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Seasonal variation of microplastics density in Algerian surface waters (South-Western Mediterranean Sea)

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Abstract

Coastal waters worldwide are widely contaminated with various-size plastics, whose presence in aquatic ecosystems has been shown to produce a wide range of economic and social impacts and harmful effects on marine ecosystems. While microplastics have been reported from many regions of the Mediterranean Sea, very few data exist regarding microplastics concentration in Algerian waters. In this study, we used a Manta trawl (330 µm) at six sampling stations in Bou-Ismail Bay, Algeria (South-West Mediterranean Sea) in order to provide novel information about the occurrence and composition of microplastics along the Algerian coast. Sampling was performed seasonally at six different sampling stations in 2018, providing additional information about the spatio-temporal variability of microplastics concentrations at the sea surface. Microplastics were found in all collected samples, with highly variable concentrations of 0.95, 0.88, 1.26, and 0.36 items/m^3 in Autumn, Winter, Spring and Summer, respectively, and an overall mean concentration of 0.86 ± 0.35 items/m^3. A classification based on the shape and appearance of microplastics indicated the predominance of fibers (32%), followed by fragments (27%), films (16%), foams (13%), and granules (12%). A qualitative microplastics analysis through Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR-FTIR) revealed that microplastics were mainly composed of polyethylene (68.2%), polypropylene (24.7%), polystyrene (4.1%) and other polymers (3%). These data provide an initial overview of the quantity, characteristics, and spatio-temporal distribution of floating microplastics in Bou-Ismail Bay (Algeria).

Keywords: Microplastics; Pollution; Mediterranean Sea; Bou-Ismail Bay; Algeria.

Introduction

A half-century ago, synthetic polymers began to substitute natural materials in almost every sector, and nowadays plastics have become an indispensable part of our lives (Joel, 1995). Global plastic production increased from 1.5 Mt in 1950 to 359 Mt in 2018 (Plastics Europe, 2019), of which between 4.8 and 12.7 Mt have been estimated to enter the ocean every year (Jambeck *et al.*, 2015). Plastic pollution is the dominant type of anthropogenic debris found throughout the marine environment, often accounting for more than 60-80% of all marine litter (Andrady, 2011). Most of the plastic waste in the oceans and seas comes from land-based sources (Li *et al.*, 2016). Still, ocean-based sources also play an important role, and fishing, shipping, illegal waste disposal, and aquaculture activities can all contribute to plastic debris accumulation into marine and coastal environments (Thushari & Senevirathna, 2020)

Plastics are long-chain polymers, made by humans (Scott, 1999). They are not biodegradable and have long been considered inert materials. However, under the combined action of mechanical forces, UV and temperature, plastic items tend to fragment into increasingly small particles: the so-called microplastics (Thompson *et al.*, 2009), usually defined as microscopic plastic particles of a size less than 1 mm, but this definition may also apply to particles smaller than 5 mm (GESAMP, 2015).

There is growing information on the ecological consequences of microplastic pollution in the marine environment, and the direct and indirect effects associated with the ingestion of these particles are becoming increasingly evident (Lambert *et al.*, 2014), together with the negative toxicological effects caused by the additives they contain or other chemical contaminants they can adsorb from the surrounding waters (Cole *et al.*, 2016).

Vast amount of marine litter ends up in the Mediterranean Sea every year, a significant proportion of which (~ 80%) is generally made of plastic debris (Eriksen *et al.*, 2014; Suaria & Aliani, 2014; UNEP/MAP, 2015). As a result, the issue of plastic litter is now considered a critical pollution problem for the entire Mediterranean basin. The issue is further aggravated since demographers predict an increase in the population of 572 million inhabitants around the Mediterranean basin by 2030, with two main sides phenomena: 'coastalization' and 'urbanization' (UNEP/MAP, 2017), both resulting in increased waste production and anthropic pressure along the coastal zone, while appropriate waste management infrastructures are often still lacking (Galgani *et al.*, 2013).

The temporal trend in imports of virgin plastics into Algeria shows a steady increase with imports going from 0.096 Mt in 1992 to about 1.38 Mt in 2016. From 1992 to 2017, approximately 13.14 Mt of plastic have been imported, which represents about 11.2% of total imports of primary plastics into the African continent (BaBayemi *et al.*, 2019). At the same time, in Algeria, the annual consumption of plastic bags was about 5.5 billion in 2017 (MERE, 2017) and an estimated 0.52 Mt of plastic waste is mismanaged in the country each year (Jambeck *et al.*, 2015).

