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Original Research Article

MICROPLASTIC IN FOOD AND DRINKING WATER - ENVIRONMENTAL MONITORING DATA

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Abstract

Microplastics are present in the environment and have been found in seas and oceans, fresh water, sewage, food, air, and drinking water, both bottled and tap water. Nanoplastics can originate from engineered material or can be produced during fragmentation of microplastic debris. This paper presents an analysis of the research available in the literature on the content of microplastics in food, tap water, and bottled water. There is no legislation for microplastics as contaminants in food. Available data are from seafood species such as fish, shrimp, and bivalves, and also in other foods such as honey, beer, and table salt. In tap water, the measured amount of microplastic particles varies extensively and depends on the place of intake, type of conditioning, and water distribution system. Studies concerning bottled water have shown that water contains microplastics from disposable plastic bottles, bottles made of recycled material, and even glass bottles. The lack of analytical standards related to the adoption of the method of determination and identification of the size and form of microplastic particles was found to be problematic. The abovementioned particles were mainly identified as polyethylene (PE), polyethylene terephthalate (PET), polypropylene (PP), polyamides (PA), polyether sulfone (PES), polystyrene (PS), and polyvinyl chloride (PVC), and were between 1 and 150 µm in size. The most common shapes of the particles were fragments, followed by fibres and flakes. Toxicity and toxicokinetic data are lacking for microplastics for a human risk assessment.

Keywords: plastics, microplastics, monitoring, hazard, environment

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1. INTRODUCTION

Plastics are materials obtained by combining polymers with additional chemical compounds such as dyes or antioxidants. The added chemical compounds change the physicochemical properties, but do not change the structure of the polymers. As a result, the obtained plastics may differ in their properties depending on the purpose for which they were produced. The increasing demand for plastic products and the versatility of this material's application have a significant impact on the quantity that is produced. Plastic production in the world is growing every year; from 1950 to the current year, it has increased more than 239 times. Global plastics production in 2018 amounted to 359 million tonnes. The biggest use of plastic, as much as 141 million tonnes, has been recorded for the production of disposable packaging, the use of which has gained popularity due to the lightness of the material it is made of [16]. Note that plastic products differ significantly in terms of their function and service life. Some of the plastic products are used for a few minutes, less than a year, while others can serve us for up to 50 years or more. As a result, the life cycle - from production of the product to waste - varies greatly for different plastic products and it is not, therefore, possible to directly compare the amount of waste generated per year with the amount of annual production or demand for plastics. Despite the global upward trend, plastic production in Europe has remained almost constant since 2008 (an average of 51.2 million tonnes per year) [16]. The ever-increasing consumption of plastics and its one-time use results in difficulties with the storage and recycling of the material, which also stems from its long period of biodegradation. In Europe, 29.1 million tonnes of post-consumer plastic waste was collected in 2018, of which 32% was recycled, less than 43% was used for energy purposes, and about 25% was landfilled [2].

Regardless of the implementation of the program to reduce landfill of plastic waste at the global level, attention is still drawn to the problem of microplastics. There is no internationally recognized definition of microplastic. For the purpose of this article, it is defined as a heterogeneous mixture of materials of different shapes called fragments, fibres, beads, granules, pellets, flakes, or spheres, in the range 0.1-5,000 μm [14]. Microplastic is classified as either primary or secondary. Primary microplastics are produced, among other things, as a result of washing synthetic clothes (35%), abrasion of tires (28%), smog (24%), and are released directly into the environment. Another source includes the cosmetics industry (2%) which, since the 1960s, has been increasingly replacing natural ingredients with plastic alternatives. Secondary microplastics (approx. 69-81% of microplastics in the oceans) are parts of larger plastic products (e.g., plastic bags, fishing nets) [14]. The amount of plastic in the oceans is constantly increasing and poses a threat to living organisms. Microplastics have also been found in drinking

water (surface, ground, tap, and bottled water), food, and even air. The presence of microplastics in the environment has been the subject of numerous studies in recent years but monitoring and the consequences of its occurrence are insufficiently understood. There is no legislation for microplastics as contaminants in food, and occurrence data are limited [14, 17, 20].
This paper presents an analysis of the research available in the literature on the content of microplastics in food, tap water, and bottled water.

