

Article

Fresh Versus Beach Users' Deposited Litter in El Puerto De Santa Maria (Cádiz, SW Spain)

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Abstract: This study is based on a 10-day survey carried out at seven beaches in March 2023 in El Puerto de Santa María municipality (SW Spain). An amount of 5592 items were collected, with a combined weight of 26 kg. Fresh litter, which refers to litter transported to the shore by marine/coastal processes, accounted for 4634 items weighing 23 kg. The remaining 958 items, weighing 3 kg, were identified as litter deposited by beach visitors. The average total litter recorded during the sampling was 0.40 ± 0.07 items m^{-1} with a density of 1.85 ± 0.69 g m^{-1} . Litter materials were relatively consistent regardless of whether they were stranded by marine processes or discharged by beachgoers. Plastic dominates fresh and deposited litter followed by metal and glass, with minimal contributions of chemicals, organic matter, clothing, rubber, wood, and paper. They were identified 115 items' categories from the 184 listed in the EU Joint List: 107 for fresh and 75 for deposited litter. Food consumption-related items made up a significant portion of the total debris followed by personal hygiene and care-related and smoking-related litter. The obtained information is very useful to propose sound management actions that have to be especially devoted to raise beach users' responsibility. Last, in order to have a year-round view of litter characteristics and behavior, further investigations should be carried out during winter, when the number of visitors is very low and waves' energy is high, and summer, when opposite conditions are recorded.



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Keywords: Andalusia; Atlantic Ocean; beachgoers; coastal pollution; plastic; 3S tourism

1. Introduction

Beaches constitute a fundamental natural and tourist resource worldwide that annually moves millions of US dollars [1,2]. In Spain, the “Sea, Sun and Sand” (3S) tourism is a major source of income and employment [3]. However, the intensive use of beaches, particularly during summer months, leads to the accumulation of litter such as food remnants and wrappers, beverage bottles, cigarette butts, etc. [4], most of them consisting of plastics [5].

Marine litter, defined as any persistent, manufactured, or processed solid waste material discarded or abandoned in marine and coastal environments [6], is now widespread across the world's oceans and coasts [7–9]. Approximately 80% of the litter originates from land-based sources and is transported into marine environments through rivers, sewage, runoff, and wind [10,11], or left behind by beach visitors [7,12]. The remaining 20% comes from marine-based sources, such as offshore gas and oil extraction infrastructures, and fishing and shipping activities [13,14]. Once litter enters the marine environment, it is transported by currents, winds, and waves and reaches remote locations and deep

ocean floors [15]. About 70% of the marine litter settles on the ocean floor and the rest is distributed between the beach and the water column [16–18].

Litter negatively impacts the environmental quality of beaches and coastal waters, harming native flora and fauna and endangering beachgoers' health. The presence of beach litter poses significant risks to wildlife, including ingestion by mammals, reptiles, fish, and seabirds; the entanglement in abandoned fishing gear [19–22]; and the transport of alien species and adsorbed contaminants like Persistent Organic Pollutants (POPs) and heavy metals [23]. Additionally, litter poses safety hazards to beachgoers, including cuts, injuries, and biological risks associated with medical waste [24]. Litter economically impacts fishing activities [25] and tourism [26], as clean beaches are a major criterion for tourist destinations [27]. The presence of general litter and, especially, of potentially hazardous and unattractive items such as syringes, vials, etc., have negative effects on beach tourism, bringing to tourist days lost, i.e., to relevant economic losses [28]. As an example, at different municipalities in Brazil, Krelling et al. [26] evidenced that the presence of >15 litter items m^{-2} (or 30 items per linear meter) caused a reduction in local tourism incomes by 39%, i.e., losses of up to USD 8.5 million per year.

A substantial portion of beach litter (around 80%) is composed of plastics, which accumulate in marine environments due to their widespread use, great durability, and low recovery rates [29–31]. The management of solid waste on beaches has become a highly significant environmental issue worldwide, especially in tourist destinations, and Andalusia is one of the most popular Spanish destinations for national and international tourists [32,33]. Generally, the amount of litter is directly related to the number of beach users and inversely related to its geographical distance to a population center [34,35] (Gabrielides et al. 1991; Frost and Cullen 1997). The amount of litter recorded on urban beaches is strictly related to local population density as observed by Ariza et al. [36], Asensio-Montesinos et al. [37], and Williams et al. [38], who conducted studies on different coasts of Spain; Nachite et al. [39], who conducted a study on beaches in Morocco; Topcu et al. [40], who studied the Turkish Western Black Sea Coast; and Katsanevakis and Katsarou [41], who studied beaches in Greece. Lastly, changes in the number of beach visitors due to seasonality increase the amount of litter and such seasonal variability makes it difficult to establish a proper waste management plan [4,34].

On the beaches of El Puerto de Santa María municipality, in Cádiz Bay, on the Atlantic side of Andalusia (Spain), the presence of litter is a constant concern for authorities and the local population [38], as evidenced by the significant amounts of collected litter by local beach-cleaning company. In March 2023 alone, 80 kg of paper, 960 kg of glass, 940 kg of plastic packaging waste, and 18,780 kg of general waste were gathered [42]. Despite the efforts by authorities and public awareness campaigns, litter is a plague for beaches, particularly for those with high visitor numbers. The present paper focuses on the analysis of “fresh” (i.e., litter transported to the shore by marine/coastal processes) and “deposited” litter (i.e., discharged by beach users) over a 10-day long survey along seven beach sectors in the municipality of El Puerto de Santa María. Dissimilarly from most studies around the world that focus on single or seasonal surveys with limited attention to short-term dynamics [43], this research is based on an innovative daily monitoring program conducted over ten consecutive days during early spring (15–24 March 2023), complementing and making a further step onward with respect to previous research conducted in the region by Williams et al. [38] and Asensio-Montesinos et al. [44,45], which investigations were based on isolated sampling campaigns and Ciufegni et al. [46] that focused on daily variations in the abundance, typology, and accumulation rates of “fresh” beach litter. It is relevant to highlight that fresh litter often shows signs of prolonged exposure to saltwater and marine processes, such as abrasion, discoloration, and the presence of biofouling. Deposited

litter, in contrast, is composed of new, not degraded/abraded/discolored items recently discharged by beach users. This dual approach is essential to identify the specific behavior and distribution patterns of each litter category, which in turn allows us to address their origins and to adopt sound management efforts to prevent their arrival to the coastal environment. This research also investigated the origin of beach litter to have deeper insights into its dynamics by analyzing label and brand information on collected items: this allowed us to distinguish between locally sourced litter items and the ones transported from other countries. Despite this, the analysis has a few limitations, e.g., brand nationality does not always reflect the country of manufacture since items produced abroad are often widely distributed in Spain [47], and this investigation is very valuable in understanding the broader context of beach litter sources. Understanding the characteristics and sources of beach litter is crucial for developing effective prevention and management measures.

As highlighted in previous studies [48], scientific interest in marine and beach litter has increased significantly in recent decades, and publications on such topics have exponentially grown since 2010. Despite this progress, the implications of beach litter for human and ecosystem health emphasize the need for ongoing interdisciplinary investigations. This study contributes by addressing key knowledge gaps, offering new data on litter provenance, and exploring short-term dynamics of litter deposition to guide sustainable management strategies. Finally, the methodology employed in this research can be adapted and applied to other areas where baseline information on the studied parameters is available and results obtained can be extrapolated to other coastal areas under similar conditions.

2. Materials and Methods

2.1. Study Area

El Puerto de Santa María municipality belongs to the province of Cádiz, in the Andalusia region (Southwest Spain), and faces the Atlantic Ocean (Figure 1). It is a major tourist destination with around 1.2 million residents and 8 million overnight visitors recorded in 2022, 80% of whom stay within 30 km from the coastline [49]. This highlights the significance of beach tourism driven by coastal appeal and favorable weather conditions throughout most of the year [24,50].

