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The trapping of microplastics in the *Posidonia oceanica* aegagropiles in Tunisian coastal areas—Southern Mediterranean

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Plastic and microplastic debris (MP) constitute the most important pollutants of the solid litter with a high risk of sediment accumulation. *Posidonia oceanica* (L.) Delile is the main marine seagrass of the Mediterranean Sea which forms immense underwater meadows and deposits of seagrass beds covering the facades of sandy beaches. They are formed by roots and rhizome fragments gathered in fibrous marine balls, called aegagropiles (EGs), having the ability to trap several pollutants from the beaches and mainly microplastic. The present study aims at evaluating microplastic contamination in aegagropiles collected from four locations along the Tunisian coast in the southern Mediterranean basin (two northern sites (S1 and S2) and two southern-central sites (S3 and S4). Microscopic analysis revealed that red and blue microplastics dominated at all sites, with black fibers and fragments being the most prevalent forms and yellow (S3) and transparent particles in S1, S2, and S4. Polymer identification conducted using nuclear magnetic resonance (NMR) and Fourier-transform infrared spectroscopy (FTIR) detected microplastic types with contamination levels and microplastic accumulation variation among the four sites including polystyrene (PS) at sites S1, S3, and S4; ethyl vinyl acetate (EVA) at S1 and S3; polyethylene terephthalate (PET) at S1 and S2; and polyvinyl chloride (PVC) at S2 and S3. Our results highlight close relationships between anthropogenic activities, extensive plastic use, and elevated microplastic pollution in marine ecosystems, particularly in seagrass beds. These findings emphasize the importance of monitoring microplastic contamination to preserve the health of Mediterranean coastal environments.

KEYWORDS

***Posidonia oceanica*, aegagropile, microplastics, acid digestion, NMR spectroscopy, FTIR, stereomicroscopy**

Introduction

Waste management is becoming a major issue with the increase in human population density; indeed, recent studies have highlighted a serious issue of marine litter (De Luca et al., 2025; Sarkar et al., 2025). It is well documented that the human-produced waste which accumulates in marine environments consists essentially of large quantities of microplastics in water like rivers, lakes, seas and oceans (Fraissinet et al., 2025; Gurjar et al., 2023; Jamsek et al., 2024). Research has demonstrated that UV light and low temperature facilitate the breakdown of conventional plastics into smaller fragments, commonly known as microplastics. These microplastics are subsequently transported into marine environments through runoff (Nguyen et al., 2025). In fact, the plastic material size ranging from 1 µM to 5 mm has been classified as microplastic (Cole et al., 2011). Microplastics are divided into primary and secondary microplastics (Bhuyan et al., 2021). The main source of primary plastic involves cosmetic products, personal healthcare products, and children's products (Hartmann et al., 2019). However, the major sources of secondary plastics are fragmented products produced via the physical fragmentation as well as the biological and chemical degradation of large-sized plastic material (Sait et al., 2021; Yuan et al., 2022). It is important to mention that most current studies on microplastic toxicity are increasingly focused on elucidating the underlying mechanisms responsible for their toxicity (Zhang et al., 2022). The latter area of microplastics research is important considering that some of the chemicals associated with plastic contamination are able to disrupt the endocrine system in vertebrates, including fish and mammals (Gugliandolo et al., 2020; Folbert et al., 2022; Corti et al., 2023; Sharma et al., 2024). Furthermore, microplastics are readily assimilated by plankton, which can serve as a transfer route to secondary and tertiary consumers in the marine food chain, potentially leading to consequences for humans, the final consumers (Gunaalan et al., 2023). It should be noted that the smaller the size of microplastics, the more the toxicological consequences (Markic et al., 2020; Tang, 2024).

On the other hand, *Posidonia oceanica* (PO) is known as marine seagrass and an endemic species to Mediterranean Sea (De Luca et al., 2025). The shoots of *P. oceanica* constitute structurally complex ecosystems, providing adequate living conditions and ecological niches for a significant number of organisms (Boudouresque et al., 2016). On the beaches of the Mediterranean Sea, one often finds ball-shaped clumps of plant debris. These natural formations are called "aegagropiles (EG)," and they are usually made from fibers of the seagrass *Posidonia oceanica*, whose size diverges from millimeters to centimeters (Verhille and Le Gal, 2018). These balls occupied large areas, notably after storms. Research revealed that EG are formed by hydrodynamic flows and composed of different plant fibrous elements (PO) and sand grains (Matheson et al., 2017). The leaf cells of *Posidonia* are distinguished by their thin and lignified walls, and thus the fibers offer the rigidity necessary to form EG (Piñeiro-Juncal et al., 2021).

PO plays an important ecological role by acting as a sink for contaminants, particularly by storing them in its roots and shoots, thereby helping in reducing their availability in the marine environment (Tahir et al., 2019; Sghaier et al., 2025). It actively removes certain pollutants, sequestering a portion within its tissues and thereby limiting their transfer through trophic networks. Moreover, several studies highlight the role of *P. oceanica* as an effective bioindicator of marine pollution, as well as a long-term archive of contaminants through accumulation in the matte (the dense, long-lasting underground structure formed by intertwined rhizomes, roots, and trapped sediments), which serves as an environmental memory of pollutant inputs (Telesca et al., 2015; Sghaier et al., 2025).

