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Evaluation of Microplastic Pollution in Water of Shatt Al-Arab River, Southern of Iraq

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ABSTRACT

Due to the increasing use of plastics in various areas of life and the difficulty of their degradation in the environment, they have negative effects on the aquatic environment and health. Surface water samples were collected from four selected sites along the Shatt al-Arab River monthly for the period from October 2023 to March 2024 to investigate the microplastic contaminant. Water samples were passed through sieves with mesh sizes of 2000, 500, 125, and 63 microns. Microscopic fragments were collected from each sieve for further analysis. Microscopic examination confirmed the presence of microplastics at all sampling sites, which included strands, fibers, irregular fragments, and threads—these forms were prevalent across all detected samples. Energy-dispersive X-ray spectroscopy (EDX) analysis detected carbon spectra in several water samples: at the Qarmat Ali site (sizes 500, 125, and 63 microns), the Bradyia site (sizes 500 and 63 microns), and the Mahila and Al-Muqal sites (sizes 500 and 125 microns). However, no carbon element was detected at the Bradyia site for the 125-micron and 63-micron fractions. Fourier-transform infrared spectroscopy (FTIR) analysis revealed the presence of functional groups such as C–H, C=C, C=O, C–C, C–Cl, Fe–O, Si–O, and Al–O in microplastics retained in the 500, 125, and 63-micron size fractions. Additionally, CHNOS elemental analysis showed that carbon concentrations in the water samples were very low.

INTRODUCTION

We are currently living in what can aptly be called the "Plastic Age"—a period in which plastics have become the most widely used material by humans since their commercial development in the 1930s, due to their versatility and numerous advantages **(Geyer *et al.*, 2017; Kye *et al.*, 2023)**. Despite these benefits, plastics are extremely durable and can take decades—or even centuries—to degrade **(Hoornweg & Bhad-Tata, 2012)**, contributing to the global environmental crisis of anthropogenic waste **(Godoy *et al.*, 2020)**.

Among the various types of waste, plastic is particularly concerning because it does not fully decompose; instead, it fragments into smaller particles over time **(Chandra & Walsh, 2022; Ding *et al.*, 2022)**. These small fragments—often referred to as microplastics—have a large surface area and hydrophobic properties, enabling them to interact readily with pollutants in aquatic environments and adsorb significant quantities of organic contaminants **(Shen *et al.*, 2024)**. Since the early 20th century, plastics have been widely utilized in industrial applications and consumer goods due to their light weight, durability, and ease of production **(Al-Zawar *et al.*, 2023)**. However, this widespread use has led to extensive environmental consequences.

Microplastics, which are tiny plastic particles derived from both primary sources (e.g., personal care products and air-blasting media) and secondary sources (e.g., the fragmentation of larger plastic debris), have become increasingly prevalent pollutants in river systems worldwide **(Hussein *et al.*, 2022)**. Rivers serve as major conduits for transporting these microplastics to marine ecosystems and estuaries **(Al-Zawar, 2023)**.

Once ingested by living organisms, microplastics can cause a range of health and ecological issues. These include digestive system blockages that may lead to starvation and death **(Ibrahim *et al.*, 2025)**, as well as behavioral and physiological changes in aquatic species. In humans, exposure has been associated with toxic effects on the gastrointestinal and respiratory systems and may even contribute to carcinogenic risks due to the chemical properties of plastics and their additives **(Hussein, 2022)**.

Moreover, rivers—already burdened by pollution from domestic, industrial, and agricultural sources—are further threatened by the accumulation of household and industrial waste driven by population growth and expanding manufacturing activity. This makes natural self-purification increasingly difficult **(Gatea, 2018)**. Plastic pollution in rivers has thus emerged as a significant global environmental issue, with persistent organic pollutants accumulating on plastic surfaces, further endangering aquatic ecosystems.

