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RESEARCH PAPER

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Beach Litter on Sarayköy Beach (SE Black Sea): Density, Composition, Possible Sources and Associated Organisms

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Abstract

The composition, density and possible sources of litter were seasonally evaluated in a selected beach in the Southeastern Black Sea between June 2016 and March 2017. During the study, 84 different types of litter were determined and a total of 17015 items weighing 168.9 kg were collected. Litter density ranged between 1.22-4.17 items.m^{-2} and 11.78-37.47 gr.m^{-2}. Plastics comprised 84-91% of total litter. The most common three types of litter were foam (17%), 2.5-50 cm plastic/polystyrene pieces (15%) and caps/lids (10%). Fouling organisms found on litter belonged to Mollusca, Arthropoda and Bryozoa. Litter density showed significant seasonal differences with the highest in summer ($P<0.05$). Matrix Scoring Technique showed that river runoff (22%), landfill/dumping (21%) and fisheries (18%) were the major sources of the litter. According to Clean Coast Index, the beach was very dirty in all seasons. This study provides further evidence that there is a significant litter pollution in the Southeastern Black Sea and that the main component are plastics, which pose a great treat to Black Sea environment. This call for a scientific understanding of the fate and effects of plastics, as well as actions to reduce the amount of plastics entering Black Sea.

Introduction

Marine litter (ML) is defined as any persistent, processed or manufactured solid material (e.g. plastic, metal, paper, wood, glass) discarded, disposed or abandoned in the marine and coastal environment from land- or sea-based sources (UNEP, 2009). Over the last decades, ML has been increasingly accumulating in the sea surface, water column, sea floor and beaches (Galgani, Hanke & Maes, 2015). Plastic items are the most common litter, being associated to 60-80 % of ML (Derraik, 2002). Once they enter the marine environment, they continue to break down into smaller particles called microplastics (< 5mm) and can be transported to distant locations from their sources (Barnes, Galgani, Thompson & Barlaz 2009). Consequently, ML can be found in all seas and beaches around the world, negatively affecting marine life, human health, fishing, shipping and tourism industries and become one of the most prominent threat for the ocean (UNEP, 2005). Although promoting environmental education and responsible citizenship is probably one of the most important strategies to reduce the ML problem, there is a great need to monitor ML pollution to improve our knowledge on the scale of the problem.

Black Sea is the largest anoxic basin in the world. High river discharge of several industrialized countries into a semi-enclosed sea (Figure 1) makes this ecosystem highly vulnerable to pollution. ML is considered one of the most urgent and difficult environmental problem in the basin (BSC, 2007). Illegal dumping on river valleys or the seashore, uncontrolled landfills and poor solid waste management are the most important sources of litter in the Black Sea (BSC, 2007). Coastal cities, ports, intense fishing activities and shipping are also other sources of ML. Plastic is reported as the most abundant ML item from sea surface (Suaria, Melinte-Dobrinescu, Ion & Aliani 2015), sea floor (Topçu & Öztürk, 2010; Moncheva *et al.*, 2016; Öztekin & Bat, 2017a) and from beaches in the Black Sea (e.g. Topçu, Tonay, Dede, Ozturk & Ozturk, 2013; Vişne & Bat, 2016; Simeonova, Chuturkova, & Yaneva, 2017; Terzi & Seyhan, 2017). The most of the plastic originates on land and river discharge is considered as the main conduct of plastic litter in the basin (BSC, 2007). According to a recent study in the NW continental shelf, 4.2 tons of plastics are generated daily by Danube (Lechner *et al.*, 2014). Due to large-scale circulation pattern of Black Sea, all these passive materials are likely to be distributed through the basin, continue to break down and become a transboundary problem. Accordingly, recent researches highlight high concentrations of microplastics from Southern (Öztekin & Bat, 2017b) and SE Black Sea surface waters (Aytan *et al.*, 2016). Although the number of ML studies increased during last decade in the Black Sea, ML is a complex-growing problem, and monitoring the ML to understand the sources is crucial to take action to reduce its occurrence in the Black Sea.

The Marine Strategy Framework Directive (MSFD) of European Commission aims the protection and sustainable use of marine ecosystems. Initial assessment of status of litter is an important step to determine Good Environmental Status (GES) and to establish environmental targets and associated indicators in the region. The aim of this study is to assess the situation of beach litter in the SE Black Sea to support national and regional assessments of ML within the scope of MSFD. The present study evaluates the composition, amounts and sources, as well possible ecological impacts of ML on Sarayköy beach (RİZE) in the SE Black Sea.

