Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2022.28822

275 (2022) 116–121
November

Microplastic in tap water – preliminary tests

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Received 18 March 2022; Accepted 27 July 2022

ABSTRACT

The article aims to describe the problem related to the possibility of secondary contamination of tap water with microplastic particles. Samples were collected in situ (with minimal risk of external contamination) from individual consumers located in Upper Silesia Agglomeration. It was shown that microplastic particles were present in each of the points covered by the research in amounts ranging from several dozen (78) to several thousand (8,200) per cubic meter of water. In the samples collected for Sample Points 1 and 2, microplastics in the form of fibers dominated. Fragments dominated in Sample Point 3. The division of microplastics due to their colour was also very characteristic (at Sample Points 1 and 2 transparent microplastic fibers dominated and at Sample Point 3 microplastic particles were blue). Contamination by microplastic was present both in water from underground intakes and surface intakes. It is assumed that the microplastic in tap water is secondary contamination and its origin is the erosion of the plastic pipes in the water supply system. This indicates the need for further research to accurately determine which elements or fragments of the water supply system may be responsible for the appearance of microplastics in tap water. The conclusions take into account the guidelines for further research on the behavior of microplastics in water supply networks.

Keywords: Microplastic; Water supply system; Tap water

1. Introduction

Plastics are materials that have contributed greatly to the development of mankind. Since the invention of bakelite over 110 y ago, new kinds of materials have been constantly created, and the existing ones have been improved and refined. The first plastic was invented in the mid-nineteenth century, but plastics began to be mass-produced after World War II, and so their production increased from 1.5 million tons in the 1950s to 368 million tons in 2019. The demand for plastics in Europe in 2019 was estimated at about 50.7 million tonnes, which means an increase of 3.4 million tonnes compared to 2015 [1]. These data and the awareness that plastics are used in almost every area of life show how necessary they are for the functioning of today's society and allow us to assume that their use will continue to increase.

Unfortunately, the characteristics that make plastic so useful in many areas make it a very problematic waste. A special case of this problem is microplastic particles – those formed in microscopic sizes, and those that have become small due to decay.

Even though the problem of microplastic is already widely known, at the international level there is still no standardized definition of the size and composition of microplastics [2]. Most often in the literature, it is accepted that particles larger than 5 mm are referred to as "macroplastics", while those smaller than 5 mm are referred

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Presented at the 2nd International Conference on Strategies toward Green Deal Implementation – Water, Raw Materials and Energy (ICGreenDeal2021), 8–10 December 2021, held online by the Mineral and Energy Economy Research Institute, Polish Academy of Sciences

1944-3994/1944-3986

to as "microplastics". An additional distinction between "small" and "large" microplastics is also often mentioned and it refers to the size range of 5–1 mm for large microplastic particles and 1–1 μm for small microplastics [3]. MP represents a diverse range of materials, sizes, types, colors, and shapes [4]. Plastics consist of polymers that are mixed with plasticizers, additives, and stabilizers. There are two types of plastics: Thermosetting Plastics (TSP) and Thermoplastics (TP), which are soft when heated and hard when cooled. Therefore, TP can be recycled, such as polypropylene (PP), polyethylene (PE), polyethylene, terephthalate (PET), polystyrene (PS), polyvinyl chloride (PVC), polyamides (PA), and polycarbonates (PC). TSPs are not soft when heated and therefore cannot be recycled [5].

Despite the growing popularity of the topic and many aspects related to this pollution, such as its impact on human health or the mechanisms of particle dispersal in the environment, they are still not sufficiently studied and will be a challenge for scientists in the future years. A relatively small number of publications (in relation to the total number of publications about microplastics) deal with the topic of microplastics in tap water [6–10].

It is important that microplastics can accumulate in the water sources. The currently operating water treatment plants were not specifically designed to remove microplastics [11,12], but conventional technological processes at water treatment plants allow MP to be removed from the water, but some elements of the water treatment plant are made of plastic and it is their degradation or erosion that causes MP to enter the water after the treatment processes [8]. The use of plastic in recent years has also become widespread in drinking water installations. Plastic degrades under the influence of use and aging, and then microplastic particles are released [13]. However, the occurrence and distribution of microplastics in water supply networks, especially in pipelines, remains unclear [9].

