Federal Ministry of Education and Research

FONA Research for Sustainable Development BMBF

Plastics in the Environment Sources • Sinks • Solutions

Plastics can be found almost everywhere in the world – in the Arctic, on the seabed, on deserted islands. Small and tiny plastic particles have even been detected in living organisms. However, our knowledge of the full extent of plastic pollution is still limited: We do not know enough on the origins of plastics in the ocean, their behaviour in oceans, inland waters and soils, and how they could affect animals and humans.

Germany's Federal Ministry of Education and Research (BMBF) addresses this issue with its current research focus, an initiative called "Plastics in the Environment – Sources • Sinks • Solutions". More than 100 institutions from science, industry, civil society, and public administration are involved. The BMBF is funding 18 joint research projects and an accompanying scientific project in the five thematic areas of green economy, consumption, recycling, limnic systems, and seas and oceans. "Plastics in the Environment" is one of the world's largest research programs in this field. The aim is a comprehensive overview of how plastics are produced, used, traded and disposed of. To this end, the project partners aim to develop and establish scientific methods, instruments and standardized terms for the investigation of plastics in the environment. Using the plastic cycle as a starting point, the aim is to work with various actors to identify solutions and to put them into practice. In this context, joint projects should also be initiated with international partners from the most important countries of production and use.

As part of the flagship initiative Green Economy within the BMBF-framework programme "Research for Sustainable Development" (FONA3) "Plastics in the Environment" expands on work conducted in previous funding measures e.g.: the international funding program investigating microplastics in the oceans (part of JPI OCEANS), the ongoing joint research project "Microplastics in the Water Cycle" (MiWa) (part of the funding priority Sustainable Water Management), as well as the Socio-ecological Junior Research Group PlastX working in this area.

The PlastikNet project supports the 18 research projects and promotes scientific exchange and networking through conferences and workshops. Additionally, a Steering Committee composed of the coordinators of all 18 joint research projects and representatives of the BMBF, the project management agency and the accompanying project strengthens the exchange on cross-cutting issues between the joint projects. The Steering Committee should also summarize results and ensure their transfer into practice. To ensure that the findings from "Plastics in the Environment" have a societal impact in the long term, it is planned to create projects for schools, university seminars, pop-up exhibitions and trainings for specialists.

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Eine Initiative des Bundesministeriums für Bildung und Forschung
Plastik in der Umwelt
Quellen • Senken • Lösungsansätze

Research Sites of the Joint Projects

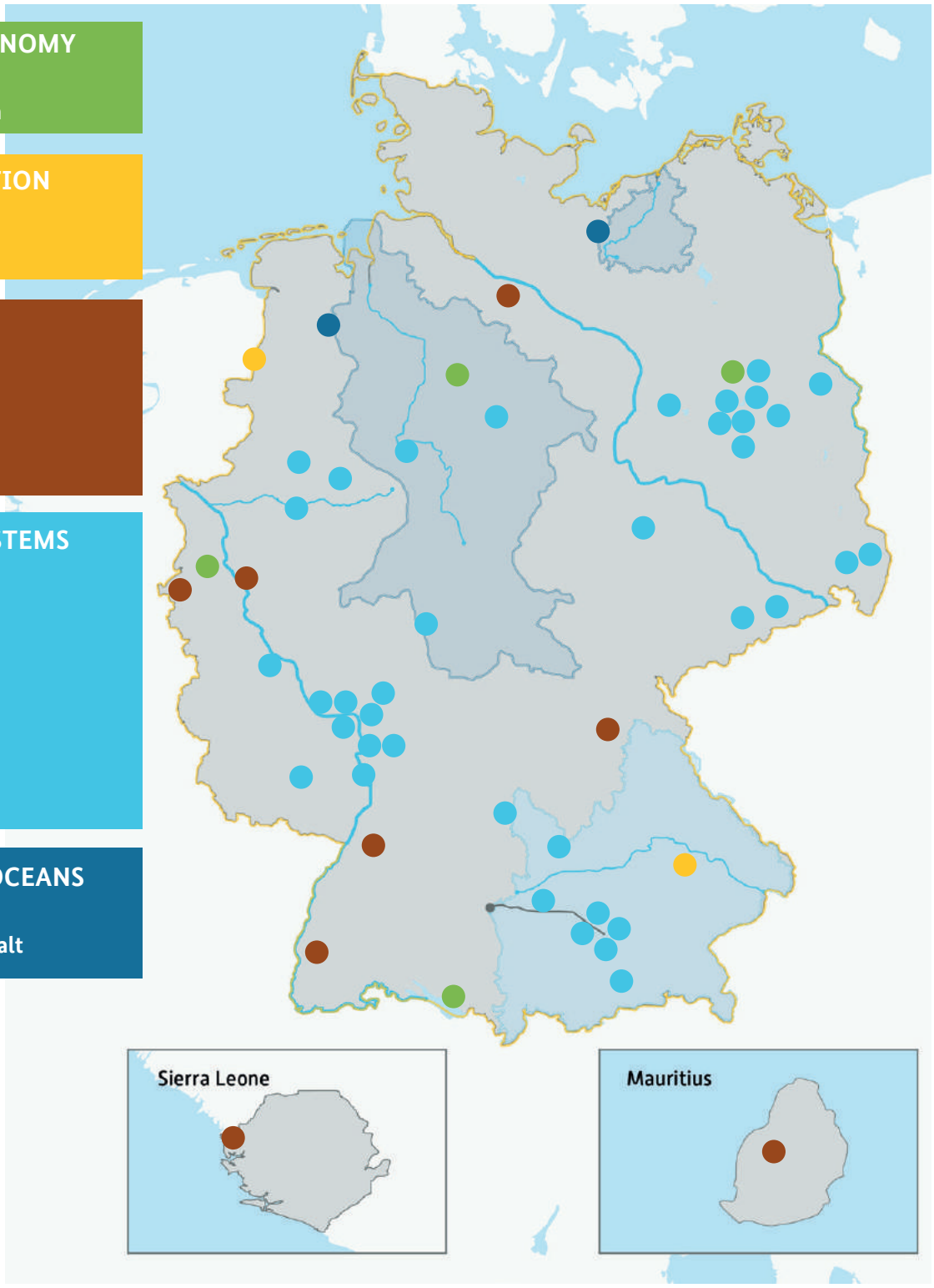
GREEN ECONOMY
RAU
TextileMission

CONSUMPTION
VerPlaPoS
PlastikBudget

RECYCLING
ReSolve
KuWert
MaReK
solvoPET

LIMNIC SYSTEMS
RUSEKU
SubµTrack
PLASTRAT
EmiStop
MicBin
MikroPlaTas
REPLAWA
ENSURE

SEAS AND OCEANS
PLAWES
MicroCatch_Balt



https://bmbf-plastik.de/en

Federal Ministry of Education and Research

FONA Research for Sustainable Development BMBF

RAU – Reducing the Environmental Impact of Microplastics from Car Tires

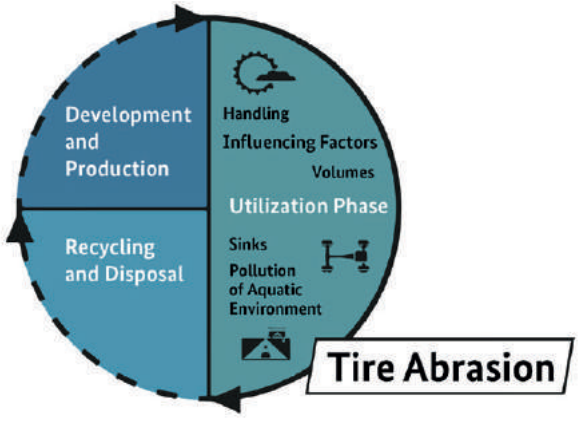
Plastics in the Environment – Sources · Sinks · Solutions

An underestimated source for microplastics in water bodies is the wear debris of vehicle tires: Worldwide, around 1.3 billion motor vehicles are on the roads whose tire debris can enter our rivers and seas through precipitation. But how and in which quantities do particles from tire abrasion get into inland waters? The joint research project RAU will investigate these questions as well as develop and evaluate strategies against these entries. The aim is to create a comprehensive understanding of the loss of tire particles throughout the entire product life cycle.

In Focus: How Much Debris is Generated by Tire Use?

In Germany alone, it is estimated that the total amount of tire wear caused by road traffic exceeds 100,000 tonnes per year. Presumably, most of it is discharged into surface waters via road drainage, usually untreated. The RAU project will focus mainly on tire particles released into the environment during tire use. Furthermore, the joint research project also investigates the entire life cycle.

In addition to use, this includes the development and production of tires as well as recycling and disposal. One of the specific tasks of the researchers is to determine, balance and evaluate the entry of tire material into street drains and from there into rivers and lakes. A major challenge in this regard is to determine the percentage of tire debris from an environmental sample both qualitatively and quantitatively. To date, no specific investigations have been carried out to determine to what extent rainwater treatment concepts are effective in removing tire particles from water.



The RAU joint research project looks at the entire life cycle of tires in order to obtain an accurate picture of tire debris from abrasion and its consequences.

Identifying Entry Paths and Quantities

Tire abrasion tests are carried out in the laboratory, on controlled test tracks and on various types of roads. In order to cover the entire product life cycle of the tire, the project participants first evaluate potential pathways of tire particles into the environment from existing literature and manufacturer data. Researchers investigate the actual amount of debris from tire use on test sites and by taking samples from road water runoffs in various areas with different types of roads. Samples can be collected directly from street drains using specially developed baskets and can then be analyzed. The researchers are developing special methods for the preparation and analysis of aqueous samples such as road runoff, solid samples such as road sweepings and air particles, adapting existing analytical methods to their needs. The analyses particularly focus on the volumes and entry points of tire particles into the environment, both, on the whole and as individual groups of substances. The project team is investigating the relationship between tire wear and driving dynamics on a test track in Wietze in Lower Saxony.

The measurement and analysis results are incorporated into pollution load simulation based on a catchment area allowing to model the entry of tire debris through street drains. Exemplary catchment areas for the simulation comprise a thoroughfare in a rural territory and main and secondary roads in an urban area.

The simulation also takes into account the extent to which selected measures – such as decentralized and centralized rainwater treatment systems or municipal street cleaning – could reduce the entry of tire debris into surface waters.

Measures for Various Locations

The researchers intend to develop an evaluation matrix based on the various contributing factors. This should enable planners, municipalities and street cleaning companies to derive suitable measures for different locations in order to reduce the entry of tire debris into the environment. It is also planned to incorporate the results into national and European standards and regulations.

Tire debris entering through street drains is one of the sources of microplastics in the environment.

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

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Tyre Wear in the Environment (RAU)

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FONA Research for Sustainable Development BMBF

TextileMission – An Initiative against Microplastics from Textiles

Plastics in the Environment – Sources · Sinks · Solutions

Textiles made of synthetic fibers such as polyester can lose tiny particles during production and washing, which enter rivers, lakes and seas via wastewater and might accumulate in the food chain. Fleece materials used for functional clothing are of particular concern. Synthetic fiber particles with a diameter of less than 5 millimetres are only partially filtered out by modern wastewater treatment plants. The partners of the joint resreach project TextileMission have taken on the task of reducing this environmental impact.