2. MICROPLASTIC IN FOOD

Microplastics mainly end up in the oceans because they are too small to be filtered or separated during wastewater treatment. Plastic waste does not dissolve in water but breaks down into even smaller particles which are often consumed by planktonic organisms and molluscs, and then it moves higher up the food chain. Experimental evidence in marine organisms indicates that microplastics have the potential to be transferred between trophic levels. Fish meal is used in the feeding of poultry and pigs, hence, plastic microparticles can be found in food of non-sea origin. Microplastics are likely to originate from other sources than the food itself, e.g., processing aids, water, air or being released from machinery, equipment, and textiles. It is, therefore, possible that the amount of microplastics increases during processing. The effect of other processes, e.g., cooking and baking, on the content of plastics is not known [6, 17]. Limited data are available on the occurrence of microplastics in foods. Based on research on the amount of plastic in products consumed by humans, it was estimated that the average person consumes 5 grams of plastic (the equivalent of a credit card) per week. Based on the average life expectancy (79 years), it was calculated that humans consume about 20 kg of plastic. The WWF report states that humans consume an average of 1,972 microplastics per week, 90% of which comes from drinking water, both bottled and tap (1,769), 182 particles with seafood, 10 particles with beer, and 11 with sea salt [14].

Selected data on the consumed products:

- Honey – The average content of microplastics reported for honey is 0.166 fibres/g and 0.009 fragments/g [8]. A total of 19 honey samples, mostly from Germany but also from France, Italy, Spain, and Mexico, were analysed for non-pollen particulates in honey. Sources are tentatively identified as environmental, that is particles having been transported by the bees into the hive, or having been introduced during honey processing, or both. Fibres and fragments were also identified by the same authors in commercial sugar samples. Mühlschlegel et al. [11] processed five representative honey samples of different origin following a standardized protocol to separate plastic-based microparticles from particles of natural origin such as pollen, propolis, wax, and bee-related debris. Five particle classes with an abundance significantly above blank levels were identified: black particles (identified as char or soot, particle 1760-8680/kg), white transparent fibres (particle 132-728/kg), white transparent particles (particle 60-172/kg), coloured fibres (particle 32-108/kg), and coloured particles (particle 8-64/kg). The microplastics were identified as cellulose or polyethylene terephthalate, and other particles were glass, polysaccharides, or chitin.

- Beer - In beer, fibres, fragments, and granules have been found in the following amounts 0.025, 0.033, and 0.017 per ml, respectively. A total of 24 German beer brands were analysed for the content of microplastics. In all cases, contamination was found [17].
- Milk - Kutralam-Muniasamy et al. [5] collected 23 milk samples from 5 international and 3 national brands of Mexican milk, and tested for the occurrence of microplastics. Results confirmed the ubiquity of microplastics in the analysed samples with an overall average of 6.5 particles/dm^3. Microplastic particles exhibited a variety of colours (blue, brown, red and pink), shapes (fibres and fragments) and sizes (0.1–5 mm). Among which, blue coloured fibres (<0.5 mm) were predominant.
- Salt - Since table salt is most often produced by the distillation of seawater, it is difficult to avoid microparticles of plastics in the final product, because the seawater itself contains microplastics. For table salts, microplastic content of between 0.007 and 0.68 particles/g has been found [3, 17].

A study by the Irish Environmental Protection Agency (EPA) [9] found that at least 24 species of fish, molluscs, crustaceans, birds, and even mammals consume microplastics. Because of this, tiny plastic particles end up in the food chain. The gastrointestinal tract of marine organisms contains the largest amounts of microplastics; however, these parts are usually removed before consumption. Nonetheless, in the case of crustaceans such as bivalves, this part is consumed and may be harmful.

