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Evaluation of Microplastics in the Surface Water, Sediment and Fish of Sürgü Dam Reservoir (Malatya) in Turkey

Duygu Özhan Turhan[1]* ⓘ

[1]Department of Biology, Faculty of Arts and Science, Inonu University, Malatya 44280, Türkiye.

Abstract

In this study, the concentration, type, size, and color of MPs in multiple environmental compartments was investigated in Sürgü Dam Reservoir. The MP concentrations in surface water were between 106.63 and 200 par.m-3. The MP concentrations in sediment were between 760 and 1.440 par.m-2. A total of 44 MPs, ranging from 0 to 3 samples per fish with averaging 0.41 MPs/individual, were extracted from gastrointestinal tracts of fish. Fibers were the predominant type of MPs in surface water, sediment and fish. The most common MP sizes were 1-2 mm in surface water, 0.2-1 mm in sediment and in fish. The dominant color of detected MPs was black in surface water and transparent in sediment and fish. Polyethylene terephthalate and polypropylene were the major polymer types of the selected particles. Of the two stations, station 1 showed a higher MP concentration level. The results of this study showed the MP concentration in SDR is relatively moderate in sediment although it is lower in fish and surface water samples. This data may assist in extending our knowledge regarding MPs pollution in freshwater systems and provides a baseline for future monitoring and assessment MPs of SDR.

Introduction

Plastics are synthetic ingredients composed of organic polymers, and are used extensively because of their low cost, transportability, and endurance (Wang et al., 2020). Microplastics (MPs) are plastics that are smaller than five millimeters long. MPs have different sizes, shapes, chemical contents, and sources of origin (Free et al., 2014; Zhang et al., 2015). In recent years, MPs have become accepted as one of the pollutants threatening the environment. Numerous negative effects of MPs in aquatic systems have been reported in the literature (Zhang et al., 2015; Sruthy & Ramasami, 2017; Ding et al., 2018; Egassa et al., 2020). For instance, MPs may cause inflammation by accumulating in body tissues or fluids of aquatic organisms, also lead to adverse conditions such as intestinal obstruction, increase in oxidative stress, and deterioration of nutrition, digestion and behavior (Jemec et al., 2016). MPs can transport pollutants, invasive species, and pathogens, as well as increase the persistence of these elements in the environment (Sighicelli et al., 2018). MPs may be perceived as food and be accidentally ingested by numerous aquatic organisms. Moreover, these MPs can be transferred between different trophic levels in the food chain (Sighicelli et al., 2018). Therefore, the transfer of MPs among organisms is another environmental risk for ecosystems (Zhu et al., 2019).

Freshwater systems are very important as sources of drinking water and because they are used for irrigation, fishing and energy production (Şahin & Zeybek, 2019). Due to the unplanned use and rapid pollution of freshwater resources, water pollution has become an important issue in Turkey in recent years (Varol, 2020). The presence of MPs in freshwaters has been reported by numerous studies on a world scale (Zhang et al., 2015; Fu & Wang, 2019; Meng et al., 2020). While many researchers have focused on MP pollution in marine ecosystems, freshwater ecosystems have received less attention (Wong et al., 2020). However, as in the former, studies of the latter have shown that MPs create a collective pollution load in aquatic environments (Egessa et al., 2020). In addition, the presence of MPs has been detected in lakes of various sizes, even in those that are relatively far from human activities (Sighicelli et al., 2018).

According to the literature, there were a limited number of studies on MP pollution in freshwater resources in Turkey. MP pollution of surface water of Cevdet Dündar Pond, Küçükçekmece Lagoon and Süreyyabey Dam Lake has been determined in Turkey. In addition to these studies, the determination of MP pollution in Sürgü Dam Reservoir (SDR), which is Turkey's freshwater resource, is thought to be an important data input on freshwater resources in Turkey (Erdoğan, 2020; Tavşanoğlu et al., 2021; Çullu et al., 2021).

SDR is used as a fishing, irrigation and recreation area. The most important water source feeding Sürgü Dam is the Sürgü Stream. This stream originates in Reşadiye, passes through the town of Sürgü and discharges to the SDR. The waste water of the villages in the town of Sürgü flows into the Sürgü Stream without first passing through a treatment plant. It is also thought that intensive agricultural activities around SDR and the Sürgü Stream cause water pollution (Erkul & Sarıgül, 2008).

The aims of this study were: (1) to obtain data about the qualitative and quantitative composition of MPs in SDR; (2) to evaluate the MP pollution in SDR seasonally and regionally; (3) to determine the effect of the Sürgü Stream on SDR in terms of MP pollution; and (4) to determine whether the fish in the study area are contaminated by MP. This study may assist to fill the data gaps regarding MPs pollution in Turkey's freshwater ecosystems, and maintain guidance for the future monitoring studies and establishment of some measures against MPs pollution in SDR.

Materials and Methods

Study Areas and Field Sampling

Sürgü Dam (38°2'6"N, 37°52'46"E) is located in the Eastern Anatolia region of Turkey and is 53 km away from Malatya city center. Sürgü Dam was built on the Sürgü Stream between 1963 and 1969. The dam is 55 m high and 690 m long. There are agricultural lands and some settlements on the shores of the reservoir (Dursun & Gül, 2018).

Surface water and sediment sampling was performed in June 2020, December 2020 and March 2021. Two sampling stations were selected in SDR. Station 1 (St.1) (38°01'18.9"N -37°54'33.3"E) sampling point was located in the lower basin close to the mouth of the Sürgü River, Station 2 (St.2) (38°01'59.0"N-37°53'25.9"E) was located farther, in the upper basin (Figure 1). The average depths of St.1 and St.2 were 7.5 m and 16 m, respectively.

For the surface water sampling, 150 L water was collected with a steel bucket from the stations and this was filtered through 5.000 µm 1.000, 200 and 91 µm pore size steel sieves (Erdoğan, 2020; Meng et al., 2020). The particles accumulating on the 5000 µm filter have been released while the particles collected from the 1000 µm, 200 µm and 91 µm filter were washed in bottles with ultra-pure water and preserved in 4% formaldehyde (Aytan et al., 2020).

Sediment samples were taken with an Ekmangrab (total area = ~0.025 m²) from the sample locations. Surface sediments to 4 cm depth were taken using with stainless-steel spoons and stored in 500 mL jar glass. Then, the jars were covered with aluminum foil and were kept in jar sat -40 °C (Aytan et al., 2020).