In this context, it is essential to identify effective strategies to mitigate the impact of chemical pollution on seagrass beds. Although various studies have investigated the distribution of microplastics in specific geographical regions and others have examined their effects on certain marine organisms, global knowledge remains limited due to the relatively small number of in-depth studies focusing on natural bioaggregates such as aegagropiles (EGs) and their role in trapping and transferring microplastics. Therefore, the present study aims to assess the accumulation of microplastics in aegagropiles and to identify the most abundant polymers present in the marine environment.

Material and methods

Sampling

P. oceanica aegagropiles were sampled at four different sites, four from the North of Tunisia including Bizerte (latitude 37°17′ 45.02″N, longitude 9°52′23.22″E) (S1), and Hammamet (longitude 10°32′29.84″E, latitude 36°22′13.76″N) (S2), and from the east-central Tunisia at two different sites: Mahdia (latitude 35°30′56.39″ N, longitude 11° 2′56.66″E) (S3) and Chebba (latitude 35°26′56.96″ N, longitude 11° 0′16.78″E) (S4) (Figure 1). These sites are characterized by tourism and fishing activities. Aegagropiles were manually collected in triplicate from seagrass banquettes (dense accumulations of dead seagrass leaves along the shoreline), as illustrated in Figure 2. The samples were placed in sterile sample bags and transported to the Laboratory of Marine Ecotoxicology at National Institute of Marine sciences and Technology for subsequent laboratory analysis.

Microplastic extraction

In the laboratory, the samples underwent a thorough cleaning process with distilled water to remove any sediment, followed by air drying at room temperature (25 °C) and low humidity for several days. The aegagropiles of *P. oceanica* were weighed using an analytical balance with a sensitivity of 0.01 mg. To dissolve and digest the organic matter, two methods were applied following Sanchez-Vidal et al. (2021), with some modifications. In the first

FIGURE 1
Map showing the four sampling areas sites along the coast of Tunisia. (S1) Bizerte, (S2) Hammamet, (S3) Mahdia, (S4) Chebba.

method, a solution containing 10% HCl and 30 mL of 30% H_2O_2 was introduced. After a reaction period of 48 h, a KOH solution (10%) was added to promote chemical digestion. The samples were dried in the oven at 50 °C for 1 week. Then, the resulting mixture containing solid residues and MP was sieved. The contents of the sieves were transferred to a glass jar for decanting. The supernatant was filtered under vacuum through a Whatman glass fiber filter with a diameter of 47 mm (GF/D, with a particle retention size of 2.7 µm). The filter cake was completely rinsed with deionized water and then dried in an oven at 60°C, and the membrane was stored in a glass Petri dish for air drying at room temperature.

With the second method, the EGs were carefully disentangled, and the fibers were sieved at 5, 0.36, and 0.2 mm using a stainless-steel sieve. The contents retained on the sieves were treated with 4–6 mL of hydrogen peroxide (H_2O_2, 30%), followed by 10% hydrochloric acid (HCl) to remove most of the organic matter and calcium carbonate. The samples were then dried in an oven at 50°C for more than 24 h.

Quality control

During the sampling, no plastic tools and materials were used. Additionally, the laboratory contamination was assessed by placing a moist filter over an opened Petri dish. The operators were required to wear cotton coats to further reduce the risk of contamination. Prior to use, the filters were meticulously inspected under a microscope to ensure they were free from any airborne microplastic particles. When handling samples, stainless-steel forceps were used to maintain the integrity of the samples.

Microplastics identifications

All extracted plastic particles were picked out with metal tweezers into a 90-mm Petri dish containing a black and white background that enabled high contrast with plastic colors and types, which was photographed. The Petri dishes were inspected for plastic debris under a Leica M60 stereomicroscope (Leica Microsystems AG, Glattbrugg, Switzerland) equipped with a CMOS microscope camera and a 6:1 zoom system, offering a continuous magnification range from 2× to 5×, with engageable click stops for precise settings (see Hassen et al., 2023).

^{1}H-NMR characterization

Using proton nuclear magnetic resonance spectroscopy (^{1}H-NMR) characterization, MP particles were dissolved in a suitable deuterated solvent. Deuterated dimethyl sulfoxide (DMSO-d6) (99.8 atom %D) and deuterated chloroform (CDCl3) (99.8 atom %D, stab. with Ag) from Deutero, Germany, were used.

The NMR measurements were performed using a Bruker Avance III 300 MHz spectrometer. Data were recorded at room temperature, at a spinning rate of 14 kHz and with a pulse length of 90° and 3.25 µs with a 5-s interval between scans (see Peez and Imhof, 2020).

