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Seasonal Influence on Environmental Indicators of Beach Waste

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***Abstract*—**The environmental indicators and the classification of beach waste are essential tools to diagnose the current situation and to indicate ways to improve the quality of this environment. The purpose of this paper was to perform a quali-quantitative analysis of the beach waste on the Curva da Jurema Beach (Espírito Santo - Brazil). Three transects were used with equidistant positioning over the total length of the beach for the solid waste collection. Solid wastes were later classified according to their use and primary raw material from the low and high summer season. During the low season, average values of 7.10 items.m^{-1}, 18.22 g.m^{-1} and 0.91 g.m^{-2} were found for the whole beach, and transect 3 contributed the most waste, with the total sum of items equal to 999 (49%), a total mass of 5.62 kg and a total volume of 21.31 L. During the high summer season, average values of 8.22 items.m^{-1}, 54.40 g.m^{-1} and 2.72 g.m^{-2} were found, with transect 2 contributing the most to the total sum with 1,212 items (53%), a total mass of 10.76 kg and a total volume of 51.99 L. Of the total collected, plastic materials represented 51.4% of the total number of items, 35.9% of the total mass and 68% of the total volume. The implementation of reactive and proactive measures is necessary so that the management of the solid wastes on Curva da Jurema Beach is in accordance with principles of sustainability.

***Keywords*—**Beach solid waste, environmental indicators, quali-quantitative analysis, waste management.

I. Introduction

A large portion of the global population lives in coastal zones within 100 km of the coast, and the trend indicates an increase in this demographic concentration [2]. According to [8], sandy beaches are an important element of the coastal ecosystems where sea and land interact and create complex bio-geochemical processes.

Reference [1] warned about the growth of areas with litter accumulation due to inappropriate disposal, inefficient municipal planning and collection systems linked to public policies that do not stimulate reusing and recycling. Degradation of the coastal areas by human activity is a problem that has been recognized worldwide [3].

Urban beaches are affected by different anthropogenic pressures: wastewater discharges, tourism, resources exploitation, increasing number of human inhabitants, urbanization, industry development, recreation uses, beach cleaning, beach nourishment, pollution, exploitation, invasive species, coastal development, and mining or global change [8]. Reference [5] highlights that beach loses its functionality of leisure and recreation when its natural elements represent a risk for the health of beach users.

Brazil has 7,408 km of coastline and approximately 442 million km^2 of coastal zones. The appropriate collection and disposal of solid wastes is the responsibility of the municipalities (Items I and V of art. 30) [4]. However, the conscious participation of the population is essential because if waste is disposed of in an orderly manner by the bathers, this practice can then streamline the cleaning process and inspire the routine service [6].

Solid waste depositing on the beach can vary spatially and temporally and understanding of this variability can assist waste managers to take appropriate actions to improve the quality of this environment [18]. The variables that constitute the different quality schemes of tourist beaches are very varied, and define a pattern approach to determine the state of a beach can be challenging [5].

Environmental indicators of beach waste can be used for better waste management on land and at sea, additionally can also stimulate public participation in the activities related to the maintenance of environmental quality, such as coastal cleanup activities [14].

The state of Espírito Santo, with 456 km of coastline and the largest population growth rate among the states of Southeastern Brazil, is extremely deficient in data related to pollution by solid wastes in this type of environment. This lack of documentation justifies the characterization of solid beach wastes as a tool for the determination of potential risks inherent to the fractions that make up these wastes, enabling the implementation of measures that favor a new approach to this issue: seeking preventive measures [1].

The Municipal Urban Cleaning Code of Vitória (capital of state of Espírito Santo) defines public wastes as being the solid wastes from urban cleaning performed on public areas and roads from the conservation of clean roads, beaches, swimming areas, public bathrooms, viaducts, green areas, parks and other public areas as well as commonly used goods of the municipalities, among others [12].

The aim of this work was to evaluate the qualitative and quantitative analysis (linear and by areas of the beach) of solid waste collected, and classify the sampled stretches and all of the studied beach.

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II. Study Area

Curva da Jurema Beach (20º18'52" S and 40º19'06" W) is situated in the city of Vitória, capital of the State of Espírito Santo (Brazil), located between the Enseada do Suá and Ilha do Boi districts. Curva da Jurema Beach is a 100% urban and artificial beach, with coconut and Brazil nut trees, small bars and gentle waves, which attracts tourists even from other states.

