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RESEARCH PAPER

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Beach Litter Pollution in Sinop Sarikum Lagoon Coast of the Southern Black Sea

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Abstract

In the present study, marine litter pollution on Sarıkum Lagoon coast which is one of the significant wetlands of the Black Sea was investigated. Beach litter survey was carried out seasonally between May 2015 and February 2016 according to 'Guidance on Monitoring of Marine Litter in European Seas' published by European Marine Strategy Framework Directive Technical Subgroup on Marine Litter. The average litter density was 1.512±0.578 items/m² and 31.875±10.684 g/m². The results indicated that the most common type of litter was plastic (95.61%) followed by glass/ ceramics (1.46%), cloth/textile (1.31%) and the other material types (1.62%) and also foreign origin litter belonging to 25 countries mainly from neighbouring countries were found on the beach. Sarıkum beach was classified as extremely dirty according to Clean Coast Index. It was observed that the litter in the region consisted mostly of mixed packaging items (41.12%) and unidentifiable litter items (33.84%). Our results show that the coast of Sarıkum Lagoon exposed to a significant amount of marine litter pollution originated from land-based sources.

Introduction

In recent years, marine pollution has affected and damaged natural life (Thompson, LaBelle, Bouwman, & Neretin, 2011) and marine litter is one of the major problems of coastal countries. Marine litter defined as *"any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment"* by United Nations Environment Programme (UNEP, 2005; 2009). Man-made objects entered the marine environment for reasons such as conscious, accidental or natural reasons. Marine litter is easily transported from one place to another with local and large current systems (EPA, 2011). Marine litter originated from various land-based and sea-based sources. Land-based sources of marine litter derive from coastal or inland areas, mainly urban disposal areas, riverine transport of litter items from landfills and other inland sources, discharges of untreated municipal sewage, medical waste, and coastal tourism involving recreational visitors. Therefore, high winds, large waves and storm surges produce result in land-based items to be introduced into the marine environment. Sea-based sources of marine litter derive from shipping and fishing activities, offshore oil and gas platforms and drilling rigs; and aquaculture installations (UNEP, 2009).

Marine litter damages ecosystems, and economic sectors such as tourism and fisheries and also impacts upon other aquatic environments. Marine litter can impact species directly, such as through entanglement or smothering of species, or indirectly, such as through changes to habitat (NOAA, 2008). The primary kinds of direct damage to wildlife are entanglement and ingestion (UNEP, 2005). Other threats to wildlife and the environment from marine litter include the transport of

invasive alien species and the disturbance of habitats from mechanical beach clean-up operations and also marine litter is believed to be a source of accumulation of toxic substances in the marine environment (UNEP, 2005; Truowborst, 2011). The marine litter found in the seas show also different effects. The accumulation of litter in the waters leads to an aesthetic deterioration. (UNEP, 2009; Sheavly, 2007). It also blocks the eyes of fishing nets by blocking their selectivity, increasing the length of fishing due to cleaning operations and reducing the amount and causing economic loss (Thompson *et al.*, 2011; Williams, Simons, & Fricker, 1993).

As a result of the investigations, it has been determined that about 60-80% of the litter is made of plastic materials and in some places this ratio is up to >90% (Gregory & Ryan, 1997; Derraik, 2002). It is estimated that between 4.8 and 12.7 million tonnes of plastic litter was released into the marine environment from costal populations in 2010 (Jambeck *et al.*, 2015). A further 1.2 to 2.4 million tonnes (Mt) of plastic is estimated to reach the oceans from inland sources via rivers (Lebreton *et al.*, 2017).

Marine Strategy Framework Directive and Guidance for Marine Litter Monitoring

The European Union aims to protect the marine environment more efficaciously in Europe with Maritime Strategy Framework Directive (MSFD). Each Member State should achieve or maintain good environmental status (GES) by 2020 (2008/56/EC). GES is based on 11 qualitative descriptors as listed in Annex I of the MSFD (2010/477/EU) and marine litter has been defined as "*Properties and quantities of marine litter do not cause harm to the coastal and marine environment*" in Descriptor 10 (Galgani, Hanke, Werner, & DeVrees, 2013). There are limited studies on marine litter pollution presenting the current state of marine litter on the Turkish coast (Topçu, Tonay, Dede, Ozturk, & Ozturk, 2013; Terzi & Seyhan, 2017; Aydın, Guven, Salihoglu, & Kıdeys, 2016). Turkey as a candidate state, need to be ensure the effective law-making and decision-making processes in order to be applied effectively in future periods.

