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MICROPLASTICS IN SEDIMENTS AND SURFACE WATER OF THE COASTAL MACTA MARSHES, A RAMSAR SITE, NORTHWEST ALGERIA

Houria CHAALAL[1*], Ahmed MEGHARBI[1], Md Rezaur RAHMAN[2], Anjelina JOFFERY KALIMUT[2] & Reda KECHAIRI[3]
[1]Environment and Sustainable Development Laboratory (ESDL), Department of Biological Science, University of AHMED ZABANA, Relizane, Algeria
[2]Department of Chemical Engineering and Energy Sustainability, Faculty of Engineering, University Malaysia Sarawak, 94300, Kota Samarahan, Malaysia
[3]Laboratory of Ecology and Management of Natural Ecosystems n°13, Department of Ecology and Environment, Faculty SNV/STU, University of Abou Bekr Belkaid Tlemcen, Tlemcen, Algeria
**Corresponding author: houria.chaalal@univ-relizane.dz*

Abstract: The Ramsar Convention recognizes the Macta marshes as a wetland of international importance due to their high biological diversity. However, the existence of plastic debris poses a risk to this environment. This study is the first in Algeria to investigate the abundance, physical and chemical identification of microplastics (MPs) in sediments and surface water of the Macta marshes. MPs were extracted using organic matter removal with 30% H_2O_2 and density separation with $ZnCl_2$. We examined the physical characteristics (shapes and colors) of MPs under a stereomicroscope, the size was measured using a scanning electron microscope (SEM), and their polymer types were identified using Fourier transform infrared (FTIR) spectroscopy. The average abundance of MPs was 253.54± 273.84 MPs/kg in sediments and 3.82± 3.14 MPs/L in surface water. Observation under the stereomicroscope revealed four MPs shapes: fibers, fragments, pellets, and films. Fibers are dominant in both sediments (80.73%) and surface water (74.41%). Red (37.27%) > black (21.52%) > transparent (15.33%) particles were the most frequent colors in sediments, whereas transparent (27.91%) > red (23.84%) > black (18.60%) dominated in surface water. SEM analysis indicated a predominance of small-sized MPs, while FTIR identified the presence of several polymer types, including HDPE (High Density Polyethylene), PET (Polyethylene Terephthalate, PS (Polystyrene), PE (Polyethylene), ABS (Acrylonitrile-Butadiene-Styrene), ASA (Acrylonitrile-Styrene-Acrylate), and PAN (Polyacrylonitrile). In the study area, domestic, industrial, marine, and recreational activities are the main sources of microplastic contamination in the Macta marshes. This pollution can be reduced through improved waste management, wastewater treatment, industrial regulation, and public awareness.

Keywords: Microplastics, sediments, ANOVA, wetland, Algeria.

1. INTRODUCTION

Wetlands are ecotones between terrestrial and aquatic environments, and this transition gives them richness, functional diversity, and multiple values (Fustec & Lefeuvre, 2000; Maltby & Barker, 2009; Mitsch & Gosselink, 2007). Unfortunately, due to the anthropic effect applied to these ecosystems (Turner, 1992), they have become more vulnerable and/or degraded (Williams, 1990).

Among the anthropogenic activities, we cite the production of plastics, on which the world depends heavily. Because of its wide use in the industrial sector, which causes an increase in production (Rochman et al., 2013), it is projected that plastic production will reach between 902 Mt (Geyer et al., 2017) to 1124 Mt (Ellen MacArthur Foundation, 2017) by 2050. Within the various applications of plastic are construction, food and packaging industries, pharmaceuticals, and other sectors (Xu et al., 2019). Although plastic has many diverse uses, its drawbacks are even greater, leading to the pollution of ecosystems (Law et al., 2010; Ryan, 2013). Plastic can be divided into large particles and it can also break down into small particles that are only visible under a microscope; these are known as microplastics (Gall & Thompson, 2015). Microplastics are defined by their size, ranging from 5 mm to 1 µm (Hartmann et al., 2019), they have been found in marine environments, lakes, reservoirs, wetlands, estuaries, and even in polar regions (Auta et al., 2017; Eerkes-Medrano et al., 2015). Microplastics are categorized into primary and secondary types. Primary microplastics are intentionally manufactured and used in products like hand cleansers, facial cleansers, and toothpaste (Lassen et al., 2015). These are specifically produced by the plastics industry (Auta et al., 2017). In addition, primarily microplastics can enter wetlands through various routes, such as sewage discharge, surface runoff, and plastic waste (Qian et al., 2020; Reynolds & Ryan, 2017). Secondary microplastics are created when larger plastic fragments break down due to abiotic factors like intense solar UV radiation and mechanical abrasion (Gazal & Gheewala, 2020).

Algeria produced around 13.5 million tons of solid waste from households, with approximately 15.31 % being plastic, equaling about 2.07 million tons of plastic waste. Regrettably, only 15 % of this plastic waste is recovered (NAW, 2020, 2021). Production has risen in both Algeria and globally, especially during the COVID-19 pandemic. Every minute, about 3 million face masks are thrown away worldwide, contributing to environmental pollution (Prata et al., 2020).

The contamination of coastal and marine ecosystems has become a major environmental problem. Microplastics pose a danger to public health (Li et al., 2022). The Macta marshes were listed in the Ramsar Convention in 2001 as a wetland of international importance, as it is home to a wide variety of flora and fauna, and is a stopover site for migratory birds (Jacobs & Ochando, 1972; Lednat & Vandijk, 1977; Metzmacher, 1979). According to Véla & Benhouhou (2007), this area is a hotspot of biological diversity.

Microplastics can be checked in various environments, such as water (Luo et al., 2019), sediments (Uddin et al., 2021), soil (Harms et al., 2021), air (Gasperi et al., 2017), and living beings (Rillig et al., 2017; Zhang D. et al., 2020). Various scientific studies and research on microplastics have been conducted (Taïbi et al., 2021; Setiti et al., 2021; Amenouche et al., 2025; Grini et al., 2022; Devi et al., 2024; Rahmani et al., 2025; Khazr et al., 2025). However, no investigation has been conducted on microplastics in the Macta marshes, Algerian wetland. Our study is the first to examine the accumulation of microplastics in sediment and surface water at the Macta marshes, a Ramsar site in Algeria.

This paper aims to analyze the abundance and physical characteristics of microplastics, including their shapes, colors, and sizes, as well as their chemical properties (type), to help Algerian authorities and local environmental agencies build a successful program to reduce contamination emissions.

2. MATERIAL AND METHODS

2.1. Study area

The Macta Marshes have a triangular shape and are bounded to the north by the Mediterranean Sea. To the east, they are bordered by Mostaganem province. In contrast to the west, Marsat El Hadjadj Beach, and Oran province, and to the south, the mountain of Beni-Chougrane. Several rivers intersect this wetland, including the Sig, Habra, Tinn, and Oued El Hammam (Figure 1).