FT-IR characterization

The Fourier-transform infrared (FTIR) measurements were carried out on a Perkin Elmer Spectrum BX FTIR device (Perkin Elmer, USA), utilizing a Golden Gate single reflection diamond ATR system (SpecacLda, USA). All spectra were obtained using 64 scans each and a resolution of 4 cm^{-1}, within the 4,000–450-cm^{-1} range (see Blindheim and Ruwoldt, 2023).

FIGURE 2
Aegagropiles collected from Tunisian beaches: **(A)** Bizerte, **(B)** Mahdia, **(C)** close-up image of an aegagropile.

Results

Microscopy identification

An examination of the colors and types of microplastics trapped in the EGs (Figure 3) revealed that the plastic items mainly consisted of fragments and threads. These were of various sizes and colors and were found to be intertwined within the examined EGs.

The frequent colors of microplastics were mainly blue and red. In site S1, the found microplastic elements included blue, black, and transparent fragments and filaments with red and yellow colors (Figure 3A).

At the S2 site (Figure 3B), red, blue, and transparent filaments were detected with the presence of black and blue fragments. Concerning site S3 (Figure 3C), black and yellow fragments are essentially observed with the presence of transparent filaments. For site S4, black and red fragments are identified (Figure 3D).

FTIR results

According to the literature (Table 1), the results obtained by FTIR showed intense absorptions at 3,250 (hydrogen bonded N–H stretch), 2,917-2,840 cm^{-1} (ns CH_2), 1,722-1,529 (amide I), 1,354, 1,249 (amide III), 1,152-1,003 (C–C str), 800-700 (CH_2 rocking), and 694-500 (Aromatic CH out-of-plane bending) cm^{-1}.

Figure 4 shows different types of polymers determined in each site. In site S1 (Figure 4A), bands at 3,300, 2,992, 1,700, 1,500, 1,250, 1,050, 750, and 550 cm^{-1} are related to polysterene (PS), polyethylene terephthalate (PET), and ethylene-vinyl acetate (EVA). Similarly, in site S2 (Figure 4B), the collected spectra revealed that bands at 2,875, 1,750, 1,650, 1,500, 1,250, 1,000, 750, 550, and 500 cm^{-1} demonstrated the existence of polyvinylchloride (PVC), propylene (PP), and PET.

At site S3 in the Tunisian east-center, as depicted in Figure 4C, bands observed at 2,900, 1,800, 1,650, 1,300, 1,150, and 1,000 cm^{-1} indicated the presence of PS and EVA. However, in site S4 (Figure 4D), the spectrum revealed the existence of PVC and PS, characterized by bands at 2,900, 1,800, 1,750, 1,600, 1,400, 1,100, 950, and 600 cm^{-1}.

^{1}H-NMR spectroscopy results

The spectra obtained for each compound separately were determined according to previous studies related to microplastic identifications (Table 2). According to the literature, in site S1, three types of microplastics are determined, namely, PS, PA, and PVC (Figure 5A). In fact, two signals can be clearly assigned to PVC, one of which with a chemical shift of 4.6-4.2 ppm (H1) corresponds to the α-Cl H atoms and the other in the range of 2.5-2.1 ppm (H2) matches with the β-Cl H atom. With respect to PS, four signals were assigned: 1.87 ppm (H1) 1.46 ppm (H2), 6.4-6.8 ppm (H3), and 7.11 ppm (H4, 5). It is worthwhile to note that PA signals at high field with chemical shifts between 3.2 and 1.1 ppm can be assigned to protons H1-H5. The signal with the chemical shift of 3.2-3.0 ppm (H1) aligns with the α-NH H atoms and the signal in the range of 2.3-2.15 ppm (H2) matches the protons H2 of the α-CO group. Signals in the range of 1.65-1.1 ppm represent CH2 groups H3-H5 of the polymer chain.

In site S2 (Figure 5B), EVA, PP, and PE can be observed. As regards EVA, five signals were assigned at 0.86 to H1, 1.25 (H2), 1.74 (H3), 2.01 (H4), and 4.85 to (H5). The PE can be assigned to two signals. The signal at 1.33 ppm (H2) corresponds to the protons of the

