FIRST INVESTIGATION OF MICROPLASTIC POLLUTION IN MONASTIR SEA SURFACE WATER (EASTERN TUNISIA)

Hela Jaziri[1], Emna Derouiche[1], Wael Koched[1], Hamdi Ben Boubaker[1], Rym Ben Dhiab[1], Rafika Challouf[1] and Sana Ben Ismail[1],

[1]INSTM – Institut National des Sciences et Technologies de la Mer,
28 ‹Rue du 2 mars 1934, – 2035 Salammbô (Tunisia),
phone +216 71 730 420, e-mail: jaziri.hela@yahoo.fr
[1]INSTM, Salammbô (Tunisia)

Abstract – Microplastic pollution in the environment is a worldwide concern, as proven by the growing research interest on this issue. Almost all the world's oceans and seas are currently contaminated with microplastics, but the Mediterranean Sea has been identified as a target hotspot of the world, with a microplastic concentration four times that of the North Pacific Oceanic threats across the globe and is becoming a topic of intense study for environmental researchers. This study is the first to investigate the microplastic abundance and composition in Monastir Sea water. In the framework of COMMON MED-project, a sampling campaign was carried out during the month of December 2020 along two radials located in front of two tourist areas with different characteristics. The first radial (T1, Palmiers Beach) is distinguished by an intense tourist activity while the second radial (T2, Marina Beach) is characterized by the presence of a marina in addition to a high rate of urbanization. Microplastics were characterized by size, type and colour using a stereomicroscope and polymers were identified using Fourier Transformed Infrared (FT-IR) spectroscopy. The results showed that the particles of microplastic (MPs), ranging between 0,31 and 4,9 mm have larger average sizes in radial T2 than those of radial T1 (2.2 mm and 1.7 mm respectively). For all the stations surveyed, white particles were the most frequently observed colours, while the most dominant type was fragment. Of all the MPs identified, High Density Polyethylene (HDPE) and Polyethylene (PE) were predominant in the water. MPs concentrations varied between 62,095.032 and 260,979.12 items / km² with a density of 4 times greater in the T2 radial compared to the T1 radial, which shows the influence of urban and marina origin on plastic contamination among seaside tourist one. In addition, the greatest concentrations were recorded at the level of stations S2 and S5 which are closest to the coast (62,095.032 and 260,979.12 items / km² respectively). This preliminary study should be consolidated by other surveys in time in order to study the effect of the season and in the space with the objective of covering the whole area and mapping the distribution of microplastics in the bay of Monastir.

Key words: Microplastic monitoring, Sea water, Polymers, Monastir, Tunisia.

1. Introduction

Among the various pollutants known to contaminate the marine environment, microplastics (MPs) are considered to be next-generation contaminants. In fact, since the

Referee List (DOI 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)
Hela Jaziri, Emna Derouiche, Wael Koched, Hamdi Ben Boubaker, Rym Ben Dhiab, Rafika Challouf, Sana Ben Ismail, *First investigation of microplastic pollution in Monastir Sea surface water (eastern Tunisia),* pp. 471-483 10.36253/979-12-215-0030-1.43

1950s, with the skyrocketing rise in the production and consumption of plastic products, the plastic flow into the environment appears to have been unstoppable and accelerating. Plastic products have become ubiquitous in everyday life. With an estimated global production of 368 million tons [36], 4.8–12.7 million tons of plastic are estimated to be released into the marine environment every year [26]. MPs pollution has become an increasing environmental issue, particularly in marine coastal systems [29].

The Mediterranean Sea was reported to host the highest concentrations of floating plastics in the world (Lebreton et al., 2012; Eriksen et al., 2014), and is therefore recognized as one of the most impacted regions in the world by plastic pollution [14; 41; 47; 5]. This situation has been exacerbated by the semi-closed nature of the Mediterranean Sea, its reduced surface waters flow, and the strong anthropization along its coasts and the resulting enormous quantities of litter ending up in the coastal environments [41].

Once in the aquatic environment, due to a combination of chemical, mechanical, and biological processes, plastic debris tends to break down into smaller micrometric debris, namely microplastics (MPs). Most commonly, MPs have been defined as synthetic organic polymer particles, less than 5 mm in size that may differ in shape, colour and chemical composition [18]. Microplastic pollution has been reported worldwide, in different environmental compartments, including water, soil, air, and biota [10;49]. Owing to their small size, MPs are potentially bioavailable to a wide range of organisms, having the potential to interact across trophic levels. Although during the last years there has been a virtual explosion of research on MPs pollution, especially in the Mediterranean Sea, there is a significant data gap for the Southern part of the basin [3; 30; 46].