The Black Sea

The Black Sea which is located between 28° and 42°E longitudes, 41° and 46°N latitudes, has only a narrow opening to the shallow (less than 75 m deep) Bosphorus Strait restricting exchange with the Mediterranean Sea; it is almost enclosed mid-latitude marginal sea (Oğuz, Malanotte-Rizzoli, Ducklow, & Murray, 2002). The Black Sea is exposed to a substantial anthropogenic impact due to big drainage basin with its densely populated coastal strip, and daily activities of these people in some manner affect the Black Sea environment and promote to marine litter problem which is originated from mostly the problem of solid waste pollution The large rivers runoff of the Black Sea (Danube, Dnieper, Bug, Dniester, Don, Kuban, Rioni etc.) transport noticeable amount of pollutants to marine environment. Additionally, fishing and shipping activities in the Black Sea can be considered as another source of marine litter (BSC, 2007). The Black Sea has a very dynamic current system allowing cross-border transportation of waste materials (Topcu & Ozturk, 2010), which in turn makes this enclosed sea is very sensitive to marine litter (Topcu *et al.*, 2013). The marine litter pollution were investigated by various researches in the Black Sea on the beaches (Topcu *et al.*, 2013; Terzi & Seyhan 2017; Simenova, Chuturkova, &Yaneva, 2017; Aytan, Esensoy-Şahin, & Karacan, 2019), the seafloor (Topcu & Ozturk, 2010; Anton, Radu, Ţiganov, Cristea, & Nenciu, 2012; Moncheva *et al.*, 2016; Öztekin & Bat, 2017a) and the sea surface (Birkun & Krivokhizhin, 2006; Suaria, Melinte-Dobrinescu, Ion & Aliani, 2015). In studies conducted in the Black Sea coasts show that litter densities seem to quite high and marine litter have pressure coastal area. Previous studies in the Black Sea coasts reported that marine litter consist of mainly plastic items (Topcu *et al.*, 2013; Terzi & Seyhan, 2017; Simeonova, *et al.*, 2017; Aytan *et al.*, 2018).

Sinop is the northernmost point of Turkey, located right at the middle of the Turkish Black Sea coast. Sinop is a residential area where industrial pollution is absent, fishing and tourism are prominent. The most important factors causing to marine pollution in the region are; domestic waste waters, pollution by the sea vessels and fisheries activities and domestic solid waste pollution (Anonymous, 2015) which is caused by increasing population, observed highly in summer months (Bat & Gökkurt-Baki, 2014). Sarıkum Lagoon is one of the significant wetlands of the Black Sea and the lagoon and its surroundings have been declared as Natural Protected Area. The Lagoon and its surroundings are subjected to a considerable amount of litter accumulation through the prevailing winds, waves and currents (Öztekin & Bat, 2017b). The objective of this study was to evaluate the abundance and composition of marine litter in the Sinop Sarıkum Lagoon Coast.

Materials and Methods

Study Area

Sarıkum Lagoon is located on the western coast of Sinop Peninsula in Central Black Sea Region. Sarıkum is located 21 km west of the city centre, between 42° 00' 00"- 42° 02' 42" N and 34° 54 '46"- 34° 58' 22" E latitudes (Figure 1). Lake Sarıkum which gives the name to the protection area is a lagoon that has formed as a result of the shore dunes that have been driven by the winds of the sea for many years in front of an old bay and the streams flowing into this bay. The lake has a connection to the sea with a channel (25-30 m), but this connection is closed from time to time due to the movement of the

coastal sand dunes (Anonymous, 2017a). The beach is 20 km away from Sinop city centre and within the boundaries of Sarıkum village. Total length of beach is approximately 4 km and the direction of the beach is the NW. Beach material consist of fine and very fine sand and the beach slope %3. There is no open source that can cause pollution around the beach. Major use of the beach only summer months by tourists but the beach are rather affected by tourism-related pollutants due to the relatively remote area. Fishing activities are carried out during the fishing seasons in the region. The beach not subjected to any clean-up activities.

