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Small plastic debris in sediments from the Central Adriatic Sea: Types, occurrence and distribution

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ABSTRACT

This is the first survey to investigate the occurrence and extent of microplastic contamination in sediments collected along a coast-open sea 140 km-long transect in the Central Adriatic Sea. Plastic debris extracted from 64 samples of sediments were counted, weighted and identified by Fourier-transform infrared spectroscopy (FT-IR). Several types of plastic particles were observed in 100% of the stations. Plastic particles ranged from 1 to 30 mm in length. The primary shape types by number were filaments (69.3%), followed by fragments (16.4%), and film (14.3%). Microplastics (1–5 mm) accounted for 65.1% of debris, mesoplastics (5–20 mm) made up 30.3% of total amount, while macro debris (> 20 mm) accounted for 4.6% of total plastics collected. Identification through FT-IR spectroscopy evidenced the presence of 6 polymer types: the majority of plastic debris were nylon, polyethylene and ethylene vinyl alcohol copolymer. Our data are a baseline for microplastic research in the Adriatic Sea.

1. Introduction

World production of plastics has strongly expanded, from 1.7 million tonnes in 1950 to 322 million tonnes in 2015 (Plastic Europe, 2016). Discarded "end-of-life" plastic accumulates particularly in marine habitats (Derraik, 2002). Marine plastic litter results from both land and sea-based sources and once at sea, larger items tend to either fragment or sink, and then accumulate on the coastline or on the seafloor, harming wild life and marine food chains (Avio et al., 2017). While pictures of macroplastic debris in ocean gyres (Moore et al., 2001) and of the excessive accumulation of plastics on coastlines worldwide (Galgani et al., 2015) have fostered the awareness of plastic pollution, small plastic debris, defined as microplastics in a size range of < 5 mm (Barnes et al., 2009), have emerged as an imminent source of plastic contamination in the marine environment only recently, as a consequence of their eluding presence in sediments and seawater (Andrady, 2011). The assessment of marine microplastic pollution is relatively recent, and extensive areas of seas remain yet poorly explored. This is the case of the Mediterranean Sea (UNEP/MAP/MEDPOL, 2009), whose shores house around 10% of the global coastal population, while the basin constitutes one of world's busiest shipping routes, and receives waters from densely populated river catchments (e.g. Nile, Ebro, Po, Rhone). Contamination by small plastic debris in the Mediterranean is a problem whose extent is only recently been recognized (Gago et al., 2015). In their review, Cózar et al. (2015) reported that floating small plastics abundances in the Mediterranean Sea were similar to those found in the Pacific Ocean gyres, while Woodall et al. (2014) reported of microplastic pollution in sediments from deep cores.

Located in the central Mediterranean, the Adriatic Sea is an elongated basin, with its major axis in the NW-SE direction, between Italy and the Balkans. The northern section is very shallow, with an average depth of about 40 m, while the central one is on average 140 m deep, with the Pomo Depressions reaching 260 m. Along the Italian coast a large number of rivers discharge into the northern and central parts of the basin, being the Po River the most relevant. The Adriatic Sea is characterized by one of the greatest floating plastic particles pollution among Mediterranean regions (Suaria and Alliani, 2014). Liubartseva et al. (2016), estimating the mean particles half-life (i.e., the time after release at which 50% of the particles still remain at the sea surface) in

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approximately 43.7 days, concluded that the Adriatic Sea is a highly dissipative system with respect to floating plastics (in contrast to the global ocean, where the half-life time of particles equals 19 years), and suggested that the main sink of floating plastics is partitioned between the shoreline and the seafloor, posing additional risk to such ecosystems. Although the distribution and accumulation of small plastic debris in Adriatic shorelines and at the sea surface is relatively documented (Laglbauer et al., 2014; Liubartseva et al., 2016; Munari et al., 2017), contributions to minimize the knowledge gap on benthic small plastic debris are still needed. To date, studies dealing with benthic small plastic debris on the Adriatic seafloor covers only few, very restricted, geographical areas: the Venice lagoon (Vianello et al., 2013), and the Telascica Bay (Blăsković et al., 2017). Larger scale data on benthic macro-litter were recently given by Strafella et al. (2015) and Pasquini et al. (2016), who investigated marine litter abundance and composition in the Adriatic with bottom trawl nets. Larger scale data on benthic small plastics are lacking.

Taking into account the global distribution and implications of small plastic debris and the early stages of studies dealing with microplastics deposition in Mediterranean sediments, and that microplastics is one of the descriptors of the Marine Strategy Framework Directive, MSFD (Gago et al., 2016), with the present study we wanted to assess, for the first time in the Central Adriatic, the quality and quantity of small plastic debris occurring in the seafloor to address the gap in knowledge and to serve as a baseline for future comparisons.

2. Materials and methods

2.1. Study area and sampling procedures

The survey was conducted in the framework of a monitoring programme (MONITA: HVDC 500 kV cc Italy-Montenegro submarine connection, carried out by Terna SpA), whose main objective was to provide information on benthic invertebrates and environment in the Central Adriatic, however anthropogenic waste data were also gathered. The sampling campaign was carried out with the research vessel "Kiya" in the Central Adriatic Sea, in November 2015. Sediment samples were taken at 16 stations located along a 140 km-long, E-W transect in Italian territorial waters from the town of Pescara to the island of Pianosa, using a Van Veen grab (area 0.1 m^2). Each station was sampled in 4 replicates; at each station, replicates were gathered at a distance of several hundred meters from each other. Sediments were sieved on board on a 1 mm mesh, so the smallest size of gathered debris was 1 mm. In Table 1 the characteristics of the sampled stations are reported.