Improving Processes and Wastewater Treatment

Current studies assume that 250,000 microplastic particles are washed out of a garment during laundry. For 100,000 fleece jackets, this corresponds to the amount of 11,900 plastic bags per year. The project partners of TextileMission are taking a multidisciplinary approach to this important entry point of microplastics into the environment: On the one hand, through research into textiles and improved production processes, they intend to develop fleece materials that release significantly fewer microplastic fibers than today. The textile research partners and the sportswear manufacturers involved are also testing bioplastics as an environmentally friendly alternative. On the other hand, the project participants are investigating the fate of microplastic fibers in the environment. To this end, they are examining material flows and developing wastewater treatment technologies for more effective removal of microplastics from wastewater. Such processes could also help to reduce the input of microparticles from non-textile sources.

Textiles made of synthetic fibers, such as polyester, emit microplastic particles during household washing: This applies to fleece fabrics in particular.

Determining the Status Quo

First, the researchers systematically collect data in laundry washing tests to determine the volumes of microplastic particles washed out of various textiles. In addition, textiles available on the market and fleece fabrics newly developed by the project partners – including fabrics made of bioplastics – are separated into different washes according to composition and colour. These are then laundered several times on washing programmes, which differ in temperature, duration and revolutions. Researchers collect the emitted microplastic particles in special filters and determine their number and size. The laundry washing tests are intended to identify materials, processing and finishing methods that release as little microplastic particles as possible. The technical factors of household laundry should be optimized in such a way that significantly fewer microfibers are released from the fabrics.

In order to learn more about the material flows, the research partners are following the course of microparticles released into the environment; their retention and persistence is investigated at different purification stages of a laboratory wastewater treatment plant. This provides important information for enhancing wastewater treatment processes. The research partners then determine the short- and long-term effects of non-retaining synthetic and biopolymer fibers on aquatic organisms. In addition, they are testing the biological degradation of fleece made of bioplastics under various (environmental) conditions. These findings are incorporated into the development of new materials.

TextileMission

Eine Initiative des Bundesministeriums für Bildung und Forschung
Plastik in der Umwelt
Quellen • Senken • Lösungsansätze

Strengthen Germany as a Production Location

The results of the joint research project TextileMission could contribute to strengthening Germany as a location for the development and manufacture of environmentally friendly products in various sectors: sports goods industry, household appliances and washing detergents as well as water technology. Furthermore, operators of wastewater treatment plants receive detailed knowledge about the retention of synthetic and biopolymer fibers in their facilities and thus indications for the further development of treatment technologies.

Washing tests are carried out to measure the extent of textile microplastic emissions. The picture shows the filter system and washing machines at the Niederrhein University of Applied Sciences.

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

Project Title
Microplastics of Textile Origin – A Holistic Approach: Optimised Processes and Materials, Material Flows and Environmental Behaviour (TextileMission)

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Innoredux– New Packaging Solutions Against Plastic Waste

Plastics in the Environment – Sources • Sinks • Solutions

When shopping, consumers need to make increasingly complex decisions with regards to packaging: Packaged? Unpacked? Bio-plastic? In view of the growing environmental pollution caused by plastic waste, the choice of the right packaging is becoming an increasingly important question for retailers and producers as well. The Innoredux joint research project brings together partners from various fields to look for innovative packaging solutions and implement them in mail-order and stationary businesses together with companies and municipalities.

Identify Successful Examples

Plastic waste in the environment and its consequences are a topic that is increasingly in the focus of consumers and politicians. However, companies have also recognized the need to develop new solutions for packaging along the value chain. The researchers in the Innoredux joint research project are investigating a number of questions in this regard: What business models already exist to reduce plastic waste? Which packaging innovations are already in use and which ones look promising? How can these be grouped together? How can innovative sustainable approaches evolve out of niches and find wider application?

The project partners examine the following product groups: foods, textiles, office supplies as well as cosmetics, hygiene, detergents and cleaning agents. With the help of ecological, social and economic analyses of the innovations, they identify successful examples in the respective sectors.

More and more textiles are purchased by mail order. This leads to an increased volume of packaging.

First Field Test in Living Lab

As the link between manufacturers and consumers, the retail sector plays a key role in the sustainable reorganization of value chains and the associated opportunities for influence. Consequently, the Innoredux project partners work together with associated partners from stationary and mail-order businesses to develop packaging solutions and test them in the city of Heidelberg in the form of a living lab. The living lab represents a new form of cooperation between science and society in which innovations are developed and tested for a certain period of time. The experience gained is incorporated into research.

Packaging research has so far concentrated primarily on technical innovations and has dealt less with issues such as waste reduction or the potential of retailers. In addition to new technologies, companies in the Innoredux joint research project are therefore testing new social innovations such as sales, purchasing and use patterns for products. Such changes in business models can make a significant contribution to reducing plastic discharges into the environment and at the same time create competitive advantages.

A Strategy against Plastic Waste

Based on the experience gained in the living lab, the researchers will develop a strategy for municipalities and companies to reduce plastic waste together with those involved in the project. This should facilitate the practical implementation of packaging solutions and spread existing trends.

The results will be made available as a company checklist and a conceptual guidance document for municipalities. The aim is to stimulate trade and the associated value chains to implement packaging-reducing innovations and thus to provide consumers with alternatives to conventional packaging.

Packaging-free shops allow customers to avoid plastics when shopping

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

Project Title
Business Models for Reducing Plastic Waste along the Value Chain: Paths to Innovative Trends in Retailing (Innoredux)

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01UP1804A

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InRePlast – Environmental Policy Instruments for Minimizing Plastic Discharges

Plastics in the Environment – Sources • Sinks • Solutions

Products made of plastics or plastic composites are omnipresent in our everyday lives. Accordingly, both the sources and the types of plastics that can be found in the sewage system - from where they can enter the environment - are also very diverse. How and which plastics end up in wastewater and how these inputs can be reduced with the help of environmental legislation is the focus of the joint research project InRePlast. Based on an analysis of sources, entry points and polluters, the researchers are developing and testing measures for behavioural changes. These measures are intended to motivate households and companies to reduce the amount of plastics entering water bodies. The project partners are also working on proposals to improve the legal framework.

How Do Plastics Enter Sewage Systems?

In Germany, plastics enter the sewage system via three main pathways. First, plastics end up in domestic wastewater due to the incorrect disposal of hygiene products via toilets, the washing of synthetic textiles or via the kitchen drain. A second entry point is wastewater from industry: small plastic particles (so-called pellets or granulates) are flushed into the sewage system as a result of losses incurred by plastic processing companies. Finally, plastics from litter in public spaces or from waste collection sites can be washed via rainwater into sewage systems.

The InRePlast joint research project investigates the quantity and type of plastics that are discharged into the sewage system from various sources within a year. This is carried out in four model municipalities in the urban region of Aachen. The municipalities are examples of different settlement structures: from rural communities to small and medium-sized towns to large cities.

Research in Four Model Municipalities

The plastic emissions are monitored and documented in the wastewater treatment plants of the model municipalities. The researchers examine all material flows for the plastics they contain: Screenings from rake screens, which filter larger particles out of the wastewater, the grit from the grit trap, in which heavy particles settle, the sewage sludge resulting from the biological treatment of the wastewater as well as the purified wastewater, which is finally discharged into a water body.

Small plastic particles from plastics processing companies - so-called pellets - enter the sewage system

In addition, the project partners investigate the plastic inputs from precipitation water on the streets and squares of the municipalities by installing nets in the drains of selected streets to collect solids and plastics. In addition to main roads and roads in industrial areas, the project focuses on roads where plastics industry companies are located. Based on the data collected from the wastewater treatment plants and the precipitation water collection, the scientists extrapolate a projection for Germany using material flow analysis.

Parallel to these investigations, InRePlast conducts surveys of households and plastics companies that provide information, for example, on consumer behaviour and the handling of plastic products. Authorities, environmental and industry associations as well as consumer organizations are additionally surveyed.

InRePlast

An Initiative of the German Federal Ministry of Education and Research
Plastics in the Environment
sources • sinks • solutions

Plastics in a wastewater plant

Developing and Testing Measures

Based on the knowledge gained about plastic emissions and entry points as well as knowledge of the polluters and their behaviour, the researchers develop behaviour-based measures to reduce or avoid these discharges. They investigate, for example, whether the polluters can be motivated by social norms or improved information to dispose of waste properly. Furthermore, the scientists examine which legal measures can contribute to reducing plastic discharges into wastewater systems.

The joint research project uses a computer model to simulate the effect of individual environmental policy instruments on plastic emissions into the sewage system. Furthermore, selected measures will be tested by field experiments in households of the model municipalities and in companies. As a result, InRePlast will provide recommendations for legislators, associations and companies as well as households.

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

Project Title
Environmental Policy Instruments to Reduce Plastic Pollution of Inland Waters via Wastewater Systems (InRePlast)

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01UP1803A-C

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FONA Research for Sustainable Development BMBF

PlastikBudget – How Much Plastic Can the Environment Tolerate?

Plastics in the Environment – Sources · Sinks · Solutions

Plastics that are released into the environment through specific use, carelessness, wear and tear or weathering are a growing problem in our consumer and throwaway society. But what amount of plastic is just about tolerable for the environment? How long does it take for plastics to degrade completely? In order to answer these questions, the joint project PlastikBudget intends to propose a per capita budget based on scientific research and thus develop a clear basis for future political decisions.

Data Basis as Foundation for Budget Approach

The global production of plastics is growing and is an important economic sector in many countries. At the same time, a lot of plastics end up as waste in soils and oceans at the end of their life cycle. Already today, the ratio of plastics to biomass from the sea is 1:5, and may increase to 1:1 by 2050. These current figures show how important a sustainability-oriented shift in the handling of plastics is.

The global and inter-generational dimension of the problem requires a collective contribution from science, politics, business and consumers to reach a solution. In order to politically regulate the future handling of plastics, it is necessary to formulate target figures for plastic emissions. This will be supported by the budget approach that will be developed within the joint research project. The project intends to determine the total permissible quantities of plastic emissions worldwide as well as the 'permitted' annual per capita emissions of plastics into the environment.

Large and small plastic parts enter the environment from various sources.

The project partners bring together scientific findings on the sources, quantities and effects of plastics in the environment and the interests of relevant stakeholders. It is not the project's priority to define a specific budget. Instead, the researchers want to point out ways how such an emissions budget can be derived from empirically verified data and social values in order to create a widely accepted framework for future political decisions.

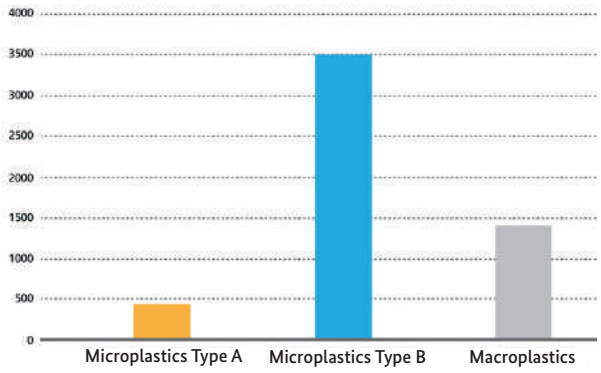
Consider Plastic Waste in Life Cycle Assessments

Furthermore, regulations on plastic emissions require that products, processes and consumer practices concerning the amount of plastics released and their downstream environmental impacts can be accounted for and thus be compared. To this end, the joint research project is developing an impact assessment methodology with corresponding environmental indicators so that plastic waste can be appropriately considered in life cycle assessments. In principle, this is already possible today: Toxic effects, e.g. from substances contained in plastics such as softening agents, can be determined using the standard categories of a life cycle assessment. The same applies to waste accumulations on land and in the ocean or climate-relevant effects such as the storage of carbon in plastic waste. Due to the increasing attention that the plastics topic has gained in environmental discussions in recent years, the project team also wants to examine new categories for environmental impacts. These could include, for example, the death of marine organisms through microplastics, the risk of smallest plastic particles accumulating in food chains or the negative aesthetic consequences of plastics in the environment.

