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Composition, sources, abundance and seasonality of Marine Litter in the Çakalburnu lagoon coast of Aegean Sea

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Abstract
The Aegean Sea is one of the most contaminated by marine litter (ML) in the World. In this study, the Turkish Aegean Region was evaluated in light of the sources, abundance and composition of ML along Çakalburnu Lagoon coast. Macroscopic ML with > 3 cm was collected and separated into composition and sources categories. ML abundance was calculated by its density in items/m^2 (Mean ± SD). Beach cleanliness was evaluated according to Clean-Coast Index (CCI). Seasonality was found as factor for ML composition, sources and abundance at Çakalburnu coast. Plastic was the most abundant material, followed by unidentifiable items. The major sources of ML were mixed packaging, domestic and fisheries activities. The mean ML density was 0.64 ± 0.09 items/m^2. Çakalburnu coast was classified as *dirty* during all seasons. Therefore, ML contamination on Çakalburnu coast represent a potential threat to coastal and marine environments. Thus, the present study can serve as a base for the elaboration of mitigating actions urgently needed at Çakalburnu Lagoon.

Keywords Marine Litter Contamination · Clean Coast Index · Çakalburnu lagoon · Aegean Sea

Introduction

Marine litter (ML) is defined as anthropogenic sea or land-based waste discharged, deliberately or unintentionally, that reach marine environments from near or distant regions (Ertaş, 2021a). Several negative impacts to humans and biota are caused by ML, such as ingestion and entanglement (Brentano & Petry, 2020; Laist, 1997; Wang et al., 2019). Land-based ML reach the seas through estuarine drainage, sewage systems or winds (Galgani et al., 2013), while sea-based ML sources are related to trade, ferries and cruise ships, military fleets, fishing and research vessels, offshore oil and gas platforms, drilling wells and aquaculture facilities (UNEP, 2009). ML is mostly composed by plastics, cigarette butts, wood, metal, glass, rubber, clothing, and paper (Andriolo et al., 2021; Özden et al., 2021). Plastic is the predominant material among ML (Corcoran et al., 2009; Dunlop et al., 2020; Rangel-Buitrago et al., 2021), including items such as food packaging, pellets, straws, bags and a diverse selection of items recorded in the marine environment (Ebere et al., 2019; Munari et al., 2016; Ribeiro et al., 2021; Vlachogianni et al., 2018). Generally, plastics items among ML, are divided into macro (> 5 mm), micro and nanoplastics (< 5 mm) (UNEP, 2015).

Small ML (< 2.5 cm) is originated from direct and indirect sources. and composed by bottle caps or plastic fragments, while common ML (< 1 m) such as plastic bags, fishing floats, buoys, balloons and packaging items are transported from rivers or maritime sources. On the other hand, larger ML (> 1 m) includes abandoned fishing nets and traps, rope, boat hulls, and plastic films used in agriculture reaches coastal areas from catastrophic events or fishing activities (GESAMP, 2016). A marine site or region can be subject to ML contamination and pollution from various sources, as ML can be transported to a specific area (Galgani et al., 2013). Thus, accurately identifying different ML items origins is a difficult task and will always have an inherent degree of associated uncertainty (Jahnke et al., 2017). Thus, this ML origins and pathways identificationin marine environment is a crucial step to monitor and effectively address this type of contamination (Krelling & Turra, 2019). In this sense, the Marine Strategy Framework Directive (MSFD)

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requires European Member States to monitor ML by applying monitoring programs to reduce its occurrence (Galgani et al., 2013).

The Aegean Sea is connected to the Mediterranean Sea, but almost completely enclosed by land, and is one of the most affected areas by ML worldwide (UNEP/MAP, 2015). In this region, ML is found lying on the shores, in superficial and bottom waters, even in pristine environments such as coastal and marine protected areas (UNEP/MAP, 2015). Çakalburnu Lagoon, located in the southwestern portion of Turkish coast, has in its surroundings a residential area where industrial activities are absent, and fishing and shipping are prominent. The most important sources of marine contamination and pollution in this region are domestic wastewaters, fisheries activities and domestic solid waste, which are increased simultaneously with the population inflow during warm months (Yılmaz & Can, 2007). Çakalburnu Lagoon is one of the significant wetlands of the Aegean Sea, qualified as a first-degree protected area and hosting thousands of bird species. This region, due to the unique climatic characteristics and living conditions, contain an important migration route and host area of flamingo which coming from Gediz delta (Balkız et al., 2007). Especially in the winter months, birds such as coot, kingfisher, cormorant, pelican and seagull use the area as a breeding ground (Yüksel, 2013; Egercioğlu & Ercoşkun, 2015). Çakalburnu Lagoon and its surroundings are subjected to a considerable amount of ML accumulation through the prevailing anthropogenic use. Thus, this study aimed to evaluate the abundance, composition and sources of ML in the Çakalburnu Lagoon coast seasonally.

