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Abundance and distribution of cigarette butts on the sand of five touristic beaches in Latin America during the COVID-19 pandemic

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ABSTRACT

Cigarette butts (CB) and cigarette butt fibers (CBF) are highly abundant and frequent residues on beach sand. Also, they are hazardous waste due to their significant toxicity and potential risk to the ecosystems' biota and the health of beach tourists. This study aimed to determine the abundance and density of CB and CBF found on the active, rest, and service zones of five pilot beaches in Argentina, Colombia, Brazil, Ecuador, and Mexico. The methodology involved collecting CB and CBF in 500 m^2 transects of urban tourist beaches using a citizen science-adapted methodology between June 2021 and May 2022, during the COVID-19 pandemic. The abundance and density of CB and CBF, and the Cigarette Butt Pollution Index (CBPI) were calculated. The highest proportion of CB was found in service and rest areas. Bocagrande (CO) reported the highest generation of CB and CBF and a severe CBPI.

1. Introduction

Beaches attract a wide range of human activities, making them an interesting subject for various research perspectives. Tourism based on sand, sun, and sea has played a crucial role in the economic development and urban expansion of coastal areas. Sun and beach tourism has high seasonality rates due to the demand being concentrated in the months when the expectations of enjoying sun and beach can be met to a greater extent (García Sánchez and Alburquerque García, 2003).

It is crucial for the marine environment to have optimal quality in order to attract tourists back to these destinations, which are affected by activities that harm biodiversity and biological growth. Plastic pollution is a widely debated impact on the tourism industry, as many single-use plastic products end up on beaches, discouraging tourists and negatively impacting their activities and experiences. Furthermore, this pollution also leads to a decline in fishing resources (Mejjad et al., 2022).

Marine debris is one of the most concerning issues generated by mass tourism. The volume of daily visitors and the deficient management of waste in such large numbers have resulted in pollution on beaches. This issue is recognized as a driving force in the analysis of beach pollution carried out with the DPSIR (driver, pressure, state, impact, response) methodology (Federigi et al., 2022). Marine litter is one of the fastest-growing anthropogenic problems in the coasts and oceans worldwide, which calls for urgent research and intervention strategies (Rangel-Buitrago et al., 2022). Annual cleanup and waste collection days on beaches worldwide have shown that plastic waste and cigarette butts are the most frequently collected waste (Ocean Conservancy, 2022).

Remarkably, out of 631 reviewed publications on beach debris (i.e.,

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covering 130 journals and 66 countries), plastic items represented the dominant material (61.3 %) (Ansari and Farzadkia, 2022). Briefly, an average abundance of plastic debris of 19.8 ± 19.5 objects/m^2 (116 ± 226 g dry weight (DW)/m^2) was observed on seven beaches around Nha Trang, Vietnam. This beach is identified as one of the most polluted in the world, supporting the notion that Vietnam is a hotspot for marine plastic pollution (Fruergaard et al., 2023). The degree of marine debris pollution is considerably high, not only in sites with anthropogenic activities but also in remote islands such as the remote Nicobar archipelago, where a total of 1438 debris objects were recorded, of which plastics were dominant (83.72 %). Among plastics, nets/ropes (38.87 %) were the most dominant, followed by plastic bags, plastic bottles, woven polypropylene bags, plastic cans, floats, and plastic cups, with densities ranging from 1.28 units/m^2 to 7.2 units/m^2 (Kiruba-Sankar et al., 2023). A total of 16,123 litter items belonging to 120 waste groups were identified at 40 bathing areas along the coast of Cádiz, Spain. Among these groups, a specific category related to smoking was included, comprising cigarettes, cigarette butts and filters, cigarette lighters, and cigarette packets, among others. Cigarette butts accounted for 67 % of the total items found, amounting to 10,833 units (Asensio-Montesinos et al., 2020). The study conducted in Cyprus, an island country in the Eastern Mediterranean whose economy is largely dependent on coastal tourism, shows an area of 20,980 m^2 that was cleaned by 214 participating volunteers who collected a total of 7658 litter items during 18 summer cleanup campaigns between 2016 and 2017 on nine Blue Flag beaches. In the top ten list of most commonly collected items by number, cigarette butts (n = 4552; 59.4 %) were the predominant litter item (Loizidou et al., 2018).

On the other hand, the impact of cigarette butts on freshwater bodies and marine and terrestrial ecosystems has gained research attention in recent years due to their potential toxicity (Yousefi Nasab et al., 2022; Araújo et al., 2022). A study conducted in marine environments of the Persian Gulf highlighted the importance of further research on the ecotoxicology of cigarette butts, showing preliminary results of mercury and lead leaching in these ecosystems and related to the abundance and discard density of CBs (Dobaradaran et al., 2018). Cigarette butts slowly degrade the environment and release their content of heavy metals, such as lead, cadmium, chromium, copper, vanadium, nickel, and arsenic, in addition to several chemicals known to be carcinogens (Qamar et al., 2020). Among the elements released, copper has shown the highest percentage of release (91 %), while molybdenum (35 %) has shown the lowest percentage. The amount of released metals is directly related to the degradation of cigarette butts, as the formation of free radicals favors the binding of metals to cellulose triacetate, i.e., the main component of CBs. Consequently, CBs can act as carriers of metals in the environment, which could pose a toxicological risk to marine organisms through the accumulation of metals in their tissues (Santos-Echeandía et al., 2021). Other hazardous substances present in cigarette butts are nicotine, tar, and polycyclic aromatic hydrocarbons (Shen et al., 2021). Cellulose acetate shows persistence and affinity with plasticizers and chemicals that can be toxic and alter microbial communities in marine sand (Quéméneur et al., 2020).

Studies have been conducted to control the impacts of cigarette butts on ecosystems, such as recycling, activated carbon materials, sound insulators, and hydrophobic fibers, but further studies are required given the complex and toxic nature of cigarette butt waste (Torkashvand et al., 2020). Lucia et al. (2023) highlighted the need to communicate the impact and risks of cigarette butts in the marine environment, as well as the need to incorporate efficient public management strategies for this type of waste. The study shows a growing risk dependent on the abundance of CBs that could affect marine organisms, highlighting their role as an emerging pollutant. Additionally, attention is drawn to the need to prioritize their removal from beaches not only as an aesthetic problem but to limit a source of pollution for the marine environment. Since 2005, many countries have implemented smoke-free policies to mitigate the impacts of passive smoking and reduce the young smoking population (Smit et al., 2023). Cigarette butts also affect visitors' health due to toxic substances and pathogenic microorganisms that can have contact with the skin or be accidentally ingested by children, damage the biota by ingestion or poisoning, and cause visual pollution by the disposal of waste on the sand (Araújo and Costa, 2019).

This current investigation studied the abundance and distribution of cigarette butt and fiber residues accumulated in the sand of five pilot beaches Pehuen Co (ARG), Bocagrande (COL), Peró (BRA), MalecónMalecón (ECU), and La Audiencia (MEX) in Latin America between June 2021 and May 2022. Additionally, this study was conducted to determine a potential association between cigarette butt and fiber residues and beach usage areas (i.e., active zone, rest zone, and service zone), tourist intensity, and beach cleaning programs. Also, cigarette butt and cigarette butt fiber pollution indexes (CBPI and CBFPI, respectively) were obtained for the five study beaches for the first time in the literature. Additionally, the study included the analysis of the cigarette butt fiber pollution index (CBFPI). It was expected that beaches with variable weather conditions and tidal regimes would show lower abundance figures, where variations in abundance determined by peak tourism seasons would also be found. Although few studies have previously investigated the abundance of cigarette butts in the composition of marine litter on beaches in the Mediterranean Sea (Kataržytė et al., 2020; Asensio-Montesinos et al., 2019), India (Perumal et al., 2023), off the coast of Chile (Hidalgo-Ruz et al., 2018), Brazil (Ribeiro et al., 2022), and Ecuador (Gaibor et al., 2020), the current study is the first to simultaneously sample beaches in five Latin American countries during the COVID-19 pandemic. The results from this study will highly assist scholars, governmental bodies, and non-governmental organizations in designing post-pandemic environmental monitoring of beaches, as well as establishing beach litter trends.

2. Materials and methods

2.1. Study beaches

The present study is developed within the framework of the collaborative project "More Citizen Science for fewer cigarette butts in the sand of tourist beaches", which is part of the Ibero-American Beach Management and Certification Network (Proplayas). This investigation was developed on five beaches in Latin American countries: Argentina, Brazil, Colombia, Ecuador, and Mexico. The study beaches were urban beaches (i.e., located in urban areas), which have various types of commercial services, accommodation, and facilities, and where recreational value considerations are often far from their conservation value (Rodella et al., 2019). The characteristics of the study beaches can be seen in Table 1, and their location in Fig. 1.