Fish sampling was performed in March 2021 with commercial fishing boat sand fishing gear. A total of 107 fish, 62 of which were *Cyprinus carpio* and 45 of which were *Alburnus mossulensis*, were caught in the lake. The fish were euthanized with MS222 (Tricaine-S; 0.25g L^{-1}) (McNeish et al., 2018). The numbers of the collected fish are shown in Table 1.

Laboratory Analysis

Wet peroxide oxidation was used to determine the presence of MPs in surface water samples (Masura et al., 2015). Water samples were transferred to a 200 mL conical flask. After filtering the solution through a 10 µm filter, 30mL hydrogen peroxide (H_2O_2) (30%) was added to the samples. Organic materials were digested with H_2O_2 at 50 °C for 72 in incubator. After this, the mixture was then filtered with 10 µm filter and moved to petri plates to desiccate (Aytan et al., 2020).

MPs were removed from sediment samples the density flotation method (Aytan et al., 2020). The saturated NaCl solution (d: 1.2 g cm^{-3}) was filtered with a 10 µm filter. Sediment samples were tranfered in glass beakers and saturated NaCl solution were added for density separation. These samples were mixed with a steel spoon for a two minutes and waited for 1 hour. This prosedure three times were repeated to ensure all MPs were obtained. The supernatant was filtered with a 10 µm filters. The residues on the filter were washed to glass beakers and, organic particles were digested using 30% H_2O_2 at room temperature for 168 h, then filtrated onto 10 µm filters, and dried in oven. MPs were

Table 1. Biometrical data and number of MPs in the digestive tracts of 2 species from SDR.

| Station | Species | n | Biometrical data of analyzed fish | | | Number of MPs in the digestive tracts | | |
			TL (mm)	TW (gr)	GITW (gr)	FO%	MP/fish for all fish	MP/fish for fish with MPs
St.1	*C. carpio*	20	30.7±2.8	378.6±54.9	13.3 ± 2.3	50	0.8	1.60
	A. mossulensis	33	15.8±1.2	46.1±2.7	1.6 ± 0.2	6.1	0.09	1.50
St.2	*C. carpio*	42	29.7±1.3	384.0±41.6	13.3 ± 2.6	40	0.60	1.41
	A. mossulensis	12	15.9±1.4	45.7±2.6	1.7 ± 0.1	8.3	0.08	1.00

n: The number of individuals, TL: Total length, TW: Total width, and GIT: Weight of the fish,
FO%: Frequency of occurrence of MPs
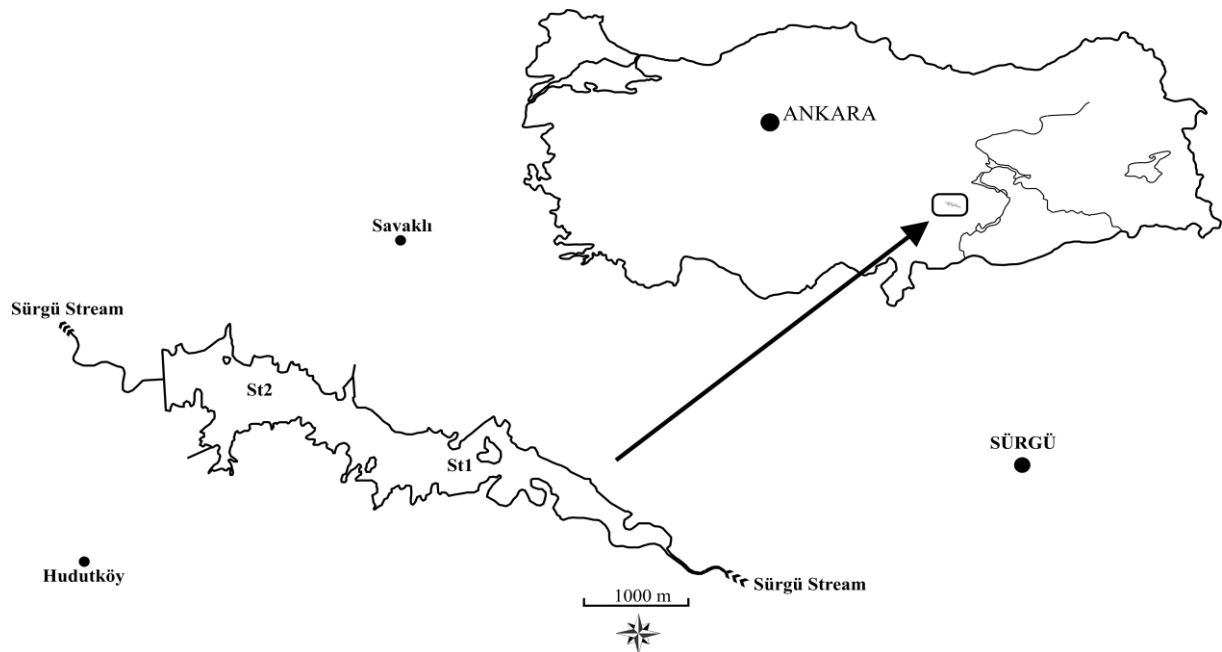
Figure 1. Sampling stations at SDR

measured with a dissecting microscope, using Euromex Image Focus 4.0 software. MPs, defined according to their morphological characterics and physical response properties, were classified according to their type, color, and size (Desforges et al., 2014; Aytan et al., 2020). The concentrations of MPs in the sediment from two stations was calculated by dividing the number of MPs by the cross-section area and was expressed as particles m^{-2} (Xiong et al., 2018).

MPs in fish were determined according to McNeish et al. (2018). The weight and the total length of each individual were measured before dissection (Table 1). The gastrointestinal tract (GIT) from the esophagus to the anus was taken from all individuals, and its weight was measured (Table 1). The GIT was then transferred to a jar filled with H_2O_2 (30%). This solution was added to remove biological material. Samples were kept at 45 °C in an incubator. After removing all organic matter, the samples were filtered with a 10 µm mesh and transferred to petri dishes, and then dried with an oven. MPs were determined per individual fish.

MPs were measured with a dissecting microscope, using Euromex Image Focus 4.0 software. MPs, defined according to their morphological characterics and

physical response properties, were classified according to their type, color, and size (Desforges et al., 2014; Aytan et al., 2020). The numbers of MPs in fish was expressed as particles per individual (Sun et al., 2019).