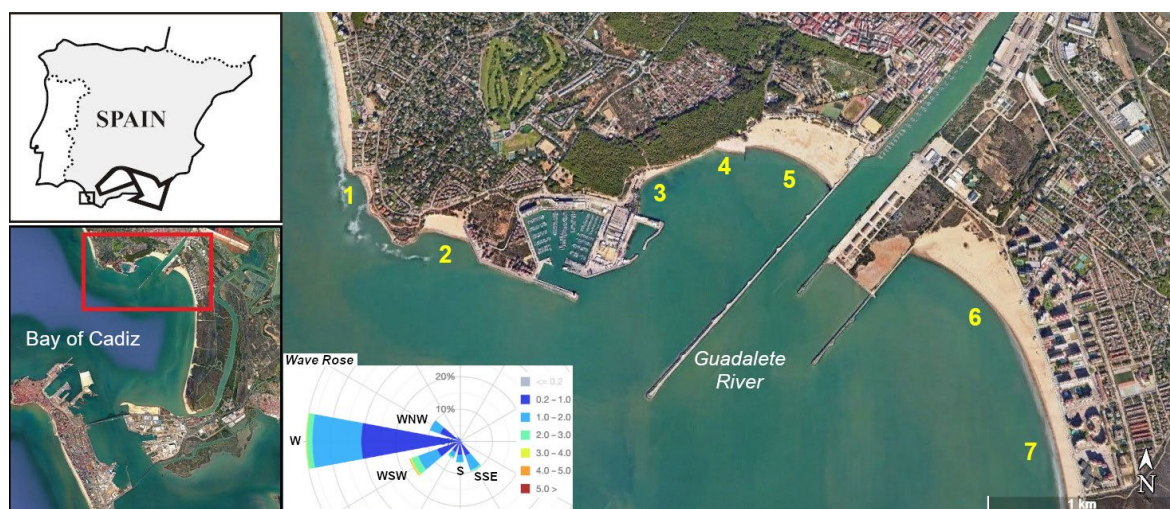


Figure 1. Location map showing the seven studied sites with wave rose for Cadiz area, observation period: 2012–2023 (source: www.puertoes.es, accessed on 15 October 2024).

The coastline of Cádiz, which features a mesotidal environment with tidal ranges between 2 and 4 m, runs in an NW–SE orientation and is influenced by both westerly and easterly winds. Atlantic low-pressure systems from the west cause significant rainfall and marine storms, and sea and swell waves are usually <1 m in height [51]. East to southeast winds, originating in the Mediterranean Sea and channeled through the Gibraltar Strait, produce smaller waves due to the limited fetch. The interaction of wavefronts with the coastline leads to a predominant southeastward littoral drift that is occasionally reversed [52]. Regarding the main rivers in the region, the Guadalquivir River, which stretches for 657 km, is the most relevant: it flows through the cities of Sevilla and Córdoba before emptying north of the Bay of Cádiz. The Guadalete River, with a length of 172 km, flows into the northern part of the Bay and empties directly into the coastal area under study. The Guadalquivir is notable for its considerable flow and significant sediment contribution to the coast, while the Guadalete River, whose mouth is armored by two jetties, contributes a much more modest amount of sediment. Both rivers provide solid waste materials to the coast, as documented by Williams et al. [38]. Lastly, it is relevant to mention the existence of two tidal creeks: the San Pedro Creek, emptying at the southern end of Valdelagrana Beach, and the Sancti Petri Creek, which empties south of the Bay of Cádiz (Figure 1).

This study covers seven coastal sectors in El Puerto de Santa María municipality (Table 1), varying in length and encompassing both exposed and sheltered beaches with different orientations, morphological states, and various natural and geological constraints such as several rocky platforms, two long jetties, a few short groins, and the Puerto Sherry port (Figure 1). Regarding their morphodynamic state, both La Puntilla and Valdelagrana are characterized by dissipative conditions, i.e., are wide and flat and composed of fine sand. La Calita, La Muralla, El Aculadero, and El Castillito exhibit intermediate conditions, showing medium to coarse sand and the presence of rocky platforms in the intertidal zone [52]. According to Williams and Micallef’s classification [27], all these sites are categorized as urban beaches. Local authorities conduct daily manual beach cleaning from October to March and mechanical clean-up from April to September.

Table 1. Lengths of sampled sectors.

Sector No.	Sector Length (m)	Location (Beach Name)
1	172	La Calita
2	258	La Muralla
3	185	El Aculadero
4	165	El Castillito
5	212	La Puntilla
6	236	Valdelagrana 1
7	181	Valdelagrana 2

2.2. Sampling and Classification Method

This study is based on a 10-day survey carried out at 7 beaches in the El Puerto de Santa María municipality from 15 to 24 March 2023. On weekdays, the company in charge of beach clean-up activities along the El Puerto de Santa María coast performed litter collection during the morning low tide. The authors of this paper conducted the sampling during the weekends. The sampling period reflected typical springtime conditions, characterized by intermediate meteomarine climate conditions between winter (i.e., strong wave energy and a limited number of beach users) and summer (i.e., low energy conditions and an increased number of visitors) [4].

Sampling was carried out during the morning low tide, in a strip of 5 m in width along the strandline [53], i.e., the strip extended 2.5 m landward and seaward of the strandline.

This area represents the high-water mark reached by the last high tide and typically contains most of the litter [38,44]. Conducting the sampling in the morning allowed for the collection of all the litter accumulated during the previous day, providing, therefore, a reliable insight into the daily litter deposition rates. The collected litter was stored with labels indicating the collection date and the name of the beach. Afterward, in the laboratory, litter items were cleaned from sand and algae, dried, weighed, and finally classified.

The number of items and the total weight of each category were according to the Joint List of Litter Categories for Macrolitter Monitoring adopted by the Marine Strategy Framework Directive (MSFD) Coordination Group in November 2019, which sets a standard for data collection on marine litter [54]. It uses a hierarchical system to classify objects by material (chemicals, textiles, organic materials, glass and ceramics, metals, plastics, paper and cardboard, rubber, and wood), function (e.g., fishing- and food-related), and size (2.5–50 cm and >50 cm), each with a specific code. This system allows for the addition of new litter type categories if needed and simplifies data grouping for analysis. For this study, a new item category was added to the 183 categories of the joint list, creating the code 'pl_hy_wws_tang' to classify plastic tangled wet wipes mixed with seaweed and fishing lines.

The number and weight of identified litter categories were recorded per each sampling day and sector of the beach. Data were normalized by dividing the total number of items collected on a specific day at each beach by the length (in meters) of the considered beach sector. This provided the number of items per linear meter (number m^{-1}). Similarly, the total weight of the litter collected was divided by the beach length to obtain the weight per linear meter (grams m^{-1}). This normalization enabled the direct comparisons of litter abundance and density across different beaches and sampling days.

A visual inspection of litter conditions was conducted to identify and categorize the litter items found along the strandline as either fresh stranded litter ("fresh" litter) or recently deposited/abandoned by beach users ("deposited" litter) according to the following criteria: Litter classified as coming from the sea showed signs of exposure to saltwater, such as erosion, wear, and discoloration from continuous exposure to waves, sun, and salinity. Additionally, the presence of marine organisms like shells, bryozoans, corals, or algae attached to litter items indicated that they had been in the water for a significant time. Litter left by beach users was easily recognizable, as it was often nearly intact or contained organic remnants (in the case of food wrappers).

2.3. Data Analysis

Data on the quantity (number m^{-1}) and weight (g m^{-1}) of litter items were obtained to gather detailed information about their amount, type, usage, and country of origin, i.e., the relationships between fresh litter and recently deposited litter. Further, all the litter items were analyzed in order to identify, when possible, their brand and other information such as the distributor and/or location of the producers and all useful data to identify their origin, i.e., the country of manufacture/distribution. When the readable information on the packaging or item was insufficient—such as in the case of candy wrappers where the brand name was visible but the production or distribution details were missing or printed in an extremely small font—additional investigations were conducted using online resources. Google was employed as the primary search engine and specific keywords, including the brand name and terms such as "production" or "distribution" were used to find further relevant information. In many cases, the brand's official website provided useful details in the "About Us" or "History" sections, as was the case for the Spanish brand Bimbo [55] and the Brazilian brand Oderich [56].

In other instances, when brand websites were unavailable or lacked sufficient details, information was obtained through alternative sources, such as Wikipedia or websites specialized in the distribution of similar products. It is worth noting that the origin of a brand does not always correspond to the location of production or distribution. For example, fishing-related items from European brands were often found to be manufactured in China, such as fishing gear from the Portuguese brand Valbaites. Therefore, the focus of this research was placed on identifying the location of distribution, as it provides more reliable insights into litter’s geographic origin and pathways.

3. Results and Discussion

3.1. Distribution of Litter

During the 10-day sampling period along the beaches of El Puerto de Santa María, a total of 5592 items were collected, with a combined weight of 26 kg; 4634 items, weighing 23 kg, were classified as fresh litter transported to the shore by marine/coastal processes such as waves and currents. The remaining 958 items, weighing 3 kg, were identified as litter deposited by beach visitors. The average litter abundance recorded during the sampling was 0.40 ± 0.07 items m^{-1} , with a density of 1.85 ± 0.69 g m^{-1} (Table 2).

Table 2. Average values of litter abundance (number of items m^{-1}) and density (weight of items m^{-1}) at surveyed beaches.