Compounding the problem, many plastic products contain harmful additives that worsen their environmental impact. Despite the high rates of plastic production and consumption in southern Iraq, studies investigating their environmental distribution remain scarce **(Naser *et al.*, 2022)**. Therefore, the present study aimed to assess the extent of microplastic pollution in the waters of the Shatt al-Arab River.

MATERIALS AND METHODS

Water samples were collected monthly from October 2023 to March 2024 at four sites along the Shatt al-Arab River in Basrah Governorate, southern Iraq: Mahila, Bradyia, Al-Muqal, and Qarmat Ali (Fig. 1). At each site, 50 liters of water were filtered using a series of stainless steel sieves arranged in descending mesh sizes (2000, 500, 125, and 63 microns).

Microplastics retained on each sieve were collected directly in the field by rinsing the sieves with distilled water. The collected materials were stored in clean glass bottles and were preserved for transport to the laboratory for subsequent chemical analysis **(Chen *et al.*, 2023)**.

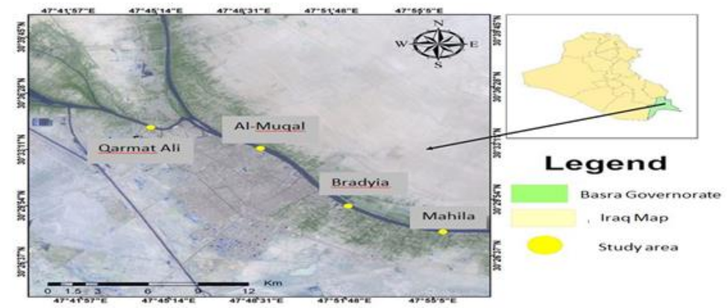

Fig. 1. Map of water sampling sites

Physico-chemical parameters

Physico-chemical parameters such as water temperature (°C), pH, electrical conductivity (mS/cm), free carbon dioxide (mg/L), dissolved oxygen (mg/L), biochemical oxygen demand (BOD, mg/L), and turbidity (NTU) were measured according to the standard methods outlined by **APHA (2017)**.

Microplastic in water

Water samples (50 liters per site) were collected monthly from October 2023 to March 2024. Samples were passed directly in the field through a series of stainless steel sieves arranged in descending order by mesh size: 2000, 500, 125, and 63 microns. Microplastics retained on each sieve were rinsed with distilled water, and the suspended materials were collected in clean glass bottles. The samples were stored until arrival at the laboratory for further chemical analysis **(Taher & Saeed, 2023; Al-Azzawi *et al.*, 2024)**.

Dry weight determination

The dry weight of the collected microplastic samples was measured following the procedure described by **Masura *et al.* (2015)**. Samples were dried at 90°C until a constant weight was achieved.

Wet peroxide oxidation (WPO)

After drying, wet peroxide oxidation (WPO) was performed to remove organic matter from the samples. A 20mL volume of Fe(II) solution (0.05 M), prepared by dissolving 7.5g of $FeSO_4 \cdot 7H_2O$ in 500mL of distilled water, was added to each sample as a catalyst. This was followed by the addition of 20mL of 30% hydrogen peroxide (H_2O_2). The mixture was heated on a hot plate at 75 °C for 5 minutes until gas bubbles appeared, indicating oxidation.

Once cooled, 6g of sodium chloride (NaCl) was added per 20mL of sample to increase solution density. The samples were then transferred to a separation funnel, and the floating fraction was collected for microscopic examination.

Microplastics were identified and categorized under dissecting and light microscopes based on shape and color. Further identification of microplastic types was carried out using FTIR, CHNSO, and EDX analysis, as described by **Sadiq and Al-Hejuje (2025)**.

Statistical analysis

A completely randomized design (CRD) was employed. One-way analysis of variance (ANOVA) was conducted using Minitab version 16.1 software. Relative Least Significant Differences (RLSD) were calculated to determine the existence of significant spatial and temporal differences ($P \leq 0.05$). Pearson's correlation coefficients were used to assess relationships among variables **(Anber & Al-Hejuje, 2025)**.

RESULTS AND DISCUSSION

The results indicated that the physico-chemical characteristics of the water samples varied within the ranges presented in Table (1).

