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Original Research Article

POLLUTION OF BEACH SAND FROM SELECTED RECREATIONAL RESERVOIRS BY MICROPLASTICS

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Abstract

The presence of microplastics have been ubiquitously confirmed in aquatic environment possessing the potential risk to the health of ecosystem. Most studies concerning microplastics are focused on water bodies, but it is considered that sediments and sands from the beaches may to be a long-term sink for microplastics. High concentrations of microplastics have been found in sand beach in Europe and all over the world. In the present studies samples of beach sand originating from three beaches of recreational reservoirs in Southern Poland (Silesian Voivodship) were analysed. Preliminary screening tests were done to evaluate the degree of microplastics pollution of the selected sandy beaches. Samples were taken once from three places on the beaches of each reservoir. Beach sections parallel to the waterline were selected at each study at the swash zone – about 1 m above the waterline. Previously, no studies were done on the presence of microplastics in these beaches. The samples taken from the beach were homogenized and mixed with saturated NaCl solutions, after separation of microplastics the pollutants were counted under optical microscope (under magnification 40 -100 x). It was found that in all three places the microplastics occurred in the beach sand samples. The most contaminated samples originated from Lisiniec recreation park (Adriatyk) which contained 340 ± 222 particles per kg/d.m. The most abundant fractions in the examined samples were fibres

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and fragments, the less abundant ones were granules. It can be concluded that recreational reservoirs beaches can be significantly contaminated by microplastics particles, but simultaneously the concentrations of these micropollutants can vary a lot between the individual places.

Keywords: microplastics, sand beaches, contamination, recreational reservoirs

1. INTRODUCTION

Contamination with plastic has increased over the past several decades and is often the dominant pollution in aquatic environments. The definition of microplastic describes fragments of plastic particles less than 5 mm. Microplastics produced as additives to a wide range of products of everyday use or coming from degradation of larger plastic objects, are regarded as the most abundant form of solid waste contamination all over the world [1]. Wind, stormwater runoff, or illegal dumping of plastic materials can be regarded as the important sources of spread of microplastics in the aquatic environment [2]. Due to the varying density of plastic particles microplastics are present in surface waters, the water column and sediment. It is suggested that sediments can to be a long-term sink for microplastics [3,4]. At present, small and large microplastics in beaches, subtidal and offshore sediments have been found. It has also been indicated that the level of plastic contamination is increasing: sediment core analysis pointed out that over the last 20 years microplastic deposition on Belgian beaches tripled [5]. In European beaches UK Beach 1.6 μm – 1 mm <1 – 8 items/50 mL, in Germany 15-7000 item/m^3 of microplastics have been detected [6]. Due to easy accessibility, sandy beaches have been the main focus of studies assessing microplastic abundance. There is no explanation in the studies why the distribution of microplastics on beaches is still little understood, and that there is a need to examine potential accumulation zones of microplastics [7]. Additionally, it was found a positive correlation between microplastic and human population density - microplastics occurred in large numbers in highly populated areas [8,9]. As the number of microplastics in the environment increases, there is a potential risk of its bioavailability to a wide range of aquatic organisms. Plastic particles may accumulate within these organisms during ingestion resulting in direct effects caused by physical injury in the intestinal tract or moved to other tissues or organs [10]. Sediment-dwelling organisms such as: echinoderms, polychaetes, crustaceans, bivalves and demersal fish uptake of microplastics are sensitive indicator species for many kinds of disturbances, and are commonly used as bio-indicators of ecosystem health. It is known that persistent organic pollutants (POPs) can sorb from, the among others, sediment on/in the plastic matrix of (micro)plastics [11,12]. These contaminants due to a higher affinity for the plastic matrix than the surrounding water leading to an accumulation onto the plastic particle. Thus, it has to aware of possible effects of both the polymer and associated contaminants when assessing the potential risks of microplastic.

The aim of the studies was to screen the occurrence of microplastics in beach sand of recreational reservoirs located in the Silesian Voivodship (Poland) as previously, and determining the level of their concentration.

