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Assessment of Microplastic Pollution in Sediments from Khor Al-Zubair, North-West of Arabian Gulf

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ABSTRACT
This study describes the concentration and distribution of microplastics at three different benthic sediment sites in Khor Al-Zubair region, North- West Arabian Gulf, Iraq. Sediment samples were separated by density difference, then Fourier transform infrared spectroscopy (FTIR) was used for analysis. Microplastics were recorded at different sites, with higher concentrations near industrial areas, and these microplastic particles were varied in shape from fragments to fibers composed of polyethylene and polypropylene polymers, indicating the clear impact of sewage discharge and domestic and industrial waste.

INTRODUCTION

Microplastic pollution has a great global environmental challenge; microplastics, defined as plastic particles less than 5mm in size, are now ubiquitous in aquatic ecosystems due to their persistence, hydrodynamic mobility, and capacity to adsorb persistent organic pollutants (POPs), heavy metals, and other hazardous substances **(Wright & Kelly, 2017)**. In the 21st century, over two billion metric tons of plastic have been manufactured globally, with nearly 75% either mismanaged or inadequately disposed of **(Geyer *et al.*, 2017)**. Recently, an estimated 11 million metric tons of plastic enter the world's oceans annually, most of which is transported via rivers – more than 267 of which have been identified as major conduits of plastic debris into marine systems **(Lebreton *et al.*, 2017)**.

Microplastics impact the food chain through their ingestion by zooplankton, benthic invertebrates, and fish. These particles can potentially cause internal injury and obstruct digestive and respiratory tracts, thus affecting feeding and respiration behavior. They also act as vectors for toxic chemicals and pathogens **(Marmara *et al.*, 2023)**. Another effect is related to reducing sediment porosity and permeability, potentially affecting microbial community dynamics **(Ericks-Medrano *et al.*, 2015)**. Furthermore, microplastics have an impact on redox and key biogeochemical cycles, particularly nitrogen, phosphorus, and carbon **(Zhang *et al.*, 2020)**.

Studies along the Kuwaiti coast and Iranian territorial waters, areas adjacent to the Iraqi environment, have recorded high concentrations of microplastics in sediments, particularly near industrial and port areas **(Abayomi *et al.*, 2017; Karbalaei *et al.*, 2019)**. **Brown *et al.* (2011**) observed the accumulation of microplastics along global beaches and coastal sedimentary environments. However, a few studies have been conducted on microplastic pollution in marine sediments within Iraqi waters. Understanding the concentration and distribution of microplastics is therefore critical to supporting conservation efforts, spatial planning, and environmental governance. This study aimed to fill this gap by assessing the abundance, distribution, and polymeric composition of microplastics in surface sediments from three coastal stations along Khor Al Zubair.

MATERIALS AND METHODS

Description of the study area

Khor Al-Zubair is located in the city of Basra, southern Iraq, overlooking the northwest Arabian Gulf. It is affected by tidal phenomena. The lower reaches of Khor Al-Zubair are located near the Kuwaiti island of Warbah, 8km southeast of the city of Umm Qasr. The total length of its channel is 40km, while its width ranges between 1-2km. The depth of the navigation channel at high tide is approximately 20 meters, and at high flood tide, the area covered by water is approximately 60km^2. It can be considered a hypersaline lagoon environment. Fishing and other aquatic life are carried out in this area using various fishing methods, such as drift gillnets, trawls, and various types of traps. The most common species are the common bream (*Tenualosa ilisha*), the threadfin bream (*Nematalosa nasus*), the bream (*Pampus argenteus*), the green bream (*Liza subviridis*), the blue-backed bream (*Liza klunzingeri*), and *Metapenaeus affinis*.

Sample analysis

Sediment samples were collected from the Khor Al Zubair area, amounting to 20 cores at different depths (0-10 and 10- 20cm) (Picture 1). The analysis of microplastic contamination in sediment samples from the Kohr Al-Zubair region was based on the methodologies of **Hidalgo-Ruz *et al.* (2012)**, **Masura *et al.* (2015)** and **Cobbock *et al.* (2017)**. These methods were used to collect sediment samples, assess the distribution and spread of microplastic particles across three coastal sites, and identify the shapes of the particles. Fig. (1) represents a map of the study sites, and Table (1) shows the GPS coordinates of the study areas.