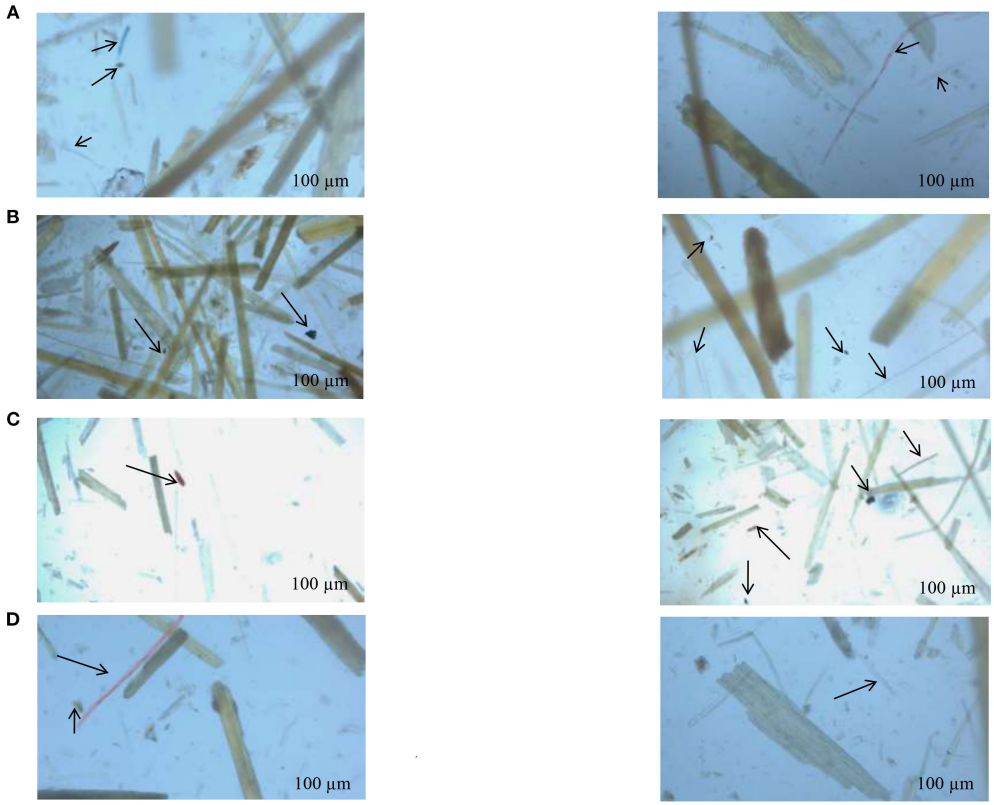

FIGURE 3
Microplastic particles found in EG extract samples under a stereomicroscope. **(A)** Bizerte, **(B)** Hammamet, **(C)** Chebba, **(D)** Mahdia.

TABLE 1 FTIR characteristic peak assignments in cm^{-1} for various types of MPs.

POLYMER	Characteristic peaks (cm^{-1})	Assignement	References
Low density polyethylene (LDPE)	2915	C–H stretching	Nishikida and Coates, 2003; Noda et al., 2007; Asensio et al., 2009; Mecozzi et al., 2016; Jung et al., 2018
	2845	C–H stretching	
	1467	CH2 bending	
	1462	CH2 bending	
	1377	CH2 bending	
	730	CH2 rocking	
	717	CH2 rocking	
Polyethylene terephthalate (PET)	1713	C=O stretching	Verleye et al., 2001; Noda et al., 2007; Asensio et al., 2009; Mecozzi et al., 2016; Jung et al., 2018
	1241	C–O stretching	
	1094	C–O stretching Aromatic	
	720	CH out-of plane bending	
Polypropylene (PP)	2950	C–H stretching	Verleye et al., 2001; Noda et al., 2007; Asensio et al., 2009; Mecozzi et al., 2016; Jung et al., 2018
	2838	C–H stretching	
	2915	C–H stretching	
	1455	CH2 bending	

(Continued)

TABLE 1 Continued

POLYMER	Characteristic peaks (cm^{-1})	Assignement	References
	1377	CH3 bending	
	1166	CH bending, CH3 rocking, C–C stretching	
	997	CH3 rocking, CH3 bending, CH bending	
	972	CH3 rocking, C–C stretching	
	840	CH2 rocking, C–CH3 stretching	
	808	CH2 rocking, C–C stretching, C–CH stretching Aromatic	
Polystyrene (PS)	3024	C–H stretching	Verleye et al., 2001; Noda et al., 2007; Asensio et al., 2009; Mecozzi et al., 2016; Jung et al., 2018
	2847	C–H stretching	
	1601	Aromatic ring stretching	
	1492	Aromatic ring stretching	
	1451	CH2 bending	
	1027	Aromatic CH bending	
	694	Aromatic CH out-of plane bending	
	537	Aromatic ring out-of plane bending	
Polyvinyl chloride (PVC)	1427	CH2 bending	Verleye et al., 2001; Noda et al., 2007; Jung et al., 2018
	1331	CH bending	
	1255	CH bending	
	1099	C–C stretching	
	966	CH2 rocking	
	616	C–Cl stretching	
Ethylene vinyl acetate (EVA)	2917	C–H stretching	Verleye et al., 2001; Asensio et al., 2009; Jung et al., 2018
	2848	C–H stretching	
	1740	C = O stretching	
	1469	CH2 bending, CH3 bending	
	1241	C (=O) O stretching	
	1020	C–O stretching	
	720	CH2 rocking	
Nylon (all polyamides)	3298	N–H stretching	Verleye et al., 2001; Noda et al., 2007; Mecozzi et al., 2016; Jung et al., 2018
	2932	CH stretching	
	2858	CH stretching	
	1634	C =O stretching	
	1538	NH bending, C–N stretching	
	1464	CH2 bending	
	1372	CH2 bending	
	1274	NH bending, C–N stretching	
	1199	CH2 bending	
	687	NH bending, C=O bending	