The chemical characterization of 65 randomly selected particules were identified using Perkin Elmer Spectrum Two FT-IR spectrophotometers in the range 400-4000 cm^{-1}. FT-IR analyzes of particules were compared with FT-IR analyzes of standard plastic structures.

The amount of MP for each fish was shown as the frequency of occurrence of MPs (FO%).

Average rainfall data in Malatya Doğanşehir district by month in 2020-2021 was obtained from the 13th Regional Directorate of Meteorology.

Contamination Control of Microplastics

Various measures were taken to avert contamination through out the analysis and processing of samples. All materials used in analysis and sampling were rinsed with ultrapure water. Immediately after the samples were collected, they were transferred to storage containers and the containers were immediately

capped. Hands and forearms were cleaned before starting the study, and a 100% cotton laboratory coat was worn during analysis. All surfaces and tools used during sampling and analysis were completely cleaned with alcohol. A procedure blank was performed no sample, during the MP analysis and processing in fish. Three petri dishes were placed a long side the stereo microscope through out the analysis. At the end of the analysis, the petri dishes were checked for MP measurements.

Statistical Analysis

Graphpad Prism software (Version 5, USA) was used for statistical analysis of MP concentrations found in fish at different stations. The data were initially tested for normality distributions with Kolmogorov-Smirnov test. The nonparametric Mann-Whitney U test was used

in pairwise comparison because the data did not show normal distribution. The difference between the groups was determined according to the degree of importance at $P<0.05$.

Results

Microplastic Analysis in Surface Water

In this study, MPs were determined at two stations in SDR in three sampling periods. In total, 141 MP particles were identified (54 particles in June 2020, 37 particles in December 2020, and 50 particles in March 2021) in the surface water of SDR. The maximum MP concentration was determined at St.1 (220 par.m^{-3}) in June 2020, and the minimum MP concentration at St.2 (106.7 par.m^{-3}) in December 2020 (Figure 2). The MPs collected from the surface water were classified in to
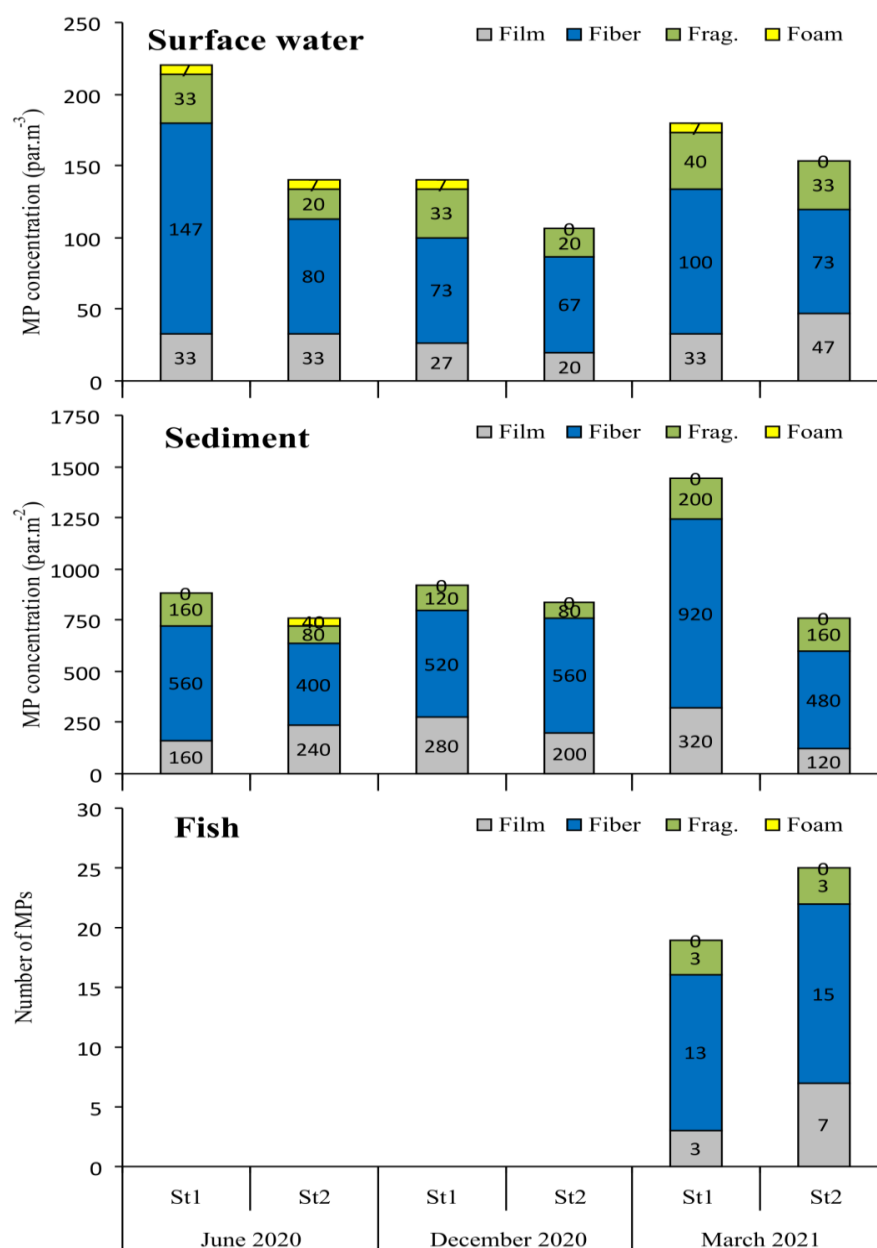
Figure 2. Concentration of MPs in surface water, sediment and fish at the sampling stations

four types: films, fragments, fibers, and foams (Figure 3). The predominant type of MP identified was fiber. In June 2020, fibers were the type of MPs with the highest concentration (62.96%), followed by films (18.52%), fragments (14.81%), and foams (3.70%). In December 2020, fibers were also the type of MP with the highest concentration (56.76%), followed by fragments (21.62%), films (18.92%), and foams (2.70%). Furthermore, in March 2021 fibers were the type of MP with the highest concentration (52%), followed by films (24%), fragments (22%), and foams (2%) (Figure 2).

The results revealed that MPs comprised 9 different colors in the surface water, black being predominant (29.63% in June 2020, 21.62% in December 2020, and 20% in March 2021) (Figure 4).

