Research Paper

Municipal Wastewater Efluent as a Source of Microplastic Pollution Crisis in the Qarasu River Water, Ardabil Province, Iran

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ABSTRACT

Background: Today, the environmental crisis of pollution of water resources with municipal and industrial wastewater containing microplastic (MP) pollutants has become a global problem. Likewise, in Ardabil Province, Iran, municipal wastewater is discharged into the water of the River Qarasu and is the primary source of the MP pollution crisis.

Materials and Methods: In this descriptive cross-sectional study, the samples were taken from 5 stations in the Qarasu (Karkarq, Sarband, Anzab Sofla, Dolatabad, and Samian villages) under standard methods in 2020. The sample analysis and MP separation method were performed based on the density difference and digestion methodology. It was completed using stereo microscopy with a digital camera, fourier transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM).

Results: Studies show that WWTPs (Wastewater Treatment Plants) are the primary sources of releasing MPs into the environment. In addition to threats to water resources, MPs are consumed and digested by aquatic organisms. As a result, MPs can affect human health, the environment, and the river's living organisms.

Conclusion: The study results showed that MPs had been introduced into the River Qarasu ecosystem. MPs can have dangerous effects on the environment and living organisms and lead to an environmental crisis of water resources. Therefore, continuous river pollution monitoring is vital in the environmental crisis.

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1. Introduction

Today, plastics and plastic products are so widespread that the idea of living without them is impossible [1-4]. The mass production of plastics in 1950 and increasing public confidence in plastics and their numerous applications have led to an environmental crisis [3]. The world without plastics (synthetic polymers) seems unimaginable, and the rapid growth of plastic production is extraordinary. Also, because of the durability, strength, and low price of plastics and their numerous applications, it has been produced more than other manufactured materials. Global statistics on the mass production of plastics show that 8300 million tons of new plastics have been produced so far, of which about 6300 million tons were converted into waste in 2015. About 9% of the plastic waste has been recycled, 12% incinerated and 79% accumulated in landfills or the environment [4]. If plastic waste generation and mismanagement continue, by 2050, microplastic (MP) waste will increase to about 33 million tons and be dumped in landfills or the environment [5-9]. A municipal or industrial wastewater treatment plant (WWTP) is an essential source for MPs to enter the aquatic environment [10]. The environmental crisis of water resources pollution in recent years has drawn the attention of many researchers and environmental activists [11-13]. Many water crises and their environmental outcomes, the destruction of water resources, and their pollution have resulted from non-environmental activities [14, 15]. The "hidden MPs crisis" has recently threatened water resources, aquatic organisms, and human health. Therefore, water consumption by humans and living organisms should be healthy, sufficient, and free of pollution [7, 12, 16]. Also, surface water, river, and other water resources pollution will make this issue an increasingly critical one in the future [16-18].

Plastic pollution has spread and been identified throughout the aquatic ecosystem due to its buoyancy and durability and the uptake and transport of toxins worldwide and in various parts of the ecosystem, including seawater, river water, sediments, and aquatic organisms around the world [17, 19-26]. MPs are less than 5 mm in size. Constituent environmental resources are divided into primary and secondary types [17, 25, 27]. Primary MPs can be found in products such as cosmetics, plastic pellets used in industry, and plastic fibers used in clothing (such as nylon) [17, 28-30]. Therefore, scratches or abrasions when washing clothes with synthetic fibers may release MPs. They are also present in cosmetics, toothpaste, synthetic fibers, and resins [31-39].

Secondary MPs result from the decomposition of larger plastics into smaller parts. Larger plastics turn into smaller plastics under conditions such as the sun's ultraviolet radiation, wind abrasion, and so on [31, 33-35]. Plastics are non-degradable and are found as emerging pollutants in marine environments worldwide, so MPs can enter the environment and aquatic life and enter the human body through the food web and threaten their health [28, 36, 37]. In addition, MPs are also present in food packaging and may enter food and affect the health of humans, living organisms, and plants [40-43]. Although MPs have been identified in the environment, there are insufficient studies on their potential and actual risks [28, 38, 44, 45]. MP debris ingested by aquatic organisms can lead to intestinal obstruction. Of course, irregular shapes and sharp edges can penetrate and damage the gastrointestinal tract. These effects can reduce food intake and ultimately lead to starvation and death of aquatic organisms [9, 32, 39].

