ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

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PLASTIC AND MICROPLASTIC IN THE ENVIRONMENT

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CONTENTS

SUMMARY

The term “microplastics” generally summarizes plastic particles that are less than 5 mm in diameter. Comprehensive scientific studies show plastic pollution of the seas, but only little is known about pollution of freshwater systems, soil and air. This report is a short review of a number of studies and activities dealing with plastics and microplastics in the environment. The report summarizes a study aimed at investigating plastic and microplastic particles in the flow of the Danube River in Austria. The study developed a method which takes the vertical, horizontal and temporal variability of plastics transport in the flow of the river into account. Thus, an annual average of plastic transport could be calculated which amounts to a range of between 6 and 66 kg per day for particles smaller than 5 mm or to a range of between 7 and 161 kg for the total plastic load. The average load of total plastic was calculated as < 41 tons/year. The study shows further that it is of paramount importance to carefully select the sampling sites as well as the sampling strategy since plastic particles have the properties of suspended particles rather than floating particles. They are encountered in the entire river profile, depending on the hydrological conditions.

Around 10 per cent of the particles found in the river can be attributed to industrial activities such as production processes, conversion and transport. 90 per cent of the plastic particles in the Danube River, however, are emitted by diffuse sources, these being littering, fragmentation and transport by wind, run-off from sealed surfaces (roads, parking spaces, residential areas), inappropriate use of products, use of cosmetics, construction activities and so forth. By the same pathways, plastic and microplastic can reach soil, air and other environmental compartments and move up in the food chain.

In order to reduce plastic and microplastic pollution of the environment, several initiatives and conventions are already dealing with the issue. Building on dialogue which was established between stakeholders from relevant institutions and organisations, the network of the European Environment Agencies (EPA Network) is supposed to keep up the momentum and bring forward crucial aspects:

- Uniform definition of “microplastics” including distinction into logical sub-categories
- Need for harmonized methods for sampling, pre-treatment and measurement in different environmental compartments
- Sustaining the momentum of action and dialogue between the stakeholders in the EU

1 GENERAL INTRODUCTION

Plastics have been serving societal development over the last 60 years due to their excellent material properties. In this period of time, production of plastic has increased from initially 1.7 million tons in 1959 to more than 280 million tons annually nowadays (PLASTICSEUROPE 2014). This number represents roughly 40 kg of plastics produced annually for each of the approx. 7 billion humans on Earth.

Some fractions of postconsumer waste, however, escape the controlled waste streams and find their way into the environment. Due to the material's stability plastic barely decomposes and thus remains for a long time in the environment. Exposure to sunlight, wind and the chemical environment alters the material and slowly forms debris the size of a few micrometers which easily can be dispersed in the environment.

Plastic waste in the environment was recognized as a problem mainly in marine regions. First reports about plastic garbage patches in the Atlantic and Pacific Oceans emerged already in the late 1970s. Due to its floating behaviour it is known to have a negative impact on marine organisms in almost all parts of the trophic layers depending on the particle size. Also transfer of plastic particles along the food chain has been observed (MOORE et al. 2004).

More than 80 per cent of marine plastics is attributed to land-based sources with rivers as the main contributors. Studies, however, in fresh water systems are rare and due to the use of different methods for sampling and measurement, results are mostly not comparable.

The present report summarizes investigations on (micro) plastics in the Austrian environment and describes efforts to establish a multi-spot sampling method to survey the plastic load in the Danube River. The report quantifies the plastic transport and annual load of the Danube River in Austria and shows relevant emission sources. The river crosses nine borders and the Danube river basin extends into the territories of 19 countries. It is considered the most international river basin in the world (ICPDR 2015). This demonstrates that only international cooperation can cope with the problem of plastic contamination. The report also emphasises the need for dialogue among all stakeholders and the coordination of European activities in order to optimize national approaches and to avoid duplication of work.

1.1 Plastic and microplastic, definition of subject

There is no legally binding or internationally standardized definition of the size and composition of microplastic. Generally, particles larger than 5 mm are referred to as macroplastics, whereas those smaller than 5 mm are described as "microplastic". Recently, an additional distinction into "small" and "large" microplastic particles has been mentioned frequently in the literature, and refers to a size range of 5 mm–1 mm for large microplastic particles and 1 mm – 1 µm for small microplastic particles.

Microplastics encountered in the environment can be of primary or secondary origin. Primary particles designate purposefully manufactured granules for further conversion processes as well as fine powders for technical applications or for addition to cosmetics (e.g. for a delicate, silky texture; improved product stability or enhanced cleansing effect). Secondary particles are derived from the breakdown of macro plastic items, mostly littered in the environment. The most commonly produced polymers are polyethylene (PE), polypropylene (PE) and polyvinyl chloride (PVC). Hence, they are also most commonly encountered in the environment. Elastomers like synthetic rubber (tyre abrasion) have also a big share in the plastics which are emitted into the environment, but there is no explicit definition which includes these materials as microplastics.

Rubber is a natural resource. However, there are also different types of synthetic rubber materials and co-polymers found in tyres. There are only few possibilities for emission reduction and, due to the type of emission as ultra-fine particles, pollution has already generated a degree of public attention in terms of air quality. These risks, however, are not closely associated with microplastics (VERSCHOOR et al. 2014).

1.2 Environmental impact

There is plenty of evidence that macroscopic plastic affects a high number of organisms, especially in the marine environment. Plastic particles are often mistaken for food by birds and turtles (MALLORY 2008, CADEE 2002, MASCARENHAS 2004, BUGONI 2001). At least 44% of marine bird species are known to ingest plastics and some species feed plastic particles to their chicks (RIOS & MOORE 2007). Entanglement of marine mammals and other species leads to reduced moving ability (LAIST 1997). Swallowed particles can lead to injuries or lead to starvation as a result of the absence of nutritional value in the plastic items.

