

MICROPLASTICS IN COASTAL SEDIMENTS OF ELCKIE LAKE (POLAND)

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Abstract:

Plastics are materials with many properties that make them extremely popular in everyday life and various industries. Studies show that plastic debris is global pollution and widespread in virtually all ecosystems. This study aimed to assess the coastal sediments of Elckie Lake in terms of the presence of microplastics. Samples of sediments ($n = 37$) from the coastal zone of Elckie Lake were drawn from different areas, including urban, rural, and tourist locations, and beaches. After the coastal sediment samples taking, they were subjected to density separation, filtration, and visual evaluation using the Olympus BX63 fluorescent microscope. Particles were classified according to the category of visible characteristics of microplastics including size, shape and colour. The results of the study showed the presence of microplastics in 84% of the examined coastal sediment samples of Elckie Lake. Fibres, flakes, granules, and foils (films) had found in 58%, 45%, 32%, and 13% of the samples that contained microplastic, respectively. The majority of the detected microplastic was 0.5–1 mm in size and black was the dominant colour. Spatial variability was perceived in microplastic concentrations, giving premises to the assumption of dependence between local human activity and the content of particles.

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Key words: microplastics, lake, coastal sediments.

Manuscript received 10 January 2021, accepted 17 May 2021

INTRODUCTION

Plastic is an overwhelmingly widespread material due to many features that distinguish it from other materials – it has good durability, toughness, rigidity and tenaciousness. It is resistant to corrosion, biologically neutral and non-toxic, moreover it features high thermal and electrical insulation (Andrady and Neal, 2009). Besides, plastic has a relatively low cost of production, is lightweight, and provides a barrier to oxygen and moisture. All of these features allow displacing other packaging materials such as glass and paper (Andrady, 2011). In 2018, global plastic production exceeded 350 million tons (PlasticsEurope, 2019), and its longevity, popularity, unsustainable use and management problems cause the accumulation of plastic wastes in the environment (van Wezel *et al.*, 2016). Microplastic, i.e. small pieces of plastic, less than 5 mm in diameter, poses particularly hazardous waste (Collignon *et al.*, 2014). Plastics fabricated in millimeter or submillimeter sizes are defined as primary microplastics (da Costa *et al.*, 2017). They may be found in cosmetic preparations, cleaning agents, household goods; they are used as scrubbers for removing rust and paint from

engines and boat hulls (Cole *et al.*, 2011; Zbyszewski *et al.*, 2014; Napper *et al.*, 2015; Peters and Bratton, 2016). Another crucial source of primary microplastics is raw materials used in the manufacture of plastic products. Accidental loss, inadequate handling, runoff from processing plants, and residues from plastic production contribute to the emergence of virgin plastic particles in the environment (Moore, 2008; Andrady, 2011; da Costa *et al.*, 2017). Microplastics might be transported by rivers, discharges from sewage treatment plants, wind, and surface runoff to freshwater and marine ecosystems (Li *et al.*, 2018). Secondary microplastics are created in the environment as a result of the disintegration of larger plastic elements as a result of physical, chemical, and biological processes. The integrity of the plastic structure is changed, leading to the formation of microplastics (Cole *et al.*, 2011; Efimova *et al.*, 2018). These processes may also occur before plastics enter the environment, for instance, during the exploitation of products such as textiles, tires, or paints (GESAMP, 2015). Considering the large number of plastic particles that enter the environment, it is generally approved that most of them are secondary microplastics (Efimova *et al.*, 2018). They have a long residence

time in freshwater systems, whether natural, modified, or artificial (Eerkes-Medrano *et al.*, 2015).