Materials and methods

Study area

Çakalburnu Lagoon is located in the south coast of Izmir Gulf in Aegean Sea coast of Turkey, from 38.406° to 38.415°N and from 27.045° to 27.060°E. The lagoon area covers 150 hectares, with width of 752 m, length of 1,054 m and depth that varies between 0.5 and 1 m, rising in the summer and decreasing in the winter seasons (Yucel-Gier et al., 2018). There is a very rich wetland ecosystem in terms of fish and bird biodiversity at Çakalburnu Lagoon (Can et al., 2007; Serdar et al., 2010). As in all wetlands, Çakalburnu faces some environmental problems. Lagoon's contamination and pollution level has increased over the last decades due to human activities and waste generation from the surrounding villages and fisheries activities. Izmir metropolitan covers 88,000 ha, with the presence of one the biggest export harbors in Turkey and 4.2 million inhabitants (Yucel-Gier et al., 2018). The fact that Izmir State Forest is closely located to the Çakalburnu Lagoon is another factor with negative consequences to its contamination and pollution levels. Especially on weekends, the forest is full of people having a picnic and lighting a barbecue, despite be prohibited). Unfortunately, most visitors discard their litters in the forest, that are carried out to the lagoon. Despite this, there is none cleanup activities at Çakalburnu Lagoon coast.

Sample collection and composition, sources and abundance classification

ML items were seasonally collected (November 2020, February 2021, April 2021 and August 2021) at five sites in the present study (Fig. 1). The samplings were performed by three persons in 100 m transects, following standardized protocols of Marine Litter Monitoring Guidance (Galgani et al., 2013). Field surveys carried out along a standard sampling unit consisting of a 100 m long coastal sector, i.e. 50 m apart from each side of an access point, extending from the landward beach limit to the shoreline (Galgani et al., 2013).

ML items were counted and recorded at the end of each sampling. ML smaller than 3 cm was not take into consideration during campaigns, due to the study scope, focused only on macroscopic items (Ertaş, 2021b). The collected ML was separated into categories according to adaptation of the method adopted by the United Nations Environment Program in collaboration with the Intergovernmental Oceanographic Commission to quantify solid waste in beach areas (UNEP / IOC, 2009). Those categories were: plastic/polystyrene, glass/ceramic, cloth/textile, paper/cardboard, processed wood, metal, rubber and unidentifiable. A total of 9 different usage types were also used to determined and categorized ML (MSFD Technical Group on Marine Litter, 2021) (Table 1). When a label or barcode was observed, the information was recorded to determine whether the items are foreign or local (MSFD Technical Group on Marine Litter, 2021).

ML abundance was calculated by its density in items/m^2 (Mean ± SD). The degree of beach cleanliness was evaluated according to Clean-Coast Index (CCI), with classes the vary between *very clean* (0-0.1 items/m^2; CCI = 0–2), *clean* (0.1–0.25 items/m^2; CCI = 2–5), *moderate* (0.25–0.5 items/m^2; CCI = 5–10), *dirty* (0.5-1.0 items/m^2; CCI = 10–20) and *extremely dirty* (> 1 items/m^2; CCI > 20) (Alkalay et al., 2007).

Statistical analysis

The ML abundance, categories and sources densities (items/m^2) were provided as Mean ± SD. Differences in ML composition, sources and abundance among seasons were analyzed by one-way ANOVA followed by Tukey multiple comparisons. The non-parametric statistics (Kruskal-Wallis test followed by the Dunn's analysis) were applied when ANOVA assumptions were not achieved. All statistical analyses were performed using Statistica® (version 13.0 (Statsoft)) with a significant level of 0.05.

Results

A total of 2.314 items of ML were collected (mean ML density is 578.5 ± 72.3 items/m^2) at Çakalburnu Lagoon. ML sizes ranged from 3 to 80 cm, distributed on eight categories of materials and nine of sources. Plastic was the most abundant material in all seasons (22.6–30.8%). The mean ML density per season vary between 457 ± 57.1 (winter) and 669 ± 83.6 (autumn) items/m², respectively. Çakalburnu Lagoon was classified as *dirty* during all seasons, according to the CCI values (Table 2).

Overall, statistically significant differences ($p < 0.05$) were seen in the ML composition, sources and abundance among seasons in various categories (Fig. 2). The ML abundance showed significant differences only between winter and spring (Fig. 2a). Considering ML composition, significant differences were found only for plastic (between spring and autumn - Fig. 2b) and cloth/textile items (between winter and other seasons, and summer and autumn) (Fig. 2d). Considering ML usage types, no statistically significant differences were found (Fig. 2j, k, l, m, n, o, p, q r) for medical and other items (between autumn and winter for both - Fig. 2o, q).