Entanglement of marine mammals, birds and other species in abandoned fishing gear and plastic waste items has been reported (MOORE 2008, DERRAIK 2002, PEMBERTON et al. 1992, SAZIMA et al. 2002, GREGORY 2009, AZZARELLO & VAN FLEET 1987, BLIGHT & BURGER 1997, BARREIROS & BARCELOS 2001, BAIRD 2000, MOORE et al. 2001). EK 2011 lists a high number of marine species prone to ingesting or entanglement in plastic items. In order to avoid entanglement, industry changed the polymer composition of some plastics in order to speed up disintegration in the environment. This, however, leads to a quicker formation of secondary particles.

The small size of microplastic particles makes them prone to bioavailability to lower trophic organisms. Many of them exert limited selectivity between particles and capture anything of appropriate size (WRIGHT et al. 2013). Higher trophic organisms feeding on plankton cannot distinguish between plankton and artificial particles in the same size range and passively ingest microplastics. One of the largest filter feeding animals, the finback whale, engulfs up to 70 cubic metres of water in one gulp and harvests its prey through its baleen (FOSSI et al. 2012). Ingestion of microplastic is observed in several other marine species such as algae, benthic scavengers, micro- and meso-zooplankton, mussels and fish. Incorporation of microplastic (3–10 µm) in mussels' tissue was observed and inflammatory effects were described after uptake of plastic particles in the digestive system. The shape of the particles showed different physiological effects. Sharp edges rather than soft shapes caused inflammations. However, no such inflammation reactions have been reported in humans yet.

The primary entrance paths of particles into the human body are both the respiratory and digestive system. The uptake of microplastics larger than 1 µm through the epidermis is unlikely (BFR 2014).

The particle size most likely to remain within the human body and to cause adverse effects is assumed to be smaller than 10 µm. For instance, small sized tyre wear particles (particulate matter PM_{10} and $PM_{2.5}$) can penetrate deep into the lungs. In inhalation studies, fine particulate matter shows a correlation with allergies, asthma, cancer, and coronary diseases (LESLIE 2014). If particles larger than 5 µm are swallowed (e.g. in foods), they most probably leave the human body by passing through the gut (HOLLMAN et al. 2013).

Besides the harmful effects caused by the physical and morphological properties of microplastics, chemical compounds can contribute to the environmental impact of microplastics. Firstly, classical organic pollutants with known toxicological profiles can leach from (micro-)plastics into the environment. Examples are phthalates, typical additives to PVC, or bisphenol A, a monomer residue in polycarbonate (PC). Other chemicals such as persistent organic pollutants (POP) are already present in the environment, and show high affinity for the surface of microplastics. There is evidence that aged microplastic particles with a rougher surface accumulate more metals (HOLMES et al. 2014).

The dynamics of pollutants leaching from microplastics into the environment versus pollutants from the environment adsorbing onto microplastics are not yet fully understood. First attempts to model these chemical dynamics have been reported for sea water (WAGNER et al. 2014).

1.3 Marine issue

Major concern about plastic as an environmental contaminant emerged in the late 1970s when studies showed that oceans are a sink for plastic waste. Since then, many studies have revealed the size of the problem and reports about the oceans' garbage patches are popular. It is estimated that 80 per cent of the plastic material in the oceans is emitted from land-based sources. Rivers are reported to be main contributors, but robust data are lacking. Approximately 20 per cent is lost or abandoned fishing gear and waste from navigation. The patches consist of plastic material of all sizes down to microscopic fragments. In some areas the plastic concentration in the oceans is up to seven times higher than that of zooplankton.

1.4 Plastic in rivers

Rivers are seen as main contributors of plastic and microplastic to the oceans. Studies in freshwaters, on the other side, are rare and robust methods to measure plastic and microplastic in a river profile are lacking. MOORE et al. (2004)

described the plastic and microplastic load for two small rivers in the metropolitan area of Los Angeles. The study points out that run-off from large metropolitan areas has a big share of the plastic load, especially after rain falls. Further investigations were carried out in the estuary of the Yangtse river in China, the River Thames in the UK, the river Rhine and the Danube river (ZHAO et al. 2014, MORRITT et al. 2014, LECHNER & KECKEIS 2014).

Other freshwater studies investigated lakes such as the Laurentian Great Lakes (ERIKSEN et al. 2013, FROKLAGE et al. 2013, ZBYSZEWSKI & CORCORAN 2011), Lake Garda in Italy (LAFORSCH et al. 2013), Lake Geneva (FAURE et al. 2013) or remote Lake Hovsgol in Mongolia (FREE et al. 2014). All these studies show that an increase of plastic and microplastic in the marine regions is well documented, whereas studies in freshwater systems are rare. Settlement areas do influence the load of plastics in the water bodies. Plastics appear in the form of micro beads, fragments and industrial particles (pellets).

2 MATERIALS AND METHODS

2.1 Sampling the Danube River

In order to determine the plastic transport in the river profile, a method was specifically developed to investigate the spatial and temporal variability by multi point sampling. Only with this information can a reliable calculation of the plastic transport and the annual load in the river be carried out.

The Institute of Water Management, Hydrology and Hydraulic Engineering (IWHW) at the University of Natural Resources and Life Sciences (Vienna) adapted two existing techniques used for determining suspended sediment and bed load transport for the new methodology. In order to examine the spatial distribution of plastics over the river section, 5–10 verticals were sampled. To determine the temporal variability, measurements were carried out at five different discharge conditions. Sampling sites were chosen close to the river's entrance to Austria and at the exit to Slovakia at road bridges which were essential for setting up the equipment needed.