The catchment area of the River Qarasu in Ardabil Province, Iran, is located in the geographical range of 47° 44′ E to 48° 42′ E and 45° 37′ N to 38° 36′ N. This river originates from the heights of Sabalan and Baghro mountains and, after joining the rivers and canals of Ardabil plain, leaves it at the Samian hydrometric station. This river is permanent and, with a length of 255 km, is one of the sub-branches of the River Aras from the Caspian Sea catchment area of about 4100 km^2.

This study investigated the water crisis and its environmental outcomes in the River Qarasu of Ardabil Province. The WWTPs are essential in releasing MPs into river water resources following the environmental crisis. Therefore, the identification of MPs in the aquatic ecosystem, which is the region's most important source of agricultural water supply, is of great importance in controlling pollution and the environmental crisis of river water resources.

2. Materials and Methods

This research is a descriptive cross-sectional study where MP contamination in the water of the River Qarasu was studied. In this study, 5 stations were determined for sampling. In each station, 3 samples, a total of 15, were taken at a distance of 100m. Sampling points were determined based on the discharge location of the Ardabil WWTPs before and after the discharge (Figure 1). The specifications of sampling stations are presented in Table 1.

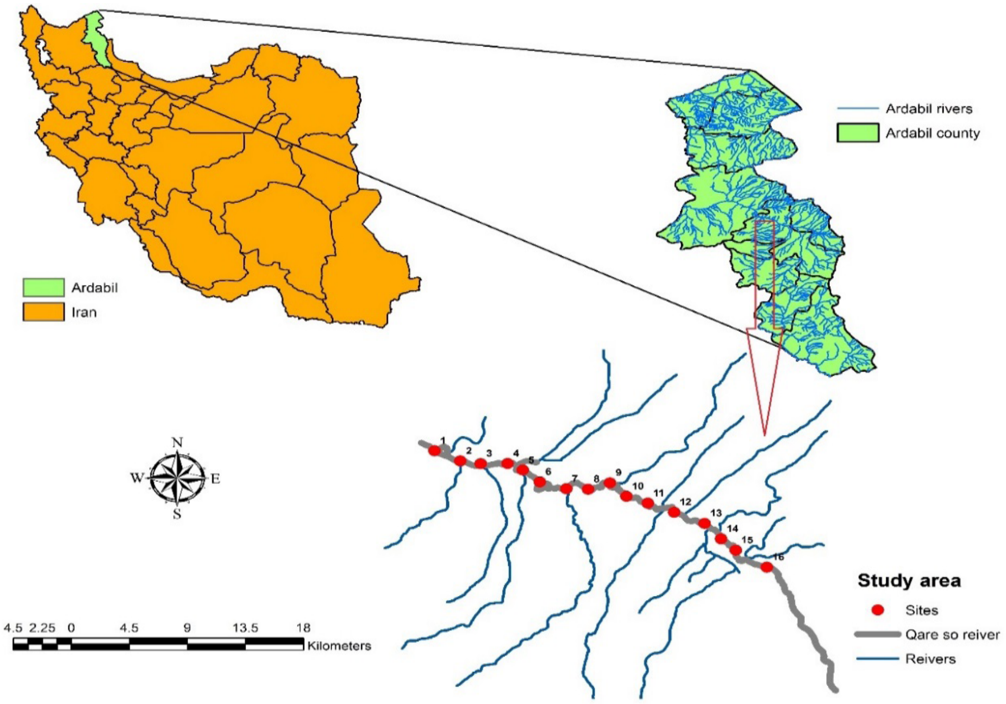


Figure 1. The sampling stations from the river Qarasu in the effluent discharge area of Ardabil wastewater treatment plants

Samples from each station were randomly mixed using a multi-point method [2, 40]. Under standard protocols for sampling MPs from the environment, sampling points were selected as scattered as possible [40]. All river water samples of this study were taken in 2020, and water samples were transferred from a depth of 0-20 cm and in the amount of 20 liters to sealed containers (previously, the containers were washed twice with distilled water) [40-42]. The samples were immediately transferred to the laboratory in less than one hour and stored in the laboratory at 4°C [40, 43].