Sample Collection and Classification

The methodology was in compliance to Marine Litter Monitoring Guidance (2013) monitoring of beach litter section prepared by MSFD GES Technical Subgroup. The survey conducted as seasonally (after the middle of the May 2015, August 2015, November 2015 and February 2016). Because of the heavily littered beach, marine litter was collected 4 sections of 50 m long transects to parallel shoreline. The stations were chosen based on the intersection point of the Sarıkum Lagoon with the sea.

In beach sampling area all litter items were collected, categorized, weighted and counted. Litter abundance was calculated as items/m² and g/m². Beach cleanliness was evaluated according to Clean Coast Index (CCI) (Table 1-Alkalay, Pasternak, & Zask, 2007).

The litter items were categorized according to the material types (plastic, cloth/textile, glass/ceramic, metal, rubber, paper/cardboard, processed wood and unidentifiable). Litter items on the coast also categorized by usage types, categorization modified based on our findings from studies conducted in the Turkey coast (Aydın *et al.*, 2016; Topçu *et al.*, 2013; Terzi & Seyhan, 2017; Aytan *et al.*, 2019) (Table 2). When a label or barcode was observed the information was recorded to determine whether the items are foreign or local.

Statistical Analysis

Marine litter densities were given as Mean±SD. Seasonal differences in the distribution of litter were tested with one-way ANOVA. Because the data were not normally distributed log transformation was applied. Statistical analyses were performed SPSS 21 software and significant level of 0.05 was accepted.

Results

A total of 20132 and 451.933 kg of litter were collected during the study. The average litter density was 1.512±0.578 items/m² and 31.875±10.684 g/m² (Table 3). Sarıkum beach was classified to extremely dirty according to CCI (Alkalay *et al.*, 2007).

Seasonal marine litter densities are given in Figure 2. There were no statistically significant differences