Very few studies have been conducted in the central region of the east coast of Tunisia despite being subjected to pressures of various origins. This area is located on the south of Cap Bon that forms the southern tip of the Strait of Sicily boarded by the Gulf of Gabes in the south. It is therefore an intermediate zone between low salinity and relatively cold waters in the North and high salinity and relatively warm waters in the south. Depending on the seasons and the daily weather conditions, marine dynamics are moreor less intense with a varying intrusion of the Atlantic water vein [2; 47; 5]. The bay of Monastir, located within this region, constitutes an area of major interest due to its high coastal population density [43]. It is a very important economic activity zone (industry, fishing, aquaculture, tourism …) that have created very strong pressures on the marine environment of this area [8].

Along the Tunisian coasts, only a few studies conducted on the contamination of waters by MPs, namely two studies conducted in the south of Tunisia, precisely, the Gulf of Gabes [47; 5] and one conducted on the surface waters of the Bizerte lagoon [46]. Within our area, few preliminary studies have been conducted so far on MPs in the sediments and biota of the Bizerte lagoon [30;9], but no study has been conducted on the contamination of its waters by MPs contamination of its waters by MPs. The present work was conducted in this regard and aims to determine the composition, distribution, and abundance of MPs in the surface waters of Monastir Bay. These preliminary data should contribute to the identification of potential local sources of this pollution. The results of this work will therefore contribute to the implementation of a management plan to reduce MPs pollution in this area.

2. Materials and Methods

2.1. Study area and samples collection

Microplastics water samplings were conducted onboard of fishing vessel during Winter 2020 within the framework of COMMON project. A total of six stations have been sampled (table 1), along two radials located in front of two touristic coasts with different characteristics in the Monastir Bay. The first radial (T1, Palmiers Beach) is distinguished by an intense touristic activity while the second radial (T2, Marina Beach) is characterized by the presence of a marina in addition to a high rate of urbanization in the area around the beach (figure 1). In each radial, three stations located respectively at 1.5: 3 and 6 miles from the coast (Table 1).

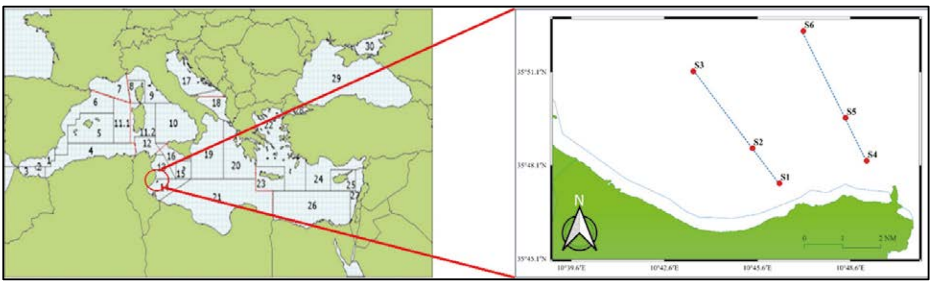

Figure 1 – Map showing the locations of the sampling stations in the Monastir Bay.

Table 1 – Sampling stations.

Transects	Sampling station	Longitude	Latitude
T1	Station 1	35°41’48	10°46’313
	Station 2	35°48’60	10°45’444
	Station 3	35°51’07	10°43’533
T2	Station 4	35°48’04	10°49’206
	Station 5	35°49’21	10°48’612
	Station 6	35°51’46	10°47’498

During the sampling campaign, a 200 µm Manta net (0.6 m width 0.2 m height) was towed at an average speed of 3 knots for 20 min for each sampling transect, yielding a total of 6 surface water samples. To gather all particles into the cod-end, the net was rinsed completely with seawater from the outside after each sampling operation. The samples were then transferred from the cod-end to 500 mL glass containers using a 0.3 mm mesh stainless steel sieve, fixed with 70 % ethanol, and transported to the INSTM laboratory for analysis.

2.2. Surface water samples analysis

The water samples were analyzed for their plastic content following the COMMON toolkit. For each sample a wet sieving is realized through a stacked arrangement of 5 mm, 1 mm, and 0.3 mm stainless steel mesh sieves. Accordingly, the litter items are classified in three size classes: small microlitter SML (300 µm – 1 mm), large microlitter LML (1 mm-5 mm), meso litter (5 mm-25 mm).

The presence of MPs was determined under a stereomicroscope (Olympus SZX7, 8x-56x) with attached digital camera. All potential particle items were manually sorted out from the sample and categorized by colour, shape (fragment, fiber, pellet, film and foam) and size. Then, each Polymer identification was carried out using a PerkinElmer Spectrum Two Fourier Transform Infrared (FT-IR) spectrometer. The number of MPs found in water samples was expressed both as items/km^2 where the area covered (km^2) was calculated by multiplying the width of the mouth of the net by the distance covered (km) during the tow.

