An Initiative of the German Federal Ministry of Education and Research

Plastics in the Environment

sources · sinks · solutions

BMBF-Research Focus "Plastics in the Environment – Sources · Sinks · Solutions"

# Key messages

## *Short version*

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# Summary

The German Federal Ministry of Research and Education (Bundesministerium für Bildung und Forschung – BMBF) has launched the National Research Focus "Plastics in the Environment" in 2017 – one of the most important scientific activities working on this topic worldwide. The main goal was initiating a systemic assessment and gaining a better understanding of the environmental consequences associated with plastic waste. In total, around 40 million Euros were spent on funding 20 joint projects across more than 100 institutions from science, economy, and practice, as well as an accompanying scientific project. Overall, the research focus has contributed to the (further) development of scientific procedures, methods, and instruments for the investigation of plastics in the environment. The existing knowledge has been expanded and important progress has been made in various areas along the entire value chain of plastics: Green Economy, consumption and consumer behaviour, recycling, freshwater and saltwater ecosystems.

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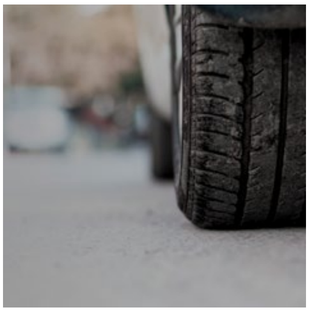
# Green Economy



Within the framework of a Green Economy, the inputs and losses of plastics along the entire value chain from production through the use phase in relevant sectors were examined with the aim of developing measures to reduce plastic inputs.

**Tire abrasion** is one of the largest sources of microplastics in the environment. Hotspots of emissions are bends, traffic lights and intersections.[1].

» In addition to reducing individual traffic, the use of wear-resistant tires and a more defensive driving behaviour are approaches to reducing the generation of tire abrasion. Emissions can also be reduced through optimized street cleaning. Previously untreated rainwater from roads should be treated appropriately at urban hotspots.

The use of products containing plastics generates **(micro)plastics emissions**, for example through **textile washing** [2], detergents and cleaning agents, as well as abrasion of products during use. Large amounts of fibrous microplastics are especially emitted when clothing is washed for the first time.

» In the case of textiles made of synthetic fibres, all stages of processing must be optimized, e.g., removing excess fibres by pre-cleaning prior to distribution.

When implementing innovations, the **entire value chain** must be considered to ensure that advantages (in terms of life cycle assessment) at one point (e.g., product packaging) do not lead to disadvantages elsewhere (e.g., transport packaging).

**Effective regulation** of environmentally friendly product design must start with the manufacturers of (plastic) products and with the objective to avoid (plastic) waste [3].

# Consumption

Important parts of the plastic cycle are consumption and consumer behaviour, but also trade and production. We investigated measures that can lead to a more sustainable consumer behaviour in a meaningful and effective way, to develop solution strategies and recommendations.

(Micro-)plastics emissions during and after the use phase of products can be significantly reduced by **extending the life cycle** of plastic products (e.g., less disposable products or fast fashion). However, the low prices of single-use solutions and primary plastics, as well as higher costs for reusable products, have so far made it difficult to substitute these materials and products.

» This can be achieved through regulatory measures: by providing **stronger incentives for avoidance** (e.g., financial in the form of packaging taxes or subsidies) or through restrictions (e.g., bans on single-use plastic (packaging) at markets, festivals, and events).

» Products whose intended use leads to their contact with or retention in the environment should be replaced by products without plastics considering sustainability aspects.

In the case of **products/packaging** in which plastics are indispensable for the function (e.g., certain medical devices) or environmentally sound (including certain consumer goods and/or reusable packaging), the following aspects must be taken into account: Designing products to be stable and recyclable; applying instructions for proper disposal; pushing for **greater standardization** of unit forms for different reusable container sizes and areas of application; establishing mandatory, **transparent declarations** of additives and excipients.

