Microparticles in the aquatic environment and in foodstuffs - are biodegradable polymers a conceivable solution to the "microplastic problem"?

Frequently Asked Questions –

Mikroplastic

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1. What is plastic and what is it used for?

Plastics are synthetically manufactured polymers, meaning large chain molecules, similar to naturally occurring long chained molecules. Popular natural examples are sugar, cellulose or latex. Plastics are important materials that have become ubiquitous in our everyday life due to their diverse and flexible material properties. These properties have enabled a vast number of technical innovations, improving resource efficiency and reducing energy consumption. In many cases, plastics are preferable to other materials. Thus, plastics have an important role alongside the more traditional materials like wood, metals and ceramics.

2. What is microplastic and how does it arise?

An official definition of microplastic does not exist yet. Currently, plastic particles and fibres that are smaller than 5 millimeters and larger than 1 micrometer are described as microplastic. Often, they are not visible to the unaided eye. Microplastics are the subject of investigation in the collaborative project MiPAq at the Technical University of Munich.

Microplastics that are intentionally produced are called primary microplastics. This includes e.g. particles that are added to household detergents or cosmetics. These can be spherical microplastics, so-called microbeads, as well as sharp-edged particles utilised as abrasives in scouring creams or peelings. Furthermore, pellets and granules, which are latter processed into other final products via injection moulding or extrusion, for example, can also be identified as primary microplastics.

In contrast, secondary microplastics are fragments that originate of larger plastic parts in the environment. Mechanical, chemical or biological processes are relevant to the production of secondary microplastics. An essential part is UV radiation, making plastics brittle and easily fragmented. Additionally, fibres that are released from synthetic clothing during washing enter aquatic ecosystems through sewage plants. These are also counted as secondary microplastics (Ivleva et al. 2017, Wendt-Potthoff et al. 2017). Another source of secondary microplastic is the abrasion of plastic products during a product's application or use. Car tires, shoe soles, bitumen in asphalt, abrasion on sport and playgrounds or on construction sites are a big part of this, to name a few (Bertling et al. 2018).

3. Where is microplastic found in the environment?

Over the last years, microplastics have been detected in more and more waters worldwide. Therefore, it can be assumed that microplastics are ubiquitous and can be found all over the world. In the oceans, larger plastic waste and microplastics can already be found in the deep sea. Since 2013, it has been shown that microplastics also occur in freshwaters like rivers and lakes (Ivleva et al. 2017, Wendt-Potthoff et al. 2017). In addition, recent results indicate that the amount of microplastic in the environment increases sharply with decreasing particle size (e.g., Imhof et al. 2016, Enders et al. 2015). A recent study, carried out jointly by a number of German federal states and the University of Bayreuth has detected floating microplastic on the water surface of all rivers and lakes investigated in southern and south-western Germany (Hess et al. 2018).

4. How does microplastic enter the environment?

Microplastics can be released into the environment in many ways. At present, it is hardly possible to quantify the individual pathways of microplastics into water bodies and to distinguish between primary and secondary microplastics. The main reason is that no routine analytical methods have yet been established, and the current state of the art of sample preparation and analysis is still very time-consuming (see questions 9 and 10).

Looking at the microplastic that has been detected in the environment to date, it can be assumed that secondary microplastic is the main source. This means that microplastics are created in the environment predominately by the fragmentation of larger pieces of plastic waste. A large portion of this waste is released into the environment through incorrect disposal (Bertling et al. 2018, Hess et al. 2018, Essel et al. 2015).