2.3. Contamination Control

In order to avoid potential contamination during sample analysis, several precautions need to be taken account as recommended by scientific literature and guidelines [22; 7; 23; 31; 5]. All consumables were taken directly out from their packaging and all equipment was carefully rinsed with Milli-Q before and after use. Samples and equipment were covered with aluminium foil where possible. In addition, filter blanks were run in parallel to verify airborne contamination occurring during both water and fish sample processing. Particles or fibers detected on filter blanks were analyzed for colour and size and then compared to those found in the analyzed samples in order to avoid false results.

3. Results

3.1. Quality control

Analysis of the control membranes revealed the presence of fibers in different colors found in the samples collected during the Winter 2020 survey in different colors. Other microplastic typologies were never detected in the control samples. The final MPs content in the water samples was given subtracted from the blank values, to avoid overestimation.

3.2. Surface water sample

Throughout the first and the second radials, microplastic particles were found in all sampled stations (table 2). The recorded abundance at the level of the second transect is four times more important, it was around of 260979.12 items/km^2 than the first transect where the abundance was 62095.03 items/km^2.

As shown in the table below (table 2), for the first transect (T1), the abundance is ranged between 17098.63 (Station 1) and 26997.84 (Station 2). However, it ranged from 24298.05 (Station 4) to 166486.68 (Station 5) in transect 2. the greatest concentrations were recorded at the level of stations S2 and S5 which are closest to the coast (26997.84 and 166486.12 items / km^2 respectively).

Table 2 – Abundance of microplastics (items/km2) found in the samples collected along the two transects (T1 and T2) during the winter Campaign 2020 in the Monastir Bay.

Transects	Abundance (items/ km^2)	Stations	Abundance (items/ km^2)
T1	62095.03	S1	17098.63
		S2	26997.84
		S3	17998.56
T2	260979.12	S4	24298.05
		S5	166486.68
		S6	70194.38

All identified particles were categorized based on their shapes, colours, size class and polymer types.

Collected microplastic particles size ranged from 0.3 to 4.9 mm. According to COMMON protocol, items were categorized into three classes: Mesolitter (5 mm-25 mm); Large Microlitter LML (1mm-5mm) and Small Microlitter SML (300 µm – 1 mm). The Large Microlitter LML are the most abundant where the percentage is 75.34 % along T1 and 94.17 % along T2.

The sizes of the particles identified range from 0.31- 4.7 mm in transect T1 with an average of 1.71 mm and from 0.31-4.9 mm with an average of 2.1 mm in the transect 2 (figure 2).

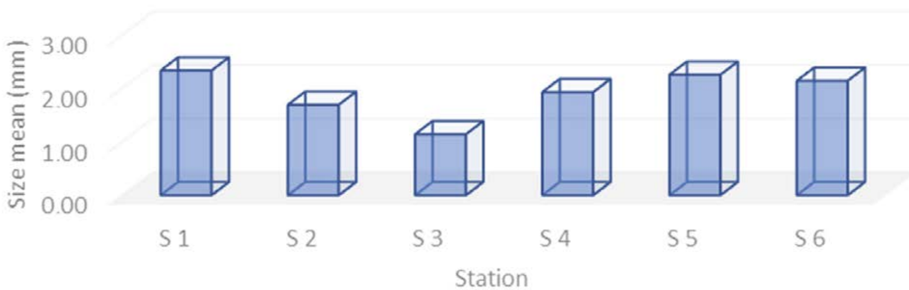

Figure 2 – Size means of particle extracted from water samples collected in the Monastir Bay per station.

Collected microplastics were sorted into five different categories: fragments, films and filaments. Fragments are dominant along both transects, with a percentage of 91.3 % 83.1 % followed by films with 8.69 % and 14.48 % for T1 and T2, respectively. The presence of filaments is recorded only in the stations of the second transect with a low percent of the order 1.18 % (Figure 3).

In this study, for all stations most of microplastics items were white opaque with a percentage of 51 %, of which 29 % in the first transect and 60.68 % in the second transect. While other colours (including, yellow, orange, blue, grey, brown), green, red and black items accounted on percentage for 32 %, 1.1 %, 11.1 and 3.9 % of total microplastics, respectively (Figure 3).