Raising Awareness of Society and the Economy

In order to implement the idea of a plastic budget, it is essential to have communication strategies that increase understanding of political decisions and raise awareness among citizens and industry regarding the negative consequences of plastic emissions. What this kind of communication could look like, whether it will prove itself in the reality check and what resistance has to be expected in the future are further important guiding questions in the project.

The results of PlastikBudget should, among other things, contribute to standardization processes such as VDI guidelines as well as DIN/ISO standards and influence political strategies, e.g. the Marine Protection Framework Directive, the German National Sustainability Strategy or the EU's Circular Economy Action Plan.



Current estimates of plastic emissions in Germany in grams per capita and year (g/cap a); microplastics are divided into type A (intentional or accidental release) and type B (release due to wear and weathering).

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

Project Title
Development of Budget Approach and LCA Impact Assessment Methodology for the Governance of Plastics in the Environment (PlastikBudget)

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VerPlaPoS – Avoiding Plastic Waste through Purchasing Decisions

Plastics in the Environment – Sources · Sinks · Solutions

Consumers play a ciritcal role in the consumption of plastics in Germany through their purchasing decisions. It is hardly possible to avoid plastics completely in everyday life – especially since many people are not aware of how much plastic they unintentionally put into circulation or into the environment when purchasing a product. However, consumers can influence the use of plastic by choosing specific products when shopping. Stakeholders from various sectors are collaborating in the joint research project VerPlaPoS to investigate how customers can avoid plastic waste directly at the point of sale through their purchasing decisions and how best to support them in doing so. This is being examined using food packaging and clothing textiles as examples.

Plastics in Retail: How Much is Generated?

While plastics in food packaging immediately catch the eye in supermarkets, they are often not as obvious in textiles. However, plastics are also involved in the packaging and transport of clothing. The project partners will therefore first determine consumers‘ knowledge on plastics and also investigate the reasons that influence the purchase of plastic-packed food or textiles. This research will be conducted directly at the point of sale, in various food and textile shops in Straubing, Bavaria. Product selection at a given point of sale also plays a significant role in the purchasing decision. Therefore, the research teams will examine the assortment in the shops. In addition, the associated plastic waste and disposal routes as well as the respective upstream value chains are considered. This will help to determine how much plastic waste a certain range of goods generates, both in the stores themselves and in the upstream steps.

Developing Strategies against Plastics

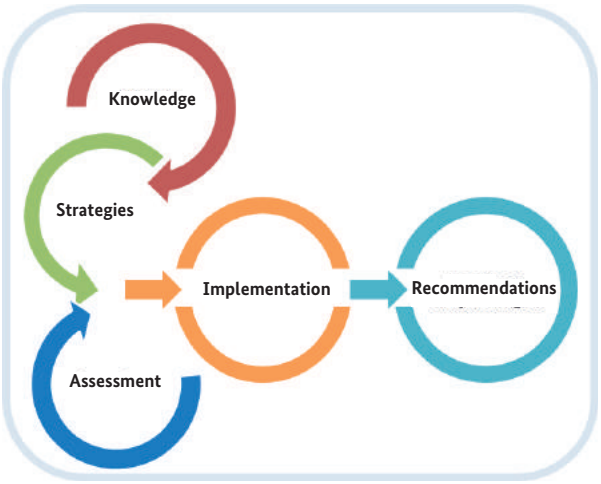
Based on the findings, the researchers will then develop specific strategies to reduce the amount of plastic consumed. In addition, they will evaluate new food packaging and test whether these are indeed more environmentally friendly than plastics. Together with partners from the textile industry, the entire textile supply chain will be examined to determine how plastics can be avoided. Where the use of plastics is unavoidable scientists are trying to develop new recycling solutions: Using innovative manufacturing processes, they plan on producing new materials for clothing.

Food such as cured meats is often found in plastic packaging.

Products and Solutions in Practice

The project participants will determine whether the new products and solutions could make a significant contribution to avoid plastics by looking at product life cycles. This information will result in a plastic index, among other things. It will summarize criteria such as the packaging material used, its recyclability and the associated environmental impact. Consumers will benefit from this index and further information on the problems caused by plastics in certain products in the form of an app. It will provide information on the overall size of e.g. the “plastic backpack” of a product and can thus influence the purchasing decision. The app will later be tested in conjunction with some of the products and solutions developed within the project in the stores of partner companies in the food and textile industries.

The plastic avoidance strategies, that are implemented in practice, form the basis of recommendations for action in the sectors investigated. With their help, retailers and consumers can contribute to avoiding plastics in everyday life.



The conceptual framework of the joint research project VerPlaPoS

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

Project Title
Consumer Behaviour Related to Plastic and its Avoidance at the Point of Sale (VerPlaPoS)

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KuWert – New Ways to Reduce Plastic Waste in the Oceans

Plastics in the Environment – Sources • Sinks • Solutions

Plastic waste is a major threat to marine ecosystems. Every year, an estimated ten million tonnes of plastic waste end up in the oceans, where they need centuries to degrade. To prevent this, effective collection and disposal systems have to be in place. However, this is not the case in many developing countries. This is where the KuWert project comes in. The researchers are developing solutions for a ship-based treatment of plastics waste. The intention is to help creating new value chains in developing countries and avoid plastic waste in the oceans.

Leakage through Interrupted Value Chains

Until now, it has not been technically and economically feasible to remove large quantities of plastic waste from the oceans. Hence, the amount of plastic waste in marine ecosystems has continuously increased and is estimated to double by 2025. Solutions are needed to reduce the emission of plastics into the environment. Functional waste disposal systems, common in industrialized countries, are often lacking in less developed countries due to uncertain political and economic conditions. There, large quantities of plastic usually leak into the environment and subsequently, especially in coastal areas, into the oceans. Recycling is virtually non-existent and value chains are thus interrupted. Consequently, plastics with a market price of up to 600 Euros/Mg are left by the roadside, although considerable parts of the population live on one dollar or less per day.

Ship-based Treatment as an Innovative Approach

The joint research project KuWert has two objectives: The reduction of plastic waste emissions into the environment and the oceans. In addition, value-added chains for the recycling and trade of the waste in the participating countries (Sierra Leone and Mauritius) will be created. The core of the concept is a ship-based solution for the collection, treatment and marketing of plastic waste. This aims at overcoming the challenges of setting up disposal infrastructures on land. A first draft of a modular platform already exists. This platform has to be equipped with the required systems: storage areas, conveyor belts, balers, shredders, washing systems, drum screens, magnetic separators, plastic detector sensors, sorting equipment, suitable construction machinery and an extruder for processing recycled plastics.

Cleaner Environment and Economic Benefits

KuWert thus tackles this problem at its core. The concept is to create incentives for collecting the plastic waste produced in households and industry through new local recycling options to prevent leakage into the environment and the oceans. In addition, valuable secondary raw materials are obtained. The mobile nature of this form of waste treatment allows ports on international trade routes to be served making it possible for the waste to reach international recycling markets. The researchers also want to investigate whether it is technically and economically feasible to produce and market products such as piles, paving stones or roof tiles from plastic waste in the target countries themselves.

Plastic waste in Sierra Leone that is washed into the oceans during the rainy season.

KuWert
Recycling of Plastics

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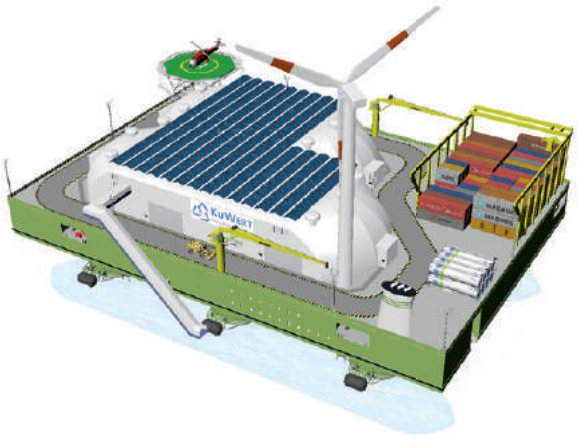
By closing value chains, people benefit not only from a cleaner environment but also economically. This provides the basis for the sustainable implementation of mobile waste treatment systems in the target countries.



Concept of a ship-based platform for the treatment of plastic waste

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

Project Title
Ship-based Treatment of Plastics for the Implementation of Value Chains in Less Developed Countries as well as for the Prevention of Plastic Inputs into the Environment and Especially in Marine Ecosystems (KuWert)

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MaReK – Improving Plastic Recycling with Fluorescent Markers

Plastics in the Environment – Sources · Sinks · Solutions

In Germany alone, about three million tons of packaging waste are generated each year and the number continues to grow. This waste is produced daily in every household, usually collected in yellow bags or bins, and then picked up. How can high-quality secondary raw materials be obtained from this waste? Is it possible to produce high-grade new packaging from used ones? Suitable technologies for sorting plastic waste are a prerequisite for such material recycling. The partners in the joint research project MareK are focusing on special fluorescent markers for this purpose. When integrated into packaging, these markers should enable the sorting of plastics from waste by type.

Markers Promote Material Recycling

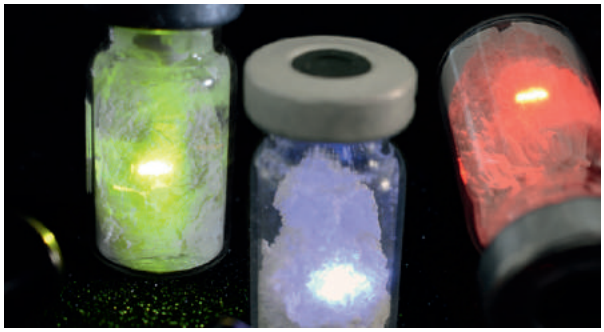
The collection, sorting and recycling of sales packaging from the household sector – also known as the post-consumer sector – has been regulated in Germany since 1991 by the Packaging Ordinance. Starting in 2019, a new packaging act will apply. Accordingly, 63% of plastic packaging must be recycled from 2022 onward so that it can be processed directly into new, high-quality products. At present, many packages are still being thermally recycled, i.e. they are being incinerated. From the perspective of climate policy, it would be desirable to expand the recycling of packaging plastics, as this can reduce CO2 emissions. Additionally, it can help to secure raw materials.

The currently used sorting technologies are not able to keep up with the further development of packaging and materials technology in material recycling. The reason is that the quality requirements for secondary raw materials obtained from recycling – also known as recyclates – are increasing, for example to enable reuse in the packaging sector.

The joint research project MaReK is therefore pursuing a new approach: this should allow for sorting products or recyclable materials independently of their physical properties. The basis of this new sorting system is Tracer-Based Sorting (TBS). This technology uses inorganic phosphors or fluorescent markers to separate plastics much more accurately. This means that in future developments it will not only be possible to differentiate according to different types of plastic, but also according to other packaging properties such as contents or multilayer systems. Thus, with the current collection systems in Germany, even more waste could be seperated and recycled to high-quality materials.