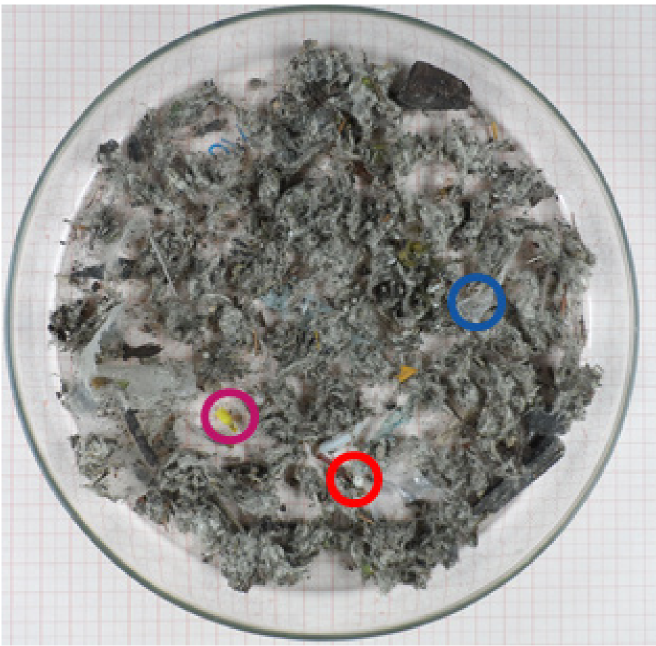
Drift nets with a mesh size of 500 µm and 250 µm were used for sampling. They were exposed at the different verticals at three depths: close to the river bed, in the middle of the water column and at the river's surface.

Despite considerable experience from marine research, differences in the sample matrices, for example waste water or soil, pose challenges not only to sampling but also to adequate sample treatment. The methodology for isolating, identifying, and quantifying microplastics in environmental samples is not yet standardised.

The mesh size of sieves and filters used during both sampling and sample processing influences the size fractions available for analysis. Since a larger amount of (in-)organic matter present in the sample can cover up plastic particles (Figure 1), sample pre-treatment such as density separation, chemical dissolution or enzymatic digestion is helpful, if not indispensable

Figure 1: Dried material sampled from the river Danube, mainly of biological origin; some plastic fragments are already visible by the naked eye.

Dried plastic fragments from the Danube River



Source: Umweltbundesamt/Köppl, Knieschek

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2.2 Measurement of plastics > 500 µm

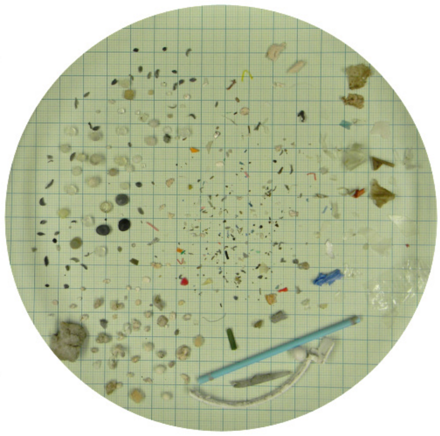
Plastic fragments larger than 500 µm can be sorted by hand, and categorized according to their shape by the naked eye, e.g. industrial granules, flakes, foam, foils or fibres. The identification of a plastic material based on properties such as colour, stability and texture is possible, but often misleading.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

Units commonly used for abundance estimates of microplastics in liquid samples are grams per volume and items per volume, with volume given in m³ or litres. For solid samples the grams or items of microplastic are related to the sample mass.

For quantification by weight, plastic particles larger than 500 µm are preferably sorted into shape categories, and then measured on a precise analytical balance (micro balance).

If the number of particles is of interest, static image analysis is applied to count particles (partly) automatically. Due to the vast range of electrostatic and optical properties of microplastics, automated particle counters with dynamic image analysis are not easily applicable.

Plastic particles from the Danube River



Source: Umweltbundesamt

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Figure 2:
Plastic particles from the river Danube (sampling net size 500 µm), sorted and roughly categorized. Particles are counted with static image software, and weighed in categories.

2.3 Measurement of plastics < 500 µm

The state of the art method for microplastic analysis is FT-IR micro-spectroscopy; a method that is also implemented in the Environment Agency Austria laboratory.

The well-established technique of infrared spectroscopy perfectly combines features of microscopy with imaging, and allows reliable detection and identification of microplastics from approximately 25 µm to 500 µm.

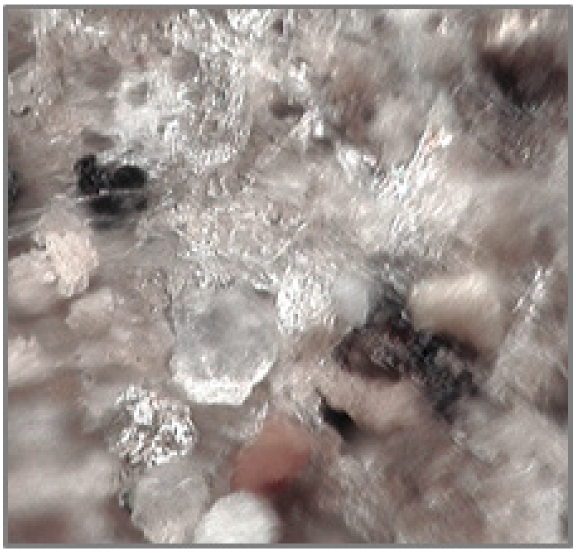
For the measurement of plastics smaller than 500 µm it is even more important to remove as much interfering non-plastic matter as possible by physical and chemical methods. Usually, only a small portion of the original sample can be measured in one analytical run. Thus, the sampling of a representative aliquot from the bulk sample requires much thought and care.

The measurement area is covered with particles, and then scanned automatically by FTIR imaging with a typical pixel size of 6 µm. Therefore, the chemical information for each 6 µm square is collected for the entire sample surface. Typically, the sample surface areas are 0.16 mm² with in-contact measurements (ATR-FTIR), i.e., 0.4 mm x 0.4 mm (cf. Figure 3), and 6.25 cm² with non-contact measurements (FTIR transmission/reflection), i.e., 2.5 cm x 2.5 cm (cf. Figure 4). The acquisition time ranges from a few minutes for the smallest measurement area to about 5 hours for the larger ones. Data analysis aims at comparing the measured data with a polymer database, and highlighting regions that are most similar to various plastic materials (polyethylene, polypropylene etc.). An example of the graphical presentation of results is given in Figure 5. The colour indicates the extent of similarity (correlation) to polyethylene. Eventually, the microplastic particles can be reliably differentiated from biological material.