Materials and Methods

Study site

Seasonal assessment of beach litter was conducted in a selected beach in the SE Black Sea (location 41º01'23''N; 40º22'40''E; sea facing 315º N) between June 2016 and March 2017 in a seasonal basis. The beach is situated in Sarayköy village with a low population (148 citizens) and is 2 km east of İyidere town (populated by 8657 citizens) and 13 km west of Rize city (populated by 331048 citizens) (TUIK, 2017). The nearest stream (Ikizdere) is at 5.8 km west and the closest harbour (Port Rize) is at 11.,6 km east. The total length of the beach is 330 m with a 20±2 m width, slope of 20-30%, and consist of pebbles (100%). The back of the beach is a cliff with vegetation and in both sides of the

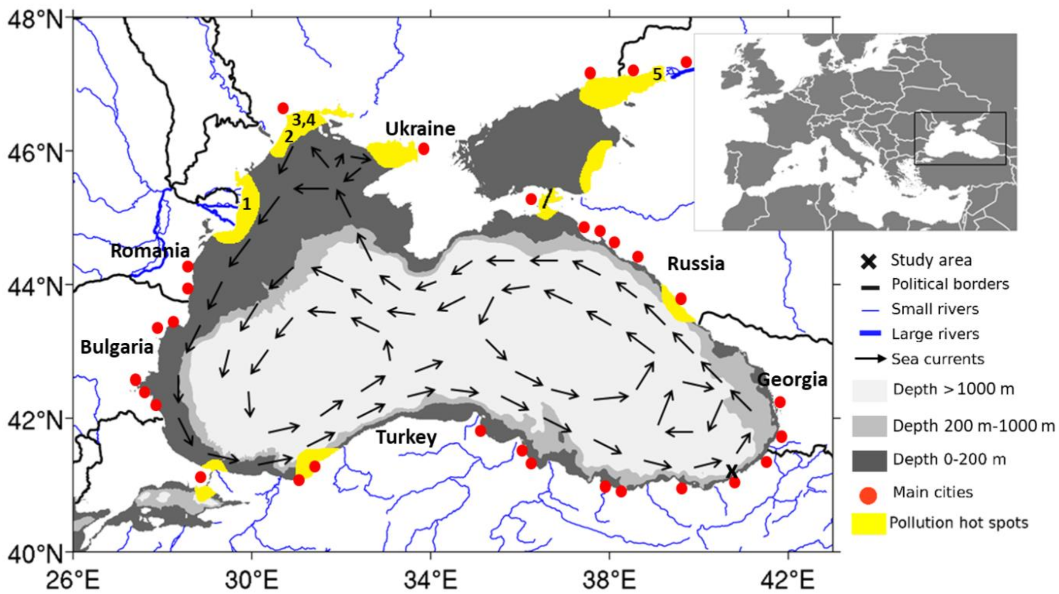

Figure 1. Map showing countries, major cities (main land-based sources), hot spots of marine pollution (adapted from BSC, 2007 and Aytan et al., 2016), rivers (1 - Danube, 2 - Dniester, 3 - Bug, 4 - Dnieper and 5 - Don) that flow into the Black Sea basin, study area (Sarayköy beach), bathymetry and a basic schematic representation of the Rim Current in the Black Sea.

beach there are two large rock groins to prevent beach erosion. Beach is mainly used for swimming/sunbathing activities by local people between June and September. In this period, there are two small beach coffees serving food and drinks.

Sampling

Litter items were collected seasonally (June, October, December, and March) by five persons in 100 m transect following standardized protocols of OSPAR for beach litter surveys (OSPAR, 2010). The whole area from the waterline to the back of the beach is surveyed (~ 20 m). A total of 83 different type of litter were determined and categorised in to plastic/polystyrene, rubber, cloth, paper/cardboard, wood (machined), metal, glass, pottery/ceramics, sanitary waste, medical waste and others (unclassified) according to OSPAR photo guide and one new litter item (pipes) was added. All litter were counted and weighed. The number of item in 100 m coast line was calculated. Abundance and weight of litter were also calculated as items.m^{-2} and g.m^{-2}. The fouling organisms were identified to lowest taxonomic level possible and recorded. Litter items with foreign labels were also recorded. According to buoyancy characteristics, litter items were also categorised as persistent-buoyant, short-term-buoyant and non-buoyant litters (Rech *et al.*, 2014).

