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Microplastics Evaluation in Tap Water in Left Side Districts of Mosul City, Iraq

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ABSTRACT

Microplastics (MPs) are considered as recently identified pollutants in the tap water of Mosul city. Limited studies on the quantity and features of microplastics have been reported. Consequently, this study examined the number and characteristics of MPs in tap water from 16 districts in left side of Mosul city, including 8 districts that receive drinking water from the Alaysar aljadid drinking water treatment plant (AJ-DWTP) and 8 districts that receive drinking water from the Alaysar alqadim drinking water treatment plant (AQ-DWTP). Infrared Fourier-transform spectroscopy (FTIR) and stereo microscopy were used to determine the microplastic abundance, polymer type, and morphology characteristics (colour and shape). The results showed that the abundances of MPs calcualted in tap water in AJ-WDN and AG-WDN were 35 to 70 items/L and 25 to 71 items/L, respectively. The predominant shape of microplastics was fiber and fragment, accounting for 93% of the identified quantities. The most common polymer types were polyvinyl chloride (PVC) (51%) followed by polyamide (PA) (16%). Statistical analysis was conducted on the results using Exel 2019. The microplastic's risk has been estimated based on the potential risk index of polymers. In both the water distribution networks of AQ and AJ, MPs' potential risk was significantly similar.

Keywords: microplastics, drinking water treatment plant, Fourier transform infrared spectroscopy, steromicroscope, tap water.

INTRODUCTION

Since 1970, plastic materials have been widely used due to their desirable properties, including strength, versatility, and economy (Almaiman et al., 2021). Globally, it has grown from 1.5 million tons in 1950 to 359 million tons in 2018 (Singh et al., 2022). Approximately, it is expected that the production of plastics will be aournd thirty three billion tons by 2050, according to estimates (C. Wang et al., 2022). There are several polymer types of plastics, including polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), polyethylene terephthalate (PET), and polyamide (PA) (Waldschlager, 2021).

Plastic pollution is considered as a main environmental problem. There are several types of microplastics: solid particles with regular or irregular shapes, and polymeric matrix particles in the range of (1 µm to 5 mm) in size (Munhoz et al., 2023). In addition, microplastics can be classified according to their origins into primary or secondary (Feld et al., 2021). Noting that the primary is already fabricated on the microscale, while the secondary results from plastic decomposition because of weathering (Park and Park, 2021).

Microplastics (MPs) have been found in many categories including sediments, food products, oceans, bottled water, freshwater, wastewater, air, tap water, and aquatic organisms (Singh et al., 2022). Tap water from different sites around the world has been detected by more scientists since 2018 (Weber et al., 2021).

Due to their small size, MPs can easily enter food chain and negatively impact organisms as well as humans (Yan et al., 2019). A study claimed that stratum corneum cells can take up MPs with tiny sizes (0.25 ± 0.06 μm) (Triebskorn et al., 2019). In the brain and epithelium, microplastics induce oxidative stress (Schirinzi et al., 2017). MPs speared in the body and particles with sizes lower than 500 μm can pass into the wall of the gut (Lusher et al., 2017). Liver and kidneys accumulate microplastics less than 20 millimeters (Deng et al., 2017). Microplastics present potential risks that should not be ignored, according to this facts.

Few research papers have examined MPs contamination in tap water (Semmouri et al., 2022; Tong et al., 2020; Kosuth et al., 2018). It is critically significant to observe that microplastics in tap water are largely dependent on both initial raw water concentrations and treatment methods used in DWTPs. The existence of microplastics in pipe scale samples from DWTPs and water samples, and distribution systems (DWDS) has been observed in a previous study (Chu et al., 2022). MPs can be released from aged plastic pipes as a result of aging mechanism and certain characteristics of plastic materials (Koelmans et al., 2019b). MPs may be emitted under influence conditions from long-time old plastic pipe materials (Zhang et al., 2022). Tap water may contain MPs due to the use of PVC, PE, or PP in pipes (Tong et al., 2020). Water purification or transport, abrasion of plastic equipment (among these materials are PA, PVC, and PE, which are commonly used in pipes) has been considered a potenial source of microplastics in drinking water (Koelmans et al., 2019b). It has been reported that drinking water contained in microplastics, where their compositions including polymer similar to those used in water packaging, purification, and transportation, and this could be a source of microplastics into drinking water (Fischer et al., 2019). The microplastic existed in tap water is regarded as a secondary contamination caused by eroded plastic from pipes used in water supply systems (Moraczewska-Majkut and Nocoń, 2022).