The **existing** (national and international) **regulatory approaches** (e.g., the EU Single-Use Plastics Directive) do not cover all relevant plastic-containing products and packaging that are discharged into the environment wholly or partially, and are furthermore strongly targeted at private consumers, which is **not sufficient** in view of their limited influence capabilities. [4].

» To bring about change in use and disposal practices, a direct contribution of the individual consumer´s behaviour should be apparent or communicable and **practicable alternatives** should be available, the same applies to easily understandable and implementable recommendations for action.

» Education and awareness-raising for a **more sustainable use of plastics** must be intensified across all age groups: with information events (e.g., training courses, participation formats), guidelines (e.g., avoidance of plastic waste, correct disposal of waste) and through educational materials (e.g., in childcare facilities, schools and universities).

# Recycling

The focus is on the development of innovative processes to facilitate recycling and the collection of end-of-life products, as well as to increase the proportion of high-quality recycling of plastic waste, thus aiming at closing the loop.

**Waste collection** in Germany requires further innovative conceptual and technological development to optimize collection and to reduce environmental pollution. This includes the expansion of separate collection systems for high-grade plastics (possibly deposit systems), the complete switch to garbage can systems for household light packaging collection and sensor-supported control mechanisms in the collection process to **reduce miss-sorting**, for example in organic waste collection.

Current sorting technology has significant shortcomings in distinguishing between food and non-food packaging, single-layer and multi-layer films, and in separating subclasses of materials (e.g., PET trays and PET bottles). To ensure more efficient processing and **high-quality recycling** of plastic products, they must be correctly separated by type.

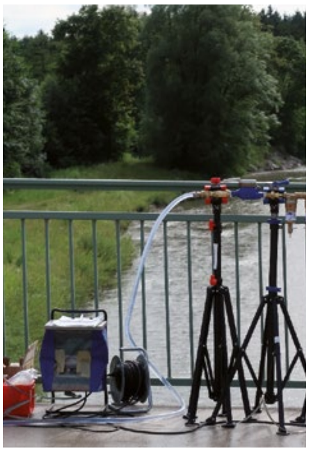
» The innovative tracer-based sorting system offers a complete technical solution for substantially improved sorting of all plastics and should therefore be used more widely.

Modern **chemical recycling processes** can contribute to higher recycling rates as a supplement to already established processes. Especially the use of complex waste streams, which have until now only been thermally processed, helps to tap valuable resources.

» The **technical and ecological advantages** of the chemical recycling processes that have been developed (revolPET®, ResolVe processes) support legal recognition for meeting the recycling quotas of the Packaging Act. [5, 6, 7]

In order to substantially **increase the actual recycling rate** in packaging recycling, all value chain stakeholders - from material development and distributors to the waste management industry - must implement and coordinate real innovations: Design-for-recycling, consistent collection, precise sorting into all distinguishable fractions, and innovative, **$CO_2$-efficient processing technologies**.

# Freshwater Ecosystems



Risk management of microplastics in freshwater requires reliable data on the occurrence, impact, behaviour, and possible input pathways. Coordinated and harmonized analytical methods are a central prerequisite for the assessment of potential hazards from microplastics and for solutions to reduce these inputs (e.g., elimination processes).

Significant progress has been made in the **analysis of microplastics** at all stages - sample collection, sample preparation and detection [8]. This knowledge forms the essential basis for the development of national, European and international standards: the **first standardization procedure** for the analysis of microplastics at the International Organization for Standardization (ISO) can soon be approved (ISO-TC-147 Water/ISO-TC-61 Plastics).

» With the application of different sampling equipment - developed in accordance with the investigation objective, environmental medium, material and representativeness - it has been demonstrated that both sampling (random sampling/continuous) and **quantification of particle numbers or polymer masses** can be reliably performed for environmental samples down to 10 µm in size.

» The **analytical range was extended** to the detection of microplastic particles as small as 200 nm by coupling field flow fractionation and Raman microspectroscopy.