To assess the contribution of different sources and pathways to litter, Matrix Scoring Technique (Tudor & Williams, 2004) was used. The litter type, labelling, distance to sources, location and the physical and geographical characteristic of beach, prevalent wind and current pattern, users-habit were considered. Possible sources (tourism, sewage, landfill/dumping, river runoff, shipping, offshore, fishing) were scored as very likely (16), likely (4), possible (2), unlikely (1), very unlikely (0.25) and not considered (0).

Mean values and standard deviations of abundances of items, general categories and total beach litter were calculated for each seasons. Based on mean abundances, the top 10 items in terms of number and weight were identified. To determine cleanness of the beach, Clean Coast Index (CCI) was calculated following to formula CCI= (TL/TA)*K, where the TL is total litter count on transect, TA is total area of transect, and K is a coefficient of 20. According to CCI, beach is ranked as very clean (0-2), clean (2-5), moderate (5-10), dirty (10-20) and very dirty (>20) (Alkalay, Pasternak & Zask 2007).

To assess the relation between meteorological condition and litter density, the wind speed, wind direction and precipitation were obtained from Turkish Meteorological Services. For analyses of seasonal differences (non-parametric analyses of variance and post-hoc-tests), the ten most common litter items comprising the ~ 80% of the total number of litter were used as input data because the contribution of each other items were < 1%.

Results

Density and Composition

A total of 17015 (mean value: 3798±2546) items resulting in 168.9 (mean value: 41.3±22.9) kg were collected in 100 m of beach between June 2016 and March 2017. The average litter density in terms of number and weight were 2.10±1.38 items.m^{-2} and 21.11 ±11.35 g. m^{-2}, respectively (Table 1). The litter density ranged between 1.22-4.2 items.m^{-2} and 12.28-37.7 g. m^{-2} (Table 1). Litter density was significantly different between seasons (one-way ANOVA, $P<0.05$; $F_{(7.21)} = 2.86$, $P= 0.0006$). Beach litter densities in summer were significantly higher compare to autumn, winter and spring (t-test, $P<0.05$).

From the 121 types of litter in OSPAR photo guide, 83 types of litter items were found (data not shown) and a new common item was added (plastic pipes). The plastics (including fragments) were the most abundant litter items in each season (1.1-3.8 items.m^{-2}) representing 84 to 91% of total litter in terms of number (Table 1). The other litter categories represented low contribution (< 2%) (Figure 2). In terms of weigh, plastics (including fragments) were again the most common items (6.78-28.99 g.m^{-2}) representing 55 to 77% of total

Table 1. Seasonal and total densities of beach litter in the study area (items/m^2 and g/m^2)

Material	Summer		Autumn		Winter		Spring		Mean (±SD)	
	items/m^2	g/m^2	items/m^2	g/m^2	items/m^2	g/m^2	items/m^2	g/m^2	items/m^2	g/m^2
Plastic/polystyrene	3.80	28.99	1.22	6.78	1.37	11.94	1.11	11.64	1.87 (1.28)	14.83 (9.73)
Rubber	0.01	0.29	0.004	0.08	0.01	0.12	0.01	0.14	0.01 (0.003)	0.16 (0.09)
Textile	0.06	2.50	0.02	1.54	0.03	2.80	0.01	0.84	0.03 (0.02)	1.92 (0.90)
Paper/cardboard	0.02	0.21	0.06	0.29	0.05	0.41	0.01	0.10	0.03 (0.02)	0.25 (0.13)
Wood	0.03	1.16	0.02	0.74	0.03	1.58	0.02	1.25	0.02 (0.01)	1.18 (0.35)
Metal	0.08	1.84	0.05	0.81	0.03	0.60	0.02	0.52	0.05 (0.03)	0.94 (0.61)
Glass	0.005	0.45	0.03	0.22	0.004	0.11	0.003	0.34	0.01 (0.01)	0.28 (0.15)
Pottery/Ceramics	0.002	0.27	0.001	0.50	0.001	0.19	0.003	0.91	0.002 (0.001)	0.47 (0.32)
Sanitary waste	0.02	0.41	0.01	0.47	0.01	0.08	0	0	0.01 (0.01)	0.24 (0.23)
Medical waste	0.05	0.11	0.01	0.17	0.02	0.13	0.02	0.16	0.02 (0.02)	0.14 (0.03)
Other	0.10	1.50	0.03	0.69	0.01	0.15	0.02	0.40	0.04 (0.04)	0.68 (0.59)
TOTAL	4.17	37.73	1.45	12.28	1.57	18.13	1.22	16.29	2.10 (1.38)	21.11 (11.35)

litter followed by clothes (5-15%), woods (3-9%) and metals (3-7%) (Figure 2) (Table 1).