High-concentration of floating plastic litter (> 2 cm) and microplastics (> 200 μm) have been reported from the off-shore Algerian basin (Suaria & Aliani, 2014; Suaria *et al.*, 2016), and higher levels of microplastics were found in surface sediments from the north African coasts of Mediterranean sea (Tata *et al.*, 2020), however the extent and impact of microplastic pollution in Algeria's marine environment is still mostly speculative, since no baseline data currently exists for the Algerian coastal waters, despite its marine environment is generally considered particularly susceptible to the accumulation of marine debris (Mansui *et al.*, 2020), due to the country's increased modernization, economic development and its particular hydrodynamic setting.

This work aims to provide an initial evaluation of the presence of floating microplastics in marine waters of Bou-Ismail Bay (south-western Mediterranean Sea), during the four seasons of the year 2018. Microplastics were sampled using a manta trawl (330 μm mesh size) to skim the sea surface where positively buoyant plastics (specific density lower than that of the surrounding water) tend to concentrate. These results are then compared with microplastic pollution data reported from other Mediterranean regions and the role of seasonal variations of surface currents and local sources in influencing microplastic distribution are also discussed.

Materials and Methods

Study area

The study site corresponds to the Bay of Bou-Ismail located 45 km west of Algiers and 25 km east of Tipaza, characterized by an area of 509 km². The location of the sampling sites was selected based on wastewater discharges by rivers Beni Messous and Mazafran, releases from tourist complexes and pollution due to fishing activity (MSPE, 2005).

Microplastics in surface seawater were collected using a Manta trawl at 6 different stations located at a distance of approximately 2-4 km from the coast in Bou-Ismail Bay (Fig. 1). To explore seasonal variations in microplastics occurrence and composition, all stations were sampled in 2018 during four different periods: January 28th (winter), April 28th (spring), June 26th (summer) and November 29th (autumn).

Sampling technique

The "Manta trawl" used in this study, has been manufactured by our research team, and it was designed to meet the specificities of the Algerian and Mediterranean coastal waters, optimizing the buoyancy characteristics of this device.

The net has a 'mouth' opening of 15x60 cm, two fins (wings) of 45 x 30 x 3 cm, and a 3 m long net with a mesh size of 330 μm to which a collector is attached at its end. To quantify the water filtered the trawl was equipped with a mechanical flow meter (Hidalgo-Ruz & Thiel, 2012). Sampling was only conducted with calm weather and sea conditions made and from the side of the ship using a rope, outside of the wake zone to avoid the collection of water affected by turbulence (Collignon *et al.*, 2012).

For each transect, the geographical coordinates of starting and ending points were recorded with a high precision calibrated Global Positioning System (GPS). The trawls were made in a straight direction at a speed of about 2-3 knots for 20 min (Doyle *et al.*, 2011). After 20 minutes of trawling, the net was rinsed several times from the outside to recover all debris in the collector (Fossi *et al.*, 2016).

The collected material mainly consisted of plankton, plant and plastic debris of all sizes. On-board, the content of the collector was recovered and transferred into 1L bottles, labelled, stored in seawater and then transported to the laboratory for sorting, counting and analysis according to standard protocols (Free *et al.*, 2014; Gago *et al.*, 2019).

The manta trawl data were normalized to the total volume filtered (V), calculated from the following formula and expressed as items/m^3:

$$V = N \times A \times C$$

N is the number of propeller revolutions measured by the

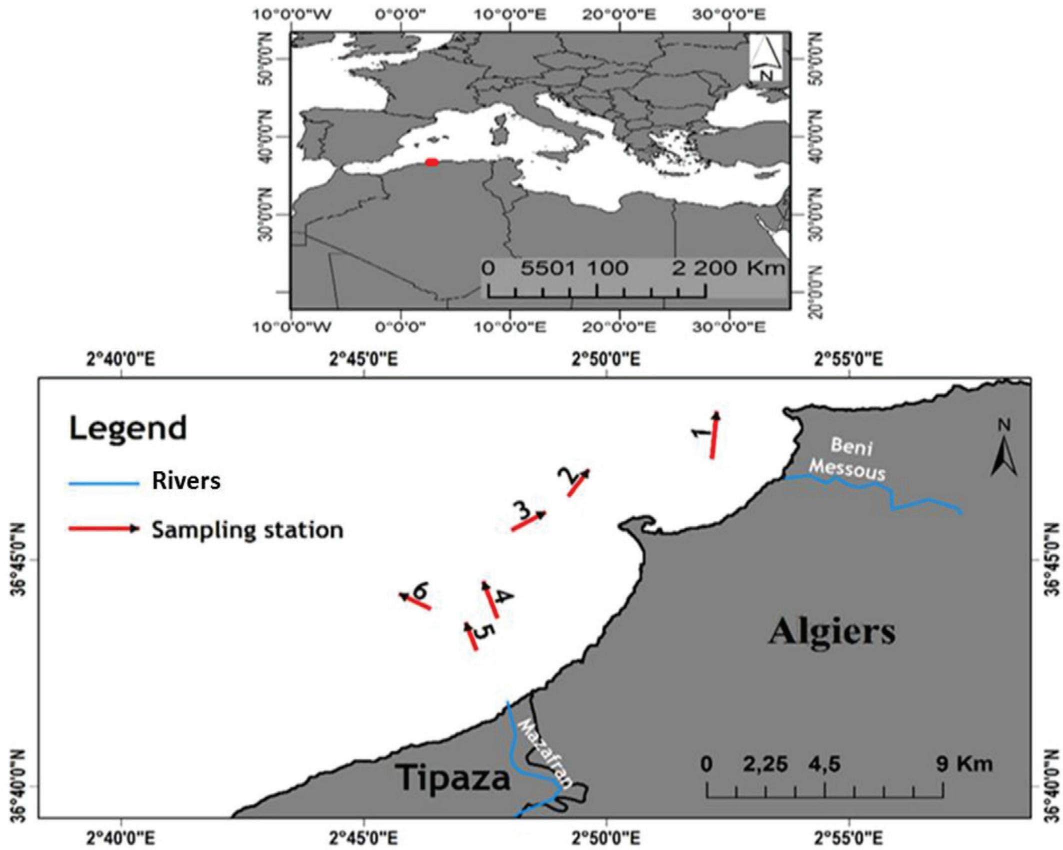

Fig. 1: Geographical location of the study area and of the six sampling stations in Bou-Ismail Bay (Algeria).

flow meter;
A is the mouth area of the trawl;
C is a constant value, typical of each flow meter, and supplied by the manufacturer.

And normalized to the total water surface filtered (S), calculated from the following formula, and expressed as items/km^2:

$$S = N \times D \times C$$

D is the horizontal opening of the net.

Visual identification of collected items

Visual detection of microplastics was made by pouring the sample through a 300 μm sieve and removing all natural or artificial litter objects of a size > 5 mm. After removing larger objects, the remaining pieces were concentrated on the sieve using distilled water (Rezania *et al.*, 2018).

Irrespective of the organic matter content, chemical digestion of all samples was obtained by adding 20 mL of 30% hydrogen peroxide and 20 mL of aqueous 0.05 M Fe(II) solution to each sample, the mixture was then placed on a hot plate set to 75 °C and the reaction was allowed to continue until all organic material disappeared (Masura *et al.*, 2015).

After digestion, the solution was sieved again (300 μm) and poured into a glass container using a minimum amount of 70% ethanol, thus facilitating the visual isolation of the plastic particles (Viršek *et al.*, 2016). Finally, the solution was poured into a glass petri dish and analyzed using a binocular magnifying glass, with an integrated camera to identify the microplastics particles (< 5 mm to 330 μm) (Klein *et al.*, 2018). Each isolated particle was classified into one of the following categories: Fragments, Foams, Fibers, Granules, Films and Pellets (Gago *et al.*, 2019), and placed in Petri dishes bearing a category name. To avoid external contamination, only metal and glass equipment was used and all materials used for sampling were rinsed with distilled water prior to use. All liquid reagents were pre-filtered and all sampling and sorting equipment was kept closed at any time to prevent airborne contamination during sample processing (Eriksen *et al.*, 2013).

Chemical Identification

To identify the polymer type of all particles suspected to be plastic, Attenuated Total Reflectance Fourier Transform InfraRed spectroscopy (ATR-FTIR; DuraSamplIR) was used. The instrument was operated in scanning transmittance mode at a mid-IR range of 650–4000 cm^{-1}. A background scan was performed to eliminate CO_2 interference (approx. 2300–2400 cm^{-1}) (Käppler *et al.*, 2015). Polymer identification was made by comparing the particles spectra to a reference library provided by the manufacturer.