» A comparative test was carried out to demonstrate that both thermoanalytical and spectroscopic methods are suitable for identifying microplastics and quantifying them with sufficient accuracy. To improve the comparability of the measurement results, methods for sampling and detection of water, wastewater, and solid samples (sewage sludge), in particular those with complex matrices, need to be further harmonized. The detection method for the investigations must be chosen based on the specific objective and research question. **Particle numbers should not be converted into mass contents and vice versa**.

Different sources of plastics and their input pathways into the environment were investigated to assess the relevance of individual **sources, pathways** and **processes**.

- A significant source of plastic parts in the environment is **littering** - carelessly throwing away and leaving plastic waste behind [9] – e.g., at major cultural events. [10, 11]. Plastic litter can lead to localized high inputs of (micro-)plastics into the environment. Other diffuse sources include sports grounds with artificial turf, construction sites, landfills, etc. [12]
- In municipal wastewater treatment plants, more than 95% of the micro- and macroplastics >10 µm are removed from the wastewater (including domestic wastewater and rainwater), which is why the **input from municipal wastewater treatment plants into water bodies is low**. With the help of further process technologies (e.g., downstream filter systems such as sand filters, cloth filters, micro screens or membrane processes), microplastic retention can be increased to almost 100%. However, fibrous particles are retained less effectively than spherical particles. Low residual levels in the effluent of wastewater treatment plants can reach surface waters. [13, 14]
  The particles ultimately accumulate in the screenings and grit traps (mainly macroplastics) or remain in the sewage sludge (microplastics) [14-16]. The latter should therefore be treated thermally and not be used in soils to avoid further agricultural microplastics discharges.
- Initial investigations indicate **high emissions** to soils and waters **via combined sewer overflows and untreated precipitation water** (from the separate sewer system or runoff from traffic areas). Further investigations are necessary to determine these inputs more precisely and to develop countermeasures. However, the reduction of plastic emissions in urban water management as an end-of-pipe solution is often associated with high technical and economic costs.

The effects of microplastics on plants and animals have not yet been comprehensively documented. Microplastics have different properties that determine whether and how they are taken in by living organisms and the extent to which they are harmful to them. Acute toxicity could not be demonstrated so far, but effects on fitness and activity have been shown in some aquatic organisms. For plastic particles < 10 µm, sufficient data is not yet available. In accordance with the precautionary principle, policy makers are responsible for **minimizing the input of plastics into the environment** in order to reduce potential adverse effects.

- Microplastics can release toxic additives that have been detected in various environmental media (water, soil, air). A **declaration obligation** of the composition of plastics and additives across the entire value chain is therefore required to deliver information to all stakeholders and to provide a basis for corresponding legal regulations.

# Saltwater Ecosystems

The focus was on mapping the spatial distribution and variability of microplastics from estuaries to coastal waters and into the Baltic Sea and the North Sea. Improving the identification of input pathways, transport routes and accumulation areas within marine waters will provide a basis for future monitoring and surveillance strategies.

Suitable sampling and sample preparation methods were developed to detect microplastics down to 10 µm in the marine environment. Software developments for spectroscopic measurements have improved and automated the identification of plastics. The analysis results were transferred to a **Marine Plastics Database** (MPDB), where they are available to stakeholders for further use.

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**Entry pathways** into estuarine areas were identified through **hydrologic and land use models**. Local inputs are negligible compared to diffuse inputs. In contrast, agricultural uses - such as the application of sewage sludge - have a major influence.

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The **input of plastic particles via estuaries** is determined by the flow velocity. Smaller microplastic particles show a higher dispersal potential and enter coastal waters much more easily from land-based microplastics sources. In river estuaries, no continuous increase of microplastics from the upper course to the estuary has been detected so far.

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The **transport and accumulation of (micro-)plastics** within coastal waters is determined by current conditions, the influence of tides and the runoff pattern. In particular, extreme weather events (heavy rain, floods) lead to growing inputs and remobilization of already sedimented particles. Biofilm formation on (micro-)plastics as well as mineral and aggregate formation cause even low-density plastic particles to sink and increase the sedimentation of plastic particles.