In addition, there are other input paths, which can also account for a large proportion of the microplastic load in water bodies. This also includes entry paths that can be tackled and reduced or eliminated under the responsibility of the industry. Two examples are the loss of pellets during transport used in plastic production, and microplastics in cosmetics. However, these two sources of input should decrease as an increasing number of producers of plastics join the “zero-pellet loss” campaign (PlasticsEurope 2015) and more and more manufacturers of cosmetics voluntarily refrain from adding microplastics. However, care must be taken with the latter, as some have only changed the declaration of the particles. The EU Commission is currently discussing various bans on disposable plastic products and the addition of microplastics to cosmetics (https://ec.europa.eu/germany/news/20180528-einwegplastik_en). Further information can be found at the Federal Environment Agency (https://www.um-weltbundesamt.de/tags/mikroplastik) or under the BEAT THE MICROBEAD campaign (www.beatthemicrobead.org).

When looking at the production and sales data of products from which microplastics can be produced, however, other entry paths also become clear. This includes the abrasion that occurs during the life cycle of plastic products such as tyres, shoe soles, bitumen in asphalt, boat surfaces or house facades (paints, coatings), sport and playgrounds or construction sites (Bertling et al. 2018). Just like synthetic fibres, which are produced when clothes are washed, this abrasion is released into the environment through waste water and mixed water discharges (Bertling et al. 2018, Miklos et al. 2016, Essel et al. 2015). These sources are likely to have a large impact in terms of the quantity of microplastic in waterways and the ocean, but mitigation strategies are difficult to develop for them.

5. Are sewage plants able to filter microplastics from waste water?

Sewage treatment plants have a relatively high separation efficiency for microplastics, depending on the technical level. It is partly assumed that more than 98% of the introduced particles can be retained (Simon et al. 2018, Talvitie et al. 2017, Carr et al. 2016, Murphy et al. 2016, Talvitie et al. 2015). Effective separation is possible, for example by using sand filtration, membrane bioreactors (Mintenig et al. 2017, Talvitie et al. 2017, Mintenig et al. 2014a) or disc cloth filters (Oldenburgisch-Ostfriesischer Wasserverband (OOWV) 2016). Sewage treatment plants are therefore not a source of microplastics, but a valuable tool for removing them from wastewater. The separated microplastic is then disposed of together with the sewage sludge. Depending on how the sewage sludge is used, the separated microplastics could therefore be returned to the environment. Current studies also show that despite the high degree of separation in sewage treatment plants, relatively large quantities of microplastics still end up in water bodies (Talvitie et al. 2017, Carr et al. 2016, Murphy et al. 2016).

6. Which connection exists between the microplastic discoveries in Germany and the plastic waste problem in the oceans?

Although Germany has a functioning waste disposal and recycling system, plastic waste and microplastics can be found in these waters. The results of the studies conducted in Germany (Hess et al. 2018), but also worldwide (Dris et al. 2018, Wendt-Potthoff et al. 2017) indicate that a large proportion of the registered plastic waste reaches the environment through improper disposal or littering. This includes large plastic parts such as bags, packaging, building materials, parts of sports equipment or broken children's toys. Once in the environment, they fragment into microplastic (so-called secondary microplastics, see question 4). Thus, a significant proportion of the plastic waste produced and disposed of on land reaches the sea via rivers and lakes and accumulates there at the end. In addition, there are microplastics from other input sources that cannot yet be precisely quantified.

Of course, one can now argue that most of the visible input (macroplastics) does not come from highly developed countries like Germany, but from emerging countries in Asia and Africa, especially those without functioning waste disposal and recycling. However, in Germany, for example, the consumption of plastic (e.g. as packaging for convenience products) is higher than in less developed countries (Schüler 2016). This means that even in Germany the risk of macroplastics entering the environment is high.

7. What happens to the plastic particles in the environment?

Microplastics accumulate due to the very good chemical resistance in the environment. The degradation time for most plastics is estimated to be several hundred years (Harrison et al. 2018). At the present, however, it is unknown whether parts of it are decomposed or whether it only decomposes into even smaller particles. The degradation mechanism depends strongly on the type of plastic and whether the particles are exposed to strong sunlight or mechanical stresses. UV radiation makes plastics brittle and more easily fragmented. Plastics on the surface of water bodies are therefore likely to degrade more rapidly than those deposited in the sediment below. In addition, depending on the type of plastic, different degrees of biodegradation can occur, e.g. due to adhering biofilm or organisms and microbial degradation.

