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Detection of Microplastics in Drinking Water Treatment Plants in Baghdad City/Iraq

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ABSTRACT

Microplastics are an emerging environmental pollutant detected in different environments, but studies in Iraq are rare, if not nonexistent. Our research aims to detect the presence of microplastics in raw water and drinking water treatment plants in Baghdad. Water samples were collected (1 liter per sample) from four drinking water treatment plants: Al-Fahama station, Al-Fath Al-Mubin station, Al-Dora station, and Al-Madaen station, which receive water from the Tigris River. The microplastic shape was determined by a fluorescent microscope examination after staining with Nile dye. FTIR spectrophotometer used to determine microplastic compounds. The results showed, according to FTIR examination, that the most critical types of microplastic compounds in water samples were Nylon, Polycarbonate, High-density polyethylene, Polystyrene, Polyamide, Polyethylene terephthalate, and Polyurethane, and Microplastics number were (17-62 MPs /L) in raw water, while in drinking water were (9-40 MPs/L). The fibers form is the predominant form of microplastics in natural and drinking for stations: Al-Fahamah (91.6%, 66.6% respectively), Al-Fath Al-Moubin (58.8%, 77.7% respectively), Al-Doura (65.3%, 52.5% respectively), Drinking water in Al-Madaen station (40.0%). At the same time, the spherical shape is predominant in the raw water of Al-Madaen station (82.2%).

In conclusion, the current study indicated the pollution of drinking water treatment plants with microplastics.

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INTRODUCTION

Since 1950, global plastic production has steadily increased, reaching 368 million tons in 2019 (Okoffo *et al.*, 2019). This steep rise can be attributed to the attractive properties of plastic, such as its low price, durability, lightweight, and good ductility, which have led to its prevalence in home and industrial applications (Kawecki *et al.*, 2018).

In 2004, Thompson formally introduced the term “microplastics” (MP), raising awareness of the increasing presence of plastic in the seas (Thompson *et al.*, 2004). This issue has become prominent among scientists, authorities, the public, and the media (Provencher, 2018). Globally, several studies about microplastics in bottled water, tap water, wastewater, and freshwater (Singh *et al.*, 2022). As a result, the small size of microplastics can enter food chains and negatively affect humans and organisms (Yan *et al.*,2019). While there is one Iraqi study about microplastics in tap water (Sultan *et al.*,2023).

In addition to the overall impact of plastic pollution, there are growing concerns about the effects of plastic pollution on the health of ecosystems. As a result, plastic has been added to

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the UN's Basel Convention on the Control of Transboundary Movements of Hazardous Wastes (Basel Convention,2020; Korcheva,2021). Researchers have not yet reached a definitive definition for microplastics but generally consider them fragments smaller than 5 mm in unspecified dimensions. Plastics can be classified according to size into macroplastic (>20 mm), mesoplastic (5-20 mm), and microplastic (1 μm - 5 mm) (Zahari *et al.*, 2022).

Microplastics are synthetic plastic particles ranging in diameter from 1 μm to 5 mm. Microplastics can be classified as primary and secondary (da Silva *et al.*, 2020). Primary microplastics are produced at a microscopic size in cosmetic products and personal care (Praveena *et al.*, 2018). Secondary microplastics are produced through the degeneration of large materials by UV radiation in sunlight, temperature changes, wave action, and other chemicals, biological impacts, and physical impacts (Fiore *et al.*,2022).

In general, the main compounds of microplastics include PET (Polyethylene Terephthalate), PVC (Polyvinyl Chloride), HDPE(High-Density Polyethylene), LDPE (Low-Density Polyethylene), PS (Polystyrene), PC (Polycarbonate), and PP (Polypropylene) (Mortula *et al.*,2021). The primary sources of microplastics are tiers abrasion, dust cities, textiles waste, and other plastics products in wastewater (Boucher and Friot, 2017). Besides, the primary sources of microplastics are in the oceans, rivers, and lakes. Where the significant pathways of microplastics into freshwater environments involve wastewater treatment plants, the collection of solid waste and its processing, and landfill waste (Ta and Babel,2022).

These particles are typically introduced into freshwater systems through sewage treatment plants and effluent (Murphy, 2016). Plastic's resistance to degradation leads to a build-up of large amounts of waste in the environment (da Costa *et al.*, 2016). There is growing evidence of the potential threat of microplastics to human health in foodstuffs and other environments, such as honey, milk, beer, seafood, table salt, drinking water, and air (Mason *et al.*, 2018). It has been observed that plastic pollution is exacerbating environmental damage (Wilcox *et al.*,2020).