Table 1
Characteristics of the sampled stations.

Station	Lat WGS84	Long WGS84	Depth	Gravels	Sand	Silt	Clay
	DDMMSS.dd	DDMMSS.dd	m	%	%	%	%
1	422722.135	141525.361	7	< 0.1	70.3	24.2	5.5
2	422749.211	141617.727	12	0.2	44.9	26.7	28.2
3	422818.279	141713.970	16	0.5	46.8	34.7	18.0
4	422841.728	141759.365	19	0.8	16.8	46.9	35.5
5	422906.371	141919.475	23	0.5	24.8	47.7	27.0
6	422911.468	142009.131	27	< 0.1	17.7	56.6	25.7
7	422902.623	142237.978	47	< 0.1	1.4	66.8	31.8
8	422845.206	142613.719	70	1.3	2.1	53.8	42.8
9	422827.571	142950.706	83	< 0.1	2.1	36.2	61.7
10	422809.807	143327.853	92	< 0.1	0.6	40.4	59.0
11	422751.858	143705.802	100	< 0.1	1.0	39.3	59.7
12	422223.749	153520.037	142	< 0.1	2.6	24.2	73.2
13	422155.845	153855.384	138	< 0.1	2.0	38.8	59.2
14	422127.828	154230.678	132	< 0.1	6.0	25.7	68.3
15	422058.645	154605.681	130	0.2	7.8	34.0	58.0
16	421907.522	154921.843	119	0.8	15.8	32.8	50.6

2.2. Sample analyses

At our laboratories, the plastic debris in sediment samples were removed under a dissection microscope (Nikon SMZ45T, magnification 3.35–300 ×), counted and weighted to the nearest 0.0001 g. The identified plastics were measured at their largest cross-section using calipers and classified into three groups: micro (1–5 mm), meso (> 5–20 mm), and macro (> 20 mm) (Gago et al., 2015). There is no general consensus on a specific size nomenclature: Barnes et al. (2009) suggested that microplastics be defined as < 5 mm particles and this approach has been used in our study. Plastic debris were also categorized according to shape, i.e. filament, film, and fragment. Filaments are cylindrical, pigmented and transparent; films tend to be flat, hard and do not tend to break or deform when pressed with a dissecting needle; fragments are particles of different colors that are hard or flexible but do not tear when pulled, nor do they shatter into many small pieces when pressed with a dissecting needle.

Plastic debris composition at the 16 stations was investigated by means of ordination analysis (nMDS) based on the Bray-Curtis similarity index calculated on quantity data.

Fourier-transform infrared spectroscopy (FT-IR) analysis of plastic debris was carried out with a CARY 600 FT-IR (Agilent Technologies) instrument. Measurements were carried out in attenuated total reflectance (ATR) configuration, with a Pike Miracle diamond cell. Tests were carried out at 25 °C in dry air. Particles were identified by comparing FT-IR absorbance spectra of the microplastics to those in a polymer reference library.

3. Results

In Table 1, sedimentary composition at 16 stations is shown. Seafloor was characterized by particles ranging from gravels (diameter between 4 and 2 mm) to clay (diameter < 0.0039 mm), according to the Wentworth grain-size classification. The fraction of finer sediments (silt + clay) was dominant from St.4 onwards, making up over 80% at the majority of stations.

A total of 64 sediment samples were analyzed from the 16 stations. Some examples of plastic debris collected during the study are shown in Fig. 1. Not all sediment samples contained plastics, but several types of plastic particles were observed in all the 16 stations. Plastic particles in the samples ranged from 1 to 30 mm in length. The samples contained

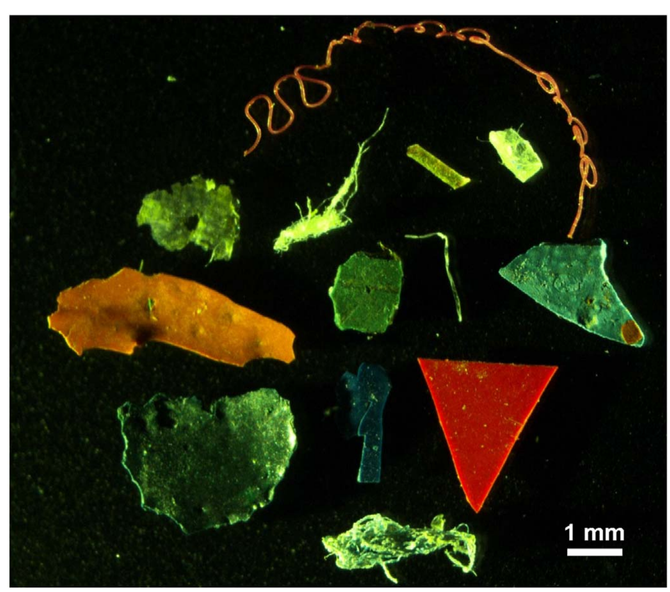

Fig. 1. Examples of the collected plastic debris. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)