2.2. Component of Collaborative Citizen Science and Education during project development

The methodology used for collecting cigarette butts and fibers included a component of Collaborative Citizen Science and Education according to the classifications of Shirk et al. (2012) and Wiggins and Crowston (2011). These projects are designed by scientists with the participation of volunteer citizens who help with monitoring, data analysis, and dissemination of findings. In these projects, participants not only acquire knowledge but also become aware of the issues being investigated. This type of project has increased in popularity in recent decades (MacPhail and Colla, 2020).

In this study, a call for volunteers was made in each country for monthly collections, with the participation of the Society for Local Development, NGOs, university students, school and university teachers, as well as beach tourists. In the initial stage of the project, a volunteer team training component was included, which included training related to the characteristics of cigarette butts and fibers, the nature and risks of cigarette waste on beaches, and the methodology for

Table 1
Description of the study beaches.

Beach	Location	Weather and tides	Beach sedimentology	Beach classification according to slope	Tourism low season	Tourism high season	Features
Pehuen Co	Province of Buenos Aires – Argentina (39° 00′14.98″ S 61° 33′05.30″ W)	Temperate climate Tides: Range: Mesotidal Type: semidiurnal	Mixed sand and gravel	Dissipative	March to November	December to February	Gently sloping beach. Framed by frontal dunes except in the most urbanized area where the dune was covered by buildings.
Bocagrande	Cartagena – Colombia (75° 33′ 42.0″ W 10° 28′ 56.7″ N)	Climate warm approximately 28C Tides: Range: Mesotidal Type: Mixed mainly diurnal	Fine silty sands	Dissipative	March to May and August to October	November to February and June to July	Urban, tourist beach, no native vegetation, only a few isolated individuals near the road consisting of palms.
Peró	Peró, Cabo Frio, Rio de Janeiro, Brazil (22°51′46.00″ S 41°59′8.62″ O)	Tropical weather Tides: Range: Microtidal Type: semidiurnal	Fine silty sands	Dissipative	May to June and August to November	December to April and July	Urban, tourist beach with small local vegetation, close to the boardwalk
Malecón	Playas Villamil, Ecuador (2°38′23,01″ S 80°23′11″ W)	Climate warm approximately 26C Tides: Range: Mesotidal Type: semidiurnal	Fine silty sands	Dissipative	June to November	February to April.	Gently sloping beach. Urban, tourist beach. The beach is part of the National Recreational Reserve "Playas Villamil"
La Audiencia	Manzanillo, México	Tropical Climate Range: Microtidal Type: Semidiurnal	Medium grain size	Intermediate	September to November	December to March July to August	Urban Tourist Beach

collecting and storing samples. In academic meetings, criteria for selecting study beaches were discussed, considering urban and tourist beaches with lengths over 500 m, areas with facilities and services, with users present throughout the year and during high and low tourist seasons or according to climate variables.

2.3. Selection of study zones

Three study zones were selected based on the activities performed in each of them, considering their recreational and tourist nature of the study beaches. The following considerations were applied to the project. A) Active zone: in the across-shore direction, around the waterline; designated for some sports and recreational activities such as walking, jogging, beach soccer, and beach volleyball. This zone allows entry to the bathing area. B) Rest zone: designated for relaxation and rest for visitors. This zone has equipment with umbrellas, chairs, and other services. C) Service zone: occupies the most landward part of the beach, an area where tourist and support services such as bars, restaurants, and souvenir shops are located (Valdemoro and Jiménez, 2006) (Fig. 2). The zoning was considered in order to establish potential differences in the state of cigarette butts that could be attributed to their location and interaction with different factors associated with user traffic or environmental factors such as wind incidence, waves, and sand particle drift, among others.

2.4. Monitoring campaigns

Twelve monitoring campaigns were conducted at each beach, with monthly frequency from June 2021 to May 2022. In each pre-defined zone according to its use, transects of 500 m in length and 1 m in width were performed, with visual identification following OSPAR guidelines (Yousefi Nasab et al., 2022). Additional considerations were taken into account, such as the ease of access to the beach, visitor flow, environmental conditions of the site, and some general data, such as the occurrence of relevant meteorological or oceanographic events or the development of social events on the beach in the previous hours.

2.5. Methodology for collecting cigarette butts and fibers, and data processing

The methodology for collecting cigarette butts (CB) and cigarette butt fibers (CBF) was carried out using 500 square meter transects through walks where manual collection of butts and fibers was performed within the transect during a period of 2 h. It is worth noting that the collection was carried out while adhering to biosecurity norms, considering the butts a hazardous waste, especially during the COVID-19 pandemic. The collected material was stored in reusable glass jars and taken to the laboratory for subsequent weighing and counting by separate units of cigarette butts and fibers according to each collection zone. Fig. 3 shows the conditions of CB and CBF found on the study beaches and how the samples were processed in the laboratory.

For this study, the cigarette butt pollution index was calculated using Eqs. (1) and (2) (Torkashvand et al., 2021). The cigarette butt pollution index (CBPI) is defined by taking into consideration the presence of numerous contaminants from cigarette butts (CBs), the possibility of leakage into the environment influenced by the presence of rain, the persistence and potential toxicity of CBs in ecosystems, and the impact on cleanup programs (Torkashvand et al., 2021).

$$CBPI = density\ of\ cigarette\ butts * E \quad (1)$$

where

$$E = 10 * \text{factors affecting pollutant release from CB to soil and water.} \quad (2)$$

Chord (Torkashvand et al., 2021): The factors that affect the release of contaminants from cigarette butts into soil and water are equivalent

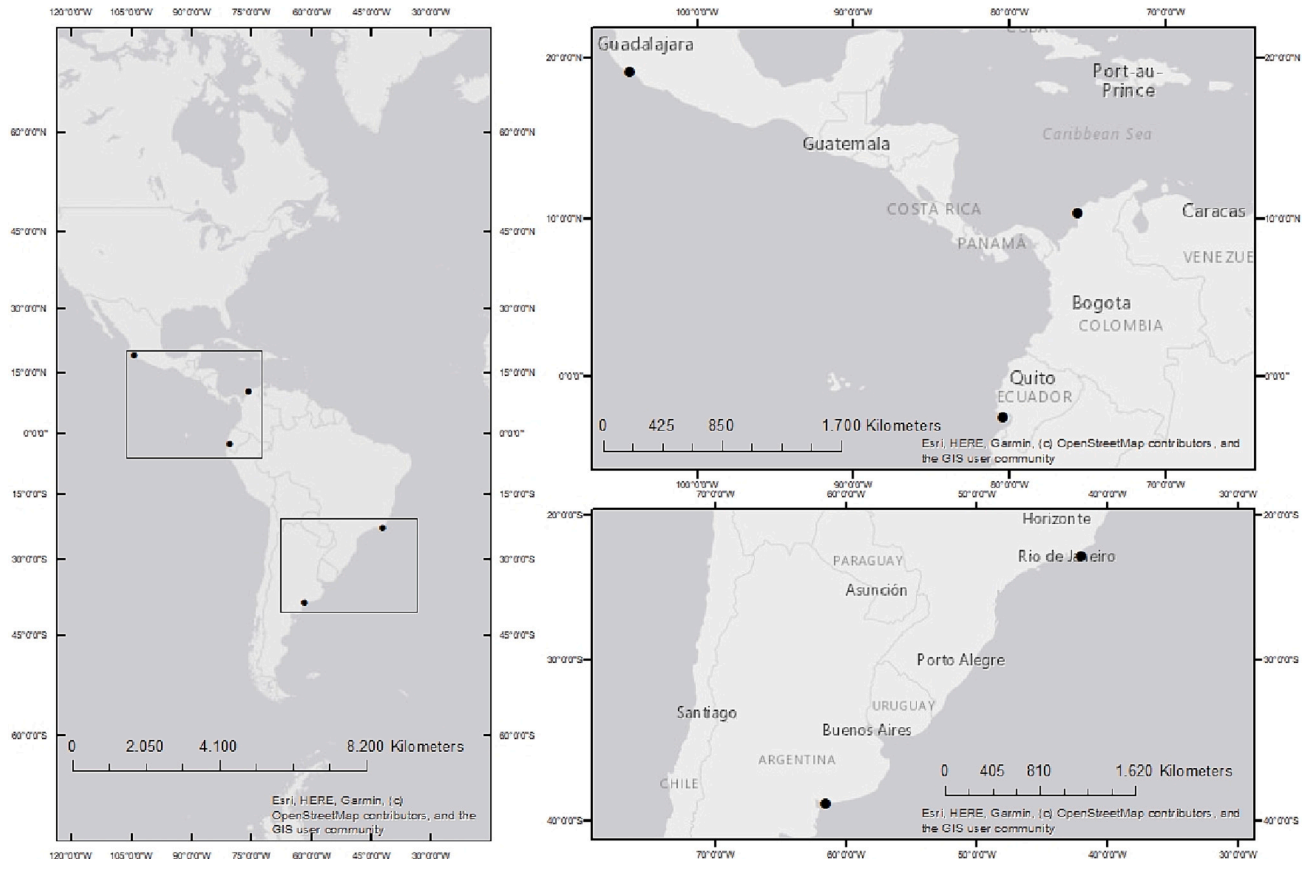

Fig. 1. Location of study beaches.

to 2 in coastal and sandy areas. Additionally, CBPI ≤ 1 very low pollution; 1.1 < CBPI < 2.5 low pollution; 2.6 < CBPI < 5 pollution; 5.1 < CBPI < 7.5 significant pollution; 7.6 < CBPI < 10 high pollution; and CBPI > 10 severe pollution.