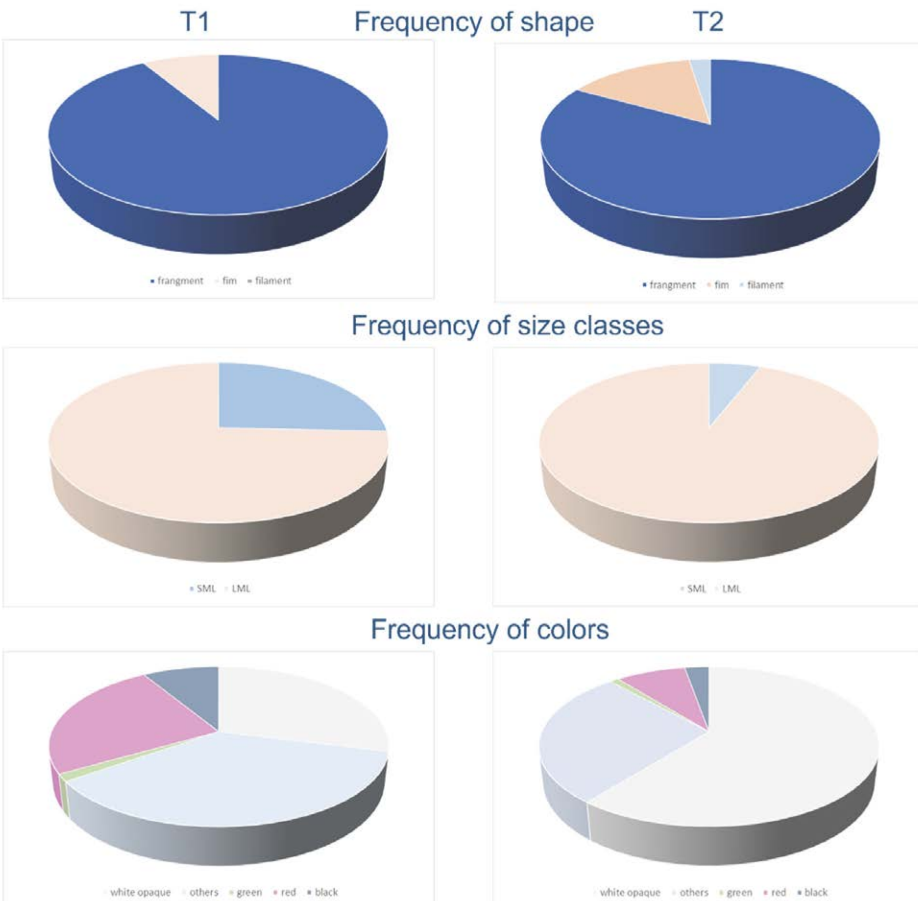

Figure 3 – Frequency (%) of particle shape, size classes and colors extracted from water samples collected in the Monastir Bay along the two transects T1 et T2.

The chemical composition of sorted items was confirmed by FT-IR analysis. Throughout both transects, 07 different polymer typologies were identified. Polyethylene high density (PEHD) made up the majority of microplastics, with 43.47 % (T1) and 63.77 % (T2), respectively, followed by Polyethylene (PE) (39.13 and 16.66 % from samples of the first and second transect, respectively), Polypropylene (PP), with 13 % (T1) and 19.5 % (T2). Less frequent polymers included (<6 %), polystyrene (PS), polyvinyl alcohol (PVA), polyamides (PA), ethylene-vinyl acetate (EVA), Cellophane (figure 4).

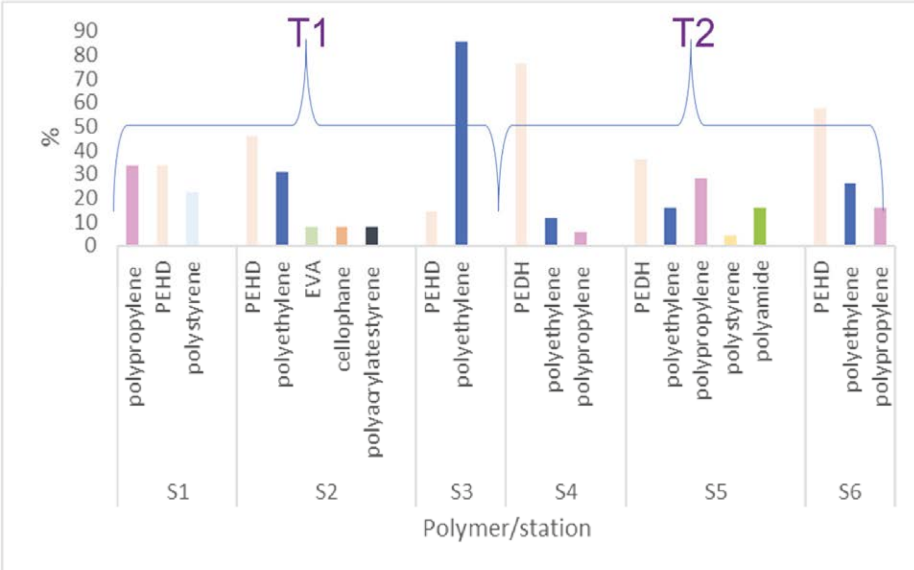

Figure 4 – Frequency (%) per station per transect of particle polymers extracted from water samples collected in the Monastir Bay along the two transects T1 et T2.