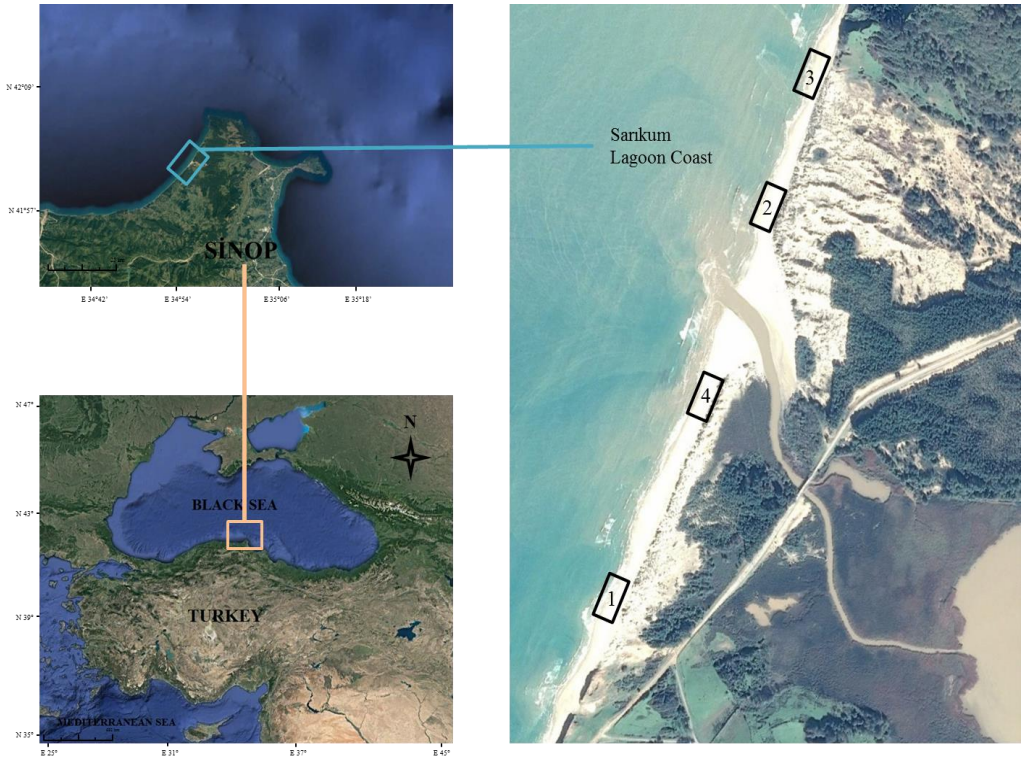

Figure 1. Study Area-Sinop Sarıkum Lagoon.

Table 1. Classification of beaches according to Clean Coast Index (Alkalay *et al*., 2007)

Numeric Index	Coast Index	Explanation
0–0.1 parts/m^2	Very clean	no litter is seen
0.1–0.25 parts/m^2	Clean	no litter is seen over a large area
0.25–0.5 parts/m^2	Moderate	a few pieces of litter can be detected
0.5–1 parts/m^2	Dirty	a lot of litter on the shore
More than 1 part/m^2	Extremely dirty	most of the shore is covered with litter

Table 2. Usage types of litter items on the coast and their material types

		Pl	Gl/ Ce	Cl/ Tex	Pap/ Cd	PW	Me	Rub	Un
Mixed packaging litter	food packaging and containers, beverage bottles and lids, general packaging materials	✓	✓		✓		✓		
Recreational litter	tourism related items (sun cream containers etc.) balloons, toys etc.	✓						✓	
Fisheries related litter	nets, ropes, buoys, sinker etc.	✓					✓		
Domestic litter	domestic utensils-household use materials (furniture parts, hangers, bulbs etc.) and personal use products (clothes, shoes and slippers, hair-combs and hairpins and sanitary items etc.)	✓	✓	✓		✓	✓	✓	
Construction related litter	pipe parts, dust masks, paint-brushes and –rollers etc.	✓		✓		✓	✓		
Medical related litter	medical items such as serum bottles, injectors and needles, medicine bottles and capsules etc.	✓	✓		✓				
Unclassified litter	materials cannot be estimated resources (broken materials especially plastic pieces)	✓	✓	✓	✓	✓	✓	✓	✓
Others	smoking (cigarette butts, lighters, cigarette packs), hunting (shot shells), industrial (machine oil containers and lids), agricultural (pesticide containers), mining activities (explosive activators) related litter items etc.	✓			✓				

*Pl: plastic, Gl/Ce: glass/ceramic, Cl/Tex: cloth/textile, Pap/Cd: paper/cardboard, PW: processed wood, Me: metal, Rub: rubber, and Un: unidentifiable

between seasons (P>0.05). The most polluted season was found as spring and followed by winter, summer and autumn. Station-based evaluations showed that stations 2 and 4 have a higher litter accumulation than stations 1 and 3 (Figure 2). The litter on the beach showed a patchy distribution and generally distributed on the back of the shore.

The most common type of litter was plastic (95.61%) for all seasons and followed by glass/ ceramics (1.46%), cloth/textile (1.31%), the other material types (1.62%). Foreign origin litter comprised 2.29% of total litter found in the beach during the study. It belonged to 25 different countries in total and 57.45% of them originated from neighbouring countries (Romania, Bulgaria, Russia, Georgia and Ukraine) of the Black Sea.

Observed litter items were classified according to usage types and in the result of these classifications mixed packaging litter (41.12%) and unclassified litter (33.84%) items were found the highest percentage in all seasons (Figure 3) and followed by domestic litter (12.47%), construction litter (4.98%), medical litter (2.64%), recreational litter (1.66%), fisheries items (0.79%) and the other groups (because of very low proportion of industrial, smoking, hunting and agricultural related litter items evaluated in other group).