3. Results and discussion

To determine the abundance of cigarette butts and fibers on beaches in five Latin American countries during the COVID-19 pandemic, citizen science monitoring was conducted between June 2021 and May 2022. Remarkably, the first quarter of monitoring (i.e., from June to September 2021) was a period marked by the reactivation of beach use in many countries after the capacity restrictions established during the COVID-19 pandemic. This is reflected in the decrease in reports of CB abundance on beaches. Additionally, the differentiation between sample collection zones by beach use area is a project contribution that has not been identified in the reviewed literature and allows for inferences on how beach management can affect the presence of cigarette butts and fibers in the sand.

3.1. Abundance of cigarette butts and fibers on the five study beaches

Fig. 4 shows the total number of units collected during the 12 campaigns carried out through transect collections (500 m^2) per use zone. In total, 29,983 units of cigarette butts and fibers were collected, with cigarette butts being the most abundant waste at 75.61 % of the total. This is important because marine debris has impacts on human health and marine fauna, as well as environmental, social, and economic impacts (Asensio-Montesinos et al., 2019). In several studies conducted on different beaches, it was determined that cigarette butts are commonly found and report high percentages of abundance within the marine litter. For instance, studies performed in Alicante, Spain, quantified marine litter abundance and determined that cigarette butts were a predominant waste, being more abundant in spring (45.61 %) and increasing in summer (61.62 %) (Asensio-Montesinos et al., 2019). Studies conducted in coastal environments in southern Spain show that the accumulation of cigarette butts (CB) during the summer months occurs despite the increased efforts of municipalities in beach cleaning operations. This suggests the need to promote educational initiatives and penalties to encourage beachgoers' responsibility. Another noteworthy finding of the study is that cigarette butts and other items are discarded indiscriminately by both national and international tourists, as well as individuals of various age groups and genders (Asensio-Montesinos et al., 2021). A study conducted on eight beaches in Brazil showed that cigarette butts account for over 30 % of marine litter, reaching a maximum of 44.9 % on some beaches (Araújo and Costa, 2021). An investigation performed on twenty beaches on the island of Cyprus in the Mediterranean during four seasons showed that of the 86.3 % (36,677 units) of identified plastic waste, 17 % (7225 units) were cigarette butts (Orthodoxou et al., 2022). The analysis of 2193 cigarette butts collected during the summer campaign on Los Santos Beach on the Brazilian coast showed that 1183 (53.9 %) were in an advanced state of degradation (Freire Lima et al., 2021).

According to Fig. 4, Bocagrande Beach in Cartagena, Colombia showed the highest abundance of cigarette butts for all monitoring events, while Peró Beach in Rio de Janeiro, Brazil reported the highest abundance of cigarette butt fibers. In all study beaches, the highest abundance is reported in the service zone, which can be attributed to the commercial use of the area, especially related to tourism and the urban beach characteristic. Another noteworthy fact is that the beach with the lowest reported abundance in both the active zone and the resting zone was Pehuen Co Beach in Buenos Aires, Argentina. This may be caused by the influence of fluctuating tides in these areas, which can transport CB and CBF to the sea or cover them with sediments. It is important to

Fig. 2. Location of active, rest, and services beach zones

review the abundance of waste generated on the beaches, with the aim of proposing effective mitigation measures to reduce or eliminate marine debris, in this case, measures applied to the reduction of the presence of cigarette butts on the beach sand (Currie and Stack, 2021). The study by Currie and Stack (2021) indicates that mitigation measures are performed through public policies on tobacco production mechanisms and consumption control, and other mitigation measures include environmental education campaigns regarding waste disposal. According to the authors and the study conducted before and after policies were implemented to control cigarette butt litter on Maui beaches in Hawaii, environmental education campaigns should be strengthened to prevent cigarette butt litter on beaches.

3.2. Density of cigarette butts in the study zones

Fig. 5a shows the density of cigarette butts (CB) found in each zone according to their use (i.e., active zone, rest zone, and service zone) on the five pilot beaches in Latin America in the four sampling quarters. The Bocagrande (CO) beach showed the highest densities of CB during the study months, reaching maximum values of up to 1.0 items/m^2. It should be noted that this study beach has a high influx of national and international tourism. The service zone reports the highest densities of CB, during the 12 months of monitoring, with a reported frequency incidence of higher values in 70 % of the study beaches. This can be attributed to the high cigarette consumption associated with the presence of bars, kiosks, and restaurants in the service area.

Regarding the Active zone in the beaches of Pehuen Co (ARG), Malecón (ECU), La Audiencia (MEX), and Peró (BRA), this zone is heavily influenced by tidal variations, where the waves could drag CB towards the sea and deposit sediments on the sand, making cigarette butts not visible on the surface and buried in the sand at depths deeper than 2 cm. This was evidenced in one of the samplings conducted on Pehuen Co (ARG) beach, where the collection was performed after a period of high tide and superficial cleaning of the sand. The removal of an approximate layer of 5 cm in thickness and a significant increase in the number of CB and CBF found in the active zone were observed.

Regarding the resting area, the density tends to have a wider range of variation in all countries, from 0.05 items/m^2 to 0.98 items/m^2. It should be noted that manual cleaning of waste is frequent in these areas, as it is the area where personnel providing rental services for chairs and tents are responsible for maintenance and cleaning of the sand. Another interesting fact is that on the beaches of Pehuen Co (ARG) and Peró (BRA), there are containers for cigarette butts in the beach access area. Another aspect found in the analysis is the variation in density found in different seasons of the year, which is attributed to different tourism flows, denoted as high and low tourism seasons. In the case of study beaches in Brazil and Argentina, the winter months (i.e., for Argentina, the months of July to August, and for Brazil, October to November, as shown in Fig. 5) also have an impact when the temperature drops significantly, and there is no influx of tourism.

The density of discarded cigarette butts in both urban environments and beaches has been the subject of interest in scientific research, according to (Ribeiro et al., 2022) in a study conducted in Brazil, where density conditions, contamination index, and discarded cigarette brands were evaluated. Determining CB density can provide interesting data for implementing reverse logistics actions aimed at improving the environment and contributing to sustainable and socially resilient cities. Additionally, in Brazil, previous studies conducted in 2007 reported the abundance of paper resulting from the decomposition of cigarette butts in Armação dos Búzios, Rio de Janeiro, Brazil (Oigman-Pszczol and

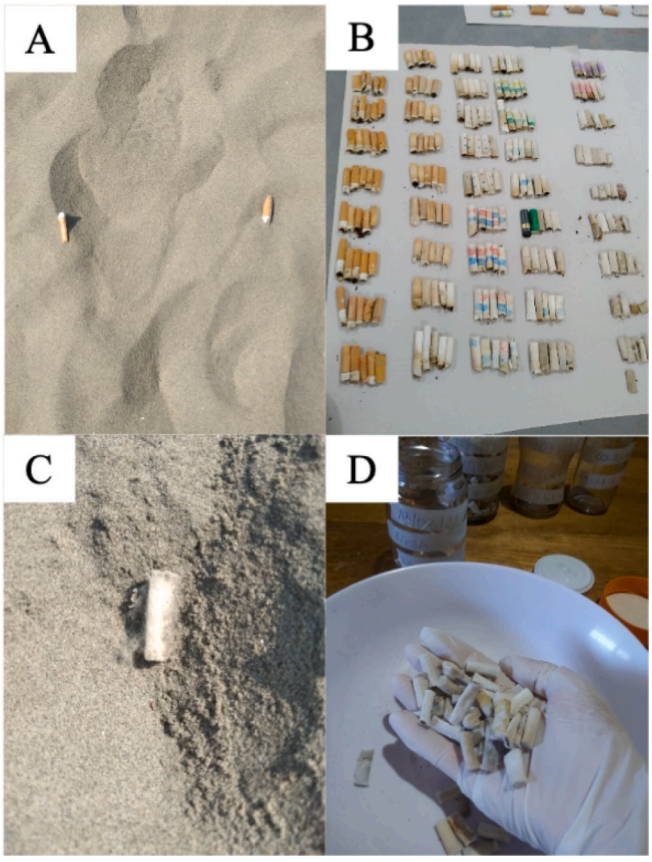

Fig. 3. CB and CBF samples in beach sand. A) Cigarette butts in beach sand, B) Method for quantifying cigarette butts (CB) in a laboratory, C) Fibers from cigarette butts (CBF) in beach sand, and D) Example of cigarette butt fiber (CBF) quantification in the laboratory.

