of primary synthetic microplastics (primary microplastics)

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Many products and industrial process are known to be a source of microplastics (<5 mm) pollution. Synthetic microparticles are either released during the use of products as such as cosmetics, from (industrial) processes (both primary and secondary micro particles) or are the result from degradation of larger plastic items (secondary micro plastics). Most synthetic micro particles will not degrade naturally, hence they are accumulating in the environment. There is building evidence that these micro particles may have a negative effect on individual animals and can accumulate in the food chain.

In order to create a future in which the release of synthetic micro particles to the environment is minimized, the Belgian federal government has ordered the design of a test to assess and prevent the emission of primary synthetic microplastics, to the environmental consultancy agency TAUW. This test has been developed to assist companies in assessing their use of synthetic micro particles and in taking measures to prevent the emission of synthetic micro particles to the environment.

Using the test, the company can attain comprehension on the use of synthetic microparticles and the resulting emissions of these particles. Sectors to whom this self-test applies are: producers of plastic granulates, rubber granulates, cosmetics, paint, glue, varnish, food, medicine; sectors who use abrasive cleaning or blasting with plastic, or sectors who use one of the above products that contain microplastics or use microplastics as tracers in the production process.

This test is set up as a series of steps that a company should follow. The test generates insight on all primary synthetic microparticles used by the company (identification), all emission pathways and quantifies the emission (analysis). It also offers a in a series of possible source measures (alternatives) and measures to stop these emissions (improvement).

The test can be used for other purposes than controlling microplastics emissions of a company. The test can be easily adapted in order to monitor emissions in a (watershed) area, within a branch of industry, within an environmental management system such as ISO 14 001, or as a method to make emission reduction obligatory by law.

Optimized materials and processes for the separation of microplastic from the water cycle – OEMP

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The increasing application of plastic products during the last 60 years, entailed an undesirable plastic input to the environment.

Small plastic particles (microplastic) are able to reach the water cycle by housholds and urban areas. Microplastics are defined as particles smaller than 5 mm and could be subdivided into two groups: Primary microplastics are engineered materials used as product additives for cosmetics, peelings and cleaning agents.

Secondary microplastics are produced from the embrittlement of common plastic products, due to physical, chemical or biological degradation processes.

This project intends the development of new restraining materials and processes for the separation of various microplastic particles (different in size, shape, type of plastic). Different entry pathways of the urban water cycle in city areas (effluent from wastewater treatment plants, combined sewer overflows, street drainage) are investigated for the purposes of optimized technical approaches, to ensure a sustainable water economy with high class standards that achieve the protection of the surface waters.
Therefore, a high class assurance is needed, that examines the different technical and natural systems with regard to their retention qualities. An integrant is an evaluable methodology of these investigations, as well as a first benchmark of the purification processes, which are developed during the project.

Abstracts: Poster

Analytics

Defining the baselines and standards for microplastics analyses in European waters (JPI-O BASEMAN)

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Since the middle of last century rapidly increasing global production of plastics has been accompanied by an accumulation of plastic litter in the marine environment. Dispersal by currents and winds does not diminish the persistence of plastic items which degrade and become fragmented over time. Together with micro-sized primary plastic litter from consumer products these degraded secondary micro-fragments lead to an increasing amount of small plastic particles (smaller than 5 mm), so called “microplastics”. The ubiquitous presence and massive accumulation of microplastics in marine habitats and the uptake of microplastics by various marine biota is now well recognized by scientists and authorities worldwide. Although awareness of the potential risks is emerging, the impact of plastic particles on aquatic ecosystems is far from understood. A fundamental issue precluding assessment of the environmental risks arising from microplastics is the lack of standard operation protocols (SOP) for microplastics sampling and detection. Consequently there is a lack of reliable data on concentrations of microplastics and the composition of polymers within the marine environment. Comparability of data on microplastics concentrations is currently hampered by a huge variety of different methods, each generating data of extremely different quality and resolution. Although microplastics are recognized as an emerging contaminant in the environment, currently neither sampling, extraction, purification nor identification approaches are standardised, making the increasing numbers of microplastics studies hardly -if at all- comparable. BASEMAN is an interdisciplinary and international collaborative research project that aims to overcome this problem. BASEMAN teams experienced scientists (from different disciplines and countries) to undertake a profound and detailed comparison and evaluation of all approaches from sampling to identification of microplastics. BASEMAN's project outcomes will equip policy makers with the tools and operational measures required to describe the abundance and distribution of microplastics in the environment. Such tools will permit evaluation of member state compliance with existing and future monitoring requirements. BASEMAN is one of four projects funded in the framework of the JPI-O pilot action "Ecological Aspects of Microplastics".

Microplastic content in freshwater – an easy and cost-efficient analysis approach

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In contrast to macroplastic analysis, there is no accepted standard for the characterization and quantification of microplastics. The most commonly used techniques include density-gradient-separation and microscope sorting followed by IR-analysis or Pyrolysis-GC. These techniques are error-prone, time consuming, expensive and are somewhat restricted when taking microplastic particles of a grain size below 100 µm into account.