The top ten litter items comprised 79 % of total litter. The most commonly found type of litter item was foam of various sizes (represented 17% of all items) followed by plastic/polystyrene pieces 2.5-50 cm (15%), caps/lids (10%), crisp/sweet packets and lolly sticks (10%), food containers (8%), bags (including shopping) (7%), drinks (bottles, containers and drums) (6%), cups (3%), pipes (3%) and plastic/polystyrene pieces 0-2.5 cm (2%) (Table 2). Litter with foreign labels comprised 0.2 % of total litter during study and mainly belonging to Black Sea countries.

Possible Sources

Matrix Scoring Technique revealed that 62% of identifiable litter was from land-based sources. River

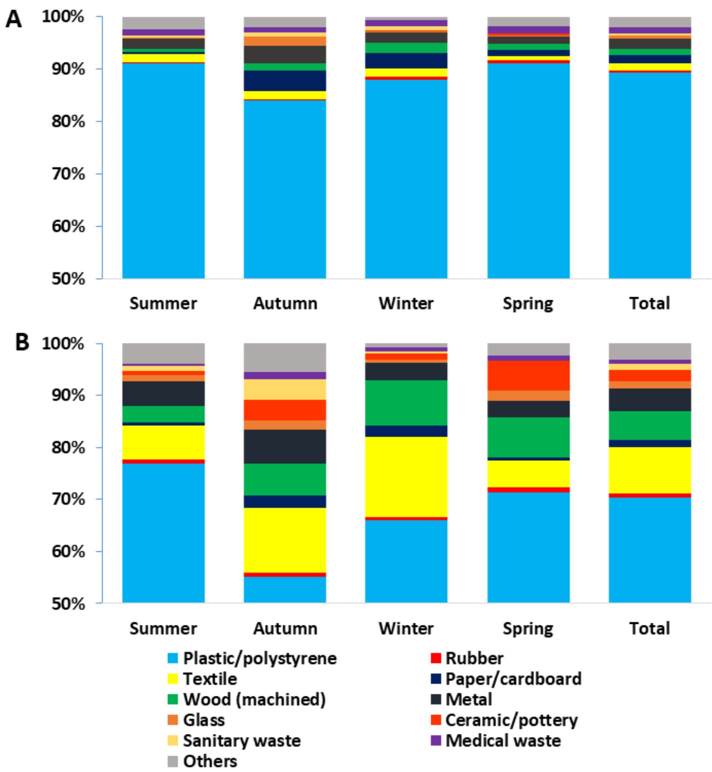

Figure 2. Composition of litter items according to material categories in terms of number (A) and weight (B). (Plastic/polystyrene consists 43 types of items including most recorded items during the study according to Table 2).

Table 2. Ten most abundantlitter items that make up ~80% of the total litter recorded on 100 m of beach between June 2016-March 2017

Rank	OSPAR ID	Type	Sources	Material	Mean number	Std (±)	%
1	45	Foam/Styrofoam	Construction/Fishing/Packing	Plastic	715	267	17
2	46	Plastic/polystyrene pieces 2.5 - 50 cm	Unclassified	Plastic	647	409	15
3	15	Caps/lids	Beverage	Plastic	412	340	10
4	19	Crisp/sweet packets and lolly sticks	Food packing	Plastic	406	534	10
5	6	Food containers	Food packing	Plastic	349	261	8
6	2	Bags (including shopping)	General packing	Plastic	293	245	7
7	4	Drinks (bottles, container and drums)	Beverage	Plastic	268	150	6
8	21	Cups	Beverage	Plastic	117	48	3
9	-	Pipes	Construction	Plastic	112	95	3
10	117	Plastic/polystyrene pieces 0 – 2.5 cm	Unclassified	Plastic	90	126	2

runoff and landfill/dumping were the most important land-based sources of litter being associated with 22% and 21% of the items recorded, respectively (Figure 3). The remaining litter from land-based sources were from tourism (beach users) (15%) and sewage (4%). The litter from sea-based sources was mainly from fishing (18%) followed by shipping (13%) and other offshore activities (7%).