Additionally, recent events in the COVID-19 pandemic have caused a surge of microplastics in coastal areas and other water bodies (De-la-Torre *et al.*, 2022). Studies show that pollution by plastic in drinking water is no less dangerous than sea pollution (Li *et al.*, 2020).

In humans, microplastics can enter the body via ingestion and inhalation (Stapleton,2021). Where microplastics in a biological system are caused inflammation, cytotoxicity, and oxidative stress. Besides, microplastics can stay intact for a period, transfer to different tissues, can accumulate in various organs (Rahman *et al.*,2021).Furthermore, the failure of the immunity system to remove microplastics can cause persistent inflammation and raise the hazard of neoplasia(Prata *et al.*,2020).

Nowadays, the detection of microplastics considers a challenge of importance. Microplastics cause disadvantageous effects on biodiversity as a result of their impedance to biodegradation (Wang *et al.*,2020).

Also, microplastics can affect health; for example, fiber microplastics are toxic due to staying a long periods in the gut and slow digestion of food (Pandey *et al.*,2022).

An enormous number of studies have determined that the mean concentration of microplastics (MP) in conventional water sources is 2.2 x 10^3 MP/M^3, with particles typically >50 μm in size (Cheng *et al.*, 2021). These studies found that raw water ranged from 1 to 6614 MP/M^3, while treated water ranged from 1 to 930 MP/L. According to the studies of Li *et al.*(2020) and Cheng *et al.* (2021), drinking water treatment plants provide an overall removal efficiency of 69.9% - 100% regardless of the treatment types (Barchiesi *et al.*, 2021).

The novelty and importance of the current study represented the detection of microplastics in Iraqi drinking water treatment plants due to fewer Iraqi studies of microplastics detection and their importance as a modern pollutant. Therefore, this study aims to detect microplastics in Iraqi drinking water treatment plants and establish a database about the presence of microplastics in drinking water.

METHODS

study sites and field modelling

Four drinking water stations were selected in the city of Baghdad, the first is the Al-Fahama water station located in the north of the city, which represents upstream of the entry of the Tigris River into the city. Al-Fahama area represents an agricultural area. Also, two stations were chosen within the center of Baghdad city, the Al-Fath Al-Mubin water station located on the edges of the Tigris River at Abu Nawas Street, and the Al-Doura water station located on the Tigris River in the Dora region in the south of Baghdad. Many wastewater treatment plants pour into the Tigris River in the center of Baghdad, some of which are untreated and others are random and unlicensed by the Municipality of Baghdad. The last station is the Al-Madaen water station located south of Baghdad, downstream of the Tigris River in Baghdad city. Besides, the Tigris River is affected by the wastewater releases from Rustamiya station through the Diyala River at its confluence with the Tigris River in the Al-Tuwaitha area, located a short distance before the Al-Madaen water station as in Figure (1).

preparation of water sample

The process of preparing the water sample was carried out according to the global protocol provided by the US National Oceanic and Atmospheric Administration Marine Debris Program(NOAA) (Masura *et al.*, 2015) by adding an appropriate amount of about 40 ml of 30% hydrogen peroxide solution to every 1000 ml of a water sample. The water sample was left for 24 -48 hours to digest organic matter; then it was added to about 32 g of table salt per 100 ml of sample water for half an hour. The water samples were filtered through a sieve with holes (38 microns). The sieve was washed with distilled water several times, from the outside towards the inside and from the inside sides towards the bottom. The washing water containing the microplastics was collected in a 2-liter glass beaker. The washing water was filtered through