The possible consequence is an increasing pollution of rivers, lakes and oceans. It is not yet known whether the presence of microplastic will lead to changes in water ecosystems, but it is a high priority in current research projects. Microplastics can adsorb organic substances due to their chemical structure and thus serve as a magnet for pollutants in water. In the MiPAq project, the so-called biodegradable plastics in particular, which are exposed to severe degradation in the environment, will be examined closely.

8. Do animals take up microplastic? What effects can this have?

A large number of different organisms with very different feeding strategies take up microplastic. These include organisms such as mussels, snails, worms, water fleas, small crustaceans and many others that serve as food sources to other animals. In this way, microplastics may also be passed on and enriched in the food web (Carbery et al. 2018, Rochman et al. 2017, Wendt-Potthoff et al. 2017, European Food and Safety Authority 2016, Setälä et al. 2014).

Current research on the possible effects of the consumption of microplastic are still contradictory due to the high complexity of the different types of plastics and their possible additives. In addition, there is little reliable data on the occurrence, size and type of microplastics in the environment needed to conduct informative and relevant environmental testing (Wendt-Potthoff et al. 2017). Microparticles can accumulate in the gastrointestinal tract, where they cause damage to sensitive tissues. Furthermore, additives present in the plastic (e.g. plasticizers, UV stabilisers, flame retardants, processing aids etc.) may leach out of the polymer and be directly toxic or have hormone-like effects.

In addition, plastics can adsorb and transport other organic pollutants. The uptake, release and effect of these substances and the resulting increased exposure of organisms is an urgent subject of research and is being investigated within the framework of MiPAq.

9. How is microplastic detected in environmental and food samples?

Since there are more natural particles in the environment than artificial ones, the detection of microplastic in environmental or food samples is a major challenge. Also, due to their varying density, some plastics are buoyant while others will sink. However, biofouling, i.e. the accumulation of bacteria, algae or other organisms, can lead to density changes and displacement. For this reason, microplastics are detected at the surface of water bodies like lakes, rivers and seas all the way down to the bottom in their sediments.

For sampling in the water column, methods with nets of different mesh sizes (often 300 µm) or filter systems (down to the lower µm range or below) are used. Due to the large proportion of organic material in environmental samples, and the resulting clogging of nets, even smaller particles are often collected. Samples of sediments are taken with grippers or lancing tubes and can therefore cover the entire particle size spectrum (Wendt-Potthoff et al. 2017).

For a correct identification of microplastics, all natural particles must first be separated. For sand and sediment particles, density separation is usually applied, where comparatively heavy material such as gravel or sand can be well separated (Imhof et al. 2012, prototype in the German museum in Munich). Organic material such as pollen, parts of plants, insects etc. are then removed with chemical cleaning steps. Here, however, the choice of chemicals is of great importance, as there are some chemicals that attack certain types of plastics. One method that does not attack plastics and degrades organic material is, for example, enzymatic degradation (Löder et al. 2017). However, this is a relatively slow and costly process.

Afterwards, the particles are analyzed by different spectroscopic methods depending on their size class (Ivleva et al. 2017, Wendt-Potthoff et al. 2017). In addition to the determination of number and size, identification of the type and shape of plastic is carried out. For details see question 10.

10. How is microplastic reliably identified?

Microplastics in environmental, food and beverage samples cannot be reliably identified with the aid of simple visual identification. Instead, the samples must be examined spectroscopically and/or with mass spectrometry (Braun et al. 2018). This makes it possible to determine exactly which material the particles found are made of and thus whether they are microplastics at all. Spectroscopic methods determine the number, shape and size of particles (Ivleva et al. 2017, Wendt-Potthoff et al. 2017, Imhof et al. 2016, Löder & Gerdts 2015). Spectroscopic methods that are often used to non-destructively examine individual particles or several particles on filters are the Fourier transform infrared spectroscopy and the Raman microspectroscopy. Fourier transform infrared spectroscopy can be used for microplastics up to a size of 10 - 20 µm (Löder et al. 2015). Raman microspectroscopy can measure particles and fibres up to1 µm (Ivleva et al. 2017, Imhof et al. 2016).

