



# Microplastic pollution in sediments in the urban section of the Qara Su River, Iran

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## Abstract

Microplastic pollution is an emerging threat to marine environments with potential environmental, social, economic, and health consequences and has become a major global environmental issue. The objective of the present study was to evaluate microplastic contamination in the ecosystem of the Qara Su River in Ardabil, Iran. Fifteen sampling sites along the Qara Su River in the Ardabil urban area were selected to collect sediment samples. The abundance and morphological characteristics of microplastics were determined by counting using a digital stereomicroscope. Micro-Fourier transform-infrared spectroscopy ( $\mu$ -FTIR) analysis was used to identify polymer type of the microplastics. In this study, the frequency and distribution of microplastics (< 5 mm) in the sediment of Qara Su River were investigated as one of the sources containing microplastics. Sediment samples were collected from five different sites (Karkarq, Sar band, Anzab Sulfa, Dolat abad, and Samian) from September to March 2020. For microplastic examination in sediment, the amount (approximately 1000 g of fresh sediment from each site) was sampled from 15 sites. Fiber microplastics (53%) and fragments (33%) microplastics were predominant. It has shown the abundance and heterogeneity of space. In this study, the highest amount of microplastics detected in sediment samples was related to the size of less than 5000  $\mu$ m (92%). The frequency of microplastics below 5000  $\mu$ m in sediment was attributed to the low capacity of existing processes in Ardabil wastewater treatment plant. The abundance of microplastics shows significant differences between sampling sites. The Qara Su River along the city of Ardabil, like many other rivers, is contaminated with microplastics. This study was the first study conducted for evaluation of the sediment environment in terms of the microplastic pollution of Qara Su River in Ardabil. Considering the amount of microplastics in sediments, further research is required to estimate the amount of microplastics released by Ardabil wastewater treatment plants and industrial town wastewater, and other possible sources of emission and to evaluate their contribution to microplastic pollution in water, sediment, and soil. This study provided a framework for future studies of microplastics pollution in the sediment of urban areas around the Qara Su River in Iran.

**Keywords** Microplastic pollution · Sediment · Microplastic analysis · Qara Su River · Ardabil

## Introduction

With increasing demand, many reservoir dams have been built on rivers to supply water for domestic and drinking, irrigation and agricultural needs (Samarghandi et al. 2017; Winton et al. 2019). Dam reservoirs, with the entry of river water, can be hotspots for microplastic contamination and accumulate on the shores, surface water, and subsurface sediments. Sediments are considered to be the main and integral part of water systems from an ecological point of view and have been recognized as a place for sedimentation of a wide range of pollutants, such as microplastics (Padedda et al. 2017). Plastics is a general term used to refer to households of organic polymers derived from petroleum resources. The

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main sources for the entry of plastics into aquatic environments, in addition to the waste generated by the residents, are wastewater treatment systems, fibers from washing fabrics and runoff, roads, fishing and marine activities, including marine activities (Zhang et al. 2015). The most important components of wastewater are suspended solids, biodegradable organic matter and pathogens (Dargahi et al. 2021; Jeddi et al. 2022; Karami et al. 2021; Sharafi et al. 2016). The highest percentage of suspended solids are mainly organic matter (Dargahi et al. 2017). A high percentage of organic compounds in wastewater are readily biodegradable, including carbohydrates, amino acids, peptides, proteins, volatile acids, and esters (Almasi et al. 2021; Dargahi et al. 2022; Shokoohi et al. 2017b). The human body wastes, food waste, paper, fabric and biological cells constitute the main mass of suspended solids in wastewater (Almasi et al. 2018; Azizi et al. 2021). These wastewater compounds can enter surface waters and pollute various surface waters such as the rivers, dams, lakes, etc. (Shokoohi et al. 2017a; Soltanian et al. 2015).

Microplastics are on the rise as an emerging pollutant in aquatic ecosystems that have affected the environment for many years (Lam et al. 2022). Rivers, seas, and oceans have been affected by microplastics environmental pollution and have been a source of environmental concern for decades (Dey et al. 2021; Fan et al. 2021a). Today, the use of plastics and plastic products is so widespread that the idea of life without them may not be understood. Their cheapness, availability, and lack of moisture absorption make them excellent packaging materials. Plastics, as a type of synthetic polymeric material with high chemical stability and strong elasticity, are widely used in the packaging, construction, textile, pharmaceutical, agricultural, and electronics industries. Global plastic production has increased exponentially since the 1950s, and in recent years has raised global concerns about improper plastic disposal and the widespread distribution of plastic waste in the environment. For example, as packaging or building materials or clothing, and has become an important part of our waste (Dey et al. 2021; Naji et al. 2019). The production and development of thousands of new plastic products accelerated after World War II and transformed the new era in such a way that life without plastics is now unthinkable for humans (Schröder et al. 2021b; Yogalakshmi and Singh 2020).