Beach	Number of Items m^{-1}			Weight of Items m^{-1}		
	Fresh	Deposited	Total	Fresh	Deposited	Total
La Calita	0.17 ± 0.12	0.16 ± 0.12	0.32 ± 0.20	0.64 ± 0.54	0.33 ± 0.17	0.97 ± 0.61
La Muralla	0.11 ± 0.09	0.06 ± 0.05	0.16 ± 0.11	0.34 ± 0.28	0.16 ± 0.18	0.50 ± 0.37
El Aculadero	0.23 ± 0.16	0.01 ± 0.02	0.24 ± 0.17	0.52 ± 0.48	0.04 ± 0.06	0.56 ± 0.50
El Castillito	0.08 ± 0.03	0.08 ± 0.05	0.16 ± 0.05	0.87 ± 1.09	0.30 ± 0.27	1.17 ± 1.05
La Puntilla	1.34 ± 0.58	0.01 ± 0.02	1.36 ± 0.62	6.49 ± 3.74	0.13 ± 0.19	6.62 ± 4.04
Valdelagrana 1	0.12 ± 0.05	0.09 ± 0.05	0.21 ± 0.07	0.67 ± 0.89	0.44 ± 0.42	1.11 ± 0.99
Valdelagrana 2	0.21 ± 0.11	0.08 ± 0.03	0.29 ± 0.10	1.65 ± 1.07	0.26 ± 0.28	1.90 ± 1.16

The findings are particularly alarming as the amounts of deposited litter were quite high considering that the survey was carried out during a low-tourism period. Such amounts are likely to exponentially increase during the summer when the number of beach users increases significantly [4].

According to data from the National Institute of Statistics (INE), published on the official website of the El Puerto de Santa María City Council, El Puerto de Santa María received a total of 667,069 tourists in 2023. While the highest influx of tourists is typically observed during the summer months, data also shows a notable increase during no-peak seasons [57].

Several authors [4,58,59] documented a sharp increase in beach litter amount during the weekends, a trend slightly reported in this paper too. The spring conditions observed during this paper included moderate wave energy and the absence of major storm events in alignment with the typical seasonal marine characteristics recorded for this region. Although no direct correlation was found between wave height and fresh litter deposition rate in the study area [46], it is reasonable to expect reduced litter inputs from marine sources (fresh litter) during the calmer summer months and an increase in litter discharged by visitors (deposited litter) [4,46].

Concerning litter distribution, a similar pattern was observed at La Puntilla and El Aculadero, which recorded the highest number of items. La Puntilla registered 1.36 ± 0.62 items m^{-1} , primarily composed of fresh litter (1.34 ± 0.58 items m^{-1})

and one of the lowest counts of user-deposited litter (0.01 ± 0.02 items m^{-1}). El Aculadero registered 0.24 ± 0.17 items m^{-1} , with 0.23 ± 0.16 items m^{-1} of fresh and 0.01 ± 0.02 items m^{-1} of deposited litter, values that coincided with those recorded at La Puntilla. Despite this correspondence in litter abundance, the types of litter found at the two beaches were markedly different. At La Puntilla, plastic wet wipes were the most abundant and concerning items, accounting for 33% of the total items collected. This highlights the significant impact and volume of improperly managed waste linked to wastewater supplies in the area. Fresh litter recollected in El Aculadero was characterized by a significant abundance of cigarette butts. Such items probably came from the Puerto Sherry area, an important nearby recreational zone, and deposited into the sea and were then washed on the beach of El Aculadero (Figure 1).

La Puntilla likely works as a “sinking” area where litter from nearby areas and the sea bottom is accumulated. This is because it is located at the end of a “funnel-like” marine water body enclosed between the coastline and the northern jetty at the Guadalete River mouth (Figure 1). Further, such affirmations were confirmed by previous studies that carried out the propagation of westerly approaching wavefronts and obtained sound indications on alongshore transport [46]. Another piece of evidence supporting these observations is the significant presence of wet wipes and other hygiene products transported by the river. Indeed, the Guadalete River is one of the main and most concerning sources of pollution, as evidenced by the large amount of wet wipes—clearly linked to wastewater discharges—which account for 33% of the total litter collected at La Puntilla [46].

La Muralla and El Castillito recorded the lowest total number of items, with 0.16 ± 0.11 and 0.16 ± 0.05 items m^{-1} , respectively. However, these two beaches exhibited contrasting patterns: lower proportions of fresh litter (0.11 ± 0.09 and 0.08 ± 0.03 items m^{-1}) compared to higher proportions of user-deposited litter (0.06 ± 0.05 and 0.08 ± 0.05 items m^{-1}). Such sites are very frequented by beach users and are energetic areas because they are located on the open coast (Figure 1) and directly exposed to wavefronts approaching from the west. A notable difference was observed between the two sectors of Valdelagrana beach. Sector no. 6 exhibited lower counts of fresh litter (0.12 ± 0.05 items m^{-1}) compared to sector no. 7 (0.21 ± 0.11 items m^{-1}) whose major litter abundance is due to its higher exposure to approaching wavefronts with respect to sector no. 6 which is partially sheltered by the southern jetty at the mouth of the Guadalete River (Figure 1).

The variability in litter distribution is represented in the boxplots of Figure 2a, which highlights significant differences among the beaches linked to the daily fluctuations in litter abundance during the 10-day sampling period.

The litter weight data supported such findings (Figure 2b). La Puntilla recorded the highest total weight of litter (6.62 ± 4.04 g m^{-1}), predominantly linked to the abundance of fresh litter (6.49 ± 3.74 g m^{-1}), and La Muralla recorded the lowest total weight (0.50 ± 0.37 g m^{-1}). Regarding user-deposited litter, beach sector no. 6 (Valdelagrana) had the highest total weight (0.44 ± 0.42 g m^{-1}) and El Aculadero showed the lowest (0.04 ± 0.06 g m^{-1}).

Comparing the results obtained in this study with those from previous research is challenging due to the differences in methodologies used, a common issue in litter investigations [60]. However, these differences also highlight the unique contribution of each approach adopted in litter studies. This paper, based on a 10-day continuous survey carried out at seven beaches, provides detailed insights into short-term temporal variability in litter accumulation that was only partially investigated in the study area by Ciufegni et al. [46]. Furthermore, the amount and type of litter range over time due to natural (e.g., wind and sea storms) and human (e.g., number of users) parameters as observed in south-eastern Spain in the framework of a marine litter tagging study [61]. That study

also highlighted an exchange of floating litter items between the nearby beaches as lighter items can be more easily removed from the beach by wind, currents, human action, etc. Heavy items (e.g., metal or glass) remain on the beach for longer periods because they are more difficult to remove by wind or currents, and, quite often, the same items remain on the same beach for several months [61]. Further investigations are required to fully understand and comprehend such variability, particularly over short-term periods, to allow the development of effective and time and/or spatially located management strategies.

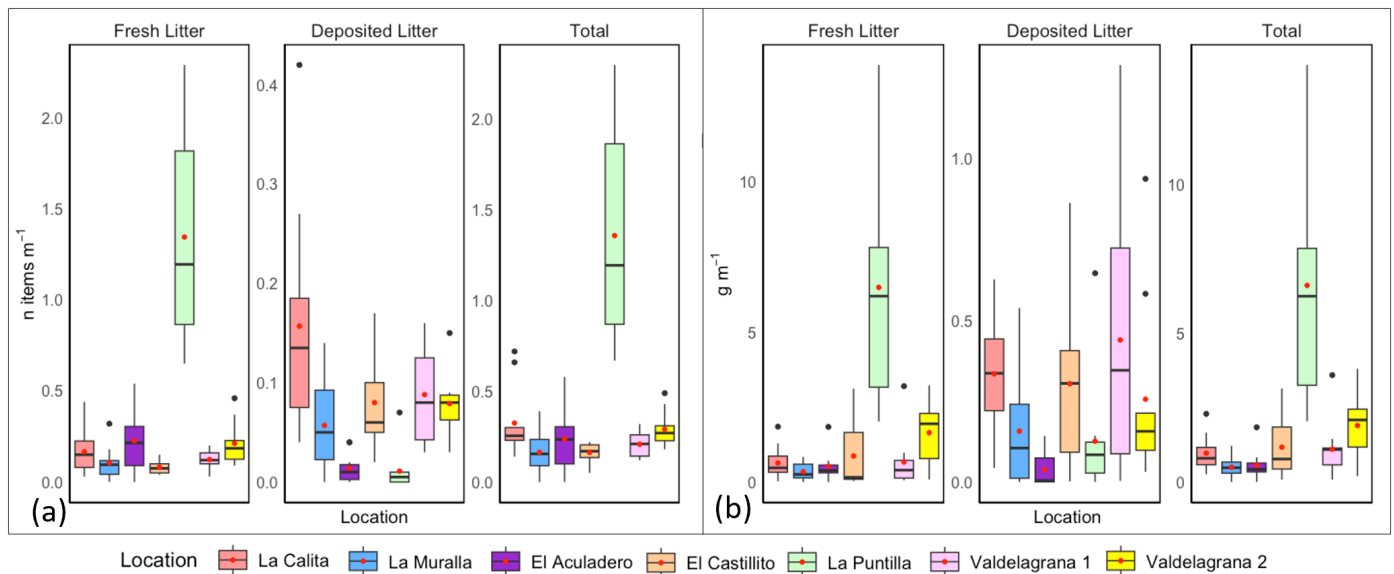


Figure 2. Box plots of beach litter abundance (a), expressed as number of items m^{-1} , and litter density (b), expressed as grams of items m^{-1} . Boxes enclose 50% of data; associated standard deviations are represented with whiskers, averages with red dots, median values with black lines and individual points outside the whiskers are outliers.