Creed, 2007). In the estuarine system of Santos-Brazil, a high presence of cigarette butts was observed and was included as an independent sampling category. The reported densities ranged between 0.755 ± 0.32 items/m^2 and 0.041 ± 0.01 items/m^2 (Ribeiro et al., 2021a). Likewise, differences in densities of discarded cigarette butts have been reported on beaches in southeastern Brazil, while for this study, differences between seasons were reported as follows: fall 0.130 ± 0.052 items/m^2, winter 0.135 ± 0.232 items/m^2, spring 0.153 ± 0.079 items/m^2, and summer 0.283 ± 0.112 items/m^2 (Ribeiro et al., 2021). In the northeast of Brazil, a study was conducted to compare the abundance and density of cigarette butts disposed of in relation to other marine debris, including eight beaches, reporting a density of cigarette butts of 0.87 items/m^2 (Araújo and Costa, 2021). The results reported by the above studies and those of the current investigation in the 5 monitored beaches in Latin America show similarities in density, varying frequencies ranging from 0.02 items/m^2 to 1.0 items/m^2 fluctuating across different zones (Fig. 5b).

The study conducted in Iran shows that the average density of discarded cigarette butts on the study beaches was 0.106 units/m^2 (Yousefi Nasab et al., 2022). The reported CB density in the northern Persian Gulf ranged from 2 to 38 items/m^2 (Dobaradaran et al., 2018). In the study conducted on the Pacific coast of Costa Rica, 14 beaches were evaluated, obtaining different types of marine debris, including cigarette butts, with a density of 0.98 pieces/m^2. This study highlights the presence of persistent cellulose acetate residue and mentions the importance of including policy measures for controlling marine debris on beaches, as well as citizen science projects that support both cleanup campaigns and environmental awareness (Sibaja-Cordero and Gómez-Ramírez, 2022).

The abundance and densities of cigarette butts found on the study beaches indicate that this type of marine litter is present and persistent in many coastal areas around the world. Studies conducted in various regions have reported that cigarette butts are among the top 10 types of marine litter found in sampling surveys and are considered hazardous, as indicated by Bat et al. (2022) in their study of nine beaches along the Turkish Black Sea coast. Efforts have been made to raise awareness among the public about the risks associated with cigarette butts as hazardous marine litter. Citizen science projects have been used as a means to collect data and raise awareness about marine litter risks on beaches, as demonstrated by a study carried out by schoolchildren on three beaches along the Moroccan Mediterranean coast. Citizen science is highlighted as a means to collect data and raise awareness about marine litter risks on beaches (Bouzekry et al., 2022).

Cigarette butts (CBs) are made up of plastic cellulose acetate fibers. Approximately 15,000 fiber strands are used in the manufacturing process and then discarded in natural environments. However, the degradation times of CBs in different natural environments, their level of hazardousness, and their relationship to microplastics generated from CBs, which may contain toxic substances derived from the original product, are still under study (Shen et al., 2021). During the initial decomposition of CBs, the filter wrapping paper is lost through various mechanisms. According to Bonanomi et al. (2020), initial decomposition takes about 30 days, leaving the cellulose acetate exposed. Cellulose acetate is composed of multiple plasticized fibers that decompose more slowly, losing approximately 66 % of their initial mass after 2 years. The study conducted by Joly and Coulis (2018) estimates that it takes between 7.5 years in compost and 14 years in soil for cellulose acetate to degrade completely. Research has been conducted on the toxicity and effects of cigarette butts (CBs) and cigarette butt fibers (CBFs), but there is still a need for more information on the broader impact of the presence of CBFs in environments. For instance, a study reported that the cellulose acetate microfibers present in leachate from smoked cigarette butts were more toxic to water fleas, with a 50 % immobilization rate (i.e., as an indicator of mortality) compared to CBs (Green et al., 2022). Despite the potential for contamination from cigarette butt fibers, they are not separated into a separate category in studies evaluating marine litter abundance and are counted as part of CBs.

3.3. Density of cigarette butts fibers in the study zones

In Fig. 6a, the density of CBF found in each of the designated study zones, active zone, rest zone, and service zone, is shown. The lowest density of CBF reported for all countries was in the active zone, with a maximum of 0.09 items/m^2. It should be noted that this zone is the closest to the sea and may be influenced by tide phenomena in some beaches that could carry CBF into the sea or leave them covered by sediments not easily identifiable by observation. Additionally, this zone receives more significant influence from sea-transported winds, which could affect the transport of CBF to other areas. Peró beach (BRA) reports the highest densities in the rest and service zones, with maximums between 0.53 items/m^2 and 0.77 items/m^2, respectively. Similarly, the beaches in Mexico, Ecuador, and Argentina present CBF densities lower than 0.1 items/m^2 in all study zones. Fig. 6b shows the frequency histogram for all the studied zones, revealing the highest density of CBF in the service area with values ranging from 0.01 to 0.14 items per square meter compared to all the other study beaches. The authors recognize the importance of conducting further research aimed at determining the abundance, density, and environmental factors that may lead to the faster decomposition of CB into CBF. This is considering the risk posed by the leaching of toxic compounds from CBF, as well as the degree of impact it may have on the persistence of microplastics derived from the plastic cellulose acetate of CBF.

Table 2 shows the cigarette butt pollution index (CBPI) obtained for the five study beaches. Additionally, the study included the analysis of the cigarette butt fiber pollution index (CBFPI), which is reported for the

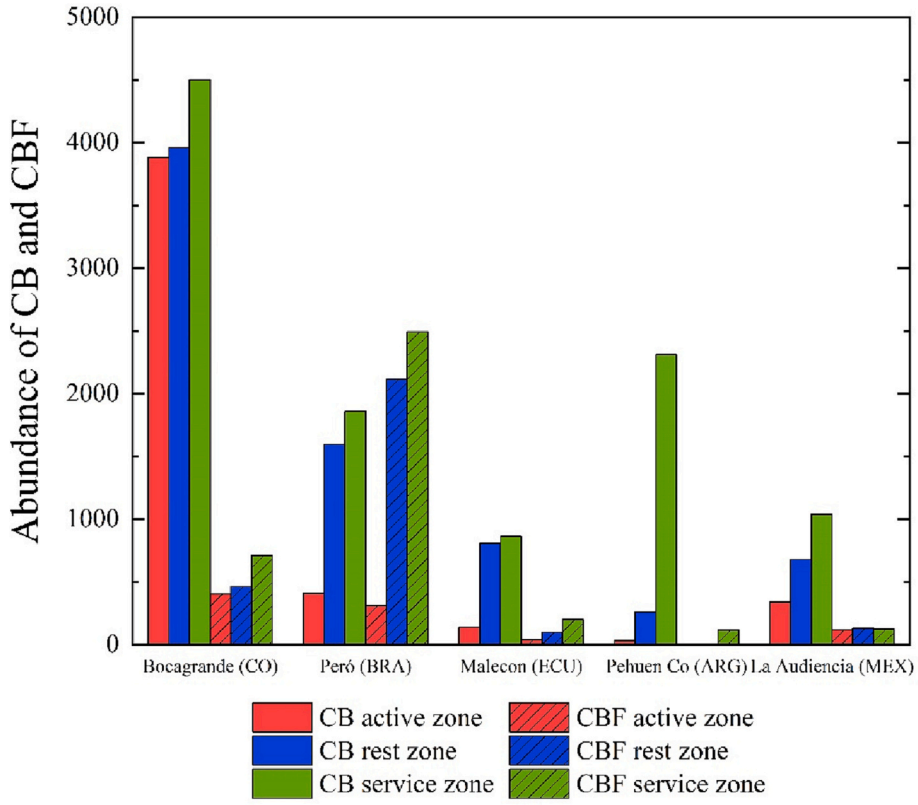

Fig. 4. Abundance of cigarette butts and fibers on the study beaches.

first time in a beach study considering the usage zones defined in this study. The Colombia beach presents the highest calculated values of CBPI, classified as severe pollution without distinction by usage zone. Furthermore, another remarkable fact is that the other study beaches show classification from significant to severe pollution in the rest and service zones. These results are similar to those reported in the literature for the three study beaches in the coastal area of the Caspian Sea, where pollution was severe to high (Yousefi Nasab et al., 2022). This is an important result because it shows the degree of danger represented by this highly abundant waste in coastal environments.