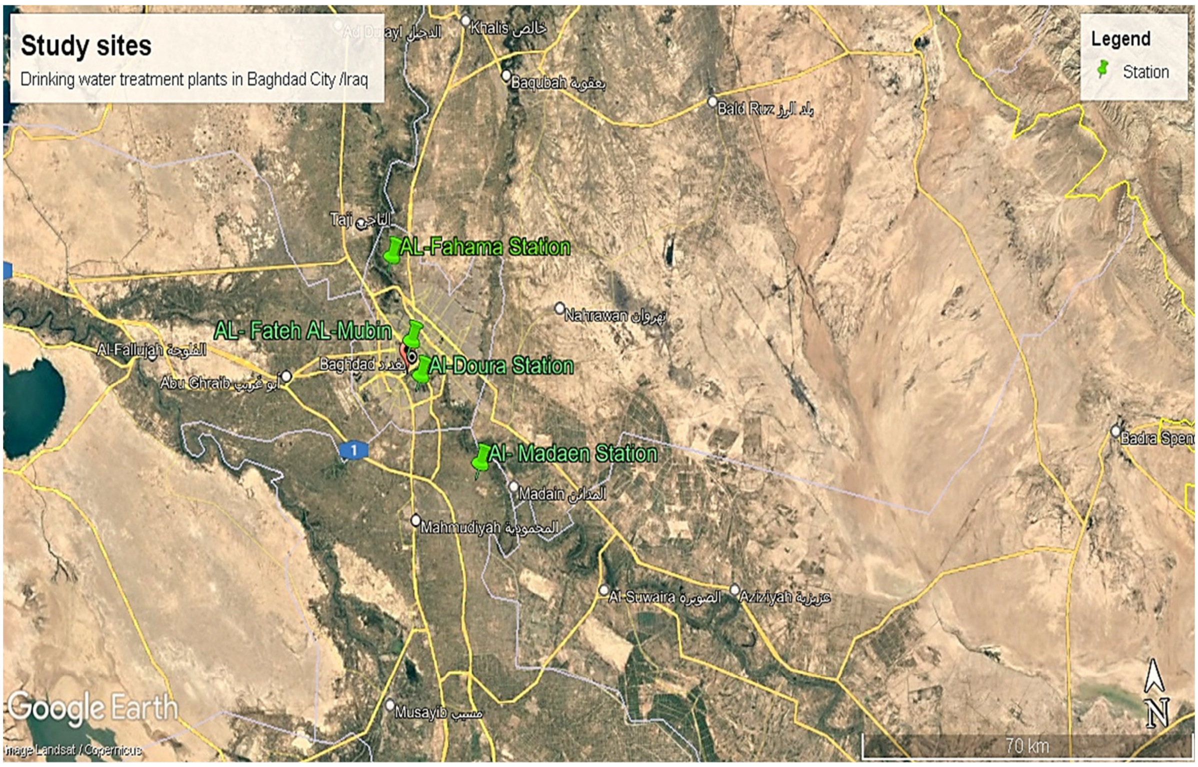


Fig. 1. The study site map of drinking water stations, including Al-Fahhama station, Al-Fath Al-Mubin station, Al-Doura station, and Al-Madaen station

cellulose filter paper (0.45 microns) using a millipore filtration unit attached to a vacuum pump. The filter paper is transferred to a glass petri dish, and the name of the station and the size of the sieve are fixed on the dish's cover to be ready for microscopic examination.

fluorescent examination

The microplastics were distinguished using a fluorescent microscope (MEIJI, MX, Japan), and the pictures were taken with a digital camera (Vision, Austria). After staining the filter papers containing the microplastics extracted from water samples with Nile red dye. A solution was prepared for Nile red dye by dissolving the powder in acetone at a concentration of 5 mg/L and leaving it for 24 hours before use. After staining, the filter papers were left for half an hour in the air to dry. The filter paper, after staining was transferred to the stage of a fluorescent microscope under a lens with a magnification of 10 × 40. A green filter was used with a wavelength of 425 nm. The microplastics were distinguished based on fluorescence, and the numbers and shapes of the microplastics were recorded for each filter paper separately.

infrared spectroscopy (ftir) analysis

Infrared spectroscopy is a suitable and standard microplastic analysis tool (Rocha-Santos and Duarte, 2015). The infrared spectroscopy method has been widely used to characterize and identify microplastic polymers due to its simple operation and accurate identification (Kappler *et al.*, 2018). In this study, spectral analyses were carried out using an ABB SPECTROL 4B spectral system PO Box 25 ,Newbury, Berkshire R G20 BBQ,UK. The fluorescent microplastics were manually separated from filter paper under the fluorescent microscope by forceps. The microplastics were placed on the prepared potassium bromide (KBr) at 1:100 to ensure smooth surfaces. A pressure of 10 tons was applied to become a circular disc form. The disc was placed on the holder of the FTIR device. The measurement is carried out in a wavelength range between 4000 cm^{-1} to 400 cm^{-1}, and transmittance from zero to 100.