Disposable plastic products and packaging contain about 50% of all produced plastics. Plastic production has increased from 1.5 million tons in 1950–359 million meters in 2018. Plastic products seem to be a serious issue for the environment and the world economy. In most cases, they are left in nature and never placed in recycling centers or landfills (Lahijan zadeh et al. 2020; Naji et al. 2018; Pan et al. 2021). After the introduction of larger plastic particles into the environment, these materials are transformed into

microplastics (smaller than 5 mm) through chemical and physical mechanisms, which differ in size, color, and shape distribution. Although plastics have stable structures and chemical properties, large plastics break down into smaller pieces when exposed to waves, weathering, and ultraviolet light. Research have shown that microplastics can be transmitted to humans through the food chain in the aquatic ecosystem, causing a series of toxic effects on human health. Plastic debris can be present in any size or shape, but microplastics are particles smaller than 5 mm (Fan et al. 2021a; Gong and Xie 2020; Lusher et al. 2020). Microplastics are classified into two categories, primary and secondary. Primary microplastics are plastic materials used in the production of cosmetics, drugs, and industrial equipment, and secondary microplastics are formed from the crushing of larger plastics. Currently, microplastics are one of the most important threats to the environment. These pollutants are present in all water ecosystems of rivers, seas, and oceans (Crew et al. 2020; Fan et al. 2021a; Liu et al. 2021; Razeghi et al. 2021).

Since some studies have shown that microplastics can be transported in the river through the food chain, they cause a series of toxic effects on living organisms. Pollution of microplastics in the environment has attracted more attention of researchers in recent years (Carlsson et al. 2021; Schröder et al. 2021b; Wagner and Lambert 2018). Microplastics, when released into the ecosystem, pose a potential threat to human health and the environment. Recently, microplastics have been widely identified in oceans, rivers, lakes, and sediments (Cincinelli et al. 2021; Galgani et al. 2021).

If the current trend of production and waste management continues by 2050, the amount of microplastics waste will increase to about 12,000 million tons and will be accumulated in landfills or the environment (Dahl et al. 2021; Huang et al. 2021). At current growth rates, plastic production will double over the next 20 years. Currently, global production and consumption of plastics are increasing rapidly with the proliferation of synthetic polymers. Because plastic degradation processes are long and therefore microplastics (MPs) potentially remain in the environment for long periods of time, further increase in plastic waste and the resulting social and environmental problems have caused widespread concern (Huang et al. 2021; Pham et al. 2021; Thomas et al. 2020; Zhang et al. 2020; Ziajahromi et al. 2021).

Considering that no study has been done in the field of microplastics in surface waters of Ardabil province, for this purpose, Qara Su River (one of the most important rivers in Ardabil province) has been selected as a pilot and various microplastics in this the river was surveyed. Qara Su River is the most important and strategic in supplying water for agriculture in the region. However, the development of upstream industrial estates, the entry of Ardabil sewage into the river

and agricultural activities, dumping of garbage along the river, etc., have all been the reasons for microplastic pollution in the study area. Therefore, the reduction of river discharge along its route due to increasing water abstraction, on the one hand, and the discharge of urban, industrial, and agricultural effluents, on the other hand, have endangered the quality of the river. Therefore, this study was performed to evaluate the microplastic contamination of the Qara Su River.

## Materials and methods

### Study area and sampling sites

Ardabil province, with an area of about 17,800 square kilometers, constitutes about 1.1% of the total area of Iran. It has about 283 km of border with the Republic of Azerbaijan from the north and leads to Gilan province from the east, East Azerbaijan province from the west and Zanjan province from the south. The catchment area of Qara Su River in Ardabil province is located in the geographical range of  $47^{\circ}$  E  $44^{\circ}$  E  $42^{\circ}$  E and  $45^{\circ}$  N  $45^{\circ}$  N  $37^{\circ}$  N  $36^{\circ}$  N. It is the most important and largest river in Ardabil province. This river originates from the Sabalan and Baghro mountains, and after joining the rivers and canals of Ardabil plain, it leaves Ardabil plain at Samian hydrometric station. This river is permanent, with a length of 255 km, which is one of the sub-branches of Aras River from the Caspian Sea catchment area and its catchment area is about 4100 square kilometers. Qara Su River in the study area is of special economic and social importance in terms of construction of Yamchi and Sabalan dams to supply drinking water and agriculture in Ardabil city upstream and Meshginshahr region downstream, respectively. This river is exposed to pollution due to the existence of three urban centers of Nir, Sarein, and Ardabil and rural centers with large populations and agricultural lands and the establishment of production and industrial units in its catchment area. Contamination of river water with various mineral and organic pollutants poses serious risks to the health of the environment and agriculture in the region. Due to the rapid population growth trend and consequently the development of urban and industrial centers around the Qarah Su River, if no serious and rapid action is taken, the human health and environment of the Qarah Su River will be threatened (Fig. 1).

### Sample collection

Sampling of sediment of Qara Su River was done from September to February 2020. Because there is no standard method for sampling microplastic, the proposed method (Naji et al. 2019) with slight changes was used for

sediment sampling in which microplastic contamination in the water of Qara Su River was studied. In this study, 5 sampling stations were determined and 3 samples were taken from each station at a distance of 100 m from each other; based on this, a total of 15 samples were taken. Sediment sampling was performed using a stainless-steel shovel. The collected samples were transferred to glass containers and covered with aluminum foil. Geographical characteristics of sampling stations are presented in Table 1.

### Microplastic extraction from sediments

In order to prepare the samples, the sediment samples were transferred to a Beaker and placed in a laboratory oven at  $70^{\circ}\text{C}$  for 72 h to completely dehydrate and dry the sediment samples. The samples were then manually crushed under a laboratory hood in a mortar (Liu et al. 2021; Uddin et al. 2020). Then, larger pieces of sand, wood, and other wastes were removed from the sample using tweezers. The crushed sediment was thoroughly mixed together. About 100 g of the dried sediment was weighed with a scale with a sensitivity of 0.1 samples and transferred to Sediment-Microplastic Isolation (SMI) device. Then, 700 ml of  $\text{ZnCl}_2$  was added to 100 g of the dried sediment mixture in the machine SMI. The density separation method was selected as the experimental method for this study. Saturated  $\text{ZnCl}_2$  solution (density of  $3.02\text{--}2.98\text{ g cm}^{-3}$ ) was selected as the buoyant solution for microplastics separation. The decision to use saturated  $\text{ZnCl}_2$  solution was made based on its high density and complete extraction of microplastics.