Regarding cigarette butt fibers, contamination is low in most of the study beaches, except for Brazil beach, where the reported classification is significant to high contamination. These data are important for future analysis and research, as cigarette butt fibers retain the hazardous nature of the material they originate from and can lead to toxicity in ecosystems (Green et al., 2022).

Studies reported in the literature more frequently show abundance in terms of the number of CB units found; however, observing both the number and weight of CB allows for a better understanding of the importance of this waste within the marine litter and its contribution to coastal zone pollution, which is necessary for establishing management strategies. The increase in abundance of discarded CB in different environments allows for estimating that the weight of CB in the world would reach 1.2 million tons per year, and according to various parameters such as world population growth, the rate of CB waste would increase by 50 % in 2025 (Torkashvand et al., 2020).

3.4. Cigarette butt pollution index (CBPI)

Fig. 7 shows a comparison between the unit weights of CB and CBF collected, indicating a trend towards a weight of approximately 0.25 g per cigarette butt unit in all countries. This finding is similar to the results obtained in the study conducted during 2015–2016 in 8 beach sites along the whole Bulgarian Black Sea coastline, where the reported weight was approximately 0.38 ± 0.158 g per CB unit (Simeonova and Chuturkova, 2019). In the report conducted along the Gulf of Nicoya, Costa Rica, an approximate weight of 0.20 g per CB unit was found (Sibaja-Cordero and Gómez-Ramírez, 2022). The reported data show slight variations that should take into account conditions such as the presence of nicotine residues, cigarette brand, and moisture absorption conditions in the environment where the CBs were discarded.

The weight variations per unit of CBF shown in Fig. 7 indicate similarities in the beaches of Colombia, Brazil, and Ecuador, with an approximate weight of 0.15 g per fiber unit, while Mexico reports the highest weight values at approximately 0.25 g per fiber unit. A reference value was not found in the literature, as most of the reviewed studies include reports in the same category for CB and CBF. It is important to conduct research that identifies environmental factors associated with the mass loss of cigarette butts, as this loss is part of the initial decomposition process, and both residues can generate different potential toxicities. The total weight of CB collected on all beaches during the project was 5881.9 g, and the total weight of CBF was 1222.5 g. The weight data obtained in the present study are interesting to understand the potential toxicity that may be present on beaches. While there is no direct correlation between weight and toxicity, the literature identifies the ecotoxicological potential of smoked cigarette butts. Toxic consequences of cigarette butt waste have been described that can affect human health, such as accidental ingestion by children playing on the beach. Nicotine ecotoxicity in children has been reported to cause immediate symptoms of nausea and vomiting, with an estimated lethal pediatric dose of 1.0 mg/kg body weight (Vanapalli et al., 2023). The toxicity generated in some species such as *P. waltoni* has been investigated, where LC50 values were determined to be 3.75, 3, 1.94, and 1.37 CBs/L at 24, 48, 72, and 96 h, respectively (Soleimani et al., 2023).

The authors indicate that these mass data should be studied to obtain information that can contribute to the management of containers to be installed for CB collection, including their capacity, materials, and the sites where they should be located. Similarly, this would provide useful

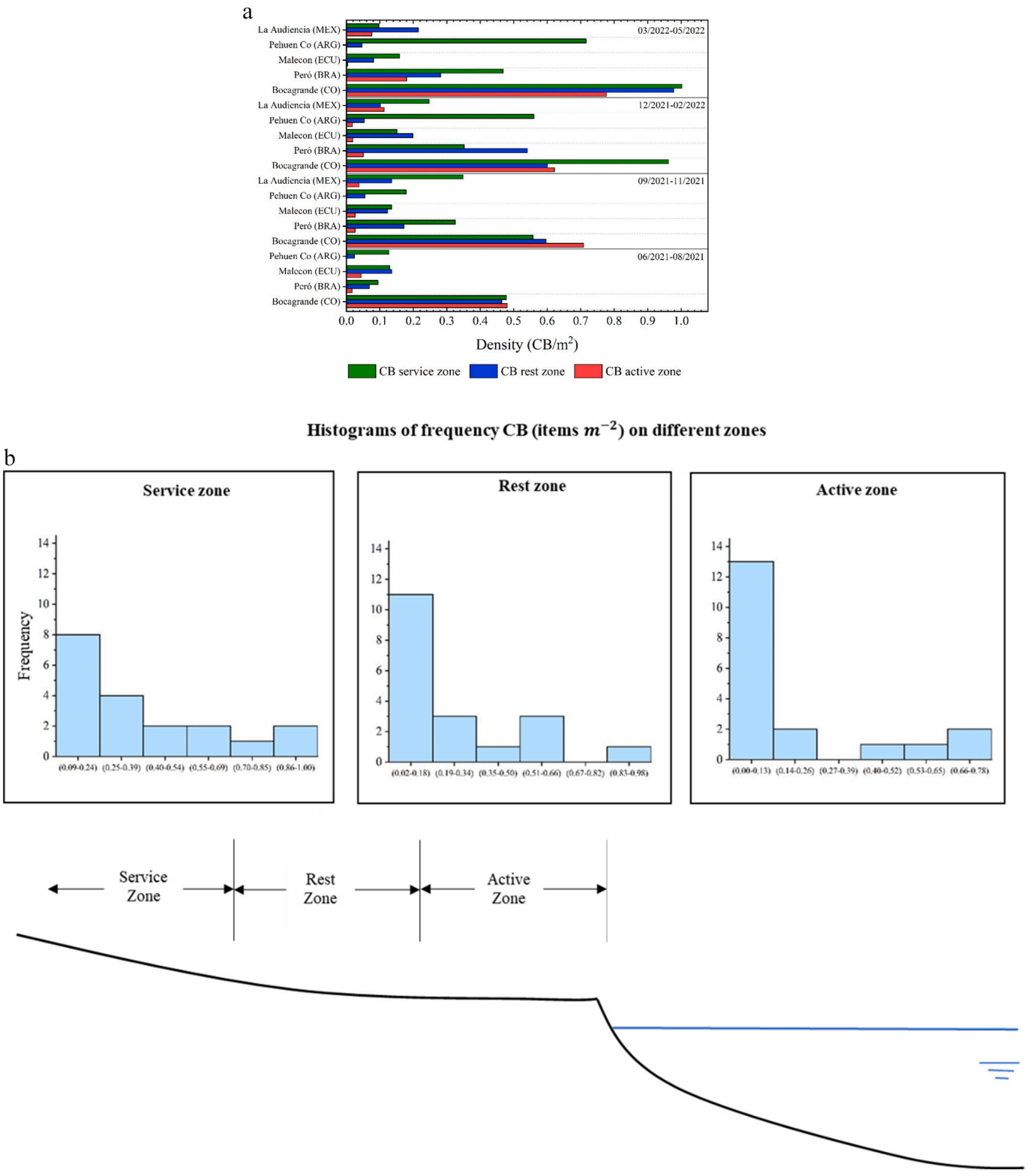

Fig. 5. a. Comparison of cigarette butt densities on the study beaches.
b. Frequency histograms of cigarette butt densities on the service, rest, and active zones of the study beaches.

information for estimating the potential for recovering CB and CBF for circular economy projects. In the case of cigarette butts, due to their high abundance in beach ecosystems, their high persistence, and their known toxic effects, it is necessary to try to establish recycling mechanisms, despite their difficult collection once they have been discarded in the sand. Research on CB recycling methods into solid materials used in industrial sectors such as construction, energy, environment, and chemistry is known in the literature. Some examples of their use in construction include the production of fired bricks, asphalt and precast concrete paving, and ceramic tiles with minimal leaching risks (Conradi and Sánchez-Moyano, 2022).

