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## MICROPLASTICS IN URBAN WATER MANAGEMENT

## MIKROPLASTIKI A MIEJSKA GOSPODARKA WODNA

### Abstract

The paper is discussing microplastics in the effluent of wastewater treatment plants and other discharges from urban areas. The aim of the discussion is to expose the challenges related to sampling and detecting plastic particles in treated wastewater. The different types of microplastics and a rough estimation of the amount of plastic which could end up in the aquatic environment is given. The work is based on a literature review of microplastic particles in treated wastewater and discusses their consequences on the aquatic ecosystem.

**Keywords:** microplastic, particle, sample, analytic

### Streszczenie

W artykule omówiono problem obecności mikroplastików w cieczach odpływających z oczyszczalni ścieków i w innych cieczach pochodzących z obszarów miejskich w celu ujawnienia trudności związanych z pobieraniem próbek i wykrywaniem cząsteczek plastiku w ściekach. Określono różne rodzaje mikroplastików oraz szacowaną ilość plastiku, który może znajdować się w środowisku wodnym. Przeprowadzone prace oparto na przeglądzie piśmiennictwa na temat obecności mikrocząsteczek plastiku w ściekach i omówiono jej skutki dla ekosystemu wodnego.

**Słowa kluczowe:** mikroplastik, cząsteczka, próbka, analiza

## 1. Introduction

When Charles Goodyear randomly identified the process of vulcanization in 1839 the development of synthetic materials took its course. Later in the 1940's after nylon was introduced, plastics processing was practiced in mass production. [1, 2] In 2014 more than 311 mill. t of plastics were produced worldwide [3]. Germany produced 18.5 mill. t in 2015 out of this amount 12.8 mill. t were exported. Additionally, 9.3 mill. t were imported. This results in an overall plastic consumption of 15 mill. t in Germany. From this amount, 2.94 mill. t were mainly used in branches of gluten, fibers, varnish and 12.06 mill. t in branches of packaging (35.2%), construction (22.7%) and automotive engineering (10.5%). Other branches and electronics, agriculture, households medicine and furniture use 31.6%. This consumption results in about 3.7 mill. t of plastic waste in Germany. 53% of the plastic waste is utilized for energy and 46% for recycling. About 1% (0.04 mill. t) ends up on dumpsites [4]. Data on plastic littering is actually not available [5].

## 2. Basic Information about plastics

The most commonly used plastics are polyethylene (PE), polypropylene (PP), polyvinylchloride (PVC), polystyrene (PS) and polyethyleneterephthalat (PET), which represent about 90% of the global plastic production [6]. Table 1 offers a survey of the attributes, the production volume and the possible uses of plastics.

**Table 1.** Attributes, production volume and the possible uses of plastics [7]

Sort	Abbreviation	Density [g/cm <sup>3</sup> ]	% of the production volume	Possible uses
low-density polyethylen	PE-LD	0.91–0.93	21	carrier bag, straw, bottle
high-density polyethylen	PE-HD	0.94	17	can, pipe
polypropylene	PP	0.83–0.85	24	bottle top
polystyrene	PS	1.05	6	electronic casing, thermal insulation material, packaging
polyethyleneterephthalat	PET	1.37	7	bottles
polyvinyl chloride	PVC	1.38	19	foil, pipe

It is shown that a large part of the produced plastic is used in different products and processes in all different ranges of application. Consequentially one big challenge is to define the pathways of plastics and microplastics which end up in the aquatic environment and to balance them.

### 3. Microplastics

Beside the subdividing particles in macro- and mesoplastics, the Marine Strategy Framework Directive (2008/56/EG) describes particles  $< 5$  mm as microplastics [8].