Microplastic pollution varies dramatically across regions due to regional differences in economic growth and levels of waste management. Thus, understanding the level of contamination of MPs in tap water within certain areas is important and necessary. In addition to establishing awareness of microplastic pollution, understanding the presence of MPs in tap water will contribute as a feedback for data collection within worldwide efforts and studies for microplastic pollution reduction.

To study the presence of microplastics in tap water, we selected Mosul city as the study location. Microplastic shape, polymer type, and colour in tap water were calculated by the use of both Fourier-transform infrared spectroscopy (FTIR), and steromicroscope (SM) from 16 locations, and potential risks to human health were assessed. The main purpose of the current study is to identify the quantities and characteristics of MPs in tap water, in order to establish a basic research foundation for the study of microplastic environmental effects.

MATERIALS AND METHODS

Data collection

A number of tap water samples (n=48) were collected in 16 districts of Mosul city from October 2022 to February 2023, 8 districts supplied water from Alaysar aljadid (AJ) drinking water treatment plant (DWTP) and the other 8 districts supplied water from Alaysar alqadim (AQ) DWTP as shown in Figure 1. Table 1 shows the areas supplied by these drinking water treatment plants. As well as, Table 2 provided by the Nineveh water directorate in Mosul city about pipeline type in the areas selected for sampling collection.

Before collecting samples from randomly selected houses, water was allowed to flow out for about five minutes, and glass bottles were washed with distilled water (Sanz-Lázaro et al., 2022). Water samples were obtained in triplicate in one-liter glass bottles and then sent for more analysis in the laboratory (Zhang et al., 2020).

Segregation of microplastics

By vacuum filtration, particle plastics were extracted from the water sample and analyzed quantitatively and qualitatively in the laboratory using a 0.45 m cellulose nitrate filter (CHMLAB GROUP, Spain). Ultrapure water was used to rinse the filter. The microplastic loaded membranes were put to glass petri dishes and stored in room temperature.

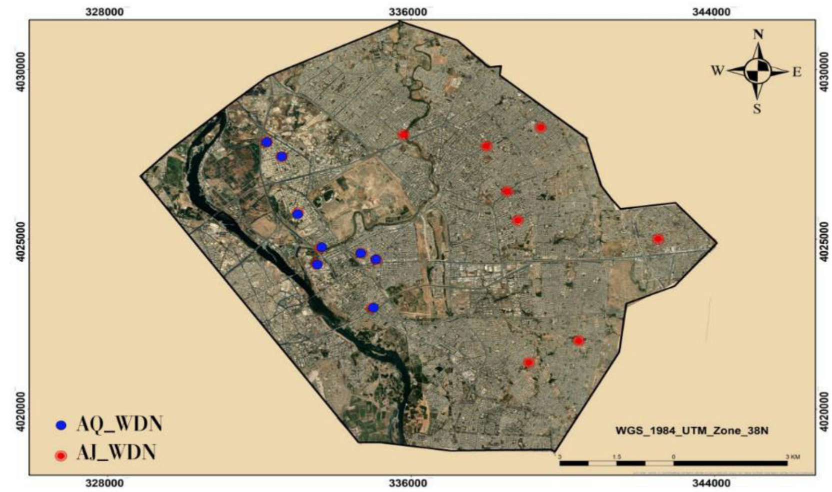

Figure 1. Sampling sites in districts supplied by AJ-DWTP and AQ-DWTP

Table 1. AJ-DWTP and AQ-DWTP provide drinking water to the following districts

DWTP	Districts
Alaysar aljadid (AJ-DWTP)	Bakr-Zahraa-Noor-aaden-Cokagaly-Qodes-Taamim-Karama-Wahda-Mythaq-Antesar. Faalah-Zuhor-Masaref-Qadisiyah-Tahrir.
Alaysar alqadim (AQ-DWTP)	Andallas-Shartah-Almajmuaa althaqafia-Nargal-Muhandesin-Zaraay-Faisaliah-Nabi younis Nuamaniyah-Maleyah-Dubbat.