RESULTS AND DISCUSSION

fluorescence microscope results

Microscopic tests represent the study of microplastics in the aquatic environment to determine their number, shape, color, etc. The results of the microscopic tests shown in Table (1) indicate

Table 1. Number of microplastics in stations

Name station	**Water sample**	Polymer	**Microplastic** Absorption band (cm^{-1})	**Previous studies**
Al-Fahama	Raw	Nylon	1634	**(Manzoor *et al.*, 2021)**
	Drink	No microplastic detected		
AL- Fateh AL-Mubin	Raw	Nylon, Polycarbonate (PC),	1634 1364	**(Manzoor *et al.*, 2021)** **(Hu *et al.*,2018)**
	Drink	High-density polyethylene HDPE Polypropylene(PP)	732 1457	**(Hu *et al.*,2018)** **(Veerasingam *et al.*, 2021)**
Al-Doura	Raw	Polystyrene PS	531	**(Veerasingam *et al.*, 2021)**
	Drinking	Polyamide (PA)	624	**(Mhiret Gela and Aragaw, 2022)**
Al-Madaen	Raw	Polyethylene terephthalate (PET)	1642	**(Mhiret Gela and Aragaw, 2022)**
	Drinking	PET Polyurethane (PU)	1642 1223	**(Mhiret Gela and Aragaw, 2022)** **(Hu *et al.*,2018)**

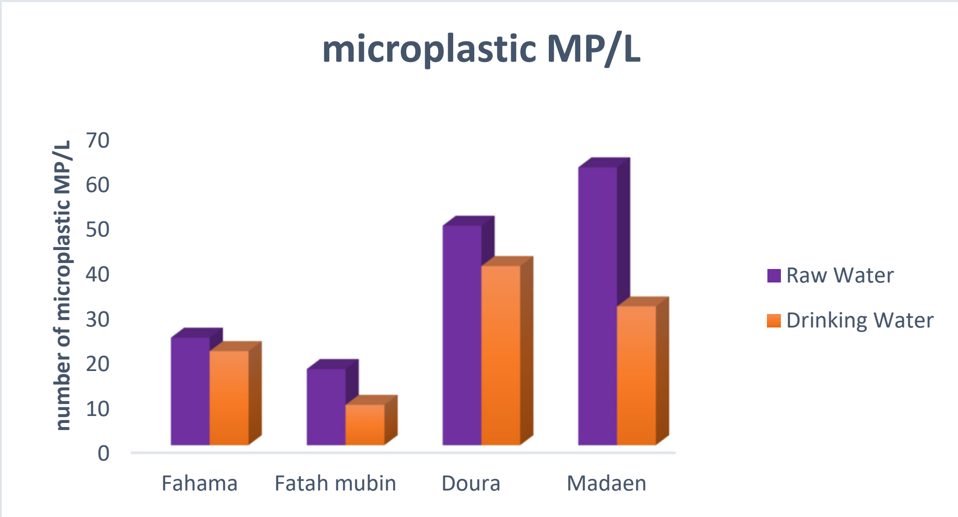


Fig. 2. Number of microplastics in the drinking water stations.