3.2. Litter Material Composition

To better understand the distribution of different litter materials, it is presented a bar plot that illustrates the relative percentages of various materials in three categories: fresh, deposited and total litter (i.e., the sum of the two previous types). The bar plot offers a clear visual comparison of how different materials contribute to the overall litter composition across these categories (Figure 3). Interestingly, concerning litter materials, the differences between fresh and deposited litter are quite small suggesting that the composition of litter found on the beach is relatively consistent regardless of whether it was transported by marine processes or discharged by beachgoers (Figure 4).

Plastic dominates fresh litter, accounting for 88.43% of all the items. This overwhelming prevalence aligns with its durability and lightweight nature. The predominant positive and neutral buoyancy of plastic items allows them to easily move at the water surface because of wind-induced and Stokes drift currents [62]. Rivers and other inland waterways contribute a large part of this floating debris, as has been observed on some beaches located near rivers' mouths in the Cádiz province [44]. Notably, plastic also includes wet wipes, which are the most abundant items in this category. Other materials such as metal (3.95%) and glass (3.22%) are present but in smaller proportions. Minimal contributions from categories like chemicals, organic matter, clothing, rubber, wood, and paper are observed.

The analysis of deposited litter reveals a small shift in material distribution. While plastic remains the most abundant material (76%), its proportion is lower than the value observed for fresh litter items. Paper, on the other hand, makes up 11.27% of the deposited litter, likely reflecting its common use and disposal on land. The increased presence of

metal (6.68%) and glass (3.44%) in the deposited litter could be attributed to the direct disposal of consumer goods and packaging on beaches or coastal areas. Despite some unidentified glass or paper fragments, the majority of the items classified as deposited litter are clearly identifiable as consumer products including cans, plastic bottles, paper cups, and cigarette packs. Notably, chemicals and organic matter are absent in this category.

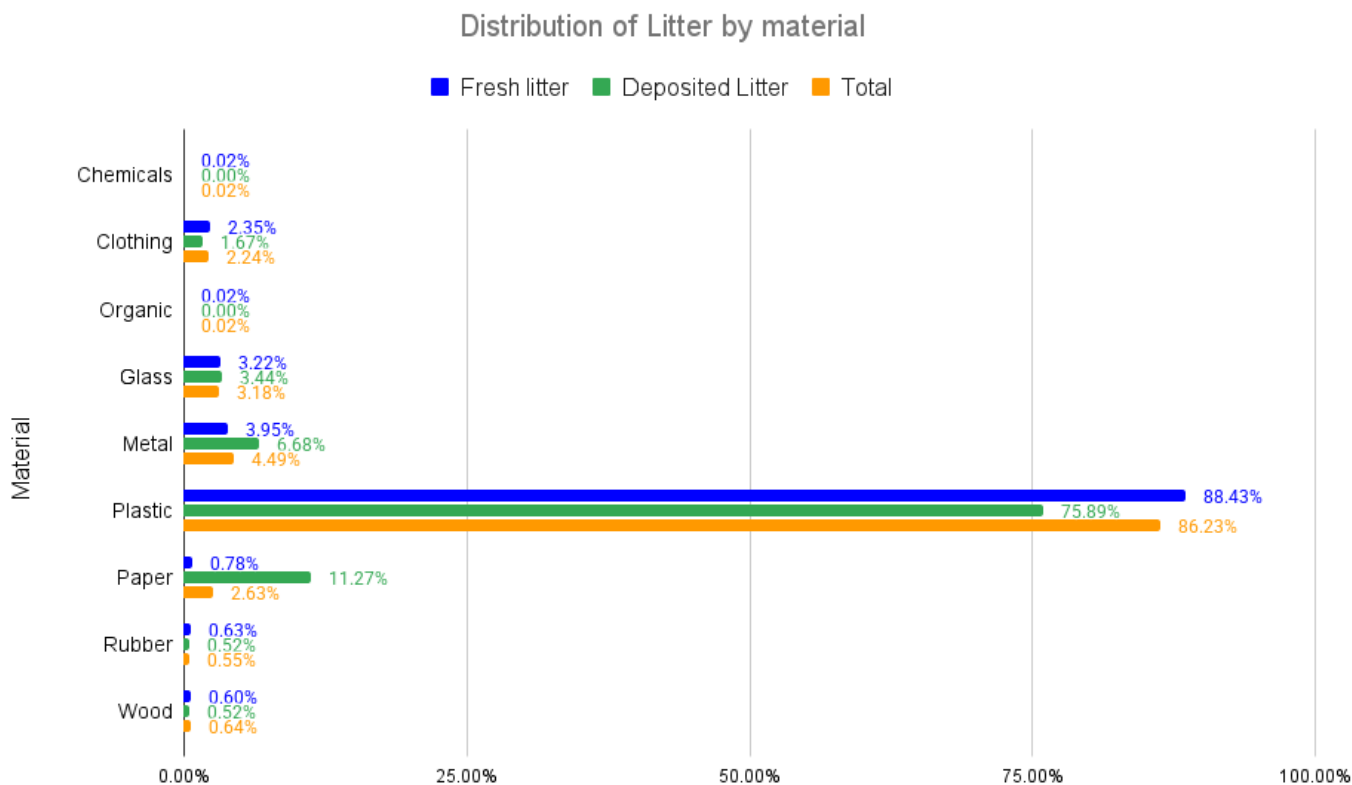


Figure 3. Beach litter composition. Calculations are based on the number of items per meter.

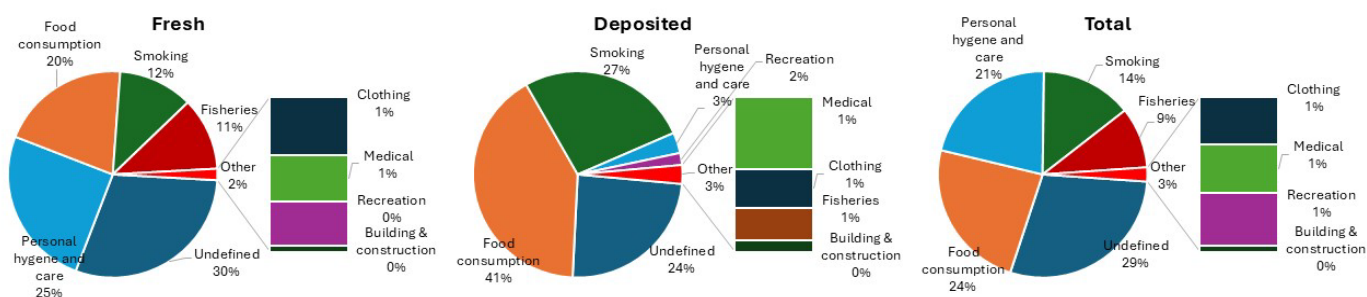


Figure 4. Beach litter classified according to the use categories proposed by the Joint List of Litter 346 Categories for Macrolitter Monitoring. Calculations are based on the number of items per meter.

The combined data for both fresh and deposited litter paints a similar picture, with plastic dominating at 86.23% of the total litter. This reinforces the persistent and overwhelming presence of plastic in both marine and terrestrial environments. Other materials, such as metal (4.49%) and glass (3.18%), remain consistent with their presence in the individual categories of fresh and deposited litter. Materials like paper (2.63%) and clothing (2.24%) are more significant in the deposited litter category.

Previous studies carried out along the Cádiz region claimed that plastic was the most abundant material [4,38,44,45]. These findings align with the long-standing evidence that plastic is the most abundant material in marine and beach litter. Since the 1970s, numerous studies have consistently reported plastic as the primary component of beach debris.

For example, a study by Gabrielides et al. [34] analyzed persistent litter on 13 beaches across Spain, Italy, Turkey, Cyprus, and Israel, finding that plastic was the dominant material collected between 1988 and 1989. Similarly, research conducted in New Zealand by Hayward [63] showed that plastic was the most common material found during surveys in 1974, 1975, 1981, and 1982. Notably, the author attributed the increase in plastic over time to changes in packaging practices, which led to greater use of lightweight and durable materials. More recently, Zalewska et al. [64] found that plastic accounted for 68.5% of the litter on the southern Baltic coast, cigarette butts and filters being particularly prevalent. In India, Mishra et al. [65] reported that single-use plastics overwhelmingly dominated other types of debris. In Itamaracá Island (Brazil), de Ramos et al. [66] identified plastic as the primary material, making up over 89% of the litter in exposed beach areas. Similarly, research by Howlader et al. [67] on seven beaches in Bangladesh revealed that plastic constituted 76.41% of the total debris. Their study also compared findings from 25 peer-reviewed articles, all of which confirmed plastic as the most abundant material in beach litter.