The MPs collected were classified into <0.2mm, 0.2-1 mm, 1-2 mm and 2–5 mm, as shown in Figure 5. The MPs' size compositions varied from 0.1 to 3.25 mm in June 2020, 0.15 to 4.08 mm in December 2020, and 0.09 to 4.62 mm in March 2021. The sizes of the MPs collected in June and December 2020 were in the range of 1-2 mm (44.4% and 40.5%, respectively). The MPs

collected in March 2021 were in the range of 0.2-1 mm (40.5%). The MPs of 0.2 mm size had the lowest concentrations in all sampling periods.

Microplastic Analysis in Sediment

In total, 140 MPs particles were identified (41 particles in June 2020, 44 particles in December 2020, and 55 particles in March 2021) in sediment.

In sediment, the maximum MP concentration was observed at St.1 in March 2021 (1440 par.m^{-2}), and the minimum at St.2 in June 2020 and in March 2021 (760 par.m^{-2}) (Figure 2). MPs collected in sediment were classified into four types: films, fragments, fibers, and foams (Figure 6). The predominant type of MPs identified was fiber.

In June 2020, fibers had the highest concentration in sediment (58.54%), followed by films (24.39%), fragments (14.63%), and foams (2.44%). In December 2020, fibers were also the type of MPs with the highest concentration (61.36%), followed by films (27.27%), and fragments (11.36%). In March 2021, fibers again had the
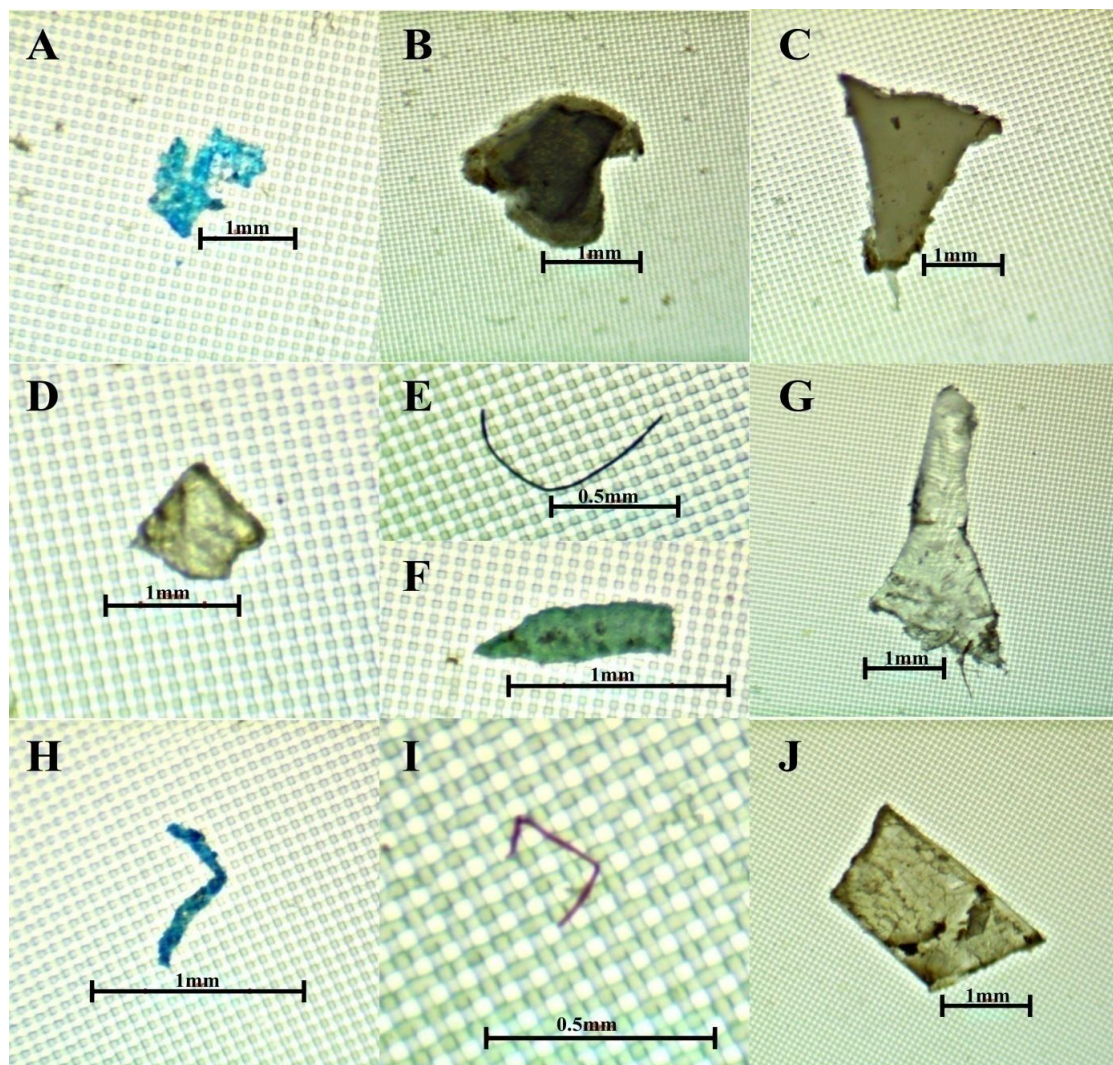
Figure 3. Microscopic images of MPs in surface water: A: Film, (PP), B: Foam, (PS), C-D: Fragment, (PET), E: Fiber, F: Fragment, (PE), G: Film, (PE), H: Film, I: Fiber, J: Fragment (PET)
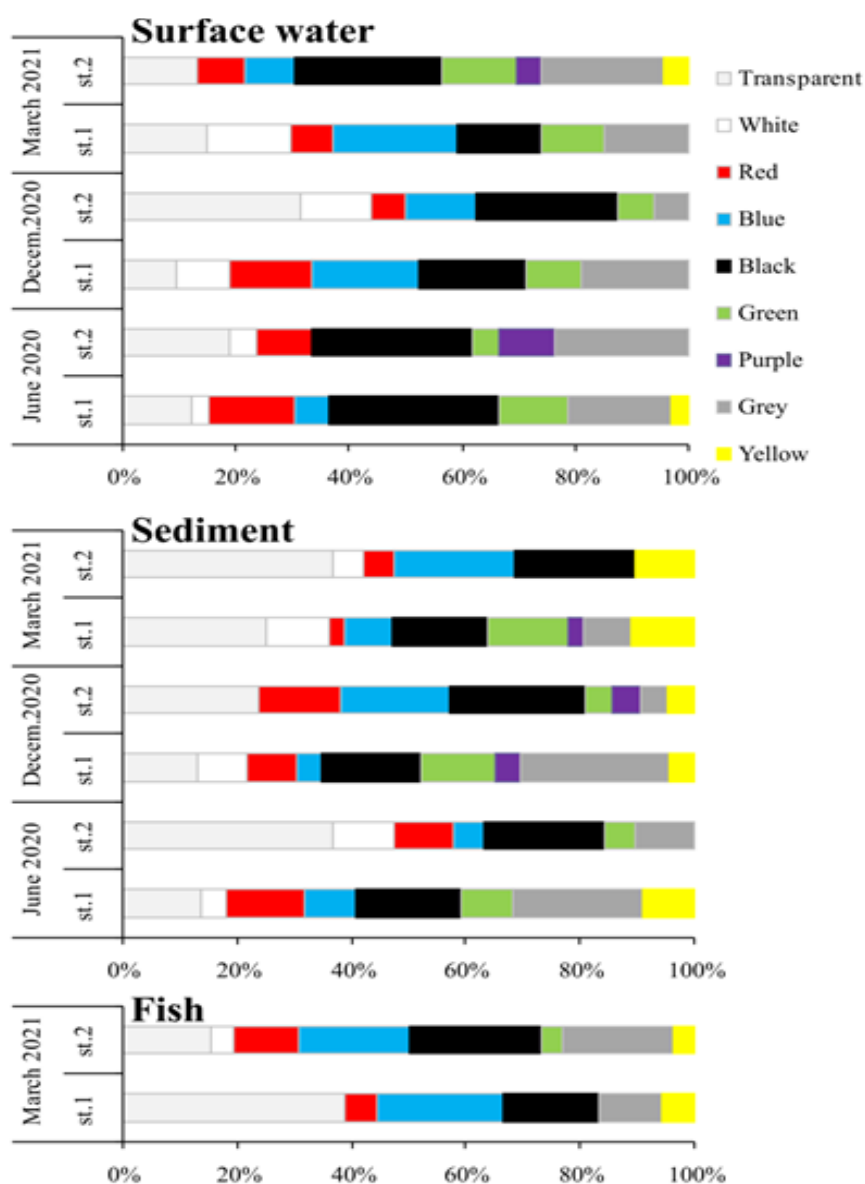
Figure 4. Percentage of colors of MPs in surface water, sediment, and fish