Current data and processing

The daily surface current velocity data products used in this study have been derived from

Copernicus marine environment monitoring service (CMEMS, http://marine.copernicus.eu/). The CMEMS products in NetCDF file, were used for the periods comprised between the 28 January 2018 and 29 November 2018, averaged over the space domain 36.0666° - 36.0833° N and 2.05°- 2.1° E. Finally, after processing using ArcGIS software, mean current velocity speed and direction were extracted, and averaged over the entire study area.

Results

Occurrence and density of microplastics

All six sampling sites in Bou-Ismail Bay were sampled seasonally, yielding a total of 24 samples (i.e. four samples per station). A total of 2913 microplastics were isolated from all samples with a 100% occurrence, confirming their widespread occurrence in the Bay throughout the year. The overall average microplastic density in Bou-Ismail Bay was 0.86 ± 0.35 items/m^3 or 101,146 ± 38,580 items/km^2 (average ± S.D.), ranging from a maximum of 1.56 ± 0.34 items/m^3 (#station 1) to a minimum of 0.57 ± 0.20 items/m^3 (#station 6) (Fig. 2).

Seasonal variation in microplastics density

Microplastics were detected in all samples collected (i.e. 100% occurrence), although with marked seasonal variations in their density (Fig. 3).

The highest microplastic concentrations were found in spring in all stations except station 6 with an average concentration of 1.26 ± 0.50 items/m^3 (maximum 2.05 items/m^3 at Station 1 and a minimum of 0.62 items/m^3 at Station 6). High concentration values were found also in autumn with a mean concentration of 0.95 ± 0.29 items/m^3 (maximum 1.44 items/m^3 at Station 1 and a minimum of 0.64 items/m^3 at Station 6). In winter, an average concentration of 0.88 ± 0.31 items/m^3 was found (maximum 1.49 items/m^3 at Station 1 and a minimum of 0.63 items/m^3 at Station 4). Lastly, the lowest concentrations were found in summer (mean 0.36 ± 0.29 items/m^3; maximum 1.26 items/m^3 at Station 1and minimum 0.04 items/m^3 at Station 2).

The shape of microplastics in Bou-Ismail Bay

Fibers, fragments, foams, granules, films and pellets were identified in Bou-Ismail Bay. The proportions of the six types of microplastics are shown in (Fig. 4). More in general, a predominance of fibers (32%) was observed, with maximum values registered in spring, especially in

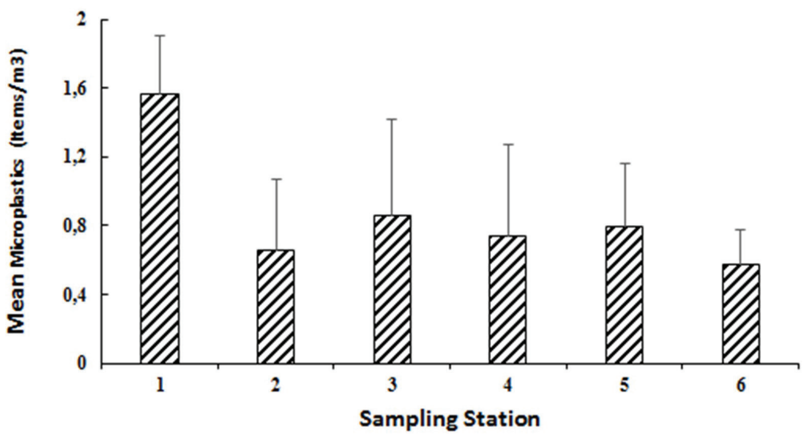

Fig. 2: The average microplastic density (± S.D) found in the six sampling stations.