Discussion

The result of our study on the coast of Sarıkum, the average marine litter amount and weight on the beach was similar to a recent study from SE Black Sea (Aytan *et al.*, 2019) and higher than compare to studies done in the SW (Topçu *et al.*, 2013), SE (Terzi & Seyhan 2017) and the NW Black Sea (Simenova *et al.*, 2017) (Table 4). Sarıkum beach cleanliness was also assessed with the CCI (Alkalay *et al.*, 2007) and it was classified to extremely dirty as it was found in SE Black Sea (Aytan *et al.*, 2019). However, same index was used in the Sinop coasts (city centre and Gerze) in the previous study and the beach was found very clean (Terzi & Seyhan, 2017). The marine litter amount of Sarıkum beach was found to be higher than the Sinop (city centre and Gerze) beaches

Table 3. Seasonal marine litter densities and beach cleanliness assessment according to CCI index

Season	items/m²	g/m²	Seasonal mean swept area - m²	CCI index
Spring	2.352±1,875	41.357±15.827	724.25	
Summer	1.294±0,458	27.244±8.307	881.2	
Autumn	1.033±0,258	19.102±3.518	1512	*Extremely dirty*
Winter	1.370±0,606	39.913±22.450	777.75	
Mean (±SD)	1.512±0.578	31.875±10.684	973.8±364.66	

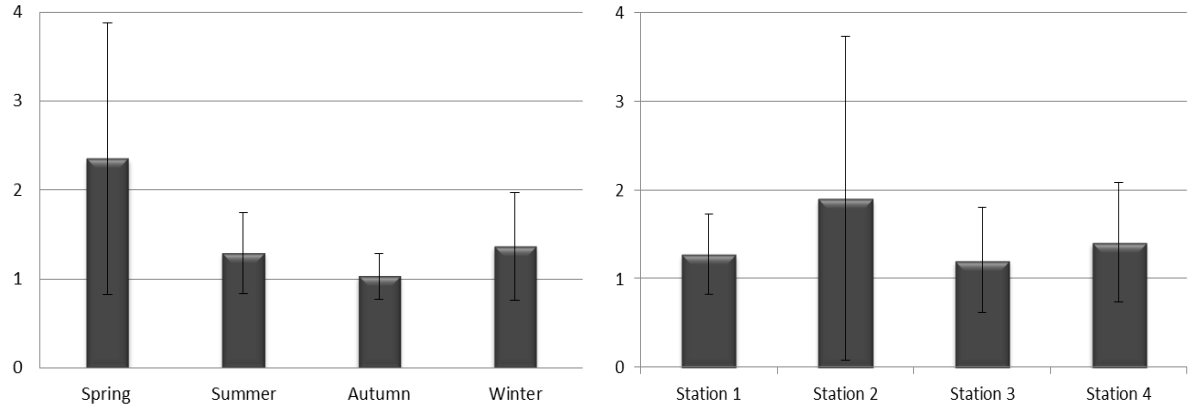

Figure 2. Distribution of marine litter densities in seasons and stations (items/m²).