The density separation methodology was chosen as the experimental method for this study. MPs were detected using the SMI methodology (a compact extraction unit that can easily extract the MPs in the sample in one step and quickly to prevent secondary contamination of the sample). It is necessary to transfer the water sample to the device to identify and count MP particles. Then 30% hydrogen peroxide solution was added to digest the organic matter, and the solution was mixed with a magnetic stirrer.

Detection by light microscopy

Optical microscopes were used to analyze and identify the color and shape of MPs as a simple and fast technique.

Table 1. Coordinates of the study area Qarasu, Ardabil

Sampling Location	Longitude	Latitude
Karkarq	366108/38 N	''354259/48E
Sarband	366426/38 N	''382838/48E
Anzab Sofla	364927/38 N	''349299/48E
Dolat Abad	364051/38 N	''315029 /48E
Samian	380811/38 N	''246078/48E

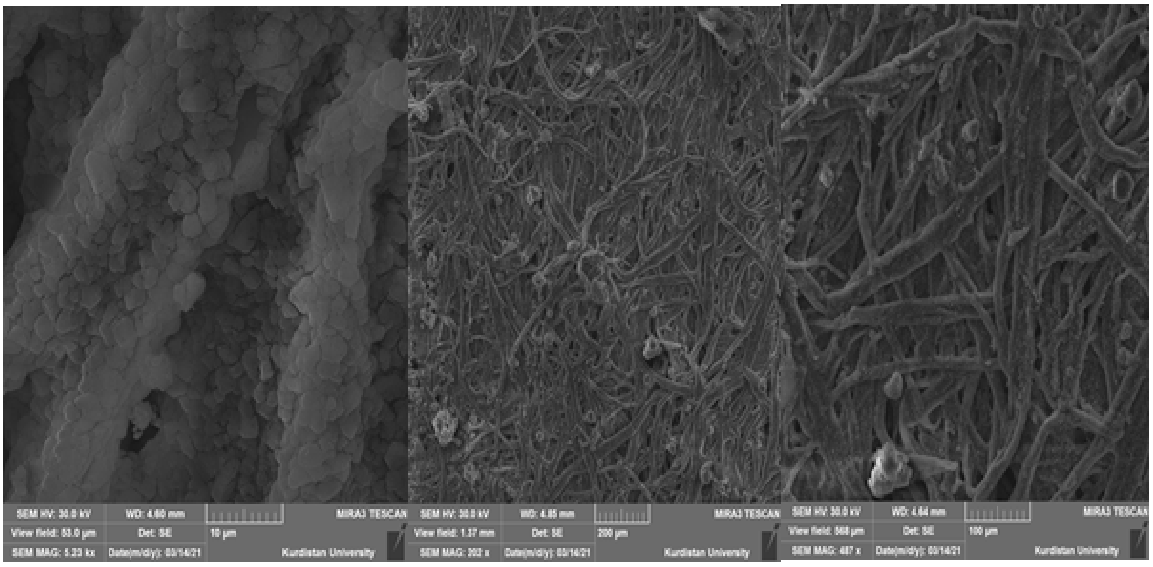


Figure 2. Microplastics identified in the water of river Qarasu, Ardabil using scanning electron microscopy

Scanning electron microscopy (SEM)

Scanning electron microscopy (SEM) was used to test and analyze the morphology of MPs, identify the compounds and present flawless and high magnification images (Figure 2).

