Plastics
in the environment

For our environment

Umwelt Bundesamt

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Contents

Introduction

Plastics are important and valuable materials. They are used in many products and production processes and are now indispensable in households and the industry because of their wide range of use and material properties (for example, they are light, flexible and hygienic). They often fulfil important functions: Plastics in the form of insulation, for example, help to save energy; as lightweight construction elements in vehicles, they contribute to lowering fuel consumption. New products are constantly being added to the market, the demand for and consumption of plastic has been increasing strongly for years. In the 1950s, the annual worldwide production was some 1.5 million tons of plastic. In 2016, it was already 348 million tons annually (including coatings, adhesives, sealants, without PET, PA and polyacrylic fibres). This is more than a 230-fold increase – with a rising trend.

Plastics are degraded very slowly in nature. If they enter the environment, they can therefore cause great damage to both ecosystems and living organisms. Plastics are everywhere: More and more often, they are found in the oceans and even inside many marine animals. They are currently also found in rivers, lakes and the soil. There is also discussion about whether there are plastic particles in the air, in drinking water and in other foods.

Why is so much plastic getting into the environment? One of the main causes worldwide is a lack of or inadequate waste and wastewater management. But there are many other sources as well. Tiny particles are released while the product is in use (so-called wear) – for example from car tyres, from construction products and when renovating and cleaning (sandblasting), (bridge) constructions, from films used in agriculture, but also from plastic fibre from clothing. Plastic particles are often intentionally added to cosmetics or cleaning materials in order to increase their cleaning effect or to improve the aesthetic appearance of the product. Some fertilisers are coated in plastic in order to prolong their fertilising effect. But careless dropping or disposal in nature (so-called littering) also introduces more and more plastic into the environment. Even in countries like Germany with a strong environmental awareness, corresponding environmental laws and regulations and a well-developed waste disposal infrastructure, plastics in the environment are still a great challenge for environmental protection.

Where do we stand? And what can we do? Where is there more need for research, where can we, and where must we, act today? In the present paper, the German Environment Agency (UBA) – with regard to Germany – will examine whether and to what extent plastics are present in the various environmental media of water, soil, air and the German marine areas, will analyse where the plastics come from and name the most important measures to reduce the input of plastics to the environment in Germany and to improve the condition of the environment. The focus is on the national level, though the European and international levels are included if it makes sense for measures to be established there too. An introductory chapter defines what plastics actually are. It explains which investigative measures are used or are still to be developed.

As Germany’s central environmental authority, the German Environment Agency ensures that there is an intact ecosystem and healthy environment in Germany, in which people can live, protected as far as possible from harmful environmental impacts such as harmful substances in the air or water. The German Environment Agency sees itself as an early-warning system which identifies possible future hazards to people and the environment at an early stage, assesses these and suggests practicable solutions. The problem of plastics in the environment has many facets and not all of these can be addressed here. For example, the possible effects of plastic in food or cosmetics affect food safety or consumer health protection and are therefore not covered in this paper.

1

General information & basis

1.1 What are plastics?

From a material science view, plastics are a subgroup of polymers. Polymers are the main component of plastics alongside low quantities of additive and/or fillers which optimise the functional characteristics of the various polymers. A polymer consists of a repeating structural unit. In practice, substances are considered polymers or macromolecules only from molecular masses of > 10,000 daltons. The preparation and characteristics of polymers are mainly determined by the linking of the polymer chains. This is why we differentiate between polymers based on the nature of their inter-connectivity:

- Thermoplastics (isolated chains)
- Duroplastics (closely meshed polymer network)
- Elastomers (widely meshed polymer chains)

Only the thermoplastic and duroplastic materials are actually defined by the concept of plastic. However, elastomers, which are also formed of synthetic polymers (e. g. styrene-butadiene rubber), chemically modified natural polymers (e. g. rayon, cellophane) and products based on synthetic polymers (e. g. fibres, varnishes, tyres) can behave similarly to thermoplastics and duroplastics in the environment and microparticles can be generated from them. For this reason, they are also covered by the term „microplastics".

It is also possible to differentiate further e. g. by the origin of the polymer building blocks (synthetic polymers versus natural polymers) or degradability under defined conditions (biodegradable polymers versus non-biodegradable polymers).

„Regulation (EU) no. 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food" defines plastic in Art. 3:

(as) a polymer to which additives or other substances may have been added, which is capable of functioning as a main structural component of final materials and articles.

Within the sense of the definition, liquid synthetic polymers (e. g. silicone oil) or water-soluble polymers (e. g. surfactants) are not considered plastics. While these are polymers, they cannot be deemed „plastic" in the narrower sense, as they are neither substances for the manufacturing of articles, nor do they form solid particles.

The German Environment Agency defines plastics as solid substances which mainly consist of synthetically produced or chemically or biologically modified natural macromolecules or polymers. They contain other substances such as additives (e.g. antioxidants, processing aids) or fillers (e.g. chalk, fibreglass) which are added to optimise the functional characteristics of the various polymers. Liquid polymers are not covered by this definition.

Size and shape

Classification according to size is a decisive factor for the assessment of environmental relevance as well as in research and method development. Plastics or plastic particles can be present in different sizes in the environment, depending on their origin. They can be classified according to their size into macro, meso and microplastics. The EU MSFD Technical Group on Marine Litter (TG ML) suggested the following classification of size which is used generally (GESAMP 2015, EC2017):

> 25 mm	→	Macroplastic
> 5–25 mm	→	Mesoplastic
> 1–5 mm	→	large microplastic particles
1 µm – 1 mm	→	small microplastic particles

International standardisation differentiates only between micro- and macroplastic. With respect to microplastic, there is a differentiation between large (1–5 mm) and microplastic (1–1000 µm). Several additional requirements shave also been defined besides the aforementioned size classes which take the geometrical form into account. Plastics smaller than 1 µm are not further differentiated[1].

Macroplastic fragments through mechanical, physiochemical or biological processes to become mesoplastic and then microplastic particles in the long term. Microplastic particles formed in this way are termed **secondary microplastics**. Plastic particles which are formed during the use of products (e. g. fibres and tyre and colour abrasion) are also termed secondary microplastics. On the other hand, **primary microplastic** is used to describe microparticles which are produced and used for their respective purpose (e. g. in cosmetics and cleaning and plastic agents).

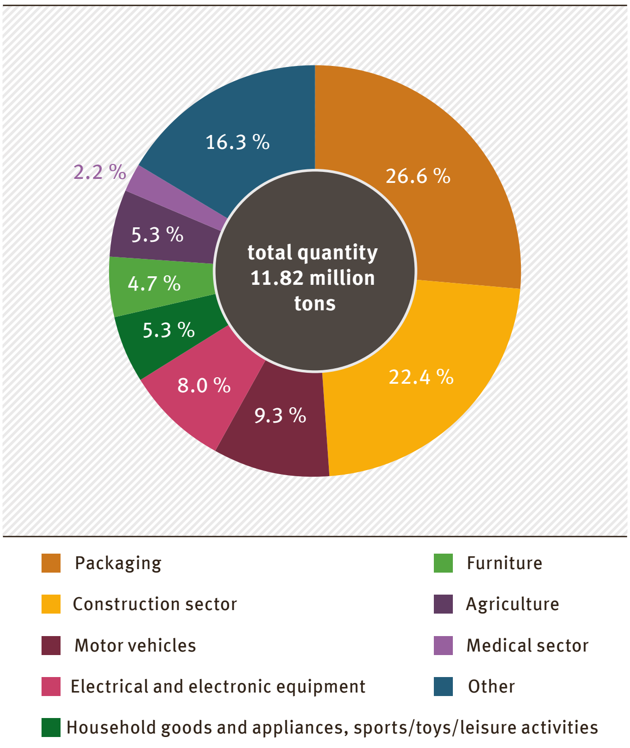
Material characteristics and areas of application

Important features of plastics are their technical characteristics: Formability, rigidity, elasticity, break resistance, temperature and heat distortion resistance and chemical resistance, which allow broad variations through the selection of macromolecules, production processes and usually by the inclusion of additives.

Because of these characteristics, plastics are used in a very wide range of products. The main areas of application are packaging and construction applications, followed – although at some distance – by vehicles and electrical/electronic products. Overall, around twelve million tons of plastic were used in products in Germany in 2017.

Figure 1

Plastic consumption per application area in Germany 2017 (new products and recycled material)

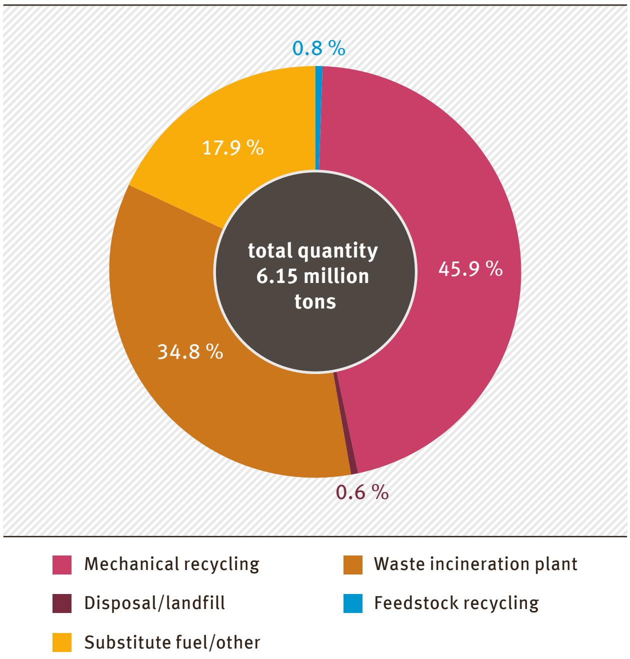


source: German Environment Agency, own compilation with data from Conversio Market & Strategy GmbH 2018

1 Plastics in the Environment – Current state of knowledge and [SOURCE: ISO/TC 61/SC 14/WG4 ISO/CD 2017]

Figure 2

Recycling of plastic waste (incl. production and processing waste) in Germany in 2017



source: German Environment Agency, own compilation with data from Conversio Market & Strategy GmbH 2018

Depending on their area of application, plastic products differ with regard to their service life and duration of use. Plastic products with very short lifespans, e.g. packaging, mainly only have a lifespan of a few minutes to a few months. However, products with a long service life last for several years (e.g. vehicles, electrical appliances) or even for decades (e.g. construction products) before they become waste.

Overall, in 2017, a little more than six million tons of plastic waste were accumulated in Germany. Of this, just under 47 percent was recycled (in Germany and abroad) and just under 53 percent was utilised for energy[2].

By comparison, in Europe (EU 28 plus Norway and Switzerland), a total average of 31.1 percent of the 27.1 million tons of plastic waste was recycled in 2016, 41.6 percent used for energy production and 27.3 percent sent to landfill. Here, it should be noted that these numbers refer to plastic waste accumulated by private or commercial end users (known as post-consumer waste). You can find the corresponding figures for Germany in footnote 2.

1.2 Methods and investigation approaches for plastics

The large diversity of methods and investigation approaches in scientific work leads to the fact that overarching and comparative assessments are currently only possible in a very restricted sense – for this reason, it is necessary to establish harmonised methods and investigation approaches.

In order to be able to assess the presence of plastics in the environment, input and transport routes within environmental media and from one environmental medium to another, it is necessary to acquire and collect comparable data. For this, the data must be collected using **harmonised or standardised and validated investigation methods**. In general, a distinction is made between chemical, physical and biological (ecotoxicological and human toxicological) methods.

In addition to analytical investigation methods in laboratories, researchers also use field methods which are essentially based on visual assessments. The methods vary depending on the question which must be answered (e.g. qualitative evidence of plastic in the environment, number of plastic fragments, quantitative survey of various types of plastic in the environment, degradation status of the plastic fragments, ecological and socio-economic effects). For this reason, there is no all-encompassing investigation method for all issues relating to plastics in the environment (see also BMBF [Federal Ministry of Education and Research] 2018).

The collected data are the basis for an adequate examination and assessment of plastics in the environment, meaning for a regular survey of sources, entry routes and entry quantities as well as the occurrence, behaviour and effects. With such data, which were also collected following the same methodology in different areas, it is then also possible to calculate the material flows of plastics within environmental media and from one environmental medium into the other (e.g. via rivers into the sea). With this process, it

2 If we only look at the plastic waste accumulated by commercial or private end users (known as post-consumer waste), this was 5.2 million tons in 2017. Of this, 38 % was mechanically recycled, just under 1 % was feedstock-recycled and around 60 % was utilised for energy. 0.7 % was disposed of/sent to landfill (as non-separable components in mineral construction waste, for example).

is also possible to check the effectiveness of measures which are intended to serve to reduce the input of plastics into the environment.

The basis for establishing such processes is data and information:

- On the representativeness of the process with regard to the medium being investigated,
- On the recovery rates or evidence and detection limits,
- On repeatability,
- On the limits of the applicability of the method,
- On the fluctuation margins of results (e. g. due to faults in sampling, internal laboratory errors or variations of the object being investigated).

Other important aspects, in particular in terms of legislation, are the duration of the investigation before presenting the results, the costs, the environmental sustainability (e. g. eliminating the use of certain chemicals) and the practical feasibility.

Therefore, it is important to develop procedures for the specific sampling of water, soil, air and biota and to capture the relevant effects in each case. Taking samples, their preparation and analysis should be comparable and quality-assured. The results must allow statistically reliable statements. Modelling approaches on the entries and distribution as well as accumulation in the environment can be a useful addition. Analysis on the temporal change of plastic occurrences in the various environmental media is an important aspect for being able to estimate how effective and efficient certain measures are.

Such methods corresponding to the above requirements are currently being developed in a **research focus on plastic in the environment**, funded by the German Federal Ministry of Education and Research (BMBF) and in the area of marine protection within the JPI Oceans Initiative, which is also funded by the BMBF, on an EU level and by the UBA together with the German coastal states.

The vast range of methods and diversity of investigation approaches which are currently used, also in scientific work, lead to the fact that overarching and comparative assessments can currently only be made in a very restricted manner.