For the initial digestion of organic matter, 10% potassium hydroxide (KOH) solution was added to the sample and placed under a laboratory hood for 48 h to completely digest the organic matter of the sample. When organic matter was removed from the samples, microplastic samples were separated using 700 ml  $\text{ZnCl}_2$  solution SMI (Baztan et al. 2018; Coppock et al. 2017; Uddin et al. 2020). One hundred g of the sample was selected and the prepared sample was transferred into SMI, and then, 700 ml of  $\text{ZnCl}_2$  solution was added to the sediment sample. The sample was mixed with a magnetic stirrer for 5 min and was allowed to settle for 30 min until the materials were completely dissolved together and the solution was deposited inside SMI. The supernatant was transferred to a laboratory glass by Pipette Filler and the resulting liquid was filtered through a Whatman paper filter NO. 42 with a vacuum pump. In order to improve the extraction efficiency of microplastics, this process was repeated three times. The microplastic filter was then placed inside a glass petri dish with a glass lid for identification (Coppock et al. 2017; Ghattavi et al. 2019; Van Cauwenberghé et al. 2015).

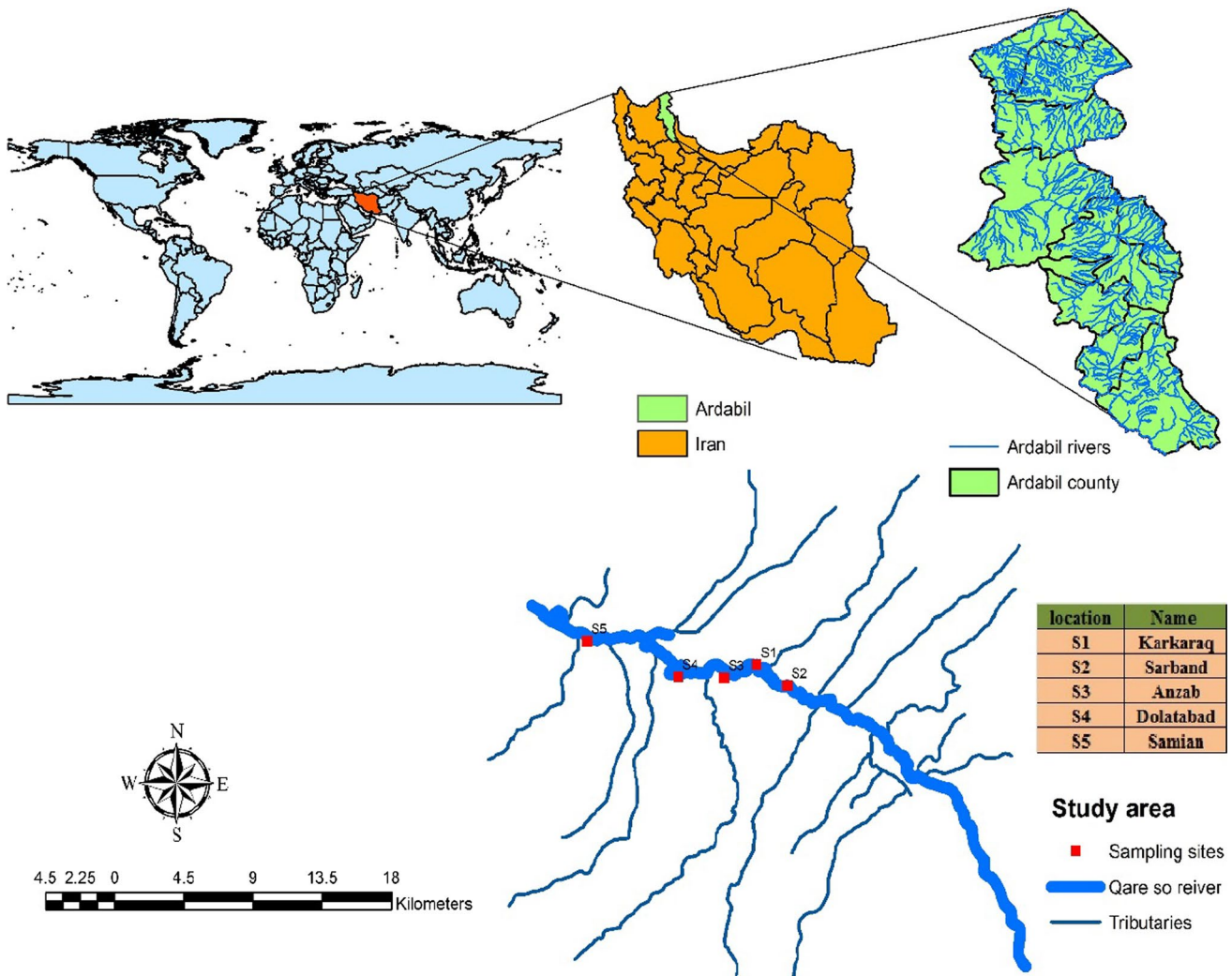


Fig. 1 Location of sampling stations on the Qarah Su River

Table 1 Coordinates of the study area sources and possible pollution of Qara Su in Ardabil River