During the high summer season months (mainly January and February), this location shows a significant increase in the number of bathers and is thus recognized as a major tourist attraction with great potential for various nautical sports (jet skiing, boating and sailing), in addition to being the stage for regional and national events.

III. Materials and Methods

A. Environmental Indicators of Beach Waste in the Curva da Jurema Beach

The first visit to the Curva da Jurema Beach took place to become familiar with the location and the workers involved in the cleaning process. Additionally, contact was made with the Vitória City Hall and the third-party company responsible for cleaning the beaches to acquire more detailed information about the beach cleaning process. Three 20-meter-wide transects were defined as the sampling areas with 20 meters of length perpendicular to the water line.

The three regions were chosen by the equidistant positioning of points along the total length of the beach. Because the beach has an approximate length of 960 meters, each 20-meter transect would theoretically be separated from the next by 240 meters, with 1,200 m^2 (3 x 400 m^2) of sampled area as shown in Fig. 1.

Four sampling campaigns for the low and high summer seasons were performed in the sample area. The campaigns during the low season were performed on 2^{nd}, 23^{rd} and 30^{th} October 2011 and 6^{th} November 2011. The collections during the high summer season were performed on 15^{th}, 22^{nd} and 29the January 2012 and 5^{th} February 2012. At the end of each sampling period, all of the material was weighed, sorted and classified based on the characteristics of each waste item [20]. The volume was determined by the fraction of the total volume of the container occupied by the debris with low compaction.

Because the sections of beach sand that were analyzed exhibited the same area value (400 m^2), it was possible to determine four environmental indicators for each of these sections known as “Item Density”, “Surface and Linear Mass Density” and “Surface Volume Density”. These values are obtained from (1)-(4) adapted of [11].

$$ID = \sum \frac{n}{20} \quad (1)$$

$$SMD = \sum \frac{m}{400} \times 1000 \quad (2)$$

$$LMD = \sum \frac{m}{20} \times 1000 \quad (3)$$

$$SVD = \sum \frac{V}{400} \quad (4)$$

where: ID = Item Density (items/m); Sum of the number of items for each transect; SMD = Surface mass density (g/m²); LMD = Linear Mass Density (g/m); Sum of the masses of the transects (kg); SVD = Surface volume density (L/m²); Sum of the volumes of the transects (L).

Fig. 1 Aerial view of Curva da Jurema Beach by Google with the location of the sampling areas and transects

Based on the environmental indicator of Item Density (1) and adopting the studies of beach contamination performed by [11], the classification adopted is presented in Table I.

TABLE I
Contamination Grades [11]

Grade	Description	ID
A	Absent; no evidence.	= 0 items m^{-1}
B	Traces; predominantly absent, with a few scattered items.	> 0-4 items m^{-1}
C	Unacceptable; widely distributed with a few accumulations.	> 4-10 items m^{-1}
D	Objectionable; heavily contaminated with various accumulations.	> 10 items m^{-1}

m = meter

Later, waste items were classified according to their use and the primary raw material in their composition [2], encompassing the 30 waste categories that were found during sampling. Within each category, the solid wastes were grouped according to the primary raw material of their composition.

IV. Results and Discussion

As expected, the evaluated environmental indicators in this study demonstrate that the amount of solid waste increased during the high summer season at Curva da Jurema Beach. Different environmental indicators were calculated from the data obtained from the collection of solid waste on the beach in the study to enable comparison with the available works in the scientific literature since there is no established standard method.

A. Item Density (ID) of Beach Waste in the Curva da Jurema Beach and Classification of Contamination Grade

Item Density results showed that, at high summer season, the beach condition is at least unacceptable in all transects studied, and only Transect 1, at low season, was classified as grade B. Table II shows the average density values of items for each transect in both seasons and their classifications according to [11].

TABLE II
AVERAGE ID IN THE LOW AND HIGH SUMMER SEASONS AND THE CLASSIFICATION ACCORDING TO [11] (CURVA DA JUREMA BEACH, BRAZIL)

Transect	Low season		High summer season	
	ID (Items.m^{-1})	Contamination grade [11]	ID (Items.m^{-1})	Contamination grade [11]
1	3.51	B	5.49	C
2	8.65	C	14.75	D
3	11.77	D	6.87	C

ID = Items density.