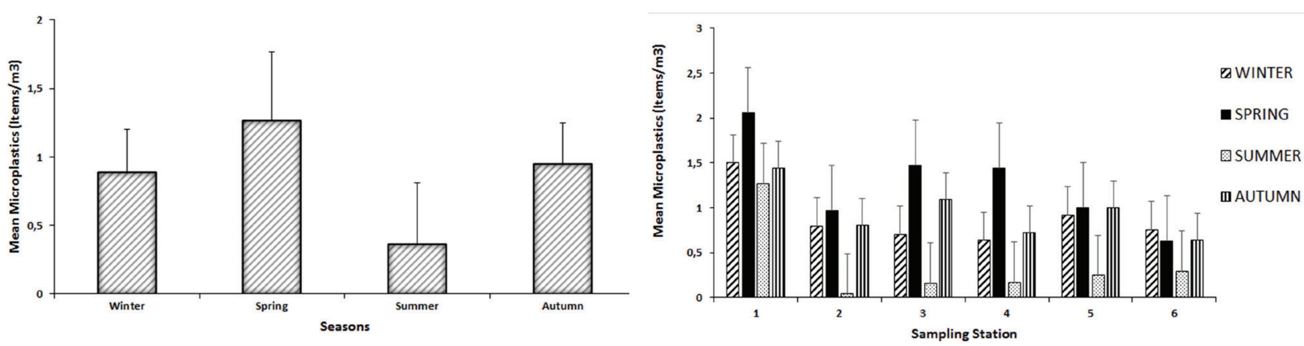

Fig. 3: Seasonal variation of microplastic density at the six sampling stations considered in this study.

stations 4, 5 and 6. Fibers, were followed by fragments (27%), with a maximum occurrence observed during the summer, and Granules (12%), which were more frequent in the two successive seasons: winter and spring. These two types of microplastics were evenly distributed especially in station 1. Plastic films accounted for 16% and were mainly concentrated in station 2 and 3. Lastly, foams (13%) were evenly distributed in all sampling stations (Fig. 4).

Polymer identification

Three main plastic polymers were detected in the surface water of Bou-Ismail Bay, Polyethylene (PE) was the most abundant (68.2%), followed by polypropylene (PP) (24.7%), polystyrene (PS) (4.1%), and other polymers (3%), similarly to what has been found in previous studies (Fossi *et al.*, 2016; Baini *et al.*, 2018; Tata *et al.*, 2020).

Discussion

Density of microplastics in Bou-Ismail Bay

The average annual density of microplastics in Bou-Ismail Bay is 101,146 ± 38,580 items/km^2. The results are in the same range as other sectors of the Mediterranean Sea (Table 1), with average density usually ranging between 116 10^3 items/km^2 (Collignon *et al.*, 2012), 130 10^3 items/km^2 (Faure *et al.*, 2015), and 150 10^3 items/km^2 (De Lucia *et al.*, 2014), and also comparable to previous studies carried out in the Bay of Marseille with an estimate of 112 10^3 items/km^2 (Schmidt *et al.*, 2018).

Spatial heterogeneity in microplastics distribution can be the result of currents, waves, riverine inputs or hydrodynamic features such as upwelling or down welling (Zambianchi *et al.*, 2014; Suaria & Aliani, 2014; van Sebille *et al.*, 2020). High concentrations of microplastics, are usually found in coastal waters because of the proximity of densely populated areas (Pedrotti *et al.*, 2016), and continental inputs from rivers (Collignon *et al.*, 2012). The illegal and unregulated discharge could also play an essential role in Bou-Ismail Bay.

Seasonal changes in the spatial distribution of microplastics

Circulation is the primary driver of microplastics transport (van Sebille *et al.*, 2020). Currents of the basin may play an important role in its transport, accumulation, and distribution (Zambianchi *et al.*, 2014). In this study, a marked seasonal variation in microplastic concentrations was found, which could be also explained by seasonal variations in surface currents intensity and direction.

The highest microplastic concentrations were found in spring, explained by the intensity of surface currents in this period is of (0.052 – 0.2 m/s), with a West-South-West direction, which could bring litter from western areas (Fig. 5), potentially suggesting a circulation of microplastics from station 6 to station 1. In autumn a decrease in microplastic concentrations at Station 1 was noticed, together with a corresponding increase in Station 6,