Table 2. The areas selected for sampling collection and their pipes manufacturing material

DWTP	Sampling site	Pipe manufacturing material
AJ-DWTP	Sukkar	DI (Ductile Iron)
	Berid	PVC
	Cokagaly	PVC
	Qadisiyah	PVC
	Noor	DI
	Bakr	PVC
	Wahadah	PVC
	Antesar	PVC
AQ-DWTP	Andallas	PE
	Zaraay	PE
	Nabi younis	DI
	Mohandesin	PVC
	Alshartah	PVC
	Alfaisaliah	PVC
	Alnuamaniyah	PVC
	Almaleyah	PVC

Quantitative and qualitative analysis of MPs

Stereomicroscopy (Motic2300S-V37-45X Zoom, Italy) was used to observe and image MPs accumulated on the cellulose nitrate filter (0.45 µm). The microplastics were classified into many categories based on their form: fiber, fragment, film, foam and others (Shao et al., 2022). They were also classified according to colour: transparent, blue, black, red, green, white, orange, yellow (Hidalgo-Ruz et al., 2012). Also, it is important to verify the composition of polymer, preferably by the use of Fourier transform infrared spectroscopy (IRAffinity-1S, SHIMADUZ, Japan). It was noted that the measured range was from (4000 cm^{-1} to 600 cm^{-1}) and the time of sample acquisition was 3 seconds. Each measurement received fifteen scans. The spectrographic degree of resolution was 4 cm^{-1}.

Microplastic particle is placed under the sample presser and sample controls the pressure applied to the sample using the built-in pressure sensor. APC program or an operation panel on the accessory can control the drive of the auto sample presser. Then, by comparing the spectra obtained with the databases from previous references to determine the type of polymer (Dalmau-Soler et al., 2022). The methods used to analyze MPs in this study can be seen in Figure 2.

DATA ANALYSIS

As a measure of microplastic abundance, items/liter was reported. As the result of analyzing each sample in triplicate, the microplastic abundance was expressed as the mean ± the standard

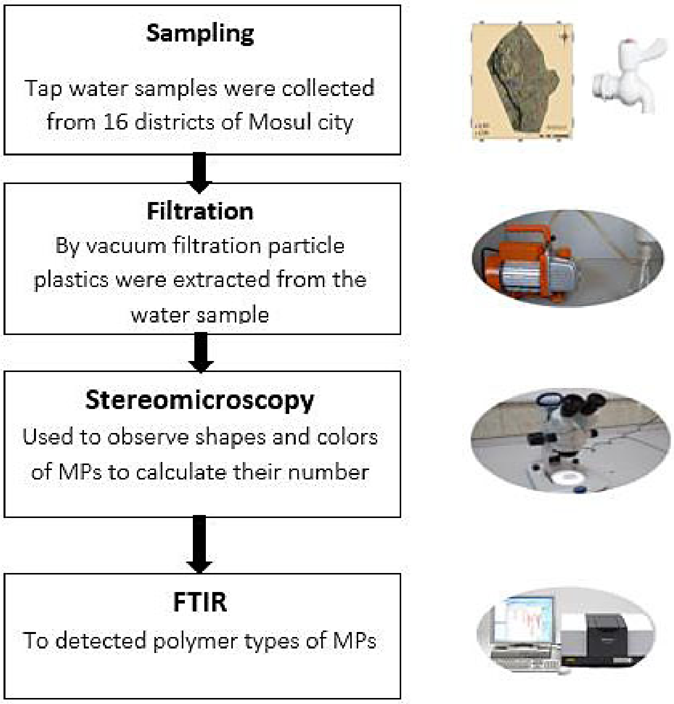

Figure 2. A graphic diagram of the procedure used for MPs analysis in this study

deviation. Microsoft Exel 2019 software was used for all statistical analyses by using ANOVA single factor. If difference in MPs number between districts (ΔMPs) more than Least Significant Differences (LSD) defined as significant difference, whreas ΔMPs were less than LSD defined as insignificant difference. LSD value calculated by following equation (Herv, 2010):

$$\mathrm{LSD} = t \propto \sqrt{2MSE/\mathrm{n}} \tag{1}$$

where: t – critical value acquired from t distribution table,
MSE – mean square within obtained from results of ANOVA table,
n – number of observations to find the means.