The presence of microplastics has been perceived on the coasts of all continents, in distant places such as subantarctic and mid-Atlantic archipelago islands, the Arctic, and even in deep-sea habitats (Eerkes-Medrano *et al.*, 2015). There are many reports in the literature on microplastics in freshwater lake ecosystems (Ballent *et al.*, 2016; Sruthy and Ramasamy, 2017; Vaughan *et al.*, 2017; Yuan *et al.*, 2019) and rivers (Klein *et al.*, 2015; Wang *et al.*, 2017a; Lin *et al.*, 2018; Rodrigues *et al.*, 2018), and many studies had realized in the marine environment (Lenz *et al.*, 2016; Zobkov and Esiukova, 2017). Their presence in aquatic environments is singularly crucial because of the risks they pose. There is also clear evidence that plastic debris is able to accumulate some contaminants, including polycyclic aromatic hydrocarbons (PAHs), petroleum hydrocarbons, organochlorine pesticides, polybrominated diphenyl ethers, alkylphenols, and bisphenol A (BPA) (Lee *et al.*, 2014; Mathalon and Hill, 2014). Many studies proved that microplastics pose a particular threat to aquatic organisms (Derraik, 2002; Moore, 2008; Desforges *et al.*, 2015; Wang *et al.*, 2016), but on the other hand, knowledge about the consequences of this phenomenon is relatively low. Many species of marine organisms consume plastic particles, confusing them with prey. The absorption of microplastics by the gastrointestinal tract causes various injuries and inhibits the digestion of food. It may also have toxic effects due to the adoption of chemicals on the particles (Tanaka *et al.*, 2013). These substances may interfere with core physiological processes, like cell division and immunity, causing diseases, reducing the ability of organisms to escape from predators or reproduce. Some of the chemicals may transfer from microplastic particles to fish tissue when ingested. According to Batel *et al.* (2016), subminiature microplastic particles have access to higher trophic levels through food chains. Besides, eating marine animals that have swallowed the debris may increase the load of dangerous chemicals in humans (Rochman *et al.*, 2013).

The objectives of the study were: (1) to assess the occurrence of microplastics in the sediments in the coastal zone of the Ełckie Lake, (2) to try to determine the impact of tourism and other sources of microplastic pollution entering the lake from urbanized and agroforestry areas, thus contributing to the knowledge and better management of the region in the future.

STUDY AREA

The Ełckie Lake is located in the area of the Ełk municipality in the central part of the Ełckie Lake District. The area of the lake is 382.4 ha, volume 57420.3 thousand m³, its maximum depth is 55.8 m, while the average depth is 15.0 m. The length of the coastline is about 18650 m (Bańkowska, 2007). Due to the distinct varieties of morphometric characteristics, three sections of the lake are distinguished: northern, central (southern), and western. The

largest part, a central one, is supplied by the waters of the Ełk River, which is the right-bank tributary of the Biebrza River. The central section is separated from the northern one by the peninsula; from the western one by a significant narrowing and shallowing. The north side is supplied by the Woszczelski Stream, to which numerous field drains flow. The creek has a dammed reservoir used as a fishing ground for the Fishery Farm (Dunalska, 2019).

The total catchment area of Ełckie Lake is 979.8 km² and the direct one is 315.1 ha. The share of particular land use in the catchment area is as follows: urbanized areas 37.3%, farming land 31.4%, forest 16.6%, crops and plots 9.7%, post-farming lands with a high proportion of natural vegetation 3.3% (Dunalska, 2019). The lake is surrounded in the east by buildings of Ełk city. Ełk (61 523 inhabitants in 2017) has two municipal beaches at the lake, exploitation of which is potentially among the primary sources of lake pollution. Ełk is a typical tourist town. There is only a small industry (wood, meat, food). The eastern side of the lake is polluted mainly by the sanitary sewage from the unsealed housing estates located on the lakeshore, rainwater discharges and traffic pollution. On the western side of the lake, there are cultivated fields and forests.

SAMPLE COLLECTION AND PROCESSING

In July 2019, 37 samples were drawn from coastal sediments for testing. The coastal zone of urban lakes may be heavily impacted by pollution from the catchment area