2.2. Sample collection

Samples for analyzing microplastics were obtained from sediments and surface water between March 07 to June 13, 2024. The specific latitude and longitude of the sampling site were determined using a Global Positioning System (GPS). A total of 22 stations were selected for sediment, and 15 surface water samples were collected from the Macta reservoir (Figure 1).

To collect sediment samples, a wooden quadrat measuring 25 cm × 25 cm (0.0625 m^2) and a steel trowel were utilized to gather sediments from the top 3 cm of the surface. Sediment samples were taken in triplicate at each sampling station (Klein et al., 2015). Before sampling, both the quadrat and the steel trowel were rinsed with distilled water to avoid any risk of cross-contamination (Camargo et al., 2022). The gathered samples were wrapped in aluminum foil and stored at 4 °C until analysis (Ibrahim et al., 2021).

For surface water sampling, 1 liter of water was collected by steel containers from a depth of 0 to 10 cm at each site (Mercy et al., 2022). To enhance accuracy, three replicates were taken per site, resulting in a total of 45 liters of water per site. The samples were stored at 5 °C.

2.3. Laboratory process

2.3.1. Granulometric analysis

To determine the textural parameters of the Macta marshes sediments, two techniques of dry and wet sieving are used. The protocol described by Tnoumi et al. (2020) was employed.

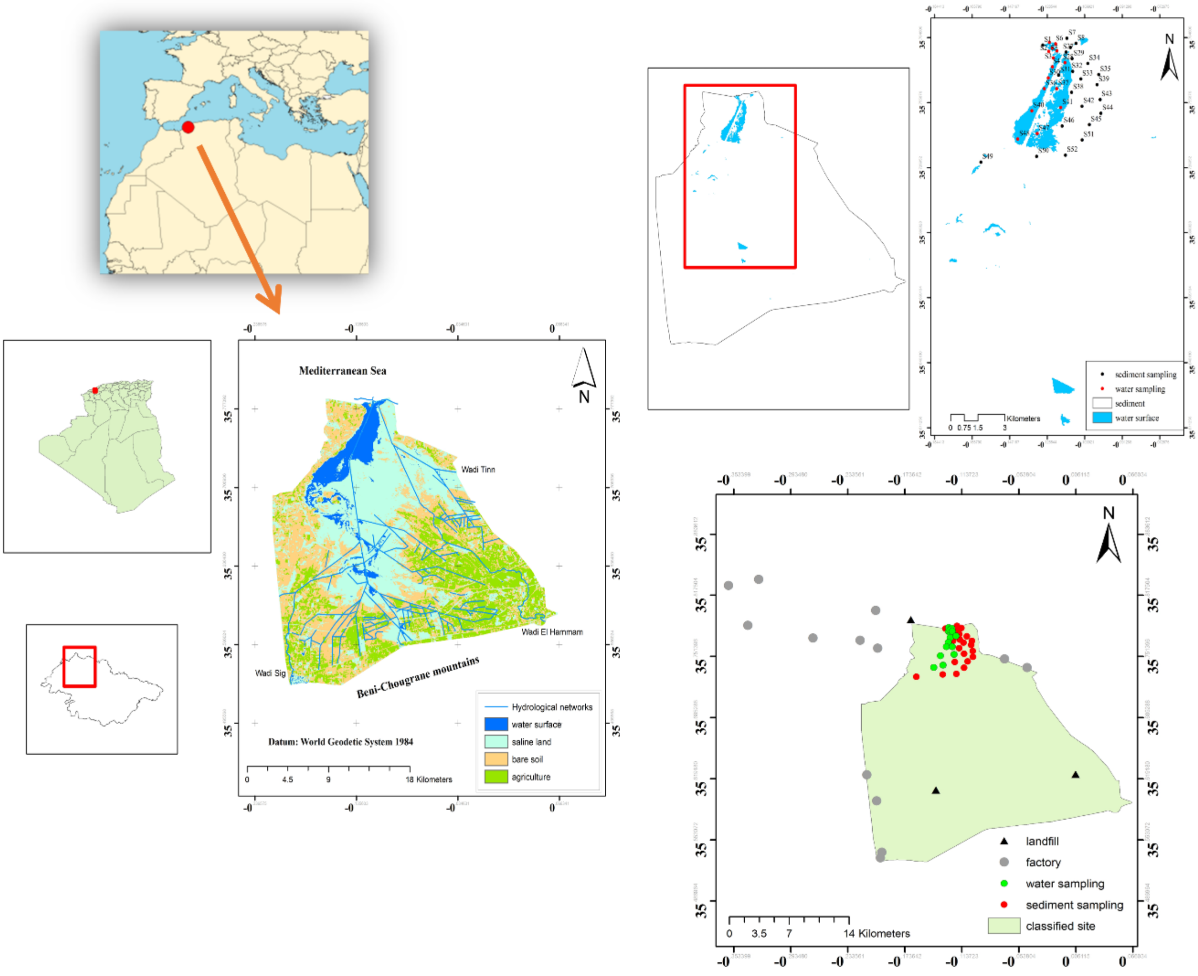

Figure 1. Location of Macta marshes, sampling sites, and pollution sources.

2.3.2. Extraction of microplastics

The methodology established by Thompson et al. (2004) was implemented with modifications in the laboratory to isolate microplastics from sediments. Sediment samples were initially desiccated at 60 °C for 48 hours and subsequently sieved using a 5 mm stainless steel mesh to eliminate bigger, undesirable particles. Subsequently, 30 g of sediment was transferred into a 500 mL beaker, followed by the addition of 30 mL of hydrogen peroxide (H_2O_2, 30 %) to oxidize and eliminate natural organic waste. The mixture was left to react overnight. Afterward, 36 mL of zinc chloride ($ZnCl_2$) solution (density ~1.58 g/cm^3) was added for density separation. A magnetic stirring bar was added, and the mixture was stirred for 30 minutes. Then, the samples were left alone for 24 hours so that the different phases could separate. After that, the mixture was spun at 1500 rpm for 5 minutes to separate the solid from the liquid. Finally, a filter paper with a 0.45 µm pore size and a 47 mm diameter was used to filter the liquid (supernatant).

For microplastic extraction from surface water, we followed the method described by Wang et al. (2020) and Su et al. (2016), with some adjustments. Water samples were placed in 1000 mL Erlenmeyer flasks, and an initial filtration was carried out using a vacuum system and a 47 mm diameter filter with a 0.45 µm pore size for each sample. This step allowed for the retention of residues and microplastics in the water. After filtering, 100 mL of 30 % hydrogen peroxide (H_2O_2) was poured into a 250 mL wash bottle. The retained material on the filter paper was then gently rinsed into 250 mL glass flasks. The flasks were sealed with aluminum foil and heated in an oven at 60 °C for 48 hours to facilitate the reaction. Afterward, a second filtration was conducted using the same filter paper (47 mm diameter, 0.45 µm pore size).