RESULTS AND DISCUSSION

Contamination level of microplastics in AJ-water distribution network and AQ-water distribution networks

The microplastics abundance in the both AJ-WDN and AQ-WDN were ranged from 25 to 71 items/L reaching an average of 50 ± 12 items/L. A previous study (Kosuth et al., 2018) in Beirut, Lebanon, reported MPs concentrations in the tap water of 0 to 61 particles/L, attracting significant media coverage.

The microplastic obtained in AJ-WDN from 35 to 70 items/L reaching an average of 53 ± 10 items/L, whereas, the microplastic existed in AQ-WDN was from 25 to 71 items/L with an average of 47 ± 13 items/L. Also, the average of MPs in tap water from a number of sites is depicted in Figure 2. In Mexico, Shruti et al. (2020) found that concentrations of microplastics in tap water within public fountains ranged from 5 to 91 particles per liter (a mean of 18 to 7 particles per liter). MPs have been found in drinking water, which may be caused by plastics used in the manufacture of water distribution network pipes (Zhang et al., 2022). Also a lots of studies (Whelton and Nguyen, 2013), mentioned that drinking water containing microplastics supported with polymer compositions resemble those found in equipments manufactured with plastic, containers, and packaging used for water purification, transportation, and packaging could be an entry point for MPs.

In the AJ-WDN, the mean number of MPs in districts at the Antesar, Bared, Bakr, Qadisiyah, Wahadah and Cokagaly were 62 ± 7, 62 ± 4, 60 ± 5, 56 ± 6, 53 ± 4 and 52 ± 5 items/L, respectively. While the MPs levels with minimum values in the districts of Sukkar and Noor were 40 ± 4, and 37 ± 3 MPs/L, respectively. Statistical analysis showed that the difference of each district with others districts was significant (ΔMPs > LSD), expect the difference between (Sukkar

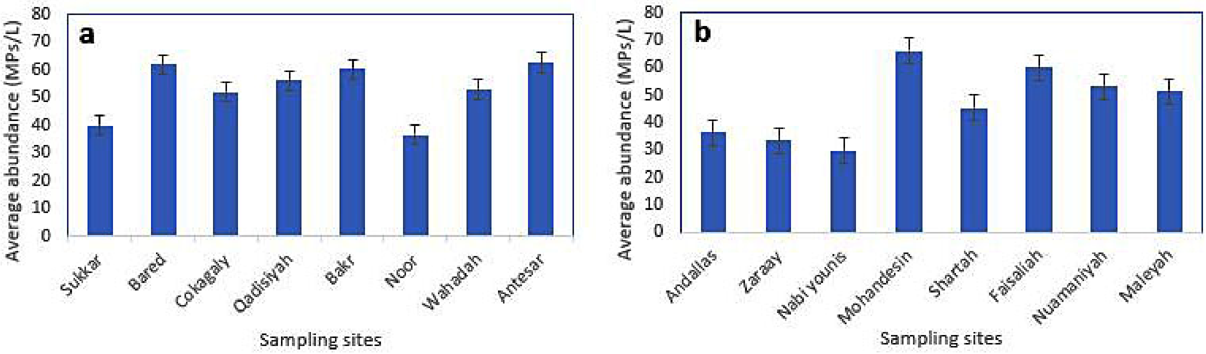

Figure 3. Average abundance of microplastics in selected districts of (a) AJ-WDN and (b) AQ-WDN

and Noor), (Bared, Antesar and Bakr), (Cokagaly and Wahadah) and (Qadisiyah and Wahadah) was insignificant (ΔMPs < LSD).