The literature shows a relationship between the amount of microplastics in tap water and the age of the water transporting network. It has been shown [14] that the increase in the amount of MP released from old plastic pipes is greater than from the second generation of MP from original plastic particles. It was found that especially small particles (1–10 μm) were released from aging plastics to a greater extent.

In Poland, the water supply networks are constantly renovated and pipeline sections are replaced. It is often possible to find use of various materials for the implementation of the network, depending on their current availability, tender specifications, and the cost of materials and manufacturing technology. A special case is the Upper Silesian Agglomeration, which represents the strong impact of mining exploitation. Due to the stresses of the rock mass, the water supply networks often become unsealed and fail, which additionally generates problems with ensuring the reliable operation of water supply systems and networks. These reasons prompted the authors to conduct preliminary studies on real problematic water supply networks. The article aims to describe the problem related to the possibility of secondary contamination of tap water with microplastic particles. The article analyzes water samples from individual consumers in Upper Silesia Agglomeration. The article describes the water supply networks for which the research was carried out, the methodology of "in-line" sampling, and sample preparation. The discussion of the research results is based on a comparison with the results of other researchers, and the conclusions take into account the guidelines for further research on the behavior of microplastics in water transport networks.

2. Materials and methods

2.1. Study area

The study of tap water was carried out at three sample points in the Upper Silesia Agglomeration in Poland.

2.1.1. Sample Point No. 1

The first sample point was located in a single-family house. The water comes from surface intakes and is treated in the following technological line:

- initial ozonation
- coagulation with aluminum sulphate
- filtration on quicksand filters
- indirect ozonation
- active carbon filtration

After passing the technological process, the water is transported to the network pumping station, 32 km away, via a gravity pipe with a diameter of Ø 1,500 reinforced concrete. The water is then transported via a network of main pipelines to expansion tanks, from where it goes to the destination town, where the pipelines are made of steel – built before 1990, gray and ductile cast iron – built before 1990, reinforced concrete – built before 1990, polyethylene and GFK – built-in 1994. The internal installation was made from PE in 2013.

2.1.2. Sample Point No. 2

The second sample point was located in a public building. Samples of water were taken from a tap located

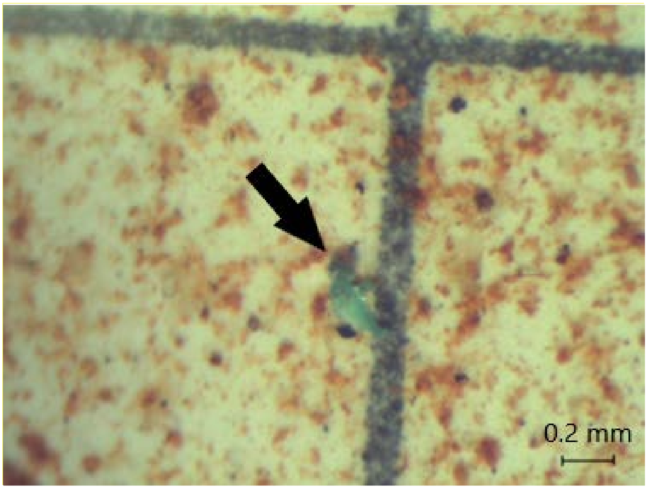

Fig. 1. Example of microplastic fragment.