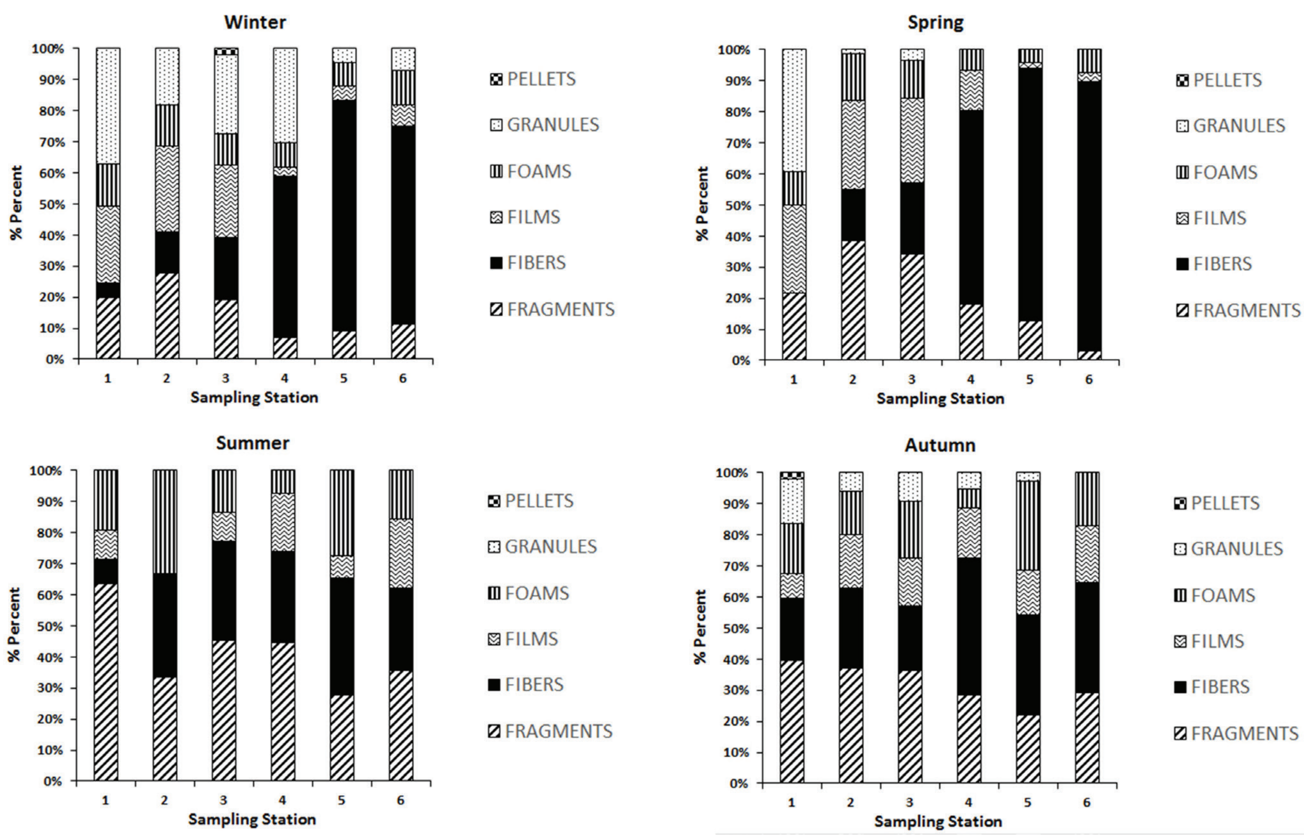

Fig. 4: Microplastics-shape compositions found in the four different seasons sampled in Bou-Ismail Bay during this survey.

Table 1. Density data of microplastics collected in the Mediterranean Sea using a Manta trawl.

Mediterranean sub-region	N° samples	Net mesh	Year of sampling	Density (items/m^3 ± SD)	Density (items/km^2 ± SD)	References
South western Mediterranean	24	330 µm	2018	0.86 ± 0.35	101,146 ± 38,580	This study
Ligurian and Tyrrhenian Seas	34	333 µm	2018		28,376 ± 28,917	(Caldwell *et al.*, 2019)
Eastern Mediterranean Basin	3	52 µm	2018	4.3 ± 2.2		(Kazour *et al.*, 2019)
Northwestern Mediterranean Sea	13	333 µm	2016	0.18–0.19		(Constant *et al.*, 2018)
Western Mediterranean Sea	24	330 µm	2013–2014		69,161 ± 83,244	(Baini *et al.*, 2018)
Western Mediterranean Sea	6	780 µm	2014	112,000		(Schmidt *et al.*, 2018)
Levantine Sea	17	330 µm	2015		140,418 ± 120, 671	(Güven *et al.*, 2017)
Levantine Sea	108	333 µm	2013–2015	7.68 ± 2.38		(Van der Hal *et al.*, 2017)
Whole Mediterranean	71	333 µm	2011		62,000	(Luis *et al.*, 2003)
Levantine Sea	7	333 µm	2016		37,600	(Gündoğdu & Çevik, 2017)
Western Mediterranean Sea	41	330 µm	2012		129,682	(Faure *et al.*, 2015)
Western Mediterranean Sea	30	500 µm	2013	0.15 ± 0.11		(De Lucia *et al.*, 2014)
Western Mediterranean Sea	40	333 µm	2010		116,000	(Collignon *et al.*, 2012)