4. Discussion

Studies on MPs in seawater along the Tunisian coasts are scarce, as they are in other southern Mediterranean regions. In Tunisia, the quantification and characterization of microplastics in water is limited to a few studies: in 2020, [47] provided preliminary results on abundance in the Gulf of Gabes. Furthermore, a study published in the same year, conducted to define the effects of environmental factors on the distribution and abundance of microplastics in the waters of the Bizerte lagoon [46]. Recently, a study that aims to conduct a characterization of the level of pollution by microplastics in the Gulf of Gabes [5]. Here we provide for the first time the investigation of microplastic abundance and composition in Monastir Bay Sea water. Our study area, constitutes an area of major interest due to its high coastal population density [43]. It is a very important economic activity zone (industry, fishing, aquaculture, tourism …) that have created very strong pressures on the marine environment of this bay [8].

The results of this study showed a significant presence of microplastics in all surface water samples along both radials with an abundance of 62095.03 items/km^2 at T1 and a 4-time higher concentration at T2, around 260979.12 items/km^2. Several factors can explain the high concentrations of microplastics observed along the study area. Among these, plastic pollution sources most likely play a major role, given that the city of Monastir is highly anthropized, with several urban, industrial, aquaculture and tourist coastal concentrations that can generate a lot of plastic litter that ends up in the sea.

The highest concentration is recorded at station 5, located 3miles from the Marina Monastir. During the sampling campaign we noted bad weather as well as the wind direction of NE during the sampling campaign can explain the fact that the concentrations of microplastics follow an upward gradient from coast to shore for both radials.

By reviewing the literature on studies conducted in the Mediterranean, we noted that several sampling methods are used, such as the mesh size, the sampling time, the unit of measurement, etc. [47; 5]. Overall, the abundance found in this study remains high compared to other concentrations found in the Mediterranean basin.

Table 3 – Microplastics abundance values found in surface waters from Mediterranean Sea.

Area	**Abundance ±SD**	**References**
NW Mediterranean	0.116 (0.892) items/m^2	[13]
Ligurian/Sardinin Sea	0.31±1.0 (4.83) items/m^2	[21]
Bay of Calvi (Corsica)	0.062 (0.688) items/m^2	[12]
W Mediterranean	0.135 (0.42) items/m^2	[20]
W Sardinia	0.15 (0.35) items/m^3	[15]
Ligurian Sea	0.103 (0.36) items/m^2	[34]
Ligurian Sea	21 000 – 578 000 items/km^2	[35]
NW Sardinia	0.17±0.32 (1.69) items/m^3	[33]
Central W Mediterranean	40 000 – 9 230 000 items/km^2	[41]
Coast of Turkey	16 339 – 520 213 items/km^2	[24]
Central and Western Mediterranean Sea	8 999 – 1 164 403 items/ km^2	[38]
Northern Ionian Sea (Greece)	0 – 1 610 000 items/km^2	[17]
Gulf of Lion	6 000 – 1 000 000 items/km^2	[39]
Southern Mediterranean/ Gulf of Gabes	25 471 – 111 821 items/km^2	[47]
Southern Mediterranean/ Bizerte lagoon	453.0 ± 335.2 items /m^3	[46]
Eastern Mediterranean Sea	0.12–0.72 items/m^3	[1]
South-Western Mediterranean Sea	$1.01 *10^5 \pm 3.8 *10^4$ items/km^2	[40]
Southern Mediterranean/ Gulf of Gabes	312 887 – 77 110 items/ km^2	[5]
Southern Mediterranean/ Monastir Bay	62 095.032- 260 979.12 items / km^2	Actual Study

Our findings identified fragment as the most predominant plastic particles in the water samples which is in agreement with several other works [25; 20; 38; 42; 5; 47; 44]. Some studies linked the predominance of fragments to the decomposition of larger plastic objects (secondary sources) than to primary inputs of MPs, such as MPs directly released from treated wastewater effluents [47; 5]. Color can be considered a good indicator of the residence time of plastic particles in the ocean and its degree of weathering as well [32]. More than 50 % of the microplastics particles collected during our campaign are opaque white in color and had fading hues, indicating that they have undergone various weathering processes over a long period of time.

In addition, the results of this study reveal the predominance of small particles, with an average size of 1.71 mm and 2.19 for the two transects T1 and T2 respectively. At the level of station 3, we recorded the smallest average size, it is of the order of 1.14 mm.

The size distribution of MPs may be related to their origin and could also reflect their degree of weathering. It has been suggested that the plastic weathering process and meteorological forcing contribute to breaking large marine plastic debris into smaller pieces, resulting in a decrease in size (Pan et al., 2019). Our results showed that along the first transect T1 a dominance of large particles in coastal stations (S1 and S2) while along T2 large particles are found in the open ocean (S6). This may infer that the particles in the first transect were of the same origin while the particles in the second transect were of different origin.

According to [16] the identification of plastic polymer types does not define the origin from which the plastic litter originates, but it does identify potential sources of plastic particles. During this study, seven types of microplastic polymers were identified (HDPE, PE, PP, PS, PVA, PA, EVA, Cellophane), allowing to deduce that the sources of plastic contamination in Monastir Bay are diverse. All these types of polymers are known to be derived from various packaging materials, consumer goods, fibers and textiles, automotive applications, building and construction, and medical applications (https://www.plasticseurope.org/). The majority of these applications can be observed along the coast of Monastir, in urban, industrial, tourist and aquaculture areas.

