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Conference on Plastics in Freshwater Environments

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Conference on Plastics in Freshwater Environments

by

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Kurzbeschreibung

Das Umweltbundesamt (UBA) und die Bundesanstalt für Gewässerkunde (BfG) organisierten eine Konferenz zu Plastik in Binnengewässern im Auftrag des Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit. (BMUB). Die Veranstaltung fand am 21. - 22. Juni 2016 in Berlin statt, mit 220 Teilnehmer_innen aus 20 europäischen und zwei nicht-europäischen Ländern. Ziel war der Austausch von Kenntnissen über Plastik in europäischen Binnengewässern und die Diskussion über dessen Folgen für die Umwelt und die Gesellschaft. Die Referent_innen und Teilnehmer_innen kamen aus den Bereichen Wissenschaft, Regulierungsbehörden, Industrie und Nicht-Regierungsorganisationen. Vorträge und Poster zu verschiedenen Themen wie Quellen und Senken, Umweltbelange, Risikowahrnehmung und Managementoptionen wurden präsentiert. In Vorbereitung der Konferenz wurde ein Issue Paper über Plastik in europäischen Binnengewässern erstellt. In diesem Zusammenhang wurde ein informeller Fragebogen an die Wassermanagementbehörden in Europe versendet, um einen Überblick über Monitoring, Risikowahrnehmung Managementoptionen zu erhalten. Die Ergebnisse dieser Umfrage wurden in dem Issue Paper dargestellt.

Abstract

The German Environment Agency (UBA) and the German Federal Institute of Hydrology (BfG) organised a conference on plastics in freshwater environments on behalf of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). The conference took place in Berlin on June 21–22, 2016, with 220 attendants from 20 European and two non-European countries. The objective was to exchange knowledge on plastics in European freshwater environments and to discuss its environmental and societal implications. The speakers and attendants had professional backgrounds in academics, regulatory authorities, industry and non-governmental organisations. Lectures and posters were presented on various topics, including sources and sinks, environmental concern, risk perception and management options. In preparation of the conference an issue paper was compiled on plastics in European freshwater environments. In this context, an informal questionnaire was sent to water management agencies in Europe to provide an overview on monitoring, risk awareness and management options. The results of this survey were presented in the issue paper.

Acknowledgement

We would like to thank all presenters and participants of the European Conference on Plastics in Freshwater Environments for their contributions. We also express our thanks to the participants of the European survey for supporting our work. Finally, we are grateful to everyone who provided information on the activities related to plastics in European freshwater environments.

European conference on plastics in freshwater environments

The German Environment Agency (UBA) and the German Federal Institute of Hydrology (BfG) organised a conference on plastics in freshwater environments in Berlin in June 2016. The objective was 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 presented lectures and posters. Invited speakers presented lectures on various topics, including sources and sinks, environmental concern, risk perception and management options. Before the conference, an issue paper was compiled on plastics in European freshwater environments (see addendum to this report). In this context, an informal questionnaire was sent to water management agencies in Europe to provide an overview on monitoring, risk awareness and management options. The results of this survey were summarised in the issue paper (see addendum, chapter 4).

Ten key facts we knew before the conference:

In advance of the conference we prepared an issue paper on plastics in freshwater environments in which ten key facts summarised the current state of research and knowledge:

1. Monitoring studies cover only individual European rivers and lakes, and spatial data for European freshwater environments are not comprehensive.
2. Temporal data are missing. In general, measurements are based on individual time points.
3. The lack of generally accepted definitions of micro-, meso- and macroplastics hamper a comprehensive monitoring of freshwater environments.
4. Sampling of plastics in freshwater environments, sample processing and analytical identification are not harmonised, including data reporting.
5. Little is known on pathways, sinks, and fragmentation of plastic materials in freshwater environments. Only rough estimations are available for the potential sources of plastic in freshwater environments.
6. There are not enough data on the loads and patterns of plastics in rivers to characterise riverine inputs into the marine environments.
7. Effects assessment of plastics in freshwater ecosystems has only just started and data are only available for a few species.
8. More investigations are required on the effects of plastic additives and the sorption of environmental pollutants to synthetic polymers in freshwaters.
9. The potential risk from uptake and accumulation of plastics in freshwater ecosystems has only been investigated in very few species so far.
10. Discussions are starting on efforts to reduce plastic inputs from various sources into freshwater environments.

Take-home messages from the conference

Presentations and discussions at the conference concerned monitoring, hazard assessment and management options. Their conclusions can be summarised in ten take home messages:

1. Plastic pollution of freshwater environments is ubiquitous. Plastic particles are ingested by a wide range of animals and the transfer of these particles to aquatic food webs is of growing concern. Very little is known about the potential toxicity of plastics to freshwater organisms but effect data for marine taxa have been published. The presence of anthropogenic pollutants in the environment should trigger an assessment that includes exposure and effects as well as source identification.

2. Plastics are indispensable to society and, by replacing other, less environmentally friendly materials, have the potential to reduce the human environmental footprint. However, the use of plastic products can result in plastic pollution of the environment, especially if adequate waste management and an awareness of the proper handling of plastics are lacking. Both need to be improved in the near future.
3. Plastic pollution impacts various areas of both wet and dry policy sectors, including energy, agriculture, transportation and health. Thus, the expertise and perspectives acquired in both are needed to tackle plastic pollution. Cost-benefit analyses should result in realistic estimates of the burden posed by plastic pollution and in an impact assessment that addresses its social, economic and environmental aspects.
4. Resource efficiency and the circular economy, which transform industrial processes from linear flows to closed material cycles, are fundamental for solving the challenges posed by plastic pollution. Because they are produced on land, plastic products need to be returned to land-based facilities to be properly disposed of. Better management of plastic waste on land requires an understanding of the entry points of plastic pollution to rivers and the seas.
5. Of the many different measures aimed at reducing or removing plastic pollution, some are already being implemented. The choice varies according to the plastic product and its geographical range. Key factors include improved waste management technologies, resource-efficient product design and greater awareness among citizens.
6. The roadblocks that prevent these measures from being universally applied must be identified.
7. Actions related to plastic waste management and environmental research should be prioritised: Where are there sufficient data to link plastic pollution to its sources? Where are appropriate solutions in place so that actions to combat pollution can be taken with immediate effects? In what areas is evidence lacking and what are the needs of research to fill in the gaps?
8. For more accurate exposure data and harmonised data reporting, a validated, consensual approach is needed to avoid conflicting assessments and to allow for evidence-based policy.
9. Better networking between European water and environment agencies is needed. These activities should also involve land-based regulation.
10. Plastics are not yet part of the Water Framework Directive but they may be addressed in the forthcoming 2019 review.

The setting of the conference

The conference was organised by the German Environment Agency (UBA) and the German Federal Institute of Hydrology (BfG). It took place in Berlin on June 21–22, 2016, with 220 attendants from 20 European and two non-European countries. The speakers and attendants had professional backgrounds in academics, regulatory authorities, industry and non-governmental organisations. The conference was opened by the Federal Environment Minister, Barbara Hendricks, and consisted of platform presentations, panel discussions and poster sessions.

Preparation for the conference included a survey on the current status of plastics in freshwater environments. The survey was conducted in the form of a questionnaire that was informally sent to the experts responsible for water monitoring and management in 28 EU member states and six other European countries. The results of the survey were summarised in an issue paper (Chapter 4).

Platform presentations, posters and the issue paper are available at the conference web site: https://www.umweltbundesamt.de/en/plastics-conference-2016.

Why did we organise this conference?

Plastic pollution was initially perceived as an aesthetic problem. In the 1990s, however, environmental researchers identified the hazards of macroplastic pollution for marine ecosystems. Since then, sampling campaigns have revealed the presence of microplastics all over the world, including in remote regions. The first results on plastics in freshwater environments were published only 5 years ago, but the problem was quickly seized upon by the public and the media.

The acute and long-term environmental risks of the ubiquitous presence of plastics are currently unknown. However, it is widely accepted that the large amounts and continuous inputs of plastics into the environment exert detrimental effects on ecosystems and human health. A precautionary approach demands a consistent characterisation of the potential risks arising from plastic pollution in the environment and the identification of the sources of these pollutants. An additional area of concern is the input of riverine plastics into the marine environment. The measurement of these fluxes should be mandatory under the Marine Strategy Framework Directive.

Non-governmental organisations have begun to address the plastic pollution issue by promoting clean-up campaigns, including citizen science projects that quantify plastic pollution in rivers and lakes. Several European countries have initiated screening studies on plastics in selected freshwater bodies. While these activities are encouraging, a consistent approach that will produce a complete picture of the situation in Europe is still missing. The conference was organised to provide:

- An overview of issues related to the monitoring and risk assessment of plastics in freshwater environments
- Discussions of research needs
- An evaluation of societal responses to plastic pollution
- An outline of the potential management options aimed at mitigating plastic pollution.

What have we learned from this conference?

Risk perception

Too little is known about the ecological effects of plastics, especially micro-and mesoplastics, in today's environment and the long-term consequences thereof. Nevertheless, European citizens have already voiced considerable concern about plastics in the environment. The recent Special Eurobarometer (EU, 2014) identified air pollution, water pollution, the health impact of chemicals in products and the growing amount of waste as the primary concerns of European citizens. All of these can be linked to plastics. In addition to the clean-up measures initiated by non-governmental organisations, the implications of plastic pollution are being addressed by regulators, policy-makers and scientists.

Sources and fate of plastics in the environment

Plastic particles < 5 mm in diameter are referred to as microplastics. These may be produced as such for industrial purposes (primary microplastics) or generated during degradation processes (secondary microplastics). Cosmetics, abrasive cleaning products and effluents from production sites are considered to be among the most relevant primary sources of microplastics, while plastic waste, laundry fibres, tyre wear, and paint are major sources of secondary microplastics.
Macroplastic materials are the most visible form of plastic pollution. These larger plastic pieces become fragmented in the environment but are hardly mineralised. As the degradation times of the various polymer types range from a few decades to several hundred years, plastic particles accumulate in marine and freshwater environments. More data are available on floating plastic particles than on plastics in the water column and in sediments.

Plastic use, society and the environment

Is the use of plastic materials environmentally sustainable? There are many examples of the benefits of plastic materials in daily life, such as their use in packaging, construction and transportation. Plastic materials in the food sector protect our food against damage, a loss of quality and microbial degradation. In the transportation sector, high-performance polymers enable weight reductions in cars, trains, ships and airplanes, resulting in less energy consumption. This explains why greenhouse gas emissions related to the use of plastic materials are often lower than those of alternative materials, whether aluminium, steel, wood or glass. Because plastics clearly meet so many different societal needs and given the positive cost-benefit relation of plastics vs. many of the alternatives, both plastic production and consumption are growing at a global scale.

However, plastic pollution is visible in the environment and has thus raised the concern of society and policy-makers. Researchers have demonstrated that plastics already pose specific risks for the environment. If the environmental pollution caused by plastics is not mitigated, then the use of plastic materials will not only continue to harm the environment but will also compromise economic, societal and ecosystem services (e.g. the recreational value of pristine environments). From this perspective, plastics may become a textbook example of market failure, as neither producers nor consumers have sufficiently considered the adverse impact of plastics. What is the anticipated response to this market failure? From the government's side, it may involve specific policies, economic instruments, voluntary agreements and increased public awareness to encourage behavioural changes.

Policy perspective

The problem of plastics in freshwater environments is on the agenda of European and national environmental authorities. The discussions thus far have focused on marine protection and land-based sources whereas freshwater environments are a new issue, currently the concern of international river commissions. As yet, the need for water management regulations has not been stated nor have collaborative monitoring initiatives been implemented.

The Water Framework Directive provides a safety net: As a monitoring tool, it can provide feedback to other, related policies and guide the selection of approaches likely to be the most effective. From a circular economy perspective, legislation targeting waste would be immediately effective. Moreover, the Water Framework Directive can supply data on waste from transportation, energy, food safety, agriculture and inland navigation as they relate to potentially affected water bodies.

The European Commission has funded monitoring projects including the "Identification and Assessment of Riverine Input of (Marine) Litter", in which riverine inputs into selected European waters were investigated. Additional EU-funded research is planned with the goal of harmonising the technical aspects of riverine litter monitoring and modelling.

The EU strategy on resource efficiency supports efforts at a circular economy. Regarding plastics in the environment, the European Commission has set three policy milestones over the last decade:

1. The Marine Strategy Framework Directive 2008 mandates a Good Environmental Status of the seas by 2020.
2. Green Paper 2013 was the first systematic and holistic approach to plastics in the environment at the European level. The paper cited UN statistics that, globally, 80% of marine plastic litter originates from land-based sources. It also examined several policy options aimed at improving the management of plastic waste in Europe.
3. In response to the Plastic Bags Directive of 2015, the Commission expects significant reductions in plastic bag use by consumers.

As part of its circular economy package, in December 2015, the European Commission presented an action plan for five priority sectors. The plan's measures cover the entire product life cycle: from production and consumption to waste management and the market for secondary raw materials. For plastics, the Commission pledged to: (i) develop a strategy on plastics in the circular economy (by

2017) and (ii) take specific action to reduce marine litter, with a view towards implementing the 2030 Sustainable Development Goals (from 2015 onwards).

At the conference, policy-makers stressed the holistic approach offered by the circular economy package, which requires communication from all sectors, including those involved in environmental, waste, resource and economic policies, to develop sustainable solutions for the use of plastics in the future. An open question is to what extent behavioural changes will take place, such as regarding packaging waste. For example, recycling appears to be a convincing strategy to reduce plastic waste whereas the more-demanding changes in behaviour and daily life that would lead to further reductions are often avoided.

Standards and definitions

An important prerequisite of obtaining consistent monitoring results is broadly accepted definitions. According to the ISO, plastic is "a material which contains as an essential ingredient a high polymer and which, at some stage in its processing into finished products, can be shaped by flow". The chemical legislation REACH defines a polymer material as a substance in which >50% of its weight consists of polymer. Size classes for the plastic particles found in the environment have been suggested by the EU Working Group on Good Environmental Status under the Marine Strategy Framework Directive and by the International Union of Pure and Applied Chemistry, among others. While the upper limits of macro-, meso- and microplastic particle sizes are broadly accepted, the borderline between micro- and nanoplastics remains poorly defined. In most studies the lower size limit was set by the limit of detection. At the conference, it was agreed that, for environmental research a clear identification of a microplastic particle requires an assessment not only of its size but also of its chemical composition, shape and physico-chemical parameters. Furthermore, the methods used in microplastic identification should be harmonised, as the variability in sampling, sample treatment, polymer identification and data reporting (e.g. particle per km^2, particle per m^3, mass per km^2, mass per m^3) makes it difficult to compare the results of the different studies.

How is monitoring currently performed and what are its challenges?

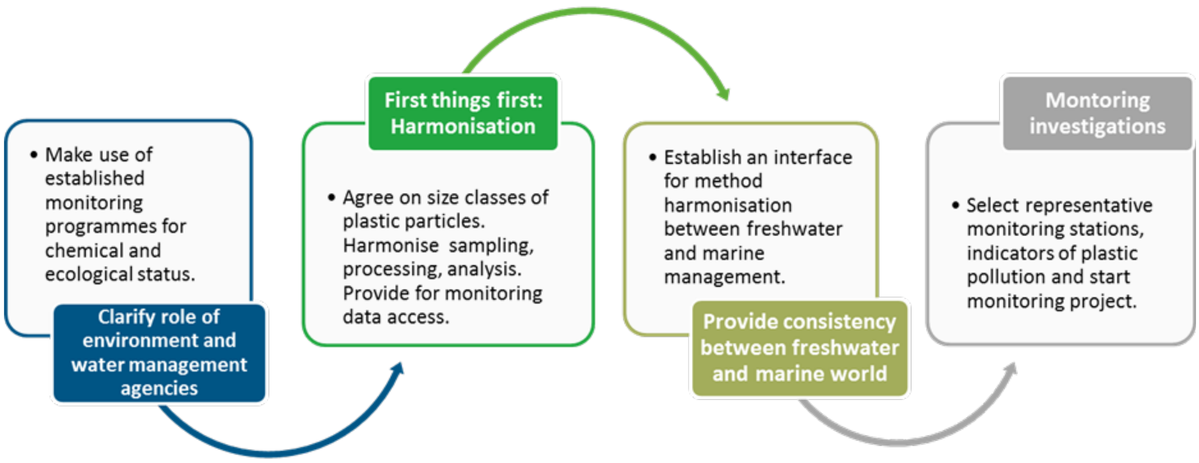
Monitoring studies presently cover only individual European rivers and lakes; thus, consistent quantitative and qualitative data are missing. The catchment areas of many rivers and lakes have high population densities and a high level of industrial activities. How does that effect plastic pollution? Are more remote areas less polluted? The concentration of plastic particles in rivers varies in the order of magnitudes but there are no plausible explanations for the differences between sampling sites. More data from a greater variety of rivers and lakes need to be acquired and analysed if we are to understand the importance of catchment size, population, meteorological and climatic differences and the level of catchment management.

Moreover, the majority of studies thus far have investigated plastics at the surface of water bodies whereas few data are available for the water column, sediments and biota. A better understanding of the fate and transfer of plastic particles in aqueous media together with more accurate mass balance determinations is needed. The Marine Strategy Framework Directive requires the reporting of riverine inputs into marine ecosystems but there are no reliable data available at the European level. However, an EU guidance document is being prepared to facilitate the reporting of riverine input.

To facilitate the design of management options with immediate local effect, investigations on potential hot spots for plastic pollution (e.g. littering, industrial emissions) should be encouraged. Modelling may support ongoing and planned investigations on plastics in the environment. However, the monitoring instruments and methods used to evaluate the marine environment need thorough testing before they can be applied one-to-one in the freshwater environment.

Environmental and water agencies have the potential to provide consistency by making use of the existing water management infrastructure in Europe. Regulatory agencies have yet to initiate joint monitoring activities. However, joining forces in research and regulation is essential for efficient monitoring activities, as is the careful evaluation of existing data. Areas of cooperation include the establishment of technical networking groups, agreement on definitions, ensuring consistency and developing links to marine regulation and waste management efforts.

Figure 1: Plastics in freshwater environments: From monitoring to management options – how do we get there? Presentation at the conference



Source: Busse et al. (2016)

Effects in the environment

Results from laboratory studies have shown that microplastics may alter freshwater communities, with effects on the individual or population level and of physical or chemical nature. To date, most effect studies have focused on acute toxicity to organisms living in the water column whereas very little is known about toxicity behaviours and sub-lethal effects. Furthermore, the impacts on sediments have been often overlooked, even though microplastic pollution may pose a particular threat to sediment-dwelling organisms.

Also of concern is the fact that plastic particles can act as vectors for invasive species, pathogens and hydrophobic pollutants in aquatic systems. For example, stabilisers and additives such as flame retardants, anti-oxidants and UV-blockers can leach into the environment or be ingested by biota together with the plastic particles.

Environmental risk assessment under REACH

The EU commission is evaluating the need for further requirements for polymers (see Art. 138 (2) REACH). In the current REACH framework, polymer molecules are exempted from registration and evaluation (but they may still be subject to authorisation and restriction). Moreover, the additives necessary to preserve the stability of the polymer are considered to be part of the substance and their separate registration is not required, unless they are imported to the EU as a substance. By contrast, normal registration requirements apply to substances that are added to improve the performance of the polymer but which are not necessary to preserve its stability. Examples of such substances include pigments, lubricants, thickeners, antistatic agents, antifogging agents, nucleating agents and flame retardants.

Plastics do not fully fit into current EU concepts for the risk characterisation and hazard identification of chemicals. The established guidelines for fate and effects testing were developed for dissolved chemicals and are not directly applicable to plastic particles. Effect assessments for plastics may therefore require the development of a new, substance-tailored toolbox, drawing on the experience gained with other particles (e.g. nanomaterials).

The large knowledge gaps on the fate and occurrence of plastic particles in the environment prevent sound exposure assessments. A major challenge is the assessment of fragmentation in the environment, from larger to smaller particles, and the simultaneous increase in particle abundance over time. In addition, the toxicity thresholds of freshwater and sediment organisms for the different-shaped particles have yet to be defined and important questions remain unsolved: How do the size, shape and type of the polymer and the presence of chemical additives affect the toxicity and hazard potential of plastic particles in the environment?

Cross-cutting discussions

Choosing between sampling campaigns and monitoring programmes

Our current knowledge on plastics in freshwaters is based on individual sampling studies initiated by researchers and regulatory authorities. Does current evidence from these studies indicate the need for a regulatory monitoring programme?