Technology Development for Pilot Use

The project consortium, which consists of five companies and research institutes, is initially examining marker materials for their suitability in plastic packaging and then further developing them. This is followed by the pilot application of the new system under technical conditions. The aim of the joint research project is to establish a marker-based sorting and recycling system that includes package labelling, an appropriate sorting process and high-quality material recycling to obtain secondary raw materials. In the first step, the project partners affix the marking material to the packaging – in the plastic itself or on the respective label. This marker has fluorescent properties and illuminates under a certain light when sorting. The sorting plant, which is being set up in Freiburg, reacts to this and sorts out the marked objects. Thus, regardless of shape, color or condition, plastics can be separated and recycled in a targeted manner.



Fluorescent markers should enable improved sorting of plastic packaging.

Thus, food packaging, for example, can be sorted and reused for the same purpose. It will also be possible, for the first time, to distinguish between different types of the same plastic. Secondary raw materials obtained by recycling will then also be suitable for applications and sales markets in which only new plastics have hitherto been used. In this way, TBS technology reduces the consumption of primary raw materials and protects the environment.

Focus on Entire Value Chain

MaReK not only focuses on the technical core, but on the entire value chain of the packaging life cycle. This means that investigations into suitable marking substances and application areas of the secondary raw materials take into account economic and ecological aspects. In order to assess the market opportunities for the marker-based sorting technology, the project partners are analyzing the associated energy and material flows and evaluating potential environmental impacts. Together with various stakeholders from business, associations, society and politics, approaches are being developed for new ways of dealing with packaging and improving waste management. The goal is to significantly increase the mechanical recycling of packaging in order to secure raw materials and protect the environment. Apart from the the packaging industry, additional sectors are being addressed for the reuse of recycled materials.

A specific IR laser pointer makes the fluorescence visible. The marker can be inserted in the label (left) or in the plastic itself (right).

Research Focus
Plastics in the environment – Sources • Sinks • Solutions

Project Title
Marker-based Sorting and Recycling System for Plastic Packaging (MaReK)

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ResolVe – New Life for Polystyrene Waste

Plastics in the Environment – Sources · Sinks · Solutions

The plastic polystyrene (PS) offers many advantages. Light, strong, water-repellent and with very good insulation properties when foamed, it can be used in a wide variety of applications, such as in sanitary and construction applications, as housing material in electronic devices and toys and for packaging. However, the disadvantage is that currently there exists no comprehensive recycling system for polystyrene. The joint research project ResolVe is addressing this problem. The partners are developing a logistics and plant concept based on chemical recycling that enables the economical reuse of polystyrene waste as a raw material for high quality new plastic products.

Chemical Recycling as Basis for Closed Loop Concept

Current recycling methods are based on material or thermal recycling of plastic waste. However, these do not represent a closed and sustainable cycle. The recyclates obtained from material recycling do not usually meet the high standards required for food packaging with regard to the purity of materials and their properties. Furthermore, many used plastics are only suitable for thermal recycling, since the quality of the material flows after sorting is not sufficient for other recycling methods.

As early as the 1980s and 1990s, intensive research was conducted regarding processes for raw material and chemical recycling of plastic waste. Raw material processes disintegrate plastics to their basic chemical components – the monomers – from which plastics can best be reprocessed. However, technical problems and economic reasons – e.g. unsuitable material flows – have thus far hindered industrial applications. Growing quantities of plastic waste, which are increasingly found in oceans and water bodies, have now led to renewed interest in raw material recycling.

The joint research project ResolVe therefore focuses on chemical recycling through thermal depolymerization: Plastics (polymers) are broken down into their basic components using heat. These can then be used to produce new plastics for any application. This creates a closed loop system. In the packaging sector, polystyrene is the only standard plastic for which thermal depolymerization works so that its individual components – styrene monomers – can be recovered. In this way, the depolymerization of polystyrene differs substantially from the pyrolysis decomposition of other packaging plastics leading to an undefined mixture of substances. In addition, depolymerization as a form of raw material recycling does not demand high material purity. This means that many consumer wastes can be used, including those that were traditionally only recycled thermally.

High-Quality New Products from Polystyrene Waste

The process that the researchers in the ResolVe project intend to develop consists of a multi-stage process: First, a relatively pure concentrate has to be produced from the polystyrene waste. For this purpose, the waste is cleaned, sorted and shredded. In the second step, the prepared material is thermally decomposed in a suitable extractor, for example an extruder which is commonly used in plastics processing. The styrene monomers are then separated from by-products, cleaned, and can be directly reprocessed into new, high quality polystyrene comparable to virgin material. Other basic materials for plastics, such as ethane, propene or benzene shall also be obtained from other products resulting in the process. Initially, the project partners are testing the depolymerization on model substances and waste samples on a laboratory scale.

Laboratory reactor with attached condensation unit for the depolymerization of polystyrene

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Developing Integrated Recycling Concepts

In addition to technical questions, ResolVe is also addressing other more general topics related to polystyrene recycling. In dialog with waste disposal companies, complete concepts for the recycling of plastic waste are being developed. To this end, the project partners are capturing the most important real material flows – including plastic waste from waters – and taking respective samples to determine their suitability for chemical recycling. Existing contacts to other research groups dealing with the collection of marine plastic waste are used for this purpose. The researchers are developing specific logistical concepts for the material flows so that high recycling rates can be achieved.

A polystyrene fraction from the German dual system of waste collection is sorted manually.

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

Project Title
Recycling of Polystyrene by Raw Material Recovery (ResolVe)

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solvoPET – High-quality Raw Materials from Waste

Plastics in the Environment – Sources • Sinks • Solutions

Mixed materials of various plastics are often used for high-quality, high-performance packaging or technical applications. These include in particular composites with polyethylene terephthalate, known as PET. At present, such mixed PET waste cannot go through material recycling; it can only be energetically recycled and is thus lost for the production cycle. The joint research project solvoPET aims at improving this. Recycling unsorted PET waste plastics using a novel process should become possible, too. The secondary raw materials obtained have the quality of virgin material and can be used for any purpose.

Preserving Valuable Raw Materials

The most commonly used packaging plastic today is polyethylene terephthalate (PET). It has special technical properties such as a high gas tightness and can therefore be used in a variety of applications, e.g. for food packaging. At present, economic recycling of PET waste is not possible due to impurities such as colouring, added substances such as an oxygen-barrier (so-called scavanger materials) and compounds with other plastics (so-called multilayer films). These „impurities" lead to discoloration or sticking and degrade the material properties. Extensively sorted PET waste plastics are thus lost for the production cycle. The same applies to PET waste from inland water bodies or from the oceans and, to a large extent, to the quantities of waste from technical PET applications such as strapping, braided hoses or shrink labels.

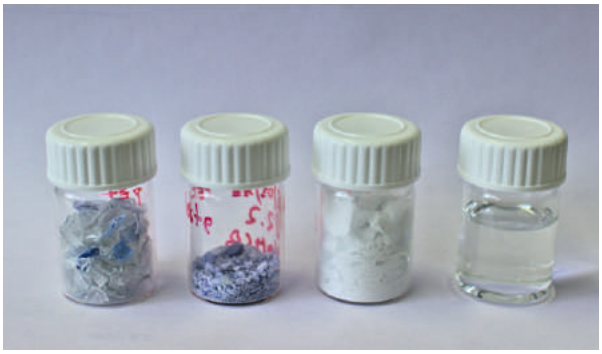
Political requirements meanwhile oblige plastic producers to high recycling quotas. For example, the EU Plastic Strategy of January 2018 states that all packaging plastics should be 100 percent recyclable by 2030. This is intended to promote the use of secondary raw materials. In order to achieve the recycling targets, existing recycling practices have to be changed. Likewise, more plastics such as PET or polyesters used in textiles should be recycled instead of being used to generate energy.

High-grade Raw Materials from Chemical Recycling

At present, mixed or contaminated plastic waste is mainly sent to mechanical treatment plants for material recycling. The clear identification and sorting of different types of plastics in these plants is only possible to some extent. As for composite materials, they do not work at all. The same applies to polyester fibres in textiles.

The solvoPET joint research project uses chemical reactions to treat such plastic waste. It aims at recycling mixed PET waste without costly presorting. The basis is the solvolysis process, which will be further developed (as part of the project). In this process, the plastic structures are broken up. The plastics disaggregate into their basic components: monoethylene glycol (MEG) and terephthalic acid (TPA). The recycled TPA and MEG have the quality of primary products and can therefore be reused for the production of new goods without restrictions.

Researchers expect the further development of the solvolysis process to offer significant added value from both an ecological and economic perspective as previously unused waste streams can be recycled. Raw materials obtained from recycled PET waste have the same quality as original goods.



From PET to its basic components terephthalic acid (TPA) and monoethylene glycol (MEG)

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Pilot Plant for a Continuous Recycling Process

The project participants want to implement and test the basic process steps for the continuous solvolytic recycling of PET plastic waste in a pilot plant. In addition to the technical processes and plant components, they also evaluate the cost-effectiveness of the solvoPET process as part of a comprehensive life cycle analysis. The requirements for a scale-up to industrial level can be derived from the experience with the technical system.

Precipitation of terephthalic acid (TPA) from dissolved PET

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

Project Title
Development of a Recycling Technology for PET Waste Plastics from Multilayer Material and Other Waste Composites (solvoPET)

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EmiStop – Microplastics in Industrial Wastewater

Plastics in the Environment – Sources • Sinks • Solutions

Industrial wastewater is one of the entry routes for microplastics into water bodies. However, little is known about how many of these tiny plastic particles are actually found in the wastewater of different industrial sectors, how their emission can be avoided and which effective purification technologies exist. The EmiStop joint research project aims to provide answers. For the first time, partners from industry and science want to compile reliable information on plastic types in various industrial wastewaters and their concentrations. In addition, they want to develop measures adapted to the respective industry so that microplastics do not get into wastewater in the first place or can at least be efficiently removed from it.

Detecting Microplastics in Wastewater

Microplastics in industrial wastewater presumably originate mainly from plastic pellets, which serve as a base material for plastic products, and from synthetic fibre abrasion during the processing and washing of synthetic textiles. Therefore, the project partners are initially investigating wastewater from companies that produce, transport or process plastics and from industrial laundries. In addition, other industries are systematically examined and evaluated to obtain a comprehensive overall picture of industrial plastics emissions.

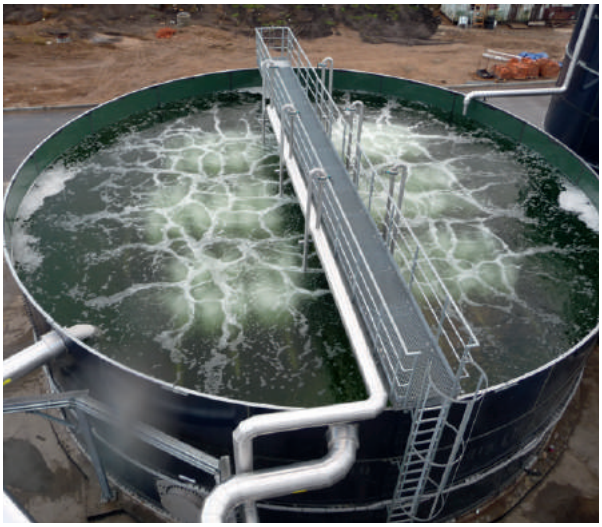
The researchers use two new methods to analyze the wastewater samples. The first is dynamic differential calorimetry, which they use to determine the type of material and the actual concentrations of plastic particles. This analytical method is used as a standard for e.g. quality assurance in plastics production, but at present less so for the analysis of environmental samples. Raman spectroscopy, on the other hand, can be used to simultaneously identify plastic particles and determine the particle numbers and sizes.