The prevalence of HDPE, PE and PP in the surface waters of the study area indicates the multiple uses of these types of polymers and confirms that they are the most used in the region [4]. In fact, it is well known that HDPE, PE and PP can be derived from various household plastic wastes such as crates, trays, bottles, caps food packaging, cans, bulk containers and various products used in personal care and cosmetics [11; 28; 48].

The present study assessed the density levels of microplastics in surface waters in Monastir Bay for the first time, which gave us an idea of the nature of the waste and the levels of microplastic pollution in this area.

5. Conclusion

This study reported a high level of microplastics in the surface water samples.

Given the multitude of pressures on the study area from anthropogenic, industrial, aquaculture, and severe fishing, further work is recommended to define the levels of plastic pollution in the area and the threat it poses to marine ecosystems and to establish effective management measures to address this emerging global threat.

6. References

[1] Adamopoulou A., Zeri C., Garaventa F., Gambardella C., Loakeimidis C., Pitta E. (2021) - Distribution patterns of floating microplastics in open and coastal waters of the Eastern Mediterranean Sea (Ionian, Aegean, and Levantine Seas), Front. Mar. Sci. 8:699000. doi: 10.3389/fmars.2021.699000.

[2] Alioua M., Harzallah A. (2008) - Imbrication d'un modèle de circulation des eaux près des côtes tunisiennes dans un modèle de circulation de la mer Méditerranée [Nesting of a water circulation model along the Tunisia coasts in a Mediterranean Sea model]. Bull. Inst. Nat. Sci. Tech. Mer de Salammbô. 2008; 35: 169–176.

[3] Anastasopoulou, A. Fortibuoni, T. (2019) - Impact of plastic pollution on marine life in the Mediterranean Sea, in Plastics in the Aquatic Environment, Part I, eds F. Stock, Reifferscheid G., Brennholt N. Kostianaia E. (Cham:Springer).

[4] Andrady, A.L. (2011) - Microplastics in the marine environment, Mar. Pollut. Bull. 62 (8), 1596–1605.

[5] Ben Ismail S, Costa E., Jaziri H., Morgana S., Boukthir M., Ben Ismail M.A., Minetti R., Montarsolo A., Narizzano R., Sammari C., Faimali M and Garaventa F. (2022) - Evolution of the Distribution and Dynamic of Microplastic in Water and Biota: A Study Case from the Gulf of Gabes (Southern Mediterranean Sea), Front. Mar. Sci. 9:786026. doi: 10.3389/fmars.2022.786026.

[6] Ben Ismail S., Schroeder K., Sammari C., Gasparini G.P., Borghini M., Aleya L. (2014) - Interannual variability of water mass properties in the Tunisia–Sicily Channel Journal of Marine Systems, 135, 14-28.

[7] Bessa F., Frias J., Kögel T., Lusher A., Andrade J. M., Antunes J., et al. (2019) - Harmonized Protocol for Monitoring Microplastics in Biota, JPI-Oceans.Bruxelles.

[8] Chaouch S., Harzallah A. (2020) - A zoomed 3d circulation model for the monastir bay: comparison to operational analyses, Bull. Inst. Natn. Scien. Tech. Mer de Salammbô, Volume 47, 2020.

[9] Chouchene, K., Da Costa, J., Wali, A., Girão, A., Hentati, O., Duarte, A., et al. (2019) - Microplastic pollution in the sediments of Sidi Mansour Harbor in Southeast Tunisia, Mar. Pollut. Bull. 146, 92–99. doi: 10.1016/j.marpolbul.2019. 06.004.

[10] Cincinelli A., Martellini T., Guerranti C., Scopetani C., Chelazzi D., Giarrizzo T. (2019) - Apotpourri of microplastics in the sea surface and water column of the Mediterranean Sea, Trends Analy. Chem. 110, 321–326. doi: 10.1016/j.trac.2018.10.026.

[11] Cole M., Lindeque P., Halsband C., Galloway T.S. (2011) - Microplastics as contaminants in the marine environment: a review, Mar. Pollut. Bull. 62 (12), 2588–2597.

[12] Collignon A., Hecq J. H., Glagani F., Collard F., Goffart A. (2014) - Annual variation in neustonic micro- and meso-plastic particles and zooplankton in the Bay of Calvi (Mediterranean-Corsica), Mar. Pollut. Bull. doi: 10.1016/j. marpolbul.2013.11.023.

[13] Collignon, A., Hecq, J. H., Glagani, F., Voisin, P., Collard F., Goffart A. (2012) - Neustonic microplastic and zooplankton in the North Western Mediterranean Sea, Mar. Pollut. Bull. doi: 10.1016/j.marpolbul.2012.01.011.