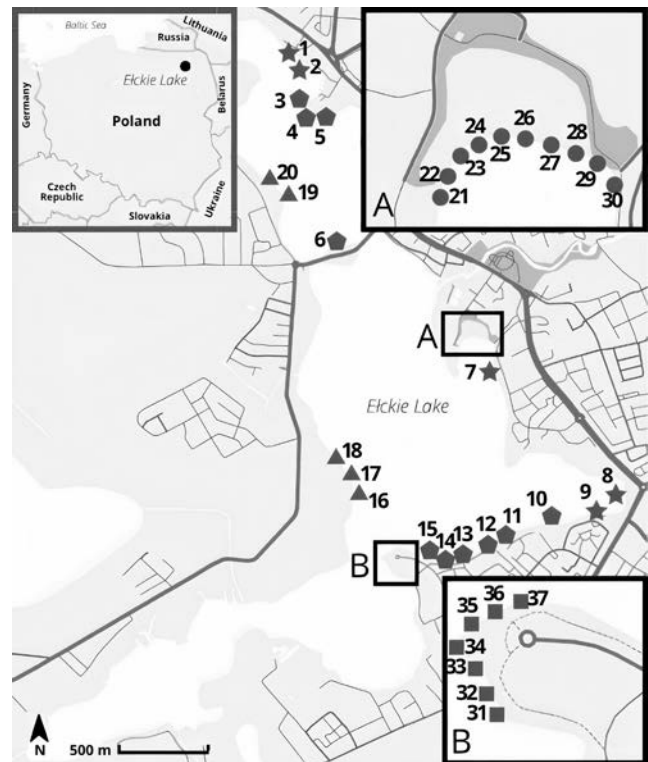


Fig. 1. Location of research points in Ełckie Lake (star – urban areas, pentagon – touristic sites, triangle – rural/forestral areas, circle – beach A, square – beach B).

(Vaughan *et al.*, 2017). Samples were collected at selected sites due to significant anthropopressure, manifested by the presence and creation of new infrastructure, thriving tourism and agricultural activities. The lake shoreline research points were split into groups based on development and use of the area: urbanized areas with research points 1, 2, and 7–9, agroforestry – research points 16–20, beach A – research points 21–30, beach B – research points 31–37 and tourist places of like the surroundings of the Elk Castle, promenades, gastronomic facilities but other than beaches – research points 3–6 and 10–15 (Fig. 1). Most samples of sediments (17 samples) were drawn from the infilling beaches A and B due to their significant use by tourists and local people. Both of them have similar morphodynamics. The beach B is attended by considerably more visitors due to the amenities of a large parking lot, water equipment rentals, playing fields, changing rooms, etc., which are not available at beach A. The pollution within the urbanized areas comprises sanitary sewage from the non-sewage housing estates located on the lakeshore, rainwater and traffic pollution (road dust). Potential contaminants from agricultural and forest areas come mainly with surface runoff from agricultural areas. In the case of beaches and places of tourist importance, the amount and type of pollution are determined highly by human factors (catering facilities, camping sites, sports fields, swimming pools, water equipment usage).

Sediment samples were drawn from the nearshore zone of the lake with a self-constructed sampler, 20 cm from the shoreline. Sediments were collected for testing from the top layer, from the depth up to 5 cm (Klein *et al.*, 2015). Larger solids (stones, sticks, branches) present in the sample were rinsed with water from the collection point and removed from the container (Yonkos *et al.*, 2014). Samples were put in glass containers and tightly closed. The weight of the collected sample was ≥ 200 g.

A 50 g of wet sediment was weighed out, then 100 ml of 5% NaCl was added and shaken for 5 minutes (Duis and Coors, 2016). After shaking, the samples were left behind for sedimentation for 24 hours (Zhang *et al.*, 2017; Ding *et al.*, 2019). Then, the supernatant was decanted carefully into the mineralizer column and 10 cm³ of 30% H₂O₂ was added. The samples were heated to 70°C and kept at this temperature until the oxidation reaction of organic matter was completed (Ding *et al.*, 2019). The samples were cooled and filtered through a quantitative filter. Filters were dried at 60°C for 4 hours (Klein *et al.*, 2015). Then the filters were examined with the bare eye – particles that were visually identified or suspected to be plastics were subjected to microscopic analysis using the Olympus BX63 fluorescent microscope. The particles were classified based on shapes and colours, according to criteria proposed by Zhou *et al.* (2018): separating granules, flakes, films (foils) and fibres among the microplastics. Regular and rigid, circular, egg-shaped or cylindrical debris was defined as granules. Flat plastic sheets were labelled as flakes while transparent, soft and thin fragments were designated as foils (films). The fibres were defined as microplastic, the length of which

exceeded the diameter at least several times. The particles were photographed using an Olympus XC30 microscope camera.