2.4. Microplastics Identification

Microplastic identification was conducted according to the criteria established by Lusher et al. (2020). The filter paper was examined under a stereomicroscope at magnifications between 10x and 40x to analyze its shapes and colors (Pradit et al., 2022). We sorted microplastics into four groups: fragments, films, fibers, and pellets, using the method described by Hidalgo-Ruz et al. (2012).

There are 13 groups of colors: black, blue, gold, gray, beige, brown, green, pink, red, yellow, and white. Putting pink and raspberry in the pink group, orange in the red group, and a lot of other colors in the blue group, like bright blue, dark blue, magenta, purple, and cyan (Zobkov et al., 2020).

For size analysis, samples were examined using a scanning electron microscope (SEM). Microplastics were classified into two size groups: large microplastics (1 mm - 5 mm), small microplastics (1 µm - 1 mm) (Crawford & Quinn, 2016), and the polymer content of the samples was ascertained through FTIR analysis at a resolution of 8 cm^{-1}, with measurements conducted across a spectral range of 4000 cm^{-1} to 400 cm^{-1}.

2.5. Quality Control

The experiment was kept away from any outside plastic source to keep the microplastics from getting mixed up. They used cotton lab coats and gloves that didn't have any polymers in them (Jahan et al., 2019; Jiwarungrueangkul et al., 2021). The samples in the beaker were protected from any possible contaminants in the air by aluminum foil. All of the tools and glassware used during laboratory work were thoroughly cleaned and rinsed with distilled water. During the filtration process, personal filters were used to keep anything from getting in.

2.6. Statistical Analysis

Granulometric analysis (mean (Mz), Sorting (θ), skewness (Ski), and kurtosis (KG)) was calculated based on the methodology proposed by Folk & Ward (1957). The concentration of microplastics in sediments is measured as MPs/kg, while in surface water it is measured as MPs/L. This concentration is calculated as the average ± the standard deviation. A one-way analysis of variance (ANOVA) test was performed to assess the abundance, shape, color, and size of microplastics (MPs). When p-value less than 0.05 ($p < 0.05$) indicates a statistically significant difference, whereas a p-value greater than 0.05 ($p > 0.05$) suggests no significant difference. Statistical analyses were conducted using Excel 2016, and graphs were created using Origin 2018.

3. RESULTS

3.1. Textural characteristics

It is important to know the grain size distribution of sediments because they indicate the transport processes, level of weathering, and erosional features (Jian-Wu et al., 2013; Szcześniak et al., 2023; Tanabe et al., 2023; Boggs, 2006). The textural parameters for the Macta marshes are listed in Table 1. In which, the mean grain size (Mz) varies from 1.09 to 10.46 θ. The sediments are classified as: well sorted, moderately well sorted, poorly sorted, and very poorly sorted. The Macta marshes sediments are very coarse skewed, coarse skewed, nearly symmetrical, fine-skewed, and moderately fine-skewed. Kurtosis class range from mesokurtic to leptokurtic, very leptokurtic, and platykurtic.

3.2. Analyses of microplastics in sediments

The sediment samples contained an abundance of 253.54 ± 273.84 MPs kg^{-1} of dry sediment (Figure 2). ANOVA showed no significant difference ($p = 0.99 > 0.05$, $F = 0.29$).

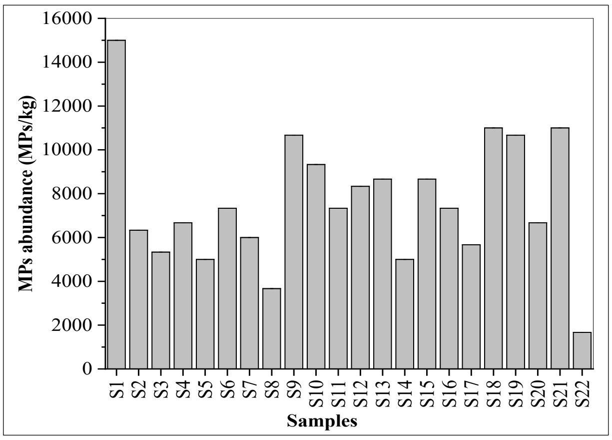

Figure 2. Abundance of microplastics across different sampling in the sediments of Macta marshes.

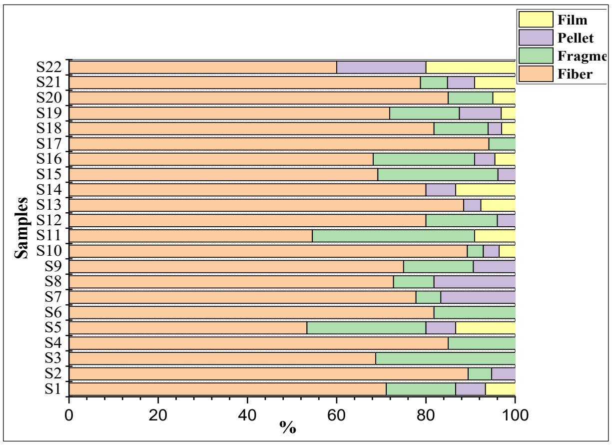

Figure 3. Percent of microplastics occurrence based on shape in different samples of sediments.

Regarding shapes (Figure 3), fibers were the most prevalent shape in sediments (80.73 %), followed by fragments (11.39 %), pellets (4.50 %), and films (3.37 %). The results for each sample are shown in

Table 1. Textural characteristics for the Macta marshes sediments [mean (Mz), Sorting (θ), skewness (Ski), and kurtosis (KG)] (Folk & Ward, 1957).