[14] Cozar A., Sanz-Martin M., Marti E., Ganzalez-Gordillo J.I., Ubeda B., Galvez J.A., Irigoien X., Duarte C.M. (2015) - Plastic accumulation in the Mediterranean Sea. PLoS One 10 (4), e0121762.

[15] de Lucia G. A., Caliani I., Marra S., Camedda A., Coppa S., Alcaro L. et al. (2014) - Amount and distribution of neustonic micro-plastic off the western Sardinian coast (Central-Western Mediterranean Sea), Mar. Environ. Res. 100, 10–16. doi: 10.1016/j.marenvres.2014.03.017.

[16] Desforges J.P.W., Galbraith M., Dangerfield N., Ross P.S. (2014) - Widespread distribution of microplastics in subsurface seawater in the NE Pacific Ocean, Mar. Pollut. Bull. 79 (1), 94–99.

[17] Digka N., Tsangaris C., Kaberi H., Adamopoulou A., Zeri, C. (2018) - Microplastic abundance and polymer types in a mediterranean environment, in Proceedings of the International Conference on Microplastic Pollution in the Mediterranean Sea (Cham: Springer), 17–24.

[18] Duis, K., Coors A. (2016)- Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects, Environ. Sci. Eur. 28:2.doi10.1186/s12302-015- 0069-y.

[19] Eriksen M., Mason S., Wilson S., Box C., Zellers A., Edwards W., Farley H., Amato S. (2013) - Microplastic pollution in the surface waters of the Laurentian great lakes, Mar. Pollut. Bull. 77 (1), 177–182.

[20] Faure F., Saini C., Potter G., Galgani F., De Alencastro L. F., Hagmann P. (2015) - An evaluation of surface micro-and mesoplastic pollution in pelagic ecosystems of the Western Mediterranean Sea.

[21] Fossi M. C., Panti C., Guerranti C., Coppola D., Giannetti M., Marsili L., et al. (2012) - Are baleen whales exposed to the threat of microplastics? A case study of the Mediterranean fin whale (Balaenoptera physalus), Mar. Pollut. Bull. 64, 2374–2379. Doi:10.1016/j.marpolbul.2012.08.013.

[22] Gago J., Filgueiras, A., Pedrotti M. L., Suaria G., Tirelli V., Andrade J., et al. (2018) - Standardised Protocol for MonitoringMicroplastics in Seawater, JPI-Oceans, London

[23] GESAMP (2019) - Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean, Gesamp Report Studies No 99. Madrid: GESAMP, pp.1–138.

[24] Güven O., Gökda˘g, K., Jovanovi´c, B., and Kıdeys¸, A. E. (2017) - Microplastic litter composition of the Turkish territorial waters of the Mediterranean Sea, and its occurrence in the gastrointestinal tract of fish, Environ. Pollut. 223, 286–294. doi: 10.1016/j.envpol.2017.01.025.

[25] Kornilios S., Drakopoulos P., Dounas C. (1998) - Pelagic tar, dissolved/dispersed petroleum hydrocarbons and plastic distribution in the Cretan Sea, Greece. Mar. Pollut. Bull. 36, 989–993.

[26] Lebreton L., Egger M., Slat B. (2019) - A global mass budget for positively buoyant macroplastic debris in the ocean, Sci. Rep. 9:12922. doi: 10.1038/ s41598-019-49413-5.

[27] Lebreton L., Greer S., Borrero J. (2012). Numerical modeling of floating debris in the world's oceans, Mar. Pollut. Bull. 64, 653–661.

[28] Leslie H., (2014) - Review of Microplastics in Cosmetics, Report R14/29, IVM Institute for Environmental Studies, Amsterdam.

[29] Martin C., Baalkhuyur F., Valluzzi L., Saderne V., Cusack C., Almahasheer H., Krishnakumar P.K., Rabaoui L., Qurban M.A., Arias-Ortiz A., Masque P., Duarte C.M. (2020) - Exponential increase of plastic burial in mangrove sediments as a major plastic sink. Sci. Adv.

[30] Missawi, O., Bousserrhine, N., Belbekhouche, S., Zitouni, N., Alphonse, V., Boughattas, I., et al. (2020). Abundance and distribution of small microplastics (< 3 mm) in sediments and seaworms from the Southern Mediterranean coasts and characterisation of their potential harmful effects, Environ. Pollut. 263:114634. doi: 10.1016/j.envpol.2020.114634.

[31] Morgana S., Casentini B., Amalfitano, S. (2021). Uncovering the release of micro/nanoplastics from disposable face masks at times of COVID-19. J. Hazardous Mater. 419:126507. doi: 10.1016/j.jhazmat.2021.12 6507.

[32] Pan Z., Guo H., Chen H., Wang S., Sun X., Zou Q., Zhang Y., Lin H., Cai S., Huang J. (2019) - Microplastics in the Northwestern Pacific: Abundance, distribution, and characteristics. Sci. Total Environ., 650, 1913-1922.