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Main **accumulation areas** of (micro)plastics are **beaches, sediments** and **harbour basins**. Especially harbour basins were identified as hotspot areas for the accumulation of dye particles. Further research is needed in this area.

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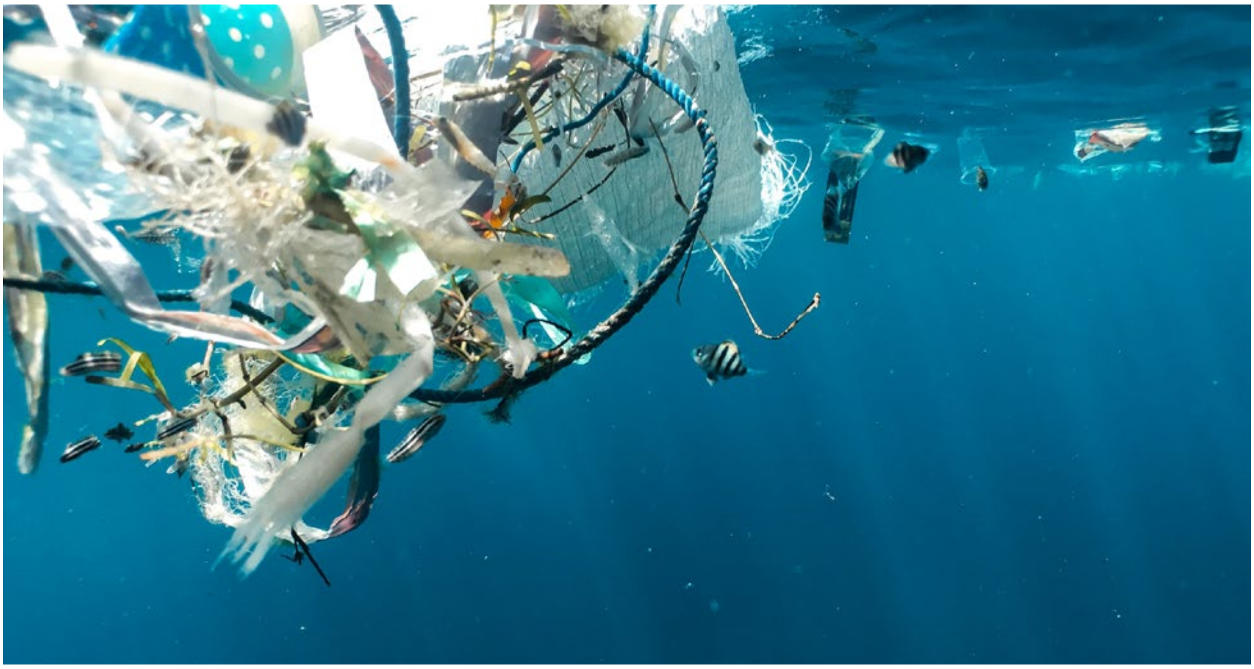
Since littering is a highly significant pathway into the oceans, **Citizen Science projects** are an important contribution against littering in rivers and oceans - not only for collecting extensive data, but also to raise awareness for this problem.



## Bibliography


[1] Venghaus, Daniel; Schmerwitz, Frank; Reiber, Jens; Sommer, Harald; Lindow, Franklin; Herper, Dominik; Pohrt, Roman; Barjenbruch, Matthias (2021): Abschlussbericht. Reifenabrieb in der Umwelt - RAU. Verfügbar unter: https://www.rau.tu-berlin.de/fileadmin/fg118/RAU/20210728_Abschlussbericht_RAU_FINAL_Team.pdf.

[2] Bendt, Ellen; Rabe, Maike; Stolte, Stefan; Zhang, Ya-Qi; Klauer, Robert; Kraas, Caroline; Alrajoula, Taher; Kolberg, Alexander (2021): Textile Mission. Textiles Mikroplastik reduzieren. Erkentnisse aus einem interdisziplinären Forschungsprojekt. Abschlussdokument. Verfügbar unter: https://textilemission.bsi-sport.de/fileadmin/assets/Abschlussdokument-2021/TextileMission_Abschlussdokument_Textiles_Mikroplastik_reduzieren.pdf.