As shown by the data in the literature [1, 18], seafood is the largest source of microplastics in food. In shrimp, an average of 0.75 particles/g are found. In bivalves, the average number of particles is 0.2-4 (median value)/g. Bivalves are consumed without the removal of the gastrointestinal tract and consequently pose a microplastic risk not only directly to humans, but also to fish and other seafood for which they are food. Exposure to microplastics was calculated for the consumption of a 225-gram portion of bivalves assuming the largest proven amount of microplastic found in bivalves is equal to 900 microplastic particles, which is equal to 7 µg of plastics (25 µm in diameter and 0.92 g/cm in density^3) [17]. On the basis of the above estimate, and taking into account the highest reported concentrations of additives or pollution in plastics as well as the total release of microplastics, it can be concluded that bivalve contribution would have a relatively minor impact on exposure to microplastics, i.e., PCB (<0.006%), PAH (<< 0.004%), and bisphenol A (<2%) [17].

In studies by Lewis et al. [7], a total of 60 flathead grey mullets were examined for microplastic ingestion. Microplastic ingestion was detected in 60% of the wild mullets, with an average of 4.3 plastic items per mullet, while only 16.7% of captive mullets were found to have ingested microplastics, with an average of 0.2 items per mullet. The most common plastic items were fibres that were green in colour and small in size (<2 mm). Of the identified plastic polymer types, polypropylene contributed the majority (42%), followed by polyethylene (25%), and polyester (16%) [7]. Rummel et al. [18] investigated the occurrence of plastics, including microplastic, in pelagic (herring and mackerel) and demersal fish (cod, dab, and flounder) from the North Sea and Baltic Sea. Plastic particles were detected in 5.5% of the fish examined, with 74% of all particles being in the microplastic (< 5mm) size range (1-7 particles/fish) and almost 40% of the particles consisted of PE.

Kwon et al. [6] summarized the presence of microplastics in food based on literature data from 2019 in 1800 articles (Fig. 1). They found that the thermoplastics (i.e., polyethylene (PE), polypropylene (PP), polystyrene (PS), and PET) comprised the majority of microplastic in food. In all foods, PE, PP, PS, and PET (including polyesters) accounted for more than 50% of microplastics. Cellophane was found to be dominant in table salt, fish, and clams. The percentage of fibres in isolated microplastics was more than 50% in various food items.

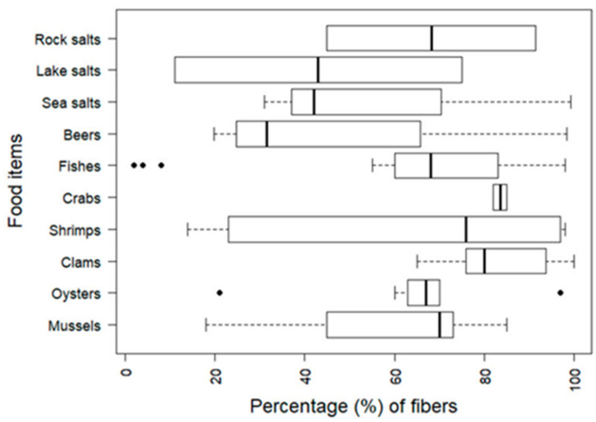

Fig. 1. Microplastics in food including filaments in different food items representing 5, 25, 50, 75, and 95 percentile value [6]

3. MICROPLASTIC IN DRINKING WATER

Studies concerning bottled water have shown that water contains microplastics from disposable plastic bottles, bottles made of recycled material, and even glass bottles [4, 12]. The particles were identified mainly as polyethylene, polyethylene terephthalate, polypropylene, polyamides, polyether sulfone, polystyrene, and polyvinyl chloride, and were between 1 and 100 µm in size (Table 1).