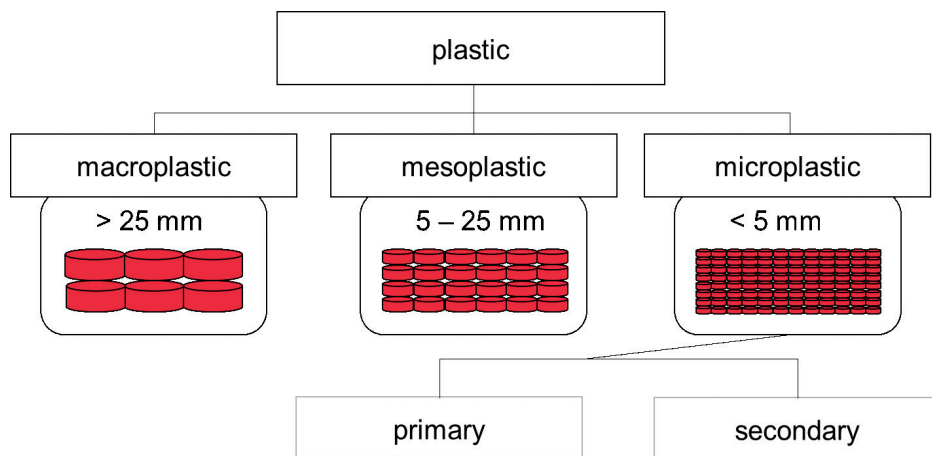


Fig. 1. Classification of plastic in the aquatic environment [8]

Microplastics occur in the aquatic environment as primary and secondary microplastic particles. Primary microplastic describes industrial defined and produced particles. They include for example pellets, which are used as basic material in the production of plastic products. [9] Another application is to use the microbeads as filler for cosmetics or as abrasives in toothpaste and peeling. To estimate the emission of microplastics from domestic wastewater the TU Berlin conducted panel tests. A group of customers (approx. 20 people) documented the usage and the volume of all critical products. For these tests primary microplastics from shampoo (Fig. 2a), peeling (Fig. 2b) and toothpaste (Fig. 2c) were separated and balanced out. The proportions of the particles are shown in Figure 2.

For the input of microplastics raised by the named products from domestic wastewater an amount of approximately  $7.5 \text{ g}/(\text{person} \cdot \text{a})$  was determined [10].

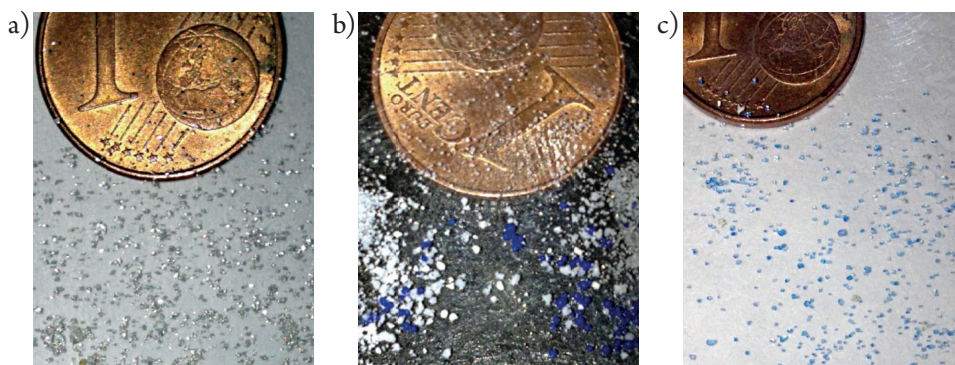


Fig. 2. Microplastics from shampoo (a), peeling (b), toothpaste (c) [10]