Limiting Emissions at the Source

In order to avoid microplastics emissions in the first place, EmiStop first looks at the industrial plant itself. It examines where the particles have the potential to enter wastewater. Together with companies, the project participants are looking for ways to reduce such pathways along the value chain, ideally through an internal recycling of plastics. To ensure that such avoidance strategies and adapted processes for wastewater treatment are actually implemented, EmiStop also engages stakeholders from science, associations and other interest groups. An expert survey is to provide information about technical and regulatory framework conditions that promote or hinder the measures.

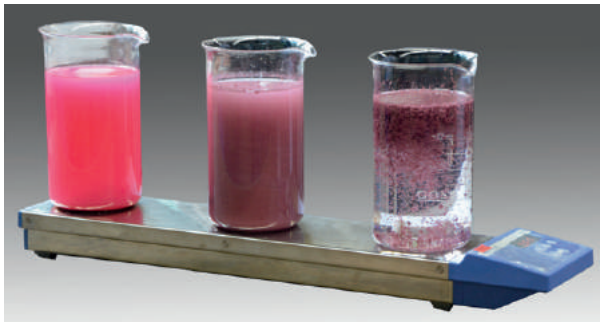
Improving Retention in Wastewater Treatment Plants

If emissions cannot be avoided, microplastics have to be removed from wastewater by suitable cleaning processes. EmiStop examines which technologies are suitable for a specific industrial wastewater. For this purpose, established processes for wastewater treatment are analyzed and optimized for the elimination of microplastic particles. In addition, the researchers are developing new flocculants that are adapted to different plastic types and can retain microplastics more effectively in wastewater treatment plants.



Industrial wastewater being treated in an open reactor.

A novel tracer test is used in laboratory and pilot trials to evaluate the existing and developed technologies. The project partners are developing special tracer particles with the properties of plastic particles and an additional magnetizable core. These can then be easily removed from the wastewater using a magnetic separator, and their magnetic properties can be measured in terms of quantity. This way, researchers can demonstrate the efficiency of different purification processes in industrial wastewater treatment plants for the elimination of microplastics. And they can show the significance of industrial microplastic emissions into water bodies. In connection with new findings on the entry routes of microplastics, adapted strategies are needed for individual industry branches to avoid plastic emissions into water bodies. The new and optimized technologies should be applicable in industrial and municipal wastewater treatment plants.



Flocculation of microplastics (left: suspended microplastics; middle: the flocculation process; right: microplastic flakes rising to the surface).

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

Project Title
Identification of Industrial Plastic Emissions by means of Innovative Detection Methods and Technology Development to Prevent the Input into the Environment via the Wastewater Pathway (EmiStop)

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ENSURE – Holistic Strategies for Handling Plastics

Plastics in the Environment – Sources · Sinks · Solutions

Plastics are durable, versatile and inexpensive to produce. While these characteristics are advantageous for production, they may have adverse effects when large amounts of plastics enter the environment uncontrolled. In particular, the extreme longevity and durability on both land and in water lead to accumulation of plastics in large quantities. The joint research project ENSURE pursues a holistic approach to reduce plastic in the environment as well as the related negative consequences. In this regard, the partners seek to develop environmentally friendly plastics. Further goals include improving methods of analyzing the environmental impact of plastics and developing strategies to promote more conscious consumer behaviors.

Detecting and Measuring Plastic Loads

Plastics are often released into the environment through so-called littering – careless disposal – and the use of secondary raw material fertilizers such as sewage sludge and compost in agriculture. In order to obtain more detailed findings about the environmental impact of plastics, the seven project partners from science and research are examining soils, wastewater treatment plants, compost, and biogas plants. Initially, they will develop sampling strategies in order to carry out investigations on the occurrence of plastics within these plants.

Within the project, researchers seek to further develop novel remote sensing methods to comprehensively detect plastics in the environment. The aim is to devise a multisensor system that indicates the type and extent of potential environmental impacts of plastics. The project participants expect to produce fast and simple mapping through airborne reconnaissance methods. This corresponds to a global demand for innovative and rapid detection methods for plastic pollution.

Researchers are testing various sensors and cameras for detecting and monitoring plastics in the environment.

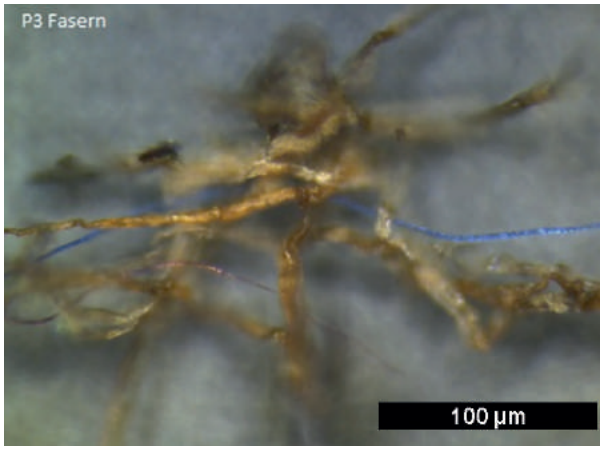
Development of Environmentally Friendly Plastics

In the next stage, the project partners seek to develop industrially relevant plastics with environmentally optimized degradation behavior. This concerns in particular PE and PET – the plastics most widely used in Germany for beverage packaging – as well as PBAT, which is often used for films. The materials should be just as stable as before, but able to degrade faster and more sustainably. This will be achieved through suitable additives that influence degradation capabilities. The entire value chain of the developed materials will also be examined. Their physical, chemical and biological stability will be tested throughout their processing. The researchers are also focusing on how the new plastics affect small animals living in soils, such as worms and mites. Whether these materials are really environmentally friendly will be tested in experiments on biological degradation of plastics.

Plastic manufacturers should be able to produce the materials developed through this project without altering their plant technology. Manufacturers, plant constructors and their operators will be able to incorporate environmentally friendly plastics into their portfolio and expand their business areas. Further major market potentials exist in the packaging, construction, agriculture and textile sectors.

Strategies to Promote Sustainability

Another component of the ENSURE joint research project focuses on consumers and their behavior in regard to plastic products. Using expert interviews, focus groups, qualitative indepth interviews and an online survey with selected target groups, the common perceptions and behavior patterns in dealing with plastic will be recorded and analyzed. The researchers want to use this data to develop behavioral offers and messages that motivate consumers to buy and use less plastic.



Microscopic image of plastic fibers whose biodegradability is being investigated in this joint research project.

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

Project Title
Development of New Plastics for a Clean Environment by Determining Relevant Entry Points (ENSURE)

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MicBin – Microplastics in the Danube River Basin

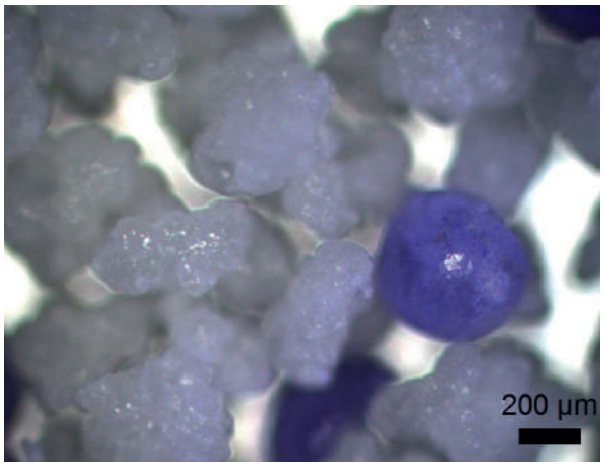
Plastics in the Environment – Sources · Sinks · Solutions

Large quantities of plastics enter the oceans through rivers and streams. However, little is known about the occurrence and transport routes in river basins. The joint research project MicBin aims to conduct an initial assessment of the entry points and the fate of plastic particles of different sizes in the German part of the Danube river basin. This study is primarily focusing on the analysis of microplastics: particles less than 5mm in size. The researchers are identifying quantities of microplastics in several Danube tributaries, investigating sources and sinks, and using models to test possible precautionary measures that can reduce the emission of plastic particles into the Danube river basin.

Measurement Campaigns for Determining Plastic Balance

The project partners are running extensive measurement campaigns at the Danube tributaries Ammer, Loisach, Würm and Amper in order to determine the quantity of microplastics entering the Danube river basin. They specifically focus on small plastic particles with diameters ranging from 2mm to one hundredth of a millimeter (10 µm), invisible to the naked eye. These particles are most frequently found in the environment and therefore of particular importance.

Through extensive sampling, targeted field studies and various analytical methods, the joint research project MicBin aims to identify the most important sources and sinks of microplastics in a large-sized river basin for the first time. The quantity, origin, transport and fate of the particles are being determined on the basis of measurement results and models of the entire Danube area. Researchers are examining wastewater treatment plants, landfill leachate and plastic waste on shores as potential sources of microplastics as well as the hitherto little investigated entry points from agriculture, ersosion and air. Additionally, they are analyzing barrages, soils and low-flow sections of water as potential sinks for microplastics.



Microplastic particles (polyethylene) isolated from a cosmetic peeling product

The project partners are also taking into account various processes such as the relocation, distribution and shredding of plastic waste in watercourses to understand the transport and alteration of the material in the environment. For different types of samples (soil, sediment, wastewater treatment plant effluent, leachate, surface water) sampling and analytical methods are being developed or optimized.

Models for Evaluating Measures in Advance

The measurement results from the rivers and field tests form the basis for further investigations with process- and transport-oriented models. This enables researchers to estimate the total loads of microplastics in the Danube river basin and to trace the fate of particles from land to sea. Using various simulations, they can also evaluate the effectiveness of targeted strategies against microplastics in the environment. These include, for example, local measures, such as the retrofitting of individual wastewater treatment plants, or restrictions that have regional effects, such as a ban on plastic films in agriculture. The models can also be adapted to other river basins and used there in a similar way.

Basis for Future Planning

From analyzing the various scenarios, the project partners will derive promising strategies to reduce plastic pollution in river basins. This could form the basis for future planning and legal requirements. In practice, this can benefit stakeholders such as associations of water and wastewater management, industry and agriculture, competent authorities as well as water supply and wastewater treatment companies.

Plastic garbage in a still water zone on the Danube

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

Project Title
Investigation and Modeling of Entries and whereabouts in the Danube Area as a Basis for Action Planning (MicBin)

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MikroPlaTaS – What Happens to Microplastics in Dams and Reservoirs

Plastics in the Environment – Sources · Sinks · Solutions

Extremely small plastic particles can be detected in varying concentrations in many inland waters. Previous studies show that fewer particles are found in rivers downstream of the reservoirs than upstream. Researchers assume that microplastics accumulate on the bottom of these water bodies. Dams and reservoirs therefore represent possible sinks for microplastics. The aim of the joint research project MikroPlaTaS is to gain a better understanding of the environmental factors that lead to the sedimentation of plastic particles in these water systems and to assess their effects on aquatic organisms.