For the quantification of plastics smaller than 500 µm, the positive plastic hits can be counted on the graphical plot. Whenever a subsample is analysed, the number of plastic items has to be related to the original sample amount.

Figure 3: Visual image of the sample area (400 x 400 µm) covered with micro particles.

Sample area covered with micro particles



Source: Umweltbundesamt/Schaden

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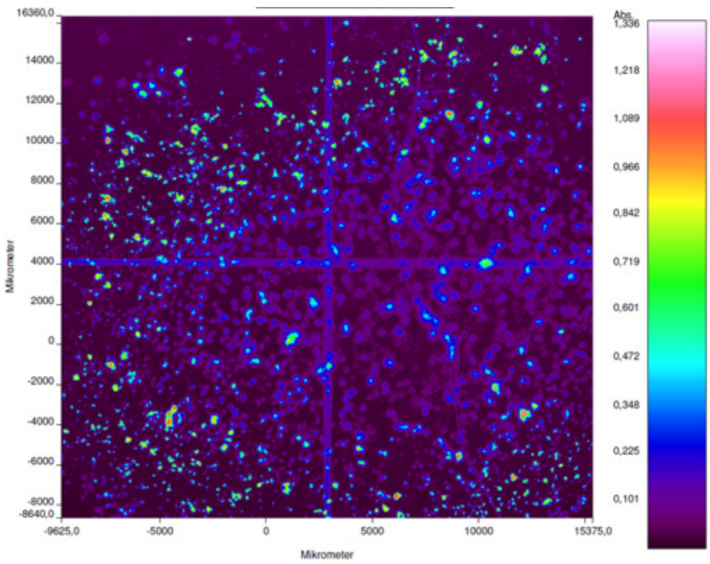
Figure 4: Chemical“ image after FTIR transmission measurement: Colours indicate the absorption of infrared radiation. A filter area sized 2.5 x 2.5 cm is covered with sediment particles and precisely positioned microplastics.

“Chemical“ image after FTIR transmission measurement



Source: Umweltbundesamt/Schaden

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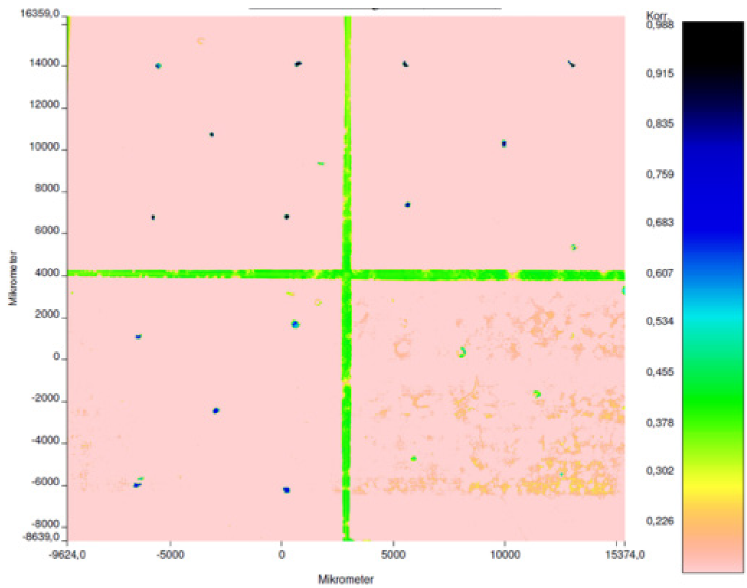
Particles with a high similarity to polyethylene



Source: Umweltbundesamt/Schaden umweltbundesamt

Figure 5: Graphical result presentation of particles having high similarity to polyethylene (PE) plastics. Five deliberately positioned particles are visible in almost all of the four quadrants.

3 RESULTS

3.1 Danube River Survey

3.1.1 Spatial and temporal distribution

At each of the two sampling sites (Aschach and Hainburg), the Danube measurements were performed at five different discharge stages. For every sampling point, the plastic transport ($mg/m^2.h$) and concentration ($mg/1,000.m^3$) was determined for both microplastic (< 5 mm) and total amount of plastic. Hence, values are available for 15 to 21 sampling points within a profile.

The distribution of plastic and microplastic depends on the morphological situation at the sampling sites. Aschach, being situated in the backwater of a hydropower plant, has a pronounced stratification of plastic particles over the water column. Most of the particles have a lower density than water and tend to float on the river's surface. There is also a higher transport rate and concentration at the right river bank than in the middle and on the left section. Hainburg, in contrast, is situated at a free flowing section of the river with a higher flow velocity and higher turbulences. Particularly at higher discharges, no explicit stratification of plastic particles could be observed.

As a consequence of the strong variability of plastic particles in the river profile, the location of sampling and the application of a multi-point method are of vital importance for a sound assessment of plastic transport in a river.

At both sampling sites, sampling took place at different discharges of the Danube River. Discharge, weighted average concentration and transport rates are depicted in Table 1. After fitting a curve to the generated transport values at different discharge values, the yield can be calculated for different time lengths. It could be shown that both plastic transport and concentration increase with the river's discharge. However, the measurements were carried out only during autumn and winter months and thus, potential seasonal effects are not taken into account.

Table 1: weighted average concentration and transport rate of microplastic and total plastic for Hainburg and Aschach at different discharges

Sampling site	Dis-charge (m^3/s)	Weighted average concentration ($g/1.000m^3$)	Transport			
			Microplastic		Total plastic	
			(g/s)	(kg/d)	(g/s)	(kg/d)
Hainburg	1,276	0.029	0.037	3.2	0.127	11.0
Hainburg	1,993	0.085	0.170	14.7	0.464	40.1
Hainburg	3,179	0.188	0.598	51.7	2.283	197.2
Hainburg	3,392	0.428	1.452	125.5	2.583	223.2
Hainburg	5,704	0.516	2.941	254.1	7.504	648.4
Aschach	765	0.057	0.043	3.7	0.077	6.6
Aschach	765	0.048	0.037	3.2	0.182	15.7
Aschach	1,020	0.039	0.039	3.4	0.067	5.8
Aschach	1,551	0.053	0.083	7.1	0.175	15.1
Aschach	2,575	0.205	0.527	45.5	1.133	97.9

3.1.2 Average transport and annual load

By means of mathematical analysis of the relationship between plastic transport and discharge, an average yield was calculated for an average discharge range. For Aschach, the margins were set at 1,100 and 2,100 m^3/s and for Hainburg at 1,500 and 3,000 m^3/s. These margins were calculated on the basis of average annual discharges of the Danube River at these sites.