The results from sampling have allowed only very rough estimates of plastic pollution in rivers and lakes. These estimates probably describe only the tip of the “plastic-polymer iceberg”, as the techniques for analysing microplastic particles in water are still laborious, time-consuming and costly. This is especially the case for plastic particles <1 µm in diameter, and even more so for plastics in the nanoscale (<100 nm). Equally challenging is the detection of plastics in complex matrices, such as suspended particulate matter and sediments. Progress in analytical techniques will enable researchers to investigate samples more efficiently and to apply those techniques to a larger diversity of plastic particles in terms of their size and type. Currently, however, the lack of both standards and resources is a practical drawback to performing representative monitoring of plastic particles in European freshwater environments. Legal monitoring requirements should accelerate method development, validation and harmonisation within the established network of European water and environmental agencies.

But is a regulatory monitoring programme for plastic particles as performed under the Water Framework Directive for chemical and other pollutants even necessary? The implementation of an additional programme would impose a considerable burden on EU countries. Perhaps more importantly, it is questionable whether this approach would be cost efficient because:

- The major sources of plastics in freshwater environments are already known and include plastic waste from waste disposal and littering.
- Management measures to reduce environmental exposure to plastic waste would be land-based.
- The immediate effect of these measures can be determined on land and thus do not require monitoring programmes covering rivers and lakes.

However, it would be useful to establish a select number of monitoring sites under the Water Framework Directive to ensure that plastic pollution is monitored at regular intervals. This would provide a European overview and guard against increases in plastic pollution over time.

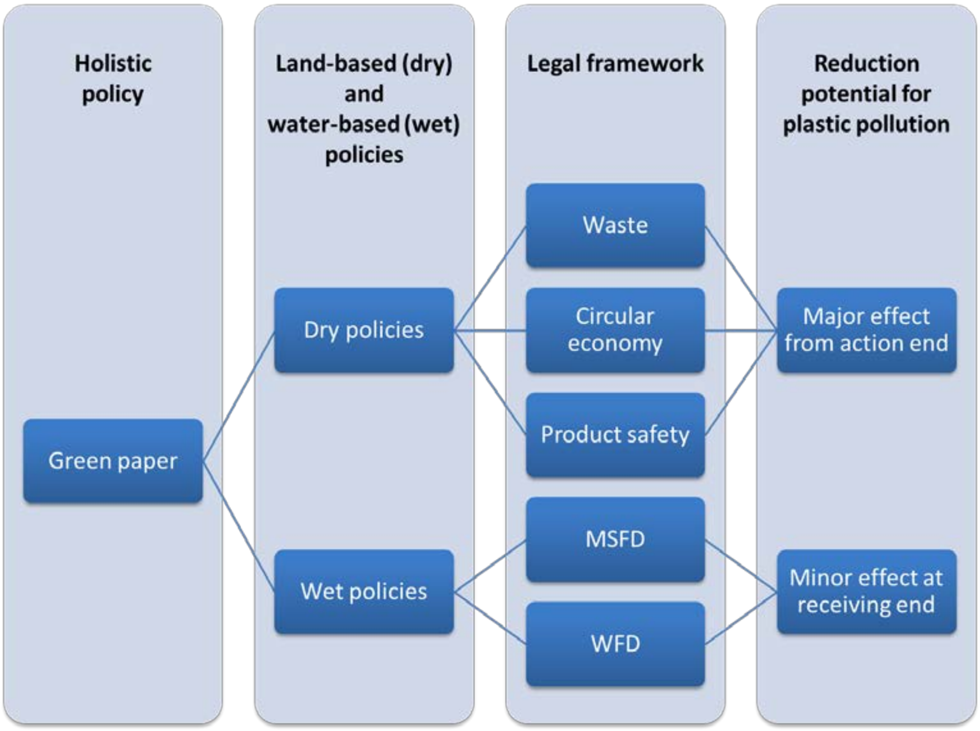
Table 1: Differences between research-driven sampling campaigns and regulatory monitoring programmes

Parameter	Sampling campaigns	Routine monitoring
Motivation	Research-driven; What is there?	Regulation: Measuring against a standard (e.g. Environmental Quality Standards) or reference condition to observe the status of the environment in a representative manner.
Strategy	Observing interactions of various plastic particles with the environment at selected sampling sites	Measuring indicator particles of defined polymer types and sizes at a representative selection of freshwater sampling sites.
Design	Individual study design	Harmonised approaches and standards for sampling, processing, measuring and data reporting.
Duration	Snapshot	Ongoing with regular intervals.

Who are the polluters, who should act?

The regulation of plastics in European freshwater environments involves several different policy sectors on the EU level, including 'wet policies' (EU legislation on water protection) and 'dry policies' (waste management, circular economy and the regulation of chemicals). But how can these policy sectors work together? The wet policy sector lacks regulations with an immediate effect on the plastic market and waste. By contrast, because most sources of plastic pollution in aquatic compartments are land-based, actions in the dry policy sector are likely to be more efficient.

Figure 2: Water- and land-based policy frameworks with respect to plastic waste in aquatic environments.



MSFD, Marine Strategy Framework Directive; WFD, Water Framework Directive

How much data do we need, are there enough data to already act?

Roughly 60 years after plastic entered the marketplace, it has found its way into aquatic ecosystems on a global scale. Identifying reference sites free of plastic particles is just as difficult as finding those free of anthropogenic chemicals. While legal provisions are in place to reduce plastic waste in the marine compartment, this is not the case for rivers and lakes. Among the actions recently taken are the reduction of plastic waste from landfills and restriction of the use of one-way plastic bags.

Do we know enough to regulate plastic inputs into the environment on a larger scale? Or do we need more data to expand regulatory efforts?

In general, ecotoxicologists evaluate the potential risk arising from the use of a substance by comparing its level in the environment against a concentration that causes a certain effect in organisms. The latter is the outcome of a laboratory study whereas the environmental concentration is a value that has either been measured or modelled. For plastics in freshwater ecosystems, not only do we lack the data needed to unravel their sources and environmental pathways but relevant information on their toxic mode of action and biological receptors are missing as well. There are over 4000 polymer types and they are found in the environment in an enormous diversity of sizes. The tremendous complexity of potential exposure scenarios is a huge challenge for ecotoxicology, as is the choice of endpoints for toxicity testing and indicators for monitoring. In the absence of a sufficient overview of the essential parameters for risk assessment and monitoring, it may even be too early to consider the problem of standardisation. Finding appropriate answers to these many issues will no doubt be a slow process.

But is there a shortcut that allows us to follow a precautionary strategy and act now rather than waiting until the risks are completely identified? A pragmatic approach would concentrate on controlling the sources of land-based plastic litter instead of investing resources in large monitoring programmes for the aquatic environment. The regulation of open landfills, which are well-known sources of aquatic pollution with plastics, in a more environmentally sound manner would reduce the amount of plastic pollution in aquatic systems with immediate effect.

What were the surprises of the conference?

New and unexpected information presented at the conference included:

- The broad consensus that management options for land and freshwaters should be linked, since most of the plastic pollution in freshwater environments derives from terrestrial sources.
- The finding that, based on current knowledge, the concentrations of microplastics in the marine environment exceed the levels in freshwaters measured in Europe. The fragmentation of larger particles to microplastics, the inappropriate management of landfills located at coastlines, and riverine input to seas—which are the ultimate sinks—are the most likely reasons.
- The recognition that atmospheric depositions of plastic particles and run-off from land-spread sewage sludge are additional sources of plastics in rivers and lakes, although how much these sources contribute to the overall level of pollution is unknown.
- The need for concern regarding the concentrations of microplastics detected in coastal sediments. The levels of microplastics in most coastal and some deep sea sediments are expected to reach or exceed ecotoxicological threshold levels unless measures are taken to reduce their entry into the environment.
- Agreement regarding the shortcomings of REACH, developed for chemicals, in addressing apparent exposures of the environment to plastic polymers and some of their additives.
- The need to make plastic recycling profitable, despite low oil prices. Legislation could help by buffering the recycling industry against the up’s and downs of the oil industry.

Addendum

Plastics in European Freshwater Environments

ISSUE PAPER (Final Version)

by

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January 2017

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List of Abbreviations

APLM	*Associação Portuguesa do Lixo Marinho* - Portuguese Association on Marine Litter, Caparica (Portugal)
ATR-IR	Attenuated total reflectance infrared spectroscopy
BPA	Bisphenol A
DOENI	Department for Environment Northern Ireland, Belfast (Northern Ireland)
DW	Dry weight
EQS	Environmental Quality Standard
FCIO	*Fachverband der Chemischen Industrie Österreichs* - Association of the Austrian Chemicals Industry, Vienna (Austria)
FPA	Focal plane array
FT-IR	Fourier transform infrared spectroscopy
GMIT	Galway-Mayo Institute of Technology, Galway (Ireland)
HAB	harmful algal bloom
HD-PE	High-density polyethylene
IMARES, Wageningen UR	Institute for Marine Resources & Ecosystem Studies, Wageningen University & Research (Netherlands)
IVM	*Instituut voor Milieuvraagstukken* - Institute for Environmental Studies of Vrije Universiteit (VU) Amsterdam (Netherlands)
KAT	Keep the Archipelago Tidy Association (Finland)
LANUV NRW	*Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen*- North Rhine-Westphalian State Agency for Nature, Environment and Consumer Protection (Germany)
LD-PE	Low-density polyethylene
LfU	*Bayerisches Landesamt für Umwelt* - Bavarian Environment Agency (Germany)
LUBW	*Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg*- The State Institute for Environment, Measurements and Nature Conservation Baden-Wuerttemberg (Germany)
MCA	Multicriteria analysis
MSFD	Marine Strategy Framework Directive
MSFD WG-GES	MSFD Working Group on Good Environmental Status
NIR	Near-infrared spectroscopy
NOAA	National Oceanic and Atmospheric Administration (USA)
NUTS	Nomenclature of Units for Territorial Statistics
PA	Polyamide
PCA	Principal Component Analysis
PCCP	Personal care and cosmetic products
PE	Polyethylene

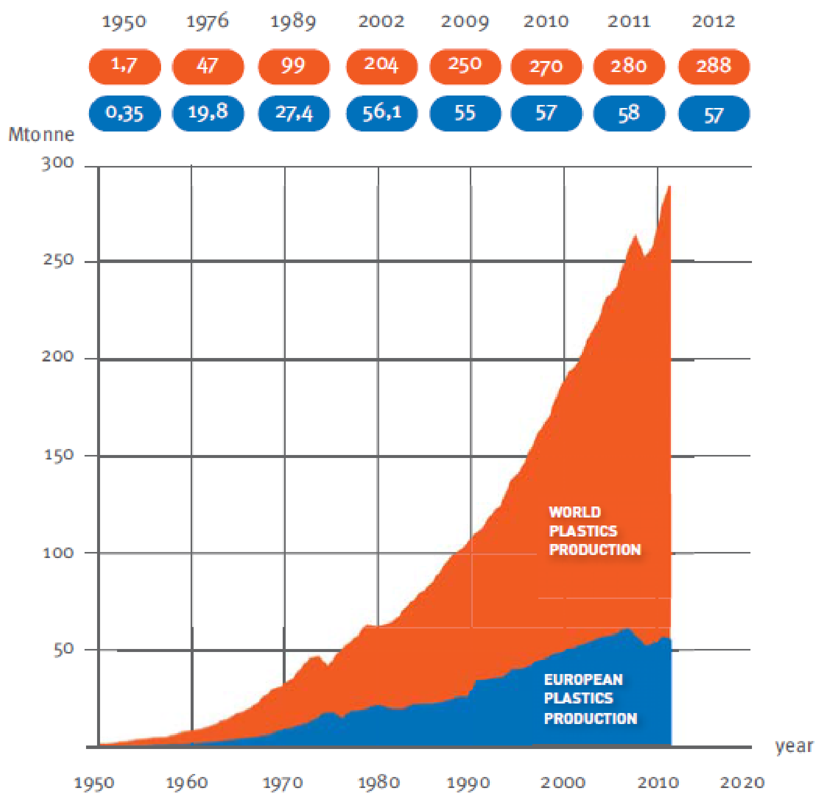
PET	Polyethylene terephthalate
PP	Polypropylene
PVC	Polyvinyl chloride
SEA	Strategic Environmental Assessment
SEM	Scanning Electron Microscopy
SPM	Suspended particulate matter
STOWA	*Stichting Toegepast Onderzoek Waterbeheer* - Foundation of Applied Water research, Amersfoort (Netherlands)
TDS-GC-MS	Thermal desorption gas chromatography mass spectrometry
TGA	Thermogravimetric analysis
TRAMP	Technologies for the Risk Assessment of Microplastics
WFD	Water Framework Directive
WFW	Waste Free Water
WWTP	Waste Water Treatment Plant

1. Introduction

The present issue paper was prepared prior to the European Conference on Plastics in Freshwater Environments held in Berlin in June 2016. Numerous publications, expert meetings and scientific conferences have discussed plastics in marine environments. This conference will be the first to address the potential problems arising from plastic pollution in freshwater environments at a European scale, as much less is known about the occurrence and the ecological risks of plastics in rivers and lakes. An informal questionnaire was sent to water management agencies in Europe to provide an overview on monitoring, risk awareness and management options.

In the environment, larger plastic items degrade into smaller particles, known as microplastics (< 5 mm in diameter). Microplastics resulting from degradation processes are classified as secondary microplastics, while primary microplastics are produced as such for industrial purposes. Since about 2005 plastics production is stable in Europe but it is still growing globally (Figure 1). In 2014 311 million tonnes were produced worldwide, 59 million tonnes thereof in Europe (PlasticsEurope 2015). The four most common polymer types, demanded in Europe, are polypropylene (PP), low-density polyethylene (LD-PE), high-density polyethylene (HD-PE) and polyvinyl chloride (PVC) (PlasticsEurope 2015).

Figure 1: World plastics production 1950 - 2012



The annual amounts of world plastics production, including thermoplastics, polyurethanes, thermosets, elastomers, adhesives, coatings and sealants and polypropylene fibres. Not included are polyethylene terephthalate (PET)-, polyamide (PA)- and polyacryl-fibres. (Source: PlasticsEurope (2013))

The general properties of microplastics were described by Verschoor (2015) as follows: “Microplastics are synthetic materials, and consist of solid particles that are smaller than 5 mm. The shape involves beads, fragments, fibres and films”. In her report, Verschoor provided the necessary background information and detailed the considerations needed for a definition of microplastics that could be applied for legislative purposes and for the development of environmental management plans.

Initially, an upper size boundary of microplastic particles of 5 mm was suggested by marine scientists meeting at the National Oceanic and Atmospheric Administration (NOAA) in 2008 (Arthur et al. 2009). In the Marine Strategy Framework Directive (MSFD) the descriptor "marine litter" distinguishes between litter particles above or below 5 mm, referred to as macro-litter and micro-litter, respectively (EU (2008), Galgani et al. (2010)). In their guidance document on the monitoring of marine litter in the European Seas the MSFD Working Group on Good Environmental Status (WG-GES) specified size classes for plastic litter: > 25 mm = macroplastics, 5 - 25 mm = mesoplastics, 1 - 5 mm = large microplastics and 20 µm - 1 mm = small microplastics (Galgani et al. 2013). Over time, the upper size boundary of 5 mm became broadly accepted not only by marine but also by freshwater scientists. However, in most of the recent studies the lower size boundary has been set by the limit of detection of the sampling procedures and applied analytical methods (see Table 3). A standard definition of the lower size boundary is required for consistent exposure assessments.

Nanoplastics, which are plastic particles below 100 nm, are discussed as an additional category of plastic pollution. So far very little is known about the distribution and occurrence of these particles in the environment. Also, the challenge for sampling and analysing these particles seem to be even greater than for microplastics. In this report, we will focus on micro-, meso- and macroplastics.

2. Sources and fate of plastics in freshwater environments

2.1 Sources

Plastics sources are usually discussed in the context of marine plastics pollution. Land-based sources (including beach litter) can account for about 80 % of the plastic debris (Andrady 2011). It can be assumed that riverine inputs of plastics into the seas significantly contribute to the marine pollution. In the following, we provide an overview on the main sources of plastic releases into the environment as far as it is relevant for freshwater environments including their catchment areas. While our discussion is based on various reports and reviews, it is not intended to serve as a complete review on the published literature.

Macroplastic materials are the most visible form of plastic pollution. They can be released into the environment, probably mainly by littering, the dumping of plastic waste, loss from inappropriately managed landfill sites[1] and during waste collection (Pruter (1987), Barnes et al. (2009), Mehlhart and Blepp (2012), and Lambert et al. (2014) as cited by Duis and Coors (2016)) while microplastics (both primary and secondary) are emitted from numerous sources.

As noted above, primary microplastics are usually defined as plastics produced in a micro-size range. They are manufactured for various applications including as ingredients of cosmetics, medicinal products and detergents, and are the raw materials in plastic production. Microplastics are also used as abrasives in blasting and other related industrial processes and as a component of paints (Lassen et al. (2015), Essel et al. (2015), Sherrington et al. (2016)). These raw materials can be released inadvertently, such as during transport or with run-off from processing facilities.

Secondary microplastics are considered as being formed by the fragmentation of larger plastic materials (meso- and macroplastics) in the environment. Important sources of secondary microplastics are tyre abrasions and littering. It has also been reported that synthetic textile fibres are discharged via household washing machines during laundering, but also via air and dust tumble drying (Sundt et al. (2014) and (Rillig 2012) as cited by Duis and Coors (2016)). Other sources of secondary microplastics are the wear of painted surfaces and road markings, plastic building materials, footwear, artificial turf, polymer modified asphalt, plastic cooking utensils, scouring sponges and cloths used in households. The removal of paint for the maintenance of the painted surfaces is an especially relevant source if it occurs outdoor (see Lassen et al. (2015) and section 4.3). According to Lassen et al. (2015) the releases of secondary microplastics can be assumed far higher than the emissions of primary microplastics into the aquatic environment.

In addition to release from industrial processes, private consumption, traffic and leisure activities, another source of microplastic emissions is agriculture. Low-density polyethylene films from agricultural crop coverings can fragment and leach into soil. In horticulture, synthetic polymer particles are used to improve soil quality (mulching) and as composting additives (Do and Scherer (2012) and Stöven et al. (2015) as cited by Duis and Coors (2016)).

Table 1 presents data from Sherrington et al. (2016) on annual European emissions of microplastics into the marine environment from six different sources and potential relevance for freshwater environments. However, according to the authors, very few of these estimates are based on reliable data and improvements in data collection methods are needed. In the meantime, the reported values should be taken as an indicator of the potential magnitude of each pollution source. The most

[1] It should be noted that waste deposited in landfills is usually covered according to standards in industrialised countries.

reliable estimation could be made for personal care and cosmetic products (PCCP), which is the source with the smallest contribution to microplastic releases whereas emissions from tyre dust are the largest.

The relevance of tyre dust as an emission source of microplastics was also reported by other authors. According to Sundt et al. (2014) wear and tear of car tyres is the most important land-based source of microplastics reaching the sea in Norway (2250 tonnes per year). Similar results were estimated for Denmark. According to Lassen et al. (2015) the major source of secondary microplastics released to the aquatic environment in Denmark is car tyres (500 - 1700 tonnes per year).