Sample	Mz (θ)	Sorting (θ)	Skewness (Ski)	Kurtosis (KG)	Mz (θ) Class	Sorting (θ) Class	Ski Class	KG Class
S1	1.26	0.52	-0.29	1.09	Medium sand	Moderately well sorted	Coarse skewed	Mesokurtic
S2	1.09	0.60	-0.18	0.96	Medium sand	Moderately well sorted	Coarse skewed	Mesokurtic
S3	1.69	0.55	-0.25	0.92	Medium sand	Moderately well sorted	Coarse skewed	Mesokurtic
S4	1.13	0.68	-0.69	1.10	Medium sand	Moderately sorted	Very coarse-skewed	Mesokurtic
S5	2.22	0.48	0.02	1.62	Fine sand	Well sorted	Nearly symmetrical	Very leptokurtic
S6	2.19	0.39	0.04	1.72	Fine sand	Well sorted	Nearly symmetrical	Very leptokurtic
S7	2.41	0.42	-0.03	1.73	Fine sand	Well sorted	Nearly symmetrical	Very leptokurtic
S8	1.53	0.86	-0.39	1.22	Medium sand	Moderately sorted	Very coarse-skewed	Leptokurtic
S9	1.66	0.59	-0.46	1.34	Medium sand	Moderately well sorted	Very coarse-skewed	Leptokurtic
S10	2.46	0.63	-0.16	1.20	Fine sand	Moderately well sorted	Coarse skewed	Leptokurtic
S11	2.03	0.69	-0.13	1.31	Fine sand	Moderately well sorted	Coarse skewed	Leptokurtic
S12	2.43	0.64	-0.4	0.99	Fine sand	Moderately well sorted	Very coarse-skewed	Mesokurtic
S13	2.10	0.49	-0.30	1.05	Fine sand	Well sorted	Coarse skewed	Mesokurtic
S14	1.37	0.92	-0.22	1.15	Medium sand	Moderately sorted	Coarse skewed	Leptokurtic
S15	8.78	1.29	0.35	0.82	Typical clay	Poorly sorted	Fine-skewed	Platykurtic
S16	9.69	1.48	0.46	0.75	Fine clay	Poorly sorted	Moderately fine-skewed	Platykurtic
S17	10.09	1.50	0.39	0.68	Fine clay	Poorly sorted	Moderately fine-skewed	Platykurtic
S18	9.34	1.83	0.51	0.87	Typical clay	Poorly sorted	Moderately fine-skewed	Platykurtic
S19	9.82	2.34	1.08	0.89	Fine clay	Very poorly sorted	Strongly fine-skewed	Platykurtic
S20	9.94	1.72	1.42	0.77	Fine clay	Poorly sorted	Strongly fine-skewed	Platykurtic
S21	10.29	2.10	0.45	0.73	Fine clay	Very poorly sorted	Moderately fine-skewed	Platykurtic
S22	10.46	2.62	1.21	0.81	Fine clay	Very poorly sorted	Strongly fine-skewed	Platykurtic

Figure 4. The one-way ANOVA results for the shapes in the sediment samples indicated no statistically significant differences ($p > 0.05$), with $F = 0.26$.

Our results on the color distribution indicated the presence of various colors (Figure 6). The most common color in the sediment samples was red, which accounted (37.27 %) of the total. The other colors in order, were black (21.52 %), transparent (15.33 %), green (9.70 %), blue (8.72 %), white (4.08 %), yellow (2.53 %), gray (0.56 %), and pink (0.28 %) (Figure 4). One-way ANOVA of color revealed no significant difference in the color of microplastics (MPs) ($p > 0.05$, $F = 0.77$).

With SEM (Figure 7), we found that small microplastics were more prevalent than large microplastics.

Small microplastics accounted for 60.62 % of the total, whereas large microplastics accounted for 39.38 %, the results for each sample in Figure 5. One-way ANOVA for size showed that sediments ($F = 0.23$) were not significantly different ($p > 0.05$).

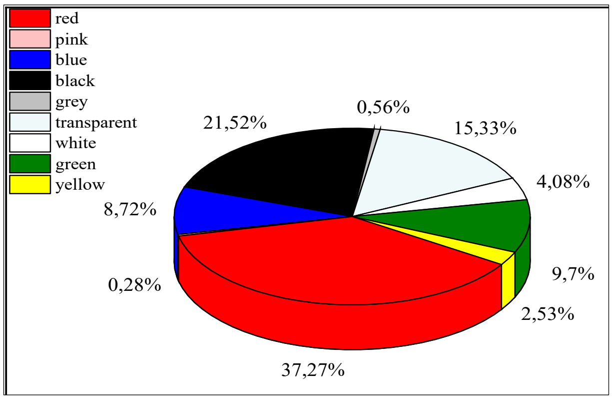

Figure 4. Percent of microplastics occurrence based on colors in sediments.

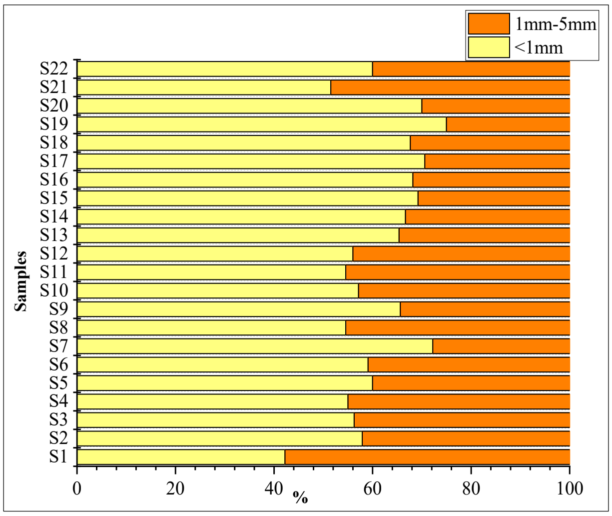

Figure 5. Percent of microplastics occurrence based on size in sediments.

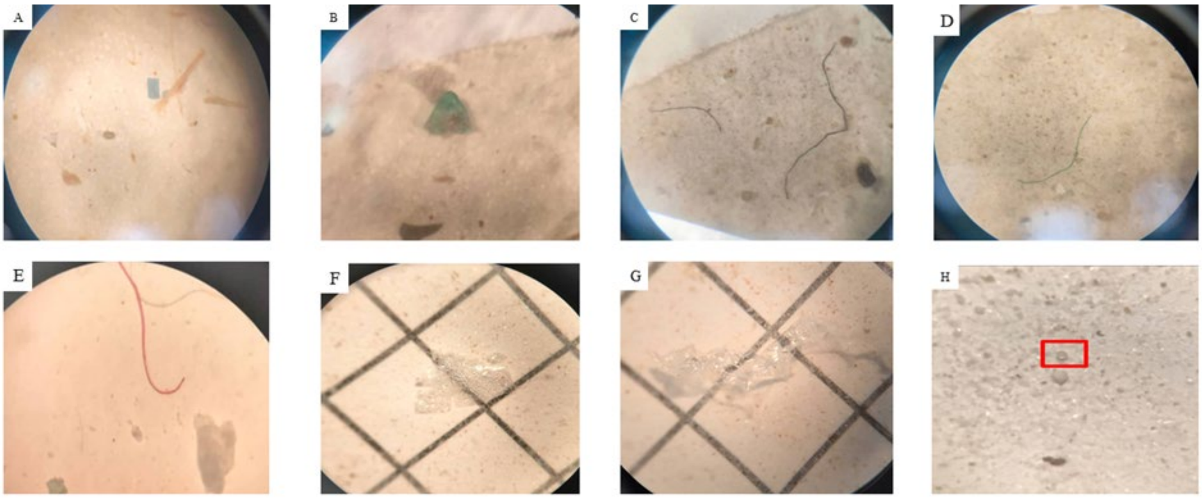

Figure 6. Examples of microplastics colors and shapes under microscope with magnification 40x collected from sediments and surface water in Macta marshes (A: blue fragment; B: Green Fragment; C: Black fiber; D: Green fiber; E: Red fiber; F/G: Transparent films; H: Transparent pellet).