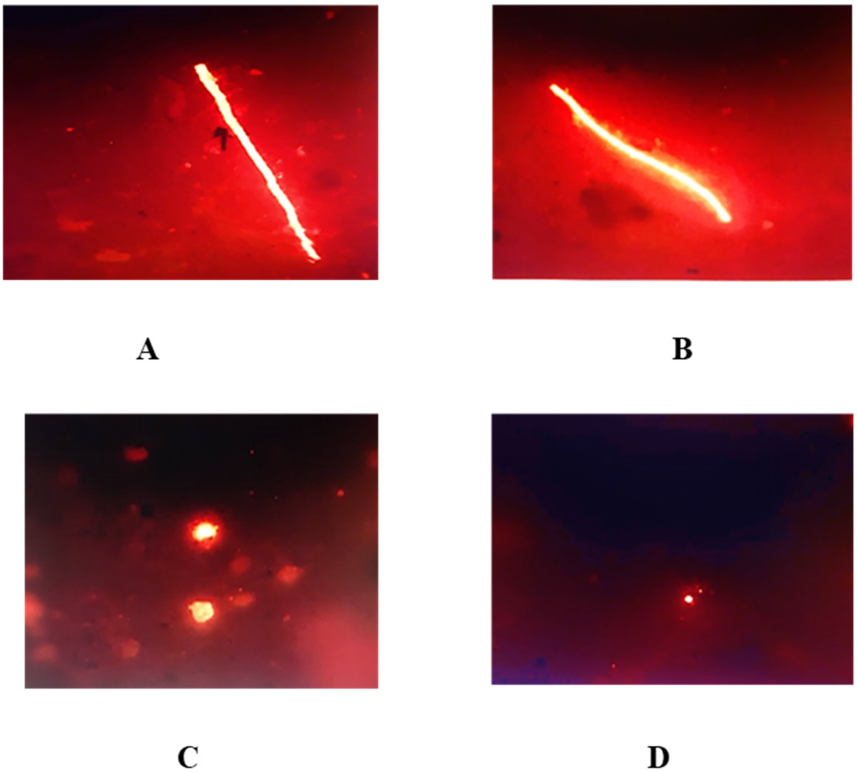


Fig. 3. Microscopic examination of microplastics by the fluorescent microscope (A, B) Fibre shape (C) Granules or Pellets shape, (D) Fragments

the presence of microplastics in the raw and drinking water of all the studied water treatment plants. The number of microplastic particles in the raw water ranged between 17-62 MPs/L, while in the drinking water, it ranged between (9-40) MPs/L. Their numbers in raw water were 24, 17, 49, and 62, while in drinking water, 21, 9, 40, and 31 in the stations of Al-Fahama, Al-Fath Al-Mubin, Al-Doura, and Al-Madaen, respectively(Table 2). It is observed that the number of microplastics in the raw water is higher than its number in drinking water. This result is consistent with what Wang *et al.*(2020) found in their study microplastics as pollutants in the aquatic environment and changes in the behavior of the environmental contaminants by reaction and absorption that lead to toxic effects, degradation, and bioaccumulation. Where the drinking water is polluted mainly with microplastics (primary and secondary) through the discharge of sewage and effluents from water treatment plants and surface runoff. There are a large number of industries that use primary microplastics for different applications, such as medicines, cosmetics, etc. After being used, where these primary microplastics are washed and become part of domestic wastewater (Singh *et al.*,2021). Since wastewater treatment plants are not equipped to remove microplastics, the effluent from these plants contains a significant amount of microplastics (Amrutha and Warrier 2020). When this effluent is mixed with freshwater sources, the microplastics become part of the freshwater supply chain for drinking water (Novotna *et al.*, 2019; Okoffo, 2019). One study reported an increased concentration of microplastics in the Chicago River due to effluents from local wastewater treatment plants (McCormick, 2014). Drinking water treatment processes are necessary to ensure adequate water quality. However, they are not entirely effective in isolating microplastics where Pivokonsky *et al.*(2018) recorded in their study the high concentrations of microplastics in raw and treated water in three water treatment plants ranged from 1473 ± 34 to 3605 ± 497particles/L in raw water , and 338 ± 76 to 628 ± 28 particles/L in treated drinking water. Also, Wang *et al.* (2020) found 6614± 1132 MPs/L (raw water) and 930 ± 72 particles/L (wastewater) in an advanced treatment plant. Negrete (2022) found that the number of microplastics in raw water ranged from 19.5 to 143.5 MPs/M^3, while in drinking water, it ranged from 0 to 8 MPs/M^3 .

When comparing the concentrations of microplastics between the stations (Table 2), it was noted that the Al-Madaen station has the highest concentration of microplastics, which may be due to the geographical location downstream of the river south of Baghdad. Previous studies indicated an increase in the concentrations of microplastics at the downstream site (Dalmau-Soler *et al.*, 2021), and it is also located near the sewage discharge site of the Rustamiya station.