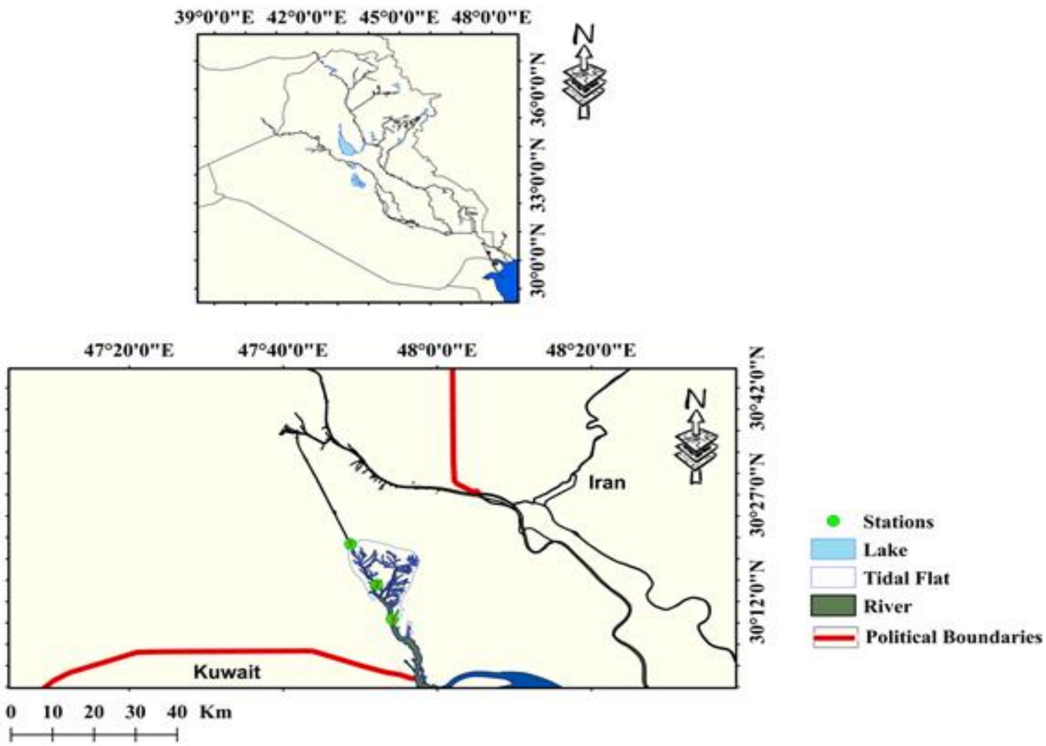

Fig. 1. The position of sampled stations

Picture 1. Collection of plastic particles from sediments of the Khor Al-Zubair station

Table 1. Geographical locations of the selected stations

Station No.	X (Longitude)	Y (Latitude)
1	47.81225	30.334583
2	47.869056	30.239528
3	47.902389	30.158667

Sediment samples were oven-dried at 60 ± 2°C for 24-48 hours until a constant weight was reached. This relatively low drying temperature was selected to prevent thermal degradation of heat-sensitive plastic polymers. Drying protocol was modified from **Mohamed Nor and Obbard (2014)**, following recommendations by **Masura *et al.* (2015)**. The dried and disaggregated samples were sieved using stainless steel mesh sieves with aperture size less than 0.3mm.

Sieving was performed according to **Hidalgo-Ruz *et al.* (2012)**. To remove organic material, samples were treated with 30% hydrogen peroxide (H_2O_2) through wet peroxide oxidation, excluding iron catalysts. The reaction mixture was incubated at 60°C until effervescence ceased. This method was adapted from **Masura *et al.* (2015**), with modification to exclude Fe (II) catalysts to avoid damaging plastic polymers.

Density separation was performed using saturated sodium chloride (NaCl) solution (1.2 g/cm^3) in a 1:3 sediment-to-solution ratio. The mixture was stirred and left to settle for 24 hours. Floating particles suspected to be microplastics were recovered. This protocol was adapted from the study of **Thompson *et al.* (2004)**. For denser polymer types, a zinc chloride ($Zn\ Cl_2$) solution (1.5 g/cm^3) was optionally used in comparative trials to enhance separation efficiency. The supernatant was filtered through pre-weighed Whatman GF/C glass fibre filters (0.3mm pore size), then air dried at room temperature under contamination-controlled conditions. This step was adapted from the investigation of **Imhof *et al.* (2012)**. Dried microplastic was examined under a stereomicroscope (40x magnification), and categorized based on their morphological characheristics, including color and shape as fragments, fibers and films. Subsequently, it was identified according to **Hidalgo-Ruz *et al.* (2012)** and **Mohamed Nor and Obbard (2014)**. Representative particles were analyzed using Fourier Transform Infrared Spectroscopy (FTIR) across the 4000-400cm^{-1} spectral range. The resulting spectra were compared with standard polymer libraries to determine the polymer type. This technique was conducted following the outlines of **Käppler *et al.* (2016)**.

RESULTS

The results showed differences in the distribution of microplastics by depth and region in the Khor Al Zubair sediments. The highest abundance of microplastics was recorded at Station 1 at a depth of 0-10cm, reaching 13.00 particles/cm², while the lowest, 3.33 particles/cm², was recorded at a depth of 0-10 particles/cm² at Station 3. Significant differences ($P < 0.05$) were recorded between the different stations. In general, the prevalence of plastic particles in surface sediments between 0- 10cm was higher than in the 10- 20cm depth, indicating a stratified distribution pattern influenced by recent sedimentation processes.

The compositional breakdown of microplastics by count revealed notable differences in particle types across station and depth. At station 1 (0-10cm), the average total microplastic abundance was 13.00 particles/cm², of which 9.67 particles/cm² were black, 1.33 particles/cm² were green, and 2.00 particles/cm² were transparent. This pattern highlights the dominance of black particles, contributing approximately 74.4% of the total count at this location. In contrast, station 2 exhibited lower overall microplastic concentration, particularly at the 10- 20cm depth, where the mean count was 5.33 particles/cm², with black particles comprising 75.0% of the total and transparent particles the remainder. Notably, green particles were entirely absent at both depths of stations 2 and 3.

At station 3 (0-10cm), the lowest mean total count was recorded (3.33 particles/cm²), with black particles accounting for 70.0%, and transparent particles making up the remaining 30.0%. These findings reflect a spatial trend where particle abundance and diversity decrease with distance from anthropogenic influence, while black particles consistently dominate across all sediment layers and sampling location. below is a Bar chart representing the average microplastic concentration (particles/cm²) in surface and subsurface sediment layers across the three stations (Fig. 2).