[3] Steinhorst, Julia; Beyerl, Katharina (2021): First reduce and reuse, then recycle! Enabling consumers to tackle the plastic crisis – Qualitative expert interviews in Germany. In: Journal of Cleaner Production Bd. 313 (2021). Verfügbar unter: https://bmbf-plastik.de/de/publikation/first-reduce-and-reuse-then-recycle-enabling-consumers-tackle-plastic-crisis.

[4] Daskalakis, Maria; Kaser, Simon; Breitbarth, Marco; Hentschel, Anja (2022): EU-Einwegkunststoffrichtlinie - Inhalte, Defizite und Anforderungen an ihre Weiterentwicklung. Factsheet 19. Verfügbar unter: https://bmbf-plastik.de/de/publikation/factsheet-19-eu-einwegkunststoffrichtlinie-inhalte-defizite-und-anforderungen-an-ihre-weiterentwicklung.

[5] Eichert, Carsten; Biermann, Lars; Salikov, Vitalij; Brepohl, Esther; Müller, Clemens; Paschetag, Mandy; Scholl,Stephan (2021): Recycling von PET-Verpackungen: Innovatives PET-Recycling aus Mehrschichtverbunden. Factsheet 6 des BMBF-Forschungsschwerpunkts Plastik in der Umwelt. Verfügbar unter: https://bmbf-plastik.de/sites/default/files/2021-05/FactSheet_revolPET_06.pdf.

[6] INEOS Styrolution (2019): Breakthrough in chemical recycling of polystyrene. Verfügbar unter: https://www.ineos-styrolution.com/INTERSHOP/static/WFS/Styrolution-Portal-Site/-/Styrolution-Portal/en_US/News%20and%20media/PR-040919-Chemical-Recycling-PS.pdf.

[7] INEOS Styrolution (2020): INEOS Styrolution reports final results of research project: post consumer polystyrenewaste becomes valuable feedstock. Verfügbar unter: https://www.ineos-styrolution.com/INTERSHOP/static/WFS/Styrolution-Portal-Site/-/Styrolution-Portal/en_US/News%20and%20media/PR-20200622-ResolVe-Wrapup-EN.pdf.

[8] Braun, Ulrike; Stein, Ulf; Schritt, Hannes; Altmann, Korinna; Bannick, Claus Gerhard; Becker, Roland; Bitter, Hajo; Bochow, Mathias; Dierkes, Georg; Enders, Kristina; Eslahian, Kyriakos; Fischer, Dieter; Földi, Corinna; Fuchs, Monika; Gerdts, Gunnar; Hagendorf, Christian; Heller, Claudia; Ivleva, Natalia; Jekel, Martin; Kerpen, Jutta; Klaeger, Franziska; Knoop, Oliver; Labrenz, Matthias; Laforsch, Christian; Obermaier, Nathan; Primpke, Sebastian; Reiber, Jens; Richter, Susanne; Ricking, Mathias; Scholz-Böttcher, Barbara; Stock, Friederike; Wagner, Stephan; Wendt-Potthoff, Katrin; Zumbülte, Nicole (2020): Statuspapier im Rahmen des Forschungsschwerpunktes Plastik in der Umwelt: Mikroplastik-Analytik, Probennahme, Probenaufbereitung und Detektionsverfahren. Verfügbar unter: https://bmbf-plastik.de/sites/default/files/2020-11/Statuspapier_Mikroplastik%20Analytik_Plastik%20in%20der%20Umwelt_2020.pdf.