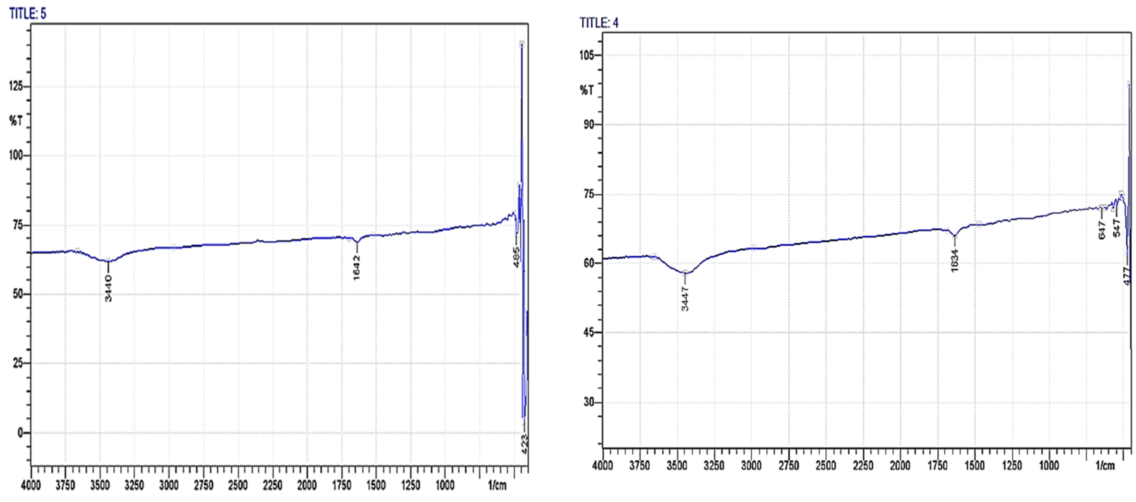
The fibers form is the dominant microplastic form in raw water and drinking water in three stations: Al-Fahamah 91.6%, 66.6%, Al-Fath Al-Moubin 58.8%, 77.7%, Al-Doura 65.3%, 52.5%, Drinking water in Al-Madaen station 40.0%, while the spherical shape is predominant in the raw water of Al-Madaen station 82.2%. The current study agreed with Lam *et al.*(2022). Fibrous microplastics were less than 1 mm which predominated and represented 97.8% of microplastic count in drinking.

fourier transform infrared spectroscopy results

At present, infrared spectroscopy is an effective method for identifying plastic polymers because their absorption peaks are well-known and easily distinguishable. The infrared analysis provides fingerprint spectra of the identified polymer for plastics and may detect the possible presence of other components (contaminants, additives, or polymer) (Jung *et al.*, 2018). FTIR is used to ensure the existence of a pure component and discover impurities, side groups, and bonds. The FTIR technique detects functional groups in a molecule and identifies inter-molecule reactions (Bandara *et al.*,2023).

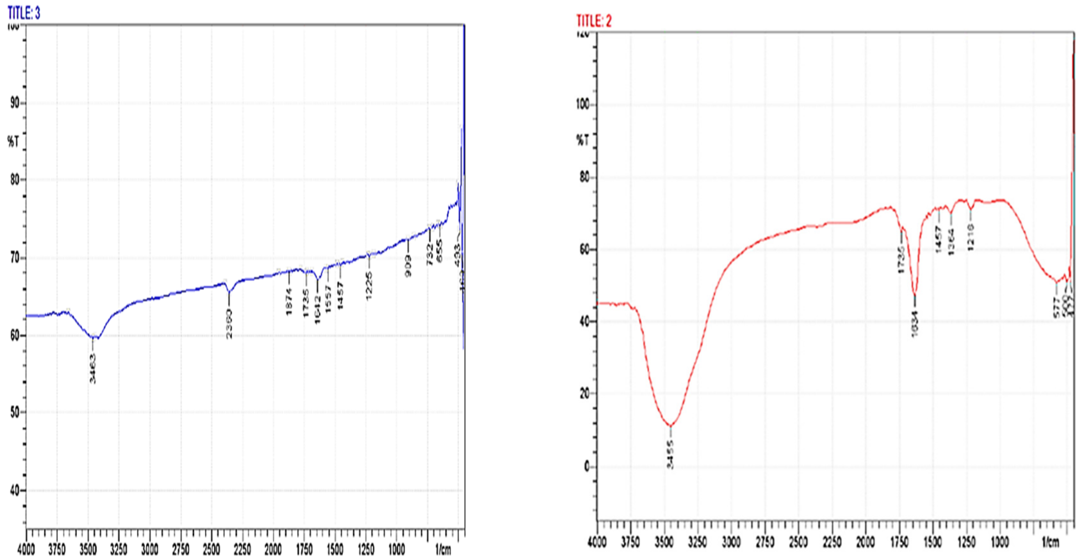
This method is currently applied to identify microplastics in different environments (Tagg *et al.*, 2015). The results of infrared spectral tests in this study are shown in Figures (4,5,6,7) for drinking water and raw water for Al-Fahama, Al-Fath Al-Moubin, Al-Doura, and Al-Madaen stations, respectively. FTIR spectra for each station were recorded in Table (2).