In the AQ-WDN, the microplastics mean abundance within the districts of (Mohandesin, Faisaliah, Nuamaniyah, Maleyah, and Sharta) was as follow: 66 ± 4, 60 ± 7, 53 ± 7, 51 ± 4, and 45 ± 5 MPs/L, respectively. Whereas the Andallas, Zaraay, and Nabiyounis districts were low: 36 ± 3 and 33 ± 6, 30 ± 5 MPs/L, respectively. Statistical analysis showed that the difference of each district with others districts was significant (ΔMPs > LSD), expect the difference between (Zaraay and Andallas), (Zaraay and Nabi Younis), (Alnuamaniyah and Almaleyah) was insignificant (ΔMPs < LSD). The Clear difference between mean number of MPs may be due to the pipes age, pipes manufacturing material (Moraczewska-Majkut and Nocoń, 2022).

The reasons of insignificant in some districts (Sukkar, Noor, Bared, Bakr, Antesar, Cokagaly, Wahadah, Nabi Younis, Zaraay, Andallas, Alnuamaniyah and Almaleyah) may be due to the pipes being made of ductile iron in these areas (Sukkar, Noor and Nabi Younis) as seen in Table 2, also the Plastic pipes changed mechanical, surface, and morphological characteristics after being exposed for long-term to water containing free chlorine may be reason for other districts Based on Gill et al. (1999), many properties can affect these changes such as temperature, free chlorine concentration, pH, exposure time and pressure.

In both AJ DWTP and AG DWTP the concentrations of microplastic abundance in raw water were approximately the same ranged from (111 to 136 items/L) reaching an average of (122 ± 9 items/L). While, the concentrations after tretment by DWTPs from (32 to 46 items/L) reaching an average of (39 ± 5 items/L). As a result, plastic pipes and raw water are the primary sources of MPs in DWNs. In general, in the present work, the multitude of MPs in tap water and raw water was comparatively high in comparison to readings determined by other studies.

Features of MPs in tap water from AJ and AQ WDN

Microplastic shapes

Different forms of microplastics are distributed in tap water over the entire sampling sites. Microplastic fibers and fragments were regarded as the most widespread form in this study (Fig. 4).

Approximately, 93% of microplastics were fibrous and fragment followed by foam 2–3%, film 1–3% and others 2%. (Feld et al., 2021) Past

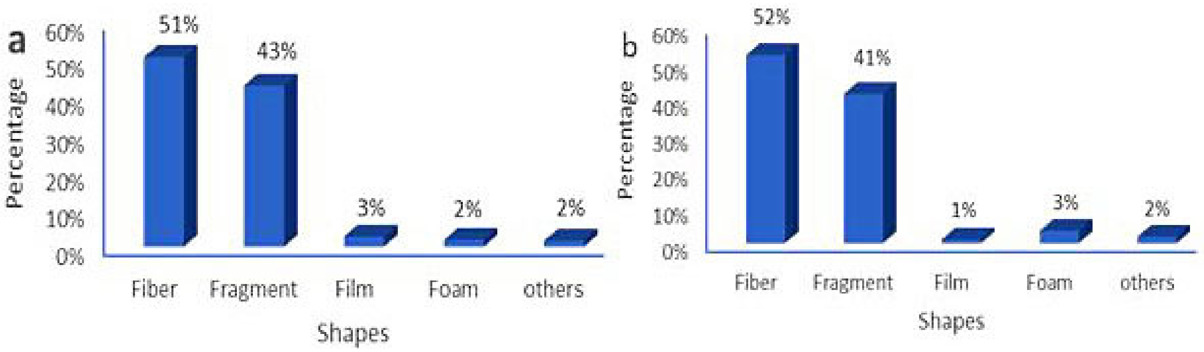

Figure 4. Percentage of microplastic shapes in selected districts of (a) AJ-WDN and (b) AQ-WDN

study mentioned that the MPs in tap water are frequently tabulated under three primary shape levels: fiber, irregular, and Pellet. Typical microplastics shapes are displayed in Figure 5.

Microplastic colours

Various colours of MPs exist, including transparent, blue, black, red, orange, yellow, and white (Ren et al., 2020), and this is an essential characteristic to take into consideration to know the MPs's sources as depicted in Figure 6. MPs vary in colour depending on the region. The most frequently identified MPs in Tap water of China (Zhao et al., 2022) were black, white, red ,blue, green, gray and transparent.