[9] Witzig, Cordula; Wörle, Katharina; Földi, Corinna; Rehm, Raphael; Reuwer, Ann-Katrin; Ellerbrake, K.; Cieplik, Stephanie; Rehorek, Astrid; Freier, Korbinian P.; Dierkes, Georg; Wick, Arne; Ternes, Thomas A.; Fiener, Peter; Klasmeier, Jörg; Zumbülte, Nicole (2021): MicBin Schlussbericht. Mikroplastik in Binnengewässern Untersuchung und Modellierung des Eintrags und Verbleibs im Donaugebiet als Grundlage für Maßnahmenplanung. Verfügbar ab Mai 2022 unter www.micbin.de.

[10] Barkmann, Luisa; Weber, Felix; Raber, Wolf; Masch, Mark; Wolff, Sebastian; Bitter, Hajo; Bitter, Eva; Kerpen, Jutta; ackner, Susanne; Engelhart, Markus (2021): Industrielle Mikroplastik-Emissionen - Handlungsempfehlungen. Verfügbar unter: https://tuprints.ulb.tu-darmstadt.de/id/eprint/20230.

[11] MicroCatch_Balt (2021): Abschlussbericht MicroCatch_Balt. Verfügbar unter: https://bmbf-plastik.de/de/publikation/microcatchbalt-abschlussbericht.

[12] InRePlast (2022): Projektergebnisse InRePlast, unveröffentlicht. Voraussichtlich verfügbar ab 2022 unter www.inreplast.de.

[13] Witzig, Cordula; Wörle, Katharina; Földi, Corinna; Rehm, Raphael; Reuwer, Ann-Katrin; Ellerbrake, K.; Cieplik, Stephanie; Rehorek, Astrid; Freier, Korbinian P.; Dierkes, Georg; Wick, Arne; Ternes, Thomas A.; Fiener, Peter; Klasmeier, Jörg; Zumbülte, Nicole (2021): MicBin Schlussbericht. Mikroplastik in Binnengewässern Untersuchung und Modellierung des Eintrags und Verbleibs im Donaugebiet als Grundlage für Maßnahmenplanung. Verfügbar ab Mai 2022 unter www.micbin.de.

[14] Knoop, Oliver; Al-Azzawi, Mohammed; Bannick, Claus-Gerhard; Beggel, Sebastian; Binder, Ronja; Elsner, Martin; Eslahian, Kyriakos; Freier, Korbinian P.; Funck, Martin; Geist, Jürgen; Gierig, Michael; Götz, Astrid; Griebler, Christian; Hunger, Cornelia; Ivleva, Natalia; Kunaschk, Marco; Meier, Florian; Müller, Ruth; Obermaier, Nathan; Pfaffl, Michael W.; Reichel, Julia; Schönbauer, Sarah; Schwaferts, Christian; Türk, Jochen; Wolf, Carmen; Zhou, Yuxiang; Drewes, Jörg E. (2021): Abschlussbericht. Tracking von (Sub)Mikroplastik unterschiedlicher Identität – Innovative Analysetools für die toxikologische und prozesstechnische Bewertung -SubμTrack. In: Berichte aus der Siedlungswasserwirtschaft. Verfügbar unter: https://bmbf-plastik.de/de/publikation/submtrack-schlussbericht.

[15] Fuhrmann, Tim; Urban, Ingo; Scheer, Holger; Lau, Philipp; Reinhold, Luisa; Barjenbruch, Matthias; Bauerfeld, Katrin; Meyer, Stefanie (2021): Mikroplastik-Emissionen aus Kläranlagen: Welche Rolle spielt die Abwasserbehandlung? In: KA - Korrespondenz Abwasser, Abfall Bd. 69, Nr. 9, S. 730–741. Verfügbar unter: http://www.replawa.de/wordpress/wp-content/uploads/2021/09/Fuhrmann-et-al_Mikroplastik-Emissionen-aus-Kläranlagen_KA-9-2021.pdf.

[16] REPLAWA: Mikroplastik-Einträge über das Abwasser in die aquatische Umwelt, Handlungsempfehlungen zurVerringerung von Mikroplastik-Einträgen im Bereich der Abwasserentsorgung, unveröffentlicht. Voraussichtlich verfügbar ab Juni 2022, unter: www.replawa.de.


## Imprint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