Considering the usage, identifiable litter was mainly beverage (21%), food (19%) and general packing (15%) items (Figure 4). Fishing related items comprised 8% of items and mainly consisted of foam fish boxes (60%) followed by, nets and ropes (16%) and crates (14%). Construction comprised 7% of items and foam/styrofoam (70%) was the most recorded construction items. Around 18% of litter (plastic pieces) were not identifiable. Considering the total abundance of litter, Clean Coast Index showed that beach was very dirty in each season (CCI for summer: 83.4, autumn: 29.1, winter: 33.3, spring:24,4).

Associated Organisms

Marine litter associated organisms were observed in spring and summer survey. Individuals, colonies and egg sacks of invertebrates belonging to Mollusca, Arthropoda and Bryozoa were encountered only on plastic items (Figure 5). A maximum of four different taxa per litter item were found.

Discussion

Composition and Density

The average amount of litter found on the Black Sea coasts varied between 0.05-5.05 item.m^{-2} according to previous works (Table 3). ML density reported here are within the range reported from the other regions in the Black Sea (Table 3). Although there are some differences in the density of beach litter between regions (Table 3), plastics constitute approximately 60-

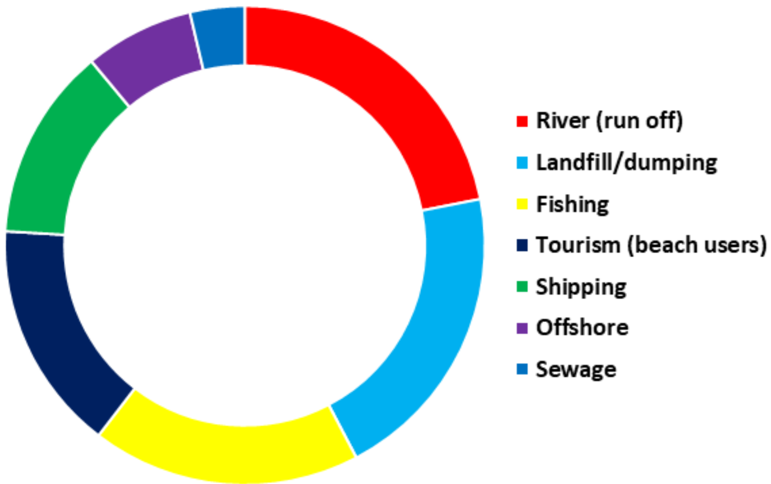

Figure 3. Schematically potential sources of litter found on Saraykoy Beach

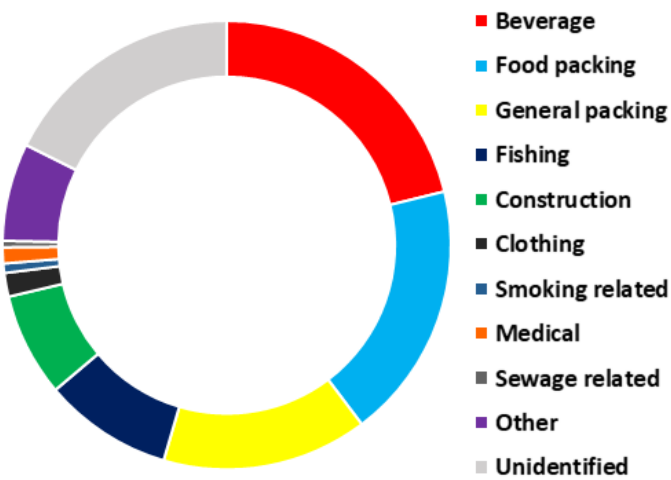

Figure 4. Usage categories of litter found on Saraykoy Beach.

Figure 5. Marine litter associated organisms: a, b, e- *Mytillus* sp. (Mollusca, Bivalvia), barnacles (Arthropoda, Crustacea, Cirripedia) and Bryozoan colony, c- barnacles (Arthropoda, Crustacea, Cirripedia), d- Gastropoda eggs (Mollusca), f- *Mytillus* sp. (Mollusca, Bivalvia).