Metal and glass, although less abundant, are common on many beaches. Despite their low proportion, these types of materials bring with them a potential hazard to wildlife and beach users. They are considered hazardous litter as they can cause cuts, infections, and other problems. Their residence time for metal items in the natural environment is usually tens of years depending on the specific environmental conditions, and it is unknown for glass items. The proportion of paper is even lower and its permanence in the natural environment is usually short compared to other materials (from days to several months depending on the type of paper and environmental conditions).

Clothing is the least abundant material but can also pose a danger to different organisms as well as contribute to environmental pollution, e.g., due to its degradation in plastic microfibers which are the most abundant types of microplastics in the world.

3.3. Litter Usage Categories

In this study were identified 115 item categories from the 184 listed in the Joint List: 107 for fresh and 75 for deposited litter. There was significant variability between beaches, with La Puntilla accounting for 84 items (combining 81 fresh and 30 deposited litter items) and El Aculadero for 39 items (38 fresh and 6 deposited). Figure 5 shows litter composition by usage category according to the Joint List of Litter Categories for Macrolitter Monitoring [54].

Among the various categories of litter, **food consumption-related items** make up a significant portion of the total debris with 1329 items identified (Figure 5). Fresh litter accounts for 936 items (20.20%), with single-use packaging such as crisp packets and sweet wrappers being the most prevalent (423 items, or 45.19%). This is followed by drink cans (93 items, or 9.94%) and plastic caps or lids (53 items, or 5.66%). Deposited food-related litter, by contrast, shows a slightly different distribution. Of the 393 deposited items, crisp packets and sweet wrappers represent an even higher share at 60.81% (239 items). Drink cans (18 items, or 4.58%) and plastic cups or lids (13 items, or 3.31%) are also present but in smaller proportions compared to fresh litter. These results emphasize the persistence and impact of single-use plastics and underline the role of human activity in driving beach and marine pollution. They suggest that each item discarded on the beach, rather than being placed in the proper waste bin, not only contaminates the beach but also poses a high risk of entering the ocean. As a result, litter ends up in the sea and returns with waves and currents to the beach. Items deposited on the sand are especially vulnerable to dispersal due to environmental factors such as wind, waves, and currents, especially in a tidal environment. Lightweight plastics, such as wrappers and lids, are easily carried by the wind or washed

away by tides, increasing their chances of entering the marine ecosystem. A relevant study by Nachite et al. [39] emphasized the significant role of beachgoers' behavior in contributing to marine plastic pollution. On the Algerian coast, 43% of all the beach litter is attributed to food and beverage consumption-related items. Indeed, the main sources of litter were poor beach users' practices and inadequate waste management [68]. Many of these items come from rivers and they are attributed to high production and human consumption [69].

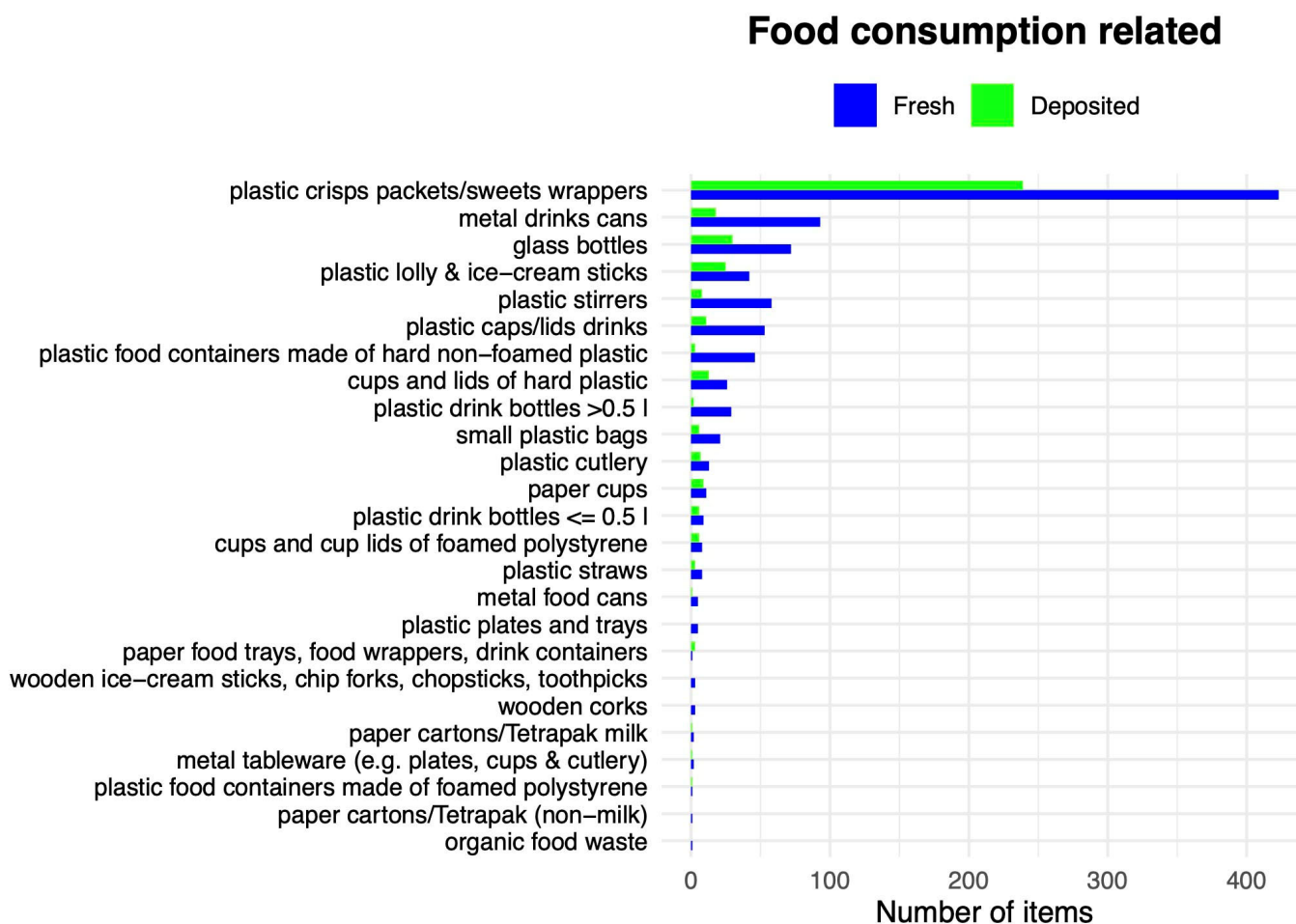


Figure 5. Food consumption-related beach litter categories by material and percentage.

Concerning heavier items such as glass, ceramics, etc., they may remain trapped in the sand or buried, where they can persist for extended periods, contributing to long-term coastal degradation.

Personal hygiene and care-related litter represents another prominent category (Figure 6), with 1198 items recorded; 1167 items were classified as fresh litter, underscoring the critical role of marine currents and rivers in transporting these items to beaches. Wet wipes dominate this category, accounting for 77.12% (900 items) of fresh litter, followed by tangled wet wipes (142 items, or 12.17%) and sanitary towels (77 items, or 6.6%). Many hygiene-related items likely reach the marine environment via rivers and sewers, often due to improper disposal or sewage system overflows, as documented in previous studies [38,46]. In contrast, the deposited litter within this category is minimal, with only 31 items recorded, including sanitary towels (2 items) and diapers (3 items). This stark difference between fresh and deposited litter suggests that most hygiene-related items are washed ashore rather than directly disposed of by visitors. Wet wipes, in particular, pose a severe environmental risk. They were frequently found entangled with fishing lines or

algae, underlining their potential to harm marine fauna and degrade seabed. Wet wipes are able to carry harmful bacteria (e.g., *Escherichia coli*), impacting both marine ecosystems and human health [70–72]. Additionally, wet wipes and sanitary towels are a source of microplastic fibers in the marine environment [73]. Finally, wet wipes are notorious for clogging sewage systems and are responsible for up to 90% of the reported blockages [74]; their improper disposal by individuals remains a critical issue [75].