The state of method development and the work of the UBA is presented in a more detailed form in appendix 1 for:

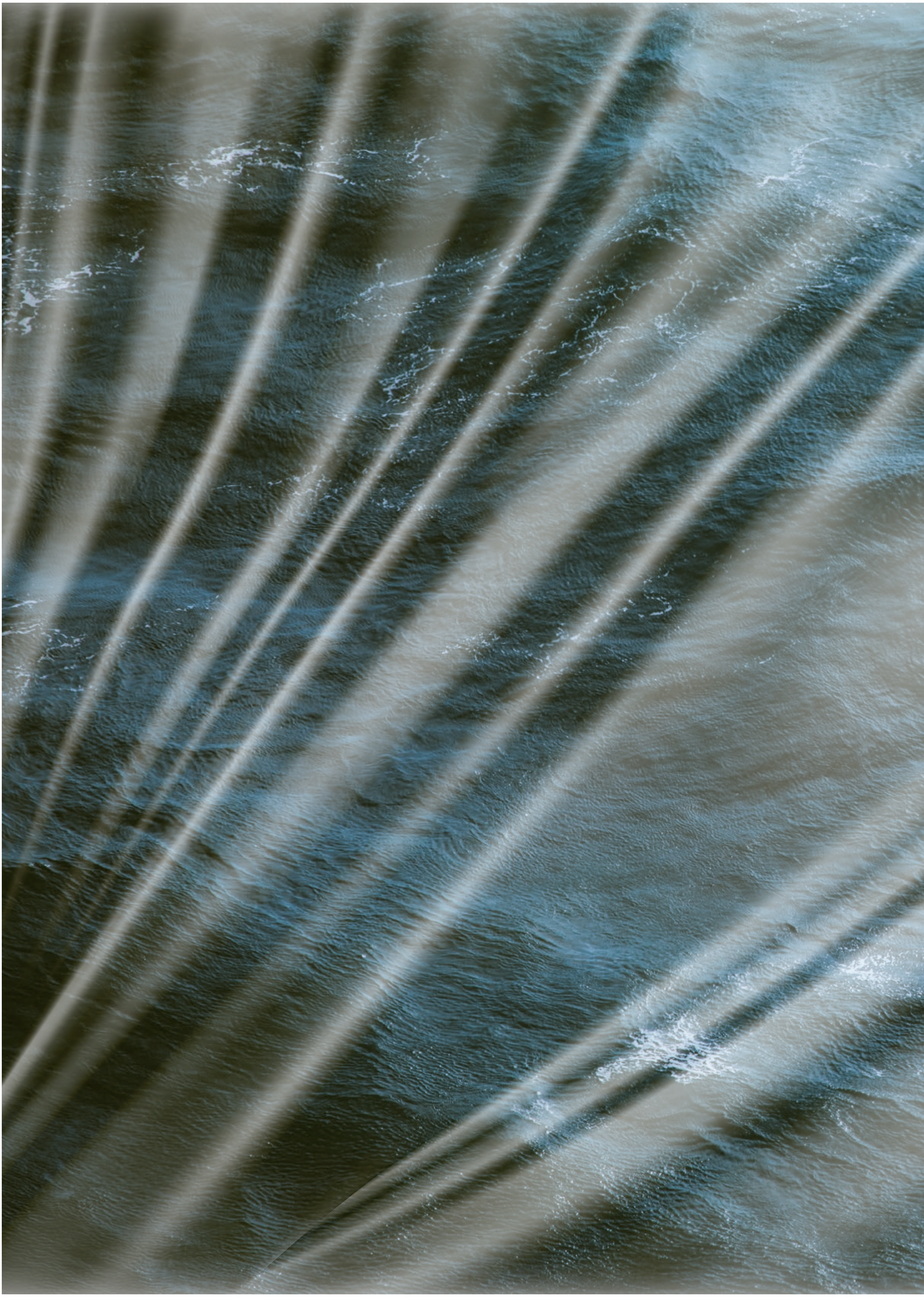
- Analytical methods (chemical and physical methods) in the laboratory,
- Field methods (partially paired with laboratory analysis) for marine protection,
- Ecotoxicological test methods and
- Human toxicological test methods.

When addressing the existing approaches as well as future recommendations for the various analysis methods, it must be considered that the approaches provide different information (e. g. particle number, mass fractions) about the object of investigation as well as define the object of investigation in different ways (e. g. size, effect). This must also be taken into account when comparing and discussing the results.

What is the German Environment Agency doing and what does it call for?

The establishment of harmonised or standardised investigation approaches in all the areas listed above is urgent. The UBA is actively participating in several research projects supported by the BMBF for the establishment of suitable sampling approaches, investigation methods and assessment concepts, and are themselves supports research projects which are geared towards methodical issues.

As the topic of plastic in the environment is an international matter with global distribution patterns, the establishment of internationally recognised investigation methods is necessary (ISO, CEN, OECD) (see also appendix 1).



2

Where do you find plastics in the environment?

2.1 Water

2.1.1 Oceans and seas

In the oceans and seas – also in German coastal waters – far too much waste can be found everywhere, plastics above all. The „good environmental status" has not been reached.

Around 75 percent of the waste found in the oceans and on beaches is plastic. The rest is made up of material such as rubber, metals, fabrics and textiles, glass, wood or paper. Plastic parts are transported over long distances and across borders by wind and ocean currents. Alongside larger pieces of waste such as plastic bags or bottles, fish crates or lost and abandoned nets (so-called ghost nets), microplastics are gaining increasingly more environmental importance and regularly crops up in marine organisms.

The EU Marine Strategy Framework Directive (MSRL (2008/56/EC)) requires the member states to monitor the impact on marine areas caused by marine litter. The following table contains monitoring data of waste, sorted into various marine compartments. It comes from regular monitoring activities on beaches (in the drift line) and on the sea floor of the German North Sea and Baltic Sea as well as the stomach contents of northern fulmars which illustrate the contamination situation with plastic parts on the surface of the German North Sea.

In order to determine the occurrences and effects of plastics in the oceans, additional data has been gathered within pilot monitoring projects for the last few years. It is not yet possible to derive any trends here due to the short collection period, but the findings give additional indications of the overall contamina-

Table 1

Occurrence of waste in the various marine compartments

Compartment	Litter on the drift line	Litter on the drift line	Litter on the surface of the sea	Litter on the sea floor	Litter on the sea floor
Investigation period	2009–2014	2011–2015	2010–2014	2011–2016	2012–2015
Investigation area	North Sea	Baltic Sea	North Sea	Southern North Sea	Baltic Sea
Methodology	Guideline for Monitoring Marine Litter on the beaches on the OSPAR Maritime Area (2010)	Guideline for Monitoring Marine Litter on the beaches on the OSPAR Maritime Area (2010)	OSPAR Guidelines for monitoring of plastic particles of fulmars in North Sea Area (2015)	Survey for the International Bottom Trawl Surveys (IBTS)	Survey for the Baltic International Trawl Surveys (BITS)
Waste	Average number of 389 pieces of waste/100 m beach section (seasonal survey)	Average number of 47 pieces of waste/100 m beach section (seasonal survey)	Pieces of plastic in 94 % of the stomachs of northern fulmars, on average 38 pieces of plastic with a mass of 0.31 g	400 pieces of waste (in 339 bottom trawling nets within the area of 12 nautical miles) 6.35 ± 11.5 kg/km²	200 pieces of waste (in 289 bottom trawling nets within the area of 12 nautical miles)
Proportion of plastic among the overall finds	88.6 %	69 %	–	91.3 %	42.0 %

sources: national monitoring activities

tion situation. The initial data from the tidal mudflats of the North Sea indicate that microplastics can be found everywhere – in all compartments. The first investigations in the Baltic Sea also suggest a wide distribution of microplastics.

In a **UBA study** (2016), the digestive tract of 258 open water fish and 132 sea floor fish of various species from the North and Baltic Seas were investigated qualitatively and quantitatively for the presence of plastics. In 69 percent of the fish samples, small microplastic pieces of under 1 millimetre in size were present (Scholz-Böttcher & Gerken, in progress). Other investigations found microplastic, mesoplastic and macroparticles in fish stomachs (Werner et al. 2016).

A **UBA study in the gannet colony of Heligoland** in 2014 and 2015 showed that 97 percent of the nests contained plastics. This was mainly materials from fishing (e. g. remains of nets, lines, cords and chafers from trawling nets), ropes and packaging (Dürselen et al., in progress).

How big is the problem?

The aim, according to the MSRL, is to achieve the „good environmental status" in the seas and oceans. With a view to descriptor 10 (marine litter), this means that „*the properties and quantities of marine litter ... do not cause harm to the coastal and marine environment*"[3].

The current situation looks different from this aim: According to a **current publication from the EU Technical Group Marine Litter,** 817 marine species are regularly affected by harmful effects of litter in the seas and oceans. Of these, 519 are affected by choking or strangulation and swallowing pieces of litter. Above all, packaging materials and ring or cord-shaped pieces of litter as well as remains of nets, lines and ropes harbour a high potential of danger for marine life. Around 17 percent of these species are on the red list or are already classified as threatened or endangered (Werner et al. 2016).

Northern fulmars in the North Sea are an indicator species for the recording of plastic particles from the surface of the sea. 94 percent of the northern fulmars found dead on beaches on the German North Sea have plastic in their stomachs, 62 percent have more than 0.1 grams (investigation period 2010–2015). Here, the ecological quality target, which was developed under OSPAR and stipulates that a maximum of 10 percent of birds should have no more than 0.1 grams in their stomach, falls far wide of the mark.

3 Appendix I MSRL, Descriptor 10

When **investigating the gannet breeding colony** on Heligoland, it was examined how many of the young, not yet sexually mature, gannets choked and were strangled by litter which was put into the nets by the parents. During the 2014 and 2015 breeding seasons, two to five times more young birds died than in other years (Dürselen et al., in progress).

No indicator species has been identified for the Baltic Sea yet. For this reason, no comparable statements are possible about the Baltic Sea at this time.

Overall, the **OSPAR *Intermediate Assessment 2017*** for the North Sea finds that litter on the coast is ubiquitous (meaning it is everywhere) and widely distributed across the sea floor. Plastics in the stomachs of northern fulmars are well over the ecological threshold value for the North Sea. No decreasing trends in the impact of litter on the beaches and from plastic particles in the stomachs of northern fulmars could be identified in the observation period of 2009 to 2014[4].

The **HELCOM *State of the Baltic Sea* report** from 2017 states that around 70 percent of the litter finds on beaches of the Baltic coastal states consists of plastic. A temporal trend cannot yet be derived due to the short investigation period. The impact of marine litter in the German North and Baltic Seas corresponds to the regional findings.

According to these, the German waters of the North and Baltic seas are also too heavily impacted by litter in the second MSRL assessment period and the „good environmental status“ was not reached for this reason.

Marine litter also has socio-economic effects on maritime sectors and particularly fishing, shipping (navigational safety) and tourism as well as on coastal communities. Cleaning beaches may require high costs, in Germany up to € 65,000/km of beach per year (Holzhauer 2016). In addition, litter in the marine environment is also considered disruptive and can endanger human health (risk of injury).

4 See https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/

What is the German Environment Agency doing and what does it call for?

Together with the responsible expert authorities in Schleswig-Holstein and Lower Saxony, the UBA is leading the national **Bund-Länder Fach-AG (Working Group of the German Federal States and the Federal Government) „Marine Waste“**. This working group has the task of implementing the EU MSRL with regard to marine waste with a scientific focus on monitoring and assessment aspects. In this context, the UBA commissions research projects for the development of various monitoring processes and their testing for feasibility in practice. The aim is to prepare and establish suitable methods for the long-term monitoring of the contamination of various marine areas and life forms by marine litter (including plastic and microplastics). The data situation is also improved.

Furthermore, the UBA has a co-leadership function in the **EU Technical Group on Marine Litter**, which has established recommendation for adequate and harmonised monitoring processes in order to support the EU member states in implementing the MSRL for descriptor 10. Furthermore, reports on the sources and effects of marine litter were presented; at present, the focus of the group is on determining the ecological threshold values and updating the monitoring protocols. Ascertaining the threshold values is required by the revised commission decision (EU 2017/848) which determines the criteria and methodical standards for the MSRL. They should determine the border between good and unsatisfactory environmental status in accordance with the MSRL. Monitoring protocols determine how monitoring should be carried out and documented.

The UBA played a significant role in the development of **regional action plans against marine litter** for the North and Baltic Seas under OSPAR and HELCOM. It participates actively and plays a coordinating role in the implementation and supports the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) in the implementation of the G7/G20 action plans against marine litter. All the named action plans aim at preventing further entries of marine waste from land and sea-based sources and to reduce the present quantities of litter in the seas in an ecological way. The removal of waste from the marine environment always covers just small amounts, takes time as well as being cost intensive and involves ecological risks such as also catching marine organisms and damaging symbiotic communities and habitats. This is why the avoidance of further introduction of litter takes top priority. The action plans also aim at raising awareness among the general public and the sectors responsible for the problem (e. g. fishing, shipping, waste and sewage management) and the necessity for research.

Alongside the BMU and the Lower Saxony Ministry for the Environment, the UBA is one of the initiators and patrons of the **Marine Litter Round Table**, which was formed to drive forward the corresponding measures of the national MSRL programme of measures on descriptor 10 from 2016. The UBA supports the working group which deals with the input of marine litter from land-based sources. Lower Saxony leads the working group on the input from sea-based sources[5].

Through projects of associations sponsored by the BMU and UBA, the fishing-for-litter initiative at the German North Sea and Baltic Sea coasts was initiated, pilot projects for communal measures against marine litter in coastal communities were brought into being and numerous education materials were developed. Other association projects relating to marine litter are currently in the planning stages.

From the UBA’s view, there is a particular need for research into the extent to which the intake of plastic particles by marine organisms causes a **potential transfer of the contained chemical substances (additives) and harmful substances** accumulating from the marine water within the marine food chain, in addition to the known negative mechanical effects. This transfer was observed in laboratory experiments. There needs to be scientific clarification on whether this causal relationship is a natural pathway, where exposure to plastic particles is significantly lower. The importance of this possible route in relation to contamination from other sources of harmful substances should be the topic of research. Furthermore, we require clarification on the extent to which plastic waste in the sea and its degradation products support the **migration, transportation and spread of non-native species and pathogens**.

5 See https://muell-im-meer.de/meeresmuell-ueberuns-ergebnisse

2.1.2 Inland waters

It is not currently known how significant the problem of plastic contamination of inland water is – we lack informative studies which examine the effect of plastics.