Table 1: Estimated annual European emissions of microplastics into the marine environment from six different sources

Emission source	Year	Lower estimated value [tonnes/a]	Upper estimated value [tonnes/a]
Tyre dust	2012	25,122	58,424
Pellet spills	unknown	24,054	48,450
Textiles	2010	7,510	52,396
Building paints	2002	12,300	28,600
Road paints	2006	7,770	18,069
Personal care and cosmetic products (PCCP)	2012	2,461	8,627

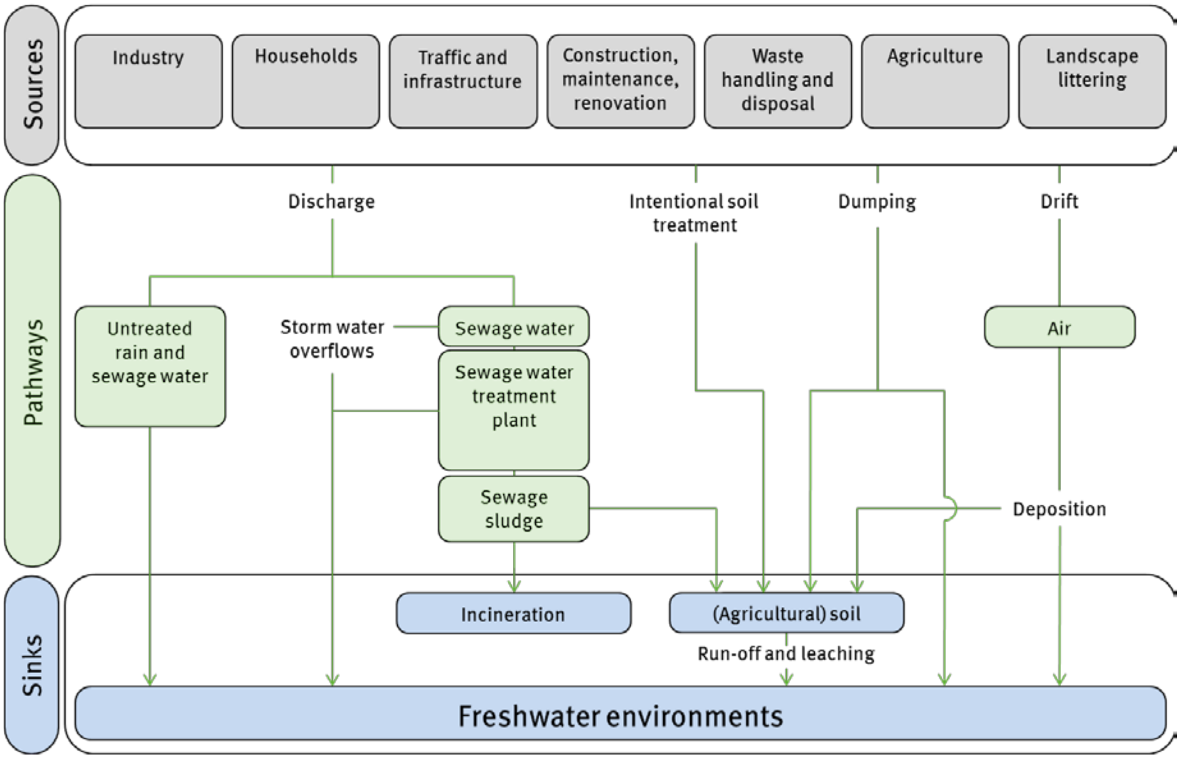
Except the numbers for PCCP the presented data should be taken as an indicator of the potential magnitude of each pollution source rather than exact outcomes of calculations. (Data source: Sherrington et al. (2016))

No estimation of the amounts of meso- and macroplastics released to the environment is currently available. The results of a study by Faure et al. (2015) demonstrate that relevant amounts of mesoplastics (5-25 mm) are present in lakes and rivers. In seven Swiss lakes the average amounts of 44 g/m^2 (referring to water surface) of mesoplastics were measured. Contrary, the average of microplastics was 26 mg/m^2 (referring to water surface). Furthermore, the mean concentrations of four Swiss rivers were 0.43 mg/m^3 for mesoplastics and 1.4 mg/m^3 for microplastics.

2.2 Environmental entry pathways

Figure 2 shows the various pathways by which plastics enter the environment. There are various reports on the exposure of freshwater environments with effluent from public and /or industrial waste water treatment plants (e.g. AWI et al. (2014), Bannick et al. (2015), Leslie et al. (2012), Schwaiger et al. (2016)). Pollution of surface waters by plastic materials can also occur by atmospheric inputs. For instance, plastic litter or microplastics, respectively, can be transported by the wind from areas of infrastructure, agriculture and industry, from uncovered landfills or during waste collection.

Figure 2: Possible exposure pathways of microplastics into freshwater environments and catchment areas



Note: The size of the boxes in the flow diagram does not give evidence of the quantitative relevance of the sources.

2.3 Degradation and accumulation in the environment

UV radiation from sunlight, mechanical abrasion, and biological degradation can lead to the disintegration of larger plastic material. While presumably all meso- and macroplastics will eventually degrade to microplastics, however, local condition will strongly influence this process (Sherrington et al. 2016). Thus, degradation is facilitated by increased temperature, but hampered by the presence of stabilisers, low temperature, low oxygen levels, fouling and coverage with water or sediment (Duis and Coors 2016). Plastics have an estimated lifetime up to hundreds of years or even longer (Moore (2008) and Barnes et al. (2009) as cited by Duis and Coors (2016)). Accordingly, once they are released, plastic materials will remain in the environment and accumulate in various compartments for many generations. Any additional future emission will add to this burden.

2.4 Modelling of land-based inputs into the seas

Modelling methods are being developed to estimate the inputs of plastics into the seas. As an example, “From Land to Sea - A model for detecting land-based plastic waste, 2016” was designed by the consultancy company Consultic Marketing & Industrieberatung GmbH (2016) on behalf of the chemical and plastics industries in Germany and Austria. The modelling approach tries to systematically determine land-based plastic-inputs into the marine environment that originate from improperly disposed litter. The approach intends to characterise and quantify main pathways of micro-, meso- and macroplastics into marine environments and discriminates riverine inputs from the total input from coastal regions. Additionally, the model includes European data on coastal region zoning, population density and socio-economy (Cieplik 2016). The knowledge gained thus far will be validated in the next step, during which the model parameters will be checked and modified if necessary and the model itself enhanced as other data become available.

3. Sampling, sample treatment and sample identification methods

Several methods were described suggesting different procedures for sampling, sample treatment and sample identification of micro-, meso- and macroplastics. However, no harmonised procedures have been established up to now.

Depending on the compartment investigated several bulk or volume reduced sampling methods have been commonly used for microplastics so far. Volume-reduced sampling methods were generally employed for water samples: manta or plankton nets with individual mesh sizes for the water surface; and various nets, which are fixed on riverbeds (e.g. eel nets, drift nets) or flow-through centrifugation in combination with cascade sieves for layers below the water surface. Apart from that, the sampling of sediments was usually conducted by means of special bulk equipment e.g. grab samplers.

The following Table 2 presents an overview on sampling, sample treatment and identification methods applied in relevant monitoring studies on microplastics.

Table 2: Overview on methods of sampling, sample treatment and identification of microplastics

	AWI et al. (2014)	Hohenblum et al. (2015a)	Löder et al. (2015)	Mani et al. (2015)
Sampling location	sewage water treatment plant outlet	Danube River	North Sea	Rhine River
Sampling device	cartridge filter 10 µm	nets 500-, 250-, 41 µm	net 500 µm	net 300 µm
Density separation	$ZnCl_2$	NaCl	sieving 500 µm	NaCl
Organic digestion	Sodium dodecyl sulphate, enzymatic degradation, H_2O_2	None	enzymatic degradation	enzymatic degradation
Water removal	sieving, filtration on aluminium oxide filter	thermal drying	filtration on aluminium oxide filter	sieving 300 µm
Detection/ identification	Identification: > 500 µm: ATR-FT-IR < 500 µm: FPA-µFT-IR	detection: visual identification: ATR-IR of sub-samples (particles > 2 mm)	identification: µFT-IR	detection: visual (particles > 300 µm identification: random controls by FT-IR)

Abbreviations: ATR-FT-IR - attenuated total reflection–Fourier transform infrared spectroscopy; µFT-IR - micro-Fourier transform infrared spectroscopy, FPA-µFT-IR - focal plane array micro-Fourier transform infrared spectroscopy

The majority of sample treatment methods include enzymatic digestion over several weeks with constant stirring (AWI et al. 2014). Alternative or additional methods include the use of oxidising agents such as H_2O_2 (Mani et al. (2015) and AWI et al. (2014)) or acids such as HNO_3 are applied to remove organic materials. However, there is risk of damaging the plastics, either by oxidation (Lindén et al. 1993), or in the case of the former, by mechanical friction.

Most procedures also require some kind of density separation to extract plastic particles. NaCl has been used in a few studies (Hohenblum et al. (2015a), Mani et al. (2015)) and results in densities of up to 1.15 g/cm^3 in a saturated solution. Solutions of high density are needed to extract particles of heavyweight polymer types such as polyester (1.24–2.3 g/cm^3). Therefore, the use of $ZnCl_2$ is more common, even though it is environmentally harmful; it results in densities of ~1.7 g/cm^3 (Imhof et al. 2012).

There is currently no consistent method for the identification of microplastics. It is, however, commonly agreed that visual identification is inappropriate as according to the literature up to 70 % of all visually identified particles are false positives (Hidalgo-Ruz et al. 2012). Recently, four methods have become increasingly adopted: (micro) Fourier transform infrared microscopy ((µ)FT-IR) (Lusher et al. 2013), Raman microspectroscopy (Van Cauwenberghe et al. (2013), Imhof et al. (2016)) pyrolysis-gas chromatography-mass spectrometry (Pyrolysis GC-MS) (Bart 2006), and combining thermogravimetric analysis (TGA) with thermal desorption gas chromatography mass spectrometry (TDS-GC-MS) designated as TED-GC-MS (Dümichen et al. 2015). Since each of these methods has its advantages and disadvantages (see Table 3) combinations are recommended.

For national or international monitoring campaigns aimed at assessing the potential threat to aquatic ecosystems posed by microplastics, harmonised methods for sampling, sample treatment and particle identification are necessary. A major problem with sampling, however, is that a lower size limit for microplastics has yet to be specified (Hidalgo-Ruz et al. (2012), Science for Environment Policy (2011)). Current research often refers to particles with grain sizes > 300 µm (Mani et al. 2015) or 500 µm (Remmel 2016). Since especially the smallest microplastic particles are probably those of interest in studies on organisms of all sizes, the ability to collect and quantify particles of all sizes, but especially those much smaller than 300 µm, from freshwater and its sediments is essential (Rocha-Santos and Duarte 2015). In addition, due to the different densities of common polymers, the sampling point in the water column must be precisely determined and recorded. These and other challenges have hindered data collection and the comparability of the obtained results (Duis and Coors (2016), Storck et al. (2015)).

Table 3: Advantages and disadvantages of different analytical methods

Analytical methods	Advantages	Disadvantages
µFT-IR spectroscopy	Easy handling even for inexperienced personnel; fast measurement possible by using a focal plane array detector Qualitative & quantitative analysis of plastic particles of various chem. composition and shape (spherical, irregular, foils, fibres)	Difficulty in detecting black particles; theoretical limit of detection of ~3 µm, practically not achievable (~20 µm); quantification of microplastic mass not possible
Raman microspectroscopy	Spatial resolution down to 1 µm; qualitative and quantitative analysis of plastic particles of various chem. composition & shape (spherical, irregular, foils, fibres); information on size distribution of particles (see Imhof et al. 2016)	Interference of fluorescence from (micro)biological and (in)organic contaminations; measurements are time consuming and require trained personnel; quantification of microplastic mass not possible
Pyrolysis GC-MS	Identification of all kinds of synthetic materials in field samples and their additives; quantification of microplastic mass possible for cleaned up samples	Quantification of large samples including their matrix not possible; sample volume is limited by crucible size
TED-GC-MS	Current state of knowledge: relatively high sample masses compared to Pyrolysis GC-MS (about 200 times higher); identifying and quantifying characteristic decomposition products of spiked PE in complex environmental samples possible (see Dümichen et al. 2015)	Current state of knowledge: Until now, only PE has been tested; pre-concentration will be necessary to measure real environmental samples (see Dümichen et al. 2015)

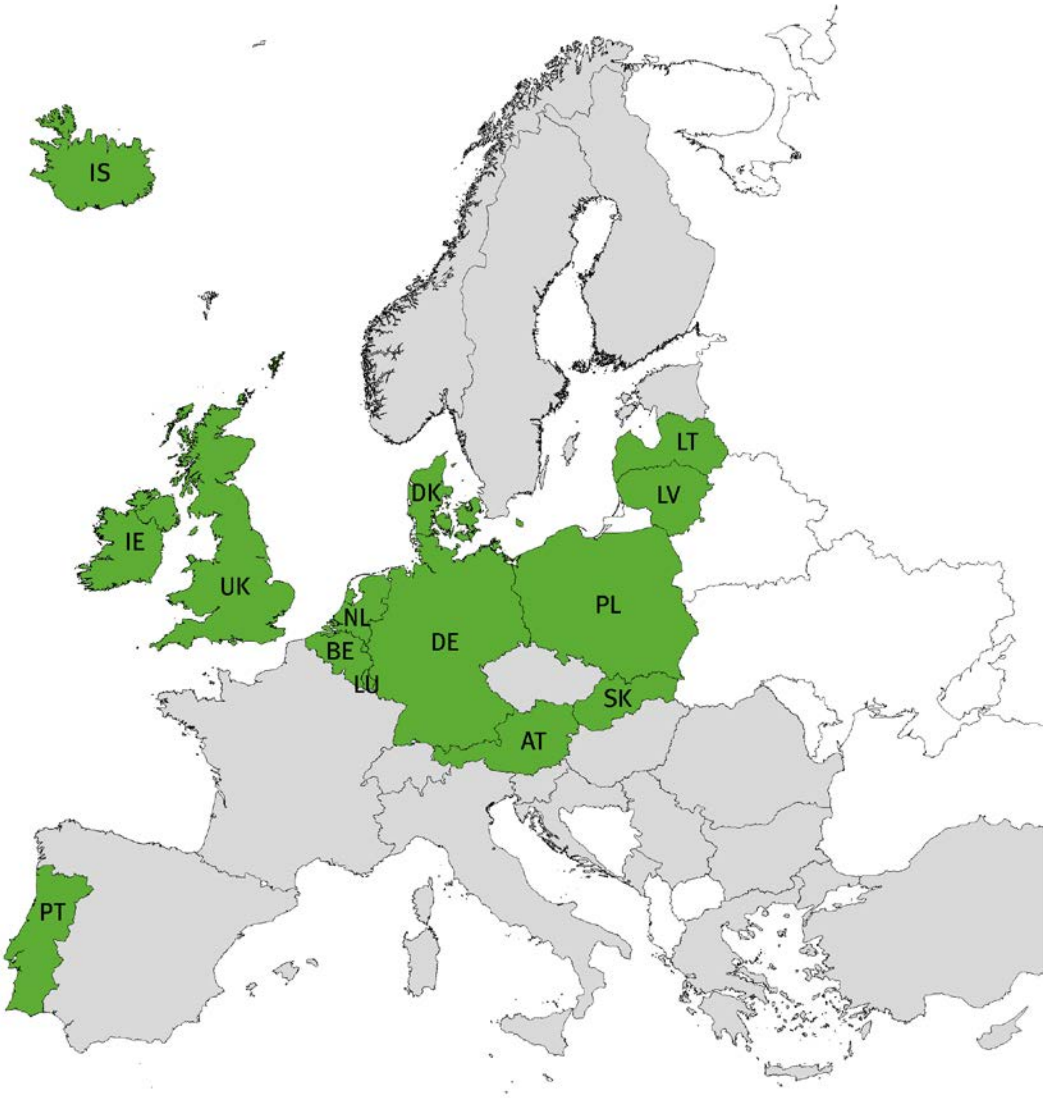
4. Monitoring studies and programmes in freshwater environments: Results of a European survey

In preparation of the European Conference on Plastics in Freshwater Environments, a survey on the current status of related European activities was conducted. The questionnaire, consisting of overall 11 questions (see Annex 1), was informally sent to the representatives responsible for water monitoring and management in Europe. Besides, those from the 28 EU member states, representatives of six other non-EU European countries (Iceland, Montenegro, Norway, Serbia, Switzerland and Turkey) were included. Of these countries, 14 (41 %) participated in the survey. A German translation of the questionnaire was sent to all federal states of Germany within the scope of a separate national survey. Fourteen out of 16 federal states participated. The results from the states were summarised in one German questionnaire for the European survey.

Figure 3 provides a map showing all of the European countries invited to participate in the survey and the actual participants. The latter are listed by country, name and national organisation in Annex 2.

The following evaluation of completed, ongoing and planned monitoring studies as well as risk perception and management options provides insights into current activities in Europe. For the most part, the evaluated questionnaires did not consistently differentiate between limnic and marine environments. However, in the subsequent evaluation only freshwater environments were considered. Below, a discussion of the responses to the questionnaire and the additional references are supplemented with the results of our own literature research.

Figure 3: Map of addressed and participating countries in the European survey



Label: *addressed countries*: grey background, *participating countries*: green background

4.1. Completed, ongoing and planned monitoring studies on plastics in freshwater environments (Questions 1, 2 and 6)

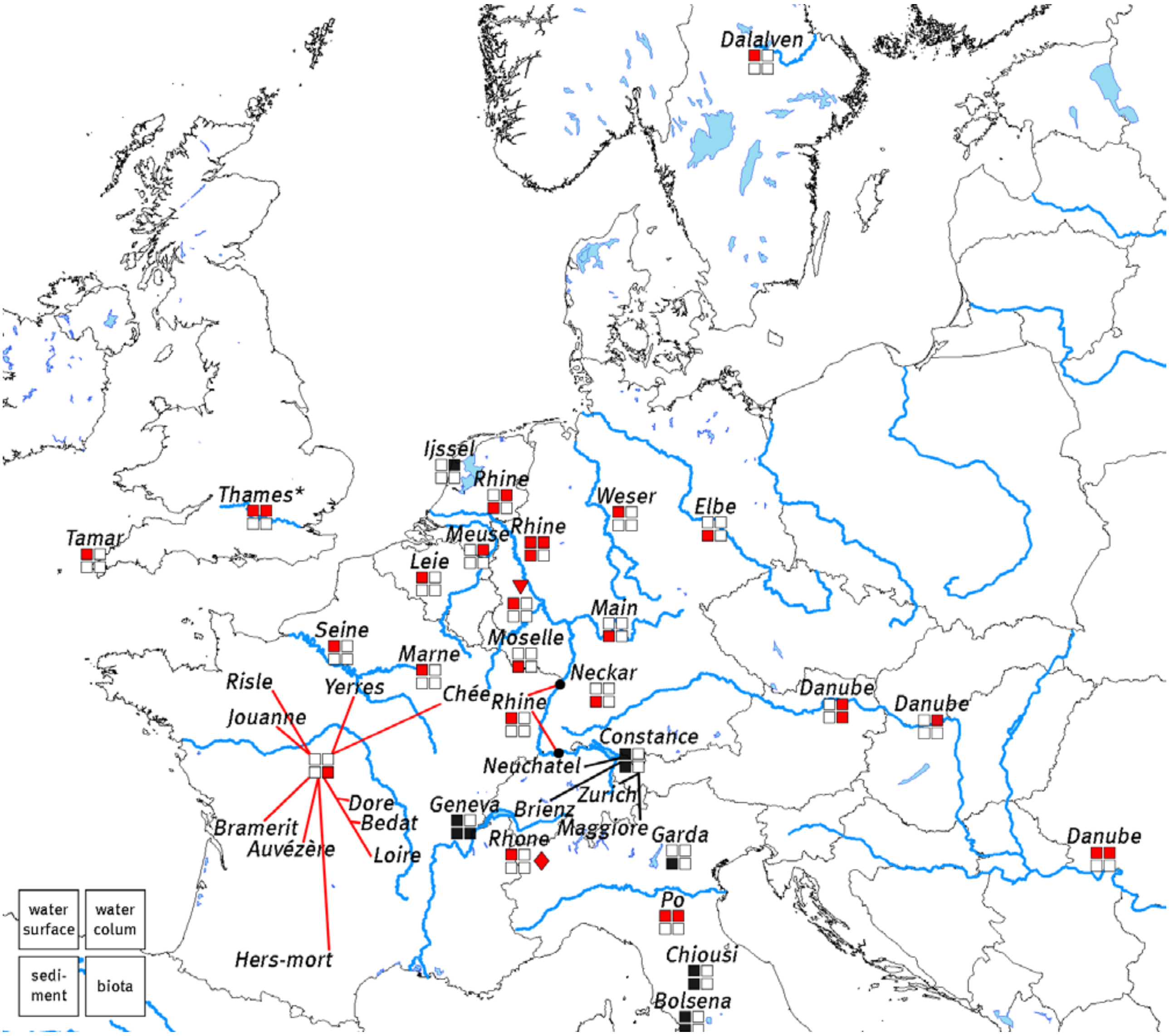
Question 1: Are investigations performed in your country on plastics in freshwater environments?

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

Question 3: Are there further plans for monitoring activities on a national level for plastics in freshwater environments?

The number of studies on plastics in freshwater environments is gradually growing. Throughout Europe, several scientific investigations of microplastics in freshwater environments have been conducted. However, long-term monitoring programmes could not be identified, neither in the context of the survey nor in an extensive literature review. Among the comprehensive short-term studies are those that have been carried out in Austria (Danube River), France (Meuse and Seine River), Germany (Main and Rhine River), Italy (Lake Garda), the Netherlands (Meuse and Rhine River) and Switzerland (Rhine River and Lake Geneva). An overview of the selected studies covering European countries and including information on compartments, sampling and analytical methods, size range, and results is provided in Annex 3. Figure 4 shows the European freshwaters that have been assessed with respect to micro-, meso and macroplastics and the analysed compartments within the water bodies of interest.