Table 1. Chemical and physical characteristics of surface water at Shatt Al-Arab sites

Parameter	Qarmat Ali Site	Al-maqal Site	Al-Bradyia Site	Mahila Site	Permissible values of drinking water (CCME, 2022)
Water Temperatur (C◦)	**16.9-29.25**	**16.9-26.6**	**16.8- 27.75**	**16.25-29.75**	**<35 ◦C**
pH	**8.09- 9.26**	**8.22-9.11**	**8.17-9.05**	**7.9-9.22**	**6.5-8.5**
EC. (mS/cm)	**2622- 3999**	**2644-3999**	**3120- 3999**	**2045-3999**	**1**
CO_2 (mg/L)	**6.99- 8.98**	**2.49-9.98**	**4.49- 14.98**	**3.99-15.48**	**25**
Turbidity (NTU)	**2.99-13.7**	**2.56-6.3**	**3.34- 12.85**	**3.67-36.55**	**5**
DO (mg/L)	**3.65- 7.35**	**3-5.35**	**3.1- 6.8**	**4 - 7.85**	**5**
BOD_5 (mg/L)	**0.25-3.85**	**0.15-1.95**	**0.85- 3.15**	**0.9- 4**	**5**

Differences in water temperature observed during the study period reflect seasonal variation, with higher temperatures recorded in October (summer) due to longer daylight hours and increased solar radiation. Conversely, the lowest temperatures were recorded in January (winter), attributed to shorter daylight periods and increased cloud cover, which absorbs part of the incoming solar radiation **(Al-Saad *et al.*, 2015; Rasheed *et al.*, 2024)**.

The pH values remained relatively stable throughout the study, showing limited fluctuations. This stability is characteristic of Iraqi surface waters, particularly the Shatt al-Arab, which contain high levels of carbonate and bicarbonate ions. These ions act as natural buffers, preventing extreme shifts in pH **(Al-Kanani, 2024)**. However, slightly lower pH levels were observed during hotter months, likely due to the biological degradation of organic pollutants that release carbon dioxide into the water, thereby lowering the pH **(Al-Hejuje, 2014)**. In contrast, higher pH levels in winter may be due to rainfall, lower temperatures, and the influx of dissolved salts from surrounding lands **(Al-Zubaidi, 2023)**.

Electrical conductivity was at its lowest value in March, which can be attributed to reduced evaporation, lower ambient temperatures, rainfall, and increased water discharge during sample collection—consistent with findings by **Al-Zubaidi (2023)**.

The concentration of free carbon dioxide was influenced by the degradation of organic matter. High CO_2 levels were associated with active decomposition, while reductions were linked to elevated photosynthetic activity or loss of CO_2 through evaporation under high temperatures **(Al-Hejuje, 2014)**.

Turbidity in water was primarily caused by suspended clay, silt, and organic matter, such as plant residues and microorganisms. These particulates reduce water quality and interfere with treatment processes. The highest turbidity levels were observed in March, attributed to reduced discharge from the Tigris, Euphrates, and Karun rivers, in addition to wastewater inputs and disturbances caused by ship and boat traffic **(Al-Tamimi, 2022)**. The growth and blooming of phytoplankton and microorganisms further contributed to increased turbidity **(Hamdan *et al.*, 2018)**.

Dissolved oxygen (DO) is essential for aquatic life. Low DO levels in warmer months were likely due to increased microbial activity and higher temperatures, which reduce the solubility of gases in water **(Moyel & Hussain, 2015)**. Higher DO levels in the Shatt al-Arab River may result from tidal mixing and oxygen production through photosynthesis by phytoplankton and aquatic plants **(Adlan & Al-Abbawy, 2022)**.

The observed decrease in biochemical oxygen demand (BOD) may be attributed to the dilution of organic pollutants by large volumes of freshwater. Additionally, lower water temperatures in winter reduce the rate of organic matter degradation and consequently decrease oxygen consumption **(Al-Baghdadi *et al.*, 2019)**.