Microplastics colours in AJ-WDN were transparent (48%), black (13%), blue (11%), red (10%), orange (5%), white (4%), green (4%), yellow (2%) and others (1%). While in AQ-WDN were mostly transparent (45%), black (16%), blue (17%), red (8%), orange (2%), green (4%), white (6%), yellow (1%) and others (2%). The dominant colours of the MPs were transparent, followed by black, blue and others colours. In

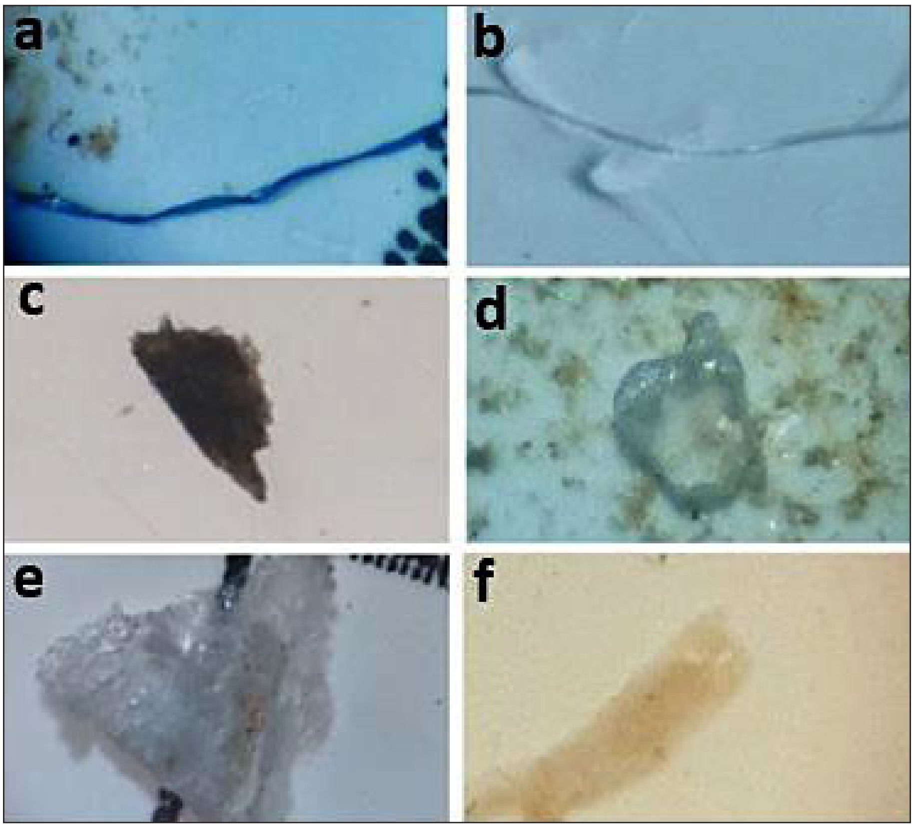

Figure 5. Images of microplastics, where (a) and (b) are fibers, (c) and (d) are fragments, (e) are foam, (f) are (film)