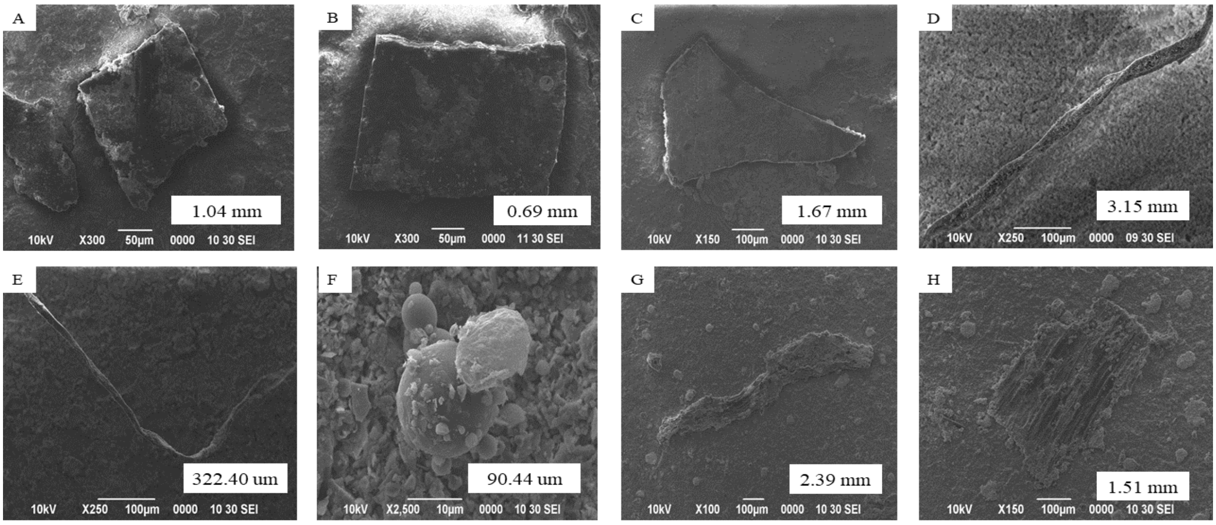

Figure 7. SEM analyses of examined MPs size in the sediments and surface waters of Macta marshes: (A, B, C): Fragments, (D, E): Fibers, (F): Pellet, (G, H): Films.

3.3. Analyses of microplastics in surface water

The abundance of MPs in the surface water samples was 3.82 ± 3.14 MPs L^{-1}. The abundance of each sample of surface water in Figure 8. ANOVA showed no significant difference in abundance ($p = 0.29 > 0.05$, $F = 1.24$).

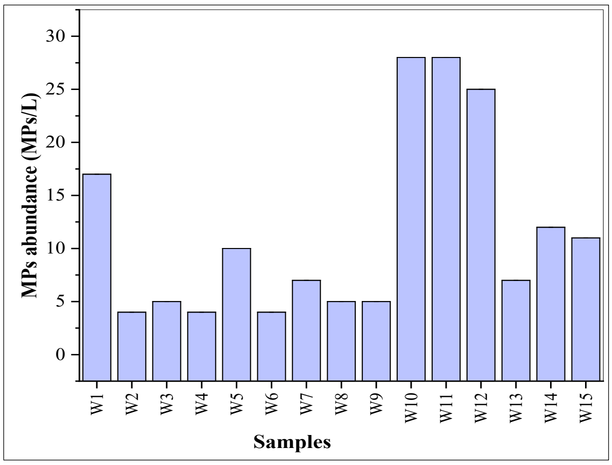

Figure 8. Abundance of microplastics across different sampling sites in the surface water of Macta marshes.

Fibers were the most prevalent shape (74.41 %), followed by fragments (16.27 %). Pellets (4.65 %) and films (4.65 %). Results obtained for each sample are presented in Figure 9. The one-way ANOVA results for the shapes in the surface water samples indicated no statistically significant differences ($p > 0.05$), with $F = 0.83$.

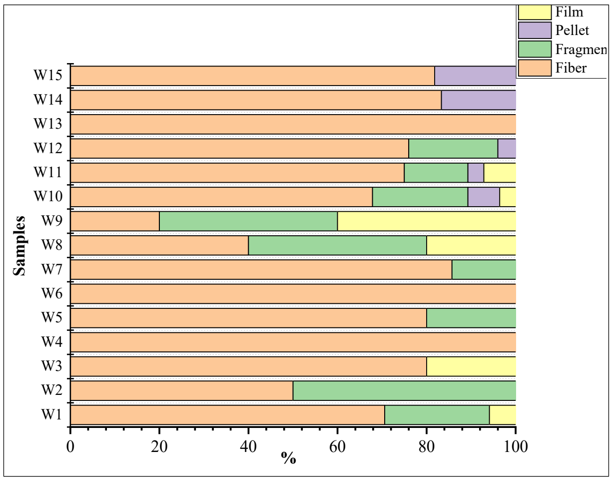

Figure 9. Percent of microplastics occurrence based on shape in different samples of surface water from Macta marshes.

Transparent microplastics were the most common microplastics in surface water samples (27.91 %). The abundance of red microplastics is next (23.84 %), followed by black (18.60 %), blue (12.79 %), green (9.88 %), yellow (4.07 %), white (2.32 %), and grey (0.58 %) (Figure 10). There was a significant difference in the colors of the surface water ($p < 0.05$, $F = 2.75$).

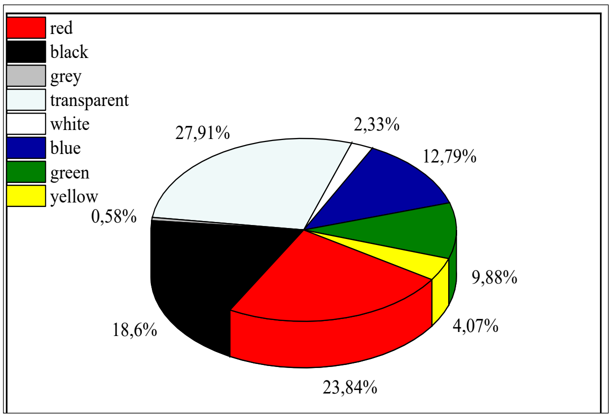

Figure 10. Percent of microplastics occurrence based on colors in surface water from Macta marshes.

Small microplastics (70.93 %) were found in surface water, but large microplastics (29.07 %). The results corresponding to each sample are illustrated in Figure 11. One-way ANOVA for size showed ($p > 0.05$, $F = 0.38$) that the size was not significantly different.