Fourier transform infrared spectroscopy (FTIR)

In this study, two samples, including water and sediments, were collected from the Qarasu to investigate the MPs in water sources. Preparation of samples and extraction of MPs by considering optimized methods and suitable for analysis process was analyzed by fourier transform infrared spectroscopy (FTIR). Accumulating MPs in Qarasu water sources and their harmful impacts on human life and environmental crises have not been accurately identified due to the lack of standard protocols (Figure 3).

3. Results

The environmental crisis of aquatic ecosystems due to MP contamination is plastic waste that can have far-

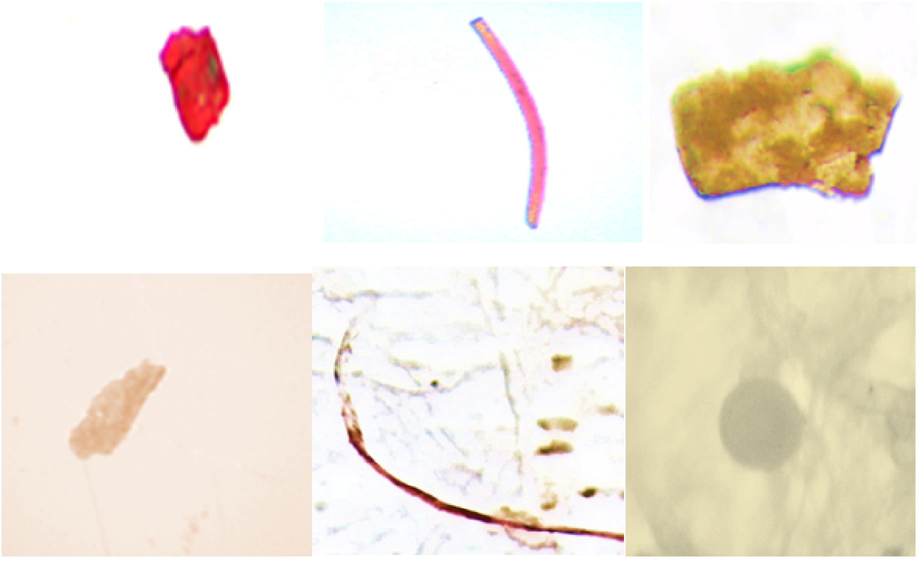


Figure 3. Microplastics detected in the Qarasu, using a stereo microscope

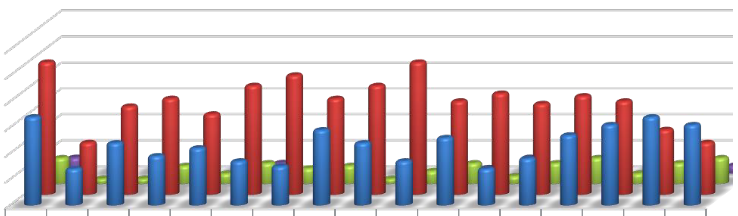
Table 2. Comparison of microplastics in Ardebil and other parts of the world

Country	Place	MP Type	Sample	Sources
Romania	River and sea	More than 90% fiber, 3% fragment	Sediment	[19]
China	Sea and river	Fiber 14%, Fragment 2.8%, Film 4.6%, Granule 74.6%	Beach sediment	[2]
Germany	River	Fiber 21.5%, fragment 34.2%, film 9.1%, granule 35.5%	Water and sediment	[49]
Germany	River	Fiber 77%, fragment 18%	Sediment	[20]
China	River	Piece 72%, foam 24%	Water and sediment	[51]
Oman	Sea	Fiber 32.5%, Fragment 45%, Film 22.5%	Beach sediment	[52]
China	Sea and river	Fiber 53.9%, fragment 38.3%	Sediment	[1]
China	Sea and river	Fiber 46.7%, film 52.2%	Sediment	[53]
Poland	River	Fiber 93%	Water and sediment	[44]
China	Sea	Fragment 57.4%, fiber 33.33%	Water	[54]
Canada	Lake	Fiber 75%, Fragment 22%	Water and sediment	[55]
China	River	Fragment 47.9%, fiber 63.4%	Water	[50]
Iran	River	Fiber 52.8%, fragment 32%, film 4.8%, granules 10%	Sediment	this study
Iran	River	Fiber 53%, fragment 33.8%, film 4.2%, granules 9%	Water	this study

reaching environmental and economic impacts on the river and marine environment. MPs are emerging pollutants that have been discussed and researched worldwide. The study results show that MP pollutants enter the Qarasu directly through the effluent of treatment plants [28].