Possible sources of contamination	Longitude	Attitude	Number	Study area
The entry of municipal wastewater into the river and agricultural wastewater	38°/366108 N	48°/354259 E	S1	Karkarq
Arrival of sewage effluent in Ardabil industrial town 2 and agricultural sewage effluent	38°/366426 N	48°/382838E	S2	Sar band
Village sewage entering the river and agricultural sewage effluent	38°/364927 N	48°/349299E	S3	Anzab Sulfa
Village sewage entering the river and agricultural sewage effluent	38°/364051 N	48°/315029E	S4	Dolat abad
Village sewage entering the river and agricultural sewage effluent	38°/380811 N	48°/246078E	S5	Samian

**Observation and identification of microplastics**

The filters were examined under an Olympus SZX16 stereo microscope, and images were taken with a digital microscope. Hot needle testing was also used to identify microplastics for greater reliability (Naji, Nouri et al. 2019). The microplastic particles on the filter membrane were imaged using an Olympus SZX16 stereo microscope with

40 X magnification equipped with a digital camera. Suspicious microplastics were first identified and photographed by a camera. The images contained a microplastic image determined by Image J software. The microplastics in the photographs were counted according to their morphology, color, and size. In this study, scanning electron microscopy (SEM) was used to test and analyze the morphology of



microplastics, identify chemical compounds, and present flawless and high magnification images.

### Quality control

Contamination with airborne microfibrils are a repeatable problem in MP research as they are pervasive throughout the environment and even within laboratories. In order to prevent microplastic contamination and reduce the possibility of contamination of the samples, they were analyzed under the hood, and all containers were covered with aluminum foil (Naji et al. 2021, 2019, 2018). To control the accuracy of the measurement, 5000 ml of distilled water was filtered on a Whatman 42 paper filter in a vacuum device. The filters were then kept in the open air for 72 h without any coating. After 72 h, these filters were observed with a stereo microscope. The results showed that there were no microplastics in the filters used.

### Data analysis

Data analysis was performed using SPSS Ver. 22 software and ImageJ 1.52 v and Microsoft Excel 2010. Also, mapping the spatial distribution of microplastics was done using ArcGIS 10.2. Analysis of variance was performed using SPSS software. According to results of Kolmogorov–Smirnov (K–S) test, all data related to the evaluated parameters with 95% confidence indicated that the data were normal. The results of sampling and measuring the parameters of size, color, and type of microplastics in the sediment environment of Qarah Su River in Ardabil were obtained by one sampling and with 3 repetitions in each station.

## Results and discussion

### Microplastics content

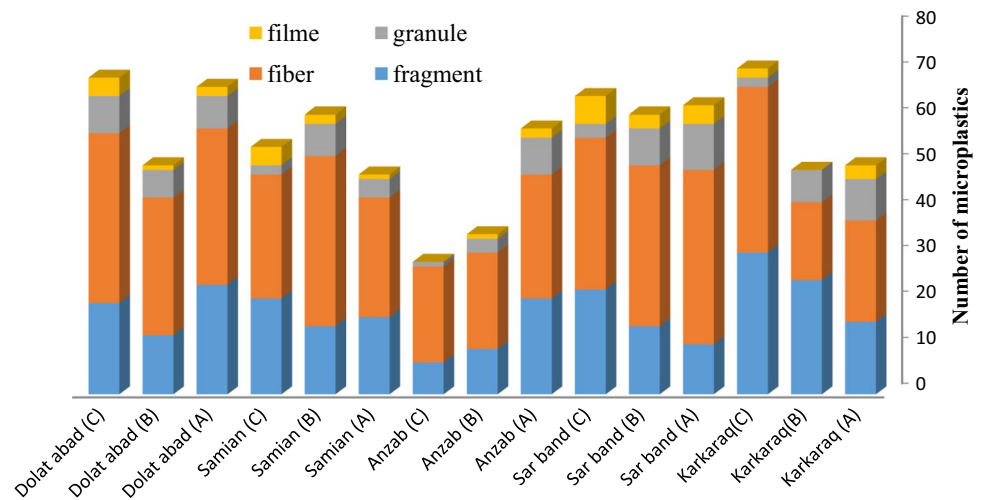
Other contaminants also accumulate in sediments, and microplastics have the ability to absorb and transfer them to living organisms. Microplastics enter aquatic environments through various industrial processes and urban and industrial wastewater. Rivers are more exposed to plastic pollution due to the density of urban population and industries in the region and human activities. The results of this study show that microplastic particles are present in the sediments of all studied stations, which indicates their wide dispersion in the sediment of the Qarah Su River. Examination of microplastics in the sediments of the studied stations in Qarah Su River in Ardabil showed that different types of microplastics including fiber, fragment, granule, and film were observed in the sediment. Among them, fibers had the highest concentration with an average of 52.8%. After