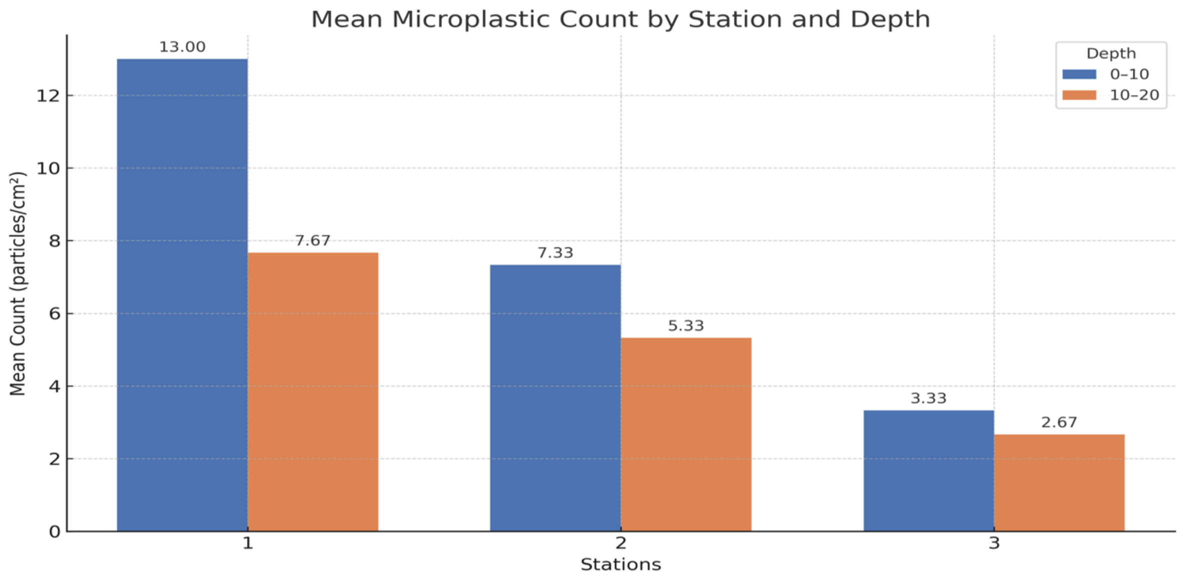

Fig. 2. Microplastic abundance by station and depth

Color analysis revealed that black microplastic particles were dominant at all stations and depths. At Station 1 (0-10cm), black particles constituted 74.36% of the mean microplastic count, followed by transparent (15.38%) and green (10.26%) particles. A similar trend was seen at other depths and locations, with green microplastics being the least abundant or entirely absent in some samples (Stations 2 and 3). Fig. (3) presents a comparative overview of the color distribution across all sampling sites.