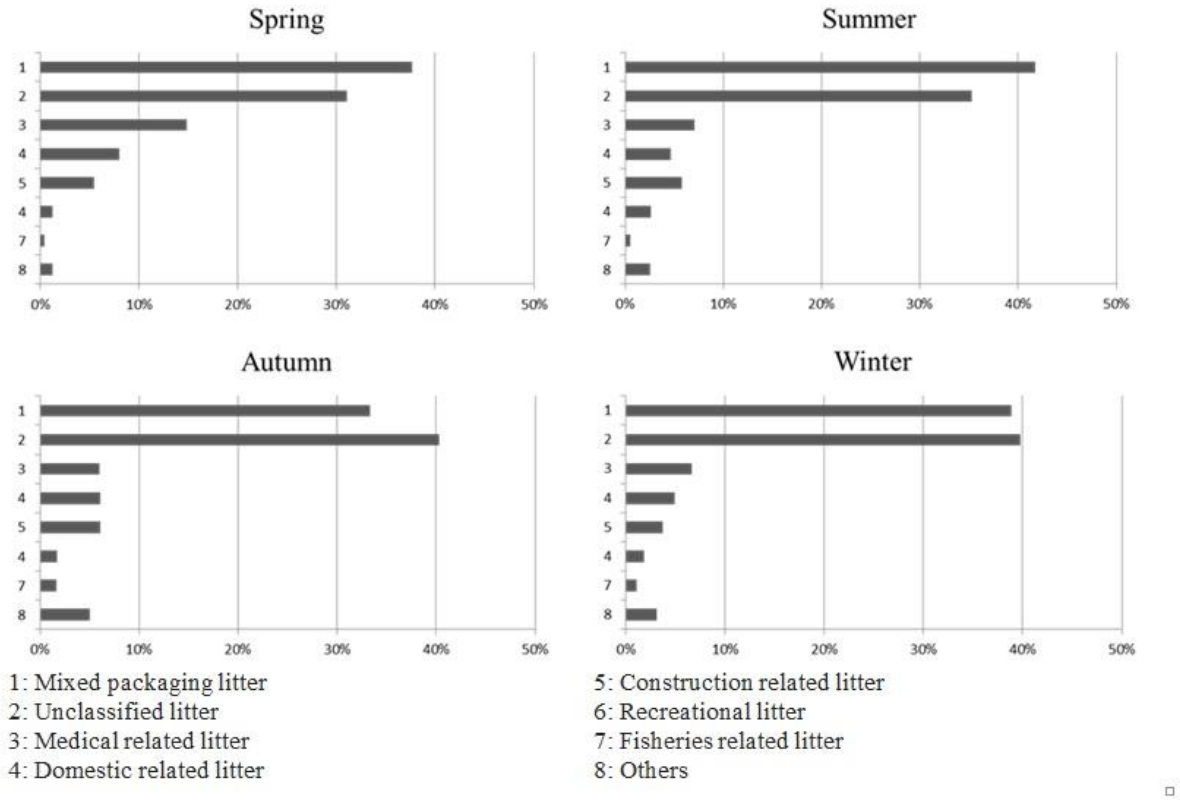

Figure 3. Classification of marine litter according to usage areas.

(Terzi & Seyhan, 2017). Differences in the results may have caused methodological differences in the surveys. Therefore this situation may have originated from the position of the Sarıkum shore. Sarıkum is open against the prevailing winds and currents of the Black Sea and forms a very convenient line in terms of storage of marine litter. The upper layer waters of the Black Sea are qualified by a preponderant cyclonic and lustily time-dependent catchment widespread cycle (Oğuz, 1995). The Main Black Sea Current, located over the continental slope, and two large-scale cyclonic gyres in the eastern and western parts of the sea; quasi-stationary anticyclonic eddies in the coastal zone, such as Batumi, Sevastopol, Caucasian, Sakarya, Sinop, etc. (Ivanov & Belokopytov, 2013). Sinop eddy may form repeatedly once or twice a year for about a season in region and the presence of this eddy mostly depends up on propagation characteristics of the meanders superimposed on the Rim Current system (Korotaev, Oğuz, Nikiforov, & Koblinsky, 2003). The dominant currents and winds have an important role for interpreting the distribution of marine litter in the region (Figure 4). The region attracts attention as one of the important litter accumulation area (Öztekin & Bat, 2017b).

When the marine litter is classified according to the material types, the plastic was found the highest percentage as in other studies in the Black Sea (Table 4). Plastic materials represent the highest percentages in marine litter in all over the world (Gregory & Ryan, 1997; Derraik, 2002). Plastics production increase from 1.5 million tonnes in 1950 to 322 million tonnes in 2015 (Plastics Europe 2016). Excessive amount of plastic materials go into the marine environment. The disappearance of plastics in nature lasts for many years, and they will be fragmented to smaller pieces. A preliminary field study was conducted in the same area before this study and evaluations were made from only plastic items in terms of different size groups (micro - <5mm, meso -0.5-2.5cm and macro ->2.5cm). The