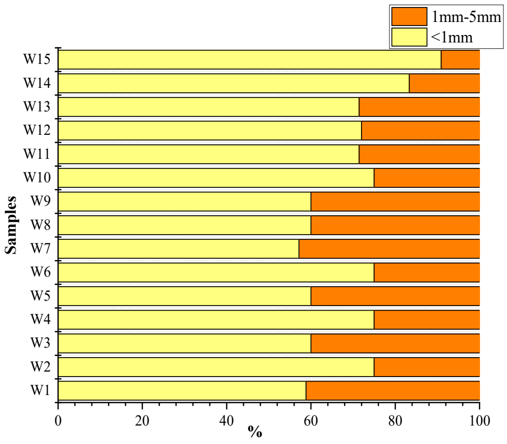

Figure 11. Percent of microplastics occurrence based on size at different samples in surface water from Macta marshes.

3.4. FTIR analysis

To determine the types of polymers present in the Macta marshes, we selected microplastics ranging from 1 mm to 5 mm to facilitate identification using FTIR techniques. Comparing of our data and spectra with the literature and spectra of other studies (Table 2), the results indicate the presence of several polymer types: HDPE (High-Density Polyethylene), PET (Polyethylene Terephthalate), PS (Polystyrene), PE (Polyethylene), ABS (Acrylonitrile-Butadiene-Styrene), ASA (Acrylonitrile-Styrene Acrylate), and PAN (Polyacrylonitrile) (Figure 12).

4. DISCUSSION

Several studies reported a significant correlation between MPs and the fine fraction of sediments: when the abundance of MPs increases, grain size decreases (Browne et al., 2011; Alomar et al., 2016; Mendes et al., 2021; Flores-Cortés & Armstrong-Altrin, 2022; Rodrigues et al., 2024). Conversely, both the research conducted by Ramos-Vázquez et al. (2024) and our own findings (P = 0.53, Pr = 0.47) show that there is no significant correlation between the presence of MPs and grain size. This is attributed to the fact that the distribution and accumulation of microplastics (MPs) are affected by particle density and environmental exposure (UV).

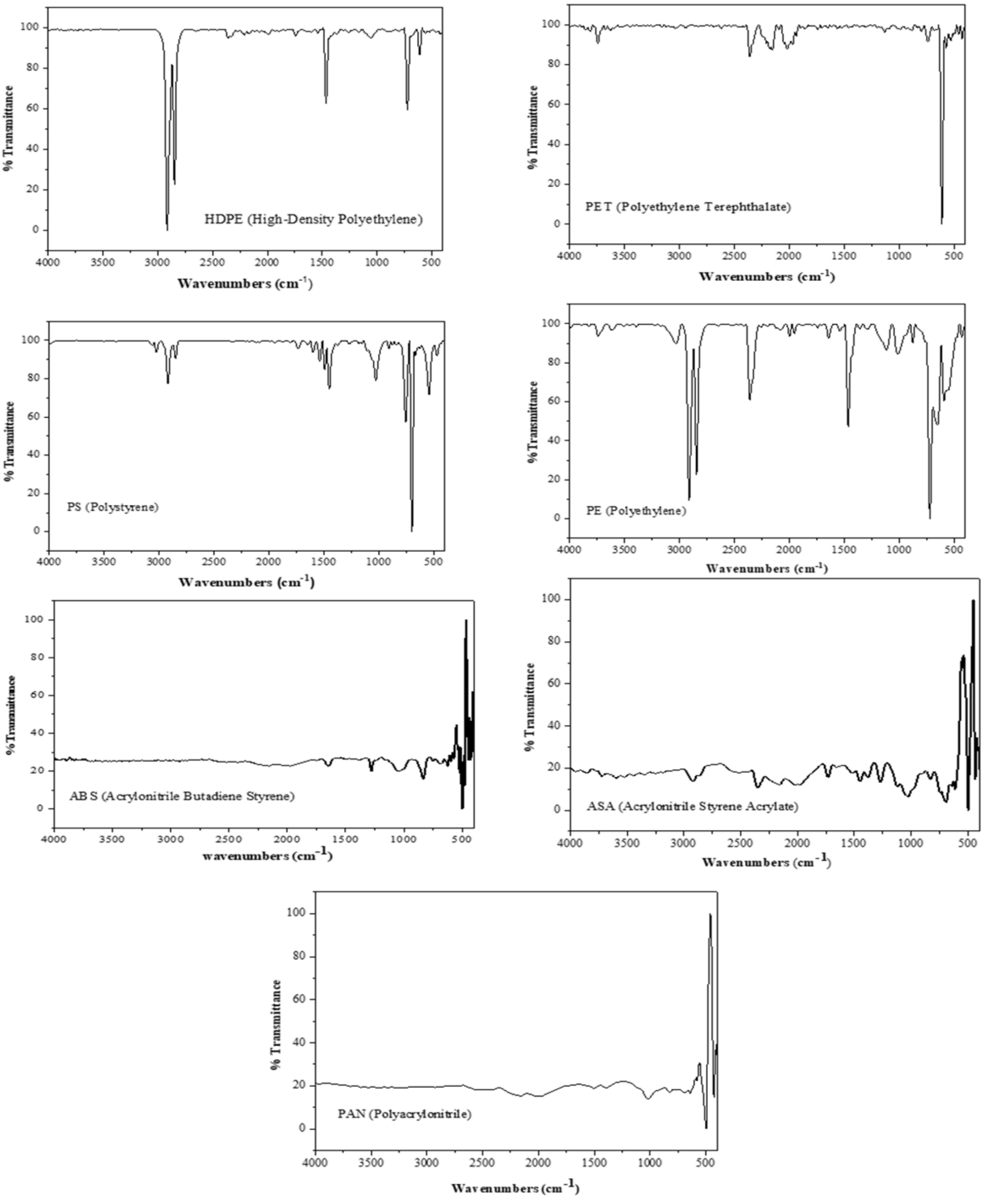

Figure 12. Result of FTIR analyses reporting the polymer types.

Table 2. Comparison of microplastic abundance in sediments and surface waters with global, Algerian, and nearby regional studies.