Personal hygiene and care related

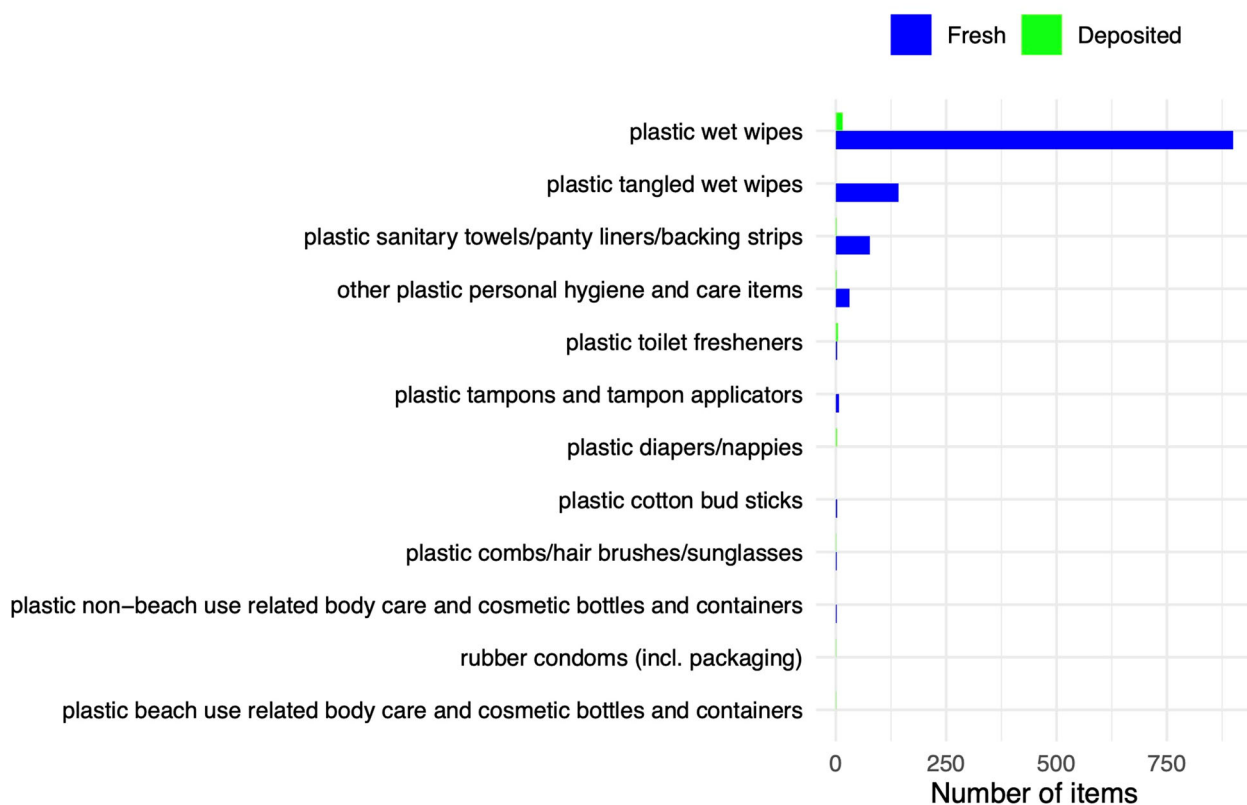


Figure 6. Personal hygiene and care-related beach litter categories by material and percentage.

Along the coast of Cádiz, **sewage-related litter** accounted for 5.5% of the total items. In addition to sanitary towels and wet wipes, this category included cotton bud sticks, condoms, panty liners, etc. [38,44]. In Morocco, sewage-related debris, mainly composed of nappies and condoms, represented 0.2% of the total beach litter. Due to living and consumption habits, swabs and wet wipes are not commonly seen on these beaches [39]. In other, more distant places, this type of litter is also common on coasts and rivers, e.g., in the UK [76] and several countries surrounding the Black Sea [77].

Smoking-related litter also forms a substantial component of beach debris (Figure 7), with 791 items recorded in total. Among fresh litter, cigarette butts with filters overwhelmingly dominate, making up 96% (514 items) of the category. They are very polluting items: there are over 5000 compounds in cigarettes, among these, at least 150 (of which 44 are found in large amounts) are considered to be highly toxic [78]. When burned, many of the chemicals present in cigarettes produce new compounds [79,80] that are easily transported to aquatic environments where they can be detected [78].

Smoking related

■ Fresh ■ Deposited

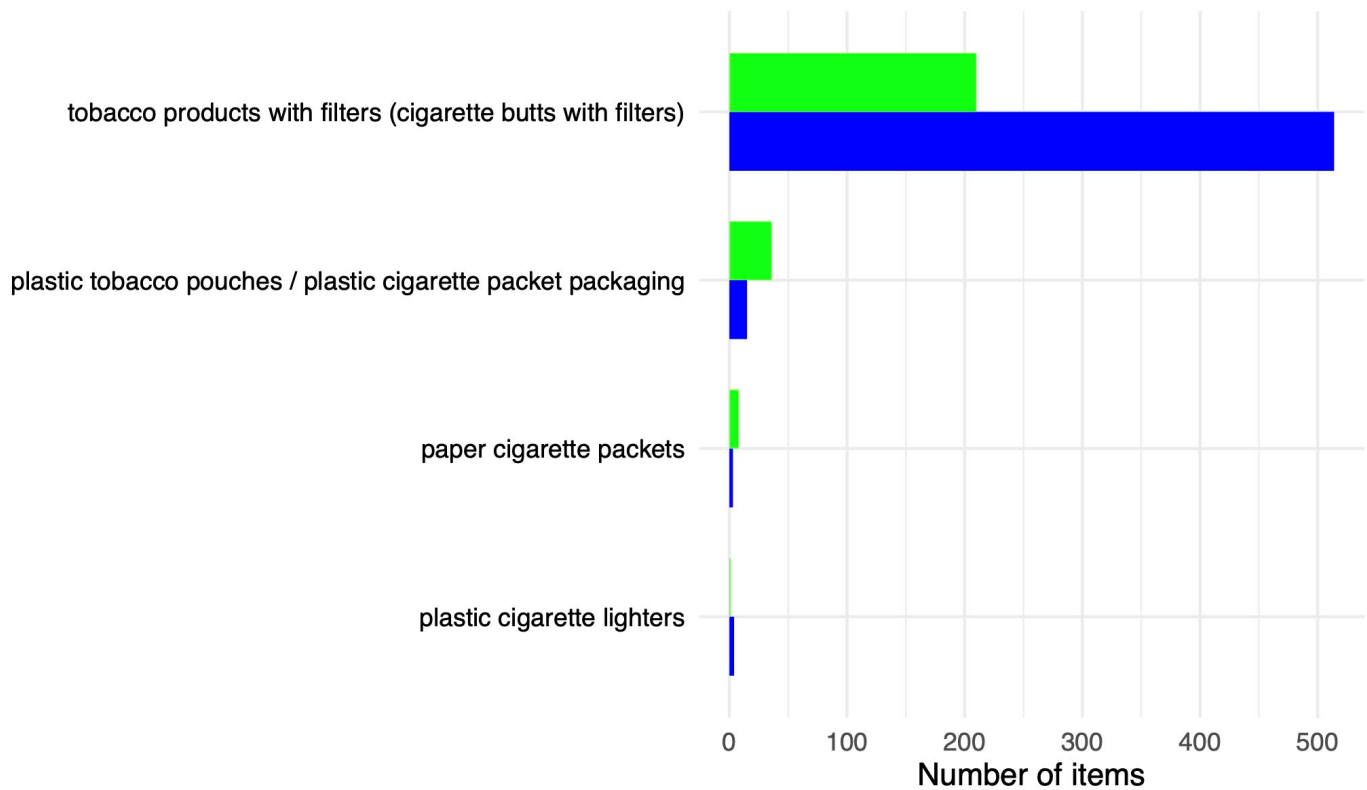


Figure 7. Smoking-related beach litter categories by material and percentage.

Deposited smoking-related litter amounts to 255 items, of which cigarette butts still comprise the majority (210 items, or 82%). They are often discarded directly by beachgoers, enter into the sea, and are successively washed ashore. The presence of cigarette butts on beaches results from a combination of human behavior and environmental factors. Many are directly discarded on beaches by smokers, particularly during peak tourist seasons, while others originate in urban areas where improper disposal leads to transport by wind and urban runoff through drainage systems. Their buoyancy allows cigarette butts to float for extended periods, enabling their movement via rivers and currents into coastal zones. Natural factors, such as wind and waves, further facilitate their accumulation on beaches [81]. Research conducted by Ribeiro et al. [82] on Brazilian beaches, as well as studies in East Java, Indonesia [83], Moroccan Mediterranean beaches [84], and several countries in Latin America [85], highlight the widespread issue of smoking-related litter. Cigarette butts, lighters, and tobacco packaging are ubiquitous on beaches, posing environmental and aesthetic concerns.

The undefined use category constitutes a substantial portion of the total litter, with 1617 items, making it the most abundant category for fresh litter. This category includes items that are difficult to categorize, such as foamed polystyrene fragments, unidentified plastic pieces, and metal bottle caps. Despite their small size, these fragments contribute significantly to the global gathered mass of litter and are challenging to manage due to their varied and often unidentifiable origins. Their small size also allows them to pass through the mesh of sieves used during beach cleaning operations, further complicating their recollection [4]. The abundance of small plastic pieces, such as fragments and polystyrene

foam, is a recurring issue on beaches worldwide. These items are consistently found in the top ten of beach litter categories [86,87], reflecting their pervasive nature and the difficulties associated with their management and removal.