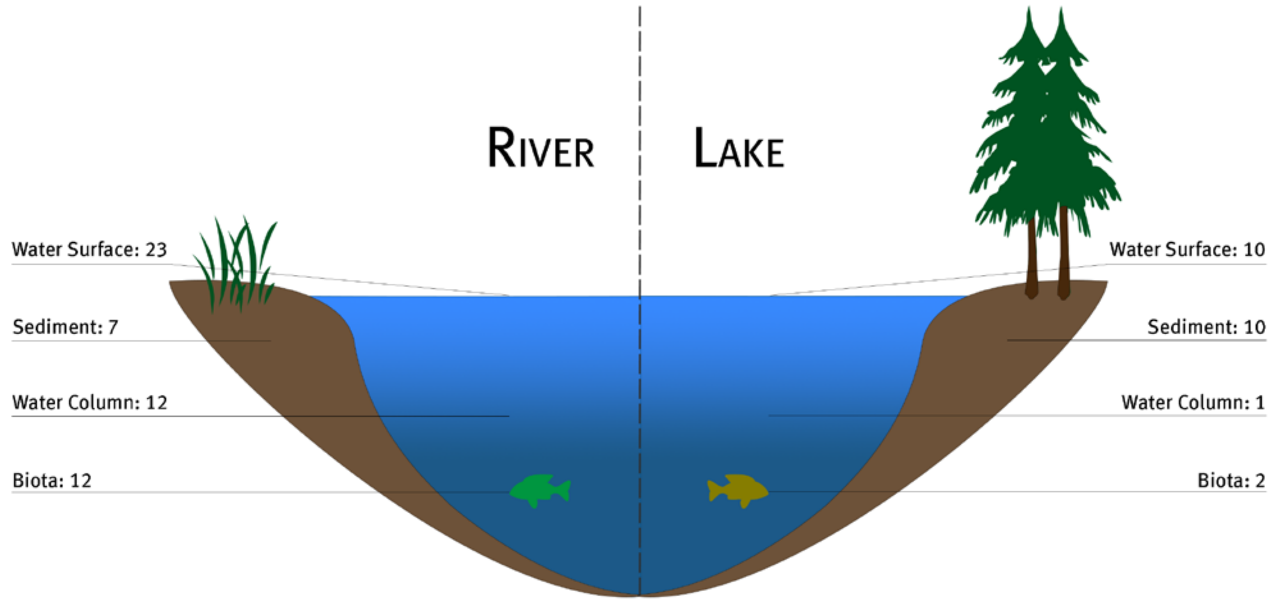
Figure 4: Map of monitored European freshwater environments with respect to micro-, meso- and macroplastics



Checkerboard boxes indicate the investigated compartments (see legend at the bottom left of the figure) and summarise all investigations performed at a specific river or lake in one country (multiple references in transboundary studies). Labelling of freshwater environments: red - rivers, black - lakes. ▼ indicates the following Rhine tributaries: Rivers Emscher, Lippe, Ruhr, Sieg, and Wupper, ♦ the following Swiss Rivers: Aubonne, Venoge and Vuachére, and * includes the River Thames and its tributary, the Duke of Northumberlands River. The data were compiled from selected studies referred to in the context of the survey and from an extensive literature search (detailed in Annex 3).

Figure 5 shows the investigated compartments, including water surface, water column, sediment and biota, in European rivers and lakes. Overall, plastics have been monitored more frequently in rivers than in lakes. Nonetheless, the total number of monitoring studies on plastics conducted in European freshwater environments since 2010 is relatively small: In total, monitoring of 34 rivers and ten lakes in eleven European countries was reported by the participants of the survey and in scientific literature.

Figure 5: Schematic overview of the compartments investigated in monitoring studies on plastics in European freshwater environments



The legend presents the number of investigations conducted on the following compartments: water surface, water column, sediment and biota. The data were compiled from the studies reported by the survey participants and those identified in an extensive literature survey (see Annex 3). The classification "water surface" includes samplings of the top layer of the water column (performed mainly by manta trawl). Note: The numbers in the legend refer to the number of compartments investigated per river or lake but do not correlate with the total number of monitoring studies.

According to 36 % of the survey participants, investigations of plastics in freshwaters had been performed in the respective countries and details on the completed and ongoing monitoring studies were available. In the following sections, relevant information from the studies provided by the survey participants is summarised. Information on the studies identified through a literature review is provided in Annex 3.

Completed studies

According to the results of the European survey, monitoring studies were completed in Austria, (Danube River), Belgium (Leie River), Germany (Rivers Weser, Rhine and its tributaries) and the Netherlands (Lake Ijssel, Rivers Meuse and Rhine), together with an international investigation covering rivers in Italy (Po), the Netherlands (Rhine), Romania (Danube) and Sweden (Dalålven).

In a preliminary study of the Danube River (**Austria**), the abundance of microplastics (> 500 µm) in the water column was evaluated by Hohenblum et al. (2015a) on behalf of the Federal Environmental Agency, Austria. This study included the development of a method that takes into account the vertical, horizontal and temporal variability of plastic transport in the water column. According to the authors, plastic transport and the annual plastic load in the river can be reliably calculated only by multi-point sampling. The study was conducted at two sampling sites: in Aschach, close to the river's entrance into Austria, and in Hainburg, at its exit to Slovakia. Concentration ranges of 0.039–0.205

mg/m^3 and 0.029–0.516 mg/m^3, respectively, were reported. The majority of the sampled plastic particles were PE and PP polymers, as determined by attenuated total reflectance infrared spectroscopy (ATR-IR). Over 50 % of the extracted plastic particles consisted of fragments, 4–10 % were pellets and 2.1–2.8 % were green lenticular flakes (Hohenblum et al. 2015a).

In **Belgium**, two sampling campaigns were conducted in 2014 with the purpose of investigating the overall litter problem in the Leie River. In these campaigns floating litter (> 5 mm) was investigated. The scope of the study was extended to cover the investigation of microplastics as well (Craenenbroeck et al. 2014).[2]

In the context of a study by the University of Bayreuth (**Germany**) the abundance of microplastics and mesoplastics in the Rhine River, four Rhine tributaries (Rivers Ruhr, Lippe, Sieg, Wupper and Emscher) and the Weser River were investigated (Laforsch 2015). At three sampling points along the Rhine, the total plastic amounts ranged from 0.928 to 4.45 particles/m^3. The highest concentration was measured near Düsseldorf in the Rhine-Ruhr metropolitan area. Among the Rhine tributaries, the highest concentration was measured in the Emscher River close to where it joins the Rhine. The plastics concentration of 15.7 particles/m^3 (total plastic amount) was expected due to high wastewater content of the sample. Measurements up-stream and down-stream a wastewater treatment plant (WWTP) at the Ruhr River near Duisburg showed a considerably higher concentration of total plastics at down-stream than at up-stream sampling site (up-stream site: 4.81 particles/m^3, down-stream site: 166 particles/m^3). Along the Weser River the total amount of plastic particles was 0.487 particles/m^3. The sampled particles were identified by means of ATR-FTIR spectroscopy. In many samples the common polymers polyethylene, polypropylene und polystyrene were detected (Laforsch 2015).

Overall six references were submitted by the **Netherlands**, including the studies “Microplastic profile along the Rhine River” (Mani et al. 2015), “Microplastic in the rivers Meuse and Rhine” (Urgert 2015) and “Identification and Assessment of Riverine Inputs of (Marine) Litter” (Hohenblum et al. 2015b). Three national studies of microplastics in sediment, sewage and biota were conducted by the Institute for Environmental Studies (Instituut voor Milieuvraagstukken, IVM) of the VU University Amsterdam (Vrije Universiteit Amsterdam, Netherlands) (Brandsma et al. (2013), Brandsma et al. (2015), Leslie et al. (2013)). Thereby freshwater environments were investigated with respect to WWTPs (influent, effluent and sewage sludge), river suspended particular matter (SPM) and sediments. The study of Leslie et al. (2013) was limited to the Netherlands surface waters. The other five Dutch studies included transboundary monitoring at the Rhine and other rivers (see below).

Monitoring study conducted in the Netherlands:

Leslie et al. (2013) investigated in addition to North Sea sediment, treated wastewater effluents and marine biota, the sediment of two **Rhine** estuaries, which were considered as possible hotspots. The latter sites contained the highest number of microplastic particles in all investigated sediments with an average of 3,300 particles/kg dw. By contrast, the mean concentration range of the sampled North Sea marine sediments was 440 - 770 particles/kg dw.

Transboundary monitoring studies including Netherlands freshwaters:

Mani et al. (2015) evaluated the abundance and composition of microplastics (300 µm - 5 mm) in the surface layer of the **Rhine River** along an 820 km stretch between Basel and Rotterdam. The mean concentration from 11 sampling sites located in **Switzerland**, **France**, **Germany** and the **Netherlands** was 0.893 particles/m^2. Microplastic concentrations reached a peak in the Rhine-Ruhr metropolitan area, with a maximal concentration of 3.9 particles/m^2 at Rees. In fact, sampling points at

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[2] Further details were not attainable since only a report in Flemish was available.

Rees and Duisburg accounted for >66 % of all particles recovered during the entire campaign. The microplastics consisted of opaque spherules (45.2%), fragments (37.5 %), transparent spherules (13.2 %), fibres (2.5 %) and others (1.1 %). Polystyrene (29.7 %) and polypropylene (16.9 %) were the most dominant polymers. According to Mani et al. (2015) the profile study along the river demonstrated considerable pollution of the Rhine River.

During research of a master thesis, Urgert (2015) investigated the abundance and composition of microplastics of the European rivers **Meuse and Rhine** in 2014. Over a period of less than 6 months weekly samples were taken at each of the three monitoring locations (**Netherlands**: Eijsden, Lobith; **Germany**: Bimmen) and a single sample at one additional sampling site (**Germany**: Bad Honnef). Mean concentrations of microplastics (size range: 0.125 - 5 mm) in the water column were higher in the Rhine River (0.56 mg/m^3, 56 particles/m^3) than in Meuse River (0.14 mg/m^3, 9.7 particles/m^3). Visually identified microplastic particles were classified into the following groups: films, miscellaneous microplastics, white and transparent spherules and scrubs. Polymers were identified by means of Raman- and FT-IR spectroscopy. In the Meuse River, PE, comprising films, miscellaneous microplastics and scrubs were predominantly identified whereas in the Rhine River the predominant polymers were PE and polystyrene (Urgert 2015).

The comprehensive study by Hohenblum et al. (2015b) included preliminary monitoring of plastics in the Dalålven River (Ålvkarleby, **Sweden**), Rhine River (Rotterdam, **Netherlands**), Po River (Ferrara, **Italy**) and Danube River (Galati, **Romania**) in addition to an assessment of riverine plastic litter inputs into the marine environment, which will be further discussed in section 4.2. The abundance of both micro- and macroplastics was evaluated using various sampling methods simultaneously (manta net, waste free water (WFW) sampler and pump-manta net method) in order to consider the size range of 0.3 - 25 mm and to test the feasibility of the monitoring approach. The pump method was applied in the Dalålven River out of necessity, because of local limitations in setting up other sampling equipment. To enable comparisons, the manta-pump method was also applied at the sampling point of the Po River. Concentrations at the sampling point of the Rhine River were measured two times (Hohenblum et al. 2015b). The results of the study are summarised in Table 4.

Additionally, the study included the qualitative analysis of several different microplastic categories (fragments, pellets, foam, fibres and others) using infrared and ATR-FT-IR spectroscopy in conjunction with an identification of likely sources. Fragments were the most prevalent particles identified in the Rivers Po and Rhine, whereas plastic particles in the Rivers Danube and Dalålven consisted mostly of fibres. By far the highest number of pellets was recovered in the first sampling of the Rhine River (Rhine I). Among all given microplastic categories, fragments were identified as the largest with 45 % of all extracted particles. The analysis of polymer material was conducted on 16 % of all extracted particles. Polyethylene was identified as the most common polymer material in all investigated rivers. Likely sources could be estimated for 44 % of the recovered meso-sized particles (5 - 25 mm) and included industrial packaging (25 %) and urban emissions (5 %, including wastewater sources). Furthermore, other sources of plastic litter identified in the study were amongst others agriculture, fisheries, households, medical waste etc. (Hohenblum et al. 2015b).

Table 4: Comparison of plastic concentrations in the rivers Dalålven, Rhine, Po and Danube by using different sampling methods

	Manta net (micro sized particles < 5 mm)*		Waste free water sampler (meso sized particles > 5 mm)*	
	Manta trawl	Pump manta net	Surface	Suspension
Dalålven		4.5 p/m³ 2 mg/m³		
Rhine I (measurement 1)	1.77 p/m² 2.45 mg/m²		0.01 p/m² 15.86 mg/m² 0.05 p/m³ 79 mg/m³	0.01 p/m³ 0.24 mg/m³
Rhine II (measurement 2)	0.31 p/m² 0.04 mg/m²		0.01 p/m² 1.54 mg/m² 0.04 p/m³ 7.7 mg/m³	0.002 p/m³ 0.8 mg/m³
Po	2.04 p/m² 0.78 mg/m²	20.3 p/m³ 0.5 mg/m³	0.01 p/m² 0.75 mg/m² 0.03 p/m³ 3.8 mg/m³	0.03 p/m³ 2.5 mg/m³
Danube	1.06 p/m² 0.12 mg/m²		0.07 p/m² 7.55 mg/m² 0.37 p/m³ 38 mg/m³	0.24 p/m³ 5.3 mg/m³

The particle numbers were normalised to uniform units (either m³ or m²). Sampling at the Rhine River was conducted twice. *Mesh sizes were 0.3 mm for manta net and 3.2 mm for WFW sampler. Unit p: particles. Data source: Hohenblum et al. (2015b)

In the context of two studies Brandsma et al. (2013, 2015) investigated SPM in the Rivers **Meuse** (**Netherlands**) and **Rhine** (**Germany** and **Netherlands**) as well as Lake **Ijssel** (**Netherlands**) in regard to abundance of microplastics in the size categories 1 - 300 µm and 300 - 5000 µm. In 2013, mean microplastic concentrations of 1400 particles/kg dw (Meuse River) and 1700 – 4900 particles/kg dw (Rhine River, two sampling points) were derived. Whereas, 1800-6880 particles/kg dw (Meuse River, 3 sampling points), 990 particles/kg dw (Rhine River, single sample) and 2000 particles/kg dw (Lake Ijssel, single sample) were found in 2015. The majority of microplastics detected in both sampling years were in the size category < 300 µm, with fibres and spheres rather than foils as the most frequently detected shapes (Brandsma et al. 2013, Brandsma et al. 2015).

Monitoring reported outside the scope of the European survey:

Finland did not participate in the survey. However, a report was submitted by the **Finnish** association KAT which operates in the areas of the Baltic Sea, Lakes Päijänne and Saimaa and in the Pirkanmaa region (Gustafsson et al. 2016). As part of the "Clean Beach" campaign, information on the amounts and types of litter was gathered for those locations (see section 0). KAT offers a guide booklet to volunteer groups, including companies, associations, municipalities and private individuals, that provides practical tips, general information as well as materials and instructions on litter reporting. To ensure the comparability of the data, participants are provided with a standardised litter reporting form. Besides macroplastics, other types of litter, including paper, metal, glass and ceramics, are recorded. Two campaigns were carried out by KAT in two consecutive years (2014, 2015).

Whereas in 2014 only marine areas had been covered, in 2015 the target areas were extended to all surface waters located in the KAT operating area; thus, besides seashores, 11 sites at lakes and 4 sites along river banks were added. Among the 36,400 litter items that were counted at all clean-up sites, plastics were the most prevalent (68 %, including cigarette butts). Fewer plastic items were collected along river banks than at lakeshore and seashore sites. However, according to Gustafsson et al. (2016), the results provide only a preliminary description of the freshwater litter situation in Finland, due to the small number of included lake and river sampling sites as well as various uncertainties in the reported data.

Ongoing and planned studies

Beyond the already conducted studies, several further monitoring programmes on plastics in freshwater environments are either ongoing, currently scheduled or under discussion.

The Galway-Mayo Institute of Technology (GMIT) is currently preparing a study which will focus amongst others on the scale and scope of microplastic pollution in **Irish** freshwaters (Officer 2015-2016).[3]

Furthermore, a monitoring programme in **Scotland** has been initiated. A study on micro- and nanoplastics in wastewater treatment systems and receiving water in the context of a Scottish Hydro Nation PhD Scholarship is still ongoing (2015-2019).[4]

Fifty-seven percent of the survey participants, who represented Austria, Belgium, Denmark, Germany, Lithuania, Luxembourg, the Netherlands and Portugal, stated further plans for monitoring studies. Although, there have been several project ideas, there are no exact plans of implementation in Austria. Nevertheless, the **Austrian** survey participant mentions activities that aim towards harmonised definitions, methods and thresholds on an EU wide level.

Belgium also has no plans on a solely national level, but as a member of the European Union, it takes part in the INTERREG project, which includes the Maas River.[5]

The **Danish** report "Microplastics: Occurrence, effects and sources of releases to the environment in Denmark" (published by the Danish Environmental Protection Agency) provides, in addition to a comprehensive overview of the sources of primary and secondary microplastics (further described in section 4.3), a catalogue of possible new studies to be carried out by competent authorities in Denmark and covering the following topics: applications and releases, occurrence and fate and the effects of microplastics. The list also includes the study "Fate of microplastics from freshwater to the marine environment" (Danish Environmental Protection Agency, 2015–2017) (Lassen et al. 2015).

Five federal states of **Germany** have initialised monitoring programmes, which will primarily assess the occurrence of microplastics in the water surface of German freshwater environments (mainly rivers). Meso- and macroplastics are addressed to a lesser extent. Four projects are already underway but the data have yet to be published. The Bavarian Environment Agency (LfU) is currently investigating emission pathways, abundance and distribution as well as the potential accumulation of microplastics in Bavarian freshwater environments. The State Institute for Environment, Measurements and Nature Conservation Baden-Wuerttemberg (LUBW) has initiated a monitoring programme with 20 sampling points along the Rivers Rhine and Neckar and other rivers with various wastewater proportions as well as at the Lake Constance. A study of microplastics occurrence in North Rhine-Westphalia has been launched by its State Agency for Nature, Environment and Consumer Protection

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[3] http://erc.epa.ie/droplet/modalFull.php?cid=17928

[4] http://www.hydronationscholars.scot/scholar_bio_Maricela_Blair.html

[5] No further information was provided.

(LANUV NRW). The University of Bayreuth (Bavaria) is conducting measurements of the water phase and sediments at four sampling points along the Rivers Rhine and Mosel, but sample analysis and data evaluation are currently ongoing.

Rijkswaterstaat, the executive body of the Ministry of Infrastructure and Environment in the **Netherlands** that manages the country's main highway and waterway networks, has planned a pilot study to monitor microplastics for 2016 and 2017. The freshwater compartments surface water (duplicate samples at 6 locations), sediment (replicate samples at two locations) and biota (replicate samples at four locations) will be included. To ensure the future harmonisation of the methods used in that study and subsequent ones, the implementation strategy recommends the outsourcing of sample analysis and evaluation as well as cooperation with both the IVM of the VU Amsterdam and the project "Technologies for the Risk Assessment of Microplastics" (TRAMP), led by the Wageningen University.[6] Additionally, the Foundation of Applied Water Research (STOWA) has launched a comprehensive study of microplastics from the country's WWTPs, to be completed by 2017.[7]

4.2. Riverine loads of plastics and riverine inputs into the marine compartment (Questions 4 and 5)

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 was reported by almost 30 % of the surveyed European countries, including Austria, Belgium, Germany and the Netherlands. Existing data on riverine inputs into the marine environment were reported by Denmark, Germany, Latvia and the Netherlands (29 %).

In the above-mentioned study of Hohenblum et al. (2015a), the annual average range of transport was calculated: 6 - 66 kg/day for microplastic particles (<5 mm) and 7 - 161 kg/day for the total plastic load[8] in the **Danube** River (**Austria**), determined at the sampling sites Aschach and Hainburg. The annual load was calculated using the average annual hydrographs of each of the years 2009 to 2014 for both sampling sites. The annual microplastics load was estimated less than 17 tonnes/year, and the total plastic load <14 - 41 tonnes/year. However, the authors pointed out that since only a few measurement points were used in the calculations these values should be considered as preliminary estimates.

In their determination of the microplastics profile along the **Rhine** River, Mani et al. (2015) estimated a daily discharge of 191.6 million particles (at and beneath the surface) into the North Sea. This value was extrapolated from the average concentration measured during a 1-day sampling at Rees, Germany, where downstream the river splits into numerous arms. According to the authors, the values measured at Rees are more representative of riverine inputs into the North Sea than values obtained at the sampling points Zuilichen or Rotterdam or the sum of both (Mani et al. 2015).