In the last years, a method (the so called Balance Method) for the determination of fossil matter in mixed waste has been developed at the TU Wien (Fellner et al. 2007/2011). The Balance Method is based on the distinctly different chemical composition of moisture- and ash-free biogenic and fossil organic matter. At laboratory scale, an elemental analysis is used to determine the content of the elements C, H, N, S and O in the dried sample as well as the ignition residue.

$$X_b \cdot m_b + X_f \cdot m_f = TX_{sample} - TX_i \cdot m_i$$

Based on different mathematical balances, a system of equations can be created, which is defined by the individual contributions of the elements (X = C, H, N, S, O), their corresponding material data and the measurable values TX_{sample} and TX_i (b = biogenic, f = fossil and i = inert). A data reconciliation algorithm is applied to reveal the quantity of the unknown mass fractions (biogenic m_b, fossil m_f and inert matter m_i) including their uncertainties.

Currently, this method is modified in order to be applied to water and wastewater samples. In a first test series the microplastic content in different samples taken from a wastewater stream has been successfully quantified. The method demonstrated good results by either making use of an oxidation before the elemental analysis (utilizing hydrogen peroxide to reduce the organic part to a hardly oxidisable lignin matrix) or by analysing the unaltered sample for its C, H, N, S, and O content. Either way used, a sample volume of 2 – 3 g was enough to precisely quantify the contained fossil matter (microplastic) by means of the adapted Balance Method.

In contrast to the above-mentioned methods, which are limited to certain grain sizes, the described technique offers the possibility to characterize solid samples independent from the size of the microplastic particles. However a routine application of the adapted Balance Method ultimately requires detailed knowledge about the elemental composition of both, the organic (biogenic) and the fossil part (plastics).

Identification of Small Microplastic Particles (<500 µm) in Water Samples by FT-IR Micro-Spectroscopy and Imaging – Possibilities & Challenges

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Large microplastic particles (larger than 500 µm) are often sorted by hand, and categorized according to their shape by the naked eye, e.g. industrial granules, flakes, foam, foils or fibres. The identification of a plastic material based on properties such as colour, stability and texture is possible, but often misleading. A more reliable way to confirm plastic material is infrared (IR) spectroscopy, for example in-contact measurements with an ATR (attenuated total reflection) accessory.

Small microplastic particles (smaller than 500 µm) require different approaches for detection and identification, especially for water samples with considerable content of solids. Again, infrared spectroscopy is a suitable technique, which can be upgraded by the features of microscopy and imaging.

For the measurement of plastics smaller than 500 µm it is important to remove as much interfering non-plastic matter as possible by physical and chemical methods. Usually, only a small portion of the original water sample can be measured in one analytical run. Thus, it is crucial to provide a representative aliquot from the bulk sample, in particular with higher solids content.

We show applications of FT-IR micro-spectroscopy and imaging to water samples, and address the possibilities as well as challenges in identifying microplastics from approximately 25 µm to 500 µm size on particle loaded filter material.

A semi-automated procedure for data analysis of FT-IR images is presented; the result is the number of identified plastic items smaller than 500 µm. In addition, we critically discuss a method to estimate the weight of identified plastic particles. For comparison of environmental data on microplastics in different environmental compartments, the measurement as well as data analysis procedures have to be harmonized on an international level.

Development of Standard Operating Procedures for Sampling of Microplastic in Waste Water Treatment Plants

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Studies on the occurence of Microplastic (MP) in freshwater systems and their behavior in technical systems, such as waste water treatment plants, gained more and more interest of the public and scientific communities. So far, only a few studies on MP in waste water treatment plants were performed. The published results differ and mainly focused on measurements of the plant effluent. The used sampling procedures often remain unclear and lack of confirmability. The published studies vary in sample number, size and volume at which usually grab samples were taken. Even storage of the samples vary and sometimes plastic jars were used. Particle sizes mainly were determined by the use of screens of different mesh sizes, delivering often just coarse subdivisions but no real size distributions. The type of MP were usually determined by FT-IR or Raman- spectroscopy, whereas pretreatment vary strongly. Hence, no general standard operating procedures (SOP) for sampling and analytics are established yet and there is a need for standardization.

Waste water plant operators are specifically interested in studies on the behavior of MP, e. g. possible sources and sinks within the treatment plants. Therefore, mass balances needs to be performed and could be used for comparison of different treatment steps and entire plants. However, these mass balances require SOP for sampling and analytics too.

The poster is intended to initiate discussion and will present our attempt for the development of SOP for sampling at different places to achieve qualified measures to be used for mass balances. The aimed SOP thus need to be ideally adapted to the local conditions, e.g. sample points such as plant influent, clarifier effluent and excess sludge, taking different representative samples, such as grab samples, 2 or 24 hours mixed samples, and representative sample volumes. The latter one might be crucial for locally performed analytics and shipment to water laboratories for further investigations. Furthermore, the samples should be possibly taken by the local operators.