Many items fall into categories that cannot be attributed to a specific use, but often come from already known items that are fragmented, especially plastics. These categories represent a substantial proportion in different beach litter studies. For example, plastic fragments are considered as a major component of marine litter in some sites such as Scotland [88] and Brazil [89]. Other common items besides plastic are pieces of processed wood or metal of undefined origin, which represent the majority of items on remote Antarctic beaches [90].

Fishery-related litter represents a significant portion of total litter (11.4%), i.e., 534 items, of which 528 items belong to fresh litter. This category is dominated by plastic fishing lines (120 items), plastic floats for nets (2 items), and tangled fishing ropes (66 items), all of which are often lost or abandoned at sea. This type of litter is particularly harmful to marine environments as it can entangle animals, degrade habitats, and contribute to the proliferation of microplastics in ocean ecosystems. Identifying items linked to fishery activities can be challenging because most of them can belong to different categories. For example, items like ropes, strings, and lines cannot always be exclusively attributed to fisheries, complicating the accurate estimation of their contribution to marine litter [87]. Despite these challenges, fishing remains a significant source of plastic debris as highlighted on the west coast of Scotland [91]. Other studies carried out along the coasts of Cádiz have recorded a lower percentage (2.1%) of fishery-related litter [44]. In the Spanish Mediterranean, fishing activities in spring and summer consisted of 3.1 and 1.2%, respectively, of the total items [46].

Other categories of litter include **medical-related** and **clothing-related** items. Medical-related litter accounts for 38 items, including single-use face masks (6 items), plastic gloves (9 items), and plastic medical fragments (13 items). Although these numbers are small when compared to food and hygiene-related litter, the environmental risks posed by disposable medical products are significant. Clothing-related litter, including textiles and plastic gloves, also contributes 38 items to the overall debris. Both categories are associated with direct beach disposal or inflow from nearby waterways. This type of litter has also been found on Mediterranean beaches (<1%) [92] and coastal lagoons [93].

3.4. Provenance of Objects

The brands of 320 items were identifiable and therefore allowed for an analysis of their manufacturing origins and distribution; particular attention was devoted to determining whether they were distributed or not in Spain. This relatively small proportion (5.7%) of identifiable items is primarily due to the large presence of undefined fragments (741 items) and items such as plastic wet wipes (1058) and cigarette butts (724). Additionally, a significant portion of fresh litter had brand details faded or erased due to prolonged exposure to water, salt, and/or sunlight, making their identification impossible.

As expected, 77% of the items with an identifiable brand belonged to the deposited litter category. Plastics were the most abundant material (77.81%), followed by metal (16.25%) and paper (4.06%).

Among the identifiable items, 83% were food-related. The most common items were crisp packets and drink cans (Table 3), both typical remnants of the waste left behind by beachgoers. These results further confirm that leisure activities on beaches contribute significantly to the deposited litter category [39].

Table 3. Litter-related categories within different usage groups (in bold). FL = “fresh litter”; DL = “deposited litter”.

Usage and Category	FL	DL
Fishery-related	5	10
other plastic fishery-related items not covered by other categories	5	10
Food consumption-related	56	210
metal bottle caps, lids, and pull tabs from cans	3	8
metal drinks cans	18	19
metal foil wrappers and aluminum foil		1
metal food cans	1	
other paper items		1
paper cartons/Tetrapak		2
paper food trays, food wrappers, and drink containers		4
plastic caps/lids drinks	2	5
plastic commercial salt packaging		1
plastic crisp packets/sweet wrappers	30	153
plastic drink bottles		6
plastic food containers made of hard non-foamed plastic	2	7
plastic shopping/carrier/grocery bags		1
plastic stirrers		2
Medical-related		1
other plastic medical items (swabs, bandaging, adhesive plasters, etc.)		
plastic medical/pharmaceuticals containers/tubes/packaging		1
Personal hygiene and care-related	5	9
other plastic personal hygiene and care items	2	1
plastic bottles and containers of cleaning products	1	
plastic non-beach use-related body care and cosmetic bottles and containers	2	4
plastic wet wipes		1
rubber condoms (incl. packaging)		3
Recreation-related		6
plastic crisp packets/sweet wrappers		2
plastic pens and pen lids		2
plastic shopping/carrier/grocery bags		1
plastic toys and party poppers		1
Smoking-related	3	6
electronic cigarette		2
paper cigarette packets	3	4
Undefined use	4	5
footwear made of plastic—not flip flops		2
plastic shopping/carrier/grocery bags	1	2
other identifiable non-foamed plastic items	3	1
Total	73	247

It is important to note that the nationality of a brand does not always correspond with the country of manufacture. For instance, products from a foreign brand may be widely distributed in Spain, which complicates the determination of the country of origin of the considered litter item. In such cases, efforts were made to assess whether the item was or not distributed in Spain. Among all the items analyzed, only one object was neither produced nor distributed in Spain, i.e., a condiment container (likely for mayonnaise or ketchup) from the Brazilian brand Oderich (Figure 8a). Two significant observations about this item merit attention:

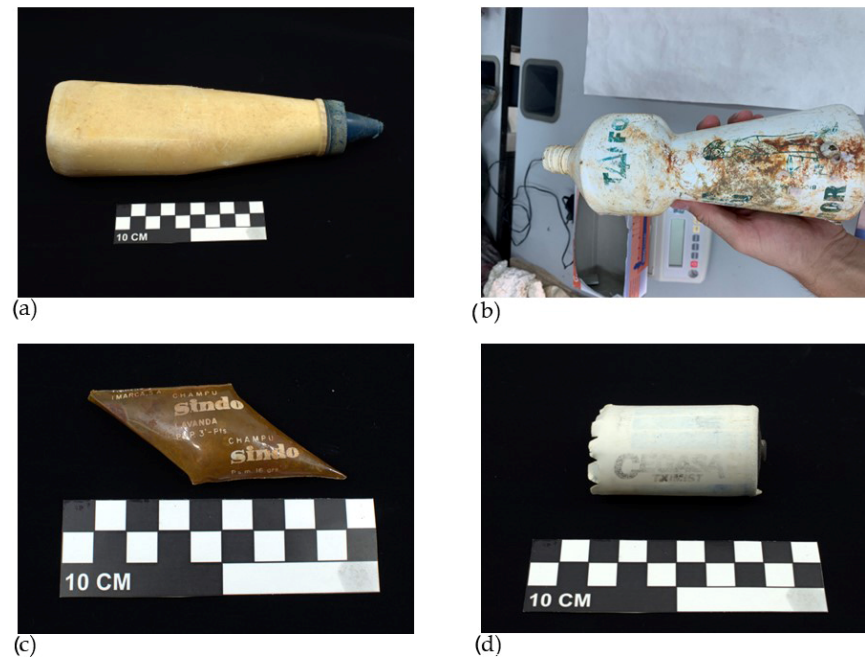


Figure 8. (a) Condiment container (likely for mayonnaise or ketchup) from the Brazilian brand Oderich. (b) A household cleaning product by Taifol. (c) A single-use shampoo packet by Sindo. (d) A Cegasa battery.

- Its outdated packaging: Despite an extensive online search, the specific packaging design of this container could not be matched to the current products, suggesting that it may represent an outdated or discontinued design. The container includes an embossed detail that allowed the brand and other information to be identified. In contrast, modern Oderich containers found online seem to rely solely on labels, lacking such embossed features. Attempts to contact the company for information regarding the product’s manufacturing timeline were unsuccessful, leaving its exact age uncertain.
- Its transoceanic journey: Information on the Oderich website indicates that the brand does not distribute its products in Spain or Europe [56]. This suggests that the container could have been in the ocean for many years, traveling thousands of kilometers before it was washed ashore. Its relatively preserved condition, despite its presumed age, highlights the durability of plastics and underscores the longevity of marine litter in aquatic ecosystems.

In addition to the Oderich container, three other notable items were identified. Each item’s design and branding hinted at its age, and manufacturers were contacted for further details, though only one provided a response. These items included the following:

A household cleaning product by Taifol (Figure 8b): The branding and logo on this container were well preserved, allowing identification as a product from a Seville-based company, Taifol. The retro-style illustration of a woman cleaning suggests it is decades old. Attempts to contact the company to confirm its age were unsuccessful.

A single-use shampoo packet by Sindo (Figure 8c): This packet appears to date back to the 1960s or 1970s based on vintage advertisements and references found online, including a *YouTube* video [94]. Although the brand Sindo no longer exists, its inclusion in historical advertising highlights its age. This packet was even featured in an article on the blog “Vivir Sin Plástico”, emphasizing its role as a historical artifact from the early era of single-use plastics [95].

A Cegasa battery (Figure 8d): The manufacturer of this battery responded to inquiries, estimating that the item is approximately 30 years old based on its packaging design. The presence of these aged items provides compelling evidence of the longevity of plastics, in particular, hard plastic (as HDPE), and their ability to persist in marine environments over decades, even maintaining their structural integrity and identifiable features [96]. This persistence highlights the importance of better understanding the long-term impacts of marine litter and gives guidance to management [97].