RESULTS

Significant variability was observed in the number of microplastics depending on the sampling location (Table 1). Locations exposed to strong human impacts like increased urbanization and tourism activities stand out by a noticeably higher presence of microplastics besides areas with agricultural and forestry uses. The study showed the presence of plastic particles in 80% of the samples tested from urbanized areas and in all samples collected at beaches and tourist sites. Microplastics were not observed in samples from agroforestry areas. In the coastal sediments of Elckie Lake, microplastic particles were detected in 84% of the tested samples. The quantities and shapes of the plastic particles differed depending on the place of sampling (Fig. 2). The dominant shape of plastic particles were fibres – their presence was perceived in 58% of the samples containing microplastic. Black was the most frequently detected colour in this type of debris (68% of all fibres). Other colours observed in the fibres included blue, red, white and yellow (Fig. 3). Most (62%) of the detected fibres were 0.5–1 mm in size, 24% – above and 14% – below the beforenamed range. Flakes, granules, and foils (films) were present in 45%, 32%, and 13% of the samples in which plastic debris was found, respectively. Flakes had silvery colour and regular shapes; the granules were black, while the films were transparent. Most of the detected flakes, granules and foils were 0.5–1 mm in size (respectively 77%, 71%, and 60% of mentioned shape particles) (Fig. 4).

Table 1. Summary of the mean (\pm SD) concentration of microplastics in Elckie Lake (number of microplastic particles per 1 kg wet mass of sediment).

Name of sampling group	No. of samples	Mean number of particles (n/kg w.m.)
urban	1, 2, 7–9	22.8 \pm 6.2
touristic	3–6, 10–15	27.3 \pm 12.8
rural/forestal	16–20	n.d.
beach A	21–30	31.3 \pm 8.0
beach B	31–37	28.4 \pm 8.8

n.d. – not detected

DISCUSSION

Studies of sediments from the urbanized areas (points 1, 2, and 7–9) showed the presence of plastic particles in 80% of the samples, mainly as silver flakes (53%) and fibres (41%), mostly black. There is a high probability that the mentioned flakes were glitter particles. The rest of the particles were granules. Fig. 5A shows a microplastic separated from the sediments at point 2, which was set at the lakeside outlet of the rainwater drainage system. Particles in the shape of black fibre may come from synthetic textile

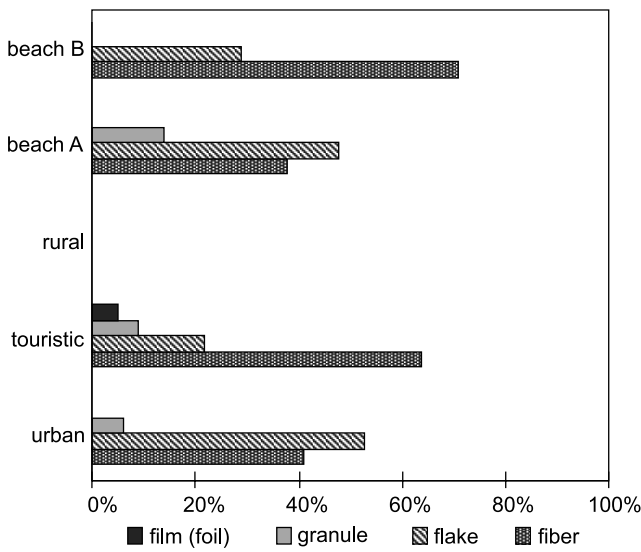


Fig. 2. Percentage distribution of the shape of plastic particles depending on the place of occurrence

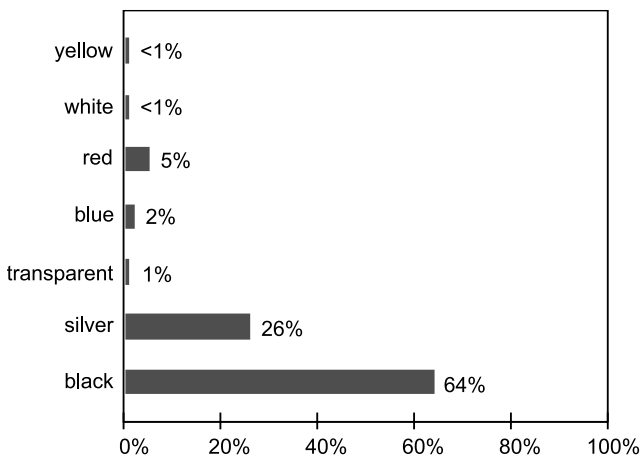


Fig. 3. Percentage distribution of the colour of the particles.