highest concentration (63.63%), followed by films (20.00%), and fragments (16.36%). Foams were not observed in December 2020 and March 2021 (Figure 2).

MPs in sediment samples were classified by color into white, black, blue, transparent, red, yellow, gray, purple, and green; the percentages of each are shown in Figure 4. Transparent (24.4% and 29.1%) and black (19.5% and 18.2%) were the predominant colors in June 2020 and March 2021, respectively. In December 2020, black was the most common (20.5%), followed by transparent (18.2%).

The MPs' size compositions varied from 0.17 to 3.41 mm in June 2020, 0.11 to 3.33 mm in December 2020, and 0.13 to 4.12 mm in March 2021. The MPs collected in December 2020 and March 2021 were in the range of 0.2-1 mm (36.0% and 36.4%) and 1-2 mm (25.0% and 34.5%, respectively). The MPs collected in June 2020 were in the range of 1-2 mm (43.9%) and 0.2-

1 mm (24.4%). The MPs measuring 0.2 mm had the lowest concentrations in all the sampling periods (Figure 5).

Microplastic Analysis in Fish

At least 1 MP was discovered in 27 of the 62 *C. carpio* and 3 of the 45 *A. mossulensis*. In addition, the number of MPs detected in *C. carpio* and *A. mossulensis* samples were 40 and 4, respectively. Calculations of MP data in fish samples and representation of Table 1 were made according to Sun et al., (2020). There were 0.65 MP/fish for all fish (62) and 1.48 MP/fish for fish with MPs (27) in *C. carpio* samples. Furthermore, there were 0.09 MP/fish for all fish (45) and 1.33 MP/fish for fish with MPs (3) in *A. mossulensis* samples. Considering all the fish samples used in this study, the frequency of occurrence (FO%) of MPs for *C. carpio* and *A.*
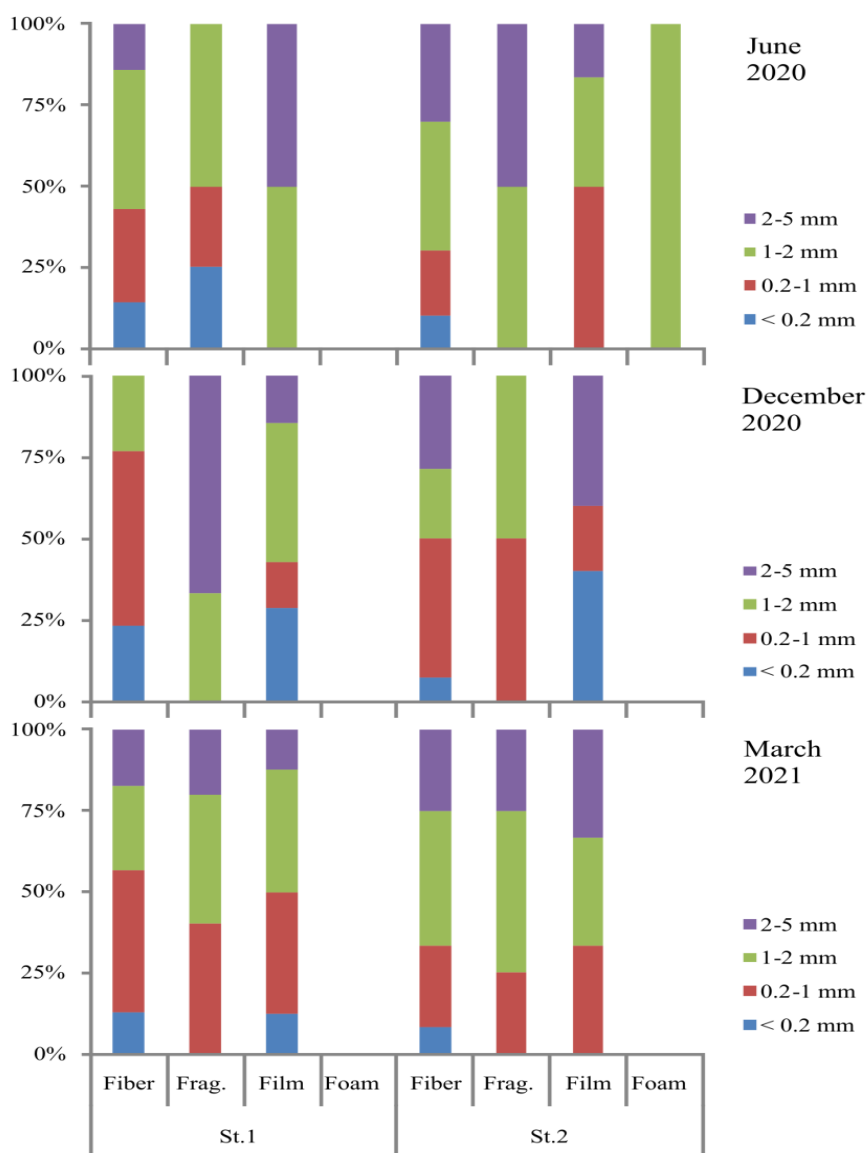
Figure 5. Size composition of MPs in surface water according to sampling stations

