Note

Plastic levels in sediments closed to Cecina river estuary (Tuscany, Italy)

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ABSTRACT

This study focuses on plastic distribution levels (shape, size, colour, type) in sediments from the coastal area of Cecina (Tuscany, Italy). Samples are collected in three sampling stations along six transect settled randomly along the shoreline and along the final tract of the Cecina river. Recorded plastic size ranges within 62.51–13,462 μm (average values 1591 ± 837 μm). Microplastics (< 5000 μm) represent over than 97% of the total even if mesoplastics (5000–25,000 μm) are also recorded (2%). Over than 60% of recorded plastic items are higher than 500 μm. Measured levels range within 72 (ST2)–191 (ST4) items/kg d.w. Fragment > Fiber > Granule in each of the tested sampling site. Plastic litter levels recorded in study evidence low pollution compared to the existing literature supporting the occurrence of good environmental levels in Cecina coastline for the "Marine litter" descriptor.

The Marine Strategy Framework Directive (MSFD - Directive 2008/56/EC) indicates marine litter as one of the 11 descriptors to define marine ecosystems environmental status and to target the "Good" level in 2020 (Galgani et al., 2013). Litter represents the new ecotoxicological concern in marine ecosystems (NOAA, 2008). The European Food Safety Authority (EFSA) examined the existing literature on the subject (EFSA, 2016) and reported scarcity of available data on the presence, toxicity and fate of microplastics to perform a complete risk assessment for human consumption. In the next years, recent researches are developed to fill knowledge gaps on plastic litter in marine ecosystems focusing on effects of plastic on top predators and marine species (Cole et al., 2011; Fossi et al., 2016); marine trophic webs (Ivar do Sul and Costa, 2014; Setala et al., 2014); exposure risks due to adsorbed chemicals (Cole et al., 2011; Browne et al., 2008); safeness of commercial seafood products (Van Cauwenberghe and Janssen, 2014; Santan et al., 2016; Pellini et al., 2018; Renzi et al., 2018a, 2018b). Human inputs from inland and local coastal hotspots affect microplastic loads in marine ecosystems. Rivers represent a source of particular interest for litter loads in marine ecosystems (Guerranti et al., 2017).

Marine litter encompasses different types of litter such as wood, rubber, paper, glass, and metals even if plastic represents on average over than 50% of the total amount of litter recorded in a study performed in Baleari Island (Martinez-Ribes et al., 2007). Quantification of plastic litter in different environmental matrix, ecosystems, and geographical areas are essential to define baseline levels of marine litter targeting objectives defined by MSFD.

This study aimed to define baseline levels and features (shape, size, colour, type) of plastic litter in sediments from Cecina shoreline and the final tract of the estuary of Cecina River to evaluate levels. Over than 50% of the total surface of the municipality of Cecina is covered by cultured fields. With the exception of the Cecina estuary, almost all the coastal area is covered by beaches, natural woods, and by the natural reserve.

Sampling sites were selected by a random extraction of their coordinates within 5 sampling areas (500 m of length) defined as reported in Fig. 1. A control site (ST06) was randomly selected outside of the sampling area. The control area was located in front of the Biogenetic natural reserve "Tomboli di Cecina" (D.M. 13/07/1997). Sampling was performed during summer 2017 to evaluate loads during the maximum impacted season by the human presence. In each sampling sites, samplings were performed along six transect perpendicular to the coastline. Each transect was sampled at three different subsampling stations named: A = emerged (dried sand, out of direct water actions); B = shore (average level of water); C = submerged (always submerged by water) to evaluate differences in microplastic distribution concerning depositional environments. Sediment samples (5 cm of depth) were collected in wide 1 L mouth glass jars taking three replicates within a radius of 1 m as reported by literature (Blašković et al., 2017). Laboratory analyses were performed by salt extraction using a saturated solution and subsequent filtration onto paper fibers (0.45 μm filter disks) by vacuum pump using a decontaminated glass bottle apparatus as reported by the literature (Fastelli et al., 2016). Saturated salt solution was made by the dissolution of marine iodate salt (Coop) filtered onto (0.45 μm filter disks) to avoid pollution by litter from the marine