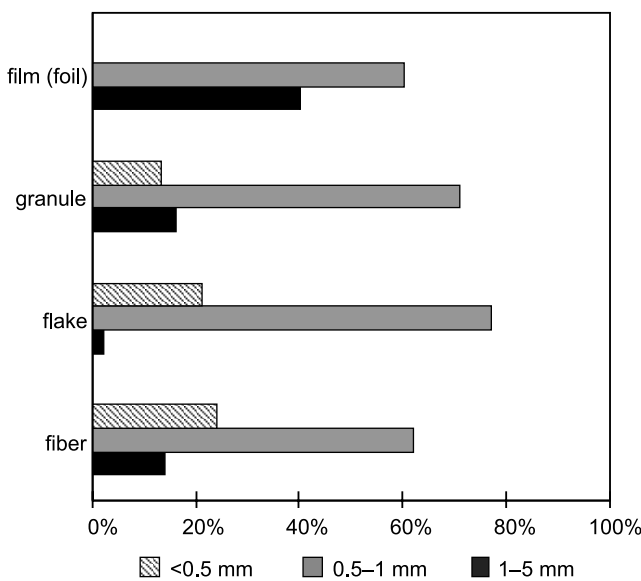


Fig. 4. The percentage size distribution of particles for each shape.

materials, which were rinsed off by surface runoff from urbanized areas. Rainwater runoff may also contain plastics such as fragments of worn tires and soles or road marking paint residues (Horton *et al.*, 2017). Moreover, heavy rainfall increases the volume of stormwater and also affects the microplastics amount directed to the rainwater drainage system. It is caused by forces, which wash away microplastic particles from hardened surfaces, leading to the transport of more pollutants along with the stormwater to the reservoir. Rainwater may be discharged to the sewage system and treated in WWTP or transported separately to the reservoir with or without treatment, which can significantly affect the amount of microplastic particles in the reservoir (Magnusson *et al.*, 2016). In a study carried out by Piñon-Colin *et al.* (2020), between 66 and 191 plastic particles per liter of rainwater was noted in Tijuana (Mexico), with the highest number recorded in industrial land use. Smoking waste may be a crucial factor influencing the amount of microplastic in this group. The Keep America Beautiful Campaign reports that cigarette butts represent 25 to 50% of all collected garbage from roads and streets. Cigarette butts are tossed away on the streets, thrown into a storm drain and then into a reservoir (Novotny *et al.*, 2009).

The western lake shoreline is located in an agroforestry area – points 16–18 sit near a forest, 19 and 20 close to arable farming and grassland. Sediments collected there did not contain particles that undoubtedly constitute microplastics. Nevertheless, agriculture may be one of the secondary sources of microplastics in the environment. Plastic bedding and foil tunnels are applied to control humidity and temperature and to slow down the growth of weeds. Moreover, cords and bale wrappers, containers, packaging and nets are materials that may relatively easily shred after exposure to sunlight and high temperatures. Greater and denser particles more often remain in the soil. On the other hand, lighter ones are carried by wind and surface runoff easier, and may enter into a water ecosystem (Horton *et al.*, 2017). A sewage sludge used as a fertilizer for agricultural purposes may release microplastic particles to the environment. Wastewater treatment plants are generally very effective in removing microplastics from wastewater, but plastic debris accumulates in the sludge significantly. Microplastic in the sludge may come from washing machine leachate and hygiene products such as toothpaste, soaps, scrubs and other sources (Corradini *et al.*, 2019). In Europe and North America, about 50% of sewage sludge is processed with the aim of agricultural use. Nizzetto *et al.* (2016) estimate that between 125 and 850 tons of microplastic per million inhabitants are added annually to European agricultural soils through direct application of sewage sludge or as processed biosolids.