For microplastic, the average transport at Aschach amounts to a range of between 6 and 40 kg per day, and at Hainburg to between 6 and 66 kg per day. For the total plastic transport, the average at Aschach amounts to 10 to 59 kg per day and at Hainburg to 7 to 161 kg per day.

The annual load was calculated using the average annual hydrographs of the years 2009 until 2014 for both sites. The annual load for microplastic amounts to < 7 tons/year at Aschach and < 17 tons/year at Hainburg. The total plastic load amounts to < 14 t/a at Aschach and < 41 t/a at Hainburg. As only few measurement points are available so far, these values can be seen as a first estimation.

3.1.3 Origin of plastics

Plastic particles in the Danube River were characterized and the material identified by means of infrared spectroscopy. The particles were classified in five categories: fragments, foil, fibre, foam and pellet.

Pellets are the only particles which can be directly associated with industrial activity. They can enter the environment during production or plastic conversion processes or get lost on the transport route as loss or when cleaning the transport vessel. Approx. 4% of the particle mass at Aschach and approx. 10% at Hainburg was identified as pellets. On the other hand, 90 to 96 per cent of the plastic particles in the Danube River can be allocated to diffuse sources, these being littering, fragmentation and transport by wind, run-off from sealed surfaces (roads, parking spaces, residential areas), inappropriate use of products, construction activities and so forth.

3.2 Environmental compartments

From water to soil

In Europe, the run-off from sealed surfaces, domestic sewage, and industrial waste water is mostly treated in waste water treatment plants (WWTP), where larger plastic fragments are mechanically removed. Apart from plastic litter and industrial residues, these fragments stem from inappropriately disposed plastic items flushed down the toilet (e.g. foils) or textile fibres from washing machines. Microplastics added to shower gels and peelings also end up in the sewage; the European consumption of microplastics in this particular cosmetic application is estimated at 4,360 tons/year (2012, GOUIN et al. 2015).

A few studies have investigated microplastics in different inlet and outlet flows of WWTP. Unfortunately, the sampling methods, sample volumes and microplastic identification are hardly comparable. Thus, the results obtained show large variation, but still give a general idea of the retention behaviour of microplastics (BRANDSMA et al. 2013, DRIS et al. 2015, LESLIE et al. 2013, MAGNUSSON & NOREN 2014, MINTENIG et al. 2014, ZUBRIS & RICHARDS 2005).

Numbers reported for one litre of waste water in the inlet stream range from 15 “particles” to 320 “fibres”. In one litre of clean WWTP run-off the numbers are lower, from less than one particle to nearly 100 particles. This reduction in particles indicates their accumulation in the sewage sludge. Values reported for sewage sludge range from 1,000 to more than 20,000 particles per kilogram dry mass. If the sludge is applied onto farm land for fertilising purposes, these microplastics are spread further into the environment. Microplastics have already been detected in soil after sewage sludge application (ZUBRIS & RICHARDS 2005).

From soil to groundwater

Once microplastics have found their way into soil, they might potentially penetrate from the soil through to the ground water. In fact, soil and sediments build a natural barrier to particles. The effectiveness of the barrier effect is influenced by the particle properties (e.g., size, shape, surface charge, density) as well as by the soil properties such as pore size, preferential flow paths, and organic content. Typical pore sizes in silt and sand range from approx. 400 nm to 400 µm; pore sizes above 400 µm are found in coarse sand. Given the prevalent pore sizes in soil, the search for microplastics in ground water has to focus on the lower micron range. The detection of microplastics in ground water has not yet been reported.

Air

Plastic particles can be dispersed in air as a consequence of processing plastic material, e.g. on construction sites, or by special applications of microplastics such as sand blasting. Thus far, it has not been investigated whether the processes of abrasion, erosion, and fragmentation of plastics in the environment, driven by wind and water, significantly contribute to airborne microplastics. The air pollution by particulate matter of any kind is, most commonly, measured as PM_{10} or $PM_{2.5}$. However, the differentiation of plastic content is not part of routine analysis.

Micro-sized particles from tyre wear were found in air (CHEMRISK LLC 2011) as well as in roadside surface soil samples (UNICE et al. 2013, EMEP & EEA 2013). The total tyre wear for Germany is estimated at 111,420 tons/year, with a plastic content of approx. 39% (KOCHER 2010), which equals 43,454 tons/year.

The Environment Agency Austria recently calculated a total tyre wear of 6,766 tons/year, based on Austrian road traffic. A share of 1,128 tons/year appears as suspended solids, and 677 tons/year are fine particulate matter with the ability to penetrate deep into the respiratory system.

4 LESSONS LEARNT

4.1 International collaboration

In order to take effective measures to reduce plastic and microplastic pollution in the environment, several pre-requisites are needed:

- Robust and comparable environmental data which describe the state of the environment in terms of plastic and microplastic pollution in different environmental compartments (**research needed**)
  - A uniform **definition** of “microplastics” including a sub-categorization of size ranges
  - Need for harmonized methods for **sampling and pre-treatment** of samples for different size ranges of the category “microplastics”
  - Need for harmonized and validated **measurement methods** for different environmental matrices
- **Assessment tools** to evaluate the effects of plastic and microplastic particles in organisms.
- Plastic pollution does not stop at political borders and thus, **international collaboration** to tackle the problem is needed. This includes co-ordination of national and international activities to take advantage of existing knowledge and to avoid duplication of work. The **EPA Network**[1] can play an important role in this context.
- A consistent **dialogue between all involved stakeholders** in order to support mutual understanding of positions and activities. The conference “Eliminating plastic and microplastic pollution – an urgent need”[2] was a first step to bring together stakeholders from policy-making organisations, governmental organisations, industry, science, and NGOs to form a joint understanding and build momentum.