2. MATERIAL AND METHODS

2.1. Study area

The research was carried out with the use of beach sands originating from three various recreational reservoirs located in the Silesian voivodeship (Figure 1). Width of beaches studied varied between 21 and 70 m. For the purpose of this study sand was defined as loose granular (in our study 40% wet), which consisted from mineral particles smaller than gravel but coarser than silt, and contained also some organic material. This type of sand is typical for recreational reservoirs, where organics are due to the bringing by human and animals.

In the western part of Częstochowa (over 200 thousand inhabitants) there is the Lisiniec Recreation Park (40 ha of green areas). Its central part are 3 water reservoirs (Adriatic, Baltic and Pacific) with a total area of about 11 hectares. They were created after flooding the former clay workings used by the local population. A beach was set up on the Adriatic (1) reservoir from where sand samples were taken in 3 places for research.

Zakrzew Lagoon (2), is located on the border of Kłobuck (13 thousand inhabitants), 15km north-west of Częstochowa). The Biała Oksza River flows through the lagoon. The lake is oblong, rectangular in shape. It has an area of 9.5 hectares and a coastline of 1600 meters. There are two small islands on the lake. The west of the lagoon is wild and overgrown, while in the east in the summer season there is a summer recreational and recreational swimming pool with a sandy 55-meter beach, from which 3 samples of sediment were taken for research.

The recreational water reservoir Ostrowy (3) on the Biała Oksza River (Kłobuck district) is located between the villages of Ostrowy nad Oksza and Borowa in the Miedźno commune, Kłobuck poviat. It occupies 39 ha of area. The water mirror has a width of 200 to 250 meters. It was created from the damming of the Biała Oksza River. At that time, the Oksza River was dammed and a retention reservoir with an area of 39 hectares, surrounded by forest, was filled. The reservoir performing the function of retention and flood control has a beach near the dam, from which 3 samples of sediments were taken for research.