The analysis showed the presence of microplastic in all sampling points located at the beaches. At beach A the presence of fibres was noted in 60% of the samples, granules – in 50%, and flakes – in 40%. Foils were not present. Flakes made up 48%, fibres – 38%, granules – 14% of microplastics found in this location. 75% of samples from the beach B contained flakes and 25% – fibres. Granules

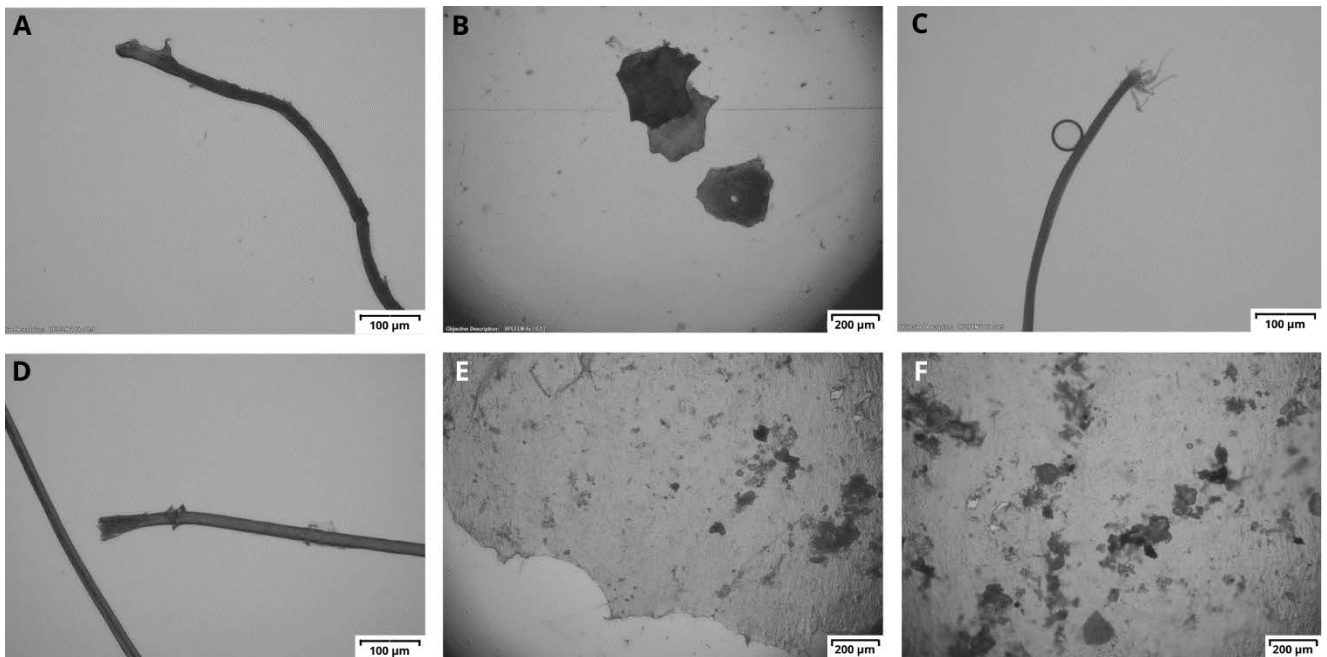


Fig. 5. Microplastic in the form of: A – black fibre (point 2 – urbanized areas), B – flakes (point 21 – beach A), C – black fibre (point 10 – tourist areas), D – red fibre (point 29 – beach A), E and F – transparent film as an example of mesoplastic (point 13 – tourist areas).

and films were not present in the sediments in this group. Flakes made up 71%, fibres – 29% of plastic debris found on beach B. The majority (61%) of plastic particles separated from beach A were larger than 1 mm; at beach B most particles were 0.5–1 mm in size (57%). The separated flakes were in the form of silver-grey hexagons resembling glitter (Fig. 5B). The presence of this type of microplastic at the city beach may be argued by cosmetic products usage – filter creams, lotions, lipsticks, and glosses, or nail polishes, and other containing glitter, as well as the loss of particles from clothes decorated with brocade. Glitter has a wide range of applications, but also target group – including children, teenagers, and adults of both sexes, which enforce its prevalence among microliters. Considering the shapes and sharp edges of the brocade particles, they pose a more acute threat to the environment and living beings than other debris (Yurtsever, 2019). The shapes and colours of the microplastic vary greatly depending on the beach. Microplastics are not only found at beaches during summer – it is a non-biodegradable pollutant that is subjected to constant migration. Outside the summer season, plastic particles are usually delivered in lesser amounts, making them less noticeable in the surface sand. However, in addition to tourism, contributions to the amount of microplastic at beaches may include surface runoff from within the city and associated pedestrian and vehicular traffic. Research conducted by Claessens *et al.* (2011) along the Belgian coast showed plastic fibres, which constituted 88% of microplastics; contents of granules and plastic films were much lower – 7% and 5%, respectively. Lee *et al.* (2013) reported high content of microplastic at the South Korean beaches near the mouth of the Nakdong River, which flows through a densely

populated area. The nature and intrinsic properties of the microplastic (such as shape or size) significantly influence its distribution as well as its subsequent complex interactions between physical, chemical, and biological processes.