In the region, a total of 7 countries including Turkey (Izmir Gulf) contributed to the plastic litter contamination. They were Greece, Libya, Egypt, Israel, Syria and Lebanon in the decreasing order of the plastic abundance. The dominance of plastic from the first three countries was reasoned to be owing to its closeness to the island. The dominance of plastic from the Greece was reasoned to be owing to its closeness to the Aegean coast of Turkey. Foreign origin litters are thought to be predominantly dropped or thrown materials from tourism and trade ships.

Discussions

Composition of marine litter on Çakalburnu Lagoon

In several studies it was mentioned that the average of plastic among ML range between 61% and 87% (Asensio-Montesinos et al., 2020; Aydın et al., 2016; Gjyli et al., 2020; Munari et al., 2016; Nachite et al., 2019; Nelms et al., 2017), reaching up to > 90% in places such as Portugal, Ionian Sea, Italy and Australia (Pieper et al., 2019; Poeta et al., 2016; Prevenios et al., 2018; Wilson & Verlis, 2017). Thus, plastic percentages found on Çakalburnu Lagoon less than the worldwide average is probably related to lagoon discharge is more protected from wave energy compared to other regions (Addamo et al., 2018). In this sense, the ML entrance is partially prevented. Another important reason is that people stood in their homes because the restrictions imposed by the government due to the COVID-19 pandemic. In this way, picnic areas such as Izmir State Forest were used less, and less human-induced litter was thrown into the nature. In addition, plastic items showed significant difference between seasons, which may imply on different approaches to mitigate this contamination through the year.

The unidentifiable items were the second abundant among ML (14.4–19.7%). Those items are impossible to identify due to high degradation stages, which indicates a possible old disposal in the environment (Dunlop et al., 2020; Topçu et al., 2013). Ertaş (2021a, 2021b) found similar percentage on Homa Lagoon coast (18%) and higher on East Mediterranean Adana Akyatan Lagoon coast (51%). Thus, although being the second most abundant material, the percentage of unidentifiable items among ML on Çakalburnu Lagoon are similar as compared with the that of Homa Lagoon but differs from other lagoons coast such as Adana Akyatan. This is probably due to the location of the lagoons. Although Homa lagoon is far from the city center, its less directly affected by human-induced litter. Çakalburnu Lagoon is close to the city center but litter types generally include materials that people use in their routine life. Adana Akyatan Lagoon is located in a very urbanized area with intense fishing activities. However, since the lagoon is quite open to wave movements and wind, there are many different types of unidentified litter accumulation.

Cloth/textile was the third abundant material among ML on Çakalburnu Lagoon (10.1–20.3%). However, the worldwide trend of percentage of cloth/textile among ML is way below, up to 2.7% (García-Rivera et al., 2017; Mokos et al., 2019; Öztekin et al., 2020; Simeonova et al., 2017; Vlachogianni et al., 2018). Thus, the high amounts of cloth/textile, compared to other sites around the world, may require different or more direct approaches to mitigate contamination.

The paper/cardboard was the fourth abundant material among ML (9.4–14.0%). These percentages are slightly higher that the worldwide trend, that reaches up to 7.2% (Consoli et al., 2019; García-Rivera et al., 2017; Gjyli et al., 2020; Ribeiro et al., 2021; Šilc et al., 2018; Simeonova et al., 2017). The percentages of rubber items on Çakalburnu Lagoon ranged between 6.3% and 10.7% of all ML. Those percentages are higher than the ones found on worldwide beaches, reaching up to 3% (Consoli et al., 2019; Garcés-Ordóñez et al., 2020; García-Rivera et al., 2017; Olguner et al., 2018; Öztekin et al., 2020; Rangel-Buitrago et al., 2019). On the other hand, the percentages of metals varied between 7.4% and 9.4% of all ML, which is in the same range of worldwide trend, ranging from 3 to 25.1% (Cau et al., 2018; García-Rivera et al., 2017; Rangel-Buitrago et al., 2017; Rangel-Buitrago et al., 2019; Terzi et al., 2020). The percentages of processed wood, and glass/ceramics on Çakalburnu Lagoon vary between 5.7% and 8.4%, and 4.6% and 6.3% of all ML, respectively. These percentages were slightly higher or similar to the worldwide trend, that can reach up to 5.1% (Prevenios et al., 2018; Rangel-Buitrago et al., 2019; Šilc et al., 2018; Veerasingam et al., 2016).