4.2 Further recommendations

- Freshwater systems are major contributors of plastics to the marine systems. Thus, special focus should be laid on investigations in surface waters. Only an overview about the situation in Europe can enable an assessment of relevant measures to tackle the problem.
- Systems which drain sealed areas directly into surface waters have high relevance in terms of input of plastics and microplastics. Data are rare and surveys are needed.

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[1] The EPA Network is an informal grouping bringing together the heads and directors of environment protection agencies and similar bodies across Europe. The Network exchanges views and experiences on issues of common interest to organisations involved in the practical day-to-day implementation of environmental policy.

[2] held in Brussels on 11 and 12 May, 2015 (http://epanet.pbe.eea.europa.eu/ad-hoc-meetings/workshop-plastics-environment-11-12-may-2015)

- Awareness raising campaigns in areas with a significant input of plastics and microplastics targeted at the general population as well as at staff in production and retail. Awareness should be raised for avoiding littering (purposeful shopping, proper disposal) as well as for extending lifetime (by repair etc.).
- Support of anti-littering campaigns
- Implementation of industrial conventions like “Zero Pellet Loss” to prevent plastic waste from getting into the environment.
- Preference to take measures at source, not at the end of the pipe
- On the European scale, marine littering and microplastics in surface waters and in the environment should be reflected in the next State of the Environment Report SOER, to be issued by the European Environment Agency EEA in 2020.

5 OUTLOOK

On the European scale, plastic and microplastic pollution has already been identified as an urgent matter and several initiatives and activities deal with this topic. There are a number of international conventions concerned with the topic (OSPAR, HELCOM, UNEP, Barcelona Convention, Bucharest Convention, EU MSFD etc.), which are mostly related to a specific marine region.

At the stakeholder conference "Eliminating plastic and microplastic pollution – an urgent need", which took place in Brussels on 11th and 12th of May 2015, a number of suggestions for improving the knowledge base and addressing further action areas were elaborated.

In order to keep the momentum of the conference alive, the participants concluded that the network of the European Environment Agencies (EPA Network) was an appropriate organisational structure to bring forward and to coordinate activities in the EU member states in this field. A number of Environmental Agencies already indicated interest to support the network's activities. This approach was also acknowledged by industry, the European Commission and further stakeholders. Close contacts to existing conventions like OSPAR, HELCOM, UNEP and to other activities and stakeholders is needed and should be maintained by any follow-up activity. The Environment Agency Austria was asked to continue the initiative for plastics and microplastics with the support of other EPA Network members and stakeholders.

The designated role of the EPA Network is to establish an interest group which steers the activities of a working group of experts nominated by the contributing EPA Network member states. Work will be carried out in the form of a project and funds will have to be raised to finance the activities. The establishment of the interest group is subject to discussion with the EPA at the plenary meeting which takes place in Reykjavik, Iceland, in September 2015. Main items will be to work on a uniform definition of the composition and size ranges of microplastics, harmonization of sampling, pre-treatment and measurement methods for plastics and microplastics in limnic water systems and the continuation of the dialogue with stakeholders.

Representatives of the interest group will inform Commissioner Karmenu Vella and his cabinet personally later in 2015 about the outcome of the conference and about follow-up activities undertaken by the EPA Network. Commissioner Vella gave a keynote speech at the plastics and microplastics conference in Brussels in May 2015.

6 REFERENCES

AZZARELLO, M.Y. & VAN VLEET, E.S. (1987): Marine birds and plastic pollution. Mar. Ecol. Prog. Ser. 1987, 37: 295–303.

BAIRD, R.W. & HOOKER, S.K. (2000): Ingestion of plastic and unusual prey by a juvenile harbour porpoise. Mar. Pollut. Bull. 2000, 40: 719–720.

BARREIROS, J.P. & BARCELOS, J. (2001): Plastic ingestion by a leatherback turtle Dermochelys coriacea from the Azores (NE Atlantic). Mar. Pollut. Bull. 2001, 42: 1196–1197.

BFR – Bundesinstitut für Risikobewertung (2014): Polyethylenhaltige Polyethylene-containing microplastic particles:health risk resulting from the use of skin cleansing and dental care products is unlikely. BfR opinion No.. 032/2014, 3 January 2014. http://www.bfr.bund.de/cm/349/polyethylene-containing-microplastic-particles.pdf

BLIGHT, L.K. & BURGER, A.E. (1997): Occurrence of plastic particles in sea-birds from the eastern north pacific. Mar. Pollut. Bull. 1997, 34: 323–325.

BRANDSMA, S. H.; NIJSSEN, P.; VAN VELZEN, M.J.M. & LESLIE, H.A. (2013): Microplastics in river suspended particulate matter and sewage treatment plants. Report R14/02, version 1. IVM Institute for Environmental Studies. Amsterdam.

BUGONI, L.; KRAUSE, L. (2001): Marine debris and human impacts on sea trutles in southern Brazil. Mar. Pollut. Bull. 42 (12), 1330–1334.

CADEE, G.C. (2002): Seabirds and floating plastic debris. Mar. Poll. Bull. 44(11), 1294–1295.

CHEMRISK LLC (2011): Tire and road wear particles (TRWP) global sampling project. Summary report. Pittsburgh. S. 1–45.

DERRAIK, J.G.B. (2002): The pollution of the marine environment by plastic debris: A review. Mar. Pollut. Bull. 44: 842–852.

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. (accepted).

ERIKSEN, M.; MASON, S.; WILSON, S.; BOX, C.; ZELLERS, A.; EDWARDS, W.; FARLEY, H. & AMATO, S. (2013): Microplastic pollution in the surface waters of the Laurentian Great Lakes. Marine Pollution Buletin 77 (2013): 177–182.