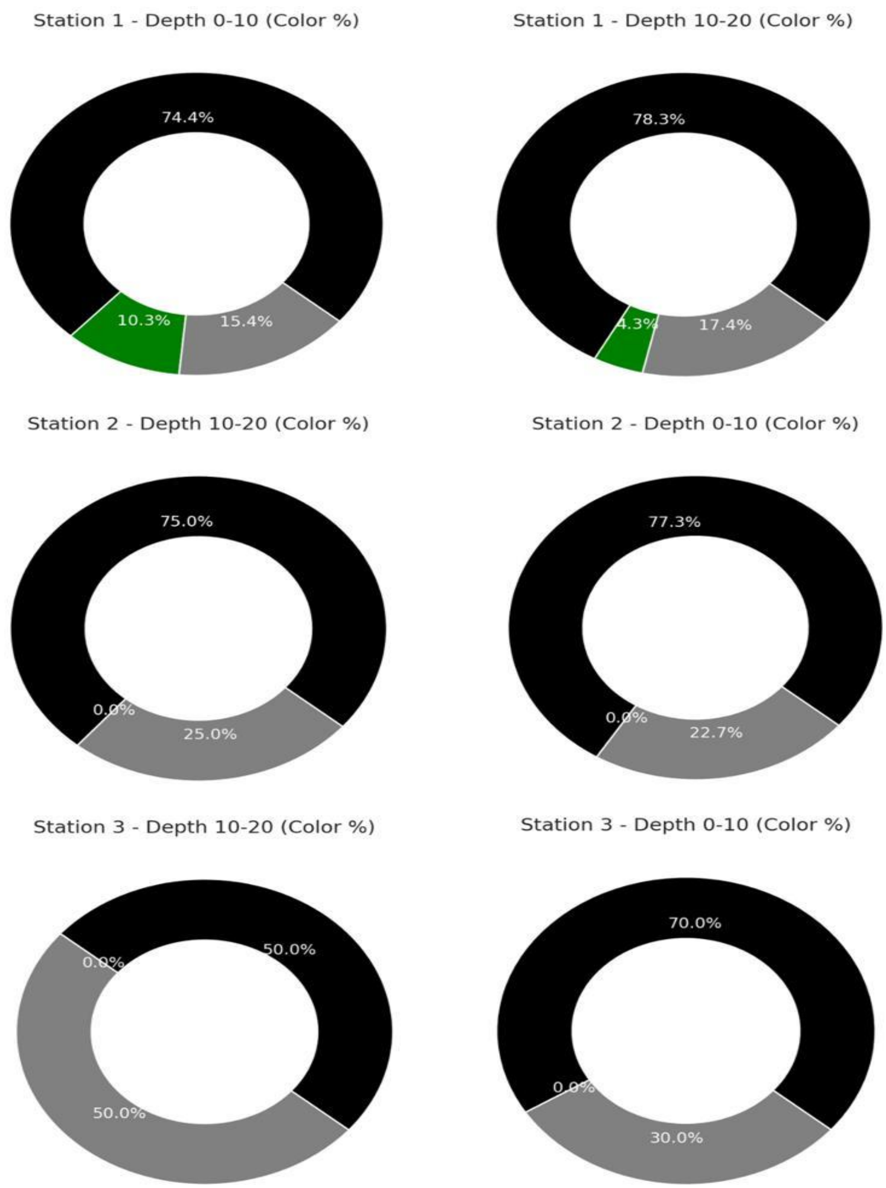

Fig. 3. Color composition of microplastics by station. (Black: Black particles, Gray: Transparent particles, Green: Green particles)

The morphological analysis of microplastic particles revealed a predominance of fragments across all sampling station and sediment depth, with fibers constituting a secondary but consistent shape category. At station 1, fragments accounted for 65.0 and 60.0% of the particles at depths of 0- 10 and 10- 20cm, respectively, while fibers made up 35.0 and 40.0%. At station 2, fragment comprised 70.0% at the surface layer and 68.0% at the deeper layer, with corresponding fiber percentages of 30.0 and 32.0%, indicating a relatively balanced shape distribution across depths. Station 3 exhibited the highest fragment proportions, with 80.0% in surface sediments and 75.0% at 10- 20cm depth. Fiber contents at this station were 20.0 and 25.0%, respectively, as shown in Table (2) and Figs. (4, 5).

Table 2. Microplastic shape percentages by station and depth

Station	Depth (cm)	Fragments (%)	Fibers (%)
1	0-10	65.0	35.0
1	10-20	60.0	40.0
2	0-10	70.0	30.0
2	10-20	68.0	32.0
3	0-10	80.0	20.0
3	10-20	75.0	25.0

These results suggest that fragment-type microplastics are the most prevalent across the study area, possibly derived from degraded consumer plastics, packaging, or marine litter. Fiber presence, though lower, may reflect contributions from textile wastewater, fishing gear, or rope-derived debris. The spatial variation in shape composition could be influenced by differences in hydrodynamic conditions, sedimentation rates, and local anthropogenic activities.