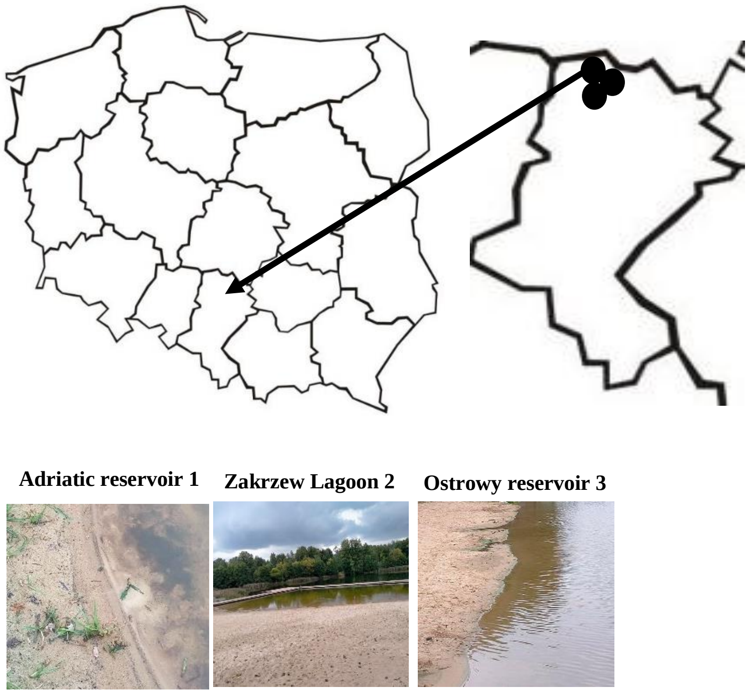

Fig. 1. Sampling places of sand beaches in the study

2.2. Sediment sampling and processing

Beach sections parallel to the waterline were selected at each study site at the swash zone - about 1 m above the waterline. At each section, three replicate samples were collected every 15 m with a metal frame of 15 × 15 cm (a surface area of 225 cm−2). The upper 5 cm sediment layer was taken from the frame with a metal spoon and placed in a glass jar (approx. 1 dm^3 of sediment) rinsed before sampling with tap water pre-filtered on MGF glass filters 0.7 μm pore size. Jars were covered with aluminium foil and tightly closed. After delivering to the laboratory each sediment sample was homogenised, and a subsample of a volume of 50 cm^3 was taken to be analysed. The subsample was put to the glass beaker (400 ml in volume) and mixed with 200 ml of saturated NaCl solution (1.2 g cm−3 as suggested by [13], filtered on MGF glass filters 0.7 μm pore size (checked in advance for contamination). NaCl is one of the most common salts for density separation because it is commonly available, cheap and environmentally friendly

[14] and it is recommended by both the MSFD Technical Subgroup on Marine Litter [15] and NOAA [16]. The mixture was vigorously stirred with a magnetic stirrer or at least 2 min and left afterwards for settling. After 1 h the supernatant was filtered under vacuum on MGD glass filters of 2.7 μm pore size. This procedure was repeated three times, i.e. three subsequent decantations of the sample were performed. Each filter was put on a separate petri dish, covered with a glass lid and left to dry in the laboratory dryer at the temperature 45–50 °C [21]. Microplastic particles were then visualised by Delta Optical SZH-650 B/T microscope. The samples were taken directly from the dried samples, as the whole one was counted. The samples were counted under magnification 40 ÷ 100x depending on the particle sizes. An analysis of the types of microplastics was also carried out. Four types were distinguished based on the shape and origin: fibers (very small thread-like fibers that come from synthetic fabrics), fragments *(secondary microplastics generated by the breakdown of larger pieces)*, granules (small plastic pieces of regular of a regular spherical shape, of usually primary sources), and films (small fragments generated by the breakdown of larger pieces of foils).

The research work was a screening test that allowed a preliminary assessment of the degree of microplastic contamination of beach sand. Further detailed studies are planned. Microplastic particles were firstly counted directly. In cases where there was doubt as to whether a fragment was microplastic, samples were stained with Nile Red. Nile Red is low cost and simple to use hydrophobic, metachromatic and photochemically stable dye that shines under fluorescence microscope and because of this make more easy to distinguish between plastic and non-plastic samples.

3. RESULTS AND DISCUSSION

The results of quantitative analysis of microplastics are given in Table 1. Average content of microplastics particles taken from the beaches ranged from 38 to 340 particles per kgd.m. Standard deviations of the results were relatively high, which is typical for temporary samples as the ones collected in the study. The most polluted beach was Lisiniec recreation park one (Adriatyk) which contained 340 ± 222 particles per kg d.m. The less polluted ones were the samples taken from Zakrzew Lagoon with microplastics' content at level 38 ± 22 particles per kg d.m. Samples taken from reservoir Ostrowy on the Biała Oksza River beach were polluted with average content of microplastics equal to 124 ± 61 particles per kg d.m. The data obtained in our study are within the results obtained by other authors for various sand beaches – Table 2.

It should be emphasized that most of the results included in Table 2 concern sea beaches, with differ in terms of characteristics from the beaches of recreational reservoirs. First of all, coastal beaches undergo more intensive erosion taken by the waves and also during the day the level of water vary a lot as a result of sea tides. In the case of coastal beaches, it was stated that the amount of microplastics' depends highly on the location of the beach. Ferreira Nascimento Maynard et al. [17] have observed that high amounts of microplastics in beach sand can be related to the estuary which suggest that the rivers play important role in microplastics pollution of the coast. Moreover, definitely the rivers on highly urbanised areas are more polluted by microplastics' than the rivers on non-industrialised regions [2]. The results obtained by Dacewicz et al. [18] also confirm the importance of large municipal rivers as a source of microplastics particles. The authors also have stated that stagnation of water promotes presence of the smaller microplastics particles. The similar results were obtained by Nocoń et al. [19] who observed that dam reservoirs (in which water flow is significantly slower than in rovers) accumulates microplastics in their bodies, in the sediment samples. Definitely the water flow is one of the important factors affecting microplastics accumulation in the sediments, and beaches of the reservoirs. The fates of microplastics in water body are also be affected by e.g. suspended solids concentration in the river flow [19].