which could be probably explained by an inversion in the direction of the current coming from the north-east (Fig. 5). But in winter, station 1 experienced a slight increase in microplastics concentrations, which could be probably explained by a return current flowing West-South West during winter (Fig. 5).

The lowest concentrations were found during summer, when surface currents flow from the North-West towards the land (Fig. 5), potentially leading to the stranding of marine litter along the coastline, although field data from this region are missing and very little is still known about the main factors influencing microplastics stranding and/or resuspension dynamics.

According to previous studies, there are no permanent hydrodynamic structures in the Mediterranean Sea, since seasonal and interannual variation affects the movement of the water surfaces and the distribution of microplastics (Cózar *et al.*, 2015), thus substantially preventing the formation of permanent accumulation features, although local retention of floating plastics in mesoscale eddies forming off-shore along the Algerian continental shelf has been suggested by previous studies (Suaria & Aliani, 2014; Pessini *et al.*, 2018).

Characteristics of microplastics in Bou-Ismail Bay

Among the six types of microplastics in Bou-Ismail Bay, fibers were dominant, especially in the stations off the mouth of Mazafran River in Stations 5 and 6, characterized by a liquid flow rate of 43.8 million m^3/year, followed by fragments. The high percentage of fibers and fragments suggests that the breakdown of larger plastic items into secondary microplastics, wastewater transported by rivers and fishing gear are the primary source of microplastics contamination at our sampling locations (Browne *et al.*, 2011). Granules and pellets were distributed especially in station 1. This can be explained by the contributions of Beni Messous river, which has a discharge rate of 28 million m^3/year, and the proximity of the urban discharges as well as the thrusting of plastic waste by easterly winds that characterizes the zone. At the same time, this area is also characterized by a relatively low-dynamic in the summer period and a weak Eastern current that could promote the arrival of these buoyant fragments during this season.

Plastic films were primarily concentrated in stations 2 and 3. This could be explained by the close proximity of