that, fragment with an average of 32.8% and granule 10.2% and film with an average of 4.8% had the highest concentration in Qara Su River sediment, respectively (Table 2 and Figs. 2 and 3). Recent studies have shown that sediment is the final destination of many microplastics. Even microplastics, which were less dense than water, enter sediments through biological processes, such as attaching to other organisms, and then sinking into the water. According to the table above, the concentration of microplastics found in the sediment of all stations is decreasing in the following order: Fiber < Fragment < Granule < Film. In a study by Scherer et al. (2020), they found that microplastics in river sediment in Germany included 21.5% fiber, 34.2% fragment, and 9.1% film, granules (Scherer et al. 2020). Schröder et al. (2021a, b) have shown that in terms of the type of microplastics in the coastal sediments of the Fjord Mountains, the Western Baltic Sea in Germany was composed of fiber with 77% and fragment with 18% (Schröder et al. 2021a). Li et al. (2020), in a study, showed the sediments of Chongming Island in the Yangtze Estuary, China, fiber with more than 24% and fragment with 72% of the identified microplastics (Li et al. 2020). Zhang et al. (2020), in a study, found that the types of microplastics in the Pacific sediment were fiber with 52.5%, fragment with 30%, and film formed about 17.5 microplastics (Zhang et al. 2020). The results showed that the microplastics identified in Qara Su River in Ardabil included fragment, fiber granule, and film, and in the studied stations, two types of microplastics, pellets and foams were not identified. Kor et al. (2020) found that in Oman coastal sediments, microplastics including fiber, fragment, and film types were about 32.5%, 45%, and 22.5% (Kor et al. 2020). In the study of Mao et al. (2021), the microplastic type in the sediments of Wuliangshuai Lake, northern China, contained 53.95% fiber and 38.3% fragment (Mao et al. 2021). Fan et al. (2021a, b) found that in surface waters and Yangtze River sediments along the city of Chongqing, China, 46.7% of microplastics was fiber and 52.2% was film (Fan et al. 2021b). The type of microplastic fiber detected was mainly in the sediments of Karkaraq village station, which was located in the effluent discharge of Ardabil treatment plant. Studies show that PE and PP microplastics are commonly

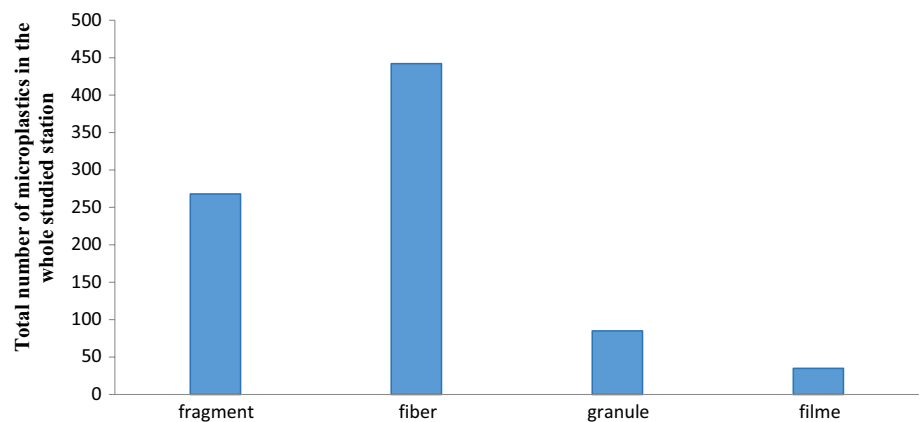
**Table 2** Percentage of total microplastics in the sediment sample by station

Type of microplastics (%)				Station Location
Granule	Film	Fragments	Fiber	
11	3	42	44	Karkaraq
11	7	26	56	Sar band
10	6	30	54	Anzab Sulfa
11	4	31	54	Dolat abad
8	4	32	56	Samian

**Fig. 2** Microplastics extracted from the sediment of Qarah Su River in Ardabil



**Fig. 3** Comparison of types of microplastics identified in Qarah Su River of Ardabil



used in sanitary ware including toothpaste, facial cleansers, and clothing (Alavian Petroody and Hashemi 2021; Pojar et al. 2021). While in the present study, the percentage of microplastics of fiber, fragment, granule, and film type were about 53%, 33%, 10%, and 4%, respectively; it shows the difference in the source of microplastics entering this river. Zhou et al. (2020) found that the type of microplastics in the sediment of the Yuanjiang Riverbank, Nanning City, and southern China was as follows: fiber (14%), fragment (2.8%), foams (74.6%), and film (4.6%). They formed the sediment of the river (Zhou et al. 2020). Furthermore, the results of studies show that these types of plastics are present in sediments. In the present study, microplastics have entered river sediments through the effluent of the Ardabil wastewater treatment plant. The microplastics identified in this study were somewhat similar in type to the results of the fiber and fragment microplastics of China, Oman, and the Pacific in the research of Zhang, Liu et al., Kamalodin Kerr et al., Dongdong Zhank et al. In the study of Felismino et al. (2021), in Simcoe Lake, Canada, it was reported that the microplastics were 75% fiber and 22% fragment,

which corresponds to some extent with the abundance of microplastics observed in the sediment of Qara Su River in Ardabil (Felismino et al. 2021). The difference in the amount of microplastics in the sediment depends on several factors such as the population covered, the amount of microplastics entering the river, and the sampling and extraction method.

Naji et al. (2019) showed that microplastics are spread in the marine environment through household activities, cosmetics, synthetic fabrics, or by the decomposition of large plastics in the presence or absence of ultraviolet radiation and observed in floating form in the sea, suspended in a column of water, or as sediments in the seas and oceans. Also, in a study conducted by Abbasi et al. (2019), it was concluded that with each wash of clothes made of plastic fibers, the most microplastic particles, which enter the aquatic ecosystem, are of fibro fragment type. Also, according to studies by Yanguan Zhu et al., with each wash of synthetic clothing, about 1900 microplastic particles of the fiber type are released into the environment. Finally, there has been the possibility of an increase in fiber microplastics due to the entry of wastewater into the aquatic environment. Due

to the fact that there is Ardabil industrial town 2 upstream of the river, there is a possibility of releasing microplastics from the water treatment plant into the Qara Su River in Ardabil. In addition, the effluent of Ardabil treatment plant contains the highest abundance of microplastics of the fibro fragment type (piece). The reason may be the conditions of the wastewater treatment plant and the inefficiency of proper filtration during wastewater treatment in Ardabil.