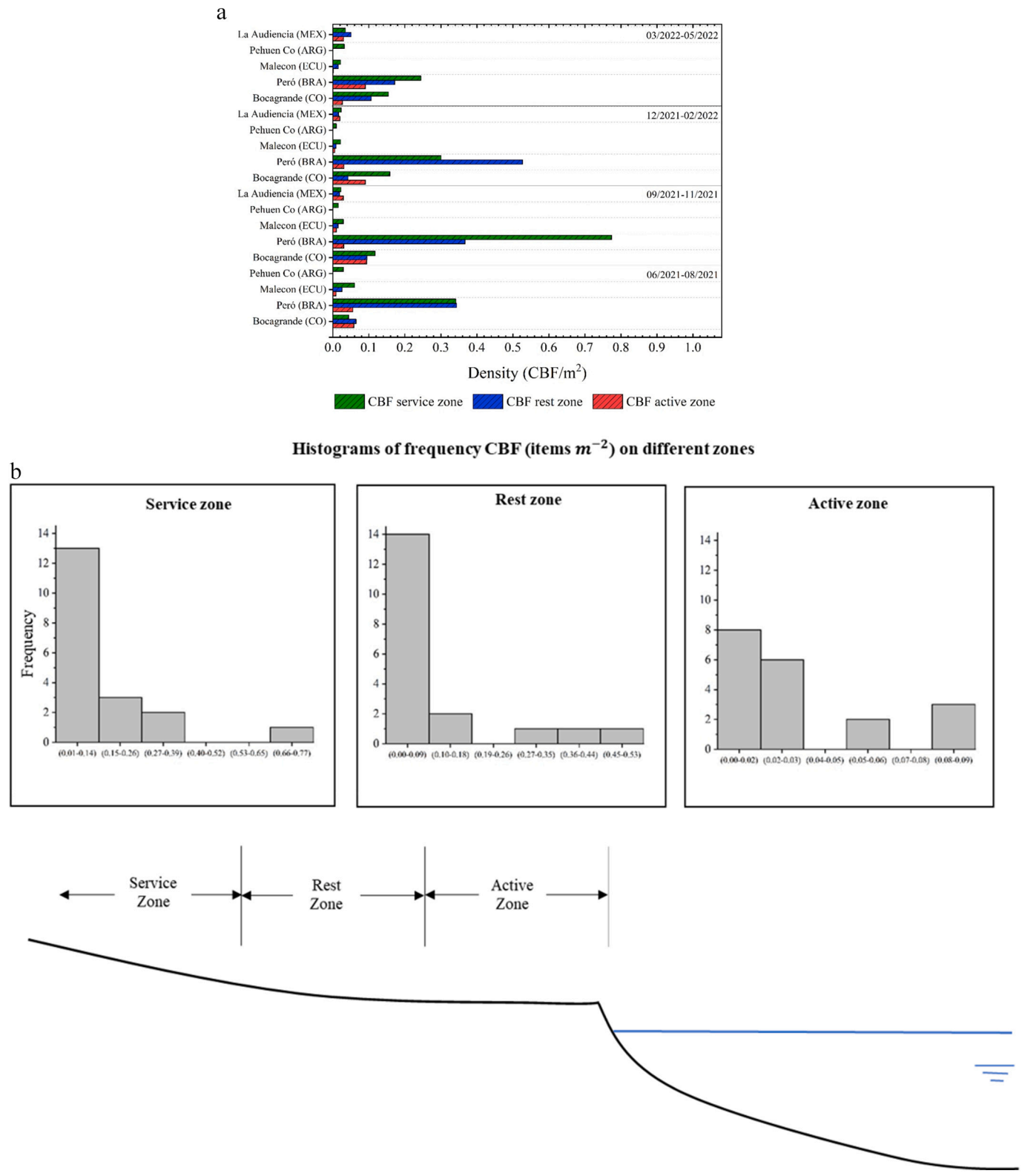

Fig. 6. a. Comparison of cigarette butt fibers densities on the study beaches.
b. Frequency histograms of cigarette butt fiber densities on the service, rest, and active zones of the study beaches.

4. Conclusions

The study conducted on five pilot beaches in Latin America compared the abundance and density of discarded CB and CBF on the sand, including study areas according to their use, evaluating the active zone, resting zone, and service zone. The highest abundance of CB on the sand was found on Bocagrande (CO) beach, while the highest abundance of CBF was reported on Peró (BRA). The mean density of cigarette butts varies between 0.6 items/m^2 and 0.1 items/m^2, showing a classification according to the Cigarette Butt Pollution Index (CBPI) of severe to

Table 2
Calculation of CBPI and CBFPI in study beaches.

Beach	Zone	CB average density (item/m^2)	CBPI	Classification Torkashvand et al., 2021	CBF average density (item/m^2)	CBFPI	Classification Torkashvand et al., 2021
Bocagrande (CO)	Active	0.647	12.9	Severe pollution	0.067	1.3	Low pollution
	Resting	0.660	13.2	Severe pollution	0.077	1.5	Low pollution
	Service	0.750	15.0	Severe pollution	0.119	2.4	Low pollution
Peró (BRA)	Active	0.068	1.4	Low pollution	0.052	1.0	Very low pollution
	Resting	0.266	5.3	Significant pollution	0.352	7.0	Significant pollution
	Service	0–310	6.2	Significant pollution	0.415	8.3	High pollution
Malecón (ECU)	Active	0.023	0.5	Very low pollution	0.007	0.1	Very low pollution
	Resting	0.135	2.7	Pollution	0.016	0.3	Very low pollution
	Service	0.144	2.9	Pollution	0.033	0.7	Very low pollution
Pehuen Co (ARG)	Active	0.005	0.1	Very low pollution	0.000	0.0	Very low pollution
	Resting	0.045	0,9	Very low pollution	0.000	0.0	Very low pollution
	Service	0.396	7.9	High pollution	0.022	0.4	Very low pollution
La Audiencia (MEX)	Active	0.076	1.5	Low pollution	0.026	0.5	Very low pollution
	Resting	0.151	3.0	Pollution	0.028	0.6	Very low pollution
	Service	0.231	4.6	Pollution	0.027	0.5	Very low pollution

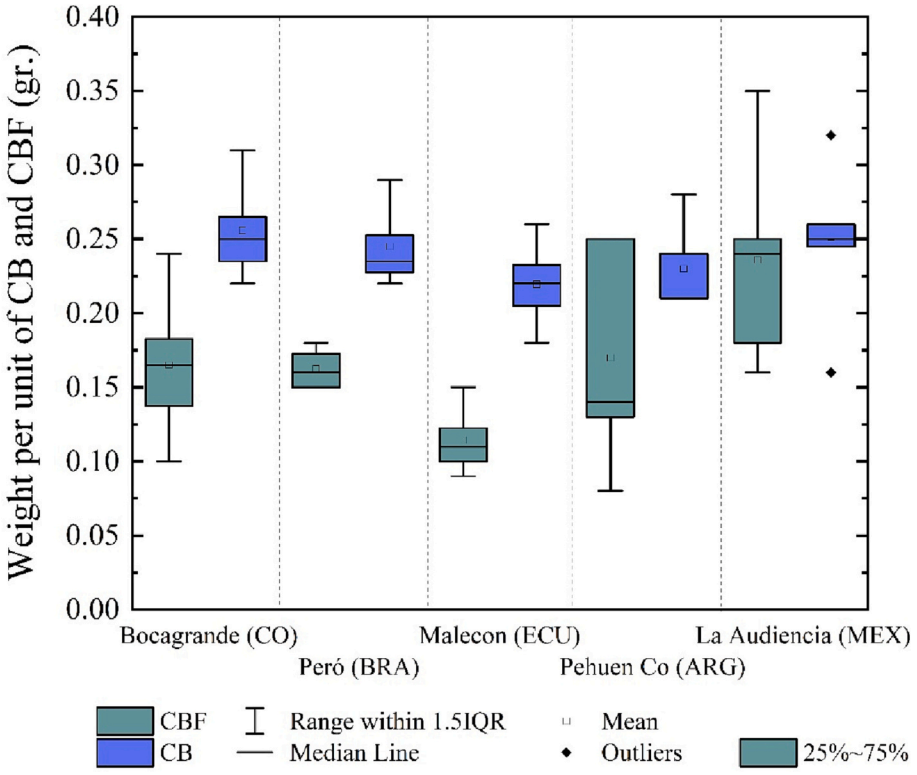

Fig. 7. Comparison of weight per unit of CB and CBF on the study beaches.

significant pollution on some beaches. As for CBF pollution, it is considered low in all countries except Peró (BRA), where the density is high, averaging between 0.3 and 0.4 items/m^2. The authors consider that further research should be conducted to establish comparisons between environmental factors that influence the persistence of CB and CBF on beaches. It is recommended to include CBF as an independent category in the sampling categories due to the persistence of cellulose acetate fibers over time in beach ecosystems, and both CB and CBF should be considered in decision-making on beach management, whether in terms of policies for smoke-free areas or the management of devices for separate collection of CB and CBF. Discarded cigarette butts and fibers in marine environments are a topic that should generate new research aimed at establishing education and environmental awareness mechanisms that prevent the disposal of these persistent and hazardous wastes, which represent a risk to the health of users and the biota of the ecosystem. As a final recommendation, it is considered necessary to continue with this type of study to determine if there are significant changes in the abundance and density of CB and CBF in periods following the COVID-19 pandemic, as there are currently no usage restrictions on beaches.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

Ansari, M., Farzadkia, M., 2022. Beach debris quantity and composition around the world: a bibliometric and systematic review. Mar. Pollut. Bull. 178, 113637 https://doi.org/10.1016/j.marpolbul.2022.113637.