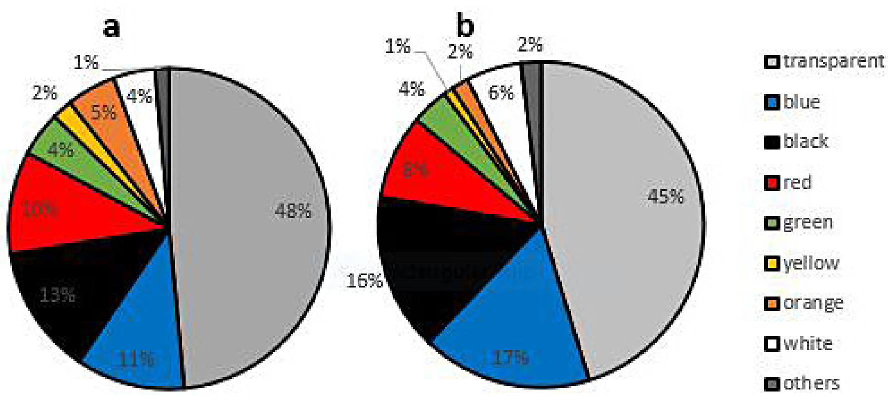

Figure 6. The colours of MPs in selected districts of (a) AJ-WDN and (b) AQ-WDN

recent years, the colour of the MPs in Tap Water in Hong Kong were blue, yellow, white, black, and transparent microplastics (Lam et al., 2020) and the presence of microplastics in tap water has received considerable attention in recent years. Although microplastics in drinking water pose a low concern for human health at current levels of exposure, there is a need to understand the potential pathways for human microplastic exposure. With the application of Rose Bengal staining, microplastics in 110 surface water-sourced tap water samples from urban sources in Hong Kong were qualified and morphologically characterized. A total of 224 items were identified in 86 (78.2%, while the transparent microplastics is considered as the dominant type, then followed by other colours (Wang F. et al., 2022) according to the main source of examined plastic particles.

Composition of microplastics

The findings revealed that a total of 2394 microplastics were detected. There were five polymer types detected in the tap water (Figure 7).

The polymer types in both districts of AJ-WDN and AQ-WDN were as follow; PVC 50–52%, PA 15–17%, PET 12–14%, PE 9–12%, PP 2–5%, PS 2–3% and Non identified 3–5%. PVC, PA, PET, and PE, where these polymers are frequently the material of plastic pipes, are considered a likely source of microplastics in drinking water because of pipe abrasive, release of polymers, the breakdown of additives, and leaching of metals (Koelmans et al., 2019a; Whelton and Nguyen, 2013). Moreover, the highest percentage of PVC at each WDN may be due to use widely the pipes of PVC in drinking water networks in Iraq as depicted in Table 2. It is measured that PVC pipes constitutes 66% of the overall buried drinking water distribution pipe system globally as reported by (Whelton and Nguyen, 2013). The presence of other types of plastic polymers (PET, PE, PP and PS) in tap water are because of their initial concentration in raw water intake in addition to the used treatment method in water treatment plants (WTPs) (Eerkes-Medrano et al., 2015; Dalmau-Soler et al., 2022). In addition, a PA is the base material for nylon, which is widely used in clothing, household products, and various industrial applications (Michler-Kozma et al., 2022).

POTENTIAL RISK EVALUATION OF MICROPLASTICS

To evaluate the MP ecological risks, classical methods were used (Delta et al., 2022). Following is an expression of the related model:

$$\mathrm{RI} = \sum_{i=1}^{n} Ei \,,\; Ei = Ti \times \left(\frac{Ci}{C0}\right) \qquad (2)$$

It is noted that both (*RI* and *Ei*) represent potential environmental risk factors, while *Ti* represents coefficient of chemical toxicity of constituent polymer, and *Ci*/*C*0 represents the ratio of measured concentration microplastics to background concentration, respectively. In this study, the lowest concentration of MPs can be defined as background value because of shortage of background data. In Table 3, various risk levels are presented based on *Ei* and *RI*.

Microplastics pose some potential risks in selected districts of both AJ-WDN and AQ-WDN, according to a preliminary assessment. We calculated the potential risks of five types of polymers