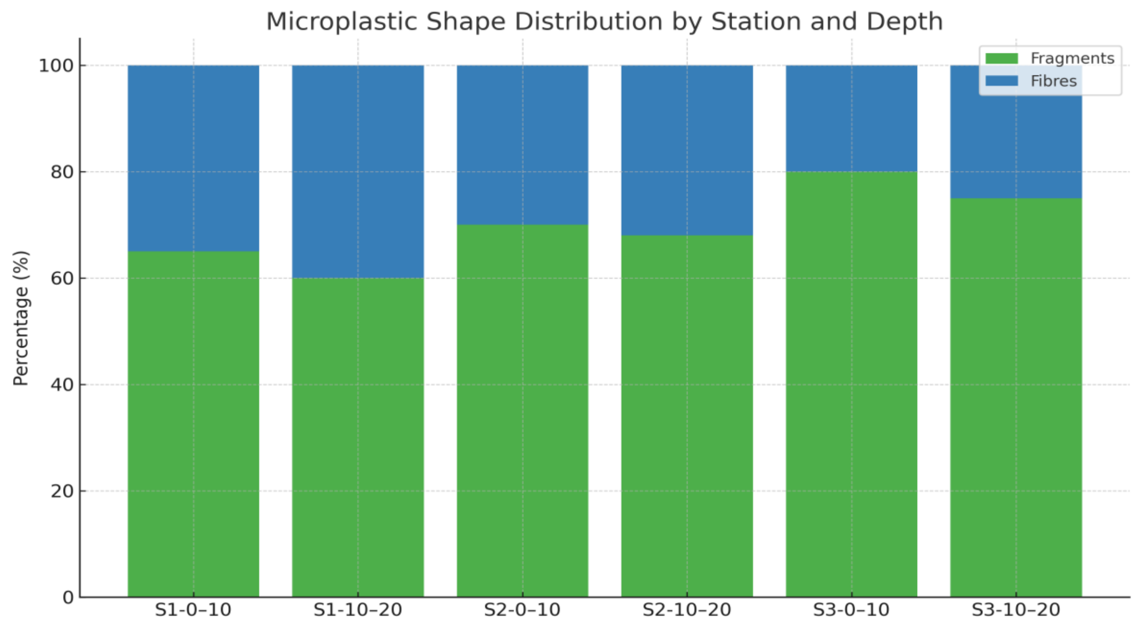

Fig. 4. Microplastic shape distribution by station and depth

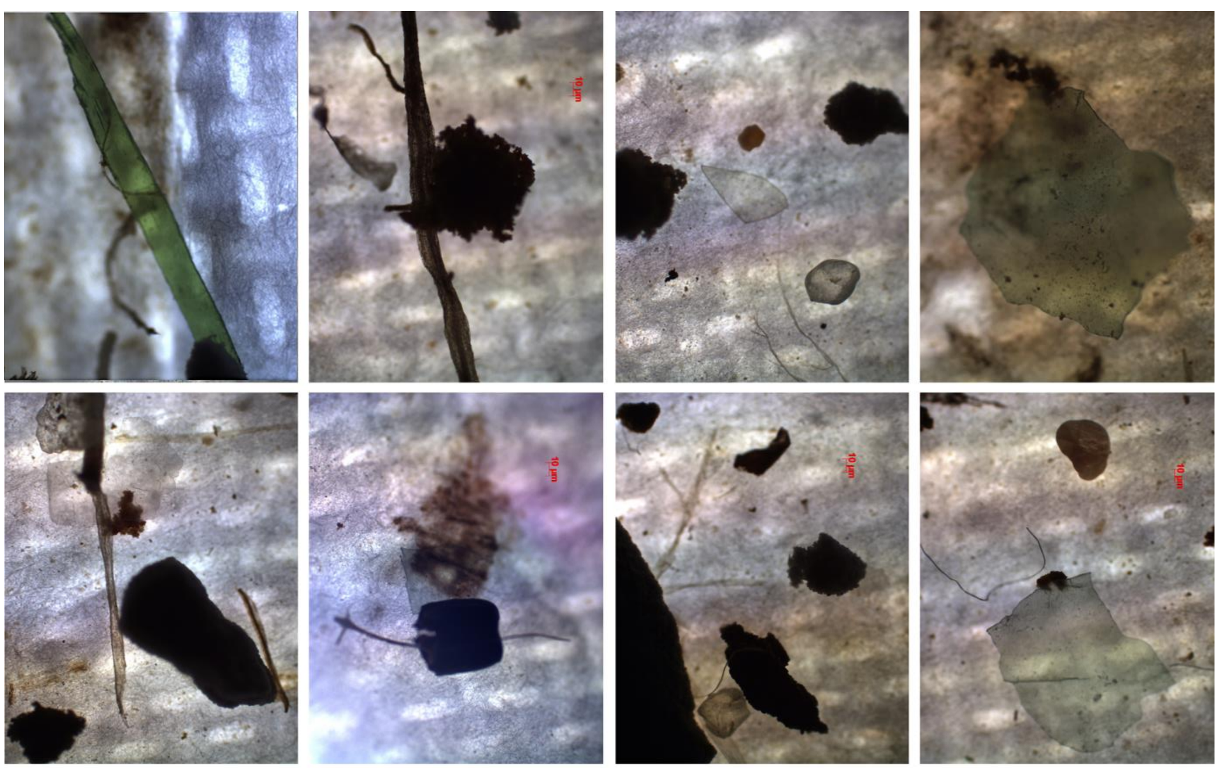

Fig. 5. Microscopic view of microplastic particles, collected at various stations in Khor Al-Zubair

FTIR analysis was conducted on representative microplastic particles of black, green, and transparent colors recovered from Khor Al-Zubair sediments. The black and transparent particles exhibited prominent absorbance peaks at 2911-2913, 2845-2846, 1462-1463, and 1370cm^{-1} which are consistent with the standard FTIR spectra of polyethylene (PE) and polypropylene (PP).