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Fig. 1. Representation of sampling areas and sampling sites sampled. Red and yellow lines evidence sampling areas (500 m of length). Coordinates of sampling sites (ST1_6) were randomly extracted within each sampling area. Notes: ST1 – Cecina town; ST2 – Free-access beach; ST3 – river; ST4 – Estuary; ST5 – First artificial dam; ST6 – Biogenetic natural reserve "Tomboli di Cecina" (D.M. 13/07/1997). Three coast-wide transect were performed in each sampling site: A = emerged (dried sand, out of direct water actions); B = shore (average level of water); C = submerged (always submerged by water). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

salt (Renzi and Blašković, in press). Filters were stored in glass Petri dish and dried in oven at 40 °C till constant weight. The collected plastic items were analysed by stereomicroscopy (Nikon SMZ-800 N), images were collected by high-resolution digital camera linked to the microscope (Nikon, DS-Fi2) and post processed by Nikon's software for the imaging analysis (Nikon ACT-1). All identified items were divided in shape (Galgani et al., 2013; Alomar et al., 2016), colour (Blašković et al., 2017) and dimensional classes (Fastelli et al., 2016) reported by the literature. Plastic items were collected with micro tweezers and stored in Eppendorf tubes for further µFT-IR (Nicolet iN10 MX, Thermo Scientific) confirmation. BsRC (certified laboratory ISO 9001:2015) applies a severe control procedure under guidelines of the UNI EN ISO 17025 to ensure quality of data. Quality control and quality assurance was performed as described by Renzi et al. (2018a, 2018b). Experimental blanks were performed to evaluate possible crossover contamination during air exposure in laboratory as detailed reported by previous studies performed by the research group (Fastelli et al., 2016; Blašković et al., 2017). Univariate (Prism software, Graph-pad Software) and multivariate (Primer v5.0) statistics were performed for data analyses considering a $p < 0.01$ statistically significant to check factors of variability such as distance from the estuary and distribution in different depositional environments. Sizes of plastic litter range within 63–13,462 µm (average values 1591 ± 837 µm) as reported in Table 1. Macropalstics (> 25,000 µm) are not recorded. Microplastic (MPs; 63–5000 µm) is the principal litter class recovered (97%) even if also mesoplastic (5001–25,000 µm) is recorded (2% of the total amount of items recorded). Over than 60% of plastic items are higher than 500 µm. Levels of MPs measured in Cecina range within 72 (ST2)–191 (ST4) items/kg d.w. These results are lower than values reported by the literature for sediments from other Mediterranean areas such as Aeolian Archipelago Islands (Fastelli et al., 2016), Southern Tuscany coastline (Cannas et al., 2017), Regional Park of Maremma (Guerranti et al., 2017), Croatia (Blašković et al., 2017), and Caorle (Renzi et al., 2018a) as reported in Table 2. Fragments are the dominant MPs shape in the study area. As evidenced by the Fig. 2a, results in almost all-sampling area show that Fragment > Fiber > Granule levels. Other shapes are not represented significantly. Fragments > Fibers > Granule respectively in A, B, and C sampling sites suggesting possible effects due to the wave energy in microplastic distribution among different depositional environments. Granules are highly represented in A and B than in C

Table 1
Plastic litter size. Dimensional range (minimum, maximum), mean length and standard deviation (SD) are reported per sampling station and expressed in micrometers. ST1 – Cecina town; ST2 – Free-access beach; ST3 – Fluvial sampling station; ST4 – Estuary sampling station; ST5 – First artificial dam; ST6 – Biogenetic natural reserve "Tomboli di Cecina" (D.M. 13/07/1997).

	Min	Max	Mean	SD
ST1	97.9	3299.8	933.3	507.7
ST2	73.4	13,462.1	1360.8	860.9
ST3	121.8	4168.6	2168.1	1169.8
ST4	62.5	5234.5	1340.9	222.4
ST5	171.2	5233.6	2540.6	740.6
ST6	212.7	2221.8	1171.7	110.1

Table 2
Plastic litter items recorded in sediments: a comparison among levels measured in this study and those reported by the recent literature.
Notes: 1) Stations ST2 - ST4 (min-max); 2) Different habitat, Mäerl bed habitat, *C. nodosa* bottoms, Amphioxus sands; 3) Different Islands; different levels of impacts; water depth 30 m; 4) Talamone - Capalbio (min-max); 5) River estuary; 6) Highly human exploited beach.