As a result of the lack of information about reference compounds in the FTIR infrared spectroscopy test device, also it is not provided with the electronic library; the polymer types were recorded based on the wavelength of absorption peaks, as compatible with the results of previous studies (Hu *et al.*, 2018; Veerasingam *et al.*, 2021;Manzoor *et al.*, 2021; Mhiret Gela and Aragaw, 2022). Also, the results of current study indicate the presence of Nylon microplastics in the raw water samples in the Al-Fahamah station at the peak with wavelength



A B

Fig. 4. A and B: FTIR infrared spectral tests (peaks spectra for microplastic compounds) **in** raw water for Al-Fahama station



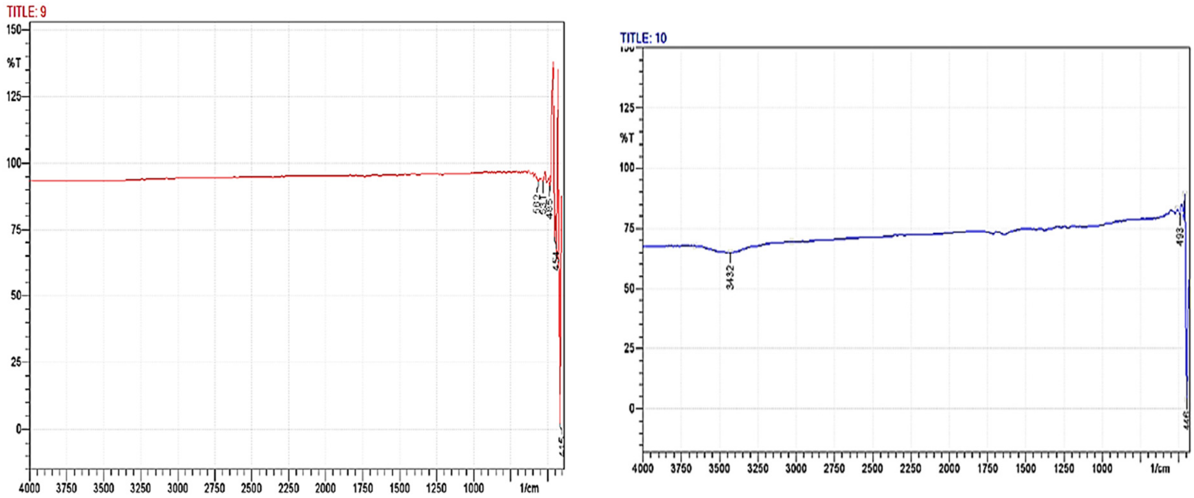
A B

Fig. 5. FTIR infrared spectral tests (peaks spectra for microplastic compounds) **(A)** Drinking water and **(B)**Rraw water for AL- Fateh AL-Mubin station

1634.