The results of this study show the presence of MPs in the water of the Qarasu in Ardabil. The MPs found were mainly fiber and fragments, consistent with other studies in other parts of the world. Numerous studies have shown the uptake and transfer of other pollutants to MPs from the aquatic environment and then their transfer to organisms (Table 2).

Different types of MPs such as fiber, fragment, granule, and film were observed in the water of the Qarasu. Among them, fibers had the highest concentration with an average of 53%, followed by fragments with 33.8%, granules with 9%, and films with 4.2%. Their frequen-



	max	min	Samian (C)	Samian (B)	Samian (A)	Dolatabad (C)	Dolatabad (B)	Dolatabad (A)	Anzab (C)	Anzab (B)	Anzab (A)	Sarband (C)	Sarband (B)	Sarband (A)	Karkaraq(C)	Karkaraq(B)	Karkaraq (A)
fragment	34	14	24	19	22	17	15	29	24	17	26	14	18	27	31	34	31
fiber	51	20	34	37	31	42	46	37	42	51	36	39	35	38	36	25	20
granule	10	2	2	7	4	8	6	7	2	5	8	3	8	10	4	8	10
filme	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 4. Identified microplastics in the Qarasu in Ardabil in the studied stations

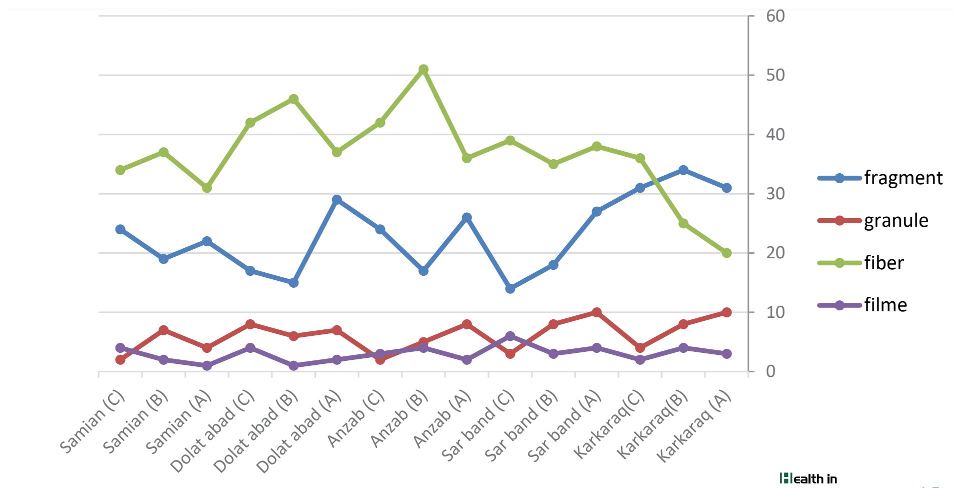


Figure 5. Microplastic forms of the Qarasu identified in the studied stations

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cies in the studied stations of the Qarasu are shown in Figures 4 and 5.

In this study, microscopic examination of MPs showed the predominance of fiber and fragments in the Qarasu. The most important source of dominant MPs entering the river is from Ardabil industrial and WWTPs.

The results showed that the MPs identified in all the studied stations had different colors, including white, brown, blue, black, red, yellow, green, and clear. The color variation of the identified MPs is due to the arrival of the effluent of the Ardabil City treatment plant and the wastewater of the industrial town, which contains MPs obtained from washing and sanitary ware (Figure 6).