The field of research „plastic in inland waters" was only recently pushed into environmental and political focus. Accordingly, regulations and standards for taking samples and analysis methods have not yet been agreed: To date, environmental investigations have only reported on particle numbers in individual bodies of water (UBA 2017). The available data do not make any statements regarding masses and do not cover the rivers and lakes in terms of their breadth and diversity. In one of the few overarching investigations in 2018, however, five federal states came to the conclusion that microplastics are present in all investigated measurement sites in the catchment areas of the Rhine, Danube and Weser (LANUV, 2018).

As well as a sound spatial overview, we also lack comparisons over time. The measurement data are generally the result of selective investigations. There are currently only a few systematic studies on the source of plastics in the catchment areas of rivers and lakes. The way in which plastics behave in inland waters and how they fragment into smaller particles have also not been researched sufficiently up until now. We also lack verified data about the transportation of plastics in inland waters and their inclusion in the sediments of rivers and lakes. There have also been few findings up until now about the movement of plastics from rivers to seas.

How big is the problem?

Plastic in rivers, lakes and shores is an aesthetic problem, on one hand – we avoid the unsightly, littered spots, their recreational value decreases. In addition to being an aesthetic problem, plastics found in rivers, lakes and their shores also pose ecotoxicological risks. We do not currently know the extent of the problem of plastic contamination in inland waters. On one hand, experts have only thoroughly investigated a few bodies of water for plastics. Things are made more difficult due to the fact that the data collected up until now are frequently not comparable. On the other hand, we lack detailed studies which investigate the effects of the plastics. The classic ecotoxicological tests were developed for substances. For this reason, several ecotoxicologically problematic additives found in plastics such as plasticisers or flame retardants are already well regulated. These tests, however, are not suitable for particles. Whether and how plastic particles get into the tissue of plants, amphibians or fish, whether they cause damage and accumulate in the food chain of the rivers and lakes, are questions which have barely been studied until now and the previous results cannot be generalised. One task of research into this field is now to identify such plastic particles and organisms which are suitable as indicators for the diverse plastic contamination and its effects – a great challenge. Only once this question has been answered can a structured assessment of the contamination be conducted and an ecotoxicological assessment of plastic particles in inland waters based on adequate toxicity tests be made.

What is the German Environment Agency doing and what does it call for?

First and foremost, plastics get into inland waters – differently from getting into the sea – with the drainage of rain from sources which are connected with the use or improper disposal (littering) of plastics. We must therefore apply measures to reduce this, above all in the area of **waste management** (see chapter 3.1.1) and **sewage management** (see chapter 3.1.3).

The Working Group of the Federal States and the Federal Government on Water Issues (LAWA) should therefore work together with other federal states and federal government working groups such as LABO (soil protection), LAGA (waste), the Federal States and Federal Government Working Group on Waste water as well as the Federal Committee for Air Pollution Control (LAI) on improving the **data situation** in all areas and putting together **management options** based on this. Here too, the precaution principle should apply and any entry of plastics into the surface waters should be avoided for the sustainable protection of natural water resources.

Within the context of various projects, the UBA is already researching the **plastic flows into and within inland waters** and championing the development of monitoring methods and an impact-related basis for assessment for microplastics. With these goal, the UBA is participating in the 4th Joint Danube Survey in 2019.

2.1.3 Drinking water

According to the current state of knowledge, plastic particles in drinking water are not a problem for the environment and health – plastic components from pipe materials and valves, however, may not dissolve into drinking water.

There are currently **barely any investigations carried out with robust methods** on the occurrence of microplastics in drinking water. Small plastic particles can only get into drinking water if they break through the natural and technical filtration processes (natural filtration = soil or sediment passage, technical filtration = treatment). This pathway is improbable everywhere where drinking water is obtained from well-protected resources, in particular from groundwater, spring water or river bank filtration (together around 80 percent of drinking water production in Germany) or from well-protected drinking water reservoirs. In places where drinking water is directly abstracted from a river or lake, there is a particularly extensive water treatment system with several filtration processes. Plastic breaking through these systems is also improbable.

Plastics and other organic materials (e. g. elastomers, coatings) are used as piping materials and in valves for the distribution of drinking water. However, from a scientific point of view, we cannot assume that plastic particles get into our drinking water from there. However, other substances (residual monomers, additives, reaction products or impurities) from materials unsuitable for pipes and valves can dissolve in the water and be transported into drinking water – not as

particles but as molecules dissolved in the water. For this reason, Section 17 of the German Drinking Water Ordinance has regulated the use of materials coming into contact with drinking water since 2012.

How big is the problem?
Until now, we assumed that the exposure of people to additives and harmful substances and microplastics dissolved in water was rather low. The European Food Safety Authority has also come to this conclusion in their current statement (EFSA 2016).

Microplastics have never been found in drinking water up to now. This is also unlikely to happen, as in Germany, most of the water resources used as untreated water are very well protected from contamination which may contain microplastic (see above and chapter 2.1.2) and because we are very familiar with the high effectiveness of the filtration processes used in the treatment of drinking water. Because for decades, these have been monitored with regard to other small, relevant particles (such as bacteria). Indeed, this theoretical deduction should be validated by means of investigations.

What is the German Environment Agency doing and what does it call for?
Looking at the **filtration of the smallest particles** in the treatment of drinking water – as mentioned above – further investigations should take place, particularly for particles at the nanometre scale to either safely rule out exposure of people via this infiltration pathway or to clarify the conditions under which microplastics can overcome the safeguards for drinking water in order to better protect against impurities occurring as particulates, colloids or dissolved in the water in such situations. Suitable investigation methods are currently being established.

The German Environment Agency is currently involved in the development of methods to investigate the **occurrence of microplastics and nanoplastics in water**, including particularly sensitive methods delivering sufficiently reliable results for the probably very low concentrations in drinking water. Furthermore, the UBA is investigating the **toxic effect of microplastics in the BMBF joint project „microplastics in the water cycle – taking samples, treating samples, analysis, occurrence, removal and assessment („MiWa")** within the RiSKWa[6] funding measure.

Section 17 of the **German Drinking Water Ordinance** has been regulating the **use of materials coming into contact with drinking water** since 2012. The German Environment Agency is continuing to implement this ordinance by developing assessment criteria for all groups of materials. This needs to be done on an ongoing basis because plastics are constantly being further developed for use in sealants, coatings, cement and hoses. This ordinance applies the same principles as for the European harmonised regulation of plastic in contact with food products. Accordingly, the German Environment Agency is driving forward the **EU-wide harmonisation of the assessment of materials coming into contact with drinking water**. Only in this way can we protect the German market for valves, piping and other components of drinking water installations effectively from cheap imports from the plastic components of which harmful substances can get into the drinking water.

Furthermore, the German Environment Agency is conducting **research into the release of even small quantities of plastic components such as monomers** released and dissolved in water if polymers are slowly degraded or additives such as plasticisers are suddenly released from ageing material.

6 See https://www.fona.de/de/mikroplastik-im-wasserkreislauf-21854.html

2.2 Soil

The occurrence and effects of plastics in the soil are largely unknown.

Plastics primarily find their way into the soil from littering (e. g. cigarette butts, packaging), fertiliser (sewage sludge, organic waste, digestate, compost – see chapter 3.1.2), sedimentary deposits from water during flood events, from (construction) product applications (e. g. thermal insulation materials, grass paver, fences, agricultural films) and from tyre wear (see chapter 3.1.5) (Dümichen et al. 2017; Elert et al. 2017). Plastics age and remain in the soil for different lengths of time. Plastics may be translocated from the soil to groundwater, into rivers, lakes and finally into the oceans by precipitation and surface runoff, depending on their particle size and properties as well as the soil conditions.

There are a few investigations and calculations on the magnitudes of these kinds of transfers. Precise statements have not been possible until now as neither standardised methods for sampling nor for the analysis (Dümichen et al. 2015) of plastics in the soil are available.

How big is the problem?
The effects of plastics in the soil have been largely unknown until now. Studies which investigate the effect of plastic on soil fauna have been lacking to the largest extent until now. However, there are indications that plastic particles are ingested by soil organisms, e. g. earthworms, and transported into deeper soil layers (Chae & An 2018). No studies exist at present which deal with the absorption of microplastics in plants. It has only been proven that nanoparticles can be absorbed by plants. Other considerations and investigations relate to the known effects in oceans and inland waters. Here, on one hand, the surface and material characteristics of the plastics themselves are considered and, on the other hand, the possible transport mechanisms combined with the soil characteristics. It is to be expected that organic substances, organic pollutants and heavy metals accumulate on the surface of the plastic particles as is the case in other environmental areas. It is furthermore expected that plastic particles are populated with organisms. The symbiotic relationships in the soil are different than in water, it must therefore be investigated whether other effects can be observed because of this. We lack detailed or validated ecotoxicological test methods to be able to do this.

What is the German Environment Agency doing and what does it call for?
The UBA-funded **study „Plastic in the soil – occurrence, sources and effects“** focuses in the first stage on the development, adjustment and validation of robust and standardised methods (see also chapter 1.2). With these methods for sampling, pretreatment of samples and analysis, the screening of various soils for relevant plastics (determination of the total content, but also individual compounds) is planned. Then, it should be investigated which type of plastic reaches the soil from which pathway in which quantity.

The results will be submitted to standardisation committees (e. g. DIN/ISO) as the standardisation and harmonisation of methods is the basis for consistent data within the context of an assessment strategy. Once the results of the project are available, in a second stage, robust information can be collected, for example on the quantitative input of plastic via all pathways into the soil, or about the time the plastics remain in the soil and their possible degradation (duration, necessary environmental conditions).

Even if there are currently only a few studies on the occurrence and effects of plastics in the soil, the UBA is trying to reduce the introduction of plastic into the soil, particularly where this is already possible, for example in agriculture. For example, solutions must be found in the collecting of communal organic waste to avoid plastic bags or at least to remove them before the waste is composted (see also chapter 3.1.2).

2.3 Air

Plastics occur in ambient air in concentrations relevant to environmental or health protection only as tyre wear.

According to the current state of knowledge, plastics in ambient air play a role as components of particulate matter, where almost exclusively tyre wear represents a relevant source (see chapter 3.1.5). As particulate matter, these particles damage human health, special effects of airborne plastic on ecosystems have not been identified thus far.

How big is the problem?

Fibres and coloured fragments from synthetic polymers have already been found in rainwater and foodstuffs. However, it cannot definitively be clarified whether these were introduced through the air or whether this was contamination during the taking of samples. Routine light microscope investigations in accordance with VDI Guideline 2119, which are carried out by the German weather service on particles which were previously collected on transparent adhesive plates, have not yet provided any notable evidence that plastic particles occur in the air which are not attributed to tyre wear.

Indoors, fibres and polymer particles get into the air primarily through wear of textiles and clothing. The significance of this is still currently being discussed. For indoor areas, the emissions of additives from plastics (notably the plasticisers, but also certain flame retardants) play an important role when conducting health assessments on plastics.

What is the German Environment Agency doing and what does it call for?

At the moment, the UBA **does not see any need to conduct its own research** into the occurrence and behaviour of plastics in ambient air, as this area of air pollution control is not a priority for the UBA from a scientific point of view. However, it cannot be ruled out with certainty that plastics occur in the atmosphere in concentrations relevant for environmental or health protection. For this reason, the UBA is making its expertise available to third parties, in particular research institutes and authorities who are initiating the **necessary fundamental research** in this area.

The German Environment Agency would welcome a reduction in particulate matter emissions from tyre wear as a general contribution to a reduction of particulate matter pollution. However, there are no special health risks caused by particulate matter emissions from tyre wear compared to particulate matter from other sources. As other measures are easier to implement for the reduction of particulate matter emissions from road traffic, in particular by reducing brake wear, a reduction of emissions from tyre wear would generally be welcomed, but is currently not granted any special priority.

3

How do plastics find their way into the environment?

3.1 Sources and input paths from land

3.1.1 Waste management

Good waste management is the central prerequisite for avoiding plastic waste in the environment and closing material cycles.

As well as the careful handling of plastics, a well-structured collection and disposal infrastructure is the basic requirement for avoiding plastic entry into the environment. In Germany, we have a well-organised waste management system. Since 2005, it has no longer been permitted to take residential waste (residual waste) to landfills without pre-treatment with thermal or mechanical or biological processes. Plastic waste then generally does not end up in a landfill: Close to 100 percent of collected plastic waste is recycled or recovered energetically.

How big is the problem?

Beyond collection purposes, it is important from the view of environmental and resource conservation that plastic is kept in circulation for as long as possible, meaning to recycle plastic waste in a predominantly ecologically meaningful manner. Here in Germany, there is still potential – particularly for waste generated by private or commercial end users. In this area, the recycling rate is currently at just under 39 percent (as of 2017). For this, plastic waste must be collected separately from household waste in order to prevent unnecessary contamination and to feed it back into recycling channels. Of course, recycling is only possible if the plastic waste can be sorted and is suitable for recycling. For this reason, it is important to think about the end of a product's service life even during the development of the product, and to take into account the possibilities for recycling. Even today, this is done much too rarely in product design (see chapter 4.1).

What is the German Environment Agency doing and what does it call for?

Deposit and return systems have proven to be an effective instrument to „bring back" more waste. With such a system, clean and easily recyclable plastic flows can be generated (for example, deposit system for single-use beverage bottles). At the same time, less waste is disposed of in the environment (see chapter 4.2).

The UBA is committed to implementing the obligations of separate collection, inter alia, of plastic waste, as stipulated by the Circular Economy Act (Section 14, paragraph 1). The UBA's demand for a **better separate collection of plastic waste** and its priority input into recycling was successfully included into the amended Commercial Waste Ordinance successfully, for example. The UBA is also committed to ensuring that **more electrical and electronic waste** is collected. In addition to discussions with manufacturers, waste disposal companies, retailers, municipal and environmental associations as well as the federal state governments, the UBA is examining which measures can improve and further simplify the returning of waste. Here, among other things, a research project is planned to identify the collection deficits, uncover the disposal routes of the improperly disposed old electrical appliances and to develop measures and recommendations to increase the quantity collected. At the same time, the UBA is working on recommendations for waste disposal companies. The aim is to recover as much plastic and other raw materials as possible, but to remove harmful substances from the cycles at the same time.