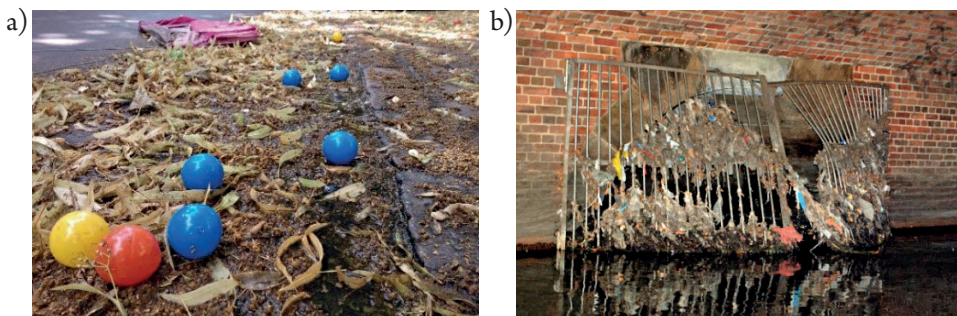


Fig. 3. Plastic in rainwater runoff (a) and mixed sewage water (b) in Berlin

Secondary microplastic describes fragments or fibers which rise by biological, chemical or physical degradation of sizeable particles [9]. Consequently, microplastic particles occur in different size, form and colour. Figure 3 shows macroplastics in the effluent of rainwater runoff (Fig. 3a) and in a mixed sewage water system (Fig. 3b) which could end up as grinded microplastics in the aquatic environment.

#### 4. Microplastics in the aquatic environment

Plastic debris in the aquatic ecosystem amount to 80% of the total waste [11]. Because of its low density and its durability plastic is transported over wide distance by the rivers and the wind [12] so that it has been found on isolated islands, the Arctic and Antarctic zone [13]. Two big garbage patches developed in the North Pacific and the North Atlantic Ocean. The great Pacific garbage patch, which was discovered in 1997 is approximately as big as central Europe and it is estimated to contain 1 million plastic particles and parts per square kilometer [11]. Except for the garbage patches, microplastics are ubiquitous in the aquatic environment, which has been indicated in scientific studies in the recent past [14, 6]. The plastic debris in the oceans increased to 80% from land [7, 15]. A reasonable part is transported by rivers to the oceans however only a few studies have been conducted [16, 17].

The consequences of the ubiquitous plastic load on the aquatic ecosystem is diverse; in comparison to natural flotsam such as wood; the plastic parts and particles can act as carriers, which can transport attached organisms over wide distances far away from their geographical origin. The introduced organisms may suppress the native species and influence or change the ecosystem [18].

In 2012 an interaction between plastic debris in the ocean was registered with 663 marine animal species, this describes an increase of 40% in comparison to the year 1997. In more than 50% of the cases living organism become entangled to the debris or they absorb them. Meanwhile, different kinds, forms and sizes of plastic particles are found meanwhile in stomachs of mammals, fishes and birds [19].

Planktivorous animals ingest microplastics with their nourishment beside microplastics was verified in shrimps, which absorbed zooplankton with microplastics [20] and in mussels which transferred microplastics to crabs [21].

In this manner microplastics could enter the food chain and spread in the food web [22, 23, 24]. Absorbed microplastics can have different effects. Experiments with mussels showed that microplastics accumulate in the mussel and cause inflammatory changes of the cells [11]. Especially because the experiment was performed under conditions with high microplastic concentrations. It is yet to be verified up to what extent the results are transferable in the environment [5].

Often non - digestible plastic particles are not excreted, so that the animals starve with stuffed stomach. Sharp edged particles may harm the mucosa of the animals. In addition to the mechanical characteristics microplastic particles may transport harmful substances like plasticizer or adsorbed persistent substances. They possibly escape from the plastic in the alimentary canal and have an effect on the organism. Some of them are carcinogenic or mutagenic or they can affect the hormonal balance [11].

Currently, coherent toxicology methods for the evaluation of microplastics (especially for particles with few  $\mu\text{m}$ ) are missing.