Table 4. Beach litter densities in Black Sea coasts

Region	Density (items/m²)	Density (g/m²)	Plastic ratio (%)	References
Southern Black Sea Turkey Sinop-Sarıkum coast	1.51±0.58	31.90±10.70	95.61	This study
South-Western Black Sea Turkey İstanbul coast	0.88±0.95	-	91	Topçu *et al*., 2013
South-Eastern Black Sea Turkey Sinop, Samsun, Rize, Trabzon coast	0.16±0.02 (0.03-0.58)	3.35±1.63 (0.44- 14.74)	≥61.65	Terzi and Seyhan, 2017
Western Black Sea Bulgarian coast	0.0587±0.005 0.1343±0.008	-	84.3	Simeonova *et al*., 2017
South-Eastern Black Sea Turkey Rize-Sarayköy coast	2.10±1.38	21.11±11.35	92	Aytan *et al*., 2019

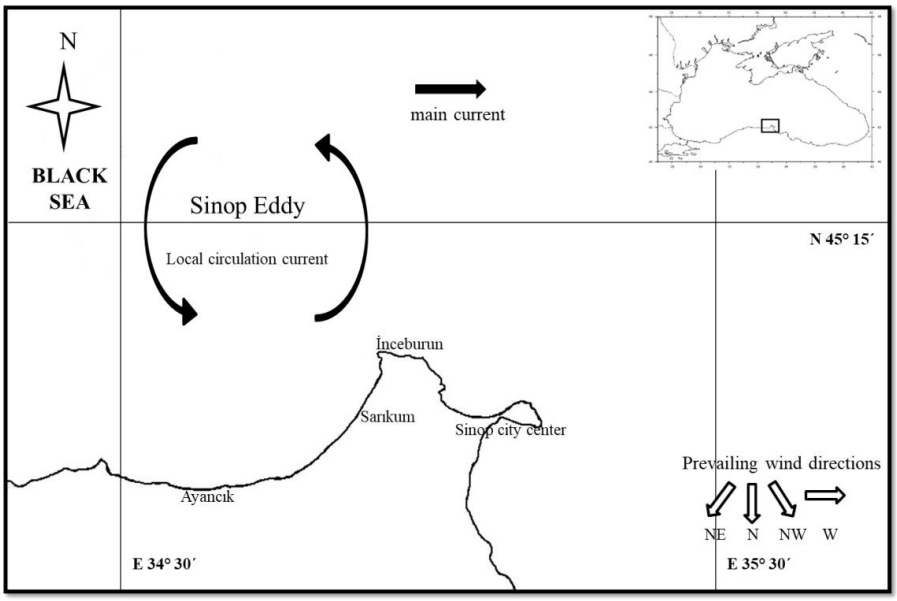

Figure 4. Current and wind directions of sampling area (current directions adapted from Korotaev et al., 2003).

results of the study show that the density of fragmented plastic particles in the region was quite high in all size groups (Vişne & Bat 2016). During the study there was considerable amount of unclassified litter items (33.8%) on the coast as in other studies in the Black Sea (Topçu *et al.*, 2013; Terzi & Seyhan, 2017; Aytan *et al.*, 2019). In the Sarıkum beach this group mainly consisted of plastic pieces (>2.5 cm) that are formed as a result of the breakdown of large plastics (~99% of unclassified litter items). Various factors (mechanical, biological, photic and thermal abrasion) causes the fragmentation of plastics (Andrady, 2011; Cole, Lindeque, Halsband, & Galloway, 2011; CIESM, 2014) and it is defined as microplastics when it is less than 5 mm (Arthur, Baker, & Bamford, 2009). Microplastic pollution was reported from beaches to seafloor, seawater, freshwater and even marine organisms all over the world (Retama *et al.*, 2016; Isobe, Uchiyama-Matsumoto, Uchida & Tokai, 2017; Tsang *et al.*, 2017; Wang, Ndungu, Li, & Wang, 2017; Bråte, Eidsvoll, Steindal & Thomas, 2016) and recently from Black Sea (Aytan *et al.*, 2016; Öztekin & Bat, 2017b). These plastic particles can be easily transported to the marine environment by the winds and the waves and they pose a serious threat to the Black Sea ecosystem. It is possible that the living organisms of the Black Sea may suffer with negative effects of plastics such as consumption, entanglement and smothering.