Potential Factors for Accumulation of Microplastics

Plastic particles are typically lighter than water; thus, most particles should swim on the surface while only a few float in water or sink to the bottom. However, this is exactly what happens over time. A prediction of sedimentation behavior is therefore important as it can be used to estimate the pollution of downstream waters as well as the effects on various aquatic populations. There are several reasons why the plastic particles may behave contrary to expectations. For example, it is possible that the density of the particles increases due to fouling. It is also conceivable that they absorb more water through weathering. Furthermore, microplastics could stick to surfaces or be consumed by animals.

Tracking Down Causes in Environment and Laboratory

The researchers want to experimentally determine the plastic concentration in sediment and which mechanisms cause particles to sink as well as to compare these to the results of field tests. Three industrial water reservoirs in Saxony (Bautzen, Quitzdorf and Malter) and three dammed areas in North Rhine-Westphalia (sections of the Ems, the Lippe and the former sewage fields of the city of Münster) serve as field investigation sites.

Dams and reservoirs offer ideal conditions to act as sinks for particles due to their decreasing flow velocity. In Germany alone, there are over 300 reservoirs, and almost all major rivers are dammed several times. In these water systems, which are important for water supply and leisure use, significant microplastic loads are expected, but have not yet been investigated. Because dams are regularly monitored by their operators, there are existing databases for the environmental conditions. The project partners are conducting chemical and biological analysis of water and media samples to examine them for microplastics. So-called sediment traps are being used at selected sites to quantitatively determine the amount of suspended particles sinking at different times of the year and to establish whether microplastic particles are present.

Moreover, MikroPlaTaS also examines the microbial colonization of plastic particles and the role of these biofilms on sedimentation. Researchers are investigating the deposition of overgrown microplastics in laboratory experiments under various environmental conditions: in light, in the dark, with oxygen and without oxygen. This work provides major impulses for the third focus of the joint research project. The aim here is to determine the ecological effects of plastic particles with different

At the water reservoir in Bautzen, employees of the state dam administration show the researchers where to use boats for sediment sampling.

biofilms on cohabitation in plankton as well as in the sediments of water bodies. The planned experiments range from small laboratory vessels with individual key species such as water fleas, rotifers, nematodes and snails to artificial ponds with complex biological communities, so called mesocosms.

Risk Assessment and Recommendations for Action

The project partners will present a risk assessment for the contamination of dams and reservoirs with microplastics as well as concrete recommendations for practical action. A better understanding of the distribution, deposition processes and effects of microplastics in dams and reservoirs will enable researchers to assess the natural self-cleaning potential in these water areas. These findings can be used for water management and future construction measures. If, for example, the deposition of small plastic particles proves to be environmentally compatible, concepts could be developed to promote this process. The practical recommendations for the handling of microplastics are being developed with the practical partners of MikroPlaTas – the State Dam Administration for the Free State of Saxony, the City of Hamm, and the North Rhine-Westphalia Nature Conservation Academy (NUA).

Roundworm with recorded microplastic (1 µm, blue fluorescent)

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

Project Title
Microplastics in Dams and Reservoirs: Sedimentation, Spread, Effects (MikroPlaTas)

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PLASTRAT – Reducing Input of Microplastics into Inland Waters

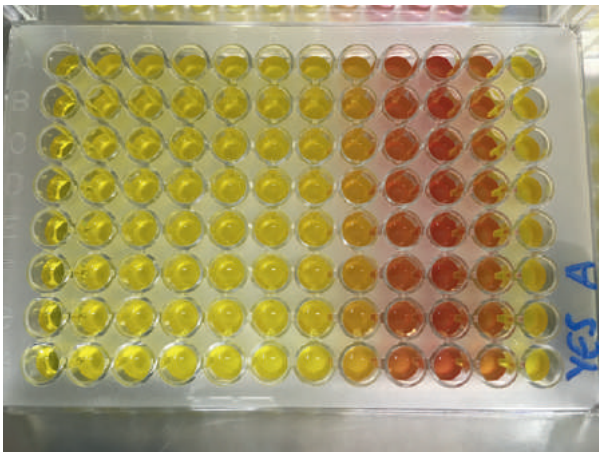
Plastics in the Environment – Sources · Sinks · Solutions

While plastic waste and microplastics in the oceans have been investigated for some time now, little is known about their effects in inland waters. How do plastic particles enter rivers and lakes? What is their impact on people and the environment? How can the released plastic particles be safely, effectively and efficiently eliminated from water? The joint research project PLASTRAT will provide answers to these questions and develop solutions to reduce the entry of plastic into limnic systems.

Entry Points and Consumer Behavior

The primary entry routes for plastic particles into surface waters stem from urban water management: discharges from rainwater and mixed water sewers as well as wastewater treatment plants. Furthermore, the particles are washed out of agriculturally-used sewage sludge, compost and digestate. It is unclear how significant each of the individual sources is and what options exist, such as through technical procedures, for avoiding these emissions. Therefore, the PLASTRAT project focuses on the pathways of plastic particles. For example, the researchers consider tire abrasion as an emission source and examine sewage sludge as a possible microplastic sink. They are also working on suitable methods for sampling, processing and analyzing microplastics in various media such as water, sediment and sludge.

Consumer behavior also plays a major role when examining microplastic sources. In addition to hygiene articles such as wet wipes or tampon packaging, this includes clothing (e.g. fleece jackets) and dog excrement bags. Plastic particles are released into the environment from these sources during washing or improper disposal. The demands of both manufacturers and consumers of plastic products, especially regarding their properties, are being considered in detail. Researchers continue to investigate how consumers perceive environmental risks associated with plastic and what impact this has on usage and disposal practices. Additionally, they are identifying the potential for replacement materials, such as bio-based or biodegradable plastics. In doing so, they take into account factors such as altered product quality, price and risk acceptance.



Ecotoxicological testing of samples for hormonal activity

Impact of Plastic Degradation

The joint research project also sheds light on the possible effects of plastic particles on people and the environment. To this purpose, researchers are analyzing the environmental changes in various types of plastics: how are plastic residues broken down in freshwater and sewage sludge? What happens to potentially dangerous additives such as plasticizers and can these have hormonal effects or other harmful impacts on living organisms? Changes in the plastic surface can also be significant for the absorption and desorption of pollutants from microplastic particles. The project partners want to determine what exactly happens using experiments at wastewater treatment plants.

PLASTRAT

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Plastik in der Umwelt
Quellen • Senken • Lösungsansätze

Practical Solutions

In parallel with investigations about pathways and environmentally induced changes of plastic particles, the project partners are exploring methods of removing microplastics from wastewater. Researchers are analyzing whether advanced wastewater treatment, such as ozonization and sand-activated carbon filtration or ultrafiltration membranes, enables the elimination of microplastics.

The joint research project also aims to present solutions that go beyond microplastic research. The interdisciplinary research teams plan to develop a joint evaluation system for the environmental compatibility of different types of plastics and, building on this, to establish criteria for a quality seal for practical use. This could serve as a guide for consumers and decision-makers for more environmentally sound handling of plastic products. Information on the harmful effects, distribution or elimination possibilities of plastics or products would allow for evaluation and thus selection between several alternatives.

The Holzkirchen wastewater treatment plant is used for sampling in the project.

Research Focus
Plastics in the Environment – Sources • Sinks • Solu-tions

Project Title
Solution Strategies to Reduce Entries of Urban Plastic into Limnic Systems (PLASTRAT)

Grant Number
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REPLAWA – Less Plastics from Wastewater

Plastics in the Environment – Sources · Sinks · Solutions

Wastewater treatment plants play a central role in reducing plastic emissions into the environment because they act as direct interfaces to water bodies. However, it is still unclear how wastewater treatment plants can contribute to counteract the spread of plastics, and especially tiny plastic particles – microplastics. The goal of the joint research project REPLAWA is to gain new insights. The partners are analyzing the entry points of plastic through wastewater systems into water bodies and examining the possible sinks within wastewater treatment and in sewage sludge. In addition, they are testing and evaluating the effectiveness of various technical procedures for plastic elimination.

Inventory of Microplastic Entries

To date, there is no standardized method for determining the presence and quantities of microplastics in wastewater and sewage sludge. Therefore, one focus of the REPLAWA project is on the further development of sampling, sample preparation and analysis methodology. Practical and robust methods are the prerequisite for clarifying entry points of microplastics into water bodies and for determining their dimension. Furthermore, by providing information on how much plastic is removed in the individual clarification stages, the joint research project allows to evaluate technical solutions for reducing entries and to derive general recommendations for action.

The inventory of the entry points into water bodies is carried out at a section of the Lippe river basin. The researchers analyze combined wastewater discharges and rainwater discharges with and without further treatment, such as soil filters and wastewater treatment plant effluents. REPLAWA also examines the entry of microplastics via sewage sludge onto agricultural land: microplastic particles can be washed out into surface water through applied sewage sludge and manure. Investigations in the area of the Steinhof wastewater treatment plant (central wastewater treatment plant of the Braunschweig Wastewater Association) provide information on the effects to groundwater since the treated wastewater has been used for decades as irrigation water and part of the sewage sludge for agricultural purposes. In addition, the project partners are collecting and evaluating data on the entry points into wastewater.

Evaluating the Cleaning Processes

To assess the effectiveness of technical processes for retaining plastics in wastewater treatment, investigations are being conducted for the different treatment stages of conventional wastewater treatment plants: inlet, screen, grit trap, pre-clarification, activation, secondary clarification and effluent. The other discharged material flows, such as sewage sludge, are also sampled and analyzed. Additionally, the researchers are collecting and evaluating the discharge from wastewater treatment plants using advanced processes for solids separation, e.g. spatial filters, microsieves or membrane aeration, on several large-scale plants in Germany. They intend to further develop these technical systems with comparative studies on a semi-industrial scale.

Plastics in the wastewater treatment plant after a heavy rain event

REPLAWA

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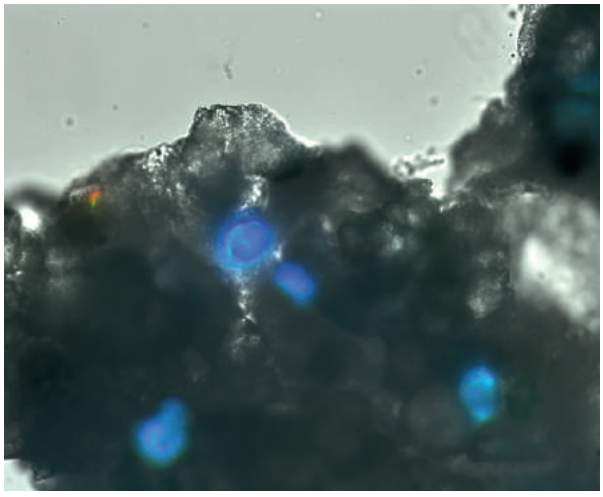
Technical and Political Recommendations for Action

Based on the investigation results, the project partners seek to determine whether one of the separation technologies should be preferred in the future and whether retrofitting of existing wastewater treatment plants with appropriate separation equipment is necessary.