A comprehensive study of riverine inputs of micro and mesoplastics into the marine compartment was conducted as part of the already above mentioned project by Hohenblum et al. (2015b). Their report serves as a consultation draft for the European Commission Directorate General Environment under Framework Contract No.ENV.D.2/FRA/2012/0025.[9] Four European rivers were selected to assess the amount of riverine litter discharged into the connecting seas including the **Dalålven** River

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[6] http://www.stw.nl/nl/content/technologies-risk-assessment-microplastics-tramp

[7] http://www.stowa.nl/projecten/Onderzoek_naar_de_lotgevallen_van_microplastics_op_een_rwzi

[8] The size range for the total plastic load was not specified in Hohenblum et al. (2015)

[9] https://etendering.ted.europa.eu/cft/cft-display.html?cftId=76

(Baltic Sea), the **Rhine** River (North Sea), **Po** River (Mediterranean Sea), and the **Danube** River (Black Sea). The study included a quantitative analysis of marine inputs, estimated as the number of particles and the plastic load mass per unit time (per second and year) (see Table 5). All selected rivers were identified as carriers of microplastics and thus as sources of marine litter (Hohenblum et al. 2015b).

Table 5: Estimates of riverine input of plastics into the marine environment

	Manta net (micro sized particles < 5 mm)	Waste Free Water Sampler (meso sized particles > 5 mm)	
	particles/year	Tonnes/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 Dalålven River no WFW samples were collected since the location was not suited for this equipment set up. Sampling at the Rhine River was conducted twice. Source: Hohenblum et al. (2015b)

Concluding it has to be mentioned that two surveyed countries, Austria and the Slovak Republic, are landlocked and were therefore unable to provide explicit data on plastic input into the marine environment.

4.3. Main sources and pathways for plastics in the freshwater environments (Question 3)

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

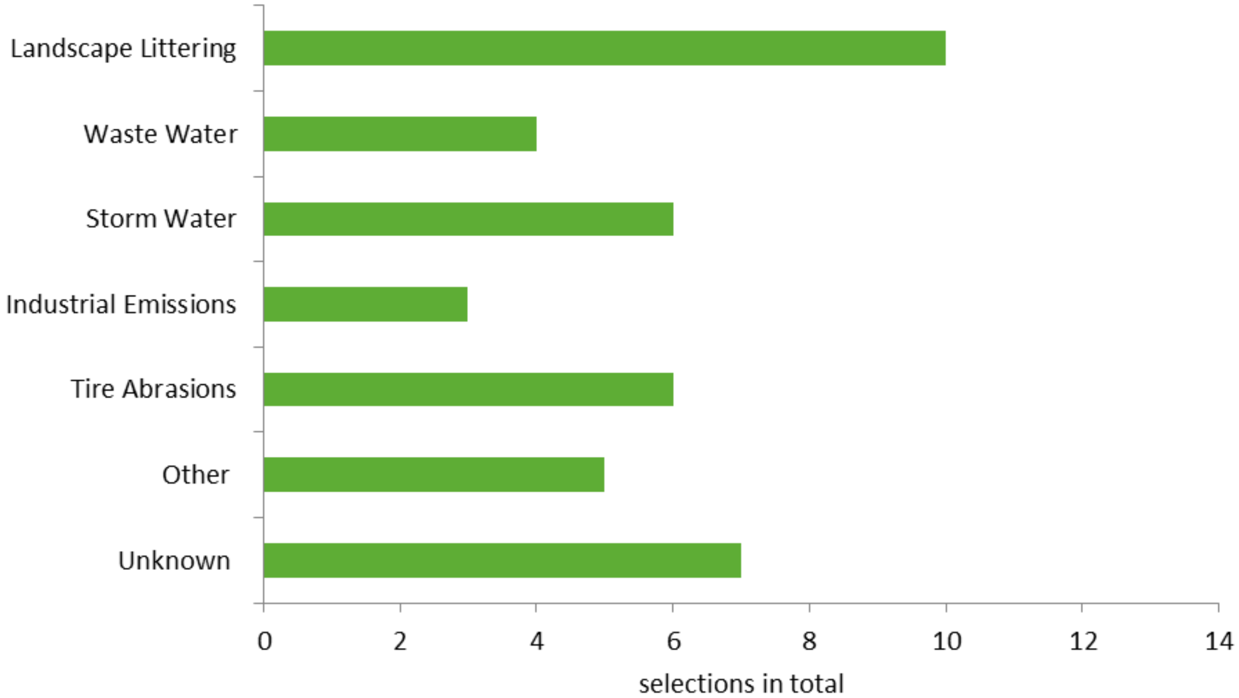
Figure 6 shows the results of the conducted survey with respect to the main sources of plastics and the pathways by which plastics enter freshwater environments, as assessed within the context of the survey. The results are plotted as the total number of participants who selected the particular response option.

Landscape littering was perceived as accounting for the largest amount of plastic entering freshwater environments, as this response option was selected by 70 % of the survey participants. “Unknown” was chosen in 50 % of the answered questionnaires, followed, in descending order, by “Storm Water”, “Tyre Abrasions”, “Other”, “Waste Water” and “Industrial Emissions”, all with <50 %. The option “Other” included “illegal dumping” (Belgium), “paint, footwear, road markings (microplastics)” (Denmark), “free plastic litter (throwaway) from land” (Iceland) and “detergents, paints” (Netherlands).

Since data on the main sources and pathways of plastics in freshwater environments are scarce, assessments by the survey participants were most likely based on educated guesses rather than on studies. This conclusion is supported by the relatively high number of participants who chose the option “Unknown”.

In the **Austrian** Danube study by Hohenblum et al. (2015a), purified plastic particles were identified by means of ATR-FT-IR and classified into one of five categories: fragments, foils, fibres, foams and pellets. Of these, only pellets can be directly attributed to industrial activity according to the study. These plastic particles presumably enter the environment during production or conversion processes as well as due to material loss along transport routes and during cleaning of the transport vessels. Industrial activities such as production processes, conversion and transport accounted for 4–10 % of the identified particles in the Danube River whereas the vast majority (90–96 %) were considered as emissions from diffuse sources, e.g. run-off from sealed surfaces, littering, fragmentation and transport by wind (Hohenblum et al. 2015a).

Figure 6: Main sources and pathways of plastics into freshwater environments as reported by the European survey participants

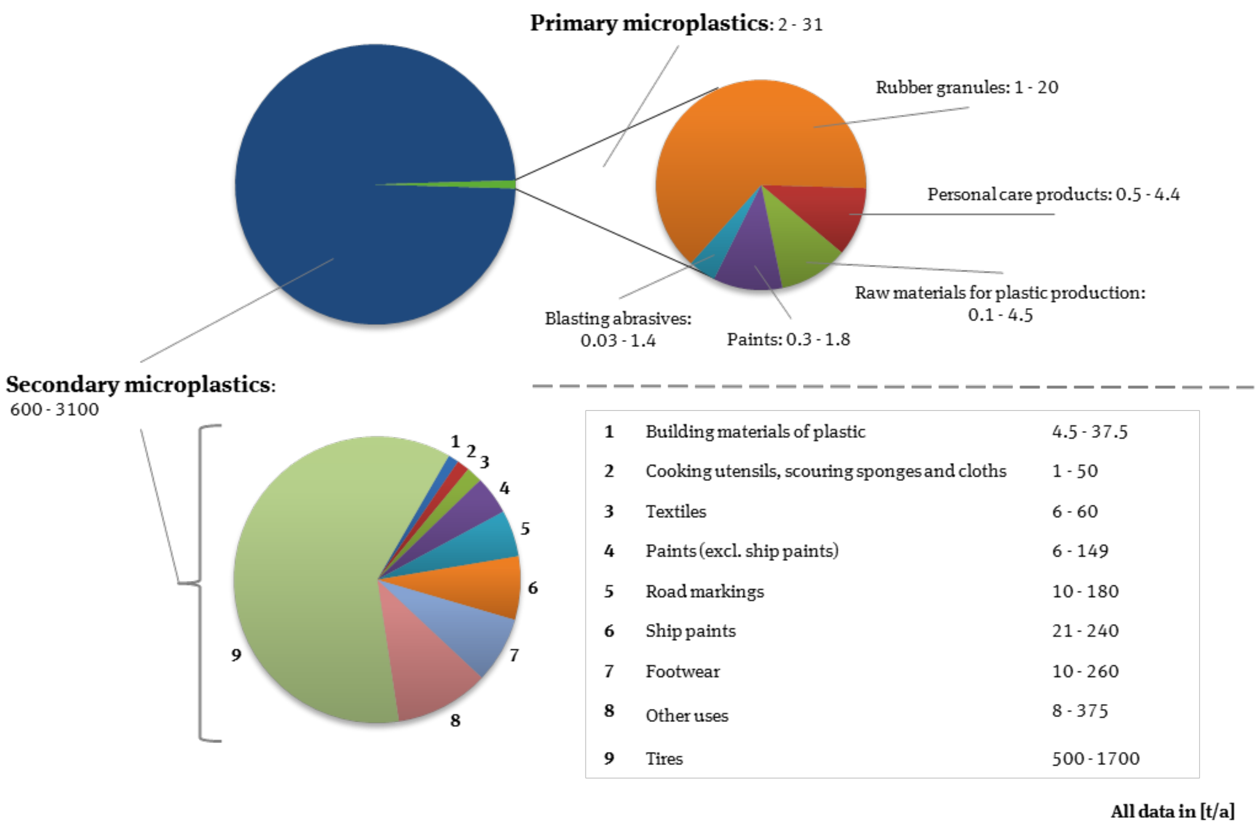


The results of the questionnaires are presented as the selections in total of the participants who selected the response option. Multiple answers without a specific ranking were also possible. Data source: Results of the European survey

Craenenbroeck et al. (2014) reported that the Leie River (**Belgium**) receives most of its litter through tourism activities, such as hiking or cycling on trails along its banks and recreational boating, but also from industry emissions and illegal dumping.

The government of **Denmark**, through its Finance Act for 2015, has allocated funds to investigate the environmental impact of microplastics. A series of projects are planned (see also section 4.1). The project “Microplastics: Occurrence, effects and sources of releases to the environment in Denmark”, published by the Danish Environment Protection Agency, provides a comprehensive overview of the estimated emission sources of primary and secondary microplastics in Denmark, including their use and release pathways into the environment. Figure 7 displays the estimated emissions of microplastics into the aquatic environment after sewage treatment. Besides sewage treatment plants, emissions occur via stormwater and urban run-off or via direct inputs into the aquatic environment (e.g. activities in harbours or ships). Only 10 – 20 % of the microplastics particles in stormwater are retained since not all stormwater sewers are equipped with settling lagoons. The emission estimates were derived from data compiled from the literature and from direct enquiries to Danish trade organisations and individual companies. The primary and secondary microplastics whose emissions are summarised in the figure differ in their size, morphology and chemical composition. Thus, quantifications of discharges in terms of numbers of particles would lead to different distributions; for example, the particles in plastics raw materials and rubber granules are larger than other particles occurring as dust or powder. However, expression of the amounts indicated in number of particles per year was not possible due to insufficient data (Lassen et al. 2015).

Figure 7: Primary and secondary microplastic emissions into Danish aquatic environments



Top left: Estimated emissions of primary (green) and secondary (blue) microplastics in Denmark; top right: estimated emissions of primary microplastics (attached lines); bottom left: contributions of secondary microplastic sources; bottom right: estimated emissions of secondary microplastics; **all data in tonnes/year**. Note that the given numbers indicate the resulting emissions directly after entering surface waters. Estimated emissions of secondary microplastics do not take into account their formation from macroplastics in the environment. (Data source: Lassen et al. 2015)

The total amount of microplastic discharges to sewage in Denmark was estimated as 2000 to 5600 tonnes/year. Although tyres and textiles were the main sources, other sources were cited as contributing significantly to the total amount. Furthermore, Lassen et al. (2015) pointed out that because the estimates were based on emissions occurring in the immediate recipient water, the extent to which particles are spread further within the environment could not be determined.

Verschoor et al. (2014) provided a systematic inventory and prioritisation of land-borne sources of primary and secondary microplastics (< 5 mm) in the **Netherlands**. The Dutch National Emission Register served as the template, with literature data and the results of a previous expert meeting as additional sources. Prioritisation was based on a multi-criteria analysis (MCA). The 56 sources of microplastics identified in the study were analysed according to the following criteria: relevance (volume of plastic emission), feasibility of the measures (alternatives and quick win) and perceived urgency (media attention, options for consumers choice or action perspective). The determined priority list (scale of 1 to 10) was derived from the qualitative scores provided by a group of experts representing the National Institute for Public Health and the Environment (RIVM), Rijkswaterstaat and Deltares. The highest priority scores were attributed to plastic debris comprising "packaging materials" (score: 9) and “general litter” (score: 8). Other sources with a relatively high assigned priority score (7) were “waste collection”, “cosmetics”, “paint, lacquer, dyes”, “fibres and clothing”, “loading, unloading, transfer of microplastics” and “run-off from paved surfaces”. According to Verschoor et al. (2014), the priority list serves to identify the sources that should be targeted for emission reduction measures. However, the prioritisation of microplastic sources was not solely determined by the scale of their respective emissions as some sources with moderate emissions were assigned a relatively high priority score. For instance, “cosmetics” received a priority score of 7 due to available alternatives, a large amount of publicity, public awareness of microplastics in cosmetics as well as clear courses of action for consumers and industry. The emission source “tyre wear” was assigned a priority score of 6 even though in the Netherlands an estimated 17,000 tonnes of tyre-derived particles are annually released into the environment (Verschoor et al. 2014). However, there are currently very few possibilities to reduce microplastic emissions caused by tyre wear. Verschoor et al. (2014) recommended that the study should be viewed as a preliminary ranking of priorities, due to the limited availability of relevant data.

In **Scotland**, the specific issue of identifying the main sources and pathways of plastics is currently being researched by the Scottish Microplastic Research Group[10] but the results of that study are not yet available.

4.4. Effect studies (Question 7)

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

Only two completed studies on ecological effects of plastics in freshwater environments were submitted in the context of the European survey; both were from **Austria**.

In the above-mentioned Danube study by Hohenblum et al. (2015a), 30 fish individuals (species: *Barbus barbus* and *Leuciscus cephalus*) were assessed regarding plastic ingestion. The fish were examined by autopsy and analyses of their intestinal contents for plastic particles. However, plastic particles were not identified in the intestines of any of the 30 test animals obtained from the **Danube** River near Vienna (Hohenblum et al. 2015a).

Given the above-mentioned findings of plastics in the **Danube** River and the hypothesis that suspended microplastics are components of the food sources of indigenous fish species, the need for further research was concluded by the Austrian authorities. The Federal Government of Upper Austria therefore commissioned the Technical Office for Water Ecology to conduct the pilot study “Microplastic in fish” (Lumesberger-Loisl and Gumpinger 2015). In that study the digestive tracts of 840 fish individuals were analysed for the presence of plastics. Within this group 791 individuals were caught at three sampling points along the Danube River and 49 individuals of edible fish were provided by a professional fisherman from the Linz area. The investigation led to the identification of one plastic particle in each of only two individuals of wild fish and no microplastics in the digestive tracts of the edible fish.

Besides those studies, several further investigations in other countries are ongoing, currently scheduled or under discussion, including the following four projects. Consequently, their results are not yet available.

The above-mentioned catalogue of proposed studies by **Danish** authorities (see section 4.1) includes the study “Effects on freshwater organisms and especially species used for regulatory testing purposes” (Danish Environmental Protection Agency, 2015–2017) (Lassen et al. 2015).

[10] http://www.masts.ac.uk/research/masts-community-projects/scottish-microplastic-research-group/

In **Germany**, the Bavarian Environmental Agency (LfU) initiated an investigation of the potential accumulation of microplastics in biota, such as bivalves and fish, under field as well as standardised laboratory conditions.

The **Irish** survey participant referred to an ongoing 1-year desk-study "Scope, fate, risks and impacts of microplastic pollution in Irish freshwater systems" (Officer 2015–2016) (see also section 4.1). The expected outcomes of the study include an appraisal of the risks posed by the identified potential impacts.[11]

Within the above-mentioned research project "TRAMP" (see section 4.1), the effects and risks of micro- and nanoparticles in freshwater environments in the **Netherlands** are currently being assessed.[12]

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[11] http://erc.epa.ie/droplet/modalFull.php?cid=17928

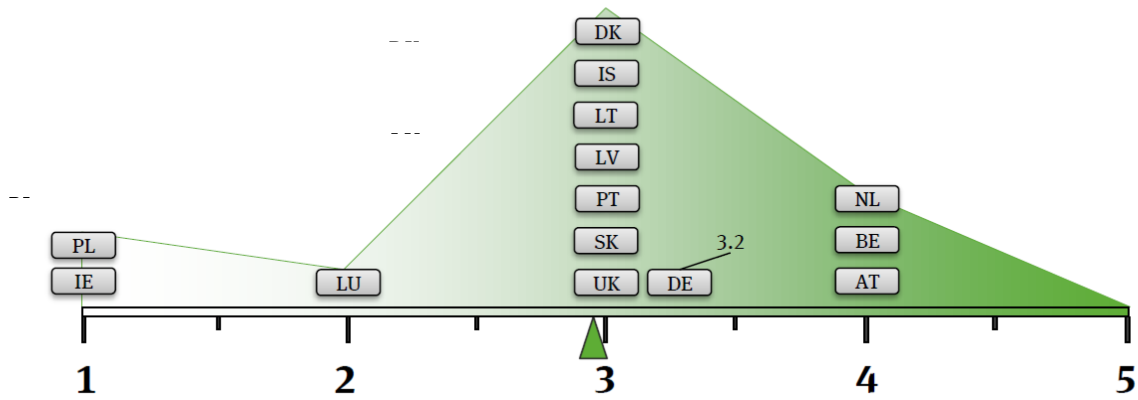
[12] http://www.stw.nl/nl/content/technologies-risk-assessment-microplastics-tramp

4.5. Risk perception of plastics in freshwater environments (Question 8)

Question 8: How are plastics in freshwater environment perceived in your country e.g., with regard to media reports, social networks, campaigns of non-governmental organisations?

The risk posed by plastics in freshwater environments was perceived by the survey participants as being in the intermediate range, based on a scale of 1 (low) to 5 (high) (Figure 8). The average value was 2.9, with a range of 1 - 4. Countries providing higher ratings, i.e. Austria, Belgium, Germany and the Netherlands, were those with existing monitoring programmes and currently implemented measures. It should be noted that in some cases plastics in freshwaters were difficult to distinguish from terrestrial and marine litter.

Figure 8: The perceived risk of plastics in freshwater environments according to the surveyed European countries



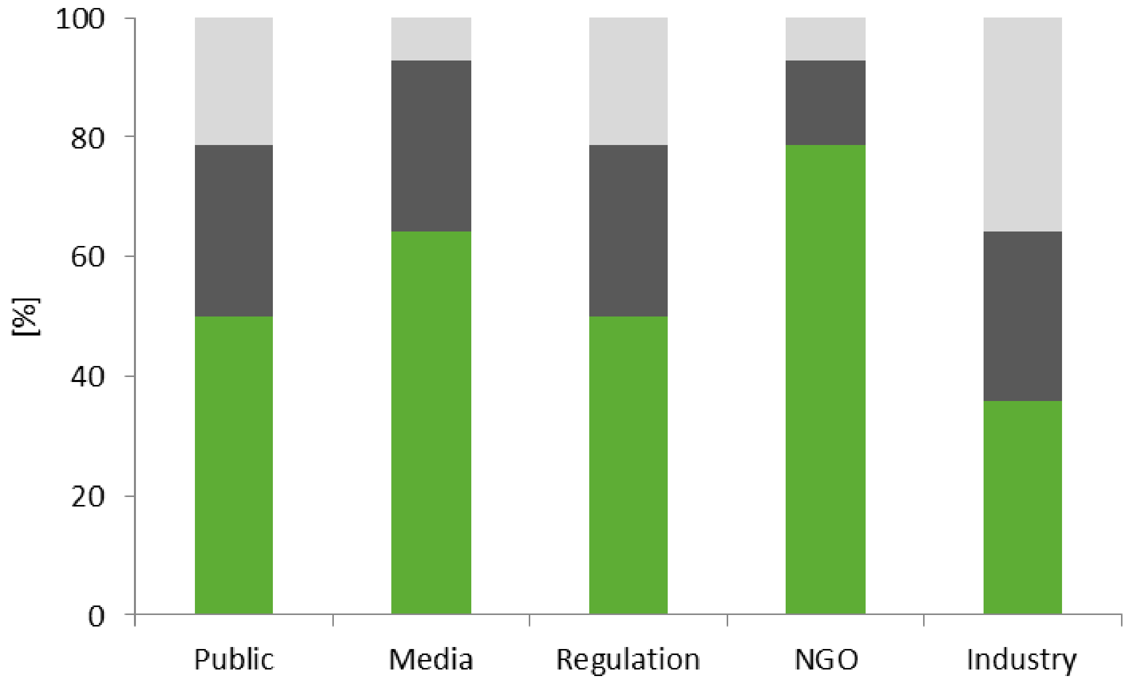
Risk perception was rated on a scale of 1 (low) to 5 (high). The mean score was 2.9 (marked by the green triangle). The German rating is the average value of the ratings provided by the individual surveyed federal states. Data source: Results of the European survey

4.6. Discussions on reduction measures (Question 9)

Question 9: Are there discussions in your country on reduction measures for plastics in freshwater environments?