Location	Sea	Levels items/kg d.w.	Colour features	Reference	
Cecina	Central Tyrrhenian	72–191	White (10–30%) Tan (20%) Blue (10–30%)	This study	1
Caorle - Slovenian	Northern Adriatic	137–703	All colours represented	Renzi et al., 2018a, b	2
Croatia	Northern Adriatic		Clear (25%) White (22%) Black (15%)	Blašković et al., 2017	
Aeolian Archipelago	Southern Tyrrhenian	151–679	Green (20%) Black (28%) Others (10%)	Fastelli et al., 2016	3
Capalbio - Orbetello	Central Tyrrhenian	62–466	Colours: all, black, blue	Cannas et al., 2017	4
Albegna	Central Tyrrhenian	453	Colours: all, black, blue	Cannas et al., 2017	5
Osa	Central Tyrrhenian	286	Colours: all, black, blue	Cannas et al., 2017	5
Ombrone	Central Tyrrhenian	118	Black and Blue	Guerranti et al., 2017	5
Capalbio	Central Tyrrhenian	1069	Colours: all, black, blue	Cannas et al., 2017	6

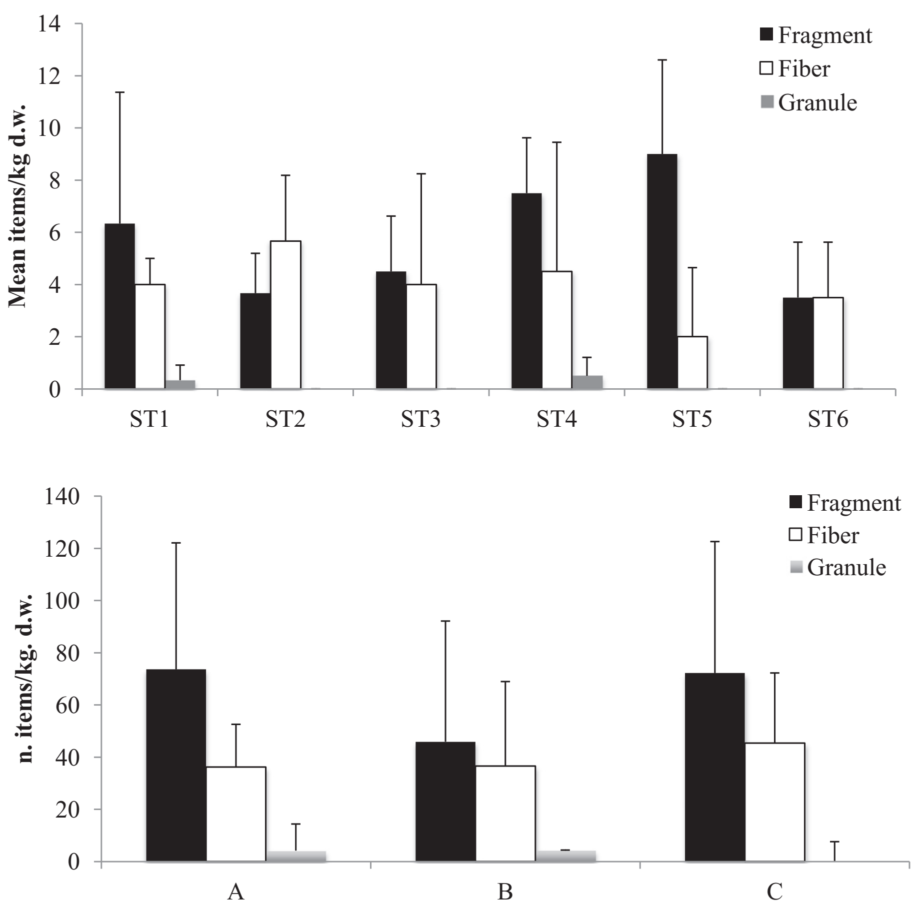
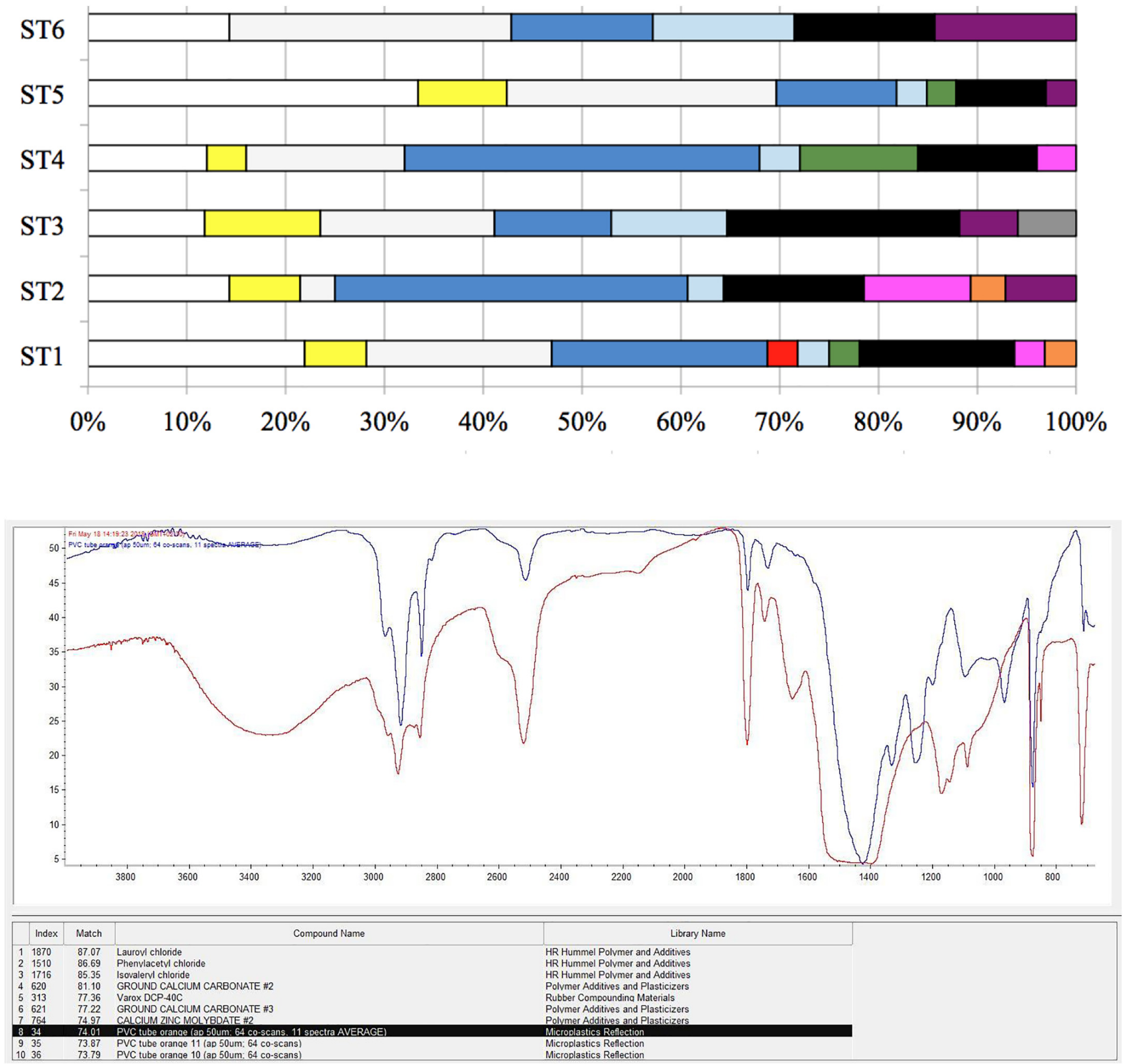