The new **Packaging Act** which came into force on 1 January 2019[7] specifies ambitious recycling quotas for plastic packaging waste from private households (58.5 percent from 2019 and 63 percent from 2022 instead of 36 percent as before) and thus sets a clear signal for increasing plastic recycling. For the first time, it is stated that recyclable product design is to be promoted (Section 21).

In a further research project, the UBA is currently investigating the technical potential for increasing **plastic recycling** as well as the **use of recycled materials**.

More **recycled plastic** should also be used in new products. The task is to create a market for these products. The UBA sees a main lever for increasing the demand for plastic products containing recycled materials in sustainable public procurement. However, it is currently not transparently clear how much recycled material is contained within products. A corresponding product declaration would be a viable solution. In a further research project, the UBA is examining various possibilities of increasing the use of recycled materials and the demand for plastic products containing recycled materials.

From the view of the German Environment Agency, the prerequisite for a recycling economy is that all players cooperate with each other across the whole value chain and that information, for example about product compositions and materials, is available in a transparent form. You can find a comprehensive overview of the necessary measures for increasing plastic recycling, promoting a market for recycled materials and for increasing the use of recycled materials in products in a UBA position paper (UBA 2016)[8]. The recirculation of plastics is also a central concern of the EU. This was made clear with the publication of the EU plastic strategy[9] in January 2018.

7 From January 2019, the Packaging Act supersedes the previously applicable Packaging Ordinance.

8 UBA position paper „Steigerung des Kunststoffrecyclings und des Rezyklateinsatzes";download at: https://www.umweltbundesamt.de/publikationen/uba-kernelemente-zur-steigerung-des

9 A European strategy for plastics in the recycling economy: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2018%3A28%3AFIN; more information at: http://europa.eu/rapid/press-release_IP-18-5_en.htm

3.1.2 Sewage sludge, composts and digestates

The introduction of plastics into and onto the soil via sewage sludge and composts must be reduced – according to the UBA, the applicable regulations on limiting the entry of plastics are not sufficient.

Sewage sludge, digestates and composts are considered secondary raw material fertilisers in Germany. With fertilisation, plastics can find their way into the environment, in particular into the soil.

Sewage sludge contains the plastic transported in the untreated waste water[10] which was removed from the it in the waste water treatment plant. During the co-fermentation of substrates in the digestion tank (e. g. food waste), plastics can also enter from another area. Even in composts and digestates from separately collected organic waste, there is sometimes significant contamination with plastic particles. This is due, for example, to the use of conventional plastic bags as a means of collecting organic waste, the fermentation of food waste with packaging remains as well as inadequate technology in the treatment plants for removing plastic remains from waste biomass.

How big is the problem?

Article 4, no. 4 of the German Fertiliser Ordinance stipulates limit values for impurities for secondary raw material fertilisers. Plastic is also listed as one of the impurities. These limit values differ for hard and soft plastics and are a total of 0.4 percent by weight for particles (> 2 mm based on visual recognition) in relation to the dry mass for hard plastics and other impurities (paper, glass, metal) and 0.1 percent for soft plastic such as foils. These legal requirements on the limitation of plastic entry into the soil are not sufficient, according to the UBA. In the current draft of the amendment of the Fertiliser Ordinance, aspects of the current discussion on plastics have already been taken up.

Extrapolated, the **limit values** for the current quantities recovered materially in Germany of 560,000 tons of sewage sludge and approximately eight million tons of compost and digestate allow the entry of up to 20,000 tons of plastic via compost and digestate, and 4,000 tons of plastic via sewage sludge into the environment each year. Current estimations based on average values of quality assurance for composts and digestate yield plastic entries from organic waste recovery of approx. 1,000 and 3,400 tons per year.[11]

New investigations revealing high particle numbers in composts confirm the occurrence of plastics in secondary raw material fertilisers, however, these allow no comparison with the current limit values, as only the particle number was determined and not the mass (Weithmann et al. 2018).

What is the German Environment Agency doing and what does it call for?

The UBA recommends the introduction of a **common limit value for all plastic impurities**, regardless of their particle size and the type of plastic.

A suitable **investigation method** is required in order to be able to ascertain the plastic content. For this reason, the UBA will begin analysis of composts, digestates and sewage sludge with the thermo-analytical method TED-GCMS. This is to be accompanied by method comparisons, in particular with the previously applied optical and gravimetric processes. From the view of the UBA, Germany should also advocate for consistent, demanding limit values on a European level.

Independent of the threshold values, plastics in organic waste can already be reduced using two approaches:

- Reducing the amount of waste wrongly thrown together organic waste through information and educating the population as well as an improved monitoring of organic waste at the collecting stage;
- Reducing the amount of plastic particles in finished compost through improved techniques for separating foreign matter from organic waste in waste treatment plants.

10 Plastic which were mechanically removed by raking are disposed of elsewhere.

11 Preliminary results of the UFOPLAN project: Kunststoffe in der Umwelt – Erarbeitung einer Systematik für erste Schätzungen zum Verbleib von Abfällen und anderen Produkten aus Kunststoffen in verschiedenen Umweltmedien (FKZ 3716 34 326 0), not yet published.

To get more people to collect organic waste separately, special paper bags (e. g. with a wax coating) and biodegradable plastic bags are now being recommended more and more frequently. It should be noted that these bags are suitable for collecting organic waste only if they are certified in accordance with the corresponding standards (EN 13432 or EN 14995), are made of predominantly renewable raw materials and can be almost completely broken down in composting and fermentation plants which treat the organic waste. The degradation required in the named standards can only be ensured under the conditions of industrial composting.. For this reason, the biodegradable bags should not find their way into the environment and are also not suitable for your compost heap at home.

If a city or district decides to use collection bags from biodegradable plastic because of the advantages for the collection of organic waste, the UBA recommends distributing correspondingly labelled, biodegradable organic waste collection bags via the respective disposal company. In this way, it can be ensured that only the suitable bags are used and no conventional plastic bags end up in the organic waste. This reduces the input of long-life pieces of plastic into the soil.

3.1.3 Urban waste water

The removal of plastic, including microplastics, by waste water treatment plants (WWTPs) with biological purification stages is very successful – for stormwater overflow and for waste water from separation sewers, treatment must be improved.

Plastics can end up in the urban waste water from various sources:

- From the waste water in **domestic or commercial areas** (e. g. via hygiene products, microplastics from washing and cleaning agents, abrasion from waste water pipes, fibre breakages from textiles during washing, production residues),
- Through **effluents** from sealed areas and buildings (e. g. tyre wears, weather damage to surfaces, artificial turf pitches, outdoor construction materials).

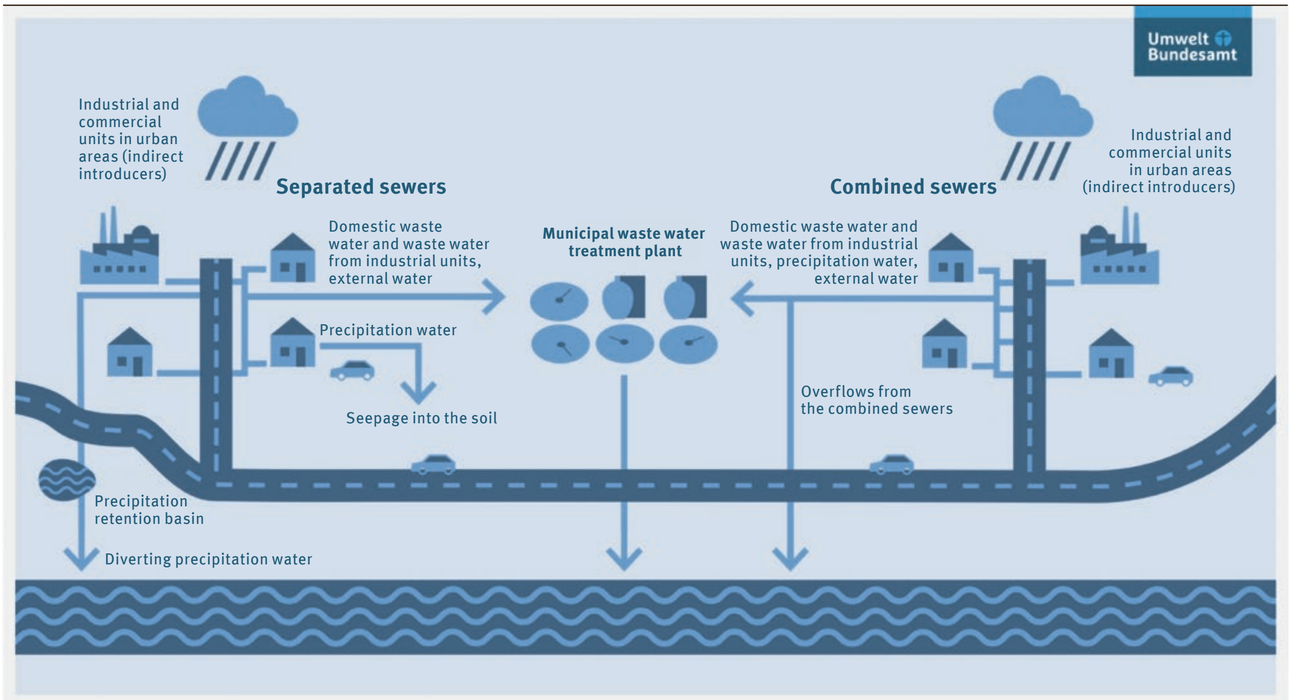
Waste water treatment in Germany
Urban waste water, meaning domestic and commercial waste water (sewage) and external water (groundwater flowing into the sewer system), as well as water flowing from fixed surfaces in inner-city areas, are collected in the sewer system. In the sewer system, we differentiate between separated sewers and combined sewers[12]. Both systems can be found in Germany in similar amounts. In Germany, urban waste water treatment plants treat around five billion cubic metres of domestic waste water each year. In addition, they treat around two billion cubic metres of water from precipitation as well as the same quantity of external water[13]. Over 96 percent of households in Germany are connected to the public sewer system.

12 In separated sewers, precipitation water flowing from sealed areas is collected separately, if applicable after a simple mechanical treatment, discharged into surface waters, while in combined sewers, the precipitation water is collected in the waste water canalisation and passes a waste water treatment plant together with the waste water. During heavy rain when the capacity of the waste water network is exceeded, the waste water from the combined sewer partially flows via bypasses to the water bodies directly and without passing a waste water treatment plant in order to avoid damage to the waste water treatment plant. This occurs less than 1 percent of the time annually, but affects an estimated 10 to 15 percent of the overall waste water quantity.

13 Own estimation

Figure 3

Schematic overview of the urban waste water system (own depiction)



source: German Environment Agency

Table 2

Waste water flows in Germany

Waste water flow	Type of treatment	Volume in million m³
Waste water (domestic/commercial)	Treated in waste water treatment plants	5080[a]
External water		2240[b]
Precipitation		2570[b]
Overall waste water quantity		9890
Storm water overflow	Not treated in waste water treatment plants, partial mechanical treatment	1310[b]
Discharge of precipitation water	Not treated in waste water treatment plants, partial mechanical treatment or natural processes[c]	3960[b]

a Destatis Fachserie 19 Reihe 2.1.2, Öffentliche Wasserversorgung und öffentliche Abwasserentsorgung – Öffentliche Abwasserbehandlung und -entsorgung, [Public water supply and public waste water drainage – public waste water treatment and disposal] 2013, Statistisches Bundesamt, Wiesbaden 2015
b Own estimation
c Trenches, rainwater retention basin

source: German Environment Agency

Plastic can consequently get into the environment through four different pathways from the **urban waste water systems**.

- Via **effluent of waste water treatment plant** if treated waste water is drained into water bodies or used for irrigation. The predominant part of the plastic present in the untreated waste water is removed beforehand and can be found in the sewage sludge;
- Via **mixed waste water** when mixed water from treatment plants is discharged into the surface water during stormwater events to prevent damage to the sewer infrastructure (channels, pumps, treatment system);
- Via the **untreated precipitation water,** if rain-water gets into surface waters from the separated sewer – mainly without effective treatment;
- Via the **sewage sludge**, if this is used in agriculture, landscaping and for recultivation, plastics removed from the waste water in the treatment plant end up on and in the soil (see chapters 2.2 and 3.1.2).

Suitable and robust investigation methods which can determine the overall content have been available for all four entry pathways for just a short while (see also chapter 1.2). For this reason, the measurement data which was available until now only allows statements which must be made through plausibility considerations. At the moment, the German Environment Agency is running various research projects to be able to improve the data situation and make valid statements based on this.

How big is the problem?

It can currently be assumed that the waste water treatment plants of size classes 4 and 5[14] corresponding to the legal requirements remove over 90 percent of the introduced solid substances (filterable substances). After mechanical treatment, where large particles (also including micro and macroplastic) are removed in a sieving process, depending on the region or catchment area, between 600 and 1,000 mg of suspended solid per litre remain in the waste

14 256 waste water treatment plants of size class 5, meaning with an expansion size of more than 100,000 population equivalents treat almost half of the urban waste water. Treatment plants of size class 4 with an expansions size of 10,000 to under 100,000 population equivalents then treat a further 41 percent (4,100 million cubic metres).This means that around 90 percent of the waste water generated is treated by plants of size 4 and 5. These systems are technically well equipped, including biological treatment.

water. The contents in the effluents of suspended solids **in the waste water treatment plant** are predominantly in the one-figure milligram per litre range[15]. Among these suspended solids making their way through the waste water treatment plant, plastic only makes up a very small amount. Initial investigations of the German Environment Agency of waste water treatment plants indicate contents considerably lower than one percent plastic in relation to the suspended solids in the treatment process. These findings are generally confirmed by other studies. The treatment in the waste water treatment plants therefore works effectively, the entry of plastic into the environment here when compared with other sources is rather low – **treated waste water** should therefore be considered less of a priority in relation to further measures.

By comparison, **combined water overflows** into the environment are more problematic. Here, during heavy rainfall, untreated waste water gets directly into the surface waters as the uptake capacity of channel systems and treatment plants is not sufficient. The drainage of **precipitation from the separated sewers** is not ideal, as critical substances (tyre wear, etc.) are very inadequately removed. With advancing climate change, it could be assumed that heavy rain events and thus also the overflowing of combined water will further increase.