## 5. Microplastics in Urban Water Management

Figure 4 indicates that the different pathways of microplastics are complex although a balancing of the pathways has not been performed so far. Decreasing microplastic particle concentrations have been verified over the treatment stations of a wastewater treatment plant (WWTP) and in the ocean [25]. The plastic tyre wear particles are assumed to be

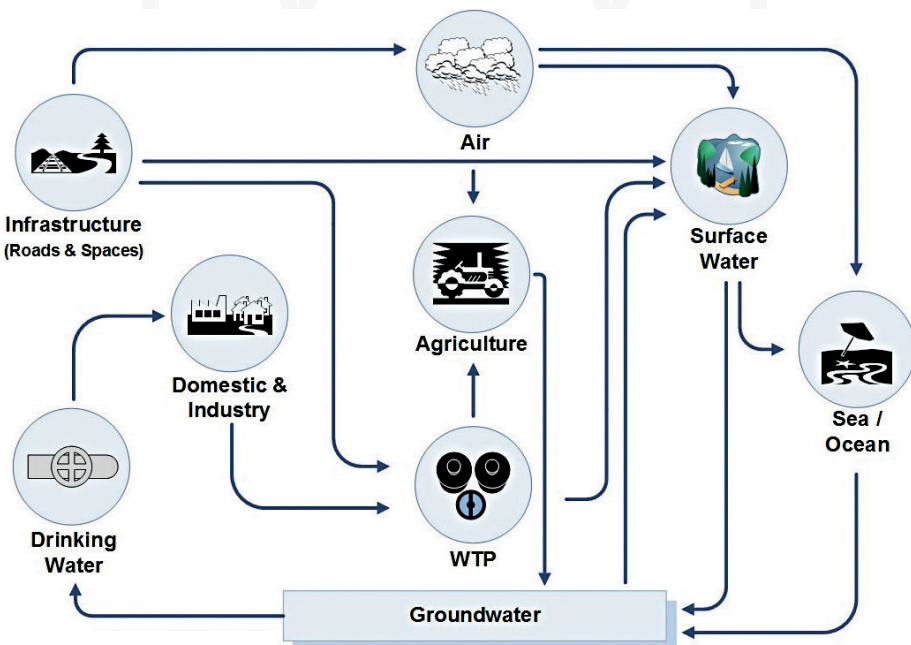


Fig. 4. Pathways of microplastics in the aquatic environment

a part of the fine particulate matter and the rain water runoff. Furthermore, the consumption of private households and the usage in industrial production processes may contribute microplastic particles to the aquatic environment.

In urban water management microplastics can get to the aquatic environment through the following pathways in principal :

1. If microplastics are not restrained sufficiently in wastewater treatment
2. By combined wastewater overflow
3. By discharging rainwater runoff

Currently, only a few studies about the microplastic exposure and –removal in WWTP are available. New studies in Finland, Germany, Russia, Austria, Sweden and USA found different quantities of microplastics in the purification process of the WWTP. The results differ widely in terms of validity and resilience, because different techniques of sampling, preparation and analytical equipment was used as shown in Table 2.

**Table 2.** Microplastics at the effluent of wastewater treatment plants (WWTP) [25, 26, 27, 28, 29, 30]

Location	Sample volume	Sampling equipment	Particle/ l	Analytical equipment
WWTP in Finland [25]	2–285 l	filtertube: Ø= 60 mm mesh size: 20 µm, 100 µm, 200 µm	8.6 ± 2,5 particles 4.9 ± 1,4 fibres	optical microscope
12 WWTPs in Germany [26]	390–1000 l	sieve with mesh size: 500 µm stainless steel candle filter with mesh size: 10 µm	0.077–0.712 (8.85 l) (particles < 500 µm) 0–0.052 (particles > 500 µm) 0.098–4.808 (fibers)	optical microscope, ATR – FTIR* micro – FTIR
WWTP in Russia [27]	8 l	filtertube: Ø= 60 mm mesh size: 20 µm, 100 µm, 300 µm	16 fibrous 7 synthetic 125 black	optical microscope
WWTP in Austria [28]	20000 l	sieve batch with 3 sieves mesh size: 63 µm, 630 µm, 5 mm	Less than 0.001 (particles > 63 µm)	optical microscope
WWTP in Sweden [29]	1000 l	filter holder/net: Ø= 80 m mesh size: 300µm	3.75 ± 1.25 fragments 0.5 ± 0.5 flakes 4 ± 0.58 fibers (particles ≥ 300 µm)	optical microscope, ATR – FTIR
7 WWTPs in USA [30]	189000– –9570000 l	stack of 3 (4) sieves mesh size: (20µm), 45 µm, 180 µm, 400 µm surface skimmer with mesh size: 125 µm	0 particles 0 fibers  (3.12*10 <sup>-7</sup> –2.43*10 <sup>-6</sup> ) particles skimmed	optical microscope  FTIR