Araújo, M.C.B., Costa, M.F., 2019. A critical review of the issue of cigarette butt pollution in coastal environments. Environ. Res. 172, 137–149. https://doi.org/10.1016/j.envres.2019.02.005.

Araújo, M.C.B. de, Costa, M.F. da, 2021. Cigarette butts in beach litter: snapshot of a summer holiday. Mar. Pollut. Bull. 172, 112858 https://doi.org/10.1016/j.marpolbul.2021.112858.

Araújo, M.C.B., Costa, M.F., Silva-Cavalcanti, J.S., Duarte, A.C., Reis, V., Rocha-Santos, T.A., da Costa, J.P., Girão, V., 2022. Different faces of cigarette butts, the most abundant beach litter worldwide. Environ. Sci. Pollut. Res. 29 (32), 48926–48936. https://doi.org/10.1007/s11356-022-19134-w.

Asensio-Montesinos, F., Anfuso, G., Williams, A.T., 2019. Beach litter distribution along the western Mediterranean coast of Spain. Mar. Pollut. Bull. 141, 119–126. https://doi.org/10.1016/j.marpolbul.2019.02.031.

Asensio-Montesinos, F., Anfuso, G., Ramírez, M.O., Smolka, R., Sanabria, J.G., Enríquez, A.F., Arenas, P., Bedoya, A.M., 2020. Beach litter composition and distribution on the Atlantic coast of Cádiz (SW Spain). Reg. Stud. Mar. Sci. 34, 101050 https://doi.org/10.1016/j.rsma.2020.101050.

Asensio-Montesinos, F., Oliva Ramírez, M., Aguilar-Torrelo, M.T., Anfuso, G., 2021. Abundance and distribution of cigarette butts on coastal environments: examples from Southern Spain. J. Mar. Sci. Eng. 9 (2), 129. https://doi.org/10.3390/jmse9020129.

Bat, L., Öztekin, A., Öztürk, D.K., Gürbüzer, P., Özsandıkçı, U., Eyüboğlu, B., Öztekin, H. C., 2022. Beach litter contamination of the Turkish middle Black Sea coasts: spatial and temporal variation, composition, and possible sources. Mar. Pollut. Bull. 185, 114248 https://doi.org/10.1016/j.marpolbul.2022.114248.

Bonanomi, G., Maisto, G., De Marco, A., Cesarano, G., Zotti, M., Mazzei, P., Libralato, G., Staropoli, A., Siciliano, A., De Filippis, F., La Storia, A., Piccolo, A., Vinale, F., Crasto, A., Guida, M., Ercolini, D., Incerti, G., 2020. The fate of cigarette butts in different environments: decay rate, chemical changes and ecotoxicity revealed by a 5-years decomposition experiment. Environ. Pollut. 261, 114108 https://doi.org/10.1016/j.envpol.2020.114108.

Bouzekry, A., Mghili, B., Aksissou, M., 2022. Addressing the challenge of marine plastic litter in the Moroccan Mediterranean: a citizen science project with schoolchildren. Mar. Pollut. Bull. 184, 114167 https://doi.org/10.1016/j.marpolbul.2022.114167.

Conradi, M., Sánchez-Moyano, J.E., 2022. Toward a sustainable circular economy for cigarette butts, the most common waste worldwide on the coast. Sci. Total Environ. 847, 157634 https://doi.org/10.1016/j.scitotenv.2022.157634.

Currie, J.J., Stack, S.H., 2021. Getting butts off the beach: policy alone is not effective at reducing cigarette filter litter on beaches in Maui, Hawai'i. Mar. Pollut. Bull. 173, 112937 https://doi.org/10.1016/j.marpolbul.2021.112937.

Dobaradaran, S., Schmidt, T.C., Nabipour, I., Ostovar, A., Raeisi, A., Saeedi, R., Khorsand, M., Khajeahmadi, N., Keshtkar, M., 2018. Cigarette butts abundance and association of mercury and lead along the Persian Gulf beach: an initial investigation. Environ. Sci. Pollut. Res. 25 (6), 5465–5473. https://doi.org/10.1007/s11356-017-0676-9.

Federigi, I., Balestri, E., Castelli, A., De Battisti, D., Maltagliati, F., Menicagli, V., Verani, M., Lardicci, C., Carducci, A., 2022. Beach pollution from marine litter: analysis with the DPSIR framework (driver, pressure, state, impact, response) in Tuscany, Italy. Ecol. Indic. 143, 109395 https://doi.org/10.1016/j.ecolind.2022.109395.

Freire Lima, C., dos Santos, Amaral, Pinto, M., Brasil Choueri, R., Buruaem Moreira, L., Braga Castro, Í., 2021. Occurrence, characterization, partition, and toxicity of cigarette butts in a highly urbanized coastal area. Waste Manag. 131, 10–19. https://doi.org/10.1016/j.wasman.2021.05.029.

Fruergaard, M., Laursen, S.N., Larsen, M.N., Posth, N.R., Niebe, K.B., Bentzon-Tarp, A., Svenningsen, S.K., Acevedo, N., Trinh, B.-S., Tran-Thi, P.T., Doan-Nhu, H., Nguyen-Ngoc, L., Andersen, T.J., 2023. Abundance and sources of plastic debris on beaches in a plastic hotspot, Nha Trang. Viet Nam. Mar. Pollut. Bull. 186, 114394 https://doi.org/10.1016/j.marpolbul.2022.114394.

Gaibor, N., Condo-Espinel, V., Cornejo-Rodríguez, M.H., Darquea, J.J., Pernia, B., Domínguez, G.A., Briz, M.E., Márquez, Lady, Laaz, E., Alemán-Dyer, C., Avendaño, U., Guerrero, J., Preciado, M., Honorato-Zimmer, D., Thiel, M., 2020. Composition, abundance and sources of anthropogenic marine debris on the beaches from Ecuador – a volunteer-supported study. Mar. Pollut. Bull. 154, 111068 https://doi.org/10.1016/j.marpolbul.2020.111068.

García Sánchez, A., Alburquerque García, F.J., 2003. EL TURISMO CULTURALY EL DE SOLY PLAYA: ¿SUSTITUTIVOS O COMPLEMENTARIOS? Cuad. Tur. 11, 97–106. Recuperado a partir de. https://revistas.um.es/turismo/article/view/19581.

Green, D.S., Tongue, A.D.W., Boots, B., 2022. The ecological impacts of discarded cigarette butts. Trends Ecol. Evol. 37 (2), 183–192. https://doi.org/10.1016/j.tree.2021.10.001.

Hidalgo-Ruz, V., Honorato-Zimmer, D., Gatta-Rosemary, M., Nuñez, P., Hinojosa, I.A., Thiel, M., 2018. Spatio-temporal variation of anthropogenic marine debris on Chilean beaches. Mar. Pollut. Bull. 126, 516–524. https://doi.org/10.1016/j.marpolbul.2017.11.014.

Joly, F.-X., Coulis, M., 2018. Comparison of cellulose vs. plastic cigarette filter decomposition under distinct disposal environments. Waste Manag. 72, 349–353. https://doi.org/10.1016/j.wasman.2017.11.023.

Kataržytė, M., Balčiūnas, A., Haseler, M., Sabaliauskaitė, V., Lauciūtė, L., Stepanova, K., Nazzari, C., Schernewski, G., 2020. Cigarette butts on Baltic Sea beaches: monitoring, pollution and mitigation measures. Mar. Pollut. Bull. 156, 111248 https://doi.org/10.1016/j.marpolbul.2020.111248.