Table 1. Characteristics of microplastics in drinking water

source	bottled water	size, µm	number of particles/dm^3 range, average	microplastic type
Oßmann et al., 2018 [15]	glass	1	3074–6292	PET in bottles made of plastic PE, styrene, butadiene in glass bottles
	disposable PET		2649	
	recyclable PET		4889	
Schymanski et al., 2018 [19]	glass	5-20	50	PET, PP, PE
	disposable PET		14	
	recyclable PET		118	
Mason, Welch, Neratko, 2018 [10]	PET	6.5-100	325	PP, nylon, PS, PE, PEST
source	**tap water source**	**size, µm**	**number of particles/dm^3 range, average**	**microplastic type**
Strand et al., 2018 [20]	subsurface	10-100	0-0.8	PET, PP, PS, styrene, PUR
Mintenig et al., 2019 [13]	subsurface	20	0.0007	PS, PVC, PE, PA

The most common shapes of these particles were fragments, followed by fibres and flakes. In a study conducted by Mason et al. [10], 259 bottles of 11 popular brands of bottled water were analysed for the presence of microplastics (research has shown that bottled water contains an average of 325 microplastic particles per litre), only 17 out of 259 bottles were found not to be contaminated with microplastic. None of the brands studied were completely contamination-free with Nestlé Pure Life bottled water achieving the worst results; the most contaminated sample contained 10,390 particles per litre. Also, well-known in Poland, Danone's Aqua brand contained up to 4713 particles. San Pellegrino (Nestle) and Evian (Danone) bottled water had the best results with less than 300 particles. In terms

of tap water testing, the number of published results is much smaller and the measured amount of microplastic particles varies extensively depending on the place of intake, type of conditioning, and water distribution system (Fig. 2). As can be seen, despite the fact that studies have shown, for example, in the United States, that more than 94% of tap water is contaminated with microplastics, found in tap water sampled at sites including Congress buildings, the US Environmental Protection Agency's headquarters, and Trump Tower in New York. Lebanon and India had the next highest rates. European nations including the UK, Germany and France had the lowest contamination rate, but this was still 72%.
The number of particles per litre does not exceed 10. Compared to the amount of microplastic particles in bottled water, these amounts are negligible.

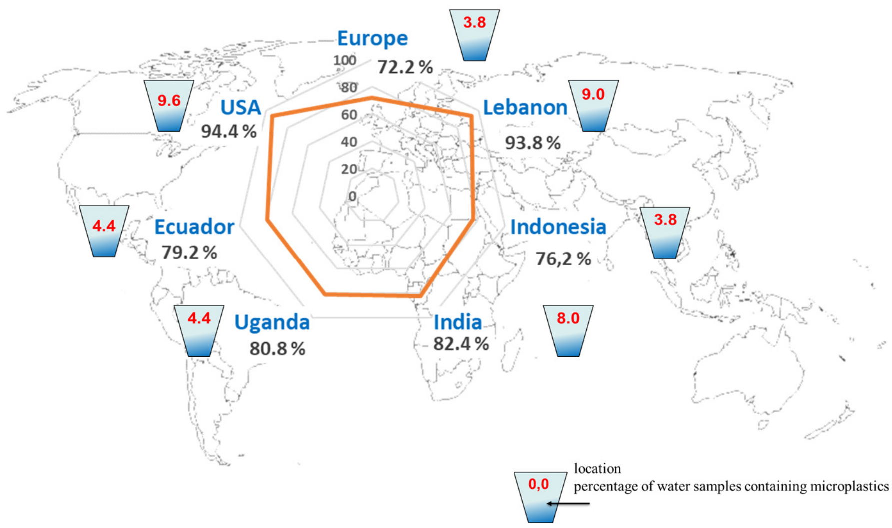

Fig. 2. Measured amount of microplastic particles in tap water (based on [20])

4. CONCLUSIONS

The analysis of the data in the literature shows that the main problem appears to be the lack of analytical standards related to the adoption of the method of determination and identification of the size and form of microplastic particles. In conclusion, there are currently no conclusive results from comprehensive studies on the content of microplastics in drinking water and food and its impact on human health. The absence of such an impact has also not been definitively confirmed. The following may pose a threat to human health due to consumed microplastics: the particles themselves, which cause mechanical damage; chemical substances resulting from the plastic's composition and adsorbed on the surface of microplastics from the environment; and microorganisms colonising on microplastics, i.e., biofilms. Certain types of plastics are believed to be endocrine disrupting, causing reproductive problems, or to be carcinogens, and cause other health problems. The presence of microplastics in the environment is certain, but effective monitoring and the consequences of their occurrence are still insufficiently understood.

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