Izmir is one of the most important summer tourism cities on the Aegean Coast. Therefore, many people carry out sunbathing activities and actively use the coasts in warm months. As a result, materials such as cloth/textile, paper/cardboard and metals are transported either directly by water fluxes or wind influences. Considering that Çakalburnu lagoon shores and the nearby Izmir State Forest receive ML from different sources, actions to mitigate the abundance of a specific categories of ML, may need different approaches, when compared to the ones been carried out worldwide. Therefore, these actions need to consider the results found in the present study to better assess the ML monitoring on Çakalburnu Lagoon. For instance, regional environment education programs should be organized to increase awareness of ML pollution in this area. Government authorities can work in partnership with local non-governmental organizations to develop and implement integrated policies and regulations in this region.

Considering the seasonality, only two of the eight ML composition categories assessed in the present study showed statistically significant differences (plastic – spring and autumn; cloth/textile – between winter and the other seasons, and summer and autumn). Few studies disclosed the seasonal significant differences on ML composition. Asensio-Montesinos et al. (2019a) found that ML composition varied considerably by season at Alicante, Spain. On the other hand, Terzi and Seyhan (2017), Williams et al. (2017) and Ribeiro et al. (2021) found that most of those categories also had no significant differences between seasons at Black Sea coast, Northern Ireland and Southeast Brazil coastline, respectively. The ML inputs on coastal environments are often related to tourist activities (Campana et al., 2018), being amplified during summer and vacation periods (Asensio-Montesinos et al., 2019a). Moreover, alternative sources including rivers, wind, local hydrodynamics and residents may also contribute with ML inputs to these zones (Ribeiro et al., 2021). Thus, ML composition tends to present significant seasonal differences.

Sources of marine litter on Çakalburnu Lagoon

ML usage types at Çakalburnu Lagoon were compared to values previously reported to Homa Lagoon coast (Ertaş, 2021a) in Aegean Sea and Adana Akyatan Lagoon coast (Ertaş, 2021b) in East Mediterranean (Table 3). The sources showed similar categories and percentage ranges in Homa, Akyatan and Çakalburnu. The major source category of ML in all sites was mixed packaging litter [Homa, Adana Akyatan and Çakalburnu (20.0-27.4%)]. The domestic source had almost similar percentage in all sites (12.0–23.0%), as seen for construction and medical sources (3.0-8.2% and 2.6-5.0%, respectively). Fishing extension nets are used intensively İn Izmir Gulf (Ayaz et al., 2004). Illegally operating trawlers and fishing gears are one of the main fishing gears that damage the extension nets and cause these nets to disappear (Ayaz et al., 2004). These ghost nets lost or thrown under water constitute the main source of fisheries related litters over time (FAO/UNEP, 2009). The fisheries activities were far more intense at Çakalburnu, Homa and Adana Akyatan (10.0–23.0%). Considering unclassified sources, Adana Akyatan had way above percentage (20.0%) than that of Çakalburnu and Homa (11.0–17.0%). The other sources, such as smoking, hunting, industrial and agricultural items, were similar at Çakalburnu, Homa and Adana Akyatan (9.0–15.0%). Furthermore, the recreational source values were also similar at Çakalburnu, Homa and Adana Akyatan (4.0–8.0%).

Mixed packaging litter usually contains food packages and containers, beverage bottles and lids, and general packaging materials. These items are structurally derived from Polyethylene (PE) and Polypropylene (PP) (Rodgers et al., 2014). Mixed packaging litter are frequent in daily use and drifted by people coming to the beach for recreational activities such as picnic and sunbathing or by throwing these materials from ships (Paler et al., 2019).

At Çakalburnu Lagoon, domestic litter was second most dominant litter source. ML usually reach the Aegean Sea through domestic and industrial wastes and wastewater discharges, rainwater, agricultural and port activities, sea traffic and rivers merged with the sea (Doğan-Sağlamtimur & Subaşı, 2018). Pollution load covers a population of 20 million and reaches the Aegean Sea coast from the Dardanelles via wastewater discharge (Doğan-Sağlamtimur & Subaşı, 2018). Due to the insufficient sewerage system at Izmir city, the waste is dumped into the gulf. For this reason, a visible litter pollution, bad odor and discoloration increase significantly, especially during heavy rains.

Medical related items composed by tampons, disposable diapers and syringes reach water systems most often through sewerage systems (Ocean Conservancy, 2009). Munari et