Moreover, the global movement of items, such as the Oderich container, underscores the interconnected nature of marine pollution. Items originating from one region can travel vast distances, reinforcing the need for international collaboration in addressing ocean plastic pollution.

3.5. Brand Information

The identification process resulted in a list of 132 brands (Appendix A, Table A1). The Roshen Corporation, a Ukrainian confectionery manufacturer whose products are distributed in Spain by Roshen Iberia, led the list. In the second place, there is Coca-Cola, followed by Cruzcampo (a beer brand very common in the area) and other Spanish brands. Furthermore, a comparison with the data reveals that the most frequently encountered brands in this study include the top global plastic polluters [98]: Coca-Cola, Pepsi, PepsiCo, and Nestlé. Similar findings were obtained by Asensio-Montesinos et al. [45] in the Cádiz province. Many of these marks have been found mainly on food wrappers, beverages, and other objects related to human consumption.

4. Final Considerations

One of the key findings of this study is the similarity of the fresh and deposited litter item categories, often consisting of single-use plastics. The most common are plastic wrappers (often from snacks, drinks, and other consumables) and cigarette butts that are commonly deposited on beaches by visitors and subsequently washed into the sea, compromising both the cleanliness of beaches and the health of marine ecosystems. The toxicity of cigarette butts in aquatic environments has been demonstrated by numerous investigations, including different marine species, from unicellular organisms such as foraminifera to larger ones such as invertebrates and fish. Wet wipes were also very important in the study area and their presence is linked to wastewater discharges on the coast, indeed a severe health risk for beachgoers.

Despite the results obtained being very interesting and significant for the study area that is directly affected by the litter's supplies from the Guadalete River and presents a great diversity of beach types limited by different natural and man-made structures, they only reflect spring time conditions, i.e., the amount of recorded litter is linked to moderate waves' height values and a small affluence of beachgoers. Therefore, it is of relevance to repeat such field studies during winter, i.e., under stronger wave energy conditions and a very low number of beachgoers, and summer, i.e., under very low wave energy and a great number of beach users. The results can allow for establishing if the composition and the relationship between fresh and deposited litter remain constant year-round or not. Such results can have great relevance and be used to suggest—if necessary—the adoption of specific litter management actions according to the period of the year.

It is clear that a large portion of the litter found on beaches is essentially linked to tourism and recreational uses. Without proper waste management infrastructures or clear disposal guidelines, much of this waste easily enters the marine environment. The abundance of personal hygiene-related items, particularly wet wipes, highlights a different origin and behavior compared to food-related items. Wet wipes are often flushed into

sewage systems due to people's misconceptions about their safe disposal way. Despite many people believing that wet wipes are harmless, they are able to cause significant environmental damage since they are non-biodegradable. The results obtained in this paper emphasize that both behaviors—littering on the beach and improper toilet disposal—reflect a lack of awareness, but each of them requires a different approach. Anyway, marine litter is able to travel vast distances and constitutes a global problem as demonstrated by the presence of the Brazilian condiment container. This demonstrates the urgent need for international cooperation to address ocean plastic pollution given that marine pollution transcends geographical and administrative boundaries.

As outlined by Williams and Rangel-Buitrago [99], addressing the litter issue requires a combination of scientific research, prevention, mitigation, public awareness, and improvements in waste management and changes in consumer behavior. The findings of this study underscore the persistent and critical challenge posed by beach litter, highlighting the urgent need for effective policies and management strategies. Policies should focus on upstream reduction in plastic production, particularly targeting single-use items, which currently account for approximately 36% of global production [100]. Wherever possible, plastic has to be replaced by other materials that are easier to recycle or have a much higher reusable potential, such as glass. The use of biodegradable materials could be a good alternative to replace plastic food packaging items. In 2021, the European Union's Directive (EU) 2019/904 [101] on the reduction in the impact of certain plastic products on the environment, also known as the Single-Use Plastics Directive, came into force. This directive bans several single-use plastic items such as cutlery, straws, and plates. In Spain, it has been transposed into national legislation under the Act 7/2022 concerning waste and polluted soils to favor a circular economy [102]. While this regulatory framework represents a significant step forward, it does not comprehensively address the most commonly used plastic packaging materials such as bottles and food containers. These items continue to dominate the international market and major multinational corporations are expected to double plastic production by 2035 according to a Greenpeace report [103]. Such trends highlight the limitations of the current legislation to definitively eliminate the causes of plastic pollution.

A potentially transformative solution lies in the development of a global treaty to end plastic pollution. The United Nations Environment Assembly has been working toward a legally binding agreement. Despite significant progress, the fifth round of negotiations, held in 2024 in Baku (Azerbaiján), failed to reach a final agreement, postponing discussions to 2025 [104]. The delay underscores the complexity of achieving global consensus and the need for sustained advocacy and international cooperation.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Brand and usage of identified items within different usage groups (in bold). FL: fresh litter; DL: deposited litter.

Brand and Usage	Total	FL	DL
Food consumption-related	266	55	211
Roshen	12		12
Coca Cola	11	5	6
Cruzcampo	11	4	7
Pictolin	11	5	6
Ener drink evolution	9	8	1
Fleer	9	1	8
Grefusa	9		9
Halls	9	2	7
Mars	9	1	8
Bimbo	8		8
Hacendado	8	2	6
Kinder	7		7
Estrella Galicia	6	2	4
Font Natura	5	1	4
Día	4	1	3
Eliges	4		4
Fiesta	4		4
Fini	4	1	3
Gullón	4		4
Monster	4	2	2
Nestle	4	1	3
Pepsico	4		4
Reyes	4	2	2
Toffino	4		4
Blue Chamaleon	3	1	2
Butron	3		3
Don Simón	3	1	2
Kelia	3		3
Pepsi	3	2	1
Redbull	3		3
Vidal	3		3
Aspil	2		2
Carrefour	2		2
Dromedario	2		2
El turco	2		2
Heinz	2	1	1
Helios	2		2
Kidz World SL	2		2
Lacasa	2		2
Mahou	2		2
Pifarré 1911	2		2
Respiral	2		2
Rima	2		2
Schweps	2	1	1
Werther's	2		2
Witor's	2		2
Zamba	2		2
Agua España	1		1
Aguila	1		1

Table A1. Cont.

Brand and Usage	Total	FL	DL
Balconi	1		1
Bonelle	1		1
Bubbaloo	1		1
Campofrio	1		1
Casa Ricardo	1		1
Caserio	1		1
Cerveza sureña	1		1
Chips Ahoy!	1		1
Chost S.I./Snacks by Pegui	1		1
Chupa Chups	1	1	
Draku Dip & Lick	1		1
Dulciora	1		1
El Pozo	1		1
Elefante rosa	1		1
Garvey	1	1	
Gallego	1		1
Golia	1	1	
Hielos la Estrella Del Aljarafe	1		1
Jake	1		1
karlsquell	1	1	
Kibus	1	1	
Konny	1		1
LA MAR DE GAMBAS	1		1
Lindor	1		1
Makro	1		1
Marcelo Caramelo de Dia	1		1
Mentolin	1		1
Miguel Arana	1		1
Moser Roth	1		1
Nimm2	1		1
Oceanix	1	1	
Oderich	1	1	
Oreo	1		1
Osborne	1	1	
Panaderia Dolores	1		1
Panificadora de Andalucía	1	1	
Patatas fritas Navarro	1		1
Puleva	1	1	
Reese's	1		1
Revilla	1		1
Rollito	1	1	
Salem	1		1
SIGLITOS	1		1
Teleno	1		1
Tio Pepe	1		1
Tirma	1		1
Valor	1		1
Fishery-related	15	5	10
Valbaits	7	4	3
Undefined	2		2
BALLAST Decathlon	1		1
Ceperlan	1		1
Eurofish Lo&Di	1		1

Table A1. Cont.

Brand and Usage	Total	FL	DL
Light Lumica	1		1
Lineaeffe	1	1	
Livefish	1		1
Personal hygiene and care-related	14	5	9
Durex	3		3
Bolero	1		1
Carrefour	1	1	
Cinfa	1	1	
Deliplus	1	1	
Floralys	1		1
Limoncol	1		1
Mercadona	1		1
Scottex	1		1
Sindo	1	1	
Taifol	1	1	
Wecolors	1		1
Undefined use	9	5	4
Undefined	2	2	
Ayuntamiento de Cádiz	1	1	
Cagasa	1	1	
Mercadona	1		1
Pavimentosexteriores.es	1		1
Romerijow	1	1	
Tribord	1		1
Walkx	1		1
Smoking-related	9	3	6
Winston	3	2	1
Camel	2		2
Chesterfield	2	1	1
Lost Mary	2		2
Recreation-related	6		6
100 Montaditos	1		1
Bic	1		1
Happyboys	1		1
Ikea	1		1
Llacer	1		1
Lugopack sl	1		1
Medical-related	1		1
Bayer	1		1

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