Table 1. Total number of microplastics particles taken from the beaches of various recreational reservoirs in Silesian voivodeship

Sampling place	Mean number of particles per kg d.m. ± SD
Lisiniec Recreation Park	340 ± 222
Zakrzew Lagoon	38 ± 22
Ostrowy on the Biała Oksza river	124 ± 61

Table 2. Total number of microplastics particles taken from the beaches obtained by various authors

Sampling place	Mean number of particles per kg d.m. ± SD	Ref.
13 beaches in the coast of South China	93 ± 90.2 ÷ 4433.3 ± 4822.5	[20]
13 beaches in the coast of North Poland	97.6 ± 43.8 ÷ 295.2 ± 181.8	[21]
Can Gio Coast (Wietnam)	0 ÷ 6.58	[22]
Outlet of flood control reservoir (Sardis lake), USA	270 ± 30 ÷ 590 ± 360	[23]

Some beaches are however not significantly polluted with microplastics even in the vicinity of a large city [22]. On the other hand, quite high concentrations of the microplastics have been detected in the sediments taken from relatively unpopulated area [17]. It indicates that further, detailed studies are necessary to clarify the pathways of microplastic spread in the environment.

Important issue is also to know types of microplastics coming from the beaches, that is crucial in the case of their removal and evaluation of the effect on the environment. In our study we have distinguished 4 types of microplastics particles according to the shape: fibers, fragments, granules and films. Shares of the individual types in various samples are presented in Fig. 2. Exemplary images of the microplastics found in the samples are presented in Fig. 3.

According to the collected data the most abundant fractions in the beach sand samples were fibres, followed by fragments and films. The less abundant in all samples were microplastics granules. Fibres were about 60% of microplastics in sand samples taken from Lisiniec Recreation Park and Biała Oksza River. In Zakrzew lagoon the share of fibres was lower, about 37%. Fragments shares were 31%, 29% and 24% for Zakrzew Lagoon, Lisiniec recreation park and Biała Oksza River, respectively. In sandy samples taken from Zakrzew Lagoon films were almost 24%, whereas in Lisiniec recreation park only 9%. Granules shares were the lowest and in Lisiniec recreation park and Biała Oksza river were less than 2 and 1 %, respectively. In Zakrzew lagoon the granules were less than 8% which was however equal to 3 granules per kg d.m.

When considering quantitative relationships between the different fractions in individual beach sands it was observed that in Lisiniec recreation park fibres concentration was on average 204 microplastics particles per kgd.m., and this was twice as much as fragments, almost seven times more than films, and twenty five times more than granules. When we considered the ratio in the case of Zakrzew lagoon, the fibres concentration (14 microplastics particles per kg d.m.) was similar to fragments (12 microplastics particles per kg d.m.) and 1.5 times more than films. Simultaneously it was almost 5 times more than granules. In sand from Biała Oksza River Beach fibres (on average 75 microplastics particles per kg d.m.) were two and a half times more than fragments, and four times more than films.

Shape and sizes of microplastics' particles affect the fates of these micropollutants in water bodies and sediments [24]. Comparison of the results obtained by various authors suggests that percent shares of fibres, granules, fragments and foils can vary a lot. E.g. Urban-Malinga et al. have observed that on sandy beaches of Polish coast the most abundant microplastics types were, depending on location, fibers and fragments [21]. However, in some locations, such as Tricity the most abundant fraction were plastic films. The results obtained by these authors for sea beaches are, therefore, similar to the results obtained in our study. However, e.g. in Vietnam beaches the most abundant fraction was identified fragments of plastics, followed by fibres. But, in some samples, the significant fractions were granules [22].