Different types of microplastics collected from the sediments of Qarah Su River in Ardabil are presented in Fig. 4. The scanning electron microscopy (SEM) images to show the surface properties of various microplastics from the sediments of the Qarah Su River in Ardabil are presented in Fig. 5.

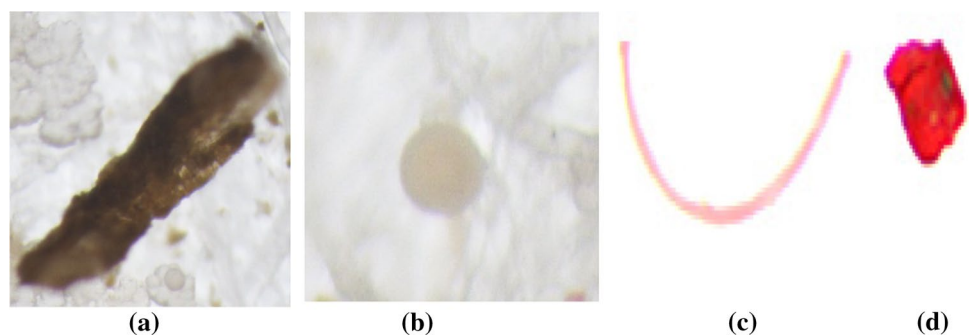
Examination of the microplastics in the river by size showed that about 25% of the microplastic particle had the size less than 100  $\mu\text{m}$ ; 8% had the size in range of 100–500  $\mu\text{m}$ ; 43% had the size in range of 500–1000  $\mu\text{m}$ ; 17% had the size in range of 1000–5000  $\mu\text{m}$ ; and the remaining 8% had the size more than 5000  $\mu\text{m}$  (Fig. 6). Microplastics are more important because of their small size and the possibility of entering the body of aquatic organisms. Due to the small size of the microplastics, they may be mistakenly fed by aquatic organisms, endangering their health as well as the health of humans and the environment. Microplastics can be a source of environmental pollutants by releasing additives to plastics in the environment. Alavian Petroody and Hashemi (2021) measured the concentration of microplastics in the sludge and effluent of the Sari wastewater treatment plant in northern Iran and stated that most of the microplastics observed are less than 500  $\mu\text{m}$  in size and most are fibers.

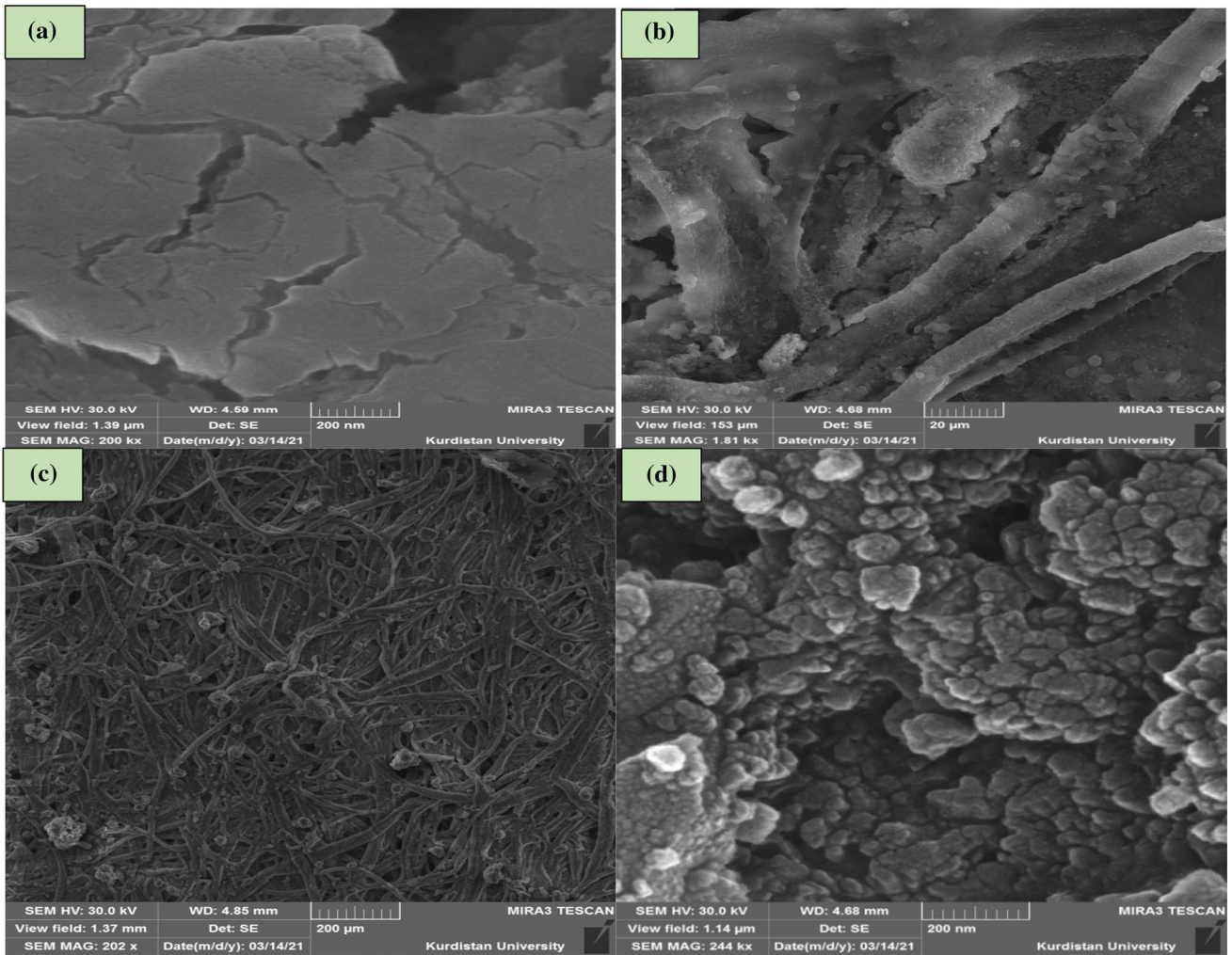
In this study, microplastics with particle sizes of less than 100  $\mu\text{m}$  (25%), 500–1000  $\mu\text{m}$  (42%), and 1000–5000  $\mu\text{m}$  (17%) were widely identified in river sediment samples, which was related to microplastic particles the size of less than 5  $\mu\text{m}$  (92%). The entry of these microplastic particles can be due to the entry of wastewater from Ardabil wastewater treatment plant into this river. Turan, Arkan et al. (2021) in Turkey showed that there were more microplastics less than 5000  $\mu\text{m}$  in the wastewater discharge, so they concluded