Packaging materials were the most common litter items on the coast all seasons (mixed packaging items-41.12%) as in other studies in the Black Sea (Terzi & Seyhan 2017; Aytan *et al.*, 2019). This category was generally consist of beverage related items (>50% of mixed packaging litter items groups), food packaging related items and general packaging items. The general material types of these products were plastic (~97% of mixed packaging litter items) and composed of mainly single used materials. Terzi and Seyhan (2017) reported that the contribution of beverage and general packaging materials in marine litter was found to >50% in the SE Black Sea. In the SE (Rize) Black Sea coast beverage, food and general packaging material proportion was reported as 21.6%, 20.5% and 16% respectively (Esensoy-Şahin, Karacan, & Aytan, 2018).

Foreign litter belonging to 25 different countries were found during the study. Foreign litter that are encountered substantially belonged to the Black Sea neighbouring countries (%57). It may have been transported to the Sarıkum coast through the currents. Topçu *et al.* (2013) reported that 23% of the foreign litter in SW coast of Black Sea might came from neighbouring countries and the rest part of foreign litter might came from international shipping traffic in the Black Sea. The SW Black Sea coast has heavy ship traffic because of Bosphorus strait but the shipping traffic is not very intense in the Sarıkum coast. However there was foreign litter originated from many other countries on the Sarıkum coast. This situation may have been the transportation of litter items.

Sarıkum beach and its surroundings are used for tourism purposes very limited due to the relatively remote area so tourism-related litter (categorized in recreational litter) are encountered in very small quantities. Tourism-related recreational litter showed an increase in the summer months (Figure 3) and especially in the 1st station which is used by tourists in the summer months due to its easy accessibility. The other recreational litter in the other sampling points that may have carried by the currents and winds.

Smoking, hunting, industrial and agricultural related litter items were evaluated in other group due to very low proportion. Smoking related items (0.66%) was found the highest percentage in spring. Simeonova *et al.* (2017) reported that the cigarette butts and filters were the highest in the artificial polymer material categories quantitative distribution in the Bulgarian coast and the significant amounts of in the summer period were related to the recreational activities. Land hunting related items (0.25%), the highest was autumn and winter period and agricultural litter items (0.01%) were only found in winter season. Hunting is prohibited in the region and its surroundings due to being natural protected area and there is no agricultural land in the nearby of the region so this situation can be explained with the transportation of litter items.

Globally, 80% of marine litter is originated from land based sources and remaining 20% is originated from sea-based sources (Trouwborst, 2011). The Sarıkum is one of the important fishing points in the region. In the autumn and winter period fishery activities have been intensively carried out, there has been an increase in fishery related litter found on the coast (0.79%). Similar results have also been observed in the study of Terzi and Seyhan (2017), especially during the fishing season (15 September-1 May), the equipment used by fishermen is found in the coastal areas. Fisheries related items reported to comprise only $\leq$1% of the litter in the SW (Topçu *et al.*,2013) and SE Black Sea coast (Aytan *et al.*, 2019)

Conclusion

In conclusion study results show that the coast of Sarıkum Lagoon exposed to an important amount of marine litter pollution mainly originated from land-based sources. Foreign litter proportion from neighbouring countries had the vast majority on the beach in total foreign litter. Major rivers, currents, winds and waves of the Black Sea could affect the transportation of marine litter. Marine litter problem requires cross-border cooperation for the Black Sea countries.

Litter items on beach are consist of mainly plastics like many other studies in Black Sea. There has been an increase in the amount of plastic waste entering the marine environment due to the increased use of plastics (Ryan & Moloney, 1993; Ryan, Moore, Franeker & Moloney, 2009). The enduringness and ascending usage

of plastics make a major waste management problem (Thompson *et al.*, 2009). It is estimated that over 2 billion people globally still do not have access to adequate waste collection services and over 3 billion people globally still do not have access to appropriate disposal facilities (Anonymous, 2017b). All countries in coastal areas are facing the marine litter problem and unfortunately this has become a global problem. In order to find a solution to this problem in the world and primarily in our country, a lot of monitoring and protection work has been done and will continue to be done. The problem of marine litter can be dealt with efficaciously effective recovery systems for litter from domestic, fishing, maritime and touristic activities.

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