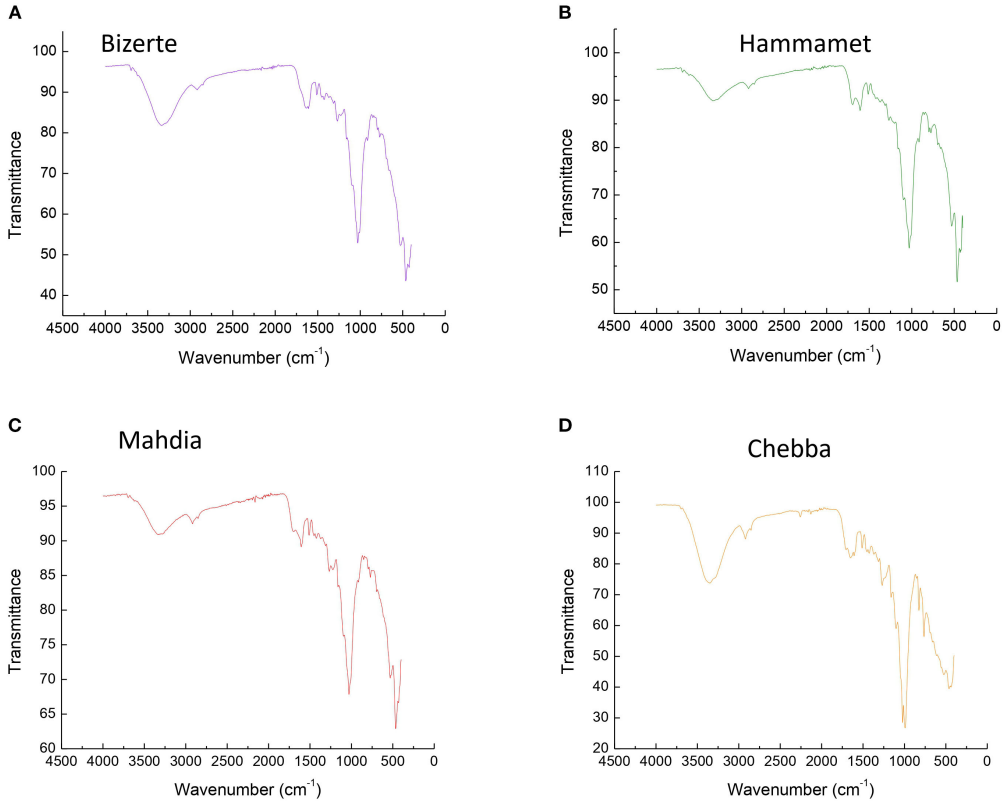

FIGURE 4
Polymers of microplastic obtained from FTIR spectroscopy reads found in **(A)** Bizerte, **(B)** Hammamet, **(C)** Chebba, and **(D)** Mahdia (assigned characteristic peaks in cm^{-1}).

CH_2 groups and the one at 0.93 ppm (H1) corresponds to the protons of the CH_3 group. Three signals defined PP and can be seen in the NMR spectrum at 0.74, 1.19, and 1.48 ppm, belonging to the methyl, methylene, and methine groups of oligo/polymeric propylene.

While PVC, EVA, and PP were determined in site S3 (Figure 5C), PA and PP were detected in site S4 (Figure 5D).

Discussion

Microplastics (MPs) are composed of various polymers, and their distribution in the environment depends on both morphological and chemical characteristics (Giaganini et al., 2023). Understanding these characteristics is important because the shape and size of MPs can influence their transport and accumulation in different environments. For instance, morphological traits may help infer how MPs are distributed across coastal areas (horizontally), whereas polymer type can affect their behavior in the water column (vertically). Although our study does not directly assess horizontal or vertical distribution, we adopted a similar approach by characterizing MPs in eagagropiles (EGs) based on morphology (e.g., fragments, threads) and polymer composition, using microscopy and spectroscopy. This characterization helps to understand the types and potential sources of MPs accumulating along the Tunisian coasts. Previous studies have similarly emphasized the importance of such classification (e.g., Anderson et al., 2017; Veerasingam et al., 2020). Microscopy identification of microplastics (Figure 3) showed that fibers particularly red (100%), transparent (100%), and blue (75%) were the most commonly observed in all samples. While the black fragment was revealed in two sites, the yellow fragment was identified in one site (Figure 3). However, Ben Ismail et al. (2022) reported different MP forms in water samples collected in the Gulf of Gabes, with fragments being the most abundant plastic form, whereas fibers, pellets, films, and foams were detected in only a small fraction. This observation was confirmed by Zayen et al. (2020), and five different categories of MP forms, fragments, films, filaments, pellets, and foam, were found in the water of the same site. The color of MP items was white in the majority, whereas blue, black, green, and red items accounted on average for 9%, 5%, 5%, and 3% of the total MPs, respectively.

In other studies, other identified colors, including yellow, orange, gray, and purple, were also present within MPs (4%; 344 of total MPs) (Zhang et al., 2022). Dahl et al. (2021) examined soil collected in PO meadows at three locations along the Spanish Mediterranean coast and reported that the most common particle colors were transparent (30%), white (18%), and green (15%), and the dominant forms were irregular (58%) and flat (30%). In addition, according to several studies, transparent particles of MPs represented approximately 20% to 70% of the total plastic-

TABLE 2 ^{1}H- NMR characteristic signal assignments in ppm for various types of MPs.