In all the samples coming from the areas of tourist importance, the presence of plastic particles with a high proportion of microplastics in the form of fibres was noted, mainly black, but also in other colours. This shape of microplastic occurred in 70% of all samples from this group (points 3–6 and 10–15). Fibres made up 64%, granules – 22%, flakes – 9%, films – 5% of microplastics found in tourist places. Their origin is probably related to clothing made of synthetic materials. Moreover, the presence of granules, flakes and foils was noted. Fibres may be lost due to fabric pill, which occurs as the material wears out. Fabrics such as polyester and acrylic are marked by high tensile and deformation strength, but pill faster in comparison to polyester-cotton fabrics. Fibre weakening leads to its rupture, thereby the release of fibres (Napper and Thompson, 2016). The observed fibre colours are primarily black and red (Fig. 5C, D). The clothing origin of red fibre seems even more likely because dyeing increases the attractiveness of a product. This process is of less importance for the production of ropes or fishing nets (Wang *et al.*, 2017b). In the sediments of the mountainous lake Hovsgol, in northern Mongolia, fibre-shaped microplastics also dominated. There is no industry around the lake, and the population density is low. The concentration of microplastic was the highest in the most populated and most tourist part of the lake (Free *et al.*, 2014).

Research shows that tourism activity may make a direct contribution to the number of microplastics from various sources, which is indicated by the materials, shapes and

colours of the particles. Polypropylene and polyethylene are mainly used as food packaging and are often carelessly discarded by tourists. Clothes may be responsible for the presence of fibres in the sediments, whereas the presence of transparent particles is reasoned by the usage of plastic bags, food boxes and wearing disposable raincoats (Xiong *et al.*, 2018). Moreover, litters such as cigarette butts are one of the microplastics sources in urban areas. Cigarette filters are made of cellulose acetate, which is susceptible to photo-degradation but resistant to biodegradation processes. They may be dropped on the beaches, but also the sidewalks or thrown away from cars with cigarette butts, which makes them a high percentage of all waste in urbanized areas (Novotny *et al.*, 2009).

Tourism often involves an increased amount of macrolitters, which enter the environment either deliberately or unintentionally. Larger plastic elements, buried in the beach sand, might be fragmented, increasing the proportion of microplastic in sand (Yu *et al.*, 2016). Some of the detected debris did not allow us to classify it as microplastic, because of its size. The element in the form of a transparent film (Fig. 5E, F), which is probably a part of a plastic bag, comes from point 13, located near the pier. According to the classification proposed by the European Working Group on Marine Litter, it should be called a mesoplastic i.e. a fragment with dimensions between 5–25 mm (Dümichen *et al.*, 2015). Edges' appearance of this one suggests that the particle was created by the fragmentation of larger plastic elements and undergoes further fragmentation itself, being a source of smaller, secondary particles. Free *et al.* (2014) showed that the dominant macroplastic objects at the lake shores were domestic plastic (plastic bottles and bags) and fishing equipment. Considering the large number of macroplastics entering the environment, most of the plastic debris in the environment is generally approved to be of secondary origin, i.e. originated as a product of weathering of greater plastic remains (Andrady, 2011; Hidalgo-Ruz *et al.*, 2012). Therefore abrasion and fragmentation of larger plastic parts should be considered as a crucial process.