mossulensis was calculated as 43.5% and 6.7% (these results were calculated from the data displayed in Table 1). When MP concentrations in fish samples were compared statistically, no difference could be determined between stations.

The MPs obtained from the fish samples were classified into three types: films, fragments, and fibers (Figure 7). The primary types of MPs were fibrils. Foams were not observed in fish samples (Figure 2). MPs ranged from 0.11 to 3.83 mm in length. As shown in Figure 5, MPs measuring 0.2-1 mm (45.5%) predominated in the fish samples. Transparent (25%), blue and black (20%) were the predominant MP colors seen in fish (Figure 4).

Polymer Types of Microplastic

A total of 65 particles were randomly chosen from particules collected from SDR, and their polymer types were determined by FT-IR. Of the these particles 62 (95.4%) were identified as MPs. The remaining particles were non-microplastic. There were polymer matrix composites of identified MPs: Polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), polyethylene (PE), polyvinyl chloride (PVC), polyamide (PA), polybutylene terephthalate (PBT), polymethyl methacrylate (PMMA). PET and PP were the main MP types (29.1% and 19.4% respectively), followed by PE (16.1%), PS (16.1%), PVC (8.1%), PA (4.8%), PBT (4.8%), and PMMA (1.6%).

Discussion

MPs can be found in all freshwater components, including surface water, sediments, and aquatic organisms. Therefore, it is important to observe them in both biotic and abiotic matrices (Meng et al., 2020).

However, various factors, such as intensive agricultural activities in the surrounding area, changes in the water flow of the Sürgü Stream, and fishing and recreational activities, may all cause pollution in SDR. In this study the presence, types, sizes, and colors of MPs

Table 2. Comparison of MP concentration in freshwater studies around the world

Sample type	Study Area	Location	Mean Concentration	Reference
Surface water (par/m^{-3})	Cevdet Dündar Pond	Turkey	233	Erdoğan, 2020
	Küçükçekmece Lagoon	Turkey	33000	Çullu et al., 2021
	Süreyyabey Dam Lake	Turkey	5.25	Tavşanoğlu et al., 2021
	Xianjia Lake	China	3825	Yin et al., 2019
	Danjiangkou Reservoir	China	6081	Lin et al., 2021
	Sürgü Dam Reservoir	Turkey	156.7	
Sediment (par/m^{-2})	Qinghai Lake	China	352.6[a]	Xiong et al., 2018
	Siling Co Lake	China	563	Zhang et al.,2016
	Vembanad Lake	India	252.8	Sruthy & Ramasamy, 2017
	Bolsena Lake	Italy	1922	Fischer et al., 2016
	Chiusi Lake	Italy	2117	Fischer et al., 2016
	Sürgü Dam Reservoir	Turkey	933.3	
Fish (number/per fish)	Van Lake	Turkey	34	Atıcı et al., 2021
	Qinghai Lake	China	5.4	Xiong et al., 2018
	Lijiang River	China	0.6	Zhang et al., 2021
	Gehu Lake	China	10.7	Xu et al., 2021
	Poyang Lake	China	9.27[b]	Yuan et al., 2019
	Sürgü Dam Reservoir	Turkey	0.41	

[a] Calculated from data provided in the research

[b] Calculated from data provided in the supplementary material.
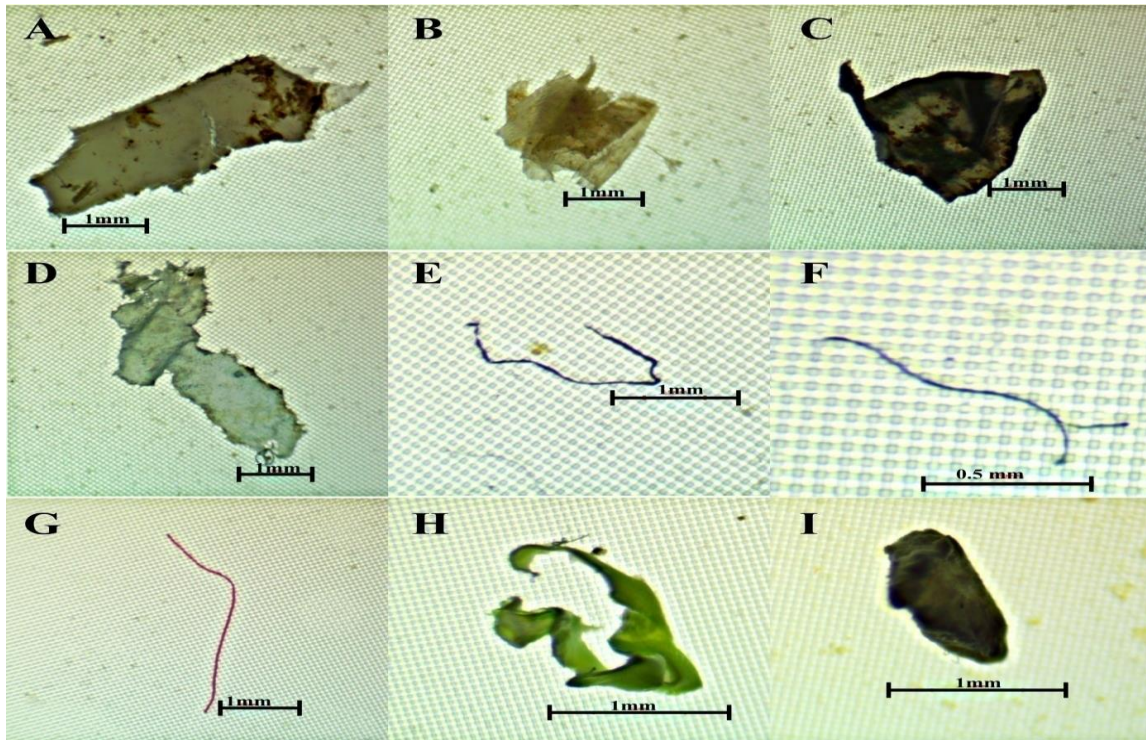
Figure 6. Microscopic images of MPs in sediment: A: Fragment, (PET), B-C: Film, (PE), D: Film, (PP), E: Fiber, (PE), F: Fiber (PP), G: Fiber, H: Film, (PET), I: Fragment, (PA).

were determined for the first time in the surface water, sediment and biota of SDR.