In addition, other methods that enable the analysis of microplastics operate with the aid of thermal decomposition and downstream gas or mass spectrometry. This includes thermogravimetry, which is often coupled with gas chromatography mass spectrometry (e.g. Dümichen et al. 2017). By means of pyrolysis gas chromatography mass spectrometry, the polymer type of the particles (e.g. polyethylene, polystyrene, etc.) can be determined via the decomposition products. In addition, it is possible to examine the additives (e.g. plasticizers) added during production. If thermodesorption is carried out prior to the pyrolysis process, additional adsorbed substances can be identified and quantified to assess the pollutant load of the particles (Fischer & Scholz-Böttcher 2017, Wendt-Potthoff et al. 2017). In the MiPAq project, analyses are performed using Fourier transform infrared spectroscopy, Raman microspectroscopy (see https://www.hydrochemistry.tum.de/en/research/ramanmicro/projects/mipaq/ for more information) and Thermodesorption (TD) pyrolysis gas chromatography mass spectrometry.

A purely microscopic and thus visual identification is not suitable for the partially very small fibres and particles due to the possible confusion with other naturally occurring materials (Ivleva et al. 2017, Löder & Gerdts 2015, Hidalgo-Ruz et al. 2012). Also, staining with dyes like Bengal pink or Nile red as well as a melting tests do not allow a clear differentiation between natural and artificially produced particles and fibres. It can, however, serve as an analytical aid through optical presorting (Lachenmeier et al. 2015, Löder & Gerdts 2015).

Since there are more natural than artificially produced particles and fibres in the environment and the spectroscopic methods are very complex, the samples must be cleaned up in advance (see question 9). These processes are also very complex and currently not yet routine or harmonised, as there is still an enormous need for research in this area. In addition, it is extremely important during sample preparation in the laboratory that the samples are not contaminated. For example, laboratory equipment and laboratory clothing made of plastic are avoided, laboratory equipment is rinsed as thoroughly as possible and work is carried out under object protection workbenches (laminar flow boxes), which reduce contamination of the samples.

However, since foreign particles and fibres can never be completely prevented from being introduced into a sample, blank samples needs to be analysed. This can be, for example, the same amount of low-particle water with which the analysis is conducted and which underwent the same laboratory processes as the sample. If the same amount of microplastic of the same polymer grade is found in the blank sample as in the correct sample, it must be assumed that these were introduced in the laboratory.

In addition, the results are strongly influenced by the sampling procedure. The sample amount and number of samples must be representative of the sampled media and contain a sufficient amount of analyte (Braun et al. 2018). If, for example, 5 litres of beer are analysed, the probability of detecting sparsely present microplastics is greater than if only 100 ml is analysed. Another source of error can be the extrapolation of very small sample quantities to larger volumes, e.g. if only 100 ml, 10 ml or even only 1 ml of 1000 ml beer can be analysed. It is also interesting whether samples were taken once or at several different times from an environment or production line. As long as it is unclear how microplastic was introduced into a food sample, it is also unclear if it is systematically introduced or only under particular conditions.

11. Is microplastic found in food or drinking water?

A large number of studies have already been carried out in which microplastic was detected in food or mineral and tap water. However, many studies have not worked with reliable methods and in some cases obtained very different results. Since microplastics are present in all oceans, it is not surprising that microplastic has also been detected in seafood. At the present time, there is evidence beyond doubt that seafood (e.g. Catarino et al. 2018, Van Cauwenberghe & Janssen 2014), fish (Roch & Brinker 2017) and sea salt (e.g. Penack 2018, Karami et al. 2017) can contain microplastic. However, the intake of microplastic through the consumption of these foods is likely to be quite low. The exposure to microplastics from the air may be higher (Catarino et al. 2018). In many organisms, as for example in fish, microplastic is frequently found in the digestive tract, which is removed before consumption (European Food and Safety Authority 2016).