Polymer	ppm	Assignement	References
PET	8.119	H1	Papini et al., 2022
	4.713	H2	
	1.33	H2	Peez et al., 2019
PE	0.93	H1	
PS	1.878	H1	Papini et al., 2022
	1.463	H2	
	6.400-6.800	H3	
	7.112	H4,5	
PA	3.2-3.0	H1	Peez and Imhof, 2020
	2.3-2.15	H2	
	1.65-1.1	H3-H5	
	7.31	(amines)	
PP	0.74	H1	Hero and Kali, 2020
	1.19	H2	
	1.48	H3	
PVC	2.000-2.500	H2	Papini et al., 2022
	4.250-4.670	H1	
EVA	0.86	H1	Ren et al., 2019
	1.25	H2	
	1.74	H3	
	2.01	H4	
	4.85	H5	

like particles, initially revealed by stereomicroscopy and afterward classified by other methods (He et al., 2025; Song et al., 2015; Mariano et al., 2021). Likewise, it is difficult to distinguish between natural and synthetic fibers when using a stereomicroscope, which are prevalent constituents in water, soil, and biota (Lusher et al., 2013; de los Santos et al., 2021; Mariano et al., 2021). This allows for the rapid identification of the shape, size, and color of the particles before subsequent characterization by other techniques. The use of microscopy combined with additional methods, such as spectroscopy, enhances the accuracy and comprehensiveness of microplastic analysis (Mariano et al., 2021).

Within the same vein, to determine the type of microplastics accumulated in EGs, FTIR and NMR analyses were carried out (Figures 4, 5). Using two spectroscopy methods allowed for defining the polymers identified in the samples. Different types of microplastics are identified, principally polysterene, propylene, ethyl-vinyl acetate, polyamide, and polyvinyl chloride which are mainly the most found.

The dominance of polymers such as polysterene (PS), polyethylene terephthalate (PET), polyvinyl chloride (PVC), and ethyl-vinyl acetate (EVA) reflects their widespread use in everyday items ranging from packaging, textiles, to construction materials commonly found in the region (Gurjar et al., 2023; Jamsek et al., 2024). Coastal tourism, which plays a vital role in the local economy, often brings seasonal surges of plastic waste, whereas urban runoff, wastewater discharge, and river inputs transport land-based sources into the marine ecosystem (Gurjar et al., 2023; Jamsek et al., 2024).

Several previous studies have confirmed similar polymer distributions in the Mediterranean and other regions (Pourebrahimi and Pirooz, 2023). According to Zayen et al. (2020), the common MP items were attributed to polyolefins, basically polyethylene and reformulated polyethylene, as well as polypropylene (PP) and ethylene–propylene copolymers, from water samples collected in near-surface waters of the Gulf of Gabes. Based on water samples taken from the Gulf of Gabes, Ben Ismail et al. (2022) characterized 11 different polymer typologies determined as PE, constituting the majority of MPs, followed by PP. Less frequent polymers included (<6%) PS, polyvinyl alcohol (PVA), polyamides (PA), acrylic (Acr), ethylene-vinyl acetate (EVA), polyvinyl chloride (PVC), ethylene propylene diene monomer (EPDM), and polyesters (mainly PET). In addition, Ben Ismail et al. (2022) admitted that from biota samples, a mixture of PE and EVA was determined. Nevertheless, Pietrelli et al. (2017) reported that PE and PP were found in significantly higher amounts in sand, whereas PE, nylon, polyester, and microfibers (as pills) were more frequently detected in EGs from samples collected along the central coast of Italy.

In this context, in Tarragona coastal regions, PP and PE fragments were the prevalent MPs on beaches, whereas polyester fibers were dominated in the bottom sediments and saltwater (Expósito et al., 2021). The abundance of fiber balls coupled with bottom sediments, organic materials, and plankton hid the true fibers present in each reservoir (Expósito et al., 2021). Nevertheless, other plastic polymers have been detected from marine sediment from the German coast showing the presence of PP in each sample (Lorenz, 2014). PS was also present throughout the samples, although it occurred less frequently than other polymer types. Denser polymers, such as PVC and PVA, have been detected alongside low-density polymers like PE. In other studies, for example, in the Venice lagoon and in PO meadows adjacent to agricultural hinterland in Spain, PE and PP were revealed as the most abundant materials in seawater and sediments. Additionally, fragments and filaments were the most common forms determined, as signaled by Grego et al. (2022).

Generally, PP, PE, and PET were admitted as common polymer types in the marine environment (Zhou et al., 2021). More deeply, PE and PP are frequently detected materials due to their low density (Pedrotti et al., 2016; Yao et al., 2024), which permits their floating and immersion. These polymers are widely used as polymers in various commodities like packaging, household plastic waste, and numerous personal care and cosmetic products (Cole et al., 2011; Plastic Europe, 2020).