Overall, all of the survey participants reported ongoing discussions on reduction measures in their countries. A large proportion of these discussions have been held by NGOs (almost 80 %) and the media (64 %), followed by public and regulatory agencies (both 50 %). By contrast, discussions in the industrial sector account for only about 36 %. However, almost 40 % of the participants provided either no or incomplete responses (shown as “not stated” in Figure 9).

Figure 9: Discussions on reduction measures for plastics in freshwater environments in the surveyed European countries



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

One prominent theme of discussion regarding reduction measures is the use of microplastics in consumer products, especially cosmetics and detergents, especially in terms of the need for EU-wide legislation to phase out microplastics in cosmetics, to prevent pollution at its source (Environmental Council of the European Union 2014). Currently, refraining from the use of microplastics is based on voluntary commitments by producers. At the Environmental Council (2014), **Austria, Belgium, Luxembourg, the Netherlands,** and **Sweden** supported an information note concerning the elimination of microplastics in products.

In the **German** survey response, awareness was emphasised in almost all given categories, except that of industry. Awareness seemed to be greatest in Northern Germany, based on frequently implemented actions to reduce litter inputs into the environment and on clean-up campaigns to remove existing litter.

The **Irish** representative noted the impacts of river basin management planning under the Water Framework Directive as well as specific actions for reducing the input of litter from land-based sources under the MSFD Programme of Measures and the OSPAR (Oslo and Paris Commission for the protection of the Marine Environment of the North East Atlantic) Regional Action Plan for marine litter. Through these processes and measures, plastic inputs into freshwater environments are expected to be reduced.

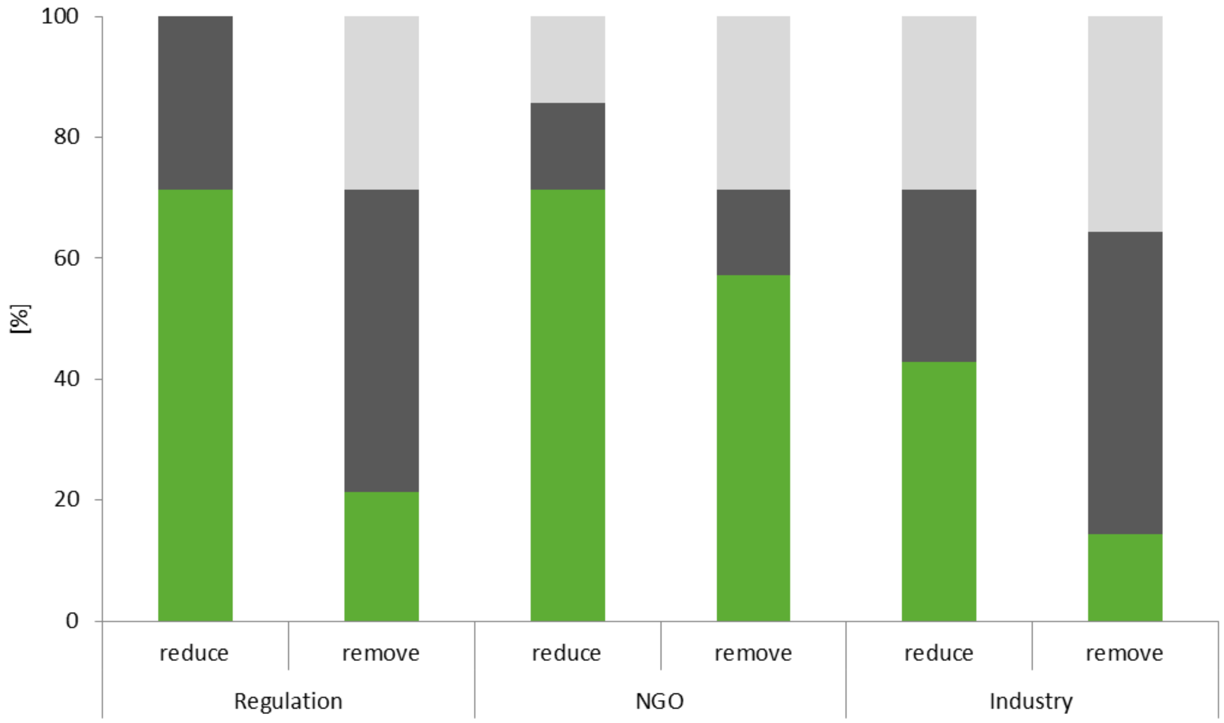
An assessment of the discussion on plastics in freshwater environments within the **United Kingdom** was accompanied by two references referring to the Scottish Litter Strategy. Specifically, the Scottish Government and Marine Scotland, a directorate of the Scottish Government that is responsible for the integrated management of Scotland's seas, are consulting on a National Litter Strategy and on a Marine Litter Strategy. Their aims are to manage litter in Scotland’s terrestrial, coastal and marine environments. Both have been subjected to a Strategic Environmental Assessment (SEA). The SEA report outlines support and actions for stakeholders and practitioners through to 2020, with a focus on encouraging individuals to take greater responsibility. The two strategies set out actions in three strategic directions: information (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). According to the SEA report the draft of the Marine Litter Strategy will incorporate activities and actions that are already underway. Relevant objectives and actions include a reduction of land-sourced marine litter entering the marine environment and improved monitoring at a Scottish scale (Environmental Assessment Team Planning and Architecture Division Directorate for Local Government and Communities 2013). However, freshwater environments were not specifically mentioned in this context.

4.7. Actions to reduce plastic inputs and remove existing litter from freshwater environments (Question 10)

Question 10: Are there existing or planned actions in your country to reduce input of plastics and/or to remove existing litter in freshwater environments?

Ongoing and planned actions concerning the reduction of plastic inputs into and removal of existing litter from freshwater environments were assessed in relation to regulations, NGOs and industry. The results are summarised in Figure 10. Overall, more European countries are planning or have already implemented measures to reduce the plastic waste into inland waters than are planning measures aimed at the removal of already existing litter. Nevertheless, 57 % of survey participants stated measures for the removal of plastic waste from freshwater environments (e.g. clean-up campaigns conducted by NGOs).

Figure 10: Existing and planned actions to reduce plastic inputs and to remove existing litter from freshwater environments



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

4.7.1 Regulations and other activities of the national governments

Measures aimed at reducing plastic inputs were reported by 71 % of the surveyed European countries. These include legislated regulatory measures and other activities carried out by national governments that seek to reduce plastic inputs. Thus, general regulations that prohibit any kind of littering have been implemented in the **Flemish region of Belgium**, within the framework of the Flemish Waste Regulation, and in **Scotland**, within the framework of "The Litter (Fixed Penalties) (Scotland) Order 2013".[13] General schemes have been set up by local authorities and municipalities to prevent littering and similar activities. In some countries, national deposit and return systems, in which disposed plastics are collected and recycled to allow their re-use as new packaging, contribute to a reduction of plastic inputs into freshwater environments. Dansk Retursystem A/S, a privately owned Danish non-profit organisation that is regulated by a statutory order, is executing one such programme in Denmark. Another one is in **Ireland**, run by the Irish company "Repak".[14]

[13] http://faolex.fao.org/docs/pdf/uk128510.pdf

[14] https://www.repak.ie/

The **Luxembourgian** Waste Management Plan, which was adopted in 2010, set the following objectives:

1. Prevent and reduce waste production and pollution from waste
2. Recover through reuse, recycling and other environmentally appropriate methods
3. Dispose final waste in an environmentally and economically appropriate way

Business operators in Luxembourg must draw up a waste prevention and management plan aimed at limiting harmful impacts of waste production.[15] The "SuperDrecksKëscht®", a cooperation between the government, the Chamber of Commerce and the Chamber of Trade, awards a quality certificate and provides reliable information for companies.[16]

Plastic bags:

Across Europe, several different measures have been introduced to limit the use of plastic bags. In **Iceland**, the Ministry of Environment has appointed a working group that will prepare an action plan. In addition, some Icelandic municipalities have recently initiated projects to implement reduction measures in the community. **Latvia and Portugal** have introduced regulatory measures to reduce the use of plastic bags. The **Latvian** Natural Resources Tax Law established a tax on the packaging of goods and services, including plastic packaging. Since 2008, the raw materials of plastics have also been taxed. The rates are lower for bioplastics packaging and higher for polystyrene packaging. To further reduce the consumption of plastic bags, the Latvian tax rates were raised again in 2014, which has discouraged storekeepers from providing plastic bags free of charge to consumers. Further increases in the Natural Resources Tax are currently under discussion. In 2014, **Portugal** made amendments to previous environmental taxation policies applied to the sectors of energy and emissions, transportation, water, waste, urban planning, forests and biodiversity, by introducing, among other measures, a tax on lightweight plastic carrier bags (€0.08 per bag + VAT). In **Luxembourg**, a cooperation between the Ministry for the Environment, the Luxembourgian Trade Confederation and the non-profit association VALORLUX initiated the project "Eco-bag" in 2004. As part of the framework of the national waste prevention plan, the project aims to largely reduce the use of one-way shopping bags and establish the reusable and recyclable bag "Öko-Tut". In the course of the project, the quantity of bags was reduced by almost 90 % (2006–2014). Since the launch of the project, the use of >560 million one-way shopping bags has been prevented, which represents a saving of 3,738 tonnes of plastics. With a consumption of about 18 lightweight carrier bags per person per year, Luxembourg already meets the reduction targets foreseen by the EU directive 2015/720.[17] Additionally, the European Commission conferred its best practice award to the "Eco-bag" project for waste prevention in 2012.[18]

Further activities:

Besides the regulatory measures already outlined, further planned actions are expected to serve as the necessary background for future regulations. For example, the **Austrian** Minister for Agriculture, Forestry, Environment and Water Management has issued a 10-Point Programme-of-Measures to improve water quality in the Danube River (Table 6). The programme is divided into measures on the

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[15] http://www.environnement.public.lu/dechets/dossiers/pggd/index.html

[16] https://www.sdk.lu/index.php/en/

[17] According to the EU directive measures taken by the member states shall ensure that the annual consumption level does not exceed 90 lightweight plastic carrier bags per person by the end of 2019 and 40 lightweight plastic carrier bags per person by the end of 2025 (EU directive 2015/720, Article 1 (2)a).

[18] http://valorlux.lu/sites/valorlux/files/files/VALLO01-4009_FactSheet_GB-4Web.pdf

European and national levels, both of which address general and interdisciplinary political, industrial and public objectives concerning the environmental issue of microplastics in the Danube River.

Table 6: 10-Points-of-Measure for the reduction of plastics in order to improve water quality of the Danube River, Austria

European Level
Uniform methods and measurement standards for plastic particles in rivers
Regulation of EU thresholds
Voluntary withdrawal 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
10-Point-Programme "Zero-Pellet-Loss Pact" with the association of the Austrian chemical industry
Continued monitoring of 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 management and waste water associations
Raising awareness in the environmental department referring to the Eurovision Songcontest as a Green Event 2015[19]

Translation of the original document prepared in German. (Original source: BMLFUW (2015a))

Additionally, the **Flemish** Port and Waterways Authorities are currently monitoring the quantity of floating litter. Associated measures have been taken to assess which methodology might be the most efficient to remove floating litter as well as litter that has washed upon shores and banks in Belgium.

The recently launched project "Plastic Waste Pathways into the Baltic Sea" is funded by the Central Baltic Programme and carried out by a **Latvian** NGO partner. The objective of the programme is a reduction of waste reaching the sea. The expected outcomes include a new methodology to model essential sources and pathways, efficient monitoring of litter in rivers and coastal areas, data from four pilot areas, list of identified and prioritised sources and actions to reduce marine litter and hazardous substances in the Baltic Sea and an increasing general awareness through different activities.

4.7.2 NGOs

According to the survey, both reductions in plastic inputs and the removal of existing litter have been addressed by NGOs within Europe, especially regarding microplastics in cosmetics, campaigns for river and beach clean-up carried out in conjunction with general nature protection measures and efforts concerning the monitoring of plastics.

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

Microplastics in cosmetics:

Two initiatives concerning the use of microplastics in cosmetics were mentioned by the survey participants from **Austria** and **Portugal**.

According to the Austrian reference, the international NGO Greenpeace has started the international campaign "Beat the Microbead", which advocates the prohibition of microplastics in cosmetics. The international campaign has included, among other actions, the development of a mobile application that uses a traffic-light-system to identify products containing microplastic and lists companies refraining from the use of microplastics in their products. The list of these companies has been complemented by the availability of "green-light" products in Austria, according to the reference.[20]

In **Portugal**, a collaboration between the Aquamuseum of Vila Nova de Cerveira (Minho region, northern Portugal) and the Portuguese Association on Marine Litter (Associação Portuguesa do Lixo Marinho: APLM)[21] has produced an interactive exhibition with the theme "Litter from the River to the Sea". Its focus is on sanitary products (e.g. scrubs) and cosmetics as a source of pollution. According to the reference, the exhibition and related activities lead to a general reaction of surprise by the part of visitors regarding this topic (the role of these products as waste sources on land, river and sea) and demonstrated the utility of improving knowledge on microplastics in household goods. The APLM intends to prepare an assessment questionnaire on this issue, to develop a related knowledge base, encourage the involvement of citizens and guide actions for environmental education.

Clean-up campaigns and litter prevention initiatives:

The survey revealed that the most significant efforts to remove existing litter from European freshwater environments have originated from NGOs. Activities of NGOs were reported by 57 % of the surveyed countries (see Figure 8), including various clean-up-campaigns in **Austria**, **Iceland**, **Latvia**, **Northern Ireland** (United Kingdom) and the **Slovak Republic**.

Efforts for litter removal in **Austria** have been initiated and are being carried out regularly by two NGOs, the Danube National Park Administration and the World Wide Fund for Nature (WWF).

The **Danish** Outdoor Council operates as an umbrella organisation for national organisations involved in a wide range of outdoor recreational activities as well as nature protection interests. The Council promotes outdoor recreation for organisations and the general public while taking into account both environmental and nature protection concerns[22]. One of the projects is the Blue Flag programme, which ensures the adequate presence of waste facilities to avoid litter and provides environmental education activities and information about the local ecosystem, including beaches and marinas.[23] Additionally, the aim of the non-profit organisation "Keep Denmark Tidy" is to reduce the amount of litter in nature.[24]

The Association Blue Army, a cooperation among public organisations, companies and NGOs, has carried out several clean-up projects along the coast of **Iceland** and in the adjacent sea. Efforts in coastal areas in 2014–2015 were mainly located in the nature reserve area of Hornstrandir in the Westfjords.

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[20] http://www.greenpeace.org/austria/de/marktcheck/News/kosmetik/2014/Mikroplastik-in-Kosmetika/

[21] http://www.aplixomarinho.org/

[22] http://www.friluftsraadet.dk/indhold/om-friluftsraadet/english.aspx

[23] http://www.blaaflag.dk/media/322061/m65_4fl_uk_de_web_enkelt.pdf

[24] http://www.holddanmarkrent.dk/

The **Finnish** association KAT (see section 4.1) is active in various fields of environmental protection, including waste collection, recycling, information and education.[25] One of its projects is the "Clean Beach Campaign", which through voluntary work aims to clean up beaches and to raise awareness of the problem of litter along the Finnish coast and in freshwater environments. KAT has carried out two beach clean-up campaigns thus far and intends to continue coordinating annual efforts, including litter reporting. The association has launched the 3-year EU project "BLASTIC" (2016)[26], which addresses the role of rivers in the Baltic Sea litter problem (Gustafsson et al. 2016).

In **Latvia**, a "Big Clean-up Day" ("Lielã Talka") has been held annually since 2008. The event is based on voluntary participation and primarily consists of gathering waste in both urban and rural areas. In 2012, the focus of the event was the clean-up of water bodies.[27]

The measures delivered by the NGO "Keep Northern Ireland Beautiful" include the "Live Here Love Here" campaign, the annual "Big Spring Clean-up" and the "Clean Coast" campaign. "Live Here Love Here" is co-sponsored by the Department of the Environment **Northern Ireland** (DOENI) and calls attention to littering and environmental pollution in Northern Ireland. The "Clean Coast" campaign, sponsored by a global producer of soft drinks, specifically promotes clean-ups of coastal and inland waterways, including freshwater environments. In **England and Wales**, the Rivers Trust, a registered charity organisation representing trusts for individual rivers undertakes clean-ups of local rivers in the respective countries.

4.7.3 Industry

Five survey participants (43 %) indicated efforts addressing the reduction of plastic inputs within the industrial sector.

The **Austrian** industrial initiative "Zero Pellet Loss" (Table 7) was launched by the Austrian Ministry for Agriculture, Forestry, Environment and Water Management and the Association of the Austrian Chemicals Industry (FCIO). The initiative was implemented and signed by the industrial partners in 2015 and aims at reducing raw materials emissions of plastics from industrial installations. It originated as part of the 10-Point-of-Programme of Measures to improve the quality of the Danube River (see Table 6) but is now a worldwide initiative that has been implemented in many companies and countries.

Actions targeting the removal of plastics from freshwater environment are conducted in the context of the awareness raising initiative "Reinwerfen statt Wegwerfen" ("toss it in instead of toss it out"). This campaign was initiated in 2012 and is based on voluntary commitment. Key issues such as separate packaging collection, increased recycling as well as measures to prevent and reduce general littering are supported in the context of the initiative. Raising awareness about the plastic problem and the importance of safeguarding the environment and its natural resources are a special focus within the project, which includes regular clean-up campaigns of different freshwater environments as well as diverse events and festivals across Austria.[28]

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[25] http://www.pidasaaristosiistina.fi/in_english

[26] The BLASTIC project demonstrates how plastic waste in urban areas finds its way into the Baltic Sea and becomes marine litter. The project provides a methodology for mapping the most important sources and pathways of marine plastic litter and for monitoring litter in rivers and coastal waters/areas. Source: https://www.blastic.eu/about-blastic/

[27] http://talkas.lv/?page=558&lng=en

[28] https://www.reinwerfen.at/organisation/reinwerfen-statt-wegwerfen.html

Table 7: Zero Pellet Loss: 10-Point-Programme of Measures

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

Translation of the original document prepared in German (original source: BMLFUW (2015b))

5. Potential risk of plastic litter in freshwater systems

Besides their entanglement in larger plastic materials, aquatic organisms often mistake plastic particles as food. The physical consequences of swallowing plastics are impaired food ingestion and altered feeding behaviour (Gregory 2009). Moreover, sharp-edged particles can cause mechanical injuries in the intestinal tract, blocking or reducing ingestion and causing indigestion (Wright et al. 2013). The ingestion of plastic particles depends on the ratio of particles to organisms and on the feeding behaviour of those organisms (Setälä et al. 2016). Direct effects due to ingestion and the fate of the ingested materials in the intestinal tract have been described especially for macroplastics (e.g., Besseling et al. (2013), Browne et al. (2008), Cole et al. (2013), Lee et al. (2013), Rosenkranz et al. (2009), Rummel et al. (2015), Sanchez et al. (2013), Setälä et al. (2014), Ugolini et al. (2013), von Moos et al. (2012), Wegner et al. (2012)). The uptake of plastic particles has been reported for more than 250 species, particularly for marine species, whereas freshwater biota has been addressed in only a few studies so far (Imhof et al. (2013), McCormick et al. (2014), Rosenkranz et al. (2009), Sanchez et al. (2013)). It should be noted that many organisms are able to egest unintentionally ingested plastic materials.

In addition to physical effects, immune reactions due to the ingestion of plastics (and perhaps tissue transfer) and/or mechanical injuries have been described (von Moos et al. (2012), Wegner et al. (2012)), together with physiological effects due to a reduced energy supply (Besseling et al. (2013), Cole et al. (2013)).

Toxic effects could be caused by additives (e.g. phthalate-based plastizisers and bisphenol A (BPA)) originally being in the plastic particles (Oehlmann et al. 2009) or by substances gradually adsorbing to the plastic particles in the environment due to hydrophobic interactions depending on the type of plastics (Bakir et al. (2012), Teuten et al. (2009), Zarfl and Matthies (2010)). Additives including persistent pollutants can be ingested together with plastic particles depending on the polymer type, plastic additives and on the sorption properties of environmental chemicals. For example, polyethylene accumulates a larger spectrum of organic pollutants than polypropylene or polyvinyl chloride (Teuten et al. 2009). Persistent organic pollutants can cause hepatic damage when in liver tissue (Rochman et al. 2013).