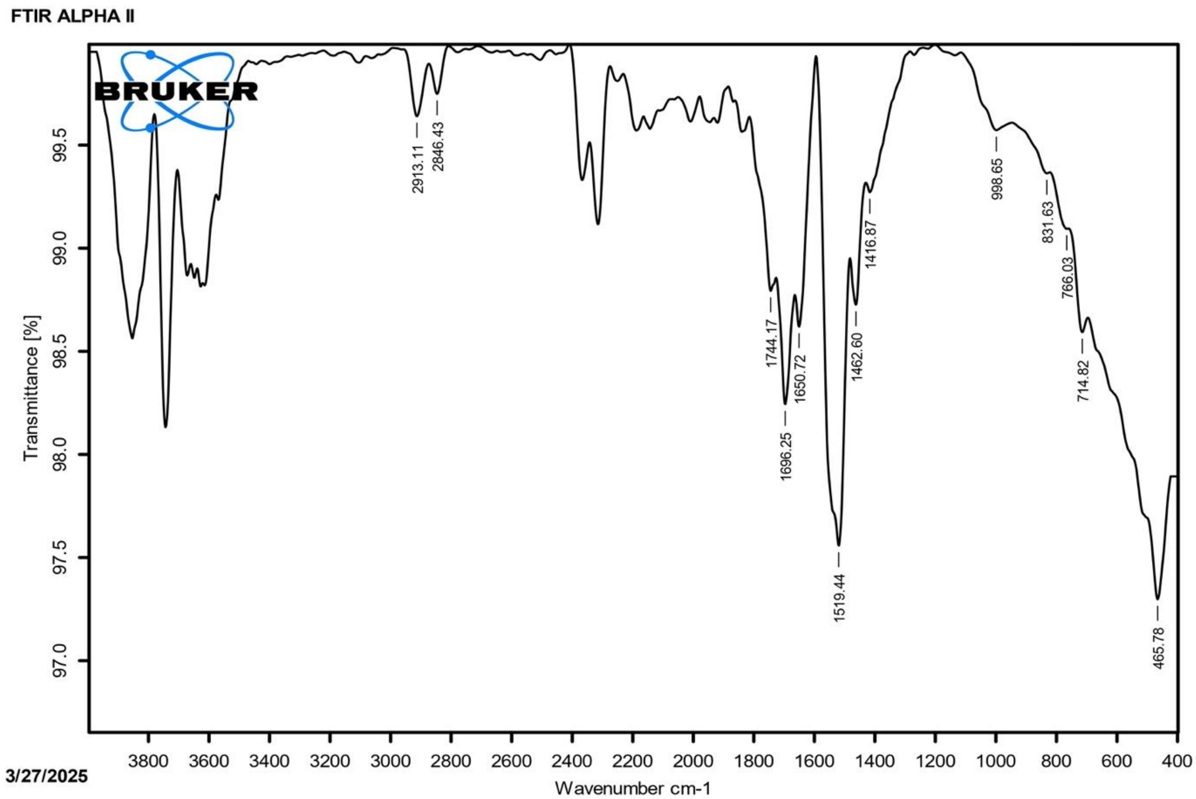

Fig. 6. FTIR spectrum of black microplastic particle

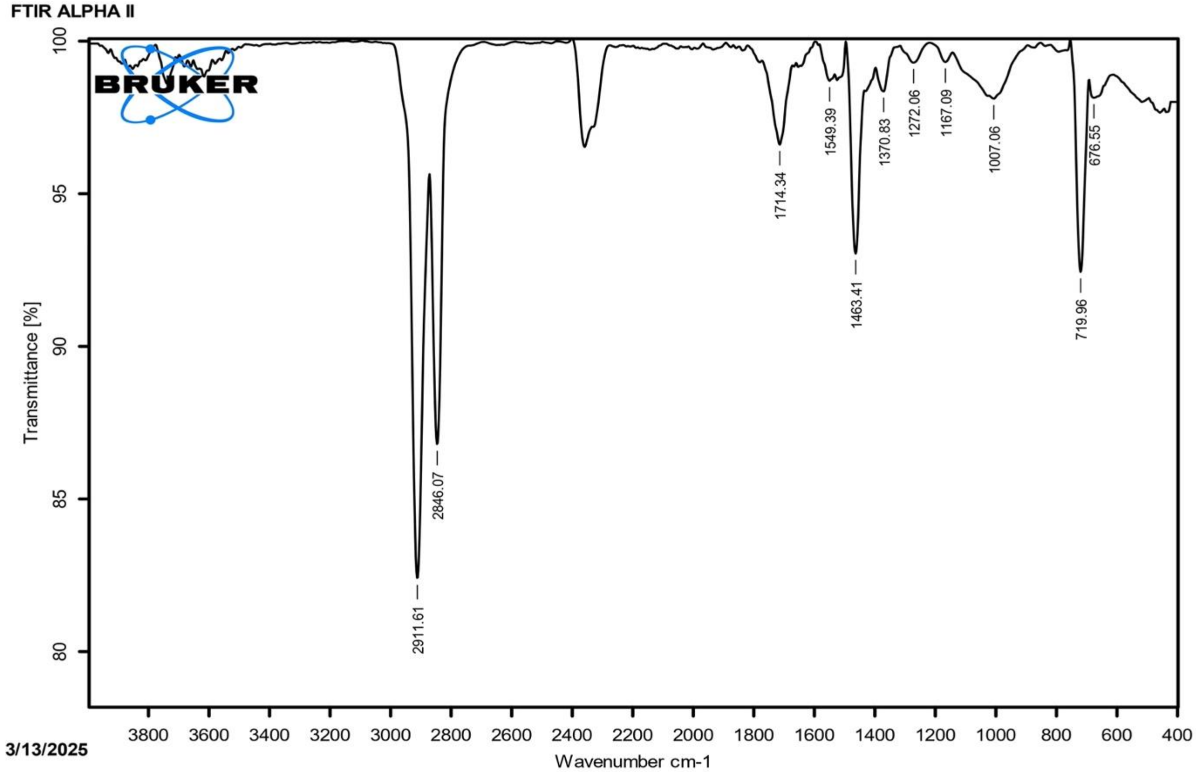

Fig. 7. FTIR spectrum of green microplastic particle

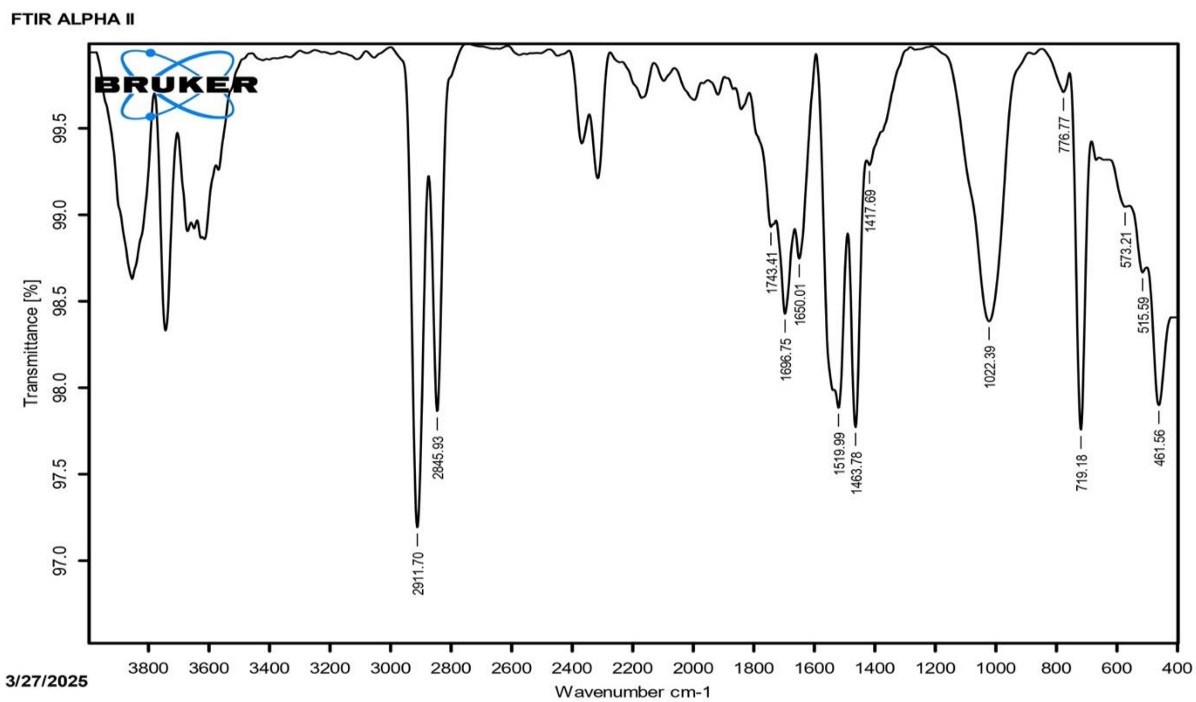

Fig. 8. FTIR spectrum of transparent microplastic particle

A one-way analysis of variance (ANOVA) was conducted to assess whether microplastic concentrations differed significantly between sampling stations and depths: At the 0-10cm depth, a statistically significant difference was observed (F= 7.96, *P*= 0.020), indicating that surface microplastic concentration vary significantly between locations. At the 10- 20cm depth, no significant difference was detected (F= 4.33, *P*= 0.068), although the *P*-value approached the threshold for significance. No significant difference (*P*>0.05) was recorded between stations 1, 2 and 3.

DISCUSSION

These results confirm that horizontal variation in microplastic contamination is more pronounced in surface sediments, likely due to differences in proximity to pollution sources and hydrodynamic conditions, vertical distribution, by contrast, remains relatively uniform within individual stations. The present study documented measurable concentrations of microplastics across all sediment samples from Khor Al-Zubair, with values ranging between 3.33 & 13.00 particles/cm^2. The highest average count was recorded at Station 1 (13.00 particles/cm^2) in the surface layer (0- 10cm), suggesting a more intense local input of plastic debris likely linked to nearby port activities and industrial discharges. In contrast, Station 3 exhibited the lowest overall concentration (3.33 particles/cm^2), which may reflect limited exposure to direct anthropogenic sources or differing hydrodynamic retention. Spatial variation in microplastic abundance across the three sampling points reflects differences in land-based inputs and proximity to pollution sources. Surface sediments (0- 10cm) generally showed higher concentrations compared to deeper layers (10- 20cm), indicating recent deposition of microplastics from ongoing environmental input. However, no statistically significant differences were observed between depths within individual stations (ANOVA, *P*> 0.05), suggesting limited vertical migration or slow sedimentation rates. Horizontal differences between stations at surface layers were more prominent and statistically significant (*P*= 0.020), supporting the influence of localized activities such as shipping, industrial discharge, and urban runoff.