Statistical analysis showed no significant differences ($P > 0.05$) in the number of microplastic particles among the four sampling sites. For the 63-micron size class, particle counts ranged from 0.180 pieces/L at Qarmat Ali to 0.206 pieces/L at the Al-Muqal site.

Morphologically, most microplastic particles were in the form of threads, followed by fibers, and then irregular fragments. The dominant colors identified were black, white, blue, and red. These findings are consistent with the observations reported by **Ismanto *et al.* (2023)**.

The highest monthly concentration of microplastics was recorded in February (0.346 pieces/L), while the lowest was observed in October (0.106 pieces/L), as illustrated in Fig. (2).

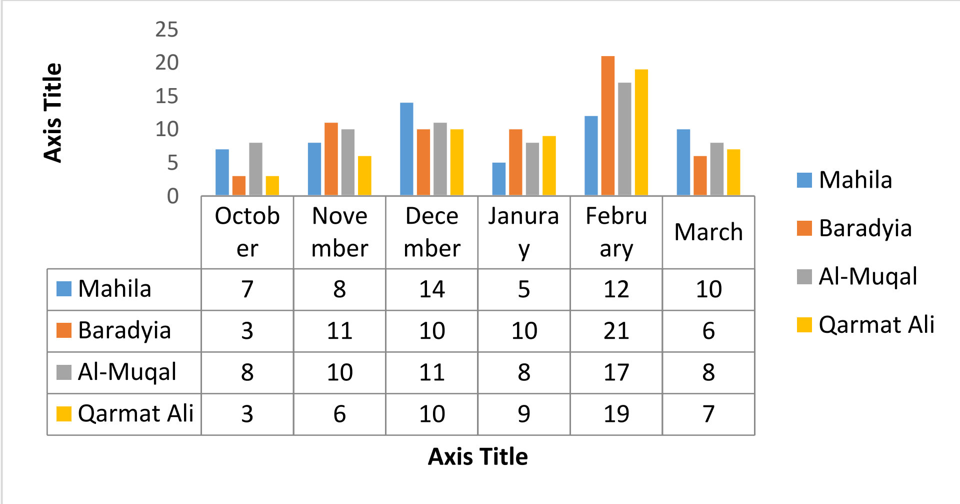

Fig. 2. Average numbers of microplastic pieces (63um) in water samples

For microplastics in the 125-micron size category, the results of statistical analysis showed no significant differences (*P*> 0.05) in particle abundance among the different sampling sites. The number of microplastic particles ranged from 0.206 pieces/L at the Qarmat Ali site to 0.370 pieces/L at the Mahila site. Most of the particles were thread-like in shape and predominantly colored black, white, blue, and red. Similar to the 63-micron size class, no significant spatial differences were observed in microplastic abundance (Fig. 3). These findings are consistent with those reported by **Gafil and Alwan (2021)**.