There are many references to microplastics in Asian freshwater ecosystems, but on the other hand, there is a massive gap concerning the sediments of the European lakes. Research on microplastics in a marine environment shows their wide distribution, persistence and significant impact on fauna (Vaughan *et al.*, 2017). Faure *et al.* (2012) show that macro- and microplastics were noted in considerable quantities on beaches and surface water of Lake Geneva. In another study, Faure *et al.* (2015) examined sediments on beaches of 6 Swiss lakes with contents of microplastics equal to 2100 ± 2000 particles/m²: Constance 320 ± 220 particles/m², Neuchâtel 700 ± 1100 particles/m², Maggiore 1100 ± 2300 particles/m², Zurich 460 ± 350 particles/m² and Brienz 2500 ± 3000 particles/m². Imhof *et al.* (2013) examined beach sediments of subalpine Garda Lake, used for drinking water supply. It is one of the most popular tourist destinations in northern Italy. At the northern shore 1108 ± 983 plastic particles/m² were found, while at the southern one, extrapolations showed 108 ± 55 drops/m².

A study of the microplastic content of two lakes in central Italy (Bolsena Lake and Chiusi Lake) showed that the content of particles in the sediments ranges from 112 (Bolsena Lake) to 234 (Chiusi Lake) particles/kg of dry sediment. The results of Chiusi Lake reveal increased fibre concentrations compared to Bolsena Lake, which may result from higher organic content and the shift of grain size distribution towards silt and clay fractions due to the shallowness and highly eutrophic character of the reservoir (Fischer *et al.*, 2016). In the paper by Turner *et al.* (2019), the radionuclide dated sediment core (²¹⁰Pb and ¹³⁷Cs) was collected from the Hampstead Pond No. 1, a lake in northern London. It was used to provide new data on the historical accumulation of microplastic waste in the urban environment. Polystyrene microplastic particles, fibres made of synthetic polyacrylonitrile, polyvinyl chloride and fibres containing synthetic dyes were identified. The content of plastic debris in the sediment samples ranged from a detection level to 539 particles per kilogram of dried sediment. Vaughan *et al.* (2017) investigated the distribution of microplastics in the sediments of the Edgbaston Basin, a shallow eutrophic lake in central Birmingham (United Kingdom), where the maximum concentration of particles reached 25–30 particles per 100 grams of dried sediment. The most frequently observed types of microplastic particles were fibres and foils. Ballent *et al.* (2016) shows that microplastics have concentrated in coastal sediments near urban and industrial regions. In the bays of Lake Ontario (Canada), the content of microplastics was over 500 particles/kg of dry sediment. The maximum concentration, reaching about 28,000 particles/kg of dry sediment, was determined in the Etobicoke Creek (a tributary of Lake Ontario). Studies on the content of microplastics were also conducted on the Tibetan Plateau, which is characterized by low population density and limited human activity. The area has the largest number of high mountain lakes in the world. Samples were taken from sediments from 4 lakes in the Siling Co basin in northern Tibet and tested for microfibre. Microfibres were detected in 6 among 7 sampling sites with concentrations ranging from 8 ± 14 to 563 ± 1219 particles/m². These results indicate the presence of microplastics even in inland lakes in remote areas with relatively low human impact, suggesting that such contamination may be a global problem (Zhang *et al.*, 2016).

CONCLUSIONS

The results of the study showed the presence of microplastics in 84% of coastal sediment samples of Ełckie Lake, thus confirming the widespread occurrence of microplastics in lake ecosystems. The shape of plastic particles consisted of fibres in the amount of 58%, then flakes 45%, granules 32%, and foils (films) 13%. Most of the detected microplastics were 0.5–1 mm in size, and black colour dominated.

Spatial variability was observed in the microplastic concentrations, giving rise to the assumption of dependence

between local human activity and the content of particles. In some places, especially on beaches, recreational areas, and coastal settlements with a strongly urbanized coastline, were observed significant amounts of microplastic.

Plastics are acutely persistent in the environment; there is an assumption that the abundance of microplastics will further increase due to the fragmentation of macroplastics present in the environment.

The conducted research indicates various sources of plastic particles penetration into the environment, from surface runoff from urbanized areas, through tourism, transport, agriculture, which should be considered in the context of broadening the general knowledge about the presence of microplastics in freshwater ecosystems, as well as an important direction in the future management of the studied region.

The obtained results suggest the necessity of further monitoring of the microplastic, not only in marine but also in freshwater environments, such as rivers and lakes.

Acknowledgements

The research was carried out as part of research project no. WZ/WB-IIŚ/2/2021 at the Białystok University of Technology and financed from a subsidy provided by the Minister of Science and Higher Education.

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