In addition to technical solutions, the joint research project is also investigating possible political options for dealing with microplastics. To this end, the partners are creating a database documenting how the issue is currently regulated worldwide. For example, many countries have already introduced a ban on microplastics in cosmetics, while Germany has so far relied on a voluntary commitment from industry. The researchers are exploring these differing approaches to microplastic by analyzing the role, interests, and political activities of different national and international stakeholders.

Following these indepth findings, REPLAWA is developing technical and regulatory recommendations for action in the field of urban water management. These are intended to help representatives from politics, administration, industry and society to identify reasonable solutions for reducing plastic emissions into the environment. The recommendations can also be applied to municipal wastewater disposal in other industrialized countries, thus providing a basis for international action in this area.



Fluorescent microplastic particles in activated sludge

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

Project Title
Reduction of the Input of Plastics via Wastewater into the Aquatic Environment (REPLAWA)

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02WPL1445 A-F

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RUSEKU – Precise Detection of Microplastics in Water

Plastics in the Environment –Sources · Sinks · Solutions

It has been observed for over 40 years now that plastics accumulate in the environment. But how do these plastics, and in particular their tiny decomposition products – microplastics – enter water bodies and wastewater? Reliable data on sources, pathways and effects on humans and the environment are still missing. The joint research project RUSEKU seeks to develop representative test methods that can accurately and quickly determine the microplastic content over various parts of the water cycle. The focus is on sampling methods in urban wastewater systems and watercourses.

Sampling as a Basis for High Quality Data

Microplastics in the environment occur in various forms: particles, fibers and film. They predominately originate from the decomposition of thermoplastic materials (materials that can be deformed under heat) by UV radiation, aging or mechanical stress. The distribution of plastic particles is extremely varied based upon the environmental media, such as water, soil or air. Also, the particles ultimately tend to accumulate in water bodies.

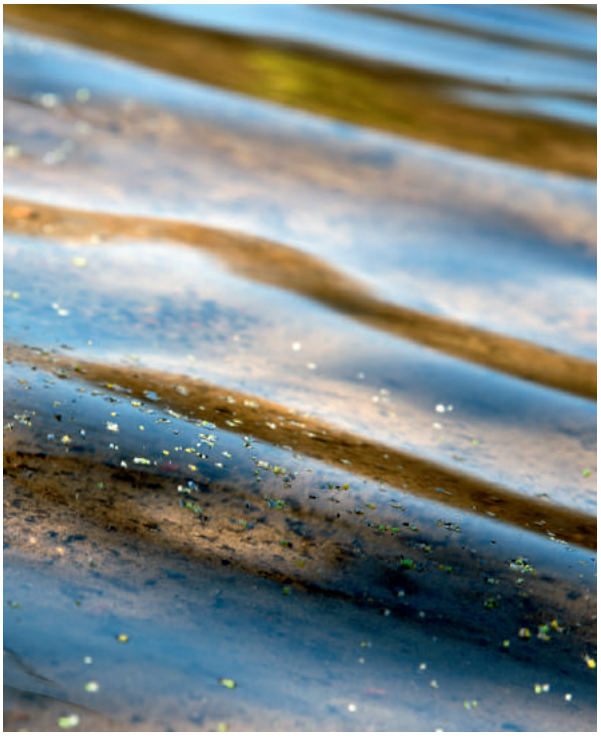
The sources, transport pathways, accumulation points, and overall loads of these microplastics in water remain unknown. Sampling is currently not standardized and therefore results are extremely varied. Existing, frequently used sampling methods, such as plankton nets are not suitable for urban areas or watercourses. The aim of the joint research project RUSEKU is to develop a reliable and practical method for water sampling across the different sections of the water cycle that is adapted to microplastic analysis. In this way, data can be systematically collected and compared. These results are an important prerequisite for preventing future microplastic emissions into water bodies.

Real-world Test in Urban Wastewater System

In order to develop new analytical methods, the researchers are first producing microplastic particles with varying properties, shapes, and sizes. The focus is on film fragments and particles from packaging, as well as fiber from textile products, because these are significant sources of microplastics in the environment. In order to fabricate realistic plastic particles, these are subjected to weathering processes, such as UV radiation and oxidation. In the laboratory and in simulation plants, the project partners are evaluating which methods can be used to detect the particles in samples quickly and reliably.

The various methods used are being further developed within the project: a suspended matter trap, a cascade filtration plant with innovative filters and metal meshes with mesh sizes less than 10 micrometers.

Next, the researchers are testing the suitability of the optimized sampling methods in real wastewater systems in Kaiserslautern. They want to determine the significance of individual entry points into the wastewater system, select suitable and representative places and times for sampling, and estimate the occurrence and loads of microplastics in the entire urban water cycle.



Microplastics are increasingly found in surface waters.

RUSEKU

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Market-Ready Methods for Microplastic Sampling

In addition, the project team will quantitatively predict the movement and distribution of microplastic particles in watercourses and the wastewater system. The project partners will integrate the results into a software that simulates complex, application-oriented cases. For this purpose, a commercially usable simulation code will be developed that limits the selection of suitable sampling points. At the end of the project, a market-ready procedure for efficient and reliable microplastic sampling should be in place. This is intended to simplify the evulation of questions regarding microplastics for legislators and to provide a basis for strategies and regulations that help to reduce microplastics in the water cycle.

Flow and pond simulation facility of the German Environment Agency in Marienfelde

Research Focus
Plastics in the environment – Sources • Sinks • Solutions

Project Title
Representative Research Strategies for an Integrative System Understanding of Specific Inputs of Plastics into the Environment (RUSEKU)

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Federal Ministry of Education and Research

FONA Research for Sustainable Development BMBF

SubµTrack – Tracking Down Smallest Plastic Particles

Plastics in the Environment – Sources • Sinks • Solutions

Microplastics in the environment are an issue whose extent and effects have not yet been sufficiently investigated. Current analytical methods make it possible to detect particles in the size range up to one micrometer (µm), i.e. one thousandth of a millimeter. Even smaller, so-called submicroparticles, were scarcely researched to date. Due to their properties, these submicroparticles are potentially even more harmful to humans and the environment than larger plastic particles. The project partners of the joint research project SubµTrack are developing new methods of analysis and evaluation, which will allow for assessment and toxicological investigations of plastic particles of different sizes.

Potential Risks of Submicroparticles

Microplastic particles reach the environment either directly or through the disintegration of plastic waste (primary and secondary microplastics). Previous investigations have predominantly dealt with microplastics between 1 µm and 5 mm. However, the effects of even smaller particles, especially in the range below 100 µm, are currently discussed. These may be cell permeable - i.e. able to penetrate cell walls - and can potentially bind more pollutants due to their relatively larger surface area. A new source for such submicroplastics is, for example, 3D printers, which are growing in popularity. Due to inadequate analytical methods and a lack of toxicological data, it is currently not possible to evaluate submicroparticles regarding their emission, fate, degradation and potential environmental effects.

Environmental Problems and Societal Challenges

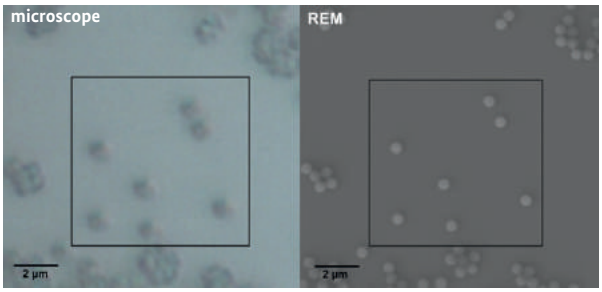
The joint research project SubµTrack specifically investigates the range of particles in the nano- as well as lower and middle micrometer range between 50 nm and 100 µm, which have hardly been defined previously. The researchers are pursuing a networked approach. On the one hand, they look at microplastics as an environmental problem and at the same time explore it as a societal challenge.

The project is divided into three main areas. The partners from science, research, public authorities and industry want to develop technologies that make it possible to reliably analyze submicroplastics.

This includes the adaptation of existing methods as well as the development of new ones for sampling, processing, and for analysis. The newly developed methods will be validated on reference particles in the laboratory, in laboratory wastewater treatment plants and in environmental samples.

Another focus is the possible effects of submicroplastic particles on water bodies and human health. To this end, the researchers are investigating the uptake of the particles and their physiological effect on aquatic organisms and cell cultures.

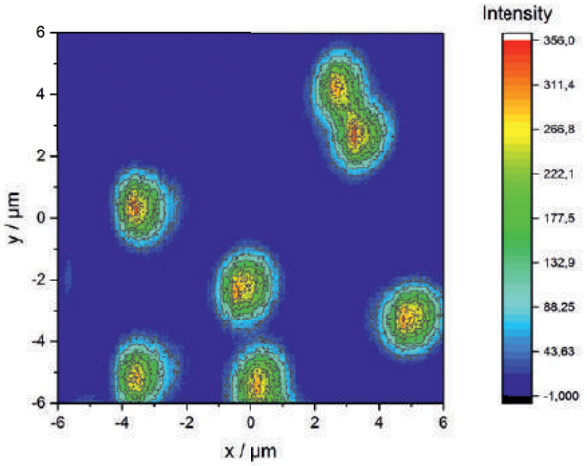
Thirdly, social, political and legal aspects will be considered. The project participants explore to what extent (sub)microplastic particles are perceived by society as a problem and explore the necessities for new legal measures.



Polystyrene particles (Ø 500 nm) in a light microscope (left) and in a scanning electron microscope (right)

Strategies for Submicroplastics

The results of the project should lay the foundation for a comprehensive analysis of submicroparticles. The methods developed are coordinated with those from other ongoing projects. This forms the basis for a meaningful risk assessment of smallest plastic particles. Taking social and political aspects into account, researchers can use risk assessment to develop strategies for action on submicroplastics and thus create the framework conditions for possible processes of societal change. In addition, the research results obtained will contribute to the further development of legal regulations and help close existing regulatory gaps.



Raman particle map: The type of polymer – in this case polystyrene – can be determined using a Raman microspectrometer.

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

Project Title
Tracking of (Sub)Microplastics of Different Identities - Innovative Analysis Tools for the Toxicological and Process Engineering Evaluation (SubµTrack)

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MicroCatch_Balt – How do Microplastics End up in the Baltic Sea?

Plastics in the Environment – Sources · Sinks · Solutions

The concentration of small and tiniest plastic particles is particularly high in river estuaries. This pollution must be caused somewhere between the source of the river and the estuary. The spectrum of possible polluters is large, and so is the range of different types of plastics that can end up in the environment. As an example of German Baltic Sea tributaries, the joint research project MicroCatch_Balt is investigating sources and sinks of microplastics in the Warnow river basin in Mecklenburg-Western Pomerania. Furthermore, important processes for the distribution of microparticles on their way to the open Baltic Sea are analyzed.

Samples Provide Information on Microplastic Content

Microplastics have been classified as a new category of marine pollution, which attracts increasing public attention and concern. Marine research is expected to provide insights into the origin, extent and effects of microplastics on water bodies and living organisms. The goal of the joint research project MicroCatch_Balt is therefore to identify the different sources and sinks of plastic particles in the tributaries of the Baltic Sea using the Warnow as an example.