In addition, plastic gets into the environment via **sewage sludge**. It is used in agriculture, landscaping and in recultivation as a fertiliser. Secondary raw material fertilisers, like sewage sludge, are subject to the law on fertilisers, which also stipulates a limit value for plastics (see chapter 3.1.2). Over the last few years, the proportion of sewage sludge being used as fertiliser has significantly degreased. This positive trend will continue, thanks to the new Sewage Sludge Ordinance[16] from 2017.

What is the UBA doing and what is its aim?

In order to be able to investigate and compare individual waste water treatment plants, **investigation concepts** must be developed – in particular with regard to a representative sampling. This is the only way that valid assessments can be made about how much plastic is finding its way into the environment via the individual pathways, which, in turn, is a basis for reduction measures. In addition, research is currently being done which deals with plastics remaining in the waste water treatment plant, and also with combined water overflows, and how these research results can be implemented in law and practice. The UBA has commissioned various institutes and scholars with carrying out these research projects, but is also actively participating in several research projects within the **BMBF research focus „Plastic in the environment“** (RUSEKU[17], ENSURE[18], SUBμTRACK[19]).

In order to reduce the entry of plastic (and other substances) into water bodies from combined water and rainwater, **new systems (rain overflow basins)** are currently being built **to store and treat** the water. The UBA is committed to further expanding such storage basins.

15 Barjenbruch, Matthias 2018: „Mikroplastik in der Siedlungswasserwirtschaft [Microplastics in the household water management system]“ presentation at the DWA seminar in Bad Hersfeld on 14/11/2019

16 See https://www.umweltbundesamt.de/publikationen/klaerschlammentsorgung-in-der-bundesrepublik
17 See https://bmbf-plastik.de/verbundprojekt/submtrack
18 See https://bmbf-plastik.de/verbundprojekt/ruseku
19 See https://bmbf-plastik.de/verbundprojekt/ensure

3.1.4 Microplastics in washing and cleaning agents and cosmetics

Primary microplastics in washing and cleaning agents and cosmetics should be legally prohibited as it is technically not necessary and can easily be replaced.

Primary microplastics are added to cosmetic products or washing and cleaning agents (detergents) as abrasive materials or opacifiers. Abrasive materials are used in toothpaste and exfoliants, opacifiers give cosmetics their colour and ensure that shower gels are not transparent, among other things.

How big is the problem?

The microplastics added to cosmetics and washing and cleaning agents can get into the environment after use via the waste water stream and may harm, for example, aquatic species. However, the amount of microplastics from detergents and cosmetics that are released into water bodies via waste water is comparatively low. A large proportion of the microplastics contained within the waste water before treatment are eliminated via sewage sludge in a treatment plant (see chapter 3.1.3). Even though it is known, according to a survey carried out on behalf of the German Environment Agency (Essel et al. 2015) that significantly larger quantities of microplastics find their way into the environment via other sources such as tyre wear, the UBA considers the elimination of microplastics in detergents and cosmetics as necessary, because this form of microplastic contributes to the impact on the environment, too and is also technically not necessary or can be replaced with other substances with better environmental properties.

What is the German Environment Agency doing and what does it call for?

The manufacturers of washing and cleaning agents and cosmetics can contribute to a reduction of microplastics introduced the environment by avoiding the use of primary microplastics, as they have already done to some extent. For many products, these can be replaced by suitable **substitutes** with comparably better environmental properties. For example, natural substances, such as bran or nutshell granules, are already used as biodegradable substitutes. Furthermore, mineral compounds such as sand can be used.

What is not a microplastic?

In cosmetics and washing and cleaning agents, other synthetic polymers are used for various technical purposes that are, however, water-soluble as opposed to microplastics. In this way, shower gels use acrylic acid copolymers as film-forming agents, for example. Some environmental organisations/NGOs also consider these water-soluble polymers as microplastics. However, these water-soluble polymers do not exist as solid particles in the products. Soluble substances such as acrylic acid copolymers therefore do not fall under the definition of microplastics as defined above.

Unlike insoluble solid microplastic particles, the hazard and risk of water-soluble synthetic polymers can be assessed individually for each polymer according to the requirements of chemicals legislation, as tests to determine the ecotoxicity of polymers to fish, daphnia and algae that are required under REACH and CLP regulations can be carried out thereby allowing an evaluation of their behaviour in the environment. Furthermore, physical damage to the gastrointestinal tract and the blocking out of food are not a concern, as this requires a substances to be in a solid state. For each water-soluble synthetic polymer, an individual hazard assessment based on the available ecotoxicity data, degradation data and exposure data should be carried out by the manufacturer of the polymer. However, as polymers are not subject to the registration obligation in accordance with the REACH regulation, almost no data is available.

Regardless of this differentiation in the definition, cosmetics and washing and cleaning agents should not contain persistent substances, or at least as few as possible. Consumers should therefore favour products which do not contain these substances, or contain them only in small quantities. The German Blue Angel label, as well as the EU ecolabel or other trustworthy labels/seals can help selecting the right products.

In a first step, the BMU and UBA have reached an agreement with the cosmetics industry about a **voluntary withdrawal of microplastics** within abrasive products such as exfoliants and toothpaste. Toothpastes are already free from microplastics. For other products, the use of microplastics in the EU was already reduced from 4,360 tons to 700 tons in the years 2012 to 2015. The voluntary approach shows a significant effect, though a further reduction is deemed necessary. For this reason, additional products should be included in a second step, such as hair setting spray, shampoos or shaving foam. The UBA also recommends to consider washing and cleaning agents, where microplastics are frequently used as opacifiers.

In the view of the UBA, a general **ban on intentionally added microplastics** for these product groups is the most effective way of reducing its entry into the environment.

A withdrawal should take place through harmonised regulations on banning the use of microplastics in cosmetics and washing and cleaning agents across Europe. A binding regulation at EU level would provide clarity for the manufacturing industry as well as for consumers. For this reason, the European Chemical Agency (ECHA) examined the possibility of a ban of intentionally added microplastics in products of all kind within the framework of the EU plastic strategy on behalf of the European Commission as well as of the so-called „oxo-degrative plastics“ within the framework of the regulation (EC) no. 1907/2006 on the registration, evaluation and authorisation of substances (REACH) and published a respective dossier on a restriction proposal on 30 January 2019[20]. This restriction under REACH would also cover cosmetics and washing and cleaning agents, among other things.

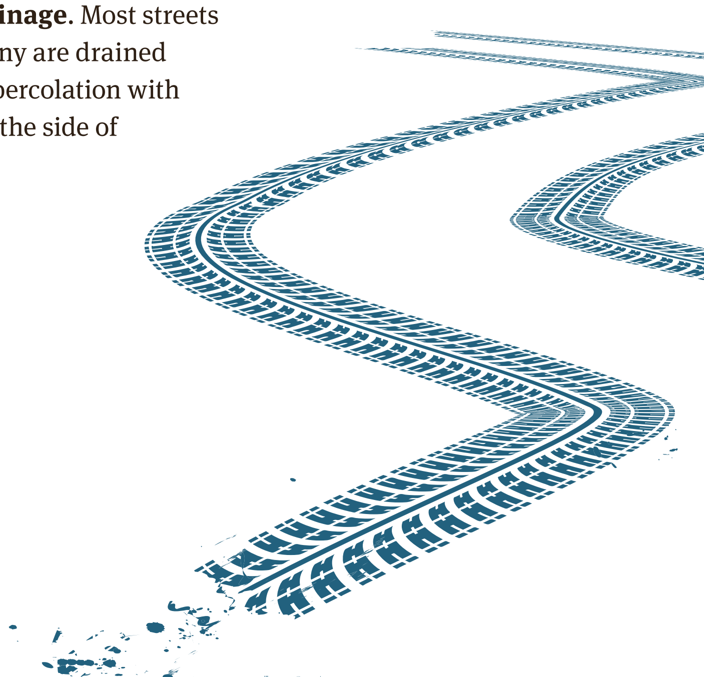
3.1.5 Tyre and road wear

Tyre and road wear are a relevant source for plastics in the environment. However, the precise distribution pathways and possible countermeasures are still unknown.

Tyre wear occurs through friction between the tyre and the road surface, where particles are frequently released from both. Consequently, this is usually wear from both, tyre and road. The former is the largest source of dust emissions from service modern vehicles. These dust emissions from tyre wear primarily (approx. 40 percent) consist of plastics. As particulate matter, these particles damage human health, specific effects of airborne plastics on ecosystems have not been proven so far (see also chapter 2.3). Overall, the share of tyre wear in the national particulate emissions is three to four percent, according to a current UBA study.

The airborne fraction of particles (TSP, total suspended particles) from tyre wear with particle diameters of less than approx. 30 micrometres initially remain entirely in the air, can be transported over long distances and washed out by rain and therefore get directly into bodies of water and the soil. Unlike pollutant emissions from vehicle exhausts, dust from tyre wear also contains sedimentable particles with larger particle diameters, which immediately settle to the ground or do not get into the air at all. In total, a total tyre wear of around 100 kilotons per year is estimated, of which around 10 percent are airborne particles (TSP).

The direct effect of the sedimentable dust fraction on **water and soil** depends on the **road drainage**. Most streets in Germany are drained through percolation with verges at the side of the road.



20 See https://echa.europa.eu/registry-of-restriction-intentions/-/dislist/details/0b0236e18244cd73

However, for streets drained by sewer systems (mainly inner city), the retaining effect highly depends on the respective rainwater treatment plants. It is necessary to differentiate between separated and combined sewer systems (see chapter 3.1.3). In separated sewers, usually only very simple mechanical treatment processes are used (e. g. filter baskets, soaking pits, etc.). It has not yet been investigated to what extent retention occurs here.

How big is the problem?

According to a study by the Federal Highway Research Institute from 2010, the overall tyre wear quantity in Germany is around 111,420 tons per year. The largest fraction is made up of **rubber and polymers with around 43,000 tons** and soot with around 38,000 tons. The emitted quantity of metals of 1,375 tons per year mainly consists of zinc.

These numbers estimate the primary emission through tyre wear. Due to the high sedimentable fraction of tyre wear, a large portion of the mass of the overall wear remains close to the source as described above. Wear from tyres gathers, inter alia, directly next to the streets. There, it results in reduction of the run-off water off the streets, which is a potential threat for traffic safety. Therefore, the green verge next to the roads is regularly removed, or „stripped off". This creates a sort of verge peeling. The stripped off material is either deposited next to the verges or also disposed in individual cases. It is assumed that large parts of the tyre wear can be found in the verge peeling which is regularly removed. Consequently, a large part of the tyre wear does not ever reach the **air** or the **soil and water**.

It is therefore expected that the sedimentable fraction of tyre wear not removed via verge peeling directly enters the soil, or the water and sewers via rainwater. Here, especially the waste water in the separated sewers is to be critically assessed – plastic from tyre wear can directly enter the environment via this route. Entries from combined waste water from inner city drainage plants lead to accumulations of tyre wear in sewage sludge of treatment plants. This is already proven for a few of the substances (see 3.1.2).

What is the German Environment Agency doing and what does it call for?

There are barely any effective short-term measures for reducing particulate matter caused by tyre wear. A direct reduction would be possible if more streets were wet-cleaned to reduce the swirling up of particulate matter into the air. This can be carried out immediately by the municipalities.

Less traffic in general would, of course, also reduce the direct particulate matter emissions, though this kind of appeal to the public has not been successful until now. For this reason, it is important to introduce **legal measures to limit particulate matter emissions caused by tyre wear.** To do so, first it is necessary to have a standardised measurement methodology. This is already being developed at an EU level. A limit of the emission with regard to the particle number and the particle mass is advisable. It is also highly necessary that no rebound effects are created with a legal regulation. First and foremost, noise emissions and the safety of vehicles should not be negatively influenced by the introduction of such legislation. The context of this is, for example, that the noise emission tends to increase when wear is reduced. In addition, the number of particles must be limited covering the whole size range so that there is no evasion to other particles sizes.

For the emission of tyre wear particulate matter, and thus plastic particles, there are currently no technical efforts to develop reduction technologies on the vehicle itself by the tyre manufacturer or the automobile industry. In this context, this was referenced in the BMBF project RAU[21] in which the company Continental participated, which is not, however, viewed as an active contribution to reducing emissions. Legal requirements have been lacking until now. The development of the corresponding technologies is technically challenging and expensive. It would be conceivable to use **modified plastic mixtures**, for example. This was referenced in the thematically

21 See https://bmbf-plastik.de/verbundprojekt/rau

related BMBF project RAU[22] in which the company Continental participates, and which tackles the tyre wear present in road areas.

The German Environment Agency actively participated in one of the Federal Ministry of Education and Research (BMBF) funded research projects (Optimised materials and processes for the removal of microplastics from the water cycle – OEMP) where special filter systems to filter the street run-off water in the drain duct were investigated.

The German Environment Agency sees a need for research in particular in the area of the detection of particle number and particle mass from tyre wear. These research activities would need to be carried out on vehicle test facilities. In order to make valid statements on the pollution inputs and occurrence of tyre wear, reliable analytical methods are required. The UBA is involved in establishing these (see chapter 1.2).

22 See https://bmbf-plastik.de/verbundprojekt/rau

3.2 Sources and entry routes from the sea

3.2.1 Shipping and fishing

Plastic litter in the oceans comes from various land-based and sea-based sources – regional differences must be taken into account to take the correct measures.

The UNEP defines marine litter as „elements manufactured by or processed by humans“ (UNEP 2005). Globally, marine litter largely comes from land-based sources, and the rest comes from sea-based sources. The sources vary depending on geographical location. The quantities and composition of marine litter can also differ significantly. They are influenced, for example, by urban and industrial areas, ports, shipping routes or fishing regions (Galgani et al. 2015). Although litter found in the oceans is made up of many materials including metal, wood, rubber, glass and paper, the material which is found by far the most frequently, at 75 percent, is plastic. As well as large pieces of litter such as plastic bags or bottles, pieces of microplastics are also regularly found in water bodies, sediments and marine organisms. These occur through the decomposition or wearing of large parts, but are also added directly to products.

In the following table, the sources of microparticles from plastic in Germany which can potentially enter the (marine) environment are listed (Essel et al. 2015).

How big is the problem?