Location	Shape	Size	Sample type	Polymer type	Reference
Gulf of Tehuantepec, Mexico	Fibers, fragments	< 5 mm	Sediment	PAM, PMA	Ramos-Vázquez et al. (2024)
Barra Norte and Tuxpan, Mexico	Pellets, lines, fragments, films	0.95 mm - 1.05 mm	Sediment	PC, PET	Pérez-Alvarado & Armstrong-Altrin (2025)
Pearl River Estuary, Hong Kong	Fragments, pellets	0.315 - 5 mm	Sediment	Expanded polystyrene (EPS)	Fok & Cheung (2015)
Five urban estuaries of KwaZulu-Natal, South Africa	Fibers, fragments, films, pellets	20 - 5000 µm	Sediment & Water	Not identified	Naidoo et al. (2015)
Al Hoceima Bay (Morocco), (near Algeria)	Fibers, fragments, pellets, films	0.15 - 5 mm	Surface water	PE, PP, PS, PET	Bouadil et al. (2024)
El-Mellah Lagoon, Algeria & Bizerte Lagoon, Tunisia (near Algeria)	Fragments (dominant), fibers (El-Mellah ~38 %)	< 5 mm	Sediment	PE, PET, PP	Khazr et al. (2025)
Western Algerian Coast (Mostaganem-Arzew-others)	Fragments, pellets, films	≥ 1 mm	Sediment	Not identified	Taïbi et al. (2021)
Bou-Ismail Bay, Algeria	Fibers fragments films, foams, granules	smaller sizes < 330 µm	Surface water	PE, PP, PS	Setiti et al. (2021)
Bou-Ismail Bay, Algeria	Fragments dominant; Sediments: fibers dominant	< 5 mm	Surface water & sediments	PE, PP, PS	Amenouche et al. (2025)
Skikda coast beach, Algeria	Fragments, pellets	1 - 5 mm	Sediment	Not identified	Grini et al. (2022)
Macta Marshes, Algeria	Fibers, fragments, pellets, film	(1 mm - 5 mm) (< 1mm)	Sediment and Surface Water	HDPE, PET, PS, PE, ABS, ASA, PAN	Current Study

Caption: polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), cellophane (CP), high density polyethylene (HDPE), polyvinyl chloride (PVC), Expanded polystyrene (EPS), polyacrylonitrile (PAN), polycarbonate (PC), polyacrylamide (PAM), polystyrene acrylonitrile (SAN), Low-Density Polyethylene (LDPE), Acrylonitrile Butadiene Styrene (ABS), Acrylonitrile-Styrene Acrylate (ASA).

Our results indicate that microplastic concentrations are higher in sediments than in surface water. Woodall et al. (2015) suggest that this is due to the higher weight and density of microplastics compared to water, causing them to sink and accumulate in sediments. Moreover, the present study reports a higher abundance of microplastics (MPs) in sediments and in surface water than the results obtained in other studies (see Table 3).

The observed differences can be attributed to several factors, including the geographical location of the study area, the sampling and extraction methods used. In our study, sediment samples were collected using a steel trowel, and surface water samples were collected using a steel container. The extraction process involved using zinc chloride ($ZnCl_2$) and hydrogen peroxide (H_2O_2). In contrast, other studies (Table 3) have employed various sampling techniques, including Van Veen grabs, Ponar grabs; these two techniques may affect surface sediment layers, causing resuspension, vertical mixing of sediment strata, and potential loss of low-density particles, which can lead to underestimation of their abundance (Hidalgo-Ruz et al., 2012; Claessens et al., 2011). For box corers, conserve sediment stratification and limit disturbance, permitting a more accurate estimate of the microplastics that have built up in the surface layers (Vianello et al., 2013).

In surface waters, employing plankton nets with different mesh sizes selectively captures specific size categories of microplastics. Larger mesh sizes often fail to capture smaller particles and fibers, which frequently predominate in aquatic environments (Lusher et al., 2014). As a result, differences in methodology significantly influence the observed distribution, abundance, and characteristics of microplastics in both sediments and surface waters. Other extraction methods have been used, including calcium chloride ($CaCl_2$), sodium chloride (NaCl), hydrogen peroxide (H_2O_2), and zinc chloride ($ZnCl_2$).

The variations in results can also be attributed to environmental pressures in areas near heavily populated rivers, as these environments are closely associated with intense human activity. The urban and peri-urban areas generate large quantities of plastic debris and synthetic fibers originating from domestic wastewater discharges, where the river mouths are considered significant routes for penetration of pollutants into ecosystems (Lots et al., 2017).

At these stations of sediments and surface water, you can often see birds drinking water and looking for food. These sampling stations are influenced by various sources of pollution, including landfill sources: domestic waste and garbage dump (Figure 1).

Factory sources: industrial zones such as the Macta desalination station, and the Algerian-Omani Fertilizer Company (AOA Fertilizers) (Figure 1). Additionally, in the north of the Macta marshes, Mediterranean Sea: Marsat El Hadjadj Beach makes the area susceptible to anthropogenic activities such as fishing and tourism. The Bethioua mineral port is situated near the river mouth of Oued El Hammam. Gardel et al. (2022) say that river mouths are places where sediments and tiny pieces of plastic tend to build up because the water currents slow down.

SEM images show that the surface of microplastics has cracks, indicating variations in the transport environment. Furthermore, the variety of microplastic shapes also points to more than one source of origin (Guo et al., 2018; Li L. et al., 2018). Fibers are observed to be the most common type of microplastics in a number of wetlands, including the Anzali Wetland in Iran (Rasta et al., 2020) and the Ramsar Wetland in Ashtamudi Lake, India (Devi et al., 2024). This is because of the shedding of staple fibers from fabrics (Yang et al., 2022). The high abundance of fibers in the Macta marshes is likely attributed to the laundry wastewater, sewage, domestic, and industrial sources. Fibers are commonly released from textiles during washing. Jiang et al. (2018) also said that fibers are common and easy to break, which is why they are prevalent in the samples. When studying other types of plastic debris, it was found that fragments were the second most common type in the Macta wetland. The primary sources of both fragments and film are likely the degradation of various plastic products, such as bags, packaging, and containers (Derraik, 2002; Nor & Obbard, 2014; Zhang et al., 2015). The plastic industry usually makes pellets from raw materials. In addition to being used in cosmetics and personal care products, such as facial cleansers, they are also utilized in the automotive industry (Mani et al., 2015; Karlsson et al., 2018).

Camargo et al. (2022) found that red was the most common color in the sediment of the Pantanal Wetlands in Brazil, which is similar to what we found. The occurrence of colored microplastics is predominantly attributed to the degradation of various plastic products frequently utilized in everyday life (Zhang et al., 2015; Wang et al., 2017).

Microplastics that are transparent are the most common type of microplastics found in surface water. According to Gündoğdu & Çevik (2017), the most common type of microplastic was clear microplastics. This is probably because clear plastic items that can only be used once are so common. Also, weak product color may fade over time due to exposure to the environment or treatment with hydrogen peroxide during lab analysis (Yin et al., 2020). On the other hand, red microplastics might be harder to break down and tend to accumulate in sediments, where they break down more slowly because they don't get much light (Corcoran et al., 2009)

The higher prevalence of small microplastics can be attributed to several factors, including fragmentation processes, hydrodynamic conditions, and rates of decomposition. Scientific research shows that bigger pieces of plastic break down over time through physical, chemical, and biological processes. This creates smaller microplastic particles (Andrady, 2011). Several studies agree with what we found, which shows that smaller microplastics are more common near the coast. Crawford & Quinn (2016) said that small microplastics are the most common type because they keep breaking up and spreading out in the environment.