Beyond the Mediterranean, studies such as Ballent et al. (2016) reported the presence of various polymers including PE, PS, PU, PVC, and PSS in high abundance in Canadian Lake Ontario, with other polymers like PET, nylon, and ABS found in smaller quantities.

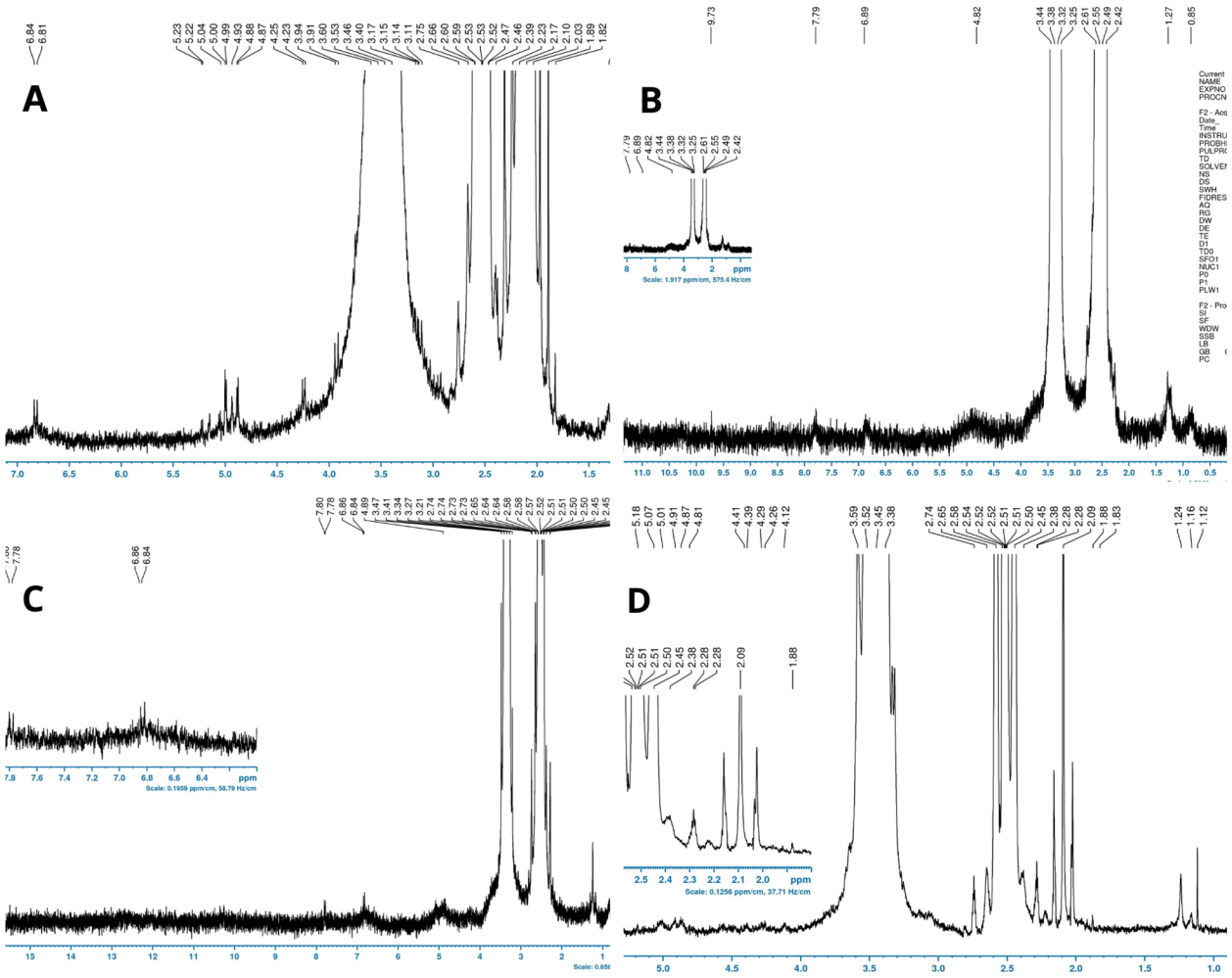

FIGURE 5
^{1}H-NMR spectra of plastic polymers found in the Tunisian coastlines of the four different sites **(A)** Bizerte, **(B)** Hammamet, **(C)** Chebba, and **(D)** Mahdia (assigned chemical shifts in ppm).

Although our study focuses on the Tunisian coast, these findings support the global ubiquity and diversity of microplastic polymer types, aligning with the polymeric variety we observed in the EGs.

The identified microplastics differ from one site to another, depending on the specific activities in these regions, such as tourism, agriculture, fishing, and industry. In fact, it is difficult to determine their origin because a single polymer may come from several products and have a huge range of sources (Ballent et al., 2016). PE, PP, PS, PA, PVC, EVA, and nylon are the most dominating forms of microplastic distributed in marine, freshwater, and estuarine environments (Zhang et al., 2022). PE and its derivatives are generally used in fishing gears (Wang et al., 2021), food packaging, agricultural film, and plastic bottles and plastic bags (Zhang et al., 2022). However, PP is used in plastic containers, food packaging, carpets, and pipes (Zhang et al., 2022). While PS is used in food containers, rubber tires, and boat hulls, surfboards, bathtubs, and shower enclosures, EVA is used as padding in the equipment of various sports such as ski boots, bicycle saddles, waterski boots, fishing rods, and fishing-reel handles (Zhang et al., 2022).