On the German beaches of the **North Sea**, 51 percent of the litter found comes from see-based sources, above all from shipping and fishing (Schernewski et al. 2018). In the overall north-east Atlantic observation area (including the North Sea), a further approx. 40 percent of litter comes from leisure and tourism activities and from community areas. This is litter (primarily plastic) which has carelessly been tossed and ended up in the sea via rivers and canals and via industry and treatment plants (OSPAR Intermediate Assessment 2017).

The situation is somewhat different for the **Baltic Sea**: On the German beaches of the Baltic Sea, most of the litter comes from tourism and leisure activities (50 percent), followed by waste water (25 percent), shipping (ten percent) offshore installations of wind turbines, for example (eight percent) and fishing (seven percent) (Schernewski et al. 2018).

Table 3*

Potential sources for the entry of microplastic particles into the marine environment (Essel et al. 2015)

Sources of microplastic particles in Germany	Quantification of the sources in tons of microplastic per year
Primary microparticles	
Cosmetics	500
Washing, cleaning and care products for commercial and industrial use	‹100
Abrasives for blasting surfaces	‹100
Micronised synthetic waxes in technical applications	100,000
Secondary microparticles	
Fragmentation of plastic waste	Unknown
Synthetic chemical fibres from articles of clothing and other textiles	80 to 400
Loss of pellets in the manufacturing and further processing of plastic	21,000 to 210,000
Tyre wear	60,000 to 111,000

* Micronised plastics are finely powdered, homopolymer waxes which can be used in diverse applications. The vast number of different applications, the lacking basis of data for the overall production quantity and the percentage proportions of applications mean that no precise details can be given on the entry quantity and whether and for how long this remains in the environment, and therefore on environmental relevance.

In general, approximately ten percent of the marine litter come from lost or intentionally discarded fishing equipment (above all nets but also dolly ropes (chafers from trawling nets), ropes, cords, fish traps etc.). According to an estimate from the WWF, in 2011 alone, 5,500 to 10,000 anchored nets were lost in the Baltic Sea. These so-called ghost nets remain a deadly hazard over decades, particularly for marine mammals, sea birds and fish. Most of the nets sink to the sea floor, but they can also remain set up there and, in some cases, continue to „fish“ for long periods of time. Studies show that the remaining fishing capacity of abandoned nets is six to 20 percent of what they catch in active use (WWF Poland 2011).

Data from the **Fishing for Litter initiative** confirm the relevance of the fishing entry pathway. Around 150 fishermen from 15 German ports on the North and Baltic Seas are currently taking part in the initiative. The marine litter caught alongside the fish is collected on board in so-called big bags and can then be disposed of in containers at ports with no charge to the fishermen. More than 75 percent of the „fished“ waste are products made from plastic. This is mainly foils, packaging, net remains and rigging (Gerke et al. 2017).

What is the German Environment Agency doing and what does it call for?

The UBA is working intensively on determining and defining the essential land and sea-based entry sources of marine litter within the framework of the **EU Technical Group on Marine Litter** (see also Veiga et al. 2015), the **regional marine protection agreement HELCOM and OSPAR** (see also Verschoor et al. 2017), the national **MSRL Fach-AG Marine Waste** as well as through the implementation of its own R&D projects. Based on the available findings, the UBA has identified the following measures as necessary to reduce the entries from sea-based sources (measures regarding land-based entries can be found in other chapters, particularly chapter 3.1):

- Within the framework of the revised directive on port reception facilities (2000/59/EC), the already intended complete **incorporation of waste disposal fees into the port fees** to be paid should be firmly anchored. This no-special-fee system is already best practice in many ports in the Baltic Sea;
- **Inspections and checks at sea** should be stepped up to curb illegal dumping into the sea and the corresponding sanctions for violations should be strengthened;
- **Digital marking and other technical measures** should be used to find and recover lost and abandoned fishing nets. Finding and recovering fishing equipment should be promoted economically and organisationally in general;
- The topic of marine litter should be firmly anchored in the **professional training for shipping and fishing**.

4

Overarching approaches

4.1 Product design

The entry of plastic into the environment can already be prevented with the design of a product.

Products cause environmental effects over their whole lifespan – around 80 percent of these effects are already determined during the design phase. For the most part, the potential entry of plastic into the environment is not considered in the design of a product at present. This presents great opportunities to set the course for avoiding discharges of plastic into the environment, but also to recycle more and close material cycles.

How big is the problem?

The design of some products increases the probability that they or their components will end up in the environment due to littering (see chapter 4.2). This includes **packaging where small items of waste are created when they are used** – for example tear-off corners of sweets wrappers, loose bottle caps or drinking straws which are wrapped in foil. The small nature of such waste frequently leads to them not being picked up during clean-up measures and then remaining permanently in the environment.

Furthermore, the trend is towards **smaller portioning and packaging sizes** to meet the increasing number of single households and to make particularly comfortable consumption possible. In the end, this leads to more material being used and thus also more waste. Out-of-home consumption is also increasing and with it the amount of to-go packaging for which the probability of an entry into the environment is increased. The trend of **oversized** (e.g. electronic products) and **excessive packaging** (e.g. for fruit which is sufficiently protected by its skins or peels) can also be observed. Reasons for this are given as, for example, better protection against thieves or longer shelf life of foodstuffs.

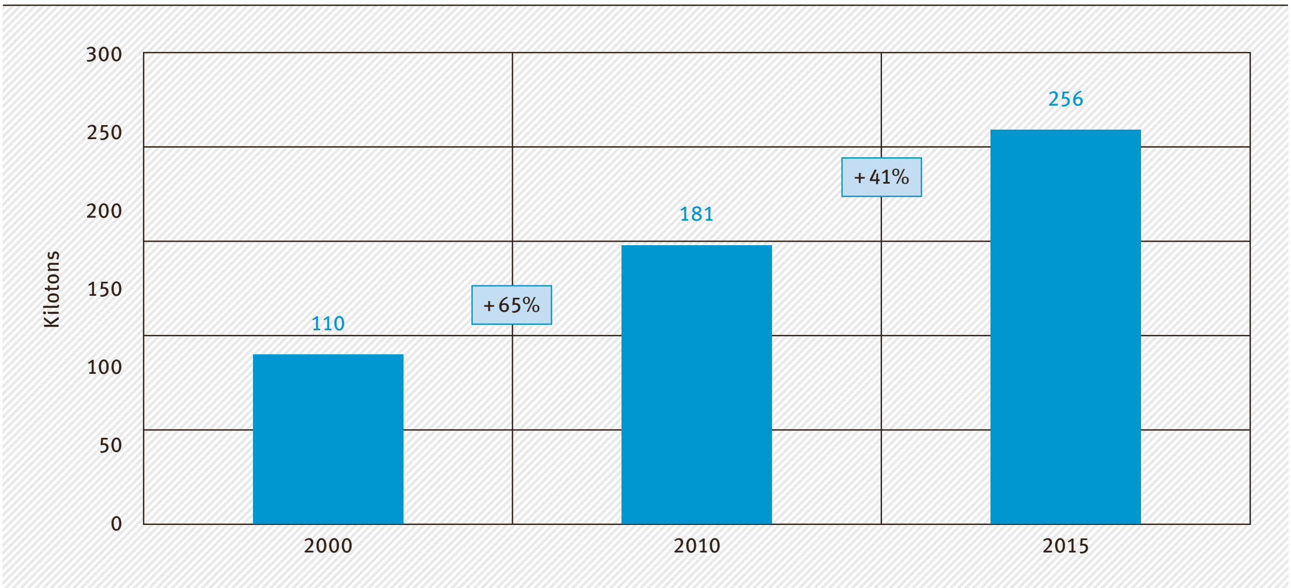
A further example for the effects of product design is the use of microplastics in cosmetics and washing and cleaning agents which can reach the environment via the waste water route (see UBA 2016a) (see chapter 3.1.4).

What is the German Environment Agency doing and what does it call for?

Waste which is not generated cannot enter the environment. For this reason, the UBA is call for **product design** generating as **little waste as possible**. This does not only prevent the entry of plastic into the

Figure 4

Consumption of service packaging in the food industry



source: Gesellschaft für Verpackungsmarktforschung mbH environment, but also helps conserve resources. Aspects such as shelf life, reusability and repairability are therefore important characteristics which are decided over in the design phase.

The promotion of closing cycles indirectly leads to a reduction of plastics entering the environment. The ability of a product to be **recycled** should be supported by the design as a basis for high-quality material recovery. Section 21 of the Packaging Act offers an incentive for this, as it stipulates that the participation fees in the dual system be coupled with the recyclability of packaging. This means that manufacturers should pay lower fees for recyclable packaging than for non-recyclable packaging.

Activities are currently being carried out at an EU level to be able to place requirements on the recyclability of products within the framework of the **Ecodesign Directive**. The **EU strategy for plastics in the recycling economy** (see EU Commission 2018) also aims at ensuring a longer shelf life, better reusability and the possibility of high-quality recycling with the design of plastic products. This also requires a **product design as pollutant-free as possible**. The use of **recycled plastics** should also be taken into account in the product design phase. In accordance with the EU plastic strategy, ten million tons of recycled plastic should be used in new products on the EU market before 2025 – this is a more than threefold increase compared to today and corresponds to around 20 percent of the current demand for plastic.

The UBA is promoting environmentally-friendly product design – for example with the **ecodesign Bundespreis** (UBA 2016b) – and is revising the basis for awarding the Blue Angel environmental label, which distinguishes particularly environmentally-friendly products. It consequently offers consumers valuable support for conscious purchasing decisions, for example for office supplies made from recycled plastics[23].

The use of compostable and biodegradable plastics is also not an environmentally-friendly solution for the problem of plastics entering the environment. Quick biodegrading requires defined conditions. However, these are not the predominant conditions in nature, or not consistently so. Degradation processes that can work in industrial composting plants cannot be guaranteed in the forest or at sea (UBA 2017). You can find more information in the recently published research project by the UBA on treating biodegradable plastics.[24]

23 You can find more information here: https://www.blauer-engel.de/en/products/home-living/recyclingkunststoffe-abfallsaecke-muelltonnen-bueroartikel/products-from-recycled-plastic-edition-march-2016

24 Survey on the treatment of biodegradable plastics. Download at: https://www.umweltbundesamt.de/publikationen/gutachten-zur-behandlung-biologisch-abbaubarer

4.2 Putting a value on plastics

Conscious handling of plastic reduces consumption and its potential entry into the environment.

We often attribute less value to plastic than we do to other materials. Plastic products are often more inexpensive than their counterparts made from wood or metal. In addition, plastic is also used for single-use products which are disposed of immediately after a short use. For this reason, consumers get the impression that plastic and the products made from it are of low value. This applies in particular to everyday consumer items, especially when they are characterised by a short lifespan or used for free products such as marketing materials (giveaways). Plastic is a **highly complex material that takes a great deal of effort to produce**. There are numerous useful and high-quality plastic products which are robust and durable and contribute to a saving of material, energy and carbon dioxide emissions during their usage phase (e.g. insulation, lightweight construction applications).

How big is the problem?

The tendency to use products just for a short while and then replace them with new ones („throwaway mentality") is encouraged in particular by this low appreciation of products made from plastic. A further effect is the careless handling of plastic waste.
In spite of the available disposal infrastructure, plastic waste is a frequent and visible problem in the environment. Above all, these are things with a very short usage phase which end up in the environment through careless tossing away or leaving behind (littering): Studies on waste in public areas (see, for example, Heeb et al. 2004 and Breitbarth and Urban 2014) as well as the drift line monitoring on the North and Baltic Seas show that, beside cigarette butts, especially packaging, such as drinks and sweets wrappers or those for outside consumption, are left in the environment above all. Plastic waste dominates the findings. Part of this waste is collected through community or municipal clean-up measures and disposed of properly, another part, however, remains in the environment, in particular in areas where there are no regular clean-up measures (e.g. on beaches which are not used for bathing). We do not know at this time how large the quantity of plastic waste is which remains in the environment in Germany.

What is the German Environment Agency doing and what does it call for?

One UBA study is currently following up on the question of the **volumes of plastic waste which remain in the environment even after clean-up measures**. Recommendations for possible reduction measures should be derived, based on these first empirically founded estimations.

In principle, we should promote a conscious handling of plastic products. Here, the UBA is committed to raising public awareness – for the purchasing of high-quality plastic products and avoiding single-use products. Plastic products should be used for as long and as frequently as possible and, of course, disposed of properly at the end of their service life so that they can be recycled as far as possible and be available for a new purpose[25].

In specific terms, the UBA is seeking to promote the strengthening of sustainable consumption as well as the **reusability of products and the ability of products to be repaired**. In a UBA research project, it is currently being researched how the increasing waste quantities of single-use coffee cups can be counteracted. In a further UBA research project, measures and approaches for reducing the littering with various products in public areas are being established based on a determination of the current situation. The national programme of measures for the aspect of marine litter within the framework of implementing the marine strategy framework directive has the goal of developing municipal and administrative requirements for avoiding or limiting single-use products in coastal communities. The Hanseatic city of Bremen is leading this programme.

The use of products made from **recycled plastic** also makes a valuable contribution to the plastic recycling economy. In order to promote the transparency of the

25 These measures are in-keeping with the recently published legislative suggestion of the EU Commission on the reduction of the effects of specific plastic products on the environment. This envisage the promotion of measures for better information about handling single-use plastic products as well as bans for single-use plastic products which are particularly common as litter on European beaches (e.g. straws or stirrers). Furthermore, the Commission expects more responsibility for the manufacturer who must ensure better disposal, for example, or ensure that they indicate any harmful environmental impact if their products are not disposed of correctly. Consumers should also be informed about the available multi-use systems with the aim of preferably using these. You can find more information on the legislative proposal at http://europa.eu/rapid/press-release_IP-18-3927_en.htm.

use of recycled plastic, the Blue Angel environmental label distinguishes products which are made up of at least 80 percent recycled plastic in their finished product (RAL UZ 30a)[26].

The national MSRL measures programme for the marine litter aspect intends to anchor **the topic of marine litter into teaching targets, teaching plans and materials.** Raising awareness among children and young people in particular is an important step towards a sustainably enlightened society with regard to avoiding waste and preventing waste from entering the environment. But educational measures within relevant sectors such as plastic production, processing and recovery or fishing and shipping are also indispensable. Some educational materials and modules have already been developed for this purpose. More are in the planning stages.