\*ATR-FTIR: Attenuated Total Reflectance- Fourier Transformed Infrared

The studies refer to sample volumes of WWTP -effluent from 2 up to 9570000 l, the filtration process is performed with mesh size from 10  $\mu\text{m}$  up to 5 mm and for taking the samples measuring cups are taken as well as different pumps at the same time [25, 26, 27, 28, 29, 30]. Mintening et al. reveals that the method for taking the samples as well as the preparation of the samples may affect the contamination of the sample with microplastics by the atmosphere and laboratory equipment significantly. Fourier Transformed Infrared (FTIR) is widely preferred for analysing microplastic particles. It allows for the determination of the type of plastic after the sample has been prepared [26]. The number of particles can be counted whereas the mass can not be determined because the FTIR focuses on the material.

To estimate the weight percent of microplastics which may summed up in the effluent of WWTP the following contemplation is made:

The particles are spherical, have an average size of 1000  $\mu\text{m}$  and consist of mostly utilized plastic PE. From the maximum concentration of 0.712 pcs/l, which is described for the German WWTPs in Table 2, results a weight percent of microplastics of 0.34 mgTSS/l.

Making an assumption that 12 mg TSS/l is the average mass of suspended solids at the effluent of a WWTP, the plastic fraction would sum up at least 3% and could be neglected related to the mass. However, a distribution of the particle size does not exist.

A benchmark for technologies of advanced wastewater treatment with the focus on microplastics has not been formulated yet. In an first measurement Mintening et al. 2014 determined for the final filtration, where cloth filtration media is installed, a reduction of 97% of microplastics. In the whole purification process of the WWTP in Russia, Talvitie et al. determined a quantity reduction of 96% for microplastics and for the whole purification process of the Swedish WWTP Magnusson et al. determined a reduction of 99,9% for the American WWTPs Carr et al. suggests that the effluent discharges of microplastics are minimal. Current studies emanate from significant amounts of microplastic particles remaining in the sludge [26, 29]. There is a further need of research for this fraction to get verifiable results. Concerning the entry from combined wastewater overflow and discharged rainwater runoff currently there is no data available. In addition, for raw sewage any valid concentrations are identified so that the degree of degradation for microplastics can just be estimated.

## 6. Conclusions

The first studies about microplastics in wastewater treatment plans suggest that the restrained grade of microplastic particles during the purification process is considerable.

To evaluate the particles at the effluent of a WWTP as a basis of deciding whether or not to implement advanced wastewater treatment is mainly depending on the ecological relevance of the particles (size, mass, number, etc.) which is not fully clarified.

Technical solutions for the effluent of WWTPs and for combined wastewater overflow, could be the installation of additional processes like for example micro sives, cloth filtration and sand filtration, which separate particles, specifically microplastics. In terms of this technologies, high performance webs and the cloth filtration media are promising solutions.



To separate microplastics from rainwater runoff decentralized systems could be implemented in road gullies at relevant sites. The different technics are currently evaluated in practical investigations (-OEMP- Optimized materials and processes for the separation of microplastic from the water cycle, BMBF-funded).

Plastics and microplastics will be preserved in the environment for many years, therefore systematic studies in the field of urban water management are reasonable and the municipality, the industry, the research and the citizen/ consumer are requested to collaborate.

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