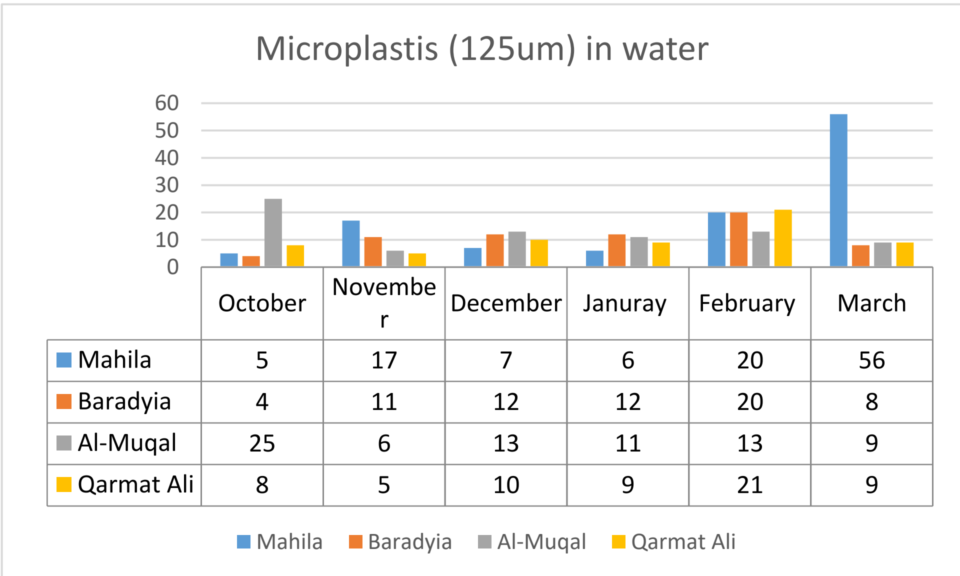

Fig. 3. Average numbers of microplastic pieces (125um) in water samples

The results showed no significant differences (*P*> 0.05) in the abundance of microplastic particles (500 microns) among the different sampling sites. The number of particles ranged from 0.140 pieces/L at the Qarmat Ali site to 0.176 pieces/L at the Mahila site (Fig. 4). Most of the microplastics were thread-like in shape and were primarily colored black, blue, red, yellow, and purple. These findings also revealed no statistically significant variation in particle abundance across sites (*P*> 0.05), consistent with the observations reported in previous studies **(Al-Sarraj & Al-Ahmady, 2022)**.

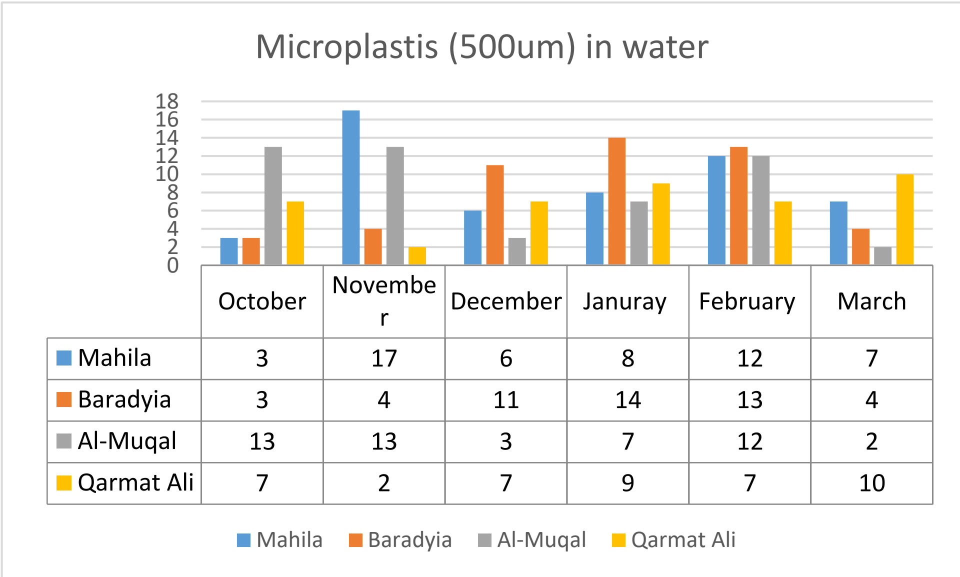

Fig. 4. Average numbers of microplastic pieces (500 um) in water samples

Anatomical microscope examination

Generally, Mahila site was the most contaminated with microplastics while the Qarmat Ali site was the least contaminated. The results of the current study showed the presence of microplastics in all samples that represented strands, fiber and irregular pieces and threads were prevalent in all species.