Fig. 2. Shape of collected plastic litter. Results are reported grouping data per sampling site (Fig. 2a) and per depositional environment (Fig. 2b). Fig. 2a. Average (+SD) values of microplastics recovered are grouped per sampling areas (number of items per kg d.w.). Fig. 2b. Average (+SD) values of microplastics recovered are grouped as beach, shore, and sea (number of items per kg d.w.). A = emerged (dried sand, out of direct water actions); B = shore (average level of water); C = submerged (always submerged by water).

sampling sites where they are founded only occasionally (Fig. 2b). These results are notably different to results recorded by the literature as well as fibers are the principal shape class reported by previous studies performed on sediments from river, coastal beach (Guerranti et al., 2017; Cannas et al., 2017) and shallow marine water (Fastelli et al., 2016; Blašković et al., 2017; Renzi et al., 2018a, 2018b). Probably this could be also due to a clear fingerprint of local river input as evidenced by the highest levels of fragments recorded in river sampling areas (ST4) and closed to the Cecina estuary (ST5). Colour fingerprint recorded in this study are reported in Fig. 3a. Sampling areas closed together show a similar colour fingerprint supporting a common origin of MPs. White, Tan and Blue colours are highly represented, on the contrary black is scarcely recorded. Colour results represent another difference with the previous literature (Table 2) supporting the hypothesis that colour fingerprints could be useful to characterize sediments on a small geographical scale-basis. Furthermore, orange plastic litter recorded in ST1, and ST2 resulted made of PVC supporting a common origin of recorded microplastics in urban impacted sampling areas (Fig. 3b). Univariate and multivariate statistical analyses performed (*nm*-MDS, ANOSIM, Pairwise test) do not highlighted significant differences among tested factors suggesting that further studies should be performed increasing sampling efforts. Results obtained in this study define actual loads and features of plastic litter in coastal sediments. Even if statistical tests do not highlight significance, chemical analyses performed highlight the common origin of microplastic from Cecina river. On a general basis, Cecina studied area resulted very low impacted by plastic litter compared to the existing literature. Inputs from the Cecina River are low if compared to levels at estuaries from literature data. Baseline data are useful to define levels in high variable coastal areas that could be of interest for further monitoring programmes and to evaluate the effectiveness of specific management actions. Further researches should be performed to improve the dataset to



	Index	Match	Compound Name	Library Name
1	1870	87.07	Lauroyl chloride	HR Hummel Polymer and Additives
2	1510	86.69	Phenylacetyl chloride	HR Hummel Polymer and Additives
3	1716	85.35	Isovaleryl chloride	HR Hummel Polymer and Additives
4	620	81.10	GROUND CALCIUM CARBONATE #2	Polymer Additives and Plasticizers
5	313	77.36	Varox DCP-40C	Rubber Compounding Materials
6	621	77.22	GROUND CALCIUM CARBONATE #3	Polymer Additives and Plasticizers
7	764	74.97	CALCIUM ZINC MOLYBDATE #2	Polymer Additives and Plasticizers
8	34	74.01	PVC tube orange (ap 50um; 64 co-scans, 11 spectra AVERAGE)	Microplastics Reflection
9	35	73.87	PVC tube orange 11 (ap 50um; 64 co-scans)	Microplastics Reflection
10	36	73.79	PVC tube orange 10 (ap 50um; 64 co-scans)	Microplastics Reflection

Fig. 3. Colour fingerprint of plastic litter and μFT-IR analyses. Fig. 3a. Data on colours are reported per sampling site. Data are expressed as percentage (number of items of a given colour versus the total amount of measured items). Bar colours represent colours of plastic recorded. Fig. 3b. μFT-IR analyses performed on orange coloured plastic litter to support the common origin of microplastics recorded in urban impacted sampling stations.

perform solid statistics on factors of interest (river load, depositional environment) evaluate seasonal trends and to verify if low levels recorded are associate or not to particular virtuous policies and management strategies of inland and/or local beaches of Cecina that could be eventually exported to other Mediterranean areas. Furthermore, as well as this area resulted low polluted compared to actual existing literature, reported data could be useful to define actual range of fluctuation of the Descriptor "Marine litter" in particular for the definition of levels included in the range of "good" that have to be first of all defined but after that they have to be achieved by 2020 according to the MWFD.

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