The predominant color of the MPs found in the Qarasu was white/brown and blue/black. The frequencies of colors were white 45%, brown 13%, blue 13%, black 7, yellow 7%, clear 2%, red 3%, and green 3%. Given that most manufactured plastics are white, blue, and black, it is expected to see such results that the mentioned colors are predominant (Figure 6). In general, the diversity of colors indicates different sources of MPs released in the environment [44]. Colored MPs, especially in river water, are potential hazards to river organisms, as aquatic animals and birds may consume tiny, colored MPs, endangering their health [45, 46].

As shown in Figure 7, the highest frequency (87%) of MPs is related to the particle size of 100-5000 µm, and the size of MP particles less than 100 µm is 11%, and the particle size above 5000 µm is about 2% (Figure 7).

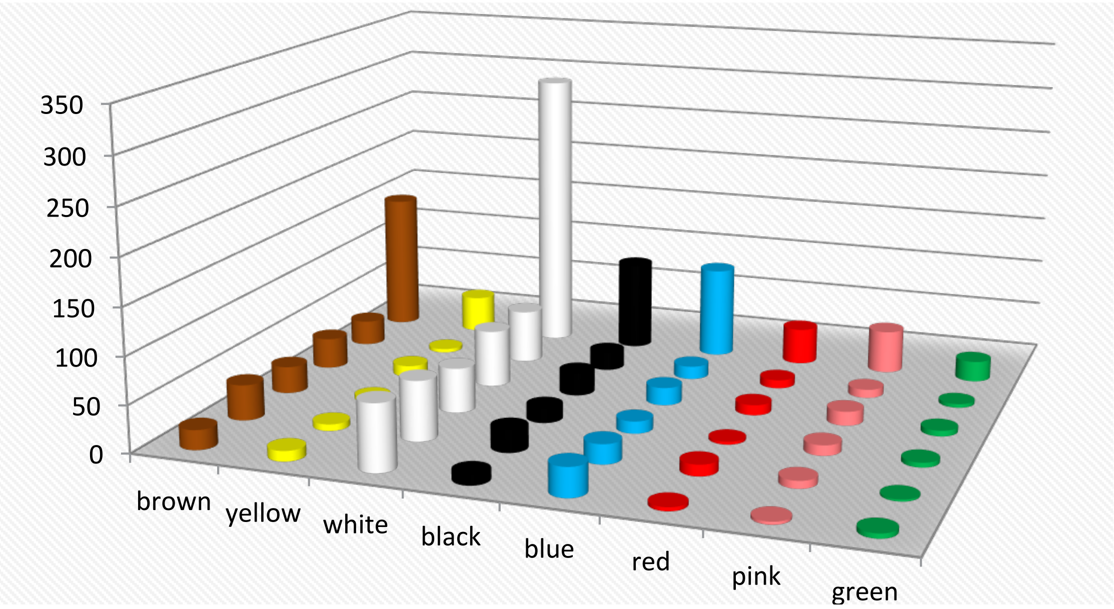

Figure 6. Microplastic colors in the studied stations in the Qarasu river

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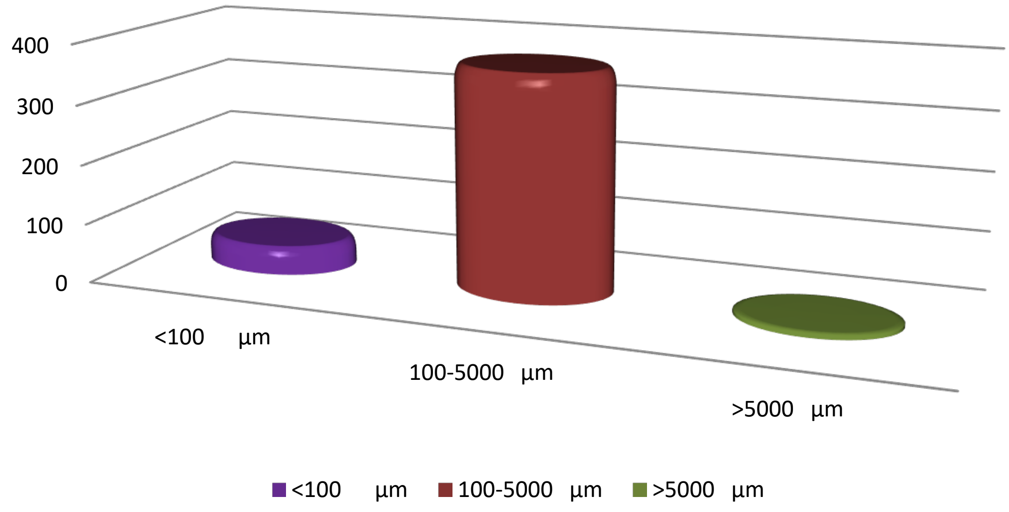

Figure 7. Percentage of microplastic size in the studied stations of the Qarasu

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This study's predominant particle sizes of MPs are 100-5000 µm. These MPs can be transported in various ways, including radionuclides, pesticides, polycyclic aromatic hydrocarbons, organic pollutants, and heavy and environmentally stable metals [47].

The results showed that MPs smaller than 100 µm were 11%, 100-5000 µm 87%, and above 5000 µm about 2%. This size reduction is mainly for two reasons. First, the river water is widely mixed with the effluent of the Ardabil WWTPs, which has led to an increase in MPs below 5000 µm of the Qarasu. Second, plastic products in the environment are subject to tear and fragmentation under the influence of ultraviolet radiation, mechanical factors due to wind flow performance, environmental conditions, and biological activity through biofilm formation [2, 48]. The results showed that most MPs were 0.01 to 5 mm large in the Qarasu.

4. Discussion

This study's results show that MP particles are present in all stations studied, indicating extensive pollution of MPs in the water environment of the River Qarasu. According to Scherer C, et al. study [49], in the River Rhine in Germany, the identified MPs were about 21.5% fiber, 34.2% fragment, 35.5% granule, and 9.1% film, showing that the concentration of MP and fibrous fibers