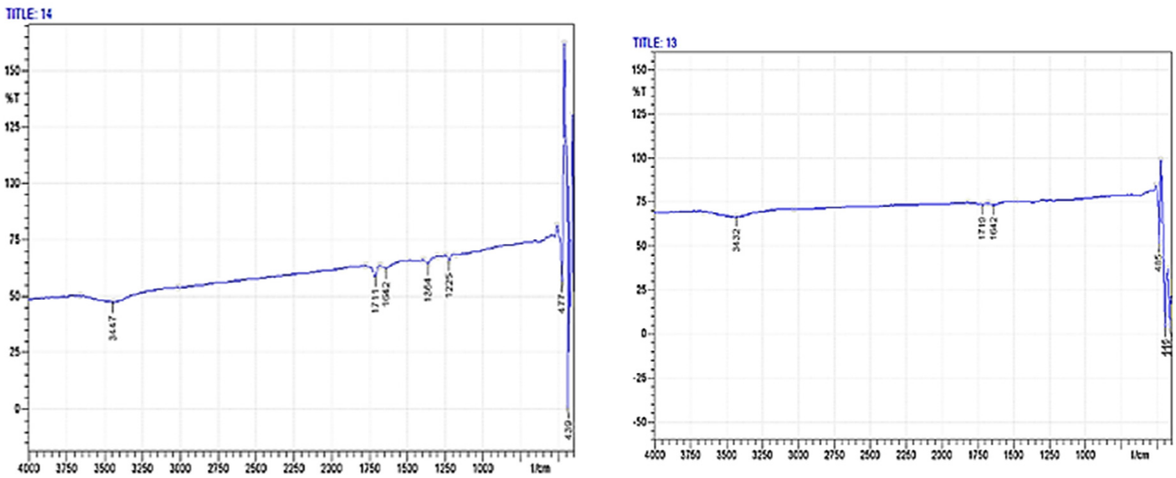
While some types compounds microplastics did not detect in some samples of drinking water. This may be due to the drinking water being polluted with microplastics, with a small size of less than 20 µm, Where the spatial resolution of the FTIR spectrum ranges from 10–20 µm (Huang *et al.*,2023). Moreover, FTIR is sensitive to different factors involving microplastic heterogeneity, microplastic aging, and the presence of organic material in the environment. It is hard to examine opaque microplastics by FTIR (Elert *et al.*, 2017).

In the Al-Fath Al-Mubin station, two microplastics were detected in raw water samples,



A B

Fig. 6. FTIR infrared spectral tests (peaks spectra for microplastic compounds) **(A)** Drinking water and **(B)** Raw water for Al-Doura station



A B

Fig. 7. FTIR infrared spectral tests (peaks spectra for microplastic compounds) **(A)** Drinking water and **(B)** Raw water for Al-Madaen station

Nylon and Polycarbonate, at peaks with wavelength 1634 and 1364, respectively, and two high-density Polyethylene and Polypropylene microplastics were detected in drinking water at peaks with wavelength 732 and 1457 respectively.In the Al-Doura station, one microplastic was detected in each of the raw waters: Polystyrene at the peak with wavelength 531 (representing the influential group). One microplastic in drinking water, which is Poly amide at a peak with a wavelength 624, and in Al-Madaen station, it was detected one microplastic in the raw water, which is Polyethylene terephthalate, at a peak with a wavelength of 1642, while in the drinking water, two microplastics compounds (Polyethylene terephthalate and Polyurethane) were

Table 2. Types of Microplastics in Drinking water stations

Stations	Microplastic (particle / L)					
	Water sample	**Fiber**	**Fragments**	**Pellets**	**Total**	**%**
AL-Fahama	Raw	22	2	0	24	91.6% fibers
	Drinking	14	4	3	21	66.6% fibers
AL- Fateh AL-Mubin	Raw	10	3	4	17	58.8% fibers
	Drinking	7	0	2	9	77.7% fibers
Al-Doura	Raw	32	12	5	49	65.3 % fibers
	Drinking	21	11	8	40	52.5% fibers
Al- Madaen	Raw	6	5	51	62	82.2% pellets
	Drinking	13	7	11	31	40.0% fibers

detected at the peak with a wavelength of 1642 and 1223 respectively.

This study's results agree with previous studies that demonstrated the presence of polypropylene the microplastic compounds in the raw water of treatment plants (Pivokonsky, 2018; Wang *et al.*, 2020; Tong *et al.*, 2020). Also, Luqman *et al.* (2021) found Polyethylene terephthalate, Low-density polyethylene in the water of treatment plants. Dronjak *et al.*(2022) observed Polyamide, Polypropylene, and Polyurethane as the microplastic compounds in raw and drinking water.

CONCLUSION

The current study appeared, according to FTIR examination, that the most critical types of microplastic compounds in water samples were Nylon, Polycarbonate, High-density polyethylene, Polystyrene, Polyamide, Polyethylene terephthalate, and Polyurethane, and Microplastics number was (17-62 MPs /L) in raw water, while in drinking water were (9-40 MPs/L). The fibers form is the predominant form of microplastics. This study is considered a new study due to fewer Iraqi studies conducted to detect microplastics in drinking water. This study encourages us to continue conducting similar environmental studies to detect the presence of microplastics in Iraqi water treatment plants in other regions.

GRANT SUPPORT DETAILS

The current study did not receive any financial support.

CONFLICT OF INTEREST

There is no conflict interesting

LIFE SCIENCE REPORTING

No life science menace was applied in this research.

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