MPs of surface water samples were acquired via the filtration of 150 L of surface water. Meng et al. (2020) have stated that one method by which to sample water is to filter large volumes from a lake. Using this method, we found an MP concentration level of 156,7 par.m^{-3} in SDR with respect to the average microplastic concentration levels in stations and sampling periods. Other research on surface water MP concentrations in the freshwater systems in Turkey have shown that MP concentration levels were 33000 TRJPs/m^3 in Küçükçekmece Lagoon, 233 MPs/m^3 in Cevdet Dündar Pond, and 5.25 MPs/m^3 in Süreyyabey Dam Reservoir, respectively. Comparing the surface water MP concentration levels covered in this study with the data
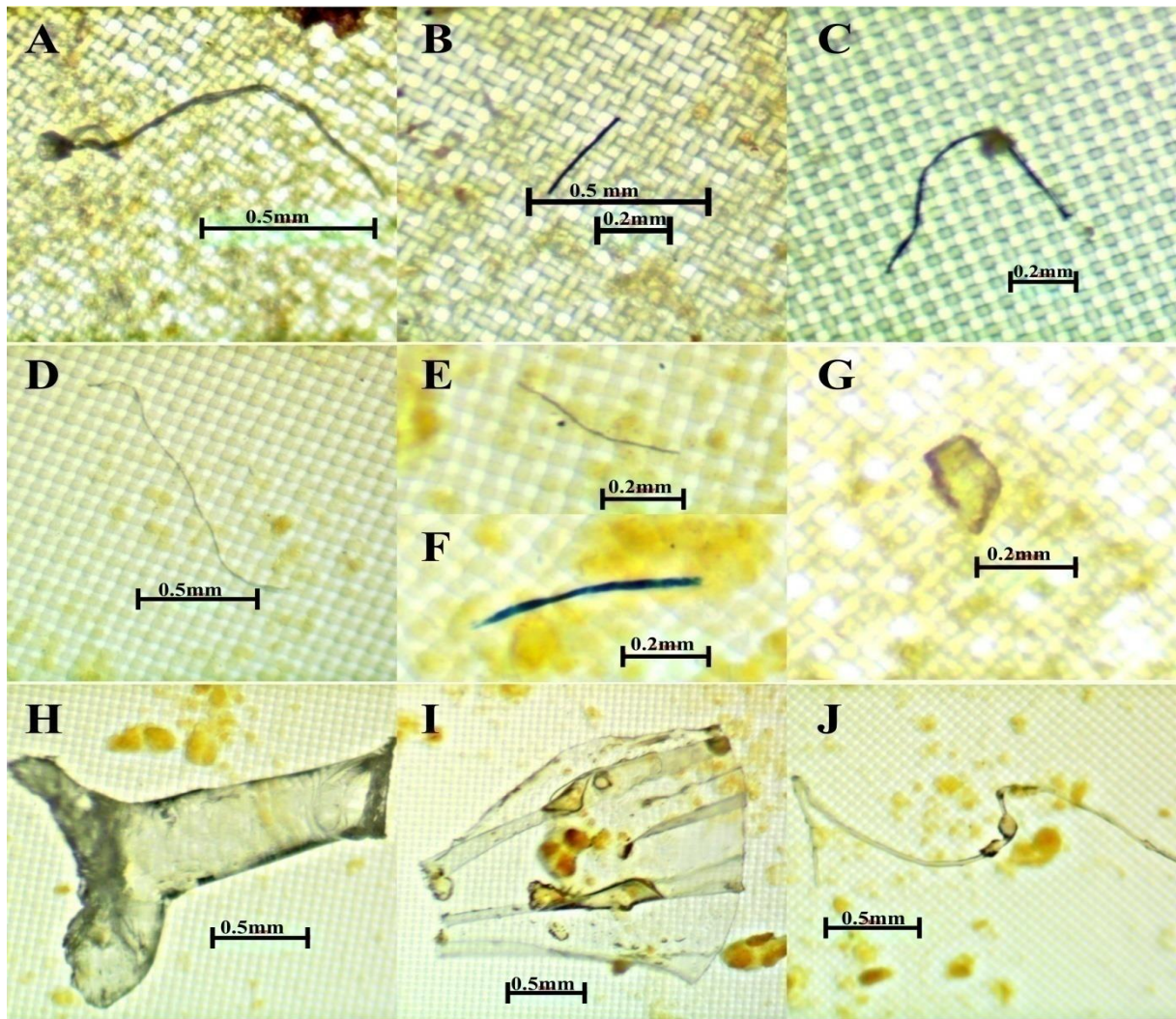
Figure 7. Microscopic images of MPs from fish GIT: A: Film (PP), B: Fiber, C: Fiber, D: Fiber, E: Fiber, F: Film, G: Fragment, (PP), H: Fragment, (PET), I: Film, (PP), J: Film, (PE).

above, it can be seen that the MP concentration in our study is smaller than those of Cevdet Dündar Pond and Küçüçekmece Lagoon yet greater than that of Süreyyabey Dam Reservoir (Erdoğan, 2020; Tavşanoğlu et al., 2021; Çullu et al., 2021). In relation to other research across the world, the MP concentration in SDR is relatively moderate in sediment although it is lower in fish and surface water samples (Table 2).