was higher than the Qarasu of Ardabil. Based on the Dahe et al. study, which examined the pollution of MPs in the surface waters of the River Yangtze, China, MPs of fiber type with an average of 63.4% pollution and fragment with an average of 47.9% were present in the river water [50], showing a concentration almost similar to the Qarasu in Ardabil. The results of this study were compared with studies in other regions. The concentration of MPs in the rivers of Canada, China, Oman, and Germany is predominantly the particles like the River Qarasu in Ardabil, and the concentration of MPs in Romanian and Polish rivers is higher than those in the present study. Most of the MPs found in other research studies have the predominant color of white and clear/black/blue. The color of MP particles, especially in river waters, is a potential hazard to river organisms, as aquatic animals and birds may consume tiny, colored MPs, endangering their health [45, 46].

The study results showed that the source of environmental pollution of the River Qarasu in Ardabil through the entry of WWTPs and the industrial town could have adverse effects on the river ecosystem and cause an environmental crisis in the river. The study results show that sewage has a substantial and decisive role in the pollution of this river. River water pollution will become an environmental crisis in the future.

5. Conclusion

Water scarcity will be one of the major environmental crises of the 21st century. Studies show that the water quality of the Qarasu in Ardabil Province was not good. Due to the limited water resources of the province and the intensification of the needs of the agricultural and industrial sectors, the water supply suitable for various uses is one of the leading environmental crises for sustainable development. In the present study, according to the results obtained, the Qarasu in the study subject is facing a severe challenge of environmental crisis, and in practice, "there is a crisis in it". However, in future research, it is necessary to study the environmental pollution characteristics of MPs in this river at different levels of the food chain and to determine the risk assessment of human health and the river water ecosystem.

Ethical Considerations

Compliance with ethical guidelines

There were no need for ethical considerations in conducting this study.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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