A simple and effective method for the detection of microplastics in fish stomachs and larvae

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The burden of microplastics in the environment is a rising threat, affecting aquatic ecosystems worldwide. To increase the chances of identifying all kinds of plastic types and sizes ingested by water organisms, the digestion of this organic matter is necessary. In the last few years, several digestion techniques and protocols were developed. However, these methods are often either time consuming or detrimental to plastics because of chemical degradation. Additionally, with a high number of digestion steps, the probability of contamination and loss of material is increasing. The main aim of this work was to develop a reliable method to completely digest organic tissue, while minimizing chemical destruction and exposure. The method should meet the following requirements: (i) using a set of chemicals that digest organic matter efficiently and cause minimal damage to plastics, (ii) keeping the number of digestion steps low and (iii) reducing the number of inorganic materials, like minerals, to improve the identification of microplastics.

The final method consists of two conjoined digestion steps using sodium hydroxide (NaOH) and nitric acid (HNO_3). Furthermore an optional density separation step, using sodium iodid (NaI) to reduce mineral residues in the sample, can be conducted. This method allowed complete dissolution of whole stomachs of fishes up to 20 cm, as well as fish larvae up to 5 cm.

The method was tested for efficacy and the remaining detrimental effects on common polymer types (PE, PP, PVC, PET, PA, and PS). With the exception of polyamide, only minor changes in surface area and weight of the test particles were observed. Polyamide however was completely dissolved during the treatment. The FTIR spectra of the individual types of plastic were not changed by the procedure. Stomachs of 6 whitefish (*Coregonus wartmanni*) were spiked with fluorescent polystyrene particles of three size classes (900 -550 µm, 549 - 300 µm and 299 -100 µm). After the individual digestion steps, the remaining particles were counted and led to an average recovery rate of 95 % and above.

In conclusion, this new method provides an effective way to detect and quantify microplastics in fish tissues. With this procedure the identification of particles and fibres was facilitated considerably, while concurrently reducing the number of working steps, the exposure to dissolving chemicals and the overall reaction time.

Analytical studies on the formation of biofilms on plastic film in freshwater systems

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Littering of plastics in the environment is a serious problem. First reports on plastic litter in the marine environment were published in the 1970s, but about 80 % of the waste present in the sea is originated from the terrestrial environment. Plastic pollution in marine systems has been receiving attention in the recent years. While the research on marine litter is more advanced already, there are immense gaps of knowledge regarding the terrestrial systems or freshwater systems. But plastic litter in fresh water systems has become a new topic of interest attracting the attention of the public. Until now very little is known and the research is in an early stage. There are some important gaps that need to be filled. There is a lack of standardized sampling and analytical methods to determine the occurrence of micro plastic particles in fresh water systems, sediments and complex biological matrices. The relevant sources and the environmental effects also have to be investigated. There is also a lack on the biological effects of micro particles on freshwater species. The aim of this work is to investigate the formation of biofilms on plastic films in fresh water systems.

In order to estimate the impact of plastic waste on freshwater systems, a reliable and standardized separation of the particles is necessary. Currently the separation process is based on a density separation. The plastic particles or fragments are detected afterwards by a chemical identification of the polymer, e. g. with fourier transform infrared spectroscopy (FTIR spectroscopy). This procedure works without any problems on the starting materials. But does this also work with samples that were exposed to aging process in nature and forming a biofilm?

In this study the formation of biofilms on plastic films in different fresh waters systems (aquarium, pond and compost suspension) were investigated. The aim was to investigate influence of the biofilm on the sinking / floating behavior and the characterization by FTIR spectroscopy. With increasing exposure time the biofilms consist mainly of green algae and diatoms is growing. The sinking and floating behaviour changed already after one week. Furthermore, the characterization of the polymer by means of FTIR spectroscopy was not possible through the biofilm. Techniques to remove the biofilm by digestion with acids, bases or enzymes are required.

Microplastics from personal care products – Potential detection bias in visual sorting

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Many methodologies for detecting and enumerating microplastics rely on a step of visual sorting, i.e. picking particles of filters, nets or sieves before further identification work (FT-IR or Raman spectroscopy) is carried out. Our work on microplastics from personal care products as part of our public engagement showed that in many products irregularly shaped, transparent-white particles dominate over 'classical' round beads. In environmental samples, these particles will not be apparent, as they neither exhibit unusual colour nor artificial shape, and might be easily be mistaken for mineral material.

SEPA engages with partner organisations and academic research groups in Scotland to ensure data will be suitable for a national baseline of microplastic prevalence. This includes the establishment of common size class boundaries, sampling methodologies and quality controls. The Scottish Microplastic Research Group under the Marine Alliance for Science and Technology Scotland (MASTS) is the main conduit for this. Issues under investigation cover the full range of aquatic media, from sewage to freshwater and the marine environment.