Fibers are important types of MPs in freshwater ecosystems (Meng et al., 2020). They mostly consist of clothing, textiles and fishing lines (Hu et al., 2020). The fibers in SDR showed higher concentrations than other MP types. Similarly, Erdoğan (2020) has reported that fiber is the predominant type of MP in Cevdet Dündar Pond. Moreover, Hu et al. (2020) have found that fibers predominate in Dongting Lake in China. The fiber pollution in SDR may owe to precipitation, atmospheric transport, aging fishing equipment, and stream flowing into the lake, as reported in the literature (Wang et al., 2021). Films, the type of MP with the second-highest concentration in the lake, are mostly formed by the deterioration of plastic bags, which are misused and

released into the environment uncontrollably (Yuan et al., 2019).

This study has shown that St.1 is more polluted than St.2 in terms of freshwater and sediment MP concentrations. The fact that St.1 was located at a higher point than St.2 in respect to the flow direction of Sürgü Stream could be a reason behind the higher MP concentration levels in St.1 Hu et al. (2020) have also indicated that rivers are an important cause of MPs in lakes. However, the low MP levels in surface waters in both stations was due to scanty rainfall in the months before December. The heavy rainfall in the months preceding June as well as the severe snowfall and melting snow before March indicate that the high MP concentration in both stations could be land-based (Figure 8).

The distribution of MP colors in SDR was found to be similar to other data reported in the Ofanto River in Italy (Campanale et al., 2020). Black and transparent MPs predominated in both studies. MPs derive their color from the plastics in which they originate, but colors can vary depending on photo degradation and the
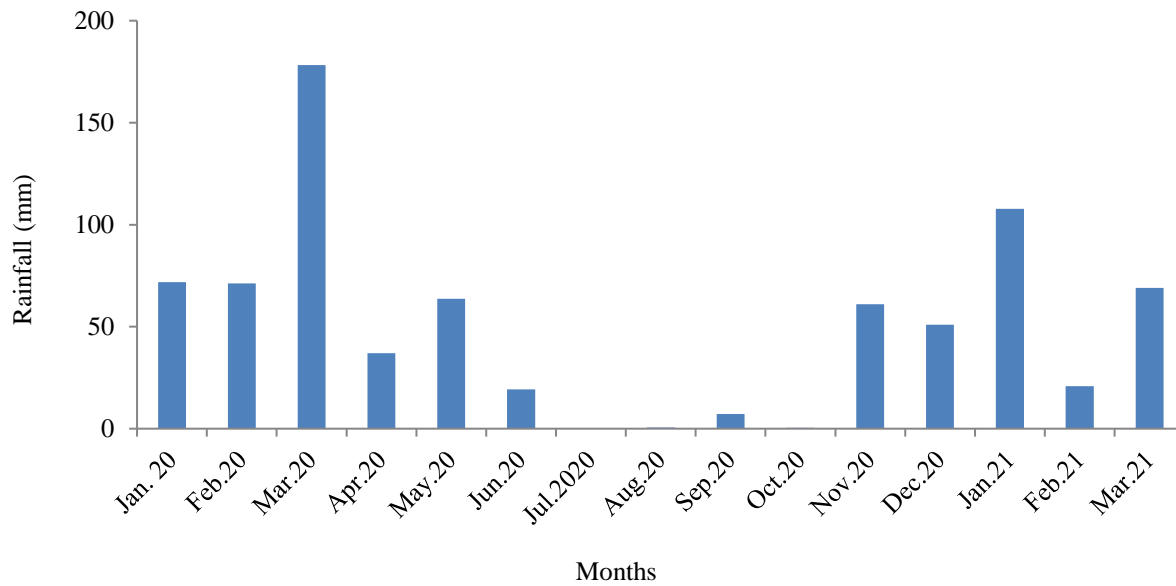
Figure 8. Average rainfall in Malatya Doğanşehir district by month in 2020–2021.

residence time of the plastics in the water (Campanale et al., 2020).

In this study, the 0.2-1 mm and 1-2 mm sizes of MPs showed high concentrations in surface water and sediment in SDR. Similarly, Egassa et al. (2020) reported that the predominant group of MPs measured 0.3-0.9 mm and the smallest 4.0-4.9 mm in Victoria Lake in Africa.

It was important to determined the composition of substances, and identification of ingredient of the MPs was made with FT-IR. PET was a widespread plastic type of collected from SDR, and as a main component of MPs. PET is often used to make plastic bottle, packages and is used as a fiber in the clothing industry. Similar to the results of this study, PET were the dominant polymer type in in surface water of the Manas River Basin, China (Wang et al., 2021). The main sources of PS and PET are thought to be from the surrounding domestic sewage and land origin (Wang et al., 2019).

This study has revealed the concentration, color and size of MPs in two freshwater fish species (*C. carpio* and *A. mossulensis*) in SDR. Higher MP concentrations were determined in *C. carpio* compared to *A. mossulensis*. Several studies have shown that MPs are ingested by fish (Lusher et al., 2016; Xiong et al., 2018; Hanachi et al. 2019). Merga et al. (2020) have similarly reported that benthopelagic (*C. carpio*) fish digest higher concentrations of MPs compared to surface-fed fish. Furthermore, Hanachi et al. (2019) have demonstrated that *C. carpio* can provide an important indicator to explain the presence of MPs in freshwater and their transport between different trophic levels of fresh water ecosystems. In the present study, MPs were detected in 50% of *C. carpio* samples collected from St.1 and 40% of *C. carpio* samples collected from St.2 (Table

1). In addition, MPs measuring 0.2-1 mm and 1-2 mm were detected at higher concentrations compared to other sizes in both fish species. According to this study, MP contamination may adversely affect the aquatic organisms of SDR. Therefore, in order to reduce MP concentrations and their effects in the studied aquatic system, the origin and entry routes of MPs in SDR should be determined.

Conclusions

In this study, the concentration, distribution, color and size of MPs in various components of the SDR ecosystem have been determined. MPs were detected at two sampling stations in three sampling periods. Generally, the concentrations of MPs at St.2 were higher than those at St.1. Fibers were the predominant types of MPs in surface water, sediment and fish samples. Transparent and black were the predominant colour, PET and PP were the common polymer types in SDR. The main sources of MPs in SDR are thought to be daily used plastic products, the wastewater discharge, the Sürgü Stream, and the atmosphereIt is especially important to control MP contamination in the rivers that flow in to the lake. Moreover, these freshwater sources should be protected through measures such as appropriate waste management, the establishment of a wastewater treatment facility, and the recycling of plastic materials.

Ethical Statement

All fish samples were collected according to the animal protocols certified by Inonu University Research Committee (2020/13-2).

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