Kiruba-Sankar, R., Saravanan, K., Adamala, S., Selvam, K., Kumar, K.L., Praveenraj, J., 2023. First report of marine debris in Car Nicobar, a remote oceanic Island in the Nicobar archipelago, Bay of Bengal. Reg. Stud. Mar. Sci. 61, 102845 https://doi.org/10.1016/j.rsma.2023.102845.

Loizidou, X.I., Loizides, M.I., Orthodoxou, D.L., 2018. Persistent marine litter: small plastics and cigarette butts remain on beaches after organized beach cleanups. Environ. Monit. Assess. 190 (7), 414. https://doi.org/10.1007/s10661-018-6798-9.

Lucia, G., Giuliani, M.E., d'Errico, G., Booms, E., Benedetti, M., Di Carlo, M., Fattorini, D., Gorbi, S., Regoli, F., 2023. Toxicological effects of cigarette butts for marine organisms. Environ. Int. 171, 107733 https://doi.org/10.1016/j.envint.2023.107733.

MacPhail, V.J., Colla, S.R., 2020. Power of the people: a review of citizen science programs for conservation. Biol. Conserv. 249, 108739 https://doi.org/10.1016/j.biocon.2020.108739.

Mejjad, N., Rossi, A., Pavel, A.B., 2022. The coastal tourism industry in the Mediterranean: a critical review of the socio-economic and environmental pressures & impacts. Tour. Manag. Perspect. 44, 101007 https://doi.org/10.1016/j.tmp.2022.101007.

Ocean Conservancy, 2022. Trash Free Seas: Cleanup Reports - Ocean Conservancy. https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/annual-data-release/.

Oigman-Pszczol, S.S., Creed, J.C., 2007. Quantification and classification of marine litter on beaches along armaçao˜dos búzios, Rio de Janeiro, Brazil. J. Coast. Res. 23, 421–428. https://doi.org/10.2112/1551-5036(2007)23[421:QACOML]2.0.CO;2.

Orthodoxou, D.L., Loizidou, X.I., Baldwin, C., Kocareis, C., Karonias, A., Ateş, M.A., 2022. Seasonal and geographic variations of marine litter: a comprehensive study from the island of Cyprus. Mar. Pollut. Bull. 177, 113495 https://doi.org/10.1016/j.marpolbul.2022.113495.

Perumal, K., Muthuramalingam, S., Chellaiyan, S., 2023. Marine litter on the beaches of the Kanyakumari, Southern India: an assessment of their abundance and pollution indices. Mar. Pollut. Bull. 186, 114443 https://doi.org/10.1016/j.marpolbul.2022.114443.

Qamar, W., Abdelgalil, A.A., Aljarboa, S., Alhuzani, M., Altamimi, M.A., 2020. Cigarette waste: assessment of hazard to the environment and health in Riyadh city. Saudi J. Biol. Sci. 27 (5), 1380–1383. https://doi.org/10.1016/j.sjbs.2019.12.002.

Quéméneur, M., Chifflet, S., Akrout, F., Bellaaj-Zouari, A., Belhassen, M., 2020. Impact of cigarette butts on microbial diversity and dissolved trace metals in coastal marine sediment. Estuar. Coast. Shelf Sci. 240, 106785.

Rangel-Buitrago, N., Williams, A.T., Neal, W.J., Gracia, C., A., & Micallef, A., 2022. Litter in coastal and marine environments. Mar. Pollut. Bull. 177, 113546 https://doi.org/10.1016/j.marpolbul.2022.113546.

Ribeiro, V.V., Pinto, M.A.S., Mesquita, R.K.B., Moreira, L.B., Costa, M.F., Castro, Í.B., 2021. Marine litter on a highly urbanized beach at Southeast Brazil: a contribution to the development of litter monitoring programs. Mar. Pollut. Bull. 163, 111978 https://doi.org/10.1016/j.marpolbul.2021.111978.

Ribeiro, V.V., Lopes, T.C., dos Santos, Amaral, Pinto, M., Póvoa, A.A., Corrêa, V.R., De-la-Torre, G.E., Dobaradaran, S., Green, D.S., Szklo, A.S., Castro, Í.B., 2022. Cigarette butts in two urban areas from Brazil: links among environmental impacts, demography and market. Environ. Res. 213, 113730 https://doi.org/10.1016/j.envres.2022.113730.

Rodella, I., Madau, F., Mazzanti, M., Corbau, C., Carboni, D., Utizi, K., Simeoni, U., 2019. Willingness to pay for management and preservation of natural, semi-urban and urban beaches in Italy. Ocean Coast. Manag. 172, 93–104. https://doi.org/10.1016/j.ocecoaman.2019.01.022.

Santos-Echeandía, J., Zéler, A., Gago, J., Lacroix, C., 2021. The role of cigarette butts as vectors of metals in the marine environment: could it cause bioaccumulation in oysters? J. Hazard. Mater. 416, 125816 https://doi.org/10.1016/j.jhazmat.2021.125816.

Shen, M., Li, Y., Song, B., Zhou, C., Gong, J., Zeng, G., 2021. Smoked cigarette butts: unignorable source for environmental microplastic fibers. Sci. Total Environ. 791, 148384 https://doi.org/10.1016/j.scitotenv.2021.148384.

Shirk, J.L., Ballard, H.L., Wilderman, C.C., Phillips, T., Wiggins, A., Jordan, R., McCallie, E., Minarchek, M., Lewenstein, Bruce C., Krasny, M.E., Bonney, R., 2012. Public participation in scientific research: a framework for intentional design. Ecol. Soc. 17, 29. https://doi.org/10.5751/ES-04705-170229.

Sibaja-Cordero, J.A., Gómez-Ramírez, E.H., 2022. Marine litter on sandy beaches with different human uses and waste management along the Gulf of Nicoya, Costa Rica. Mar. Pollut. Bull. 175, 113392 https://doi.org/10.1016/j.marpolbul.2022.113392.

Simeonova, A., Chuturkova, R., 2019. Marine litter accumulation along the Bulgarian Black Sea coast: categories and predominance. Waste Manag. 84, 182–193. https://doi.org/10.1016/j.wasman.2018.11.001.

Smit, R.A., Garritsen, H.H., Kunst, A.E., Rozema, A.D., 2023. The impact of smoke-free policies on smoking at outdoor sports clubs: a qualitative study. Public Health 214, 25–30. https://doi.org/10.1016/j.puhe.2022.10.020.

Soleimani, F., Dobaradaran, S., Vazirizadeh, A., Mohebbi, G., Ramavandi, B., De-la-Torre, G.E., Nabipour, I., Schmidt, T.C., Novotny, T.E., Maryamabadi, A., Kordrostami, Z., 2023. Chemical contents and toxicity of cigarette butts leachates in aquatic environment: a case study from the Persian Gulf region. Chemosphere 311, 137049. https://doi.org/10.1016/j.chemosphere.2022.137049.

Torkashvand, J., Farzadkia, M., Sobhi, H.R., Esrafili, A., 2020. Littered cigarette butt as a well-known hazardous waste: a comprehensive systematic review. J. Hazard. Mater. 383, 121242 https://doi.org/10.1016/j.jhazmat.2019.121242.

Torkashvand, J., Godini, K., Jafari, A.J., Esrafili, A., Farzadkia, M., 2021. Assessment of littered cigarette butt in urban environment, using of new cigarette butt pollution

index (CBPI). Sci. Total Environ. 769, 144864 https://doi.org/10.1016/j.scitotenv.2020.144864.

Valdemoro, H.I., Jiménez, J.A., 2006. The influence of shoreline dynamics on the use and exploitation of Mediterranean tourist beaches. Coast. Manag. 34 (4), 405–423. https://doi.org/10.1080/08920750600860324.

Vanapalli, K.R., Sharma, H.B., Anand, S., Ranjan, V.P., Singh, H., Dubey, B.K., Mohanty, B., 2023. Cigarettes butt littering: the story of the world's most littered item from the perspective of pollution, remedial actions, and policy measures. J. Hazard. Mater. 453, 131387 https://doi.org/10.1016/j.jhazmat.2023.131387.

Wiggins, A., Crowston, K., 2011. From conservation to crowdsourcing: a typology of citizen science. In: Proceedings of the 44th Hawaii International Conference on System Sciences - 2011. IEEE, pp. 1–10.

Yousefi Nasab, A., Oskoei, V., Rezanasab, M., Alinejad, N., Hosseinzadeh, A., Kashi, G., 2022. Cigarette butt littering consequences: a study of pollution rate on beaches and urban environments. Environ. Sci. Pollut. Res. 29 (30), 45396–45403. https://doi.org/10.1007/s11356-022-19155-5.