[33] Panti C., Giannetti M., Baini M., Rubegni F., Minutoli R., Fossi M. C. (2015) - Occurrence, relative abundance and spatial distribution of microplastics and zooplankton NW of Sardinia in the Pelagos Sanctuary Protected area, Mediterranean Sea. Environ. Chem. 12, 618–626. doi: 10.1071/EN14234.

[34] Pedrotti M. L., Bruzaud S., Dumontet B., Elineau A., Petit S., Grohens Y., et al. (2014) - Plastic fragments on the surface of Mediterranean waters, in Proceedings of the CIESM Workshop Monograph (Monaco: CIESM Publisher), 115–123. PlasticEurope.

[35] Pedrotti, M., Petit, S., Elineau, A., Bruzaud, S., Crebassa, J., Dumontet, B., et al. (2016)- Changes in the floating plastic pollution of the Mediterranean Sea in relation to the distance to land. PLoS One 11:e0161581. doi: 10.1371/journal. pone.0161581

[36] PlasticEurope (2020) - Plastics: The Facts 2020 An analysis of European plastics production, demand and waste data.

[37] Poulain P.M., Zambianchi E. (2007) - Surface circulation in the central Mediterranean Sea as deduced from lagrangian drifters in the 1990's, Continental Shelf Research, 27, 981-001.

[38] Ruiz-Orejón, L. F., Sardá, R., Ramis-Pujol, J. (2018) - Floating plastic debris in the Central and Western Mediterranean Sea. Environ. Toxicol. Pharmacol. 120, 136–144. doi: 10.1016/j.marenvres.2016.08.001.

[39] Schmidt N., Thibault D., Galgani F., Paluselli A., Sempéré R. (2018) - Occurrence of microplastics in surface waters of the Gulf of Lion (NW Mediterranean Sea), Prog. Oceanogr. 163, 214–220. doi: 10.1016/j.pocean.2017.11.010

[40] Setiti S., Hamdi B., Chernai S., Houma Bachari F., Bachouche S., Ghezali Y., et al. (2021) - Seasonal variation of microplastics density in Algerian surface waters (South-Western Mediterranean Sea, Mediterranean Mar. Sci. 22, 317–326. doi: 10.12681/mms.24899.

[41] Suaria G., Avio C., Mineo A., Lattin G.L., Magaldi M.G., Belmonte G., Moore Ch.J., Regoli F., Aliani S. (2016) . The Mediterranean plastic soup: synthetic polymers in Mediterranean surface waters, Sci. Rep. 6, 37551.

[42] Tunçer S., Artüz O.B., Demirkol M., Artüz M.L. (2018) - First report of occurrence, distribution, and composition of microplastics in surface waters of the Sea of Marmara, Turkey. Mar. Pollut. Bull., 135, 283-289.

[43] URAM (2003) - L'étude du pop de Monastir, Plan d'occupation de la plage de Monastir, Monastir, pp 56.

[44] Vasilopoulou G., Kehayias G., Kletou D., Kleitou P., Triantafyllidis V., Zotos A., et al. (2021) - Microplastics investigation using zooplankton samples from the coasts of cyprus (Eastern Mediterranean), water. MDPI 13:2272. doi: 10.3390/w13162272.

[45] Veerasingam S., Saha M., Suneel V., Vethamony P., Rodrigues A.C., Bhattacharyya S., Naik B.G., (2016) - Characteristics, seasonal distribution and surface degradation features of microplastic pellets along the Goa coast, India. Chemosphere, 159, 496-505.

[46] Wakkaf T., El Zrelli R., Kedzierskid M., Baltia R., Shaiek M., Mansourg L., et al. (2020) - Characterization of microplastics in the surface waters of an urban lagoon (Bizerte lagoon, Southern Mediterranean Sea): composition, density, distribution, and influence of environmental factors. Mar. Pollut. Bull. 160:111625. doi: 10.1016/j.marpolbul.2020.111625

[47] Zayen A., Sayadi S., Chevalier C., Boukthir M., Ben Ismail S., Tedetti M. (2020) - Microplastics in surface waters of the Gulf of Gabes, southern Mediterranean Sea: distribution, composition, and influence of hydrodynamics. Estuar. Coast. Shelf Sci. 242, 106832.

[48] Zhao S., Zhu L., Wang T., Li D. (2014) - Suspended microplastics in the surface water of the Yangtze Estuary System, China: first observations on occurrence, distribution. Mar. Pollut. Bull. 86, 562–568.

[49] Zhou Y., Wang J., Zou M., Jia Z., Zhou S., Li, Y. (2020) - Microplastics in soils: a review of methods, occurrence, fate, transport, ecological and environmental risks. Sci. Total Environ. Sci. 748:141368. doi: 10.1016/j.scitotenv.2020.141368.