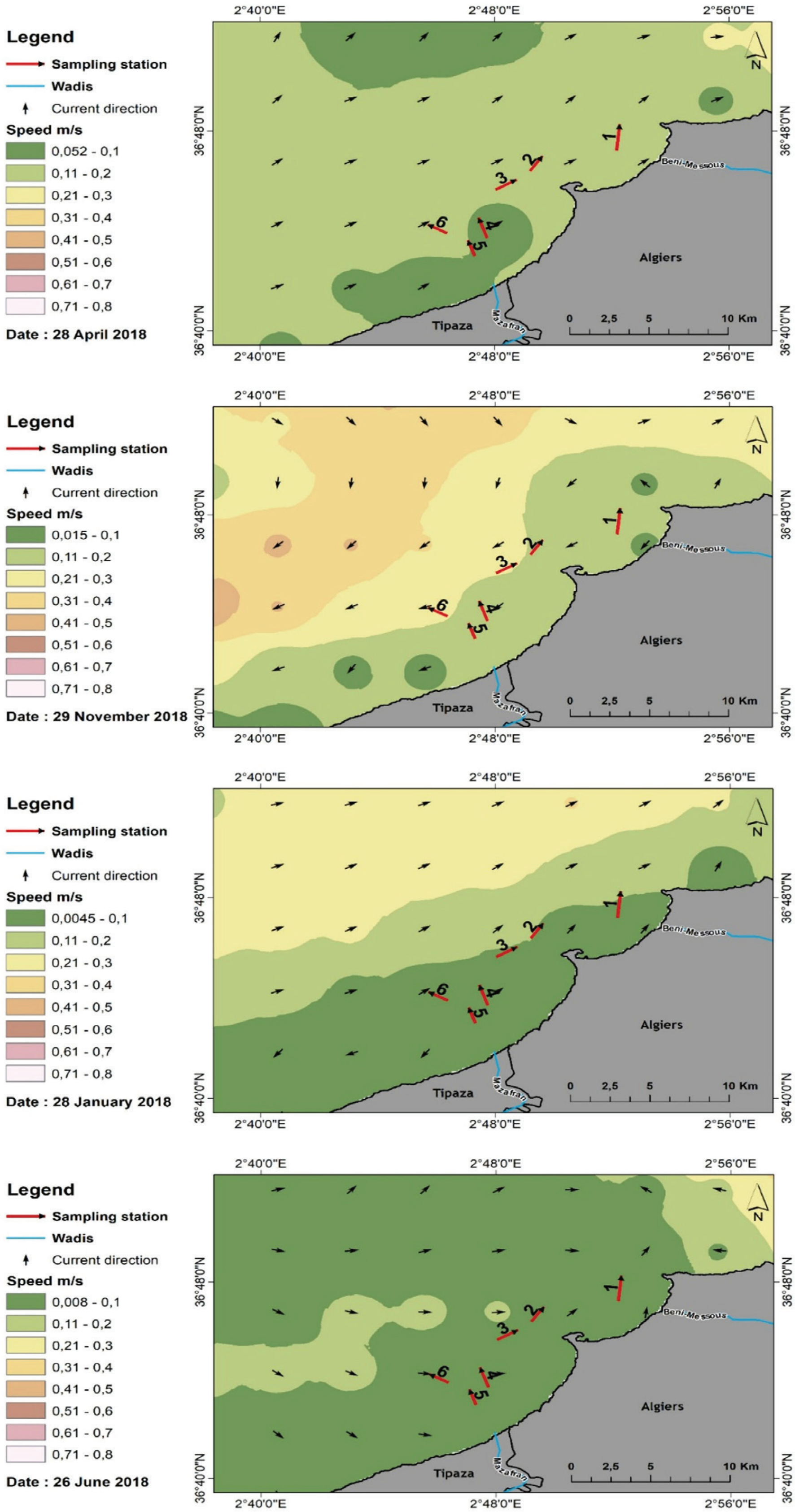

Fig. 5: Intensity and direction of surface currents in the four seasons sampled in our study area.

urban areas to these stations that, as well as the proximity of Sidi Fredj Marina, and of an intensive greenhouse agricultural application around the sampling area, which is known to be a potential source of plastic films to the marine environment. Finally, Foams were uniformly distributed across all sampling stations, with this being potentially explained by their high buoyancy and a greater propensity to be deposited by wind and waves.

The chemical composition of microplastics in Bou-Ismail Bay is dominated by PE and PP, widely used in the disposable packaging industry and having lower densities (0.89-0.95 g/cm^3 and 0.85-0.92 g/cm^3, respectively) than seawater, it is not surprising that these polymers consistently account for the majority of the plastic particles floating in surface waters worldwide (Eriksen *et al.*, 2014), including our study area as well as other sectors of the Mediterranean Sea (Palatinus *et al.*, 2019). PE has a higher impact strength but lower working temperatures and tensile strength than PP (Vasile & Pascu, 2005). The disadvantage of PP is poor UV resistance and poor oxidative resistance; therefore, it breaks down in smaller particles much faster than other polymers in oceanic environments (Andrady, 2017). Overall however, the composition of microplastics in Bou-Ismail Bay is very similar to that reported from other seas and oceanic basins worldwide (Suaria *et al.*, 2016).

Conclusion

This study identified seasonal variations in the distribution of microplastics in Bou-Ismail Bay based on 24 samples collected during the four seasons of 2018. The mean microplastic concentration in Bou-Ismail Bay was 0.86 ± 0.35 items/m^3, which is within the same range of other previously studied Mediterranean regions. Most microplastics were fibers and fragments made of PE and PP, similarly to what has been documented by other authors.

Given the potential environmental risks associated with the ingestion of microplastics by a wide range of marine organisms, better waste management practices and improved litter reduction measures must be promoted in the entire Algerian basin, targeting the main local sources on land as well as in coastal areas. As already demonstrated in other regions of the world, hydrodynamic conditions and surface currents are likely playing a key role in the distribution and accumulation of microplastics in this region as well, although further studies are clearly needed to better elucidate the relative contribution of foreign as local sources of plastic pollution in the entire Mediterranean region.

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