In studies that worked with valid methods, microplastic was detected in tap water (Mintenig et al. 2014b) and mineral water (among PET-reusable bottles, Ossmann et al. 2018, Schymanski et al. 2018). The number of detected microplastic particles in tap water and mineral water varies greatly depending on the examination method and sample quantity. Furthermore, they are always random samples, so that it remains unknown whether the quantities are constant or whether fluctuations occur with varying water treatment, processing or other exposure to machinery, for example. In the MiPAq project, selected foods and beverages are examined for microplastics in order to get a better picture of the contamination of food with microplastic and the potential entrance pathways.

12. What does this mean to humans? Is microplastic dangerous?

In principle, it can be said that microplastics are ubiquitous. In addition to natural particles such as pollen, fungal spores and fin sand (e.g. , the Sahara), our air contains anthropogenic particles such as dust and soot from combustion and microplastics (Catarino et al. 2018, Dris et al. 2017). It is therefore likely that one is exposed to microplastic from not only foodstuffs, but also from breathing air. How much microplastic is absorbed or how dust is retained in the mucosal membranes of the respiratory tract or how it passes through the gastrointestinal tract and is excreted is still unknown (Gasperi et al. 2018). It is thought to be strongly dependent on the microplastic concentration in the air or food, the size of the particles and the overall diet and living conditions (Catarino et al. 2018, Gasperi et al. 2018). Despite initial findings, a risk assessment of microparticles potentially present in food is currently not possible, as there is not enough data available on exposure and toxicity (European Food and Safety Authority 2016). Results from animal experiments are not unconditionally transferable to humans.

13. What can I do?

To reduce the plastic load into the environment, plastic waste must be reliably collected and professionally disposed of or recycled. Germany is a pioneer when it comes to recycling. Plastic for example is often collected via Yellow Bags or Yellow Bins (a dual system in German waste management). The principle of Reduce-Reuse-Recycle is more relevant today than ever: many people try to produce less waste or find creative ideas to create something new from it (“Upcyling”). These approaches should be encouraged and supported.

In general, the approach of a global circular flow economy is an important route to use raw materials as efficiently as possible and to recycle waste in the best possible way. Consumers are encouraged to dispose of or recycle their waste according to local regulations. At the same time, manufacturers should take the entire product life cycle into account when planning and manufacturing a product. For example, enabling and making it as easy as possible to repair or replace parts and ultimately to separate and recycle the raw materials used would do a lot to reduce waste and aid the recycling system.

Products containing primary microplastic particles should be avoided. Most manufacturers no longer use microplastic in their products, but the practice does remain. The BUND 2016 published a purchasing guidebook in which cosmetic products containing microplastic are listed. The guidebook also keeps a record of abbreviations for ingredients which conceal plastics.

More information can be found in the following PDF document (only in German): https://www.bund.net/fileadmin/user_upload_bund/publikationen/meere/meere_mikroplastik_einkaufsfuehrer.pdf

14. What is being investigated in the MiPAq project at TUM?

In the project "Microparticles in the aquatic environment and in foodstuffs - are biodegradable polymers a conceivable solution to the "microplastic problem"? (MiPAq) focuses on the comprehensive characterisation of microparticles (5 mm - 1 µm) in the aquatic environment and in food. The project is funded by the Bayerische Forschungsstiftung (Bavarian Research Fund). MiPAq considers the introduction, the behaviour and the impacts of microplastic in the environment and foodstuffs, including mitigation and options for technical reduction. A unique feature is the focus on comparing particle fractions from biodegradable (plastic) materials, conventional non-degradable plastics and natural (an)organic particles.

You will find more information on the project website. Further questions will be answered by the project coordinators or forwarded to the respective specialists.

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