Table 3. Studies conducted on microplastics worldwide, in Algeria, and in neighboring regions.

Location	Component	Abundance	Sampling methods	Extraction methods	Reference
Mangrove Wetlands/China	Sediment	Inside: 429 items/kg; Outside: 21745 items/kg	(top 2 cm)	Density separation by $CaCl_2$	Li J. et al. (2018)
Anzali Wetland/Iran	Sediment	June: 7836 items/kg; January: 5196 items/kg	Van Veen grab (0.2 × 0.2m)	Density separation by NaCl	Rasta et al. (2020)
	Surface water	June: 1.77 items/m3; January: 1.25 items/m^3	Plankton net (350 µm mesh size)		
Three Wetlands: Portugal, Guinea, Bissau	Sediment	5970 items/kg	Ponar grab (229 × 229 mm),	Density separation by NaCl	Ibrahim et al. (2021)
	Surface water	360 items/m^3	Bulk (120L)		
Kallar Kahar Wetland/Pakistan	Sediment	5720 items/kg	Garden shovel	Digestion by H_2O_2 Density separation by NaCl	Dilshad et al. (2022)
	Surface water	88000 items/m^3	Bulk (2.5 L)		
Ashtamudi Lake/India	Sediment	3 ± 1.69/kg	steel trowels	Digestion by H_2O_2 Density separation by NaCl	Devi et al. (2024)
	Surface water	2.75 ± 1.48/L	stainless-steel		
Joumine stream, Northern Tunisia (near Algeria)	Sediment	18.2 ± 8.27/50g	Stainless-steel spatula	Density separation by NaCl	Rahmani et al. (2025)
	Water	8.87±3.94/L	Glass bottles (2 L)		
Bizerte Lagoon, Tunisia (near Algeria)	Sediment	73.4 items kg^{-1}	Stainless-steel corer	Digestion by H_2O_2 Density separation by NaCl	Khazr et al. (2025)
El Mellah Lagoon, Algeria	Sediment	75.7 items kg^{-1}	Stainless-steel spatula	Digestion by H_2O_2 Density separation by NaCl	Khazr et al. (2025)
Bou Ismail Bay, Algeria	Sediment Surface water	0.36 ± 0.2 items/g 1.16 ± 0.8 items/m^3	Sediment cores from multiple stations	KOH digestion for water; KOH + Density separation for sediments	Amenouche et al. (2025)
Bou Ismail Bay, Algeria	Surface water	0.86 ± 0.35	Manta trawl (330 µm)	Visual sorting	Setiti et al. (2021)
Western Algerian coast	Sediment	7.6 ± 18.8 to 66 ± 107.3 items/m^2	Manual sediment sampling + sieving ≥1 mm	Manual extraction by sieving and visual sorting	Taïbi et al. (2021)
Skikda coast, Algeria Beach	Sediment	6 174–6 183 items/m^2	-	Sieving and manual separation	Grini et al. (2024)
Current study (Macta marshes)/Algeria	Sediment	16733.33 MPs/kg	steel trowels	Digestion by H_2O_2 Density separation by $Zncl_2$	Current Study
	Surface water	172000 MPs/m^3	Steel container		

A study done in estuarine and wetland areas showed that small microplastics are more common because they can move around more easily and stay in water systems for longer periods of time (Zhang K. et al., 2020). In addition, their higher numbers may be because they are easier for aquatic organisms to use, which eat them and spread them throughout the ecosystem (Setälä et al., 2014).

For the types of MPs: PE is the most commonly used material for packaging and single-use items worldwide (Plastics Europe, 2020). This kind of dispersion happens because they are heavy enough to float in water, even in wetlands (Cózar et al., 2014)

Microfibers of PET are the main source of water pollution, according to Boucher & Friot (2017). This kind is used in plastic bottles and synthetic fabrics (Browne et al., 2011), while polystyrene (PS) mostly comes from things that are only used once and packaging that is thrown away (Rochman et al., 2013).

ABS and ASA are two types of plastics often used in construction and automotive applications (Strong, 2006; Menges et al., 2001). So, PAN is mostly used in kitchen appliances, textiles, and household goods (Russell, 2007; Rosato & Rosato, 2001). Based on our results, there is plastic pollution in the Macta marshes due to urban runoff, domestic sewage, and industrial discharges.

5. SUMMARY

Microplastic distribution in Macta marshes showed clear contrasts between sediment and surface water samples. Sediments contained significantly higher microplastic abundances with 253.54 ± 273.84 MPs/kg. In contrast, surface waters exhibited lower and more variable microplastic concentrations (3.82 ± 3.14 MPs/L). This difference is due to the higher weight and density of MPs compared to water, which causes particles to accumulate and tend to sink and settle in sediment.

In both matrices, fibers were the dominant shape, accounting for 80.73 % of particles in sediments and 74.41 % in surface waters, followed by fragments, pellets, and films.

Distinct color patterns were observed between sediments and surface waters: sediments were mainly dominated by red, whereas a higher proportion of transparent particles characterized surface waters.

SEM observations revealed a predominance of small-sized microplastics in both environments, while FTIR analysis identified diverse polymer types, including HDPE, PET, PS, PE, ABS, ASA, and PAN. These differences reflect the combined influence of particle properties, hydrodynamic conditions, and local anthropogenic activities. Overall, domestic, industrial, marine, and recreational activities were identified as the primary sources of microplastic contamination in Macta marshes.

6. CONCLUSION

The current study is the first to focus on abundance assessment, physical characterization (shapes, colors, size), and type identification of microplastics in sediments and surface water in a Ramsar site, the Macta marshes. Our results indicate that the Macta mashes has a high concentration of microplastics due to the impact of domestic, industrial, and marine activities. The dominant shape of microplastics is fiber. In sediment, the color is predominantly red, while in surface water, it is transparent. This abundance is attributed to domestic discharge and industrial wastewater, as well as fishing activities, maritime operations, and the release of textiles during washing and laundry in communities. Most microplastics were sized less than 1 mm. The results of an FTIR spectroscopy analysis showed the presence of HDPE (High Density Polyethylene), PET (Polyethylene Terephthalate, PS (Polystyrene), PE (Polyethylene) ABS (Acrylonitrile-Butadiene-Styrene), ASA (Acrylonitrile-Styrene-Acrylate), PAN (Polyacrylonitrile) which indicate that the packaging, plastic bottles, and synthetic textiles were possible sources of microplastics, therefore the local authorities should investigate plastic pollution and develop a program aimed at managing and reducing solid waste in Macta marshes.

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