The morphological composition of recovered microplastics was predominantly composed of fragments, which consistently exceeded 60 % across all stations and depths. The highest proportion was observed at Station 3 (0-10cm), where fragments reached 80%, while the lowest was at Station 1 (10-20cm) with 60%. Conversely, fibers constituted 20 to 40%, with higher proportions observed in deeper sediments of Station 1 (40%) and Station 2 (32%), suggesting possible stratification or distinct input sources.

In terms of color, black microplastics were the most abundant, accounting for approximately 70 to 75% of all particles across the study area. Transparent and green particles were present in smaller proportions. The dominance of black fragments is indicative of heavily degraded microplastic debris potentially originating from discarded rubber materials, industrial plastic packaging, or abrasion from vehicle tires and marine equipment. These morphological patterns especially the prevalence of fragments are consistent with previous findings in the Gulf region, which attributed similar profiles to the advanced breakdown of consumer and industrial plastics under harsh environmental conditions.

Fourier transform infrared spectroscopy (FTIR) analysis confirmed the dominance of polyethylene (PE) and polypropylene (PP) in sediment samples, consistent with polymers used in consumer packaging and fishing gear. These findings align with polymer profiles reported in studies from Qatar and the UAE, where PE and PP were the primary microplastic constituents in coastal and sedimentary environments. In contrast, sites such as Khor Musa in Iran were dominated by polyamide (PA) and polyurethane (PU), indicating a possible difference in industrial sources and land-based inputs. When compared to previous research across the Arabian Gulf, the microplastic concentration observed in Khor Al-Zubair are of similar magnitude to those found in high-impact areas. For example, sediment sample from Khor Musa, Iran, reached up to 2,325.8 particles/kg, while Bushehr showed densities ranging between 451 and 15,391 items/m^2. Along beaches of United Arab Emirates and Qatari, values were reported up to 15,000 particles/m^2 and 1.46 million items/km^2, respectively **(Abayomi *et al.*, 2017; Naji *et al.*, 2017a; Jung *et al.*, 2018; Razeghi *et al.*, 2021)**. FTIR analysis agree with previous studies in the Arabian Gulf, for example, a study by **Karbalaei *et al.* (2019**) reported the dominance of polyethylene and polypropylene in coastal sediments along the Iranian coastal. In addition, **Song *et al.* (2015)** focused on the presence of polyethylene terephthalate plastic particles in estuaries exposed to domestic and industrial wastewater.