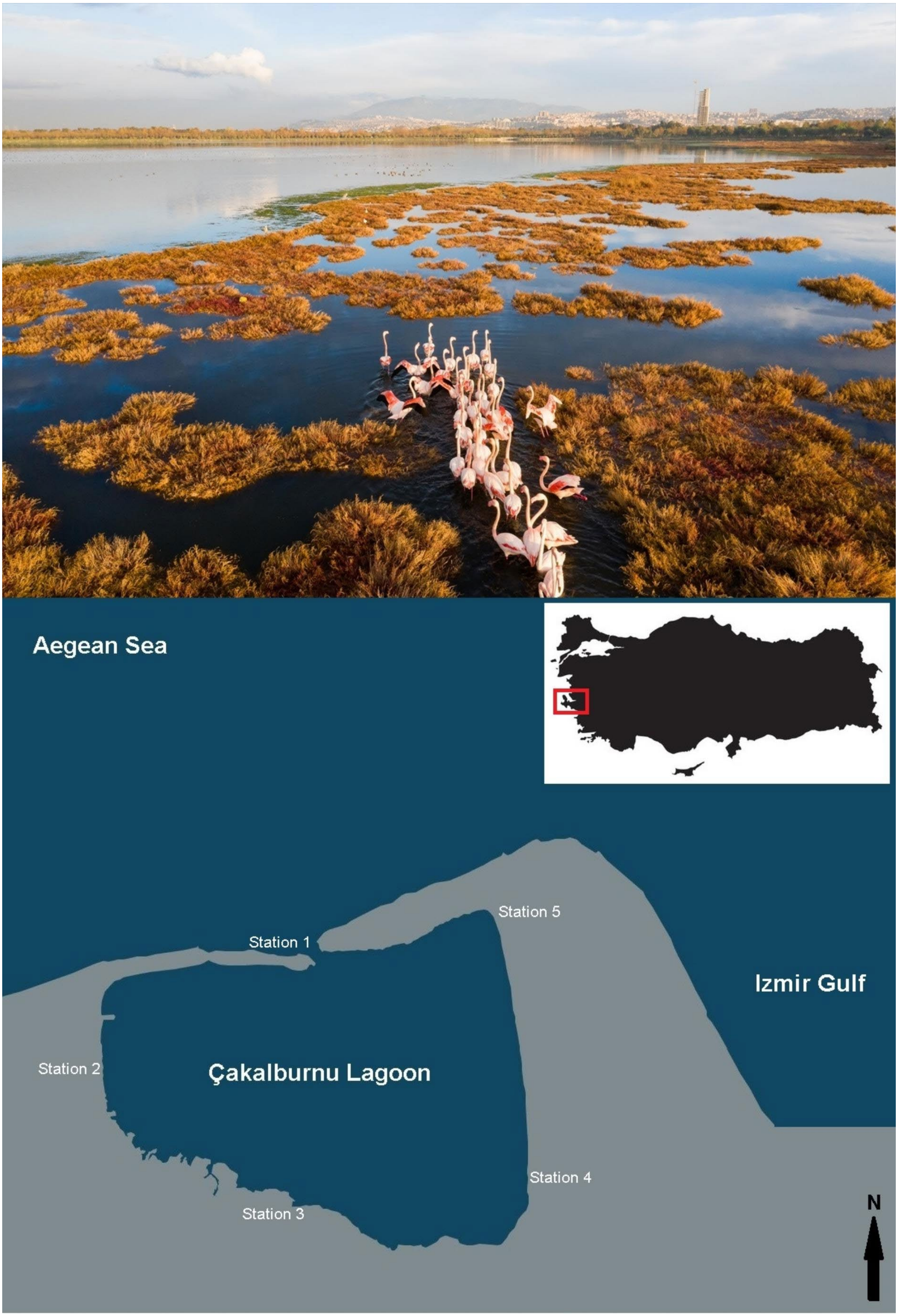

Fig. 1 Study Area and sampled sites in Izmir Çakalburnu Lagoon

Table 1 Usage types of litter items on the coast

Source	Items
Mixed packaging	food packaging and containers, beverage bottles and lids, general packaging materials
Recreational	tourism related items (sun cream containers etc.) balloons, toys etc.
Fisheries	nets, ropes, buoys, sinker, etc.
Domestic	domestic utensils-household use materials (furniture parts, hangers, bulbs etc.) and personal use products (clothes, shoes and slippers, haircombs and hairpins and sanitary items etc.)
Construction	pipe parts, dust masks, paint-brushes and –rollers etc.
Medical	medical items such as personal protective equipment, serum bottles, injectors and needles, medicine bottles and capsules etc.
Unclassified	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.
Foreign origin	all foreign labeled litters from neighboring countries (carried to the beaches by waves and wind movements from trade and tourism ships or etc.)

al., (2016) reported 1% of medical and personal hygiene items among ML collected between 2002 and 2006 in Mediterranean region. In Aegean coast, the medical related items amount were almost similar in Homa and Çakalburnu Lagoon coast (3.0–4.0%; 2.6–4.4%, respectively). Medical face masks made of plastic materials have played important roles in protecting people throughout the COVID-19 pandemic (Ammendolia et al., 2021). However, such masks have been thrown into nature randomly, accumulating on the coasts. The most common medical related items in Çakalburnu Lagoon was also the medical face masks.