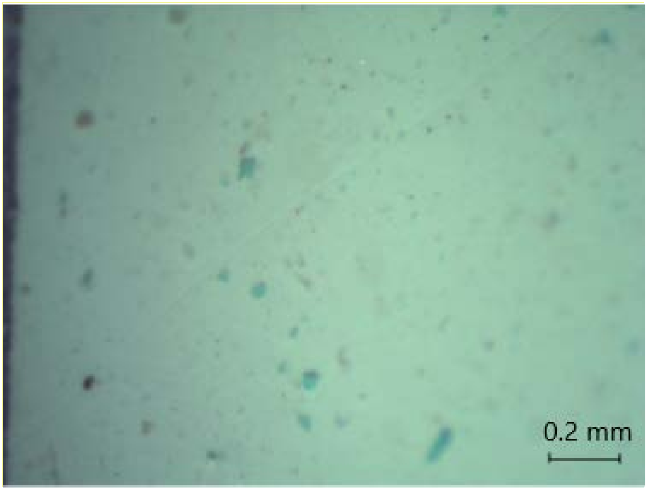

Fig 2. Example of blue fragments of microplastic.

in the university building. The water comes from underground intakes and is treated in the following technological line:

- aeration in non-pressure aerators
- first stage filtration on a de-ironing bed
- indirect ozonation
- second-stage filtration on a de-manganese bed
- UV disinfection
- disinfection with sodium hypochlorite

During the research, the water network was made of steel and cast iron pipes (now, after the network has been renovated, the pipes have been replaced with plastic pipes). The water supply network was built before 1990. The internal installation was made of steel (several dozen years ago and at present, it is not possible to find the original technical documentation).

2.1.3. Sample Point No. 3

The third point is located in an block of flats. Water comes from two groundwater intakes alternately, in which typical technological processes for this type of water are used. Water from the water treatment plants is transported to the building through the steel pipes – built before 1990 and PE pipes – built after 1990. Within the water supply network to the building where Sample Point No. 3, there are also sections made of plastic and other materials. The internal installation is made of PE.

2.2. Sampling

Samples were taken from tap water. Five water samples were taken from each point for three months. An in-line filtration method was used, that is, filtration of the water in-house without intermediate storage and/or transport. The in-line method allows large volumes of water to be sampled on-site and contamination with airborne particles is minimized [15]. Before collection, 20 L of water was drained from the tap. Then a plankton mesh with a pore diameter of 250 μm was installed on the tap. The mesh was put on the faucets of the taps after the aerator had been previously disassembled. After attaching the mesh to the spout, 1,000 L of water was passed through it (based on the reading from water meters).

After the intake was completed, the mesh was removed from the spout. The flexible clamp (previously used to attach the mesh to the battery) was left on it in such a way as to isolate the inner part of the mesh used for extraction from the external environment. The sample was then placed in a glass jar, covering the lid with paper to avoid fragments of the plastic breaking out of the cap. In this form, the samples were transported to the laboratory.

2.3. Methodology of samples preparation

Before starting the sample preparation, all elements used in the process (laboratory glass, elements of the vacuum pump system, Petri dish) were thoroughly washed with distilled water and then placed in such a way as to minimize possible deposition of microplastics from the air. After the samples were delivered to the laboratory, the microplastic which was collected in the plankton mesh was rinsed counter currently with distilled water.

Then the accumulated liquid was filtered using the "Aga Labor" vacuum pump through membrane filters with a pore diameter of 0.45 μm, with a 3.1 mm scale facilitating subsequent counting. During percolation, the top of the pump suction vessel was also secured with a plankton mesh.

After filtering was completed, the filter was carefully transferred to the Petri dish and sent for counting. The samples were observed under a "Delta Optical" microscope with a maximum magnification of 90 times. Thanks to the use of a camera coupled with the microscope, the observations were carried out on a computer screen using the ScopeImage 9.0 program. The performed activities consisted in counting microplastic particles, supported by the scale on the membrane filters.

2.4. Statistical analysis

The data for each point was expressed as a mean with standard deviation.

3. Results

The tests were carried out for the quantitative determination of microplastics contained in the tap water and its grouping due to the form and colour in which they occur. Table 1 summarizes the average concentrations of microplastics with SD and RSD values.