In contrast, the use of compostable and biodegradable plastics does not present an environmentally-friendly solution for the problem of plastics entering the environment. With the corresponding certification these types of plastics can be broken down under defined conditions in industrial composting facilities. However, these are not the predominant conditions are not common in nature, or not consistently so, which means that complete biodegradation is not guaranteed (UBA 2017). The UBA recently published a research project on the treatment of biodegradable plastics[27].

For the promotion of a conscious handling of plastic and the avoidance of plastic entering the environment, the UBA suggests the following measures:

- **Raising awareness through public relations work**, such as information campaigns and the provision of educational materials to promote the conscious handling of plastic products and plastic waste. In particular, this includes raising awareness with regard to possible reusable alternatives for (plastic)single-use products (the avoidance of waste), the proper disposal of plastic waste and the consequences of plastic waste in the environment, as well as education about biodegradable plastics;
- **Introduction of deposit and return systems to promote waste avoidance and to reduce littering.** At the same time, clean and recyclable plastic flows can be generated in this way (e. g. deposit systems for single-use bottles). At large events or if there is a high regional use of single-use food serving utensils in outdoor areas (e. g. in areas used by tourists), these should only be given out against a deposit, provided these cannot be replaced by multi-use alternatives. Furthermore, a deposit system is also conceivable for plastic fish boxes;
- The breaking down of barriers (e. g. hygiene requirements) by the legislator to increase the **use of personal containers** during the purchasing process for food and drinks as a very effective measure to avoid packaging;
- **Avoiding the use of single-use portion packaging** in catering facilities, particularly outdoors, through voluntary agreements or legal requirements;
- Increasing the use of **products made from recycled plastic** as a valuable contribution to the recirculation of plastics and thus to saving valuable resources.

A few of these measures could be implemented within the framework of the EU directive on reducing the effects of certain plastic products on the environment (so-called single-use plastic product directive).[28]

26 You can find more information here: https://www.blauer-engel.de/en/products/home-living/recycled-plastics-waste-bags-garbage-bins-office-supplies/products-from-recycled-plastic-edition-march-2016.

27 Survey on the treatment of biodegradable plastics. Download at: https://www.umweltbundesamt.de/publikationen/gutachten-zur-behandlung-biologisch-abbaubarer

28 More information at: http://europa.eu/rapid/press-release_IP-18-6867_en.htm.

5

Conclusion and overview

Most of our data on plastics in the environment currently available comes from the marine environment. Its occurrence in coastal waters has been known and described since the start of the 1970s. There are also a few findings from rivers, lakes and the soil.

Measures for reducing the use of plastics and avoiding the entry of plastic into the environment in Germany can and must be taken now, even as a precaution. These must in part go beyond the national level and also be applied at a European level and, in a few cases, also at an international level.

A major challenge for the assessment is that we currently do not have available a sufficient and harmonised investigation methodology (sampling, preparation of samples, detection) and, as a consequence, consistent data that would be collected with such harmonised methodology. With thermo-analytical procedures, mass contents of the occurring plastics can be determined, and spectroscopic processes can be used for particle numbers and sizes. However, we do not have assessment concepts for all environmental media. This means that questions are left open in the assessment of the relevance of plastic finds for the environment and human health, and in the state of knowledge about the behaviour of plastics in the environment. Here, there is still a need for further investigation and research.

With regard to harmonised investigation methods for monitoring, material flow balances, environmental assessment concepts, material requirements in directives or ordinances as well as the derivation and success monitoring of environmental and political measures, overarching efforts must be made. These include:

- The establishment of suitable sampling strategies and procedures and overarching chemical investigation methods for the various environmental media and potential entry pathways with a clear limitation of the significance of the methodology used (including analytical result, object of investigation);
- The establishment of internationally recognised monitoring requirements and investigation methods through European and international standardisation bodies (CEN, ISO) or other suitable globally active institutes and expert groups, as the topic of plastic in the environment is an international matter with global distribution patterns;
- The development of assessment methods by authorities to assess the impact situation of plastics on the environment;
- The establishment of ecotoxicological testing methods for microplastics by the OECD to record the overall effect and possible hazard potentials;
- The establishment of human toxicological testing strategies for microplastics by authorities and research for recording the overall effect and possible hazard potentials.

The following presents an overview of the measures recommended by the German Environment Agency in the various areas.

German Environment Agency recommended measures

AREA

Occurrence and effects of plastics – dissolved as well as particles – in drinking water

MEASURE RECOMMENDATIONS

- The development of measures to investigate the occurrence of microplastics in drinking water by authorities, supported by research
- The investigation of the remaining and retention of very small plastic particles and the risks of them breaking through the barriers in drinking water production and treatment
- Investigations by manufacturers, the UBA and other authorities (e. g. EFSA) on the release of free pieces of plastic from materials in contact with drinking water, in particular monomers from the breakdown of polymers and additives
- The enforcement of effective regulations for plastics in contact with drinking water within the framework of the current revision of the EU Drinking Water Directive

AREA

Occurrence and effects of plastics in inland waters

MEASURE RECOMMENDATIONS

- The establishment of standardised monitoring methods and an impact-related basis for assessment for plastics in inland waters
- The establishment of a monitoring procedure to account for large watercourses (e. g. Rhine/Danube)
- The improvement of the data situation through joint activities of the Working Group of the Federal States and the Federal Government on Water Issues (LAWA), soil protection (LABO), waste (LAGA), the Federal States and the Federal Government Working Group on Waste water as well as the Federal Committee for Air Pollution Control (LAI)

AREA

Occurrence and effects of plastic in ocean waters

MEASURE RECOMMENDATIONS

- The development of monitoring methods for the long-term monitoring of the impact of marine litter on various sea compartments and organisms (including monitoring processes for plastics/microplastics) within the framework of implementing the EU Marine Strategy Framework Directive
- A determination of base lines and deriving ecological limit values for the assessment of the marine condition by the EU Technical Group on Marine Litter
- Investigating the potential transfer of chemical substances (additives) and harmful substances contained within plastics which accumulate from sea water within the marine food chain
- Support for an ambitious implementation of the action plans against marine litter from the Marine Litter Round Table in Germany OSPAR, HELCOM, G 7 and G 20

AREA

Occurrence and effects of plastics in the soil

MEASURE RECOMMENDATIONS

- The development of methods to investigate the occurrence of plastics in the soil
- The investigation of the relevant entry pathways of plastic fractions into the soil
- Quantifying the resulting material flows
- The development of assessment methods with regard to possible ecological effects in the soil itself and for the soil-groundwater and – if possible – the soil-soil organisms pathways

AREA

Occurrence and effects of plastics in the atmosphere

MEASURE RECOMMENDATIONS

- A reduction of the particulate matter emissions from tyre wear as a general contribution to a reduction of particulate matter pollution through technological further developments

AREA

Entries of plastics via waste water

MEASURE RECOMMENDATIONS

- The development of monitoring methods for the reliable modelling of plastic entries via waste water, combined sewers and the introduction of waste water from separated sewers
- A reduction of the entry of plastics into the soil via sewage sludge through a further reduction of the use of sewage sludge in agriculture, landscaping and recultivation
- A reduction of the entry of plastics into bodies of water from combined sewers and rainwater introduction through the setting up of storage facilities and improved treatment facilities by states and municipalities

AREA

Entries of plastics via sewage sludge and composts

MEASURE RECOMMENDATIONS

- The introduction of a common limit value for all plastic impurities by the legislator, regardless of the particle size and type of plastic
- The development of a suitable measurement method by academia and the authorities to check the plastic content
- A reduction of the plastic impurities in organic waste, e. g. through increased awareness campaigns or the introduction of certified and labelled biodegradable organic waste collection bags and other suitable collection containers (e. g. wax-coated paper bags) from the respective disposal organisation
- The further development of technologies to separate foreign matter from organic waste in the waste sector

AREA

Entries of plastics via tyre wear

MEASURE RECOMMENDATIONS

- The development of suitable investigation methods
- The passing of measures for the limitation of particulate matter emissions from tyre wear by the legislator
- A reduction of tyre wear through technological further developments, e. g. changed plastic mixtures for tyres by the producers
- The definition of uniform standards across Germany by the legislator for the disposal of verge peeling

AREA

Entries of plastics via sea-based sources

MEASURE RECOMMENDATIONS

- The inclusion/integration of waste disposal fees into the port fees to be paid (no-special-fee) within the framework of the European Directive on port reception facilities (2000/59/EC)
- The stepping up of inspections/checks at sea and increasing the corresponding sanctions by the monitoring authorities to reduce illegal dumping of waste into the sea
- The organisational and economical promotion of digital marking and other technical measures to find and recover lost and abandoned fishing nets by the responsible body (federal and state authorities)
- The anchoring of the topic of marine waste as a fixed component in the professional training for the sectors which cause it, such as shipping and fishing, by federal and state authorities

AREA

Entries of primary microplastics via cosmetics and washing and cleaning agents

MEASURE RECOMMENDATIONS

- The enforcement of a general ban on microplastics among the product groups through EU-wide harmonised legal regulations on banning the use of microplastics in cosmetics within the meaning of the Regulation (EC) no. 1223/2009 and in washing and cleaning agents within the meaning of the Regulation (EC) no. 648/2004 or on the restriction of primary microplastics under the REACH regulation (EC) no. 1907/2006

AREA

Good waste management to avoid plastic waste entering the environment and closing material cycles

MEASURE RECOMMENDATIONS

- Raising awareness on the handling of plastic waste
- Increasing the level of plastic recycling
- Increasing the use of recycled products by increasing the demand, in particular through public procurement
- The thorough implementation of the Packaging Act which was brought into force on 1 January 2019 by the enforcement authorities
- Increasing the return of waste through the further establishment of deposit and return systems

AREA

Product design for the avoidance of plastic entering the environment and the promotion of material cycles

MEASURE RECOMMENDATIONS

- The promotion of product design generating as little waste as possible by taking into account aspects such as shelf life, reusability in a comparable quality and repairability through the corresponding requirements in the EU Ecodesign Directive and corresponding criteria in a suitable basis for awarding the environmental label „Blue Angel“
- Product design which counteracts the potential for littering (e. g. avoiding loose bottle caps or tear-off corners of sweets wrappers) through technological further developments

AREA

Promoting the conscious handling of plastic products

MEASURE RECOMMENDATIONS

- Raising awareness through public relations work, e. g. through information campaigns and the provision of educational materials by bodies at federal and state levels to promote the conscious handling of plastic products and plastic waste, in particular information regarding reusable alternatives for single-use products, the proper disposal of plastic waste and the consequences of plastic waste in the environment
- The introduction of more deposit and return systems by the legislator to promote the avoidance of waste and to reduce littering (as a consequence of the perception as waste with a value)
- Breaking down of barriers (e. g. reviewing hygiene requirements) by the legislator to increase the use of personal containers when purchasing food and beverages
- Avoiding the use of single-use portion packaging in the food industry, particularly outdoors, through voluntary agreements or legal requirements
- Increasing the use of recycled material in plastic products and the use of products made from recycled plastic by the consumer and public procurement by the federal, state and municipal authorities
- Working with the public to reduce the number of items wrongly thrown in with organic waste and improved monitoring of the entry flow in the collection of organic waste by the disposal organisation

The recommendations indicate the next steps for **identifying, avoiding and reducing plastics** in the environment which, in the view of the German Environment Agency, should be undertaken.

The availability of **data** on the characteristics of plastic and their effects in the environment and the availability of **monitoring methods** are also important for the success of this kind of avoidance and reduction strategy. Here, considerably more information is required than is available at the moment, also to be able to test and report on the success of the reduction measures.

In order to evoke understanding among decision-makers and the population for the corresponding measures, and to be able to establish them, it is important to continue to **raise awareness** for the topic of plastics in the environment and to **communicate** good approaches actively.

Table 4

Overview of German Environment Agency research activities on plastics in the environment

Topic area	Research activities	Research in the UBA (projects with third-party funds and own research)	Research on behalf of the UBA	Results expected within the year
Method development	The establishment of suitable sampling strategies and chemical investigation methods (determination of overall contents) for plastic and microplastics in water and waste water, as well as for treatment plants	X		2021
	The establishment of suitable sampling strategies and chemical investigation methods (determination of overall contents) for plastic and microplastics in the soil	X	X	2020
	The establishment of suitable sampling strategies and chemical investigation methods (determination of overall contents) for plastic and microplastics in organic waste as well as for composting facilities and fermentation plants	X	X	2021
	The impact assessment and establishment of a long-term monitoring system for the impact of marine litter (including plastic) on various sea areas and biota		X	2020
	The recording of the human toxicological overall effect and the recording of possible potentials for the hazards of microplastics in the water cycle, including clarifying the adsorption of harmful materials by microplastics	X		2019
The occurrence, behaviour and effects of plastics in the environment	Investigating the occurrence of microplastics in the model system of the Weser national park tidal mudflats	X		
	Investigations on quantifying the occurrence of plastics and microplastics in the Rhine and the Danube	X	X	2020
	Monitoring the impact of waste on German seas and coastal water and the ecological consequences		X	2018

Topic area	Research activities	Research in the UBA (projects with third-party funds and own research)	Research on behalf of the UBA	Results expected within the year
The occurrence, behaviour and effects of plastics in the environment	Assessing and quantifying plastic finds in fish in the North and Baltic Seas		X	2018
	Screening various soils for relevant plastics and microplastics (determining the overall content as well as individual compounds)		X	2020
	Investigations into the transfer of microplastics from the soil into the groundwater	X		2021
	Investigations into the degradation behaviour of various plastics in waste and waste water treatment plants	X		2021
Entry pathways plastics into the environment	Determining the quantities of plastic waste which remains in the environment even after cleaning processes		X	2019
	Approaches for action and measures for reducing littering		X	2019
	Ecological significance of single-use drinks containers and measures to reduce their use		X	2019
	The use of plastic products in the environment and determining the entries connected with these (including pipes, geotextiles, agricultural films, fireworks)		X	2019
	Researching the deficits in collecting old electrical and electronic appliances (containing plastic) and the disposal routes of improperly disposed-of old electrical and electronic appliances		X	2021
	Quantifying the occurrence of plastics and microplastics in waste water, water from separated sewers and combined sewer overflows	X	X	2021
	Investigating special filter systems for removing microplastics in urban water cycles (e. g. from drain ducts for street run-off water, combined sewers and treated water from treatment plants)	X		2018
	Investigating composts, digestates and sewage sludge for plastic contents including microplastics	X	X	2021
	Determining the technical potential of increasing the level of plastic recycling and the use of recycled material, approaches for increasing the use of recycled material and the demand for products containing recycled materials		X	2019, 2021

Glossary and list of abbreviations

Abrasion	The loss of material from the surface and wear of a solid body through mechanical stress.
Verge	The verge of a road is the part next to the part that is driven on in a road cross-section. Verges get bigger on their own due to road dirt and vegetation remains and are therefore usually milled off every 3 to 6 years.
Dalton	Dalton is the atomic mass unit, a measuring unit of mass. Its value is determined based on 1/12 of the mass of an atom of the carbon isotope 12C. It is not just used when stating atomic masses, but also when stating molecule masses.
External water	External water is water that infiltrates the sewer unintentionally (e. g. from the groundwater via unsealed channels), mixes with the waste water and flows together with it to the treatment plant.
HELCOM	HELCOM is an interstate commission of the states neighbouring the Baltic Sea based on the Helsinki Convention of 1992 for the protection of the marine environment in the Baltic Sea region.
Clear water	Treated water is called clear water.
Littering	Littering is carelessly leaving items behind or disposing of waste in nature and urban spaces.
MSRL	Marine Strategy Framework Directive (Directive 2008/56/EC of 17 June 2008 on establishing a framework for community action in the field of marine environmental policy).
OSPAR	OSPAR is named after both predecessors, the Oslo Convention and the Paris Convention and is a contract for the protection of the North Sea and north-east Atlantic under international law.
PA	Polyamide
PE	Polyethylene
PET	Polyethylene terephthalate
PP	Polypropylene
PS	Polystyrene
PU	Polyurethane
Recycled material	Product of recycling plastic waste (secondary raw materials) which can be used again to produce new products and thus replace primary raw materials.
SBR	Styrene butadiene rubber
WRRL	Water Framework Directive (Directive 2000/60/EC of 23 October 2000 on establishing a framework for community action in the field of water policy).