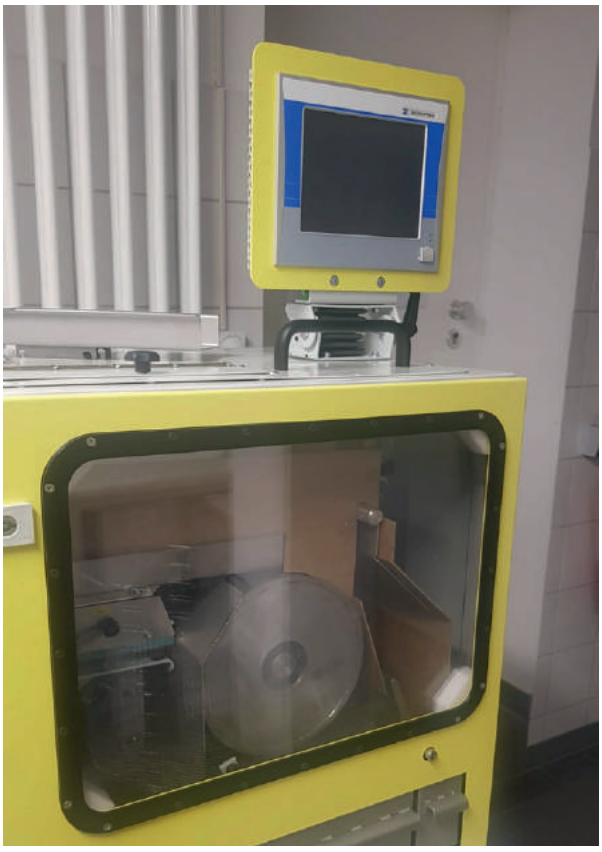
To this end, the project participants collect samples in the Warnow river basin, process and analyze them for their microplastic content. Of particular interest are possible sources: Wastewater treatment plants, agricultural drainage ditches, soil erosion, industrial areas, but also boat varnish and extreme weather events. As potential sinks aquatic organisms, such as shellfish, worms and fish, beaches, and sediments will be sampled.

Identifying Hotspots

The researchers will integrate the data obtained into various regional models, adapt them to their requirements and combine them subsequently. This will allow the scientists to determine diffuse and point sources of microplastic inputs in the entire river basin, including estuaries and coastal waters. The combined models allow conclusions as to which sources are most important in different subregions of the river basins and also how many microplastic particles reach coastal waters through various routes.

Knowledge Transfer and Networking with Other Projects

The project participants intend to communicate their findings on entry paths and sources to the public with the help of an interactive multimedia learning module: The results will be presented as of animations on a multitouch table.



A modified electrostatic plastic separator separates microplastics from sediments and arable soils.

They will be displayed in a travelling exhibition in cities along the Baltic Sea coast. Besides, the exhibition will be accompanied by plenary discussions with representatives of local environmental authorities and researchers.

The project results could also provide initial indications for recommendations for action with regard to future monitoring and strategies against microplastics. Micro-Catch_Balt contributes to the coverage of the most important aspects of microplastic pollution of Northern German watercourses and their estuaries into the oceans through strong networking with other projects and providing stakeholders with the necessary expertise. Furthermore, through cooperation with other projects the comparability with data from other German river is ensured. Thereby it is possible to compare the pollution levels of different river systems.

Students inform themselves about the latest findings from research using a multitouch table.

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

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Investigation of Sinks and Sources of Microplastics from a Typical Catchment Area to the Open Baltic Sea (Micro-Catch_Balt)

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PLAWES – The Journey of Microplastics from the River Weser to the North Sea

Plastics in the Environment – Sources · Sinks · Solutions

Existing studies on the effects of tiny plastic particles on the environment usually only provide snapshots; both the methods used and the results are hardly comparable with each other. Following a holistic approach, the joint research project PLAWES aims to contribute to filling some important knowledge gaps. In the model region of the German national park Weser-Wadden Sea, researchers are investigating for the first time how microplastics reach the sea coming from the mainland, which entry points and transport routes are involved and to what extent, as well as the risks associated with the pollution of different ecosystems.

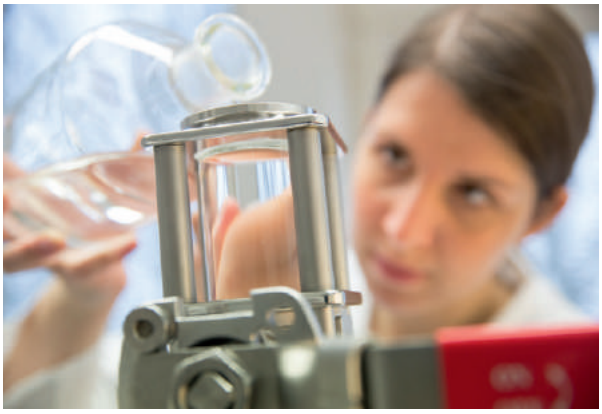
Different Ecosystems at a Glance

Which role do wind and weather, soil erosion, wastewater systems and wasterwater treatment plants play in the formation and distribution of plastic particles that are barely visible to the naked eye? How do microplastics accumulate in different ecosystems? Which interactions occur between plastic inputs in the environment and animal organisms? To date, there is far too little reliable data and knowledge available on these questions.

PLAWES is one of the first national and international research projects to investigate and evaluate microplastic pollution across ecosystems from the river catchment area to the estuary on the coast in an interdisciplinary manner and over longer periods. The Weser-Wadden Sea region offers optimal conditions for these investigations: It comprises both urban and agricultural regions, allowing the respective plastic inputs into the environment to be balanced and compared independently of one another. In addition, the Weser estuary is located in the sensitive Lower Saxony Wadden Sea National Park, which has been recognized by UNESCO as a World Natural Heritage Site.

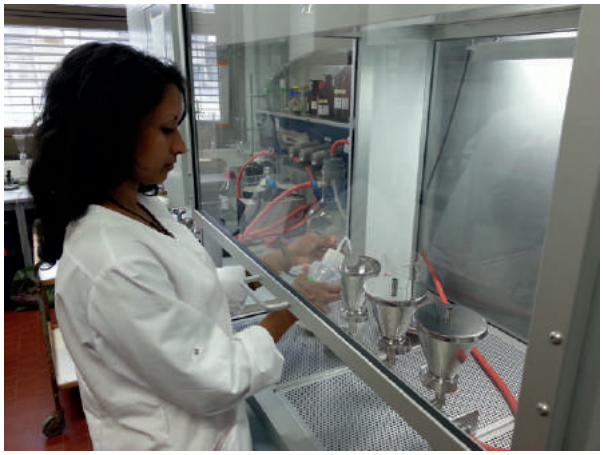
Identifying Entry Paths and Analyzing Risks

The project partners are specifically sampling the Weser and its tributaries, including the Lower Weser and the Wadden Sea, in two measurement campaigns in order to capture the contamination by microplastics. The campaigns are carried out in spring and autumn at varied water conditions on the Weser river. Additionally, the researchers will analyze various microplastic entry points as examples: important point sources such as wastewater treatment plants and separation systems as well as diffuse entries from drains and the atmosphere. They will then model the particle inputs from the various sources to obtain an overview of the quantities, transport mechanisms and accumulation zones.



Preparation of a sediment sample to filter out microplastics.

In order to assess the health risks for humans, the joint research project PLAWES investigates whether the spread of pathogens and the development of antibiotic resistance could be supported by microplastics in the environment. As microplastics can also enter the food chain via aquatic organisms, researchers furthermore examine mussels and worms in freshwaters and in the North Sea; they are interested in possible harmful effects that microplastics could have on these organisms.



Preparation of spectroscopic analysis: In the laboratory, a water sample with microplastics is purified. To do so, a method based on several enzymes is used that is gentle on plastics.

New Concepts in Environmental Education

Another focus of the project is environmental education. The results obtained by PLAWES will be integrated into new information and teaching concepts. Biology education experts will first assess what students and teachers know about plastic waste and their attitudes towards it. In order to raise awareness, they will develop teaching materials with a sound reference to everyday life. These will then be disseminated via a multilingual internet portal.

The results will also be incorporated into strategic recommendations for action for politicians, industry and civil society. In addition, the findings could contribute to the development of measures and technologies for the reduction of plastic discharges that are specifically tailored to the most important sources and entry points.

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

Project Title
Microplastic Contamination in the Weser-Wadden Sea – National Park Model System: an Ecosystem-Wide Approach (PLAWES)

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Plastic Pirates – Young People on Plastic Expedition at German Rivers

Plastics in the Environment – Sources • Sinks • Solutions

Plastics can be carried by rivers into the sea. There, it endangers animals and can enter the marine food chain. The occurrence of plastic waste, its distribution and possible sources in and at German rivers are still relatively unexplored. This is to change with the help of the citizen science project „Plastic Pirates - The Sea Starts Here“. Young people aged 10 to 16 are searching for litter on riverbanks across Germany and are thus collecting relevant information for scientists. With their help, a comprehensive overview of plastic accumulations at rivers is being created.

Research with Citizen Participation

Plastics can now be found in almost every ecosystem in the world. Rivers play a particular role here, as they carry plastic waste from the interior of a country into the oceans. So far, however, there is a lack of broad surveys on the current state of plastic waste at and in German rivers and the extent of the general pollution of river banks. The citizen science project Plastic Pirates contributes to closing this knowledge gap.

With citizen science projects, people interested in science can directly participate in the research process. That is to say, scientists and researchers work hand in hand with citizens. In the case of the Plastic Pirates, this means that young people between ages 10 and 16 provide data which is then analyzed and evaluated by the participating project partners. In the process, they concentrate on the following questions: How much and which types of plastic waste can be found on riverbanks? Where is litter accumulating, in which water areas is there less of it? Is it possible to find waste that is dangerous for people?

In this citizen science project, the young Plastic Pirates not only generate scientific data about the waste pollution of rivers, but they also gain expert knowledge and an insight into how science works. Thereby young people will be shown that science is accessible to all.

The plastic pirates take a water sample with a fine-meshed net in order to have it analyzed later for microplastics

Core Element: The Plastic Pirates Excursion to the River

The Plastic Pirates campaign provides teaching and working materials as a starting point for practice-oriented teaching units in biology, geography, chemistry or social studies and in project weeks. The material contains background information on the topics of seas and oceans, plastics and possible actions. A project booklet serves as an aid and scientific guide for the young people to collect data on their excursion to a nearby stream or river – the core element of the Plastic Pirates campaign.

The students take samples of microplastics with fine-meshed nets in rivers, classify the litter on the river bank and document the collected data in the project booklet. Later, the data will be published on a digital map of Germany.

The map shows the degree of pollution of single rivers or streams compared to each other.

In addition, the aim of the plastic pirates is to sensitize a large number of young people regarding the problem of plastic waste and, by participating in the campaign, to encourage them to reflect on and rethink their own consumer behaviour.

Citizen Science Data Create New Knowledge

All received data sets are evaluated and checked by scientists. Only then do they feed into scientific publications. This validation is necessary, because data from citizen science projects is often questioned and therefore has to be controlled carefully in order to find acceptance in science. Initial findings show that there is a plastic waste problem at German rivers, because river visitors often leave behind disposable dishes, picnic and barbecue leftovers as well as plastic food packaging.

In addition, the project partners are analyzing how plastic pollution changes from the source to the mouth of a river and they examine which river sections are most polluted. This in turn allows them to derive effective precautions that benefit rivers, oceans and ultimately all of us.

A collection of plastic waste found by students of the Gymnasium Fabritianum (Krefeld) on the banks of the river Rhine

Research Focus
Plastics in the Environment – Sources • Sinks • Solutions

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Plastic Pirates – The Sea Starts Here!

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