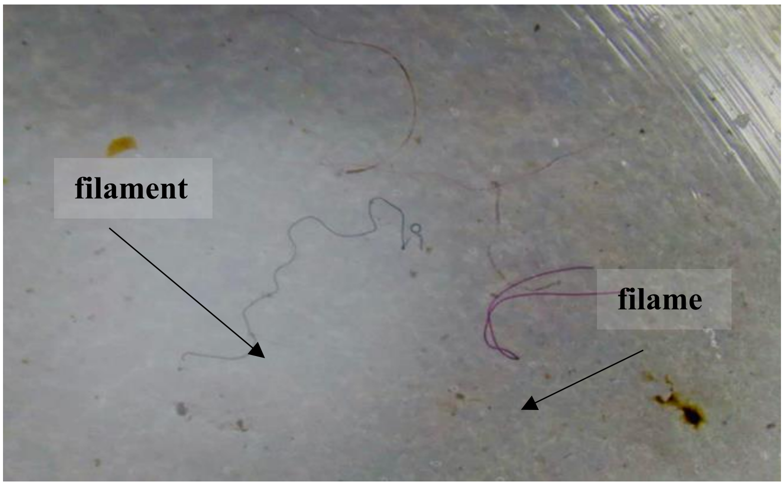

Fig. 5. microplastics at Mahila site (100 x)

The results of FTIR analysis revealed the presence of functional groups including C–H, C=C, C=O, C–C, C–Cl, Fe–O, Si–O, and Al–O in water samples collected from the study sites in the 500, 125, and 63 micron size fractions (Fig. 6). Based on the identified functional groups, most of the microplastic particles were classified as polystyrene, followed by polyethylene terephthalate (PET). These findings are consistent with those reported in previous research work **(Gafil & Alwan, 2021)**.

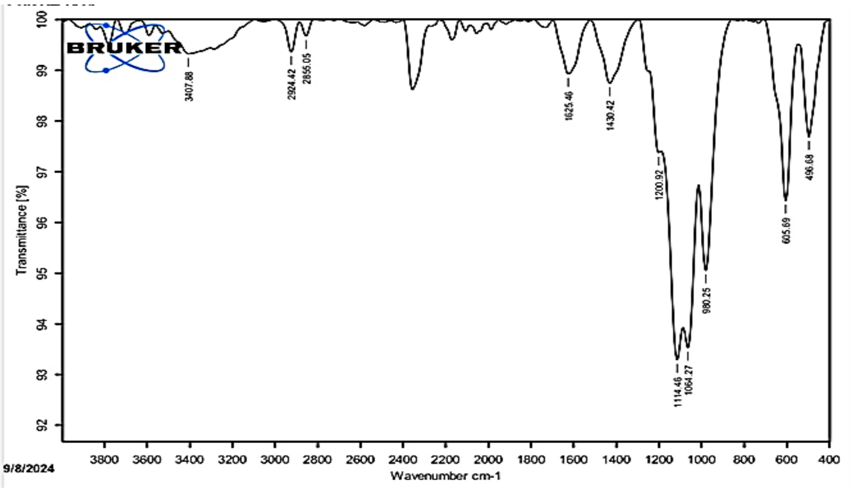

Fig. 6. Infrared spectrum FTIR in water samples at Qarmat Ali site size (500 micron)

The results of EDX (Energy Dispersive X-ray) analysis revealed the presence of carbon in several water samples. Carbon peaks were detected at the Qarmat Ali site in the 500, 125, and 63 micron size fractions, at the Al-Muqal site in the 63 micron fraction, and at the Bradyia site in the 500 and 63 micron fractions. Similarly, carbon was observed at the Mahila site in the 500 and 125 micron fractions (Fig. 7).

However, no carbon signals were detected at the Al-Muqal site in the 500 and 125 micron fractions or at the Bradyia site in the 125 and 63 micron fractions. This absence may be attributed to the very small quantity of plastic in those samples—potentially below the detection limit of the instrument—or to damage caused by high-voltage electron beam exposure during analysis, which may have led to the burning or decomposition of plastic materials **(Mahmood *et al.*, 2025)**.