The spectrum of green particles achieved an absorbance value of 1730cm^1, which is an indication of the carbonyl group present in polyethylene or polyethylene terephthalate, verifying the presence of multi polymer compounds that may affect the marine ecosystem. According to the color, the infrared spectroscopy analysis of the microplastic particles in Khor Al Zubair showed variation between black, green and transparent; the black and transparent particles were mostly polyethylene and polypropylene; these polymers have distinct peaks around 2911-2913 and 2845-2846cm^{-1} for C-H stretching, and around 1462-1463 and 1370cm^{-1} for CH_2 and CH_3 bending vibrations. A similar pattern was recorded for the green particle though showing a distinct carbonyl peak at 1730cm^{-1}, indicating oxidation or the presence of polyethylene terephthalate. A carbonyl peak indicating the presence of polyethylene terephthalate or oxidized polyethylene has been recorded in estuary waters affected by household waste discharges **(Song *et al.*, 2015**). From other side, **Safahi *et al.* (2024)** also conducted microplastic pollution in tidal sediments in the coastal areas of the North western Arabian Gulf in Iran, Qatar, Kuwait, the United Arab Emirates and the Sultanate Oman, and recorded that the most prevalent polymer types were polyamide (PA, 41.3%) and polyurethane (PU, 30%), with a smaller contribution of polyethylene (PE) and polypropylene (PP). This agree with current study, which indicates that water pollution in Khor Al Zubair is consistent with its prevalence in the neighboring territorial waters. In contrast with the current findings in Khor Al-Zubair, where FTIR analysis confirmed the dominance of PE and PP, with no detection of PA and PU in analyzed particles. The differences in polymer prevalence are likely due to local variations in plastic usage and waste disposal practices. For example, the high proportion of PA and PU in Iranian sediments may be linked to industrial zones and textile waste, while the prevalence of PE and PP in Khor Al-Zubair reflects the influence of packaging materials, fishing debris, and domestic waste. Table (3) below compares the polymer types and microplastic characteristics reported by previously studies across regions with current study in Khor Al-Zubair. This synthesis helps contextualize Iraq's findings within broader Gulf trends and reveals both shared and unique contamination signatures among the coastal environments.

Table 3. Comparison between abundance and dominant characteristics size, shape, colour, and polymer typeof microplastic from Khor Al-Zubair with those from other locations of Asia

Location	Number/kg	Size (mm)	Shape	Colour	Polymer Type	Reference
Bushehr	226	< 0.5	Fi 55%	Bc 40%	-	(Sheikhi and Mirzaei, 2023)
Qeshm mangrove	19.5–34.5	0.01–0.3 (70–97%)	Fi 56% - Fr 35%	Bc 41%	PE	(Naji *et al*., 2019)
Khark Island	295–1085	< 0.1	Fr 61.7%, Fi 37.2%	Bc, T	-	(Akhbarizadeh *et al*., 2017)
Northern Coasts	190	1–2 (44.36%)	Fi 88%	Bc, R, Bu	PE 43.42%	(Agharokh *et al*., 2022)
Strait of Hormuz	2–1258	-	Fi 83%	-	PE, nylon, PET	(Naji *et al*., 2017b)
Kish Island	530	0.25–0.5	Fr 65%, Fi 23.5%	W 32%	PE	(Petrovic *et al*., 2022)
Kuwait	37	-	Fi, Fr	Bu–W	PP, HDPE, LDPE	(Saeed *et al*., 2020)
UAE	191.7	1–2 (34%)	Fi 93%	Bc 53%	PE	(Veerasingam *et al*., 2021)
Qatar	0–665	-	P 77%	-	PE 54%, PP 24%	(Veerasingam *et al*. 2021)
Chabahar	315.4	0.1–0.5 (37.4%)	Fr 43.7%, Fi 41.7%	R, Bu (61.6%)	PP 31%, PE 24.1%	(Rigi *et al*., 2023)
Chabahar Gulf	138.3–930.3	0.1–1 (63.6%)	Fi, Fr 62.8%	W, B (49%)	PE 34.9%, PP 25%	(Kor *et al*., 2020)
Chabahar Gulf	262	< 1 (61.32%)	Fr 42.34%, Fi 32.22%	B–T–W	38% PE, 29% PET	(Hosseini *et al*., 2020)

India	4400–15300	0.1–0.5	Fi 55.65%, Fr 41.27%	Bc 38.56%	PE, PES, PA	(Gurjar *et al*., 2023)
Japan–Tokyo Bay	1800	-	Fr 75%	W 57%	PE, PP	(Matsuguma *et al*., 2017)
Vietnam	9238	0.3–2.6 (81.9%)	Fi 99.2%	Bu 59.9% – W 22.9%	-	(Nguyen *et al*., 2020)
Khor Musa	2325.8	0.1–0.5 (61%)	Fi 40%, Fr 29%	Bc 67%	PA 41.3%, PU 30%	(Safahieh *et al*., 2024)
Khor Al-Zubair (Iraq)	500–1300	0.3–1.2	Fr > Fi	Bc 70–75%, G, T	PE, PP	This study

*Fi: Fiber, Fr: Fragment, P: Pellet, Bc: Black, Bl: Blue, R: Red, W: White, T: Transparent

CONCLUSION

The study concludes that there is significant plastic pollution in the Khor Al Zubair sediments. Local sources such as industrial packaging, port operations, and fishing activities are contributing factors. The predominant forms of microplastics were fragments and fibers, primarily composed of polyethylene and polypropylene polymers.

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