ML origin identification is a crucial step in monitoring and effectively addressing this type of contamination (Ertaş, 2021a, 2021b; Krelling & Turra, 2019; Öztekin et al., 2020). Thus, additional ML studies should use this type of detailed assessment of its seasonal sources. Overall, usage types of ML categories in the present study showed significant differences ($p < 0.05$) between the four sampled seasons. Thus, seasonality is an impacting factor for ML usage types at Çakalburnu Lagoon.

The mean ML density, CCI values and classification obtained from the present study (0.64 ± 0.09items/m^2, 12.71 ± 1.78 and *dirty*, respectively) were compared to the other 26 worldwide studies (Table 4). These results are extremely worrying considering other studies in Mediterranean and Aegean coast. In this study, the values obtained from Çakalburnu Lagoon are higher than the values obtained from Cerim et al. (2014) and Gönülal et al. (2016) on the Aegean coasts. However, when we compare it with another study on the Aegean coast (Ertaş, 2021a), both coasts are considered as *dirty*.

Overall, this study revealed that the Çakalburnu Lagoon coast has higher CCI values than the other studies conducted in Aegean coast. Two sampling seasons of this study (April 2020 and August 2020) was conducted during the

Table 2 Compositions and sources of beach litter

	Category	Summer		Autumn		Winter		Spring	
		%	**Items/m²**	**%**	**Items/m²**	**%**	**Items/m²**	**%**	**Items/m²**
Materials	**Plastic/polystyrene**	29.8	0.18	30.8	0.22	24.3	0.17	22.6	0.12
	Glass/ceramic	4.7	0.03	6.3	0.05	4.6	0.03	5.2	0.03
	Cloth/textile	10.1	0.06	13.3	0.10	20.3	0.14	18.3	0.10
	Paper/cardboard	10.5	0.06	9.4	0.07	14.0	0.10	11.9	0.06
	Processedwood	6.5	0.04	8.4	0.06	5.7	0.04	7.6	0.04
	Metal	9.4	0.06	8.4	0.06	7.4	0.05	9.2	0.05
	Rubber	9.3	0.06	6.3	0.05	9.2	0.06	10.7	0.06
	Unidentifiable	19.7	0.12	17.2	0.12	14.4	0.10	14.5	0.08
Sources	**Mixed packaging**	20.0	0.12	22.0	0.16	23.6	0.16	24.8	0.13
	Recreational	7.9	0.05	7.3	0.05	6.6	0.05	5.6	0.03
	Fisheries	11.3	0.07	17.0	0.12	16.2	0.11	16.1	0.08
	Domestic	23.0	0.14	17.5	0.13	17.7	0.12	19.5	0.10
	Construction	8.2	0.05	7.2	0.05	7.0	0.05	5.8	0.03
	Medical	4.4	0.03	3.7	0.03	2.6	0.02	4.3	0.02
	Unclassified	14.3	0.09	13.9	0.10	13.6	0.09	12.5	0.07
	Others	10.1	0.06	9.7	0.07	9.0	0.06	9.4	0.05
	Foreign	0.8	0.01	1.6	0.01	3.7	0.03	2.0	0.01
Mean ML density (Items/m²)		0.605		0.722		0.691		0.524	
CCI Values		12.11		14.43		13.83		10.48	
CCI Classification		**Dirty**		**Dirty**		**Dirty**		**Dirty**	