that small plastic pieces are not removed during the wastewater treatment process and enter the aquatic ecosystem with effluents of wastewater treatment plants (Turan et al. 2021). Also, the increasing use of cosmetic and hygienic products containing microplastics such as face masks, exfoliating creams or foams, shaving pastes, body shampoos, and toothpastes has been effective in increasing microplastics in aqueous environments. Obviously, the particles with smaller size have higher specific surface area and the greater adsorption capacity (Turan et al. 2021). Therefore, due to the fact that in the study area, particles smaller than 5000 microns are predominant, and the microplastics high ability to adsorb organic pollutants and heavy metals, plastics, especially those with smaller size, can pose significant environmental hazards. The entry of significant amounts of wastewater from the Ardabil wastewater treatment plant into the Qara Su River has created potential hazards for living organisms and the environment.

Various colors were observed in the microplastics found from the sediments of Qarah Su River. The highest percentage of colors observed were white, brown, black, blue, yellow, red, and pink, respectively. White and brown were the predominant colors. The variety of colors was due to the release of effluents from the wastewater treatment plant of Ardabil city and the treatment plant of Ardabil industrial town to Qara Su River (Fig. 7). In terms of the color of the identified microplastics, white, brown, and black colors accounted for 36%, 20%, and 16%, respectively. Also, about 13, 5, 5, and 5% of microplastics were in the groups of blue, clear, yellow, and red colors, respectively. The color variation reflects the different sources of microplastics released into the environment (Gallagher et al. 2016; Sabzalipour and Nabavi 2020b). Studies have shown that colored microplastics may carry more harmful substances such as heavy metals and organic pollutants. Colored plastic particles have potential hazards for aquatic organisms. If small colored microplastics are eaten as food by living organisms, their health is endangered. Therefore, more attention should be paid to the use and release of colored plastics to the environment (Jiang et al. 2020; Sabzalipour and Nabavi 2020b; Zhang et al. 2020). In a

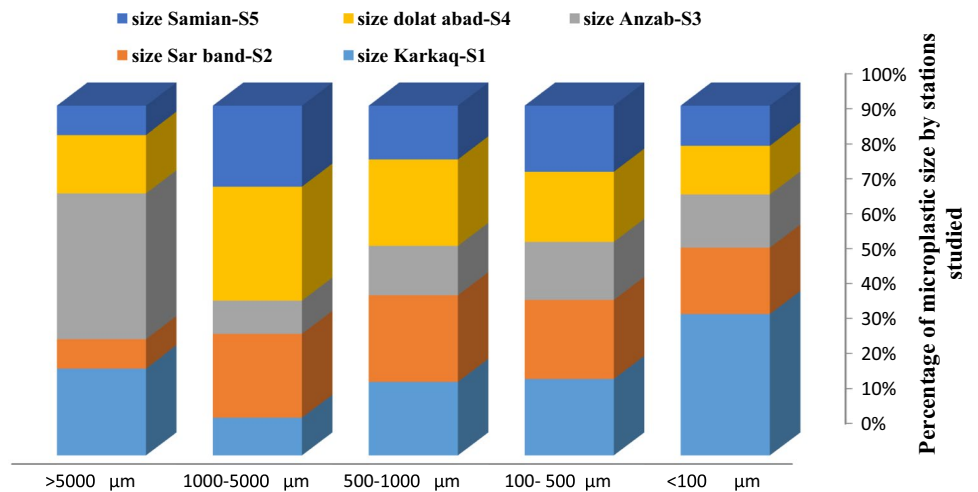
**Fig. 4** Types of different microplastics collected from the sediments of Qarah Su River in Ardabil: **a** parts; **b** fiber, c pellets, and **d** film