All of the tested samples showed the presence of microplastic (Table 1). The lowest concentration of microplastic particles was recorded in the sample from Sample Point No. 2 – 107 particles/m^3, a slightly higher value was found in Sample Point No. 1 – 124 particles/m^3. Much larger amounts of microplastics were found in Sample Point No. 3 – the average particle content was estimated at 5800 particles/m^3. The obtained test results do not allow for drawing definitive conclusions as to whether the method of water disinfection has an impact on the occurrence of microplastics in the water supply network. According to Zhang et al. [14], a critical problem with plastic pipes in the drinking water distribution systems is, inter alia, the release of polymers from pipes and decomposition of additives (plasticizers). This phenomenon is amplified by the use of disinfectants (such as chlorine, chloramine, chlorine dioxide, and ozone) because the water pipes are then exposed to an oxidizing environment [14]. The results presented in this paper, however, do not allow to unequivocally confirm this thesis, because the water supplied to all points is disinfected, while in point 3 the content of microplastics is many times higher than in points 1 and 2. It should also be noted that water supplied to point 2, due to the considerable distance from the source, is subject to re-disinfection during transport to the recipient. In order to demonstrate these relationships, research should be carried out at various points in the water supply network.

In the samples collected for Sample Points 1 and 2, microplastics in the form of fibers (Table 2) definitely dominated (appropriately 92% and 81%), similar to the research conducted in Denmark [10]. They had different sizes (from about 100 μm to a few mm). Also, Yuan et al. [15] and Kosuth et al. [6] found that microplastics observed in drinking water and their sources consist mainly of fragments and fibers of various sizes and compositions. Fragments, on the other hand, dominated in Sample Point 3 – almost 97% (Table 2). The division of microplastics due to their color was also very characteristic. At Sample Points 1 and 2, transparent microplastic particles dominated (Table 3). On the other hand, at Sample Point 3, the vast majority of microplastic particles were blue (Table 3). Similar results were obtained in the research of Yuan C. [15], which indicated the participation of microplastic in the form of nylon and PET fibers.

Apart from the fibers (Figs. 3 and 4), the samples showed microplastic fragments (Figs. 1, 2, and 4). It seems that the blue-colored pieces of plastic, responsible for the very high concentration value in the samples from Sample Point No. 3 (Table 2), should be given special attention. The blue color of the debris resembles the color of polyethylene water pipes. Unfortunately, without a detailed examination of the material from which the pipelines are made, it is impossible to confirm this thesis. The theory that the microplastic contamination comes from the water supply is also not supported by the observations of other samples taken in places where water is also supplied through pipes partially made of polyethylene (Sample Point 1), and in which no similar fragments were found. Taking into account the same sampling methodology as in other cases and multiple sampling, accidental contamination of the tested water can be excluded. The results of the tests carried out in Barcelona showed that the mains PE pipes or the linear distance to the water treatment plant are not responsible for the release of MP into the drinking water [16].

The obtained results also do not allow for the determination of the relationship between network age and microplastic contamination. Long-term exposure of plastics to the oxidative environment chemically changes the surface of the pipes and their properties [17]. Other authors suggest that oxidation of surfaces by breaking polymer

Table 1
Microplastic in samples taken from sample points

	Sample Point No. 1	Sample Point No. 2	Sample Point No. 3
Range (part./m^3)	78–161	78–131	3,400–8,200
Medium	124	107	5,800
SD	32.0	21.8	1,772
RSD (%)	25.8	20.4	30.6

Table 2
Percentages of the microplastic particles forms

MP forms	Sample Point No. 1	Sample Point No. 2	Sample Point No. 3
Fibers (%)	92	82	3
Fragments (%)	6.5	16.2	97
Films (%)	1.5	1.8	0

Table 3
Percentages of microplastic colour types

Colours of MP	Sample Point No. 1	Sample Point No. 2	Sample Point No. 3
Blue (%)	12.9	10.3	93.1
Red (%)	0	8.4	81.3
Transparent (%)	91.3	1.7	5.2