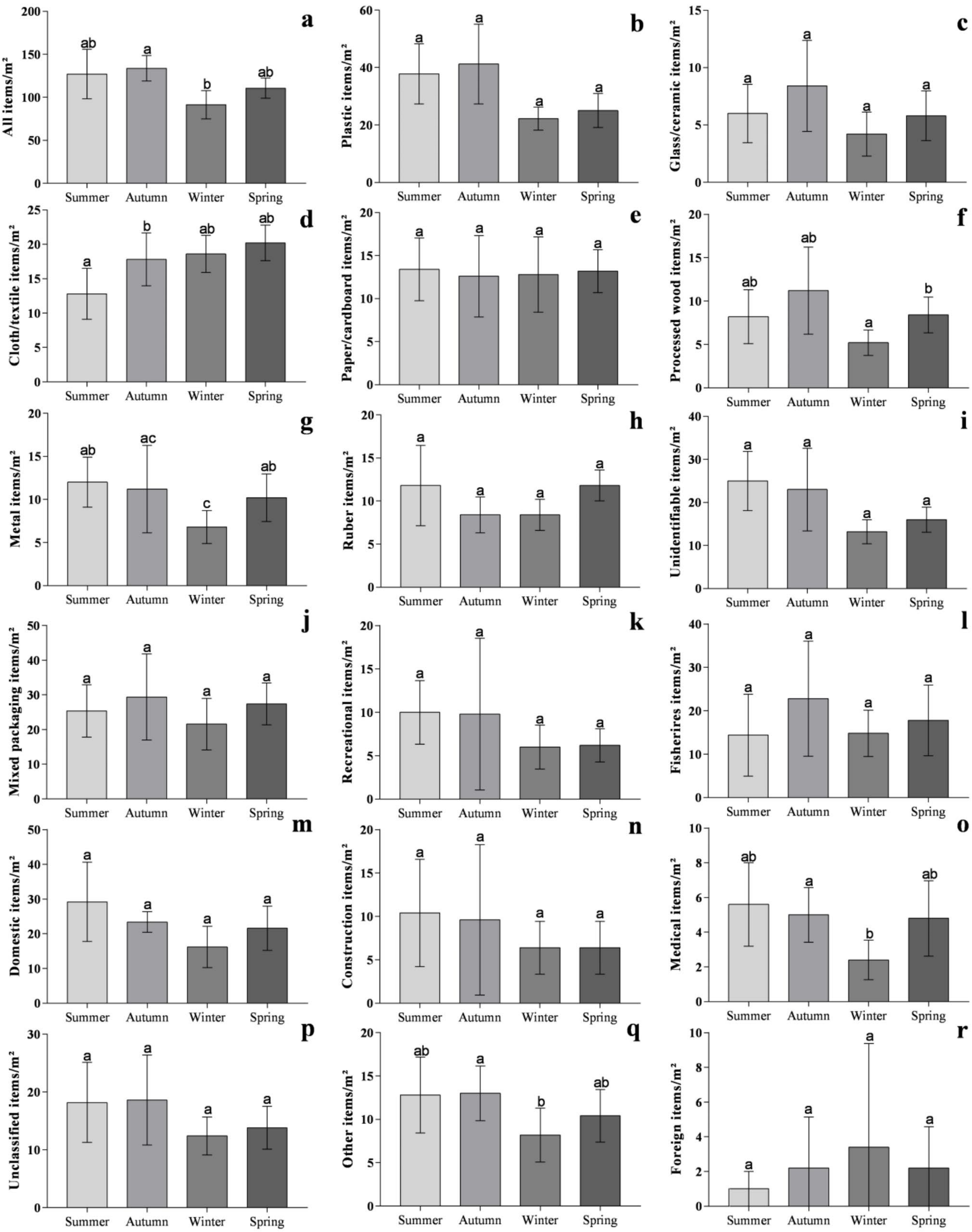

Fig. 2 Seasonal distribution (items/m^2 - mean ± sd) of different marine litter materials and sources categories on Çakalburnu Lagoon coast

Table 3 Usage types of marine litter in the present and other studies

Sources	Homa Lagoon	Adana Akyatan Lagoon	Çakalburnu Lagoon
	Ertaş (2021a)	Ertaş (2021b)	Present study
Mixed packaging	23.0–25.0%	21.0–26.0%	20.0–27.4%
Domestic	12.0–18.0%	19.0–23.0%	17.5–23.0%
Fisheries	15.0–23.0%	10.0–14.0%	11.3–17.0%
Unclassified	13.0–17.0%	11.0–20.0%	12.5–14.3%
Others	10.0–12.0%	10.0–15.0%	9.0–10.1%
Construction	4.0–6.0%	3.0–8.0%	5.8–8.2%
Recreational	4.0–5.0%	4.0–8.0%	5.6–7.9%
Medical	3.0–4.0%	3.0–5.0%	2.6–4.4%
Foreign	1.0–3.0%	--------	0.8–3.7%

COVID-19 pandemic, when the entire city has been partially restricted from tourists and non- residents. The contributions to CCI value could be mainly ascribed to activities within Izmir that occurred before and during the pandemic.

Some studies assessing temporal ML distribution showed higher densities during other seasons (Mokos et al., 2020; Vincent & Hoellein, 2017) or no quantitative differences among seasons (Ríos et al., 2018; Terzi & Seyhan, 2017). The Çakalburnu Lagoon has more ML sources contribution and population inflow during summer and autumn months. Those were the two seasons that ML abundance was higher. However, significant differences on ML abundance were only seen between autumn and winter reinforcing seasonality as an impacting factor for ML abundance at Çakalburnu Lagoon. Considering the current system of the Aegean Sea, it has been determined that the source of foreign origin litters in the lagoon comes from the coasts of the neighboring country. In addition, while the effects of marine litter on living things are reported in various studies in the world's seas, the inadequacy of studies on this subject in the region should be taken into account, and research should be conducted to examine the effects of marine litter on living things. The active use of the lagoon coast and nearby recreation areas, the intensity of sea transportation in the gulf and the dense urban population cause a significant litter problem in the region. Thus, the present study can serve as basis for future actions regarding ML mitigation at Çakalburnu Lagoon.