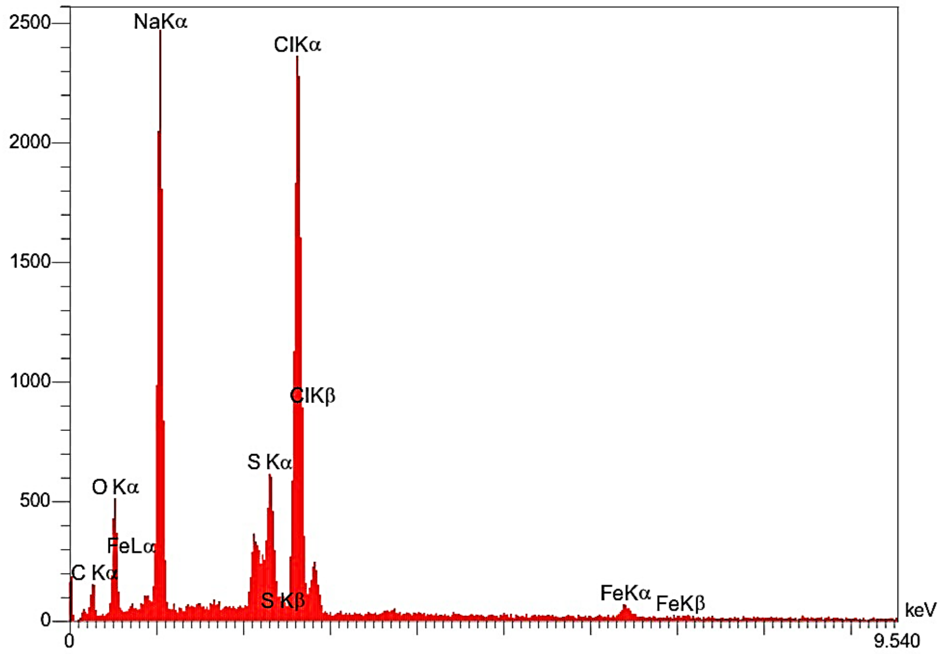

Fig. 7. EDX for water samples at Baradyia plant in sieve size (500 micron), shows the presence of carbon element

CHNOS

The results of the CHNOS elemental analysis revealed the percentage composition of elements in the microplastic samples, as shown in Table (2).

Table 2. Proportions of elements in plastic particles in study site water according to CHNOS analysis

Site	Sieve size	Carbon	Hydrogen	Nitrogen	Oxygen	Sulfur
Qarmat Ali	500	1.3605	0.5994	0.3753	-	**0**
	125	42.16	12.36	3.748	5.279	**0.859**
	63	0.8013	0.2957	-0.0019	-	**0.3474**
Al-Muqal	500	1.0578	0.5239	0.1578	-	**0**
	125	0.9758	0.4247	0.0155	-	**0.7222**
	63	0.9785	0.4055	0.0690	-	**0.5271**
Baradyia	500	0.8247	0.4059	-0.0221	-	**0**
	125	0.7537	0.3453	0.1335	-	**1.0462**
	63	1.2053	0.4744	0	-	**0.1031**
Mahila	500	1.0046	0.4766	0.1111	-	**0**
	125	1.0352	0.3978	0.0146	-	**-0.0233**
	63	0.4563	0.2448	-0.0377	-	**0.8037**

CONCLUSION

Based on the results of FTIR, EDX, and CHNOS analyses, the majority of microplastic particles identified in the water samples were composed primarily of polystyrene, followed by polyethylene terephthalate (PET). In terms of particle abundance by size, the volume of microplastics in the water samples followed the order: 2000 < 500 < 63 < 125 micrometers. Among the sampling sites, the Mahila station was found to be the most polluted with microplastics, whereas the Qarmat Ali station showed the lowest levels of contamination. Statistical analysis revealed a strong, significant inverse correlation between water temperature and pH with microplastics of 63-micrometer size, indicating that higher temperatures and pH values are associated with lower concentrations of these particles. Conversely, a strong and significant direct correlation was observed between free carbon dioxide, turbidity, and biochemical oxygen demand (BOD) with microplastics of 125-micrometer size, suggesting that these environmental factors are positively associated with higher microplastic concentrations in this size category.

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