Anthropogenic pressures, combined with insufficient waste management and densely populated coastlines typical of the Mediterranean basin, contribute significantly to the observed microplastic contamination patterns in *Posidonia oceanica* seagrass aegagropiles (EGs). Therefore, seagrass meadows constitute an area of microplastic accumulation, which accords well with the findings obtained by Cozzolino et al. (2020), who reported higher macroplastic presence in vegetated coastal areas compared with unvegetated ones. Such variation in microplastic distribution within vegetated zones is influenced by multiple factors, including anthropogenic activities, local physical drivers, and seagrass leaf morphology and spatial distribution (Unsworth et al., 2021).

Although the capacity of microplastic retention generally increases with seagrass canopy density and particle abundance, it tends to decrease with higher flow velocities, with likely varied relationships among particle types (Boshoff et al., 2023). For instance, *Zostera capensis* leaves are thinner and more flexible than the tougher leaves of *Zostera marina*, affecting their ability to trap litter (Kreitsberg et al., 2021). The significant accumulation of plastic fragments intertwined

within *P. oceanica* seagrass beds washed ashore on Mediterranean beaches supports the idea that seagrass meadows act as effective litter traps (Sanchez-Vidal et al., 2021; Sghaier et al., 2025). This accumulation is likely enhanced in sheltered coastal areas and influenced by episodic events such as storms or increased runoff during heavy precipitation (Huang et al., 2020).

Furthermore, seagrasses directly influence sediment dynamics by reducing water velocity, which promotes sedimentation and vertical accretion (Jones et al., 2020). This sediment trapping is governed by the availability of terrestrial and marine sediments, as well as by wave and tidal energy (Boshoff et al., 2023). Vegetated coastal systems thus provide the important ecosystem service of capturing and storing environmental contaminants and organic matter, including microplastics (Celis-Hernandez et al., 2020; Veettil et al., 2020; Navarrete-Fernández et al., 2022). Microplastic deposition may be further enhanced by changes in relative density caused by salinity fluctuations, biofouling, and the reduced water flow within dense seagrass canopies (Pinheiro et al., 2021; Cesarini et al., 2023).

Aegagropiles (EGs) with fibrous aggregates of *Posidonia oceanica* debris and trapped sediments play a crucial ecological role as bioindicators of plastic pollution in coastal marine environments (Sanchez-Vidal et al., 2021; Alomar et al., 2024). Formed and deposited on shorelines, especially following storm events, EGs efficiently capture and retain microplastics and other anthropogenic pollutants, integrating contaminants over time and space (Verhille et al., 2017; Sanchez-Vidal et al., 2021; Rigatou et al., 2025). Their lignocellulosic matrix (a natural structure composed of cellulose, hemicellulose, and lignin) facilitates pollutant retention, making EGs reliable tools for detecting microplastic presence and accumulation. Variations in microplastic concentration and composition across different sites reflect local human pressures and pollution sources (Sanchez-Vidal et al., 2021; Alomar et al., 2024; Rigatou et al., 2025).

Beyond trapping pollutants, EGs provide important insights into the transport and dispersal of plastic debris within marine habitats, as they are moved by waves and currents. Their visible, persistent presence on beaches offers a practical and cost-effective method for monitoring coastal plastic pollution. Utilizing EGs as indicators supports the identification of pollution hotspots, source attribution, and evaluation of waste management effectiveness (Porcino et al., 2023; Restaino et al., 2023).

Conclusion

This study demonstrated that the aegagropiles (EGs), formed from the lignocellulosic debris of *Posidonia oceanica* meadows, can serve as effective indicators of microplastic pollution along the Tunisian coasts. Through morphological and chemical characterization of the microplastics trapped in the EGs, we found a wide diversity of plastic types of plastics often entangled with the fibrous structure of the EGs. Our findings suggest that EGs contribute to both the accumulation and transport of microplastics from shallow seagrass habitats to coastal areas, in particular during storms that facilitate their movement ashore. These results highlight the ecological role of EGs in reflecting local pollution pressures and underscore the urgent need for targeted strategies to reduce plastic input into marine environments. In particular, the high occurrence of certain polymer types points to potential land-based and maritime sources. Therefore, future research should prioritize tracing the origins of these polymers as such knowledge is critical for designing effective mitigation policies and pollution control efforts.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Ethics statement

This study did not take place on any private or protected areas. No specific permissions were required for corresponding locations.

Author contributions

DS: Writing – review & editing. IC: Formal Analysis, Methodology, Writing – original draft. TB-S: Funding acquisition, Validation, Writing – review & editing. NZ: Formal Analysis, Methodology, Validation, Writing – review & editing. ME: Supervision, Validation, Writing – review & editing.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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