Toxic or endocrine disrupting effects due to polymers and/or additives such as nonylphenolethoxylate have already been described in the literature. In the environment nonylphenolethoxylate is degraded to nonylphenol. Browne et al. (2013) reported that nonylphenol desorbing from polyvinyl chloride accumulates in the tissue of the lugworm *Arenicola marina* and affects the phagocytic activity. Contrary to that, a study based on a biodynamic model indicates that nonylphenol leached from polyethylene has not been significantly ingested by *Arenicola marina* (Koelmans et al. 2014). This example emphasises the fact that our current knowledge is thus far too limited to enable reliable risk assessments. Plastic particles can act as sources and as sinks of pollutants depending on the adsorption/desorption balance. There is evidence showing that adsorbed pollutants may be desorbed in the intestinal tract of organisms due to altered milieu conditions (pH, temperature) and become bioavailable (Bakir et al. 2014). Indeed, bioaccumulative effects and the trophic transfer of microplastics (and of the sorbed pollutants) have already been reported (Batel et al. (2016), Farrell and Nelson (2013), Setälä et al. (2014), Wright et al. (2013)).

A further concern is that macro- and microplastics could serve as vectors for invasive species (Gregory 2009), harmful algal bloom (HAB) species (Masó et al. 2003) and opportunistic pathogens (McCormick et al. (2014), Zettler et al. (2013)). These organisms may be additional stressors for anthropogenically influenced ecosystems or enter more pristine regions with floating plastic particles.

6. The need for harmonisation and further investigations

Our knowledge of the distribution and abundance of micro-, meso and macroplastics in freshwater environments is far from complete, for several reasons. First, the previous monitoring projects and studies on plastics in rivers and lakes did not cover all European countries. Second, the occurrence and loads of plastics in numerous freshwaters, especially major rivers, contribute to relevant inputs into the connecting seas but this pathway has yet to be adequately investigated. Third, an important problem hampering further monitoring activities is the lack of standardised sampling, sample processing and sample identification. Rather, water samples and sediments are currently investigated using different methods and the results are therefore not directly comparable. Further research is needed to establish standard procedures to ensure consistency in monitoring water and other aquatic compartments. The first step should be to reach a consensus definition of microplastics, especially regarding their lower size limit.

A reliable risk assessment of inland waters requires further studies on the potential physical and chemical impacts of microplastics and their environmental relevance. However, despite the currently existing knowledge gaps, steps should be initiated to reduce the plastics inputs into freshwater environments with regard to the huge quantities that are released.

7. Literature

Andrady AL (2011): Microplastics in the marine environment. Marine Pollution Bulletin 62, 1596-1605, http://linkinghub.elsevier.com/retrieve/pii/S0025326X11003055

Arthur C, Baker J, Bamford H (2009): Proceedings of the International Research Workshop on the Occurrence, Effects, and Fate of Microplastic Marine Debris. NOAA Technical Memorandum NOS-OR&R-30, 1-49,

AWI, Mintenig S, Int-Veen I, Löder M, Gerdts G (2014): Abschlussbericht Mikroplastik in ausgewählten Kläranlagen des Oldenburgisch-Ostfriesischen Wasserverbandes (OOWV) in Niedersachsen - Probenanalyse mittels Mikro-FTIR Spektroskopie. 50,

Bakir A, Rowland SJ, Thompson RC (2012): Competitive sorption of persistent organic pollutants onto microplastics in the marine environment. Marine Pollution Bulletin 64, 2782-2789, http://www.sciencedirect.com/science/article/pii/S0025326X12004602

Bakir A, Rowland SJ, Thompson RC (2014): Enhanced desorption of persistent organic pollutants from microplastics under simulated physiological conditions. Environmental Pollution 185, 16-23, http://dx.doi.org/10.1016/j.envpol.2013.10.007

Bannick CG, Brand K, Jekel M, König F, Miklos D, Rechenberg B (2015): Kunststoffe in der Umwelt - Ein Beitrag zur aktuellen Mikroplastikdiskussion. Korrespondenz Wasserwirtschaft 8, 49-53,

Barnes DKA, Galgani F, Thompson RC, Barlaz M (2009): Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society B-Biological Sciences 364, 1985-1998, http://rstb.royalsocietypublishing.org/cgi/doi/10.1098/rstb.2008.0205

Bart JCJ (2006): Plastics additives: advanced industrial analysis. IOS Press, Amsterdam [u.a.]

Batel A, Linti F, Scherer M, Erdinger L, Braunbeck T (2016): The transfer of benzo[a]pyrene from microplastics to Artemia nauplii and further to zebrafish via a trophic food web experiment – CYP1A induction and visual tracking of persistent organic pollutants. Environmental Toxicology and Chemistry 35, 1056-1066, http://dx.doi.org/10.1002/etc.3361

Besseling E, Wegner A, Foekema EM, Heuvel-Greve MJ, Koelmans AA (2013): Effects of microplastic on fitness and PCB bioaccumulation by the lugworm Arenicola marina (L.). Environmental Science and Technology 47, 593-600, http://dx.doi.org/10.1021/es302763x

BMLFUW (2015a): 10 Punkte - Maßnahmenprogramm für die Qualität der Donau.

BMLFUW (2015b): Pakt „Zero Pellet Loss“.

Brandsma SH, Nijssen P, van Velzen MJM, Leslie HA (2013): Microplastics in river suspended particulate matter and sewage treatment plants, IVM Institut for Environmental Studies, VU University Amsterdam, Amsterdam,

Brandsma SH, van Velzen MJM, Leslie HA (2015): Microplastics in North Sea marine sediment and Dutch river suspended particle matter, IVM Institut for Environmental Studies, VU University Amsterdam, Amsterdam,

Browne MA, Dissanayake A, Galloway TS, Lowe DM, Thompson RC (2008): Ingested Microscopic Plastic Translocates to the Circulatory System of the Mussel, Mytilus edulis (L.). Environmental Science and Technology 42, 5026-5031, http://pubs.acs.org/doi/abs/10.1021/es800249a

Cieplik S (2016): Wege ins Meer. Kunststoffe 05/2016, 26-28, http://www.bkv-gmbh.de/fileadmin/images/bkv/PM/KU_2016_05_Wege-ins-Meer.pdf

Cole M, Lindeque P, Fileman E, Halsband C, Goodhead R, Moger J, Galloway TS (2013): Microplastic Ingestion by Zooplankton. Environmental Science and Technology 47, 6646-6655, http://pubs.acs.org/doi/abs/10.1021/es400663f

Consultic Marketing & Industrieberatung GmbH (2016): Vom Land ins Meer – Modell zur Erfassung landbasierter Kunststoffabfälle, Alzenau,

Craenenbroeck KV, Faasse iM, Van Cauwenberghe dL (2014): Monitoring en ingrepen op zwerfvuil in rivieren (case De Leie) Eindrapport, OVAM

Do TCV, Scherer HW (2012): Compost and biogas residues as basic materials for potting substrates. Plant, Soil and Environment, 459-464,

Dris R, Gasperi J, Rocher V, Saad M, Renault N, Tassin B (2015): Microplastic contamination in an urban area: a case study in Greater Paris. Environmental Chemistry 12, 592-599, http://www.publish.csiro.au/paper/EN14167

Duis K, Coors A (2016): Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects. Environmental Science Europe 28, 2, http://www.enveurope.com/content/28/1/2

Dümichen E, Barthel A-K, Braun U, Bannick CG, Brand K, Jekel M, Senz R (2015): Analysis of polyethylene microplastics in environmental samples, using a thermal decomposition method. Water Research 85, 451-457, http://www.sciencedirect.com/science/article/pii/S0043135415302141

Environmental Assessment Team Planning and Architecture Division Directorate for Local Government and Communities (2013): Marine Litter Strategy National Litter Strategy: Strategic Environmental Assessment Environmental Report, Edinburgh,

Environmental Council of the European Union (2014): Elimination of micro-plastics in products - an urgent need - Information from the Belgian, Dutch, Austrian and Swedish delegations, supported by the Luxembourg delegation. Council of the European Union Brussels

Essel R, Engel L, Carus M, Ahrens RH (2015): Sources of microplastics relevant to marine protection in Germany, German Environment Agency,

EU (2008): Directive 2008/56/EC of the European Parliament and of the council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). In: Union E (Hrsg.). Official Journal of the European Union

Farrell P, Nelson K (2013): Trophic level transfer of microplastic: Mytilus edulis (L.) to Carcinus maenas (L.). Environmental Pollution 177, 1-3, http://www.sciencedirect.com/science/article/pii/S0269749113000614

Faure F, Corbaz M, Baecher H, de Alencastro L (2012): Pollution due to plastics and microplastics in Lake Geneva and in the Mediterranean Sea. Archives des Sciences 65, 157-164, http://infoscience.epfl.ch/record/186320

Faure F, Gagnaux V, Baecher H, Neuhaus V, de Alencastro L (2013): Microplastiques sur les plages et la surface du Léman. Résultats préliminaires. Bulletin de l'ARPEA 49, 15-18, http://infoscience.epfl.ch/record/188166

Faure F, Demars C, Wieser O, Kunz M, de Alencastro LF (2015): Plastic pollution in Swiss surface waters: nature and concentrations, interaction with pollutants. Environmental Chemistry 12, 582-591, http://www.publish.csiro.au/paper/EN14218

Fischer EK, Paglialonga L, Czech E, Tamminga M (2016): Microplastic pollution in lakes and lake shoreline sediments – A case study on Lake Bolsena and Lake Chiusi (central Italy). Environmental Pollution 213, 648-657, http://www.sciencedirect.com/science/article/pii/S0269749116301932

Galgani F, Fleet D, Van Franeker J, Katsanevakis S, Maes T, Mouat J, Oosterbaan L, Poitou I, Hanke G, Thompson R, Amato E, Birkun A, Janssen C (2010): Marine Strategy Framework Directive Task Group 10, Report Marine litter, Prepared under the Administrative Arrangement between JRC and DG ENV (no 31210 –2009/2010), the Memorandum of Understanding between the European Commission and ICES managed by DG MARE, and JRC's own institutional funding, http://ec.europa.eu/environment/marine/pdf/9-Task-Group-10.pdf

Galgani F, Hanke G, Werner S, De Vrees L (2013): Marine litter within the European Marine Strategy Framework Directive. ICES Journal of Marine Science 70, 1055-1064, http://icesjms.oxfordjournals.org/cgi/doi/10.1093/icesjms/fst122

Gasperi J, Dris R, Bonin T, Rocher V, Tassin B (2014): Assessment of floating plastic debris in surface water along the Seine River. Environmental Pollution 195, 163-166, http://www.sciencedirect.com/science/article/pii/S0269749114003807

Gregory MR (2009): Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Philosophical Transactions of the R.oyal Society B 364, 2013-2025, http://rstb.royalsocietypublishing.org/roypt b/364/1526/2013.full.pdf

Gustafsson J, Siikasmaa L, Kaasalainen H (2016): Clean Beach Campaign 2014–2015, Keep the Archipelago Tidy Association

Hidalgo-Ruz V, Gutow L, Thompson RC, Thiel M (2012): Microplastics in the Marine Environment: A Review of the Methods Used for Identification and Quantification. Environmental Science and Technology 46, 3060-3075, http://pubs.acs.org/doi/abs/10.1021/es2031505

Hohenblum P, Frischenschlager H, Reisinger H, Konecny R, Uhl M, Mühlegger S, Habersack H, Liedermann M, Gmeiner P, Weidenhiller B, Fischer N, Rindler R (2015a): Plastik in der Donau - Untersuchung zum Vorkommen von Kunststoffen in der Donau in Österreich, Umweltbundesamt - BOKU Report

Hohenblum P, Frischenschlager H, Reisinger H, Konecny R, Uhl M, Mühlegger S, Habersack H, Liedermann M, Gmeiner P, Weidenhiller B, Fischer N, Rindler R (2015b): Plastik in der Donau - Untersuchung zum Vorkommen von Kunststoffen in der Donau in Österreich. Umweltbundesamt - BOKU Report REP-0547, 1-120,

Imhof HK, Schmid J, Niessner R, Ivleva NP, 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,

Imhof HK, Ivleva NP, Schmid J, Niessner R, Laforsch C (2013): Contamination of beach sediments of a subalpine lake with microplastic particles. Current Biology 23, R867-R868, http://www.sciencedirect.com/science/article/pii/S0960982213011081

Imhof HK, Laforsch C, Wiesheu AC, Schmid J, Anger PM, Niessner R, Ivleva NP (2016): Pigments and plastic in limnetic ecosystems: A qualitative and quantitative study on microparticles of different size classes. Water Research 98, 64-74, http://www.sciencedirect.com/science/article/pii/S0043135416301427

Klein S, Worch E, Knepper TP (2015): Occurrence and Spatial Distribution of Microplastics in River Shore Sediments of the Rhine-Main Area in Germany. Environmental Science & Technology 49, 6070–6076, http://dx.doi.org/10.1021/acs.est.5b00492

Laforsch C (2015): Mikroplastik Analyse Nordrhein-Westfalen, Universität Bayreuth

Lambert S, Sinclair CJ, Boxall AB (2014): Occurrence, degradation and effect of polymer-based materials in the environment. Reviews of Environmental Contamination and Toxicology 227, 1-53,

Lassen C, Foss Hansen S, Magnusson K, Norén F, Bloch Hartmann NI, Rehne Jensen P, Gissel Nielsen T, Brinch A (2015): Microplastics - Occurrence, effects and sources of releases to the environment in Denmark. The Danish Environmental Protection Agency, Environmental project No. 1793, 2015

Lechner A, Keckeis H, Lumesberger-Loisl F, Zens B, Krusch R, Tritthart M, Glas M, Schludermann E (2014): The Danube so colourful: A potpourri of plastic litter outnumbers fish larvae in Europe's second largest river. Environmental Pollution 188, 177-181, http://www.sciencedirect.com/science/article/pii/S0269749114000475

Lee K-W, Shim WJ, Kwon OY, Kang J-H (2013): Size-Dependent Effects of Micro Polystyrene Particles in the Marine Copepod Tigriopus japonicus. Environmental Science & Technology 47, 11278-11283, http://dx.doi.org/10.1021/es401932b

Leslie H, Moester M, de Kreuk M, Vethaak D (2012): Verkennende studie naar lozing van microplastics door rwzi's. H_2O 14/15, 45-47,

Leslie HA, van Velzen MJM, Vethaak AD (2013): Microplastics survey of the Dutch environment: Novel data set of microplastics in North Sea sediments, treated wastewater effluents and marine biota, IVM Institute for Environmental Studies, VU University Amsterdam, Amsterdam,

Lindén LÅ, Rabek JF, Kaczmarek H, Kaminska A, Scoponi M (1993): Photooxidative degradation of polymers by HOxxx and HO2xxx radicals generated during the photolysis of H2O2, FeCl3, and Fenton reagents. Coordination Chemistry Reviews 125, 195-217, http://www.sciencedirect.com/science/article/pii/001085459385018Y

Löder MGJ, Kuczera M, Mintenig S, Lorenz C, Gerdts G (2015): Focal plane array detector-based micro-Fourier-transform infrared imaging for the analysis of microplastics in environmental samples. Environmental Chemistry 12, 563-581, http://www.publish.csiro.au/paper/EN14205

Lumesberger-Loisl F, Gumpinger C (2015): Mikroplastik in Fischen: Pilotstudie in der oberösterreichischen Donau, Blattfisch, Technisches Büro für Gewässerökologie DI Clemens Gumpinger, Wels,

Lusher AL, McHugh M, Thompson RC (2013): Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel. Marine Pollution Bulletin 67, 94-99, http://dx.doi.org/10.1016/j.marpolbul.2012.11.028

Mani T, Hauk A, Walter U, Burkhardt-Holm P (2015): Microplastics profile along the Rhine River. Scientific Reports 5, 17988, http://dx.doi.org/10.1038/srep17988

Masó M, Garcés E, Pagès F, Camp J (2003): Drifting plastic debris as a potential vector for dispersing Harmful Algal Bloom (HAB) species. SCI. MAR. 67, 107-111, http://scientiamarina.revistas.csic.es/index.php/scientiamarina/article/view/459/471

McCormick A, Hoellein T, Mason SA, Schluep J, Kelly JJ (2014): Microplastic is an abundant and distinct microbial habitat in an urban river. Environmental Science and Technology 48, 11863-11871, http://pubs.acs.org/doi/abs/10.1021/es503610r

Mehlhart G, Blepp M (2012): Study on land-sourced litter (LSL) in the marine environment: review of sources and literature in the context of the initiative of the Declaration of the Global Plastics Associations for Solutions on Marine Litter, Öko-Institut e.V, Darmstadt/Freiburg,

Moore CJ (2008): Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. Environmental Research 108, 131-139, http://www.sciencedirect.com/science/article/pii/S001393510800159X

Morritt D, Stefanoudis PV, Pearce D, Crimmen OA, Clark PF (2014): Plastic in the Thames: A river runs through it. Marine Pollution Bulletin 78, 196-200, http://dx.doi.org/10.1016/j.marpolbul.2013.10.035

PlasticsEurope (2013): Plastics – the Facts 2013: An analysis of European latest plastics production, demand and waste data, Brussels, Belgium

PlasticsEurope (2015): Plastics – the Facts 2015: An analysis of European plastics production, demand and waste data.

Pruter AT (1987): Sources, quantities and distribution of persistent plastics in the marine environment. Marine Pollution Bulletin 18, 305-310, http://www.sciencedirect.com/science/article/pii/S0025326X87800164

Remmel J (2016): Mikroplastik in nordrhein-westfälischen Gewässern. Vorlage 16/3599 Landtag Nordrhein-Westfalen

Rillig MC (2012): Microplastic in Terrestrial Ecosystems and the Soil? Environmental Science & Technology 46, 6453-6454, http://dx.doi.org/10.1021/es302011r

Rocha-Santos T, Duarte AC (2015): A critical overview of the analytical approaches to the occurrence, the fate and the behavior of microplastics in the environment. TrAC Trends in Analytical Chemistry 65, 47-53, http://www.sciencedirect.com/science/article/pii/S0165993614002556

Rochman CM, Hoh E, Kurobe T, Teh SJ (2013): Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Scientific Reports 3, 3262, http://dx.doi.org/10.1038/srep03263

Rosenkranz P, Chaudhry Q, Stone V, Fernandes TF (2009): A comparison of nanoparticle and fine particle uptake by Daphnia magna. Environmental Toxicology and Chemistry 28, 2142-2149, http://dx.doi.org/10.1897/08-559.1

Rummel CD, Löder MGJ, Fricke NF, Lang T, Griebeler E-M, Janke M, Gerdts G (2015): Plastic ingestion by pelagic and demersal fish from the North Sea and Baltic Sea. Marine Pollution Bulletin 102, 134-141, http://www.sciencedirect.com/science/article/pii/S0025326X15301922

Sadri SS, Thompson RC (2014): On the quantity and composition of floating plastic debris entering and leaving the Tamar Estuary, Southwest England. Marine Pollution Bulletin 81, 55-60, http://www.sciencedirect.com/science/article/pii/S0025326X14001167

Sanchez W, Bender C, Porcher J-M (2013): Wild gudgeons (Gobio gobio) from French rivers are contaminated by microplastics: Preliminary study and first evidence. Environmental Research 128, 98-100, http://www.sciencedirect.com/science/article/pii/S0013935113001886

Schwaiger J, Diehl P, Heß M, Kreimes K, Mayer J, Rahm H, Reifenhäuser W, Koschorreck J (2016): Monitoring activities for plastics in rivers and lakes in Germany. In: Agency GE (Hrsg.), European Conference on Plastics in Freshwater Environments, Berlin, pp. 22-27

Science for Environment Policy (2011): Plastic Waste: Ecological and Human Health Impacts. In-depth Reports of the European Commission, 1-44,

Setälä O, Fleming-Lehtinen V, Lehtiniemi M (2014): Ingestion and transfer of microplastics in the planktonic food web. Environmental Pollution 185, 77-83, http://www.sciencedirect.com/science/article/pii/S0269749113005411

Setälä O, Norkko J, Lehtiniemi M (2016): Feeding type affects microplastic ingestion in a coastal invertebrate community. Marine Pollution Bulletin 102, 95-101, http://www.sciencedirect.com/science/article/pii/S0025326X15302009

Sherrington C, Darrah C, Hann S, Cole G, Corbin M (2016): Study to support the development of measures to combat a range of marine litter sources, Eunomia Research & Consulting Ltd, Bristol, United Kingdom,

Sofra C, Clarke B, Fowler G (2010): Microplastics in the Marine Environment: Investigating Possible Sources, Presence and Abundance. Poster presented at Student Research Meeting, Dept of Civil & Environmental Engineering, Imperial College London, 21 September 2010

Storck FR, Kools SAE, Rinck-Pfeiffer S (2015): Science Brief Microplastics in Fresh Water Resources. Global Water Research Coalition, 1-8,