EMEP – European Monitoring and Evaluation Programme & EEA – European Environment Agency (2013): EMEP/EEA air pollutant emission inventory guidebook, Part B: Sectoral guidance chapters, 1.A.3.b.i-iv Exhaust emissions from road transport.

FAURE, F.; CORBAZ, M.; BAECHER, H.; NEUHAUS, V. & DE ALENCASTRO, L. (2013): Pollution due to Plastic and microplastics in Lake Geneva. Koblenz, Germany. In: 6th International Conference on Water Resources and Environmental Research.

FOSSI, M.; PANTI, C.; COPPOLA, D.; GIANNETTI, M.; MARSILI, L. & MINUTOLI, R. (2012): Are baleen whales exposed to the threat of Microplastics? A case study of the Mediterranian fin whale. Marine Pollution Bulletin 64 (11): 2374–2379.

FREE, C.; JENSEN, O.; MASON, S.; ERIKSEN, M.; WILLIAMSON, N. & BOLDGIV, B. (2014): High-levels of microplastic pollution in large, remote mountain lake. Article in Press, Marine Pollution Bulletin.

FROKLAGE, R.; LANT, C.; MISBAH, A.; O'LEARY, E. & PAYTON, E. (2013): Assessing and Mitigating Plastic Pollution in Lake Huron. Hydra Horizons Consulting.

GOUIN, T.; AVALOS, J.; BRUNNING, I.; BRZUSKA, K.; DE GRAAF, J.; KAUMANNS, J.; KONING, T.; MEYBERG, M.; RETTINGER, K.; SCHLATTER, H.; THOMAS, J.; VAN WELIE, R. & WOLF, T. (2015): Use of micro-plastic beads in cosmetic products in Europe and their estimated emissions to the North Sea environment. SOFW Journal 141: 40–46.

GREGORY, M. (2009): Environmental implications of plastic debris in marine settings – Entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Philos. Trans. R. Soc. B 2009, 364: 2013–2025.

HOLLMAN, P.C.H.; BOUWMEESTER, H. & PETERS, R.J.B. (2013): Microplastics in aquatic food chain: sources, measurement, occurrence and potential health risks. Research report, Wageningen RIKILT – Institute of Food Safety.

HOLMES, L.A.; TURNER, A. & THOMPSON, R.C. (2014): Interactions between trace metals and plastic production pellets under estuarine conditions. Marine Chemistry 167: 25–32.

ICPDR – Internattional Commission for the Protection of the Danube River (2015): https://www.icpdr.org/main/danube-basin

KOCHER, B. (2010): Stoffeinträge in den Straßenseitenraum – Reifenabrieb. Berichte der Bundesanstalt für Straßenwesen (BASt), Reihe V: Verkehrstechnik, Band 188.

LAFORSCH, C.; IMHOF, H.K.; IVLEVA, N.P.; SCHMID, J. & NIESSNER, R. (2013): Contamination beach sediments of a subalpine lake with microplastic particles. Curr Biol 2013, 23 (19): 867–868.

LAIST, D.W. (1997): Impact of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglemens and ingestion records. In: COE, J.M., Rogers, D.B. (Eds.), Marine Debris . sources, Imapcts and solutions. Springer Verlag New York Inc., New York, pp 99–139.

LECHNER, A. & KECKEIS, H. (2014): The Danube so colorful: A potpourri of plastic litter outnumbers fish larvae in Europe's second largest river. Environmental Pollution 188 (2014): 177–181.

LESLIE, H.A. (2014): Review of microplastics in cosmetics. Scientific background on a potential source of plastic particulate marine litter to support decision-making. Report R14/29. IVM Institute for Environmental Studies. Amsterdam.

LESLIE, H.A.; VAN VELZEN, M.J.M. et. al. (2013): Microplastic Survey of the Dutch Environment. Novel Data Set of Microplastics in North Sea Sediments, Treated Wastewater Effluents and Marine Biota. Amsterdam: Institute for Environmental Studies, VU University.

MAGNUSSON, K. & NORÉN, F. (2014): Screening of microplastic particles in and down-stream a wastewater treatment plant. Report. IVL Swedish Environmental Research Institute. Stockholm.

MALLORY, M.L. (2008): Marine plastic debris in norther fulmars from Canadian high Arctic. Mar. Poll. Bull. 56, 1501–1504.

MASCARENHAS, R.; SANTOS, R.; ZEPPELINI, D. (2004): Plastic debris ingestion by sea turtle in Paraiba, Brazil. Mar. Poll. Bull. 49 (4), 354–355.

MINTENIG, S.; INT-VEEN, I.; LÖDER, M. & GERDTS, G. (2014): Abschlussbericht. Mikroplastik in ausgewählten Kläranlagen des Oldenburgisch-Ostfriesischen Wasserverbandes (OOWV) in Niedersachsen. Alfred- Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung (AWI), Biologische Anstalt Helgoland. Helgoland. 41 S.

MOORE, C.J. (2008): Synthetic Polymers in the Marine Environment: A rapidly increasing, long-term threat. Environmental Research 108 (2008): 131–139.

MOORE, C.J.; MOORE, S.L.; LEECASTER, M.K. & WEISBERG, S.B. (2001): A comparison of plastic and plankton in the north Pacific central gyre. Mar. Pollut. Bull. 2001, 42: 1297–1300.

MOORE, C.J.; LATTIN, G.L. & ZELLERS, A.F. (2004): Density of Plastic Particles found in zooplankton trawls form Coastal Waters of California to the North Pacific Central Gyre. Algalita Marine Research Foundation, 148N. Marina Drive, Long Beach, CA 90803, USA.

MORRITT, D.; STEFANOUDIS, D.; PEARCE, D.; CRIMMEN, O. & CLARK, P. (2014): Plastic in the Thames: A river runs through it. Marine Pollution Bulletin 78: 1–2, 196–200.

PEMBERTON, D.; BROTHERS, N.P. & KIRKWOOD, R. (1992): Entanglement of Australian fur seals in man-made debris in Tasmanian waters. Wildl. Res. 19: 151–159.