Table 3. Beach litter densities in the Black Sea coasts

Location	Density (items/m^2)	Plastic (%)	Reference
SW Black Sea	0.085-5.058	91	Topçu et. al., 2013
SE Black Sea	0.05-0.55	71.58	Terzi & Seyhan, 2013
Southern Black Sea	1.033-2.352	95.6	Visne & Bat, 2016
NW Black Sea	1.11	80.6	Paiu et al., 2017
NW Black Sea	0.05-0.13	84.3	Simeonova, et. al., 2017
SE Black Sea	0.16 ± 0.02	61.65	Terzi & Seyhan, 2017
SE Black Sea	1.22-4.17	92	This study

80% of ML around the world (Derraik, 2002), including Black Sea (Topçu *et al.*, 2013; Visne & Bat, 2016; Simeonova *et al.*, 2017; Terzi & Seyhan, 2017). Our results showed that plastics were the most common type of litter in the region mainly from beverage, food and general packing in agreement with previous reports from Southern coast of Black Sea (Topçu *et al.*, 2013; Visne & Bat, 2016; Terzi & Seyhan, 2017).

In the Black Sea, the highest density of litter was reported in summer from Western (Simenova *et al.*, 2017) and SE coasts (Terzi & Seyhan, 2017), and in autumn from SW coast (Topçu *et al.*, 2013). In this study, the highest density of litter by number and weight was found in summer. Our summer sampling was carried in June before the beach became actively used for swimming/sun bathing activities and the beach coffees opened for summer. From mid- June to mid-September, the beach is used by local people and daily cleaned by coffee staff. Regarding to our autumn (October) sampling, it was surveyed one month after beach became inactive. Thus, a possible cause for the high litter density observed in June, rather than in October after summer use, might be the accumulation of litter between winter and early summer. Accordingly, an aerial survey in Russian coastal waters showed that a major quantity of litter comes by rivers and rain torrents during late spring and early summer (BSC, 2007).

Deposition and retention of litter and abundance depends multiple factors, such as physical characteristic of coast, proximity to sources, weather conditions (e.g. precipitation, prevailing wind) and near-shore currents (Barnes *et al.*, 2009; UNEP, 2009). The beach surveyed can be characterized as a rocky shore with a higher retention capacity of washed litter items compared to sandy beaches (Moore, Gregorio, Carreon, Weisberg & Leecaster, 2001**).** Concerning weather conditions, during the sampling periods, both wind and precipitation were weak, and wind direction fluctuated between the SW and SE quadrants (data not shown). No statistically important relation between wind speed/direction, precipitation and litter density was found during study ($P>0.05$).

Composition of litter in this study was similar to those reported from Southern Black Sea coast (Topçu *et al.*, 2013; Vişne & Bat, 2016; Terzi & Seyhan, 2017). According to total litter recorded on 100 m of beach between June 2016- March 2017, foam was the most recorded item in agreement with previous studies (Topçu *et al.*, 2013; Terzi & Seyhan, 2017). Foam might have originated from various sources such as general packing, fishing and construction, and their contribution is difficult to identify. Fishing seems an important source since foam fish boxes are extensively used by local fishermen to transport fishes in the region. Another source seems to be the construction (insulation boards). Plastic pieces (2.5- 50 cm) were the second most common item of beach litter being associated with 15% of the items recorded in agreement with previous reports from NW (Mureşan *et al.*, 2017) and Southern Black Sea beaches (Topçu *et al.*, 2013; Vişne & Bat, 2016; Terzi & Seyhan, 2017). These small plastics pieces might easily carry to sea by winds and be abundant due to the continuous erosion of larger plastic items.

Cigarette butts were one of the most frequent litter items found on beaches in several areas in Europe (Veiga *et al.*, 2016), including the Bulgarian (Simeonova *et al.*, 2017) and Romanian coast of Black Sea (Paiu, Cândea, Paiu & Gheorghe 2017; Golumbeanu *et al.*, 2017; Muresan *et al.*, 2017). In these studies, the amount of cigarette butts and filters were closely related to the presence of tourists. However, in this study, cigarette buds and filters comprised less than 1% of total litter, in agreement with previous studies from Southern Black Sea coast (Topçu *et al.*, 2013; Terzi & Seyhan, 2017). One explanation could be that in the SE Black Sea, the beaches are used for a limited time during summer due to rainy nature and are not subjected to heavy tourist visit. High concentration of discarded or abandoned fishing nets were reported in some shelf areas of the Black Sea (BSC, 2007), however in this study, nets and pieces of nets (< 50 cm) only comprised < 1% of total litter.