Table 4 Comparisons of the values of mean ML density and CCI obtained from Çakalburnu Lagoon and that of the other worldwide studies

Location	Sampling Period	Average Litter (items/m^2)	CCI	CCI classification	References
Africa					
Mediterranean Coast	Aut./15- Spr./16	0.05	1.1	Very Clean	Nachite et al. (2018)
Mediterranean Coast	Aut./15	0.07	1.5	Very Clean	Maziane et al. (2018)
Southeastern Nigeria	Spr.- Sum./19	3.49	70	Extremely dirty	Ebere et al. (2019)
America					
Brazilian South Atlantic	Aut./17	2.78	55.6	Extremely dirty	Marin et al. (2019)
Colombian Caribbean	Unclear	5.11	102.2	Extremely dirty	Rangel-Buitrago et al. (2021)
Brazilian South Atlantic	Aut./2019-Sum./20	0.94	18.8	Dirty	Ribeiro et al. (2021)
Asia					
Israel Mediterranean Coast	Jun./12- Mar./15	0.12	2.4	Clean	Pasternack et al. (2017)
South Philippines	Aut./16	0.65	13.1	Dirty	Paler et al. (2019)
South Phillipenean Sea	Spr./18	4.25	85.0	Extremely dirty	Esquinas et al. (2020)
Qatar West Coast	Aut./19	1.98	39.6	Extremely dirty	Veerasingam et al. (2020)
Oceania					
Western Australia	Sum./12	0.33	6.6	Moderate	Smith et al. (2014)
Australia and Tasmania	Oct./11- May/13	0.15	3	Clean	Hardesty et al. (2017)
Mediterranean and Aegean Coast					
Eastern Aegean Coasts	Dec./08- Mar./11	0.01	0.2	Very clean	Cerim et al. (2014)
Northeastern Mediterranean	Apr./14	0.92	18.4	Dirty	Aydın et al. (2016)
Northern Aegean Sea	Oct./13- Apr./15	0.01	0.2	Very clean	Gönülal et al. (2016)
North-western Adriatic	May - Jun./15	0.2	4	Clean	Munari et al. (2016)
Mediterranean Coasts	Jul./14- Oct./15	0.3	6.1	Moderate	Prevenios et al. (2018)
Southeastern Spain	Spr.- Sum./18	30.96	619.2	Extremely dirty	Asensio-Montesinos et al. (2019a)
Western Mediterranean Sea	Spr./18	10.10	202	Extremely dirty	Asensio-Montesinos et al. (2019b)
East Mediterranean, Turkey	May/18	12.17	243.4	Extremely dirty	Gündoğdu and Çevik(2019)
East Mediterranean, Turkey	Jun.- Aug./18	19.5	390	Extremely dirty	Gündoğdu et al. (2019)
Southwest Spain	May- Oct./18	16.12	322.4	Extremely dirty	Asensio-Montesinos et al. (2020)
Homa Lagoon, Turkey	Dec./19- Sep./20	0.58	11.62	Dirty	Ertaş (2021a)
Akyatan Lagoon, Turkey	Aug./19 &Apr./20	2.68	53.6	Extremely dirty	Ertaş (2021b)
Çakalburnu Lagoon, Turkey	**Nov./20- Aug./21**	**0.64**	**12.71**	**Dirty**	**Present study**

Conclusions

Seasonality is an impacting factor for marine litter (ML) composition, sources and abundance at Çakalburnu Lagoon coast. Plastic was the most found material, but with fewer percentages than the worldwide trend. This Lagoon also suffers from the contamination of items present in the environment for a long period, i.e. unidentifiable. The major sources of ML were mixed packaging, domestic and fisheries activities. Çakalburnu coast was *dirty* during all seasons and is one of the most ML contaminated areas in Aegean coast of Turkey. Thus, ML contamination at Çakalburnu Lagoon threatens Aegean coastal and adjacent marine environments. Therefore, the present study can serve as basis for the elaboration of specific actions to mitigate ML contamination extremely and urgently needed at Çakalburnu Lagoon. In this regards the reduction in ML contamination could benefit from: (1) Routine beach cleaning activities, preferably involving the government, non-governmental organizations and users (residents and tourists), during warm seasons, (2) adoption of a legislative framework and regular inspections aiming to educate people and curb irregular disposal, (3) In order to implement actions aimed at reducing litter pollution, it is necessary to have knowledge of the geographical origin of litters in coastal areas, to conduct regular litter surveys, to analyze the results regarding local weather conditions and geomorphology of the coasts. The different but harmonized methods available for monitoring need adaptation and harmonization, taking into account regional differences such as the type of prevailing currents in coastal or marine areas.

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Declarations

Conflict of interest The authors declare no competing interests.

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