PLASTICSEUROPE (2014): Mobilität. http://www.plasticseurope.de/anwendungsgebiete/mobilitat.aspx

RIOS, L.M.; MOORE, C.; JONES, P.R. (2007): Persistant organic pollutants carried by synthetic polymers in the ocean environment. Marine Pollution Bulltein 54, 1230–1237.

SAZIMA, I.; GADIG, O.B.F.; NAMORA, R.C. & MOTTA, F.S. (2002): Plastic debris collars on juvenile carcharhinid sharks (Rhizoprionodon lalandii) in southwest Atlantic. Mar. Pollut. Bull. 2002, 44: 1147–1149.

UNICE, K.M.; KREIDER, M.L. & PANKO, J.M. (2013): Comparison of tire and road wear particle concentrations in sediment for watersheds in France, Japan, and the United States by quantitative pyrolysis GC/MS analysis. Environmental Science & Technology 47(15): 8138–8147.

VERSCHOOR A. et al. (2014): Quick scan and Prioritization of Microplastic Sources and Emissions RIVM Letter report 2014-0156.

WAGNER, M.; SCHERER, C.; ALVAREZ-MUNOZ, D.; BRENNHOLT, N.; BOURRAIN, X.; BUCHINGER, S.; FRIES, E.; GROSBOIS, C.; KLASMEIER, J.; MARTI, T.; RODRIGUEZ-MOZAZ, S.; URBATZKA, R.; VETHAAK, A. D.; WINTHER-NIELSEN, M. & REIFFERSCHEID, G. (2014): Microplastics in freshwater ecosystems: what we know and what we need to know. Environmental Sciences Europe 26: 12.

WRIGHT, S.; THOMPSON, R. & GALLOWAY, T. (2013): The physical impacts of microplastics on marine organisms: A review. Environmental Pollution 178 (2013): 483–492.

ZHAO, S.; ZHU, L.; WANG, T. & LI, D. (2014): Suspended microplastics in the surface water of the Yangtze Estuary System, China: First observation on occurrence, distribution. Marine Pollution Bulletin, 86, 1–2: 562–568.

ZBYSZEWSKI, M. & CORCORAN, L. (2011): Distribution and Degradation of Fresh Water Plastic Particles Along the Beaches of Lake Huron, Canada. Water Air Soil Pollut (2011) 220: 365–372.

ZUBRIS, K.A.V. & RICHARDS, B.K. (2005): Synthetic fibers as an indicator of land application of sludge. Environmental Pollution 138: 201–211.

7 APPENDIX

Comprehensive description of the sampling method/procedure for surface waters as developed for the Danube River Survey

A new sampling strategy was developed to enable measurements determining the spatial and temporal variability of plastic transport in the Danube River. The overall aim was to get a good estimation of the plastic transport and the annual loads. Therefore multi-point samples were taken over an entire cross section of the Danube in Hainburg and Aschach. The measurement instrument consisted of three nets to gain samples within the water column. 5–10 verticals were distributed over the cross section in order to determine the lateral and vertical distribution of the plastic concentrations of areas with higher or lower transport. The temporal (discharge dependent) variability was also taken into account by measuring at different hydrological conditions. This allows for an evaluation of the discharge dependency regarding plastic concentration and transport. Furthermore this makes it possible to calculate annual loads by means of a plastic-discharge rating curve.

At each vertical the measurement equipment was lowered into the water column. To gain enough stabilisation and reduce drift, the cable with the nets was connected to a bedload sampler (equipped with the bed near net), facilitating the lowering process due to its shape and weight. Three nets were positioned at different depths: near the river bed, in the middle of the water column and at the water surface. To catch also the floating particles, the uppermost net was equipped with two floaters, ensuring that the nets' intake protruded slightly above the water surface during a measurement. At the two upper layers, two nets were used, both with an intake size of 60x60cm. Normally, a mesh size of 500 µm was used, 250 µm nets were sometimes used in one of the aligning nets to clarify the differences.

Figure 6: – Assembly of the sampling equipment © IWHW/BOKU

The measurement times strongly depended on the quantity of transported organic matter continuously blocking the mesh. Normal sampling duration was around 45 minutes. During high flow conditions, it reduced to around 5 minutes as the mesh was blocked faster due to the high amount of suspended sediment particles within the range of the mesh size. Because of this the 250 µm was not deployed at high flows (especially in Hainburg), as the mesh pores filled quite rapidly.

Additionally, flow velocity was measured in the centre of the net intakes in order to calculate the volume of water filtered during the measurement. The vertical velocity distributions within the profile were determined by ADCP measurements carried out parallel to each measurement.

The nets were thoroughly cleaned after every vertical sampling and the filtered matter was taken out and stored in a sample container. After the measurements the volume of each sample was reduced, splitting them into different fractions with steel woven meshes. In the next step the samples were put in a bowl with salt water and the plastic particles were carefully visually sorted out. In the next step the wet sorted samples were dried at around 40°C and were then again visually sorted for plastic particles. After drying and weighing the plastic components, the plastic concentration (mg/1,000 m^3) was calculated by dividing the plastic mass of a sample by the filtered water volume. Then the plastic transport rate (mg/s*m) was calculated using the flow velocities from the ADCP measurements or the 3D hydrodynamic-numerical model and integrating the result over the depth of each vertical. In the last step, the plastic transport rates in the verticals were integrated over the whole cross section to get the plastic transport (mg/s) for each measured discharge.

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The report "Plastic and microplastic in the environment" is a summary review of Austrian studies and activities dealing with the pollution of the environment caused by plastic and plastic particles. The report contains information about the investigation of plastic debris in the flow of the Danube River in Austria and discusses pathways into the environment. Ninety percent of the plastic debris are emitted by diffuse sources, these being littering, fragmentation, transport by wind, run-off from sealed surfaces, inappropriate use of products or construction activities. By the same pathways, plastic and microplastic can reach soil, air and other environmental compartments and finally the food chain. The report concludes with recommendations how to tackle the challenge of reducing plastic and microplastic contamination in the environment.

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