Appendix 1: Overview of the state of methods and investigation approaches for surveying the occurrence and effects of plastics in the environment

Monitoring using analytical investigation procedures

How big is the problem?

Validated assessments for a quantitative description of possible impacts of plastics on the environment can only be made to an inadequate extent at present due to a lack of harmonised or standardised investigation methods.

Before the beginning of the investigations, it must be clarified which parameters should be collected and determined for which issue. Afterwards a suitable detection method must be selected or developed. A holistic consideration of the three areas of taking samples, preparing samples and detection is then necessary. These are grouped together specifically (with reference to the detection process). The sampling is an essential part of the investigation process, as there is a large potential for error here with regard to the overall result. With the sampling, the representative taking of investigation material must be ensured with regard to the respective medium. The same requirements can be derived for the preparation of samples. Here, it must be ensured that the plastic to be investigated is not impaired during the preparation procedure.

With regard to detection, current processes to determine the total contents (thermo-analytical) as well as with regard to the number and size of particles (spectroscopic) are used. Information on volumes or the weight of the finds may also be necessary for special research questions.

Table 5 presents a comparison of important key points of the different detection processes:

In the first stage, it is expedient to gain an overview of the overall contents (e. g. mg plastic per litre or per kilo of the investigated medium) of the mass of plastics (PE, PS, PET, PA, PU, PP, SBR) in the various environmental media or entry flows (e. g. water, soil, air, waste, sewage sludge). All size classes of plastics should be investigated here. A purely visual determination of plastics is only possible with larger macroplastic.

In addition to the overall contents of the various plastics, further aspects are also important for the assessment. These include size classes, shapes, ageing and also any additives or harmful substances which have been absorbed into the plastic for the assessment of harmful substance transfer into the environment. Knowledge about the occurrence of

Table 5

Important key points of different detection processes

Parameters	Raman scanning	FTIR imaging	TED-GC-MS	Chemical extraction
Sample amount[b]	1 µg	1 mg	20 mg	500 mg
Measurement time for the present sample amount	~40 min	3–6 h	3 h	2 h
Result information				
Identification	PE, PP, PS, PET	PE, PP, PS, PET	PE, PP, PS, PET	PS, PET
Quantification	No	No	Yes[c]	Yes
Particle size distribution/Visual Image	Yes	Yes	No	No
Aging Status	Yes	Yes/No[a]	No	Yes[c]

[a] Depending on the method used, transmissio/or ATR.
[b] Amount of sample used in these experiments.
[c] No measurements to support this statement are presented in this investigation.

source: Elert et al. 2017

natural particles is also necessary for classification. Spectroscopic investigation procedures (preferably IR microscopy and Raman spectroscopy) are an option for determining the number and size of particles.

At the moment, there is a lack of harmonised or standardised monitoring methods for plastics in water bodies, the soil, the air or materials (e. g. in secondary raw material fertilisers – cf. thesis 8) available to authorities. Uniform, validated and feasible methods in terms of cost must be created, developed or established with the aim of meeting the requirements for the future monitoring of plastics in the environment following uniform quality criteria. As a basis for a progressing risk assessment of the impact with microplastics, impact-related validation and corresponding methodical approaches must be established.

What is the German Environment Agency doing and what does it call for?
The establishment of harmonised or standardised investigation methods for the quantitative description of possible impact of plastics on the environment is urgently necessary. The UBA is actively participating in several research projects funded by the BMBF for the establishment of suitable sampling strategies and chemical investigation methods and is also sponsors research projects which are geared towards methodical issues. Some of these projects attempt to transfer the findings obtained for water to soil situations.

As the topic of plastic in the environment is an international matter with global distribution patterns, the establishment of internationally recognised process requirements is advisable. ISO is a suitable platform to group findings accordingly. The close link with the European Standardisation body CEN ensures a harmonious process in Europe. The UBA supports DIN in the establishment of process requirements on a European (CEN) and international (ISO) level.

Monitoring using field methods in the area of marine protection

How big is the problem?
The EU Marine Strategy Framework Directive (MSRL (2008/56/EC)) requires the member states to monitor the impact of marine litter on marine areas. The requirements of Decision 2017/848/EU of the Commission specify the elements, criteria/indicators and methodical standards. Waste on the coasts, on the sea floor and in the surface layer of the water column and micro-waste must be viewed as primary criteria/indicators. For the first two aspects, there is a long-term monitoring programme for the North and Baltic seas within the OSPAR beach litter monitoring and the ICES recording of litter on the sea floor. Here, the number of pieces of plastic which can be identified with the naked eye are recorded. For the third aspect, a long-term monitoring programme of the litter in the stomachs of northern fulmars was established for the North Sea which gives information about the impact of plastic litter on the surface of the sea, as the animals tend only to feed on the high seas. These criteria/indicators are also used within OSPAR and HELCOM to record the litter in marine areas of the north-east Atlantic and the Baltic Sea, they are agreed between the member states and thus comparable. Methods for the monitoring of micro-waste are currently being developed.

Two secondary criteria must also be examined within the sense of the MSRL which should be developed and applied in particular in regional cooperation. These relate to the intake of litter by marine animals and other relevant effects such as choking/strangulation of marine organisms on or in pieces of waste. The first aspect mentioned, however, must be determined by other indicator species apart from the northern fulmars which are only found the North Sea. There is also a lack of corresponding indicator species for choking.

In 2013, the EU Task Group on Marine Litter developed a guideline which is applied by the member states and is currently being revised (http://publications.jrc.ec.europa.eu/repository/handle/JRC83985). Detailed information on the national monitoring activities on litter in the sea can be read under www.meeresschutz.info .

What is the German Environment Agency doing and what does it call for?
With the support of two UBA research projects, existing and new monitoring approaches for litter in all areas of the sea and oceans are being tested. Statistical analyses of beach litter data allowed for the source analysis and the intercalibration of various monitoring methods. Two suitable methods were tested in the Baltic Sea for the monitoring of meso-litter (pieces of waste between 0.5 cm and 2.5 cm) on beaches. These are now also being applied in the

North Sea. A screening of monitoring programmes identified those which are suitable for the long-term monitoring of litter on the sea floor. Here, the suitability of geostatistical data collected during biological investigations of fisheries were tested for effectiveness and plausibility. Spatially distributed data (2010–2012) of remote sensing from aeroplanes were investigated for annual and seasonal trends and correlated with quantities of litter on the sea floor. Furthermore, the stomachs or gastrointestinal tracts of 258 pelagic and 132 demersal fish of different species in the North and Baltic Seas were investigated for nine different plastics which represent over 80 % of current plastic production.

The aim of further R&D projects is now to establish long-term and reliable monitoring methods for all necessary indicators for the assessment of the criteria of the Commission Decision 2017/848/EU for these and future subsequent measurements and to transfer the existing measurement approaches into an accepted measurement system. For this, methods which have proven themselves with upstream pilot monitoring are now prepared for long-term monitoring and a few new methods have been applied and tested in order to replace those which have proven themselves to be unsuitable. In this way, for example, the investigations in the gannet breeding colony on Heligoland are being continued. This establishes an indicator species for the choking and strangulation on marine litter for the German North Sea region. In the future, this will permit a comprehensive appraisal of the impact of litter on the German sea environment.

Determining the extent of possible effects of microplastics on organisms in the environment using ecotoxicological test processes

How big is the problem?

Microplastics can have mechanical and chemical effects in organisms. Additional impact is possible through the interaction of microplastics with other chemicals found in the environment. In addition, most microplastics often contain additives which can also have damaging effects on organisms. Microplastic particles do not biodegrade well in nature and thus may possibly influence food intake, which is why longer-term ecotoxicological tests must be carried out with relevant organisms, for example with filter animals such as daphnia or mussels.

The classic ecotoxicological test processes must be further developed for the ecotoxicological testing of microplastics. In this way, the precise characterisation of the microplastic particles is essential because, depending on the test organism, different particle sizes may be relevant, for example. In addition to the size distribution, polymer type and shape as well as the effects of the surface characteristics (e. g. aged surfaces) must also be researched. Depending on the research question being pursued, it is also important to know which further components are contained, e. g. additives. The number of particles per litre should be used as a unit, possibly through model calculation, taking into account the shape and size distribution. As well as the concentration in mass/L, the particle number should also be stated. Each test concentration should be produced directly by weighing the respective amount. The production of a master suspension which is then diluted should be avoided since errors may arise when no homogeneous suspension is present. During the experiment period, a homogeneous distribution of microplastic particles should be adhered to in order to ensure an even exposure of the organisms. This should be documented with a corresponding analysis (e. g. Raman spectroscopy). A homogeneous mixing and a correct change of medium must also be ensured when renewing the medium. Here, above all, losses due to changing the medium or an accumulation of particles in the exposure vessels must be avoided. All other test conditions and validity criteria in accordance with the test guidelines of ecotoxicological tests must be adhered to.

Depending on the thickness, size, surface characteristics and water turbulence, the particles tend to rise or sink in the water. The testing strategy should be adjusted to this by testing sediment organisms with sinking particles, for example.

What is the German Environment Agency doing and what does it call for?

There is hardly any experience for testing with microplastics, which is why further research is necessary to establish a suitable strategy. The UBA sees the most important next steps in establishing reliable, standardised methods for analysis, further research on the technical implementation of lab tests and identifying suitable, sensitive test species. The UBA has had a leading role in the development of OECD test guidelines and methods for the investigation of nanomaterials for several years. Furthermore, the UBA supports and participates in numerous research projects on the environmental behaviour and on the effects of nanomaterials. Experience from these investigations and the evaluation of studies on the environmental behaviour and effect of nanomaterials can support the establishment of standardised tests and investigation strategies for microplastics.

Determining the extent of possible effects of microplastics on people through human toxicological investigations

How big is the problem?

Microplastic finds in honey, beer and drinking water, among other things, were reported in the press (NDR 2014). The measurement method used with light microscopy is, however, a controversial one and it was not possible to verify these results to date, as suitable methods must first be developed – in particular for the reliable detection of low concentrations as they are to be expected in drinking water or foodstuffs. For one thing, concentration data is an indispensable requirement for assessing the extent of the problem, however (see also under 2.1.3 the chapter on drinking water). For another, scientific knowledge about the effects of microplastics on human health is required. These barely exist at present.

In order to assess the effect of microplastics on humans, an essential distinction between two forms of toxicity must be made. On one hand, effects arising from the particle size and, on the other hand, effects which arise from the release of harmful substances from the particles or absorption into the particles and the subsequent release in the body. In scientific literature, there is no information about the uptake pathway of microplastics into the cells of humans. In the case of drinking water, skin/mucous membranes and intestine/bloodstream are conceivable pathways. To clarify possible uptake pathways, organ-specific/human-relevant cell cultures are used and corresponding parameters such as inflammatory processes are measured. There is already extensive data on the effect of additives and monomers from the approval of plastic materials in contact with drinking water.

As with ecotoxicology, the development and establishment of a testing strategy is also necessary for human toxicology. Here, we can make use of the procedures developed in the joint project Tox-Box on assessing the relevant parameters of genotoxicity, neuro-toxicity and endocrine effects (https://www.umweltbundesamt.de/themen/wasser/trinkwasser/trinkwasserqualitaet/toxikologie-des-trinkwassers/projekt-tox-box). However, as individual substances were assessed in Tox-Box and not particles, the test strategy will need to be modified for microplastics. Here, the OECD guidelines determined for nanoparticles (www.oecd.org/env/ehs/nanosafety) are also used for orientation. In this context, both an impairment of the cell culture and the sensitive measurement technology by the microparticles must be expected.

What is the German Environment Agency doing and what does it call for?

The German Environment Agency has been involved in the BMBF joint project „microplastics in the water cycle – taking samples, treating samples, analysis, occurrence, removal and assessment („MiWa")" since 2016 within the framework of the RiSKWa funding measure (https://www.fona.de/de/mikroplastik-im-wasserkreislauf-21854.html). The aim of the MiWa project is to record the overall effect and the possible hazard potentials. This also includes examining the absorption of harmful materials into plastic, the investigation of which seems to be very difficult in terms of method, as it must be certain that the harmful material was really absorbed by the microplastics when it is present.

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Appendix 1

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