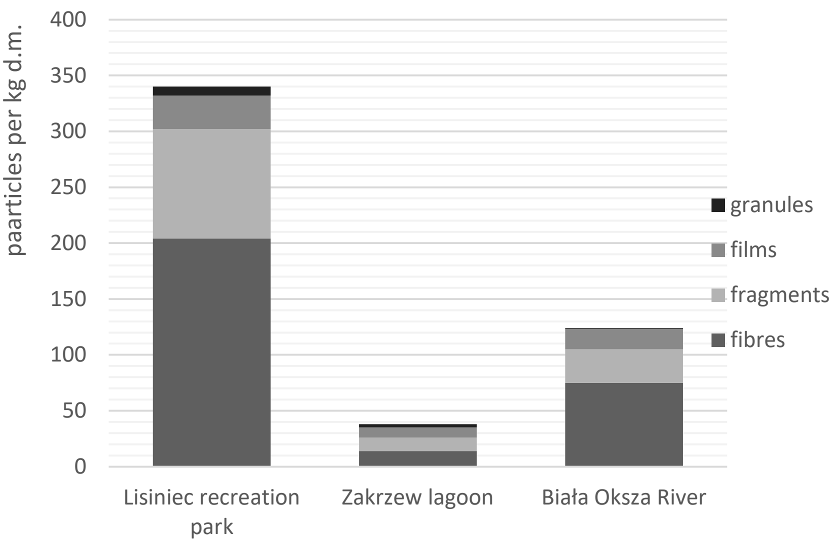

Fig. 2. Microplastics by the types taken from the beaches of various recreational reservoirs in Silesian voivodeship

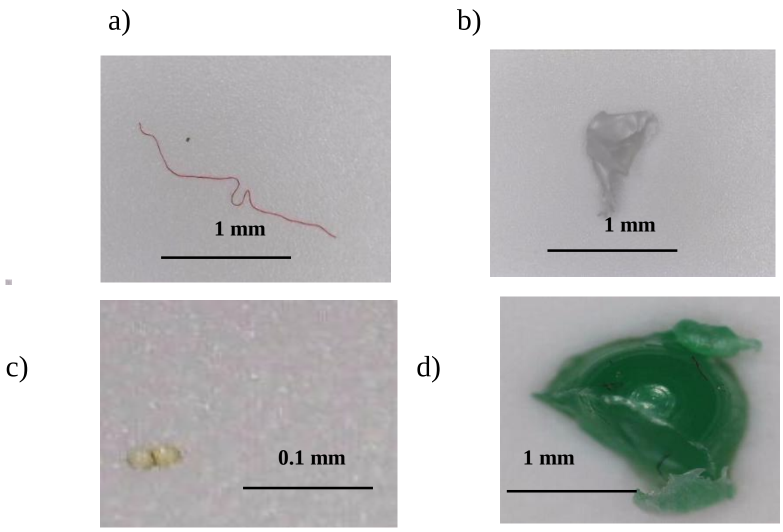

Fig. 3. Examples of various microplastics found in sandy beaches of recreational reservoirs in south Poland: a) fiber, b) foil, c) granule, d) fragment

4. CONCLUSIONS

The conclusions are as follows:

1. The results obtained in our study indicate that sandy beaches of the recreational reservoirs being tested are polluted by microplastics. In analysed sands the average concentration was from 38 to 340 particles per kg d.m. Concentrations of the pollutants is within the range observed in other studies.
2. The most polluted sand was found at the bank of Lisiniec recreational park, which is the area crowded by residents of Czestochowa city
3. The most abundant fraction in all location were fibres, which were 1.5 to seven times such much as films.
4. The less abundant fraction were granules, which consisted not more than 4& of the most abundant film fraction.
5. Recreational reservoirs beaches can be significantly contaminated by microplastics particles, but simultaneously the concentrations of these micropollutants can vary a lot among the individual places.
6. Further detailed studies are necessary among others concerning concentration seasonal variations, chemical formulas and the dependence between the sampling depth and microplastics abundance.

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