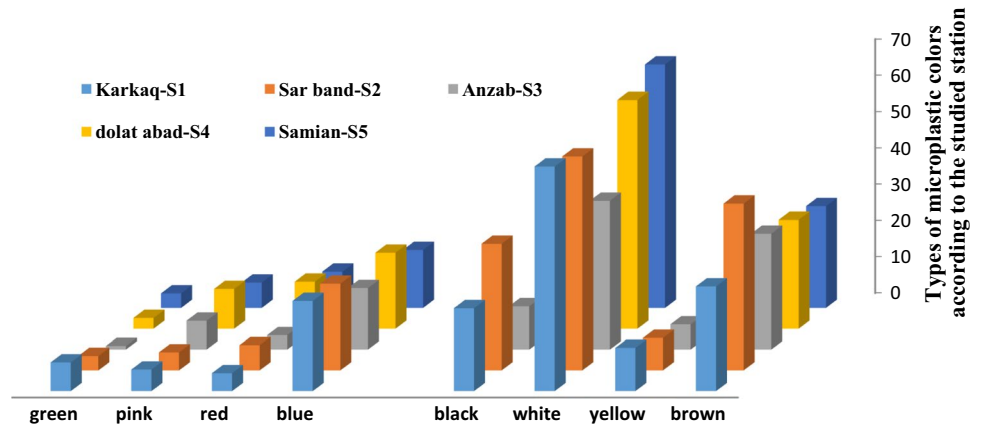
**Fig. 5** Scanning electron microscopy (SEM) images to show the surface properties of various microplastics from the sediments of the Qarah Su River in Ardabil. **A** fiber; **B** piece; **C** bullets; and **D** movies

**Fig. 6** Size classification of microplastics identified in Qarah Su River of Ardabil





**Fig. 7** Identified microplastics based on dye distribution in Qarah Su River of Ardabil



study conducted by Naji et al. (2021) in Bandar Abbas, the predominant color of the microplastics found in the sediment was white/clear, and black/gray. Given that most man-made plastics are white and black, observing such results that white and brown are predominant is not unexpected. The color of microplastic particles is a potential hazard to living organisms, because small and colorful microplastics may be eaten by aquatic animals and birds and endanger their health (Sabzalipour and Nabavi 2020a).

However, the amount of microplastics in the sediments indicates the role of Ardabil wastewater treatment plant in Qara Su River. However, the entry of microplastics due to wind and runoff caused by rainfall increases the microplastics of the river. Therefore, managing and controlling the emission of microplastics in Ardabil treatment plant should be considered as a route for transmitting microplastics to the environment.

**Comparison with other regions of the world**

This study provides the first evaluation of MP contamination in the sediment of the Qara Su River of Ardabil. The results

show the effect of the effluent of the Ardabil wastewater treatment plant in terms of the density of microplastics found in the Qara Su River of Ardabil. Comparison of the presence of microplastics MPS in sediment in the present study and other studies is presented in Table 3.

**Conclusion**

This study provides for the first time reliable data on the presence and characteristics of microplastics in the sediment of Qara Su River in Ardabil, Iran. It is necessary to identify the possible sources of the entry of microplastics as one of the causes of pollution of aquatic and terrestrial ecosystems as well as a threat to human health. This study examined reliable data on the presence, shape, and size of microplastics in the Qara Su River in Ardabil, which confirms the role of wastewater treatment plants as important sources of microplastics in the environment. The results of this study showed that a large amount of microplastics enters the environment of the Ardabil wastewater treatment plant daily. Most microplastics are less than 5000 μm in size, which

**Table 3** Comparison of the presence of microplastics MPS in sediment in the present study and other studies

References	Sample	Microplastic forms (%)				Site	Country
		Granule	Film	Fragments	Fiber		
(Pojar et al. 2021)	Sediment river	90 <	–	–	3	River and sea	Romania
(Zhou et al. 2020)	Beach sediment	21.5	34.2	4.6	4	River	China
Scherer et al. 2020)	Water and sediments	–	–	9.1	35.5	River	Germany
(Schröder et al. 2021a, b)	Sediments	–	–	18	77	River	Germany
(Li et al. 2020)	Water and sediments	–	24	72	–	River	China
	Sediments	–	52.5	30	17.5	Sea	Oman
(Mao et al. 2021)	Sediments	–	38.3	53.9	–	River and sea	China
(Fan et al. 2021a, b)	Sediments	–	53.2	46.7	–	River and sea	China
	Water and sediments	–	93	–	–	River	Poland
(Felismino et al. 2021)	Water and sediments	22	–	75	–	Lake	Canada
current study	Sediments	52.8	32.2	4.8	10.2	River	Iran

due to their small size, the surface to volume ratio of microplastics, can absorb and transfer organic and resistant pollutants and heavy metals play an important role. Also, the entry of microplastics through effluents into aquatic environments and agricultural land can increase environmental concerns. The importance of studying microplastics was the first study to evaluate microplastic contamination on the Qara Su River in Ardabil province. Due to the importance of the river, the release and receipt of high volumes of microplastics in aquatic environments by the Ardabil wastewater treatment plant, it is necessary to follow up the entry of emerging pollutants in advance by officials.

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**Data availability** The dataset analyzed during the current study is available from the corresponding authors on realistic demand.

## Declarations

**Conflicts of interest** The authors declare that there is no conflict of interest regarding the publication of this work.

**Ethics approval** There was no need for ethical considerations in conducting this study.

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