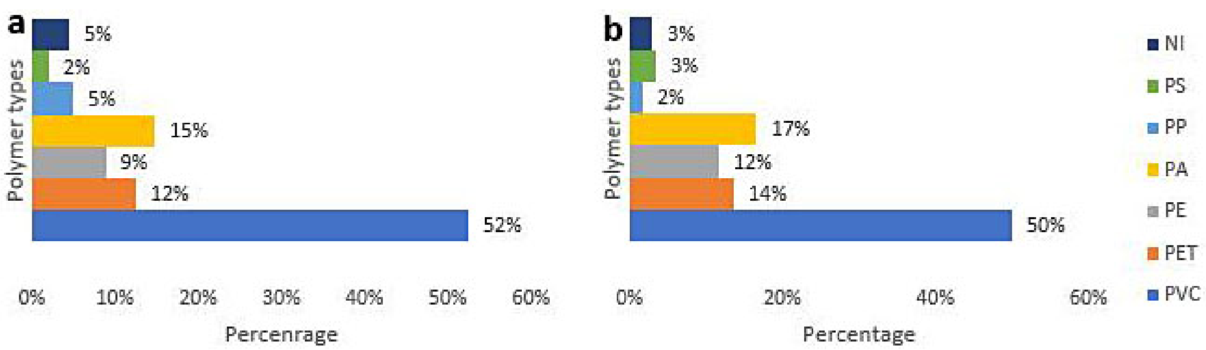

Figure 7. Polymer types percentage of microplastics in selected districts of (a) AJ-WDN and (b) AQ-WDN. Polymer identification: PVC – polyvinyl chloride, PA – polyamide, PET – polyethylene terephthalate, PE – polyethylene, PS – polystyrene, NI – non identificated polymer

Table 3. Risk categories associated with microplastics (Delta, Liu and Lai, 2022)

Potential single risk index Ei	Risk category	Potential risk index RI	Risk category
40>	Minor	150>	Minor
80-40	Medium	300-150	Medium
160-80	High	600-300	High
320-160	Danger	1200-600	Danger
>320	Extreme danger	1200<	Extreme danger

Table 4. Potential risk of different microplastics in selected districts of AJ-WDN

Polymer type	MPs/L	Ci/C0	Ti*	Ei	Risk category	RI	Risk category
PVC	27.67	0.84	10551.00	8845.79	Extreme danger	8860.894	Extreme danger
PET	6.58	0.20	4.00	0.80	Minor		
PE	4.67	0.14	11.00	1.56	Minor		
PA	7.79	0.24	50.00	11.81	Minor		
PP	2.63	0.08	0.00	0.00	Minor		
PS	1.04	0.03	30.00	0.95	Minor		
NI	2.38	0.07	0.00	0.00	Minor		

Table 5. Potential risk of different microplastics in selected districts of AQ-WDN

Polymer type	MPs/L	Ci/C0	Ti*	Ei	Risk category	RI	Risk category
PVC	23.42	0.71	10551.00	7486.95	Extreme danger	7502.822	Extreme danger
PET	6.38	0.19	4.00	0.77	Minor		
PE	5.46	0.17	11.00	1.82	Minor		
PA	7.79	0.24	50.00	11.81	Minor		
PP	0.79	0.02	0.00	0.00	Minor		
PS	1.63	0.05	30.00	1.48	Minor		
NI	1.42	0.04	0.00	0.00	Minor		

in tap water within 16 districts. The results exhibited that *RI* value of AJ-WDN measured 8860.894 as in Table 4, while *RI* value of AQ-WDN measured 7502.822 as in Table 5. It is noted that the MPs potential risk was significantly convergent in each of the AQ-WDN and the AJ-WDN. On the other hand, PVC's *Ei* values were both high in Tables 4 and 5; their high *Ei* is due to their high *Ti*. A polymer with a high *Ti* value may dominate *RI* ranges because of the huge differences in values of *Ti* between these types of polymers. The current study has only offered an index with too limited potential risk of limited polymer, where this index is measured according to the monomer (Lithner et al., 2011).

CONCLUSIONS

During this study, MPs are detected in tap water of Mosul city, which examined the factors contributing to their presence. There was evidence of microplastic contamination at every sampling site. It was observed that most microplastics were fibres and fragments (93%) in transparent, white, blue, red, black, green, orange, yellow, and other colours. Among the polymers, poly vinyl chloride (PVC) and poly amide were most abundant. Microplastic concentrations in tap water were relatively high compared to other studies, indicating that DWTPs cannot remove all particles and MPs released from aged plastic pipes in districts. PVC's *Ei* values were high in both the AJ and AQ WDN due to their high *Ti* value in this study, indicating a potential risk assessment associated with the polymer risk index. Other polymer types have very low *Ti* values, which could lead to PVC with a high *Ti* value dominating *RI* ranges. The difference of each district with others districts was significant at (ΔMPs>LSD), expect the difference between some districts were insignificant.

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