Stöven K, Jacobs F, Schnug E (2015): Mikroplastik: Ein selbstverschuldetes Umweltproblem im Plastikzeitalter. Journal für Kulturpflanzen 67, 241-250, Sundt P, Schulze P-E, Syversen F (2014): Sources of microplastic-pollution to the marine environment

Teuten EL et al. (2009): Transport and release of chemicals from plastics to the environment and to wildlife. Philosophical Transactions of the Royal Society B: Biological Sciences 364, 2027-2045, http://rstb.royalsocietypublishing.org/content/364/1526/2027.abstract

Ugolini A, Ungherese G, Ciofini M, Lapucci A, Camaiti M (2013): Microplastic debris in sandhoppers. Estuarine, Coastal and Shelf Science 129, 19-22, http://dx.doi.org/10.1016/j.ecss.2013.05.026

Urgert W (2015): Microplastics in the rivers Meuse and Rhine - Developing guidance for a possible future monitoring program. Master's thesis Open University of the Netherlands, Heerlen

Van Cauwenberghe L, Vanreusel A, Mees J, Janssen CR (2013): Microplastic pollution in deep-sea sediments. Environmental Pollution 182, 495-499, http://dx.doi.org/10.1016/j.envpol.2013.08.013

Verschoor A, de Poorter L, Roex E, Bellert B (2014): Quick scan and Prioritization of Microplastic Sources and Emissions. RIVM Letter report 2014-0156, 48 p.,

Verschoor A (2015): Towards a definition of microplastics: Considerations for the specification of physico-chemical properties. RIVM Letter report 2015-0116, 1-42,

von Moos N, Burkhardt-Holm P, Köhler A (2012): Uptake and Effects of Microplastics on Cells and Tissue of the Blue Mussel Mytilus edulis L. after an Experimental Exposure. Environmental Science and Technology 46, 11327-11335, http://pubs.acs.org/doi/abs/10.1021/es302332w

Wagner M, Scherer C, Alvarez-Muñoz D, Brennholt N, Bourrain X, Buchinger S, Fries E, Grosbois C, Klasmeier J, Marti T, Rodriguez-Mozaz S, Urbatzka R, Vethaak AD, Winther-Nielsen M, Reifferscheid G (2014): Microplastics in freshwater ecosystems: what we know and what we need to know. Environmental Sciences Europe 26, 1-9, http://dx.doi.org/10.1186/s12302-014-0012-7

Wegner A, Besseling E, Foekema EM, Kamermans P, Koelmans AA (2012): Effects of nanopolystyrene on the feeding behavior of the blue mussel (Mytilus edulisL.). Environmental Toxicology and Chemistry 31, 2490-2497, http://doi.wiley.com/10.1002/etc.1984

Wright SL, Thompson RC, Galloway TS (2013): The physical impacts of microplastics on marine organisms: A review. Environmental Pollution 178, 483-492, http://www.sciencedirect.com/science/article/pii/S0269749113001140

Zarfl C, Matthies M (2010): Are marine plastic particles transport vectors for organic pollutants to the Arctic? Marine Pollution Bulletin 60, 1810-1814, http://dx.doi.org/10.1016/j.marpolbul.2010.05.026

Zettler ER, Mincer TJ, Amaral-Zettler LA (2013): Life in the "Plastisphere": Microbial Communities on Plastic Marine Debris. Environmental Science & Technology 47, 7137-7146, http://dx.doi.org/10.1021/es401288x

Annex 1

Questionnaire on plastics in freshwater environments

Name:

Organisation:

Country:

Contact information:

Question 1:

Are investigations performed in your country on plastics in freshwater environments?

Yes ☐ No ☐

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

Yes ☐ No ☐

If available, please add a reference/weblink or a copy of the report(s) or a short summary.

Question 3:

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

1. Landscape littering ☐
2. Waste water ☐
3. Storm water ☐
4. Industry emissions ☐
5. Tire abrasion ☐
6. other ☐ , please specify:
7. unknown ☐

If available, please add a reference/weblink or a copy of the report(s) or a short summary.

Question 4:

Are there data on riverine loads of plastics?

Qualitative data (what kinds of plastics)

Yes ☐ No ☐

Quantitative information (what amounts of plastics)

Yes ☐ No ☐

If available, please add a reference/weblink or a copy of the report(s) or a short summary.

Question 5:

Are there data on riverine inputs into the marine compartment?

Qualitative data (what kind of plastics)

Yes ☐ No ☐

Quantitative information (what amounts of plastics)

Yes ☐ No ☐

If available, please add a reference/weblink or a copy of the report(s) or a short summary.

Question 6:

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

Yes ☐ No ☐

If available, please add a reference/weblink or a copy of the report(s) or a short summary.

Question 7:

Are there studies on effects of plastics in freshwater environments?

Yes ☐ No ☐

If available, please add a reference/weblink or a copy of the report(s) or a short summary.

Question 8:

How are plastics in freshwater environment perceived in your country e.g., with regard to media reports, social networks, campaigns of non-governmental organisations?

Please estimate the public perception on a scale from low (1) to high (5):

1	2	3	4	5
☐	☐	☐	☐	☐

Question 9:

Are there discussions in your country on reduction measures for plastics in freshwater environments?

	public	media	regulation	NGO	Industry
yes	☐	☐	☐	☐	☐
no	☐	☐	☐	☐	☐

Please, add an overview or examples.

Question 10:
Are there existing or planned actions in your country to reduce input of plastics

	regulation	NGO	Industry
yes	□	☐	☐
no	□	☐	☐

… and/or to remove existing litter in freshwater environments?

	regulation	NGO	Industry
yes	□	☐	☐
no	□	☐	☐

Please, add an overview or examples.

Question 11:

What agency is in charge of plastics and …

1. **freshwater monitoring questions,**
2. **water management questions,**
3. **freshwater research activities?**

Please, provide us with contact persons for the planned conference in Berlin.

Annex 2

Participants of the European survey

Country	Name	Organisation
Austria	Karl Schwaiger	Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management
Belgium (Flemish Region)	Annelies Scholaert Gwen Dons	Openbare Vlaamse Afvalstoffenmaatschappij (OVAM) / Public Waste Agency of Flanders
Denmark	Steen Pedersen	Ministry of Environment and Food
Germany	Julia Schwaiger (Peter Diehl, Maren Heß, Kurt Kreimes, Jens Mayer, Harald Rahm, Werner Reifenhäuser)*	Bavarian Environment Agency (LfU) representatives of the Environment Agencies of the Federal States of Germany
Iceland	Jóhanna Björk Weisshappel	Environment Agency of Iceland
Ireland	Donald Grant (Richard Cronin**)	Department of Environment, Community & Local Government
Latvia	Iveta Teibe	Ministry of Environmental Protection and Regional Development
Lithuania	Dovilė Zakaraitė	Marine Research Consortium, The Environmental Protection Agency (EPA)
Luxembourg	Anne-Marie Reckinger	Water Management Agency
Netherlands	Bert Bellert	Ministry of Environment and Infrastructure - Rijkswaterstaat
Poland	Przemysław Gruszecki	National Water Management Authority
Portugal	Isabel Moura	Agência Portuguesa do Ambiente/Portuguese Environment Agency
Slovak Republic	Zdenka Kelnarová	Ministry of Environment of the Slovak Republic
United Kingdom	Steve Morris	Department for Environment, Food and Rural Affairs (Defra)

* participants of the national survey conducted in Germany which addressed all federal states (representatives listed);
** additional comments submitted,

Annex 3

Overview of European studies on plastics in freshwater environments

Country - freshwater environment	Compartment	Sampling method	Identification method	Size range	Numerical unit	Mass unit	Reference
Studies in individual countries							
Austria: Danube River	river water column	driftnets (500-, 250-, 41 µm) positioned along water column	visual sorting and inspection, ATR-IR analysis of subsamples	< 5 mm, total amount of plastic		Aschach: 0.039-0.205 mg/m^3 Hainburg: 0.029 -0.516 mg/m^3 microplastics: 7-17 t/a total plastic: 14-41 t/a	Hohenblum et al. (2015a)▲
Austria: Danube River	river biota	electro fishing (30 fish individuals), autopsy	visual inspection (stereo microscope)	< 5 mm, total amount of plastic	no evidence		Hohenblum et al. (2015a)▲
Austria: Danube River	river biota	electro fishing (840 fish individuals), autopsy	visual inspection (binocular)	> 5 mm	one particle (each) in 2 fish individuals identified		Lumesberger-Loisl and Gumpinger (2015)▲
France: Rivers Auvézère, Bedat, Bramerit, Chée, Dore, Hers-mort, Jouanne, Loire (2 sites), Risle and Yerres	river biota	electro fishing (186 wild gudgeons), autopsy	visual inspection of digestive tract content (dissecting microscope)	< 5 mm	12 % contaminated fish Fish from 7 of 11 sampled streams contained microplastics		Sanchez et al. (2013)

Country - freshwater environment	Compartment	Sampling method	Identification method	Size range	Numerical unit	Mass unit	Reference
France: Rivers Marne and Seine	river surface	floating booms	ATR -FT-IR	> 5 mm		mean: 27 t/year (2008-2013)	Gasperi et al. (2014)
France: Rivers Marne and Seine	river surface	plankton net (80 µm) manta trawl (330 µm)	visual inspection (stereo microscope)	100 µm- 5 mm	mean (plankton net): 30 p/m³ mean (manta trawl): 0.35 p/m³		Dris et al. (2015)
Germany: Rivers Elbe, Moselle, Neckar and Rhine	river sediment		visual inspection	< 5 mm	34-64 p/kg dw		Wagner et al. (2014)
Germany: Rivers Main and Rhine	rivershore sediments	bulk sampling with steel spoon (3-4 kg/sample)	visual inspection (> 630 µm: naked eye, 63-630 µm: binocular microscope), FT-IR analysis of subsamples	63-200 µm, 200-630 µm, 630 µm- 5 mm	all fractions: Main: 786–1368 p/kg dw Rhine: 228–3763 p/kg dw	all fractions: Main: 43.5–459 mg/kg dw Rhine: 21.8–932 mg/kg dw	Klein et al. (2015)
Germany: Rivers Emscher, Lippe, Rhine, Ruhr, Sieg, Weser and Wupper	river surface	mini manta trawl (300 µm)	visual inspection and sorting (stereomicroscope), ATR-FT-IR spectroscopy analysis of > 500 µm	0.5 - 1 mm,1-5 mm, > 5 mm, total number of plastic particles	total: Emscher: 15.7 p/m³, Lippe: 0.155 p/m³, Rhine: 0.928 - 4.45 p/m³, Ruhr (including WWTP effluent sampling): 0-166 p/m³, Sieg: 0 p/m³,		Laforsch (2015)▲

Country - freshwater environment	Compartment	Sampling method	Identification method	Size range	Numerical unit	Mass unit	Reference
					Weser: 0.487 p/m^3, Wupper: 0.594 p/m^3		
Italy: Lakes Bolsena and Chiusi	Lake surface	manta trawl (300 µm)	Visual inspection (UV-microscope), Scanning Electron Microscopy of subsamples (only fibers	< 0.3 mm, 0.3-0.5 mm, 0.5-1 m, 1-5 mm	Bolsena: 0.82 to 4.42 p/m^3 Chiousi: 2.68 to 3.36 p/m^3		Fischer et al. (2016)
Italy: Lakes Bolsena and Chiusi	Lake sediment	stainless steel frame (area: 0.25 m^2, depth: 3 cm), sieves (5 mm)	Visual inspection (UV-microscope), Scanning Electron Microscopy of subsamples (only fibers	< 0.3 mm, 0.3-0.5 mm, 0.5-1 m, 1-5 mm	Mean values: Bolsena: 112 p/kg dw 1922 p/m^2 57 p/1000 L Chiousi: 234 p/kg dw 2117 p/m^2 64 p/1000 L		Fischer et al. (2016)
Italy: Lake Garda	lake beach sediment	random grid sampling	Raman Micro-spectrometry, Scanning Electron Microscopy analysis of subsamples	micro-plastic: < 5 mm, macro-plastic	northern shore: microplastic: 1108 p/m^2; macroplastic: 483 p/m^2 southern shore: microplastic: 108 p/m^2 macroplastic: 8.3 p/m^2 (1 sample)		Imhof et al. (2013)
Netherlands: Rhine River Estuaries	river surface sediment	5 individual grab samples for each sample	visual inspection (light microscopy)	1-300 µm, 300-5000 µm	mean: 3300 p/kg dw (2 samples)		Leslie et al. (2013)▲

Country - freshwater environment	Compartment	Sampling method	Identification method	Size range	Numerical unit	Mass unit	Reference
Netherlands: Rivers Meuse and Rhine	river water column: suspended particular matter	flow-through centrifugation	visual inspection (light microscopy)	1-300 µm, 300-5000 µm	Meuse: 1800-6880 p/kg dw (3 sampling points), Rhine: 990 p/kg dw (1 sample)		Brandsma et al. (2015)▲
Netherlands: Lake Ijssel	river water column: suspended particular matter	flow-through centrifugation	visual inspection (light microscopy)	1-300 µm, 300-5000 µm	2000 p/kg dw (1 sample)		Brandsma et al. (2015)▲
Switzerland: Lake Geneva	lake surface	manta trawl (300 µm)	visual inspection (stereo microscope)	microplastic (< 5 mm) macroplastic (> 5 mm)	microplastic: 0.048 p/m^2 (1 sample) macroplastic: 0.008 p/m^2 (1 sample)		Faure et al. (2012)
Switzerland: Lake Geneva	lake biota	manual collection of 41 fish individuals and 1 black-necked Grebe (bird)	visual inspection (stereo microscope)	microplastic (< 5 mm), macroplastic (> 5 mm)	no evidence		Faure et al. (2012)
Switzerland: Rivers Aubonne, Rhône,Venoge and Vuachére	river surface	manta trawl (300 µm)	visual inspection (naked eye, stereo microscope), FT-IR-ATR analysis of subsamples	microplastic: 300 µm-5 mm macroplastic:	Microplastic (mean): 6.92 * 10^6 p/a, 7 p/m^3; median: 1.24 * 10^6 p/a, 0.36 p/m^3 Macroplastic (mean): 1.66 * 10^6 p/a,	microplastics: mean: 0.001 t/a, 1.4 mg/m^3 median: 0.0004 t/a, 0.2 mg/m^3	Faure et al. (2015)

Country - freshwater environment	Compartment	Sampling method	Identification method	Size range	Numerical unit	Mass unit	Reference
				> 5 mm	0.012 p/m^3	macroplastics: mean: 0.001 t/a, 0.43 mg/m^3	
Switzerland: Lakes Geneva, Constance, Neuchâtel, Maggiore, Zurich, Brienz	lake surface	manta trawl (300 µm)	visual inspection (naked eye, stereo microscope), FT-IR-ATR analysis of subsamples	micro-plastic: 300 µm-5 mm macro-plastic: > 5 mm	microplastic: mean: 0.091 p/m^2; median: 0.048 p/m^2 macroplastics: mean: 0.002 p/m^2, median: 0.001 p/m^2	microplastics: mean: 0.026 mg/m^2; median: 0.009 mg/m^2 macroplastics: mean: 0.044 mg/m^2; median: 0.012 mg/m^2	Faure et al. (2015)
Switzerland: Lakes Geneva, Constance, Neuchâtel, Maggiore, Zurich, Brienz	lake beach sediment	bulk sampling (each 4.5 L)	visual inspection (naked eye, stereo microscope), FT-IR-ATR analysis of subsamples	micro-plastic: 300 µm-5 mm macro-plastic: > 5 mm	microplastics: mean: 1300 p/m^2 median: 270 p/m^2 macroplastics: mean: 90 p/m^2 median: 11 p/m^2	microplastics: mean: 920 mg/m^2 median: 110 mg/m^2 macroplastics: mean: 14000 mg/m^2 median: 480 mg/m^2	Faure et al. (2015)
Switzerland: Lakes Geneva	Lake biota	Sampling of 40 fish individuals with multi-mesh gillnets, vertical benthic and pelagic nets manuel collection of 9 birds	visual inspection (stereo microscope)	micro-plastic: 300 µm-5 mm macro-plastic: > 5 mm	3 fish contaminated: 1 – 31 p/organism 8 birds contaminated: mean: 4.3 /organism	3 fish contaminated: 0.1 – 0.3 mg/organism 8 birds contaminated: mean: 4.8 mg/ organism	Faure et al. (2015)
United Kingdom: Thames River (C,D) and tribu-	river surface		IR-spectroscopy	micro-plastic	A: < 0.05 p/L B: < 0.05 p/L C: 9.9 p/L D: 3.3 p/L	C: 0.35 mg/L, D: 0.04 mg/L	Sofra et al.▲

Country - freshwater environment	Compartment	Sampling method	Identification method	Size range	Numerical unit	Mass unit	Reference
tary (Duke of Northumber-lands River: A, B)							
United Kingdom: Thames River	river water column: water layer near river bed	eel nets	visual inspection		8490 submerged plastic particles (7 sampling sites September-December)		Morritt et al. (2014)
United Kingdom: Tamar Estuary	river surface	manta net (300 µm)	FT-IR spectroscopy of subsamples	< 1 mm, 1-3 mm, 3-5 mm, > 5 mm,	mean: 0.028 p/m^3 204 pieces of suspected plastic found microplastics (82 %)		Sadri and Thompson (2014)
Transboundary studies							
Austria, Slovak Republic Danube River	river column	driftnets (500 µm),	visual inspection	0.5–20 mm	mean (2010): 0.938 p/m^3 mean (2012): 0.055 p/m^3	mean (2010): 11 mg/m^3 mean (2012): 2 mg/m^3 mean input into the <u>Black Sea:</u> 1,533 t/a	Lechner et al. (2014)
France, Germany, Switzerland: Rhine River	river surface	manta net (300 µm),	visual sorting (stereo microscope), FT-IR Spectroscopy	300 µm-5 mm	mean: 0.9 p/m^3 mean discharge into <u>North Sea (Rees):</u> 6.99 * 10^{10} p/a		Mani et al. (2015)
France, Switzerland: Lake Geneva	lake surface	manta trawl (300 µm)	visual inspection FT-IR	micro- and meso-plastic	<u>St Sulpice:</u> 0.048 p/m^2 <u>Petit Lac:</u>	<u>St Sulpice:</u> 0.011 mg/m^2 <u>Petit Lac:</u> 0.003 mg/m^2	Faure et al. (2013)▲

Country - freshwater environment	Compartment	Sampling method	Identification method	Size range	Numerical unit	Mass unit	Reference
					0.024 p/m^2 Vidy: > 0.083 p/m^2	Vidy: 0.293 mg /m^2	
France, Switzerland: Lake Geneva	lakeshore sediments	manual collection	visual inspection FT-IR		below high water line: 5018.75 p/m^2 above the water surface: 2656.25 p/m^2 in between: 3733.33 p/m^2	below high water line: 2.2 p-mass/m^2 above the water surface: 5.91 p-mass/m^2 in between: 0.57 p-mass/m^2	Faure et al. (2013)▲
Germany, Netherlands: Rivers Meuse and Rhine	river water column: suspended particular matter		visual inspection (light microscopy)	1-300 µm, 300 µm-5 mm	Rhine (Bimmen) mean: 1700 p/kg dw, Meuse (Eijsden) mean: 1400 p/kg dw, Rhine (Lobith) mean: 4900 p/kg dw		Brandsma et al. (2013)▲
Germany, Netherlands: Rivers Meuse and Rhine	river water column	electric centrifugal pump draws river water in cascade oil sieves (1 mm, 250 µm, 125 µm)	visual inspection and Raman-/FT-IR spectroscopy analysis	0.125-0.25 mm, 0.250-5 mm	Meuse: mean: 9.7 p/m^3 Rhine: mean: 56 p/m^3	Meuse: mean: 0.14 mg/m^3 Rhine: mean: 0.56 mg/m^3	Urgert (2015)▲
Italy, Netherlands, Romania, Sweden: Rivers Dalålven, Po and Rhine	River surface and water column	mantra net (330 µm), Waste Free Water Sampler (3.2 mm), pump-manta net method	visual inspection (naked eye, stereo microscope), NIR-/FT-IR-ATR spectroscopy analysis	333 µm-5 mm, 5-25 mm	Manta net sampling[#]: Dalålven: 5 *10^{10} p/a Rhine I: 30 *10^{10} p/a Rhine II: 10 *10^{10} p/a Po: 70 *10^{10} p/a, Danube: 200 *10^{10} p/a		Hohenblum et al. (2015b)▲

Remarks:
The numerical and mass units were unified by solely applying prefixes. Unit p: particles.
Sampling locations are underlined.
▲ Not peer-reviewed
All data resulting from use of different sampling methods reported by Hohenblum et al. (2015a) are listed in Table 4 (see chapter 5.1.)