Sources

Land-based sources, particularly river runoff and landfill/dumping sites, are recognized to be the most important sources of litter in the Southern Black Sea (BSC, 2007). This is also confirmed in this study according to Matrix Scoring Technique. Municipal and industrial solid wastes, mixed with hazardous wastes are often dumped on the nearest lowlands and river valleys in the Southern Black Sea (Berkun, Egemen, & Nemlioglu, 2005), which can be transported into the sea by waves, winds and rains.

During this study, 92% of total litter were comprised by persistent-buoyant litters. The permanent circulation feature of the Black Sea is the meandering rim current (Figure 1), which encirculates the entire basin in a counter-clockwise direction (Oguz *et al.*, 1993) and may cause a dissemination of plastic items over the basin. In a survey of ten beaches in Turkish western coast of Black Sea, foreign litter made up about half of the labelled litter and it was assumed to be transported from neighbouring countries by currents or by international shipping. (Topçu *et al.*, 2013). Foreign litter was reported to comprise 2.38% of total litter in the Southern Black Sea (Vişne & Bat, 2016). In this study, foreign litter comprised only 0.2% of total litter. However, high number of foam and plastic pieces (2.5-50 cm) found on the beach might have entered the marine environment a long time ago and originated from distant sources.

Potential Harm on Associated to ML

Because of their capacity for entanglement, ingestion, transportation of invasive, pathogen species and organic pollutants (Gall & Thomson, 2015), all litter items found on beach might be considered harmful to the marine environment. They are also a reason for concern due to coastal recreation safety and aesthetics (Cheshire *et al.*, 2009). Marine litter can affect biodiversity directly by habitat lost and indirectly as artificial surface. While sinking litter might affect benthic habitat (Trouwborst, 2011), floating debris can transport marine organisms over long distances (Aliani & Molchard, 2003). Bryozoans, crustaceans, worms, hydroids and molluscs have been reported from floating litter (e.g. Aliani & Molchard, 2003; Rech, Salmina, Borrell Pichs & Garcia-Vazquez, 2018). Many of these fouling organisms are potentially classified as invasive species. In last decades the Black Sea ecosystem has been strongly affected by invasive species (Oguz, Velikova & Kıdeys, 2008). In this study, we found three different marine invertebrate egg sacks, larvae and adults on plastic litter. No exogenous species were found. However, highly buoyant plastic litter might act as surface for fouling organisms and may transport them to remote areas where they do not normally occur.

Floating plastic litter is also of particular concern due to their fragmentation into microplastic (MP) (Arthur *et al.*, 2009). Microplastics can be taken by many organisms as food, enter marine food web with potential ecotoxicological effects to marine biota and to human by contaminated seafood (Wright, Thompson & Galloway 2013; Setälä, Fleming-Lehtinen & Lehtiniemi, 2014). Recent studies in the Southern (Öztekin & Bat, 2017b) and SE Black Sea (Aytan *et al.*, 2016) have been reported high concentrations of MPs from sea surface. These studies provide evidence that the Black Sea is a hotspot for MP pollution and that they are bioavailable to many commercially and ecologically important pelagic and benthic species.

Conclusion

Monitoring of the status of the beach litter has been considered essential for the implementation of the "marine litter" descriptive of the Marine Strategy Framework Directive (EC, 2008), which aims to achieve a healthy functioning of marine ecosystems and a sustainable use of marine resources. Our results add up to increased evidence indicating that plastic pollution is a significant problem for the marine environment in the Black Sea. Land-based litter is a major source of marine litter and should have transboundary top priority for the basin. Better strategies in waste management in coastal areas have to be done by local governments to reduce the amount of litter reaching the Black Sea. Raising public awareness and social responsibility on problem will also help to reduce marine litter in a long-term period.

Although some of the negative effects of ML on marine environment are well established, there is still limited understanding on how ML behave in the highly stratified Black Sea environment and its effect on marine biota. Basin level monitoring surveys are needed to investigate status, sources, fates and effects of ML, in particular plastics. This will provide information for governments and other stakeholders to take urgent actions to reduce ML in the Black Sea within the scope of MSFD.

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