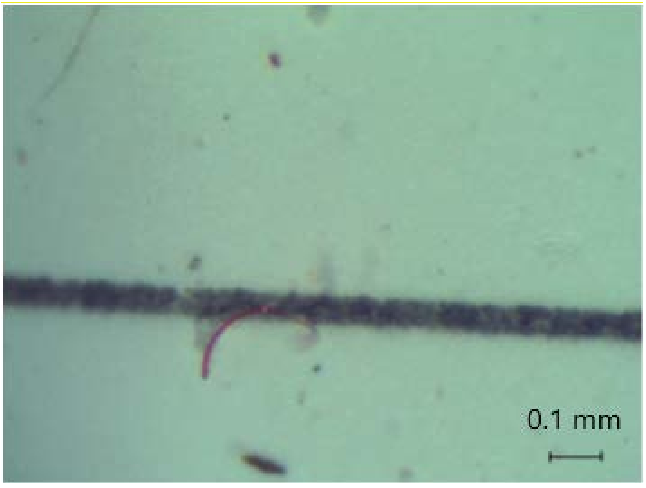

Fig. 3. Example of red fiber.

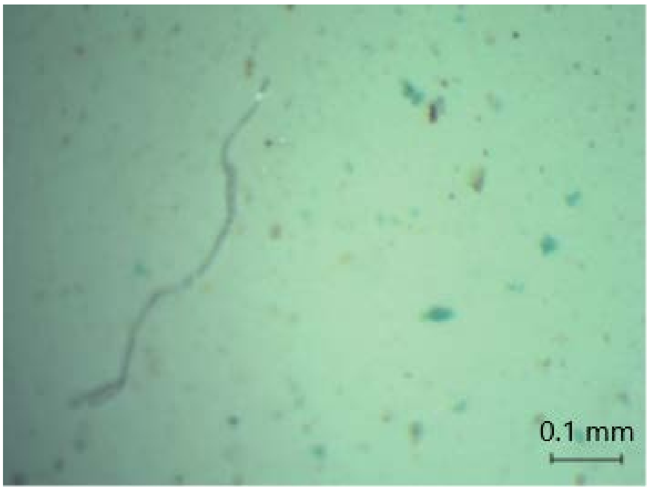

Fig. 4. Examples of transparent fiber and blue fragments of microplastic.

chains, causes cracks and mechanical damage that worsen with the age of plastic pipes [18,19]. In our case, fragments of polyethylene networks, both in the case of Sample Points 1 and 3, were made after 1990, and the result noted in point 3 exceeds the one from point 1 almost 60 times.

Taking into account the above information, it seems necessary to investigate which elements of the infrastructure can be responsible for water supply originating from microplastic contamination – whether the pollution can come directly from the intake/water treatment plant or the distribution network. Therefore, it is suggested, similarly to the research conducted by Chu et al. [9], in addition, to testing water from the water supply system, conducting detailed tests for water taken directly at the intake. So far, such studies have not been carried out due to the lack of consent of the water treatment plant managers. Water supply networks and connections to individual buildings from which the samples were taken should also be distinguished. Often, connections are much shorter operated than networks. This can have an impact on the amount of microplastic seen in tap water.

4. Conclusion

The conducted tests showed the presence of microplastic in all tested tap water samples. Thus, the reports in the scientific literature regarding the content of this pollutant in water consumed by humans were confirmed.

Pollution was present both in water from underground and surface intakes. However, the scope of the research conducted did not allow for the precise determination of the origin of microplastics in tap water. Such an undertaking would require much more extensive research covering more sampling sites – including directly at the intakes, in the process lines of the treatment plant, and in key places of the water distribution system.

In the research, it is necessary to analyze the particles to determine what material they are made of. This could confirm or disprove the thesis about the origin of microplastic contamination from the water supply system.

The high content of microplastics, and the results of studies by other researchers, allow us to state with certainty that there are many microplastic particles in the tested water, but often their small size (<10 μm) made it impossible to count them. As the research conducted by Pivokonski [7] shows, these particles, designated as microplastics, are the most numerous after the water treatment process. Therefore, there is also a need to refine the methodology of water sampling from the water supply network and apply a more precise methodology of data analysis (Raman spectroscopy, infrared microscopy (μ-FTIR) technique).

Acknowledgement

This work was supported by the Ministry of Science and the Higher Education Republic of Poland within statutory funds.

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