As can be seen in Table II, in the low season, transect 3 showed the largest sum of items, a total of 999 elements collected representing 49% of the total generated. For the high summer season, there was a significant change that translated into transect 2 being the largest contributor with 1,212 items collected (53% of the total). In both periods, transect 1 showed the least number of items, with only 14% of the total in the low season and 20% of the total in the high summer season.

For comparison, Table III shows the environmental indicators (ID and LMD) of beach wastes collected in various studies.

TABLE III
ENVIRONMENTAL INDICATORS FOUND IN DIFFERENT BEACH WASTES STUDIES [2]

Study area	ID (Items.m^{-1})	Contamination grade [11]	LMD (g.m^{-1})	Reference
Island of Dominica	4.5-11.2	C – D	51.5-153.7	[7]
Curaçao	19-253	D	1,700-11,800	[9]
Transkei Coast, South Africa	19.6-72.5	D	164.1	[16]
Second Beach, South Africa	72.5	D	72.2	[16]
Tamandaré Beach, Brazil	10.4	D	-	[1]
Cassino Beach, Brazil	4.9	C	-	[19]
Curva da Jurema Beach, ES, Brazil	7.10-8.22	C	18.2-54.4	This study

ID = Items density, LMD = Linear Mass Density.

Table III showed that in most beaches worldwide (data from 1993 until 2007), the conditions are also at least unacceptable, as well as in the Curva da Jurema Beach, which alerts to the amount of solid waste that are disposed at tourist beaches and the importance of municipal waste management.

Reference [3] carried out an evaluation of beach waste and litter during the bathing season on the Catalan coast and the analysis of monthly waste production data from various municipalities demonstrates that waste production is much larger in summer which makes it difficult to establish proper waste management programs and facilities aimed at prevention and recycling.

B. Surface (SMD) and Linear Mass Density (LMD) of Beach Waste in the Curva da Jurema Beach

Table IV shows the indicators of linear (LMD) and surface mass (SMD) densities for each transect in both seasons calculated using (2) and (3), respectively.

TABLE IV
AVERAGE LINEAR (LMD) AND SURFACE MASS (SMD) DENSITIES IN THE LOW AND HIGH SUMMER SEASONS (CURVA DA JUREMA BEACH, BRAZIL)

Transect	Low season		High summer season	
	SMD (g.m^{-2})	LMD (g.m^{-1})	SMD (g.m^{-2})	LMD (g.m^{-1})
1	0.2	4.4	1.4	28.0
2	1.3	26.8	6.2	124.2
3	2.6	51.9	2.3	46.2

SMD = Surface mass density; LMD = Linear Mass Density.

Results presented in Table IV showed that Transect 3 displayed the largest mass of waste during the low season (56%), followed by transect 2 (40%). In the high summer season, transect 2 had a much higher waste mass than the others (64%), and the second largest contributor was transect 3 (22%). Considerable variation occurred in each week during the low season, with 86% of the mass collected in the second campaign while in the following week, the material collected did not exceed 26% of the total mass.

As can be seen in Table III, Curva da Jurema Beach shows lower values for linear mass density than other beaches around the world. However, it is still necessary to establish mechanisms that further reduce the waste generation on this beach.

C. Surface Volumetric Density (SVD) of Beach Waste in the Curva da Jurema Beach

Relative to the volumetric characterization, SVD was calculated using (4). The sum of transect 3 (21.3 liters in the low season and 21.1 liters in the high summer season) and transect 2 (16.8 liters in the low season and 51.9 liters in the high summer season) represented values on the order of at least 84% of the average volume in both seasons. Considerable variation occurred in each week of the low season, with values up to 79% of the volume in the second campaign and not exceeding 36% of the volume in the following week. Relative to surface volume density, average values of 0.004 L.m^{-2} were found during the low season and of 0.014 L.m^{-2} during the high summer season.

Determination of environmental indicators helps to identify those areas susceptible to beach waste accumulation which will need more attention from local authorities for planning preventive measures and optimization of cleaning services [6].

Regarding to environmental indicator results, a typical behavior of beachgoers is to seek the minimal infrastructure necessary to satisfy their basic leisure, comfort and safety needs, a rationale directly linked to proximity to the kiosks. With the increased frequency of users on Curva da Jurema Beach in the high summer season, a greater load of waste is expected to be generated around these kiosks than in any other location. Although transect 3 shows slightly higher values in the low season for the parameters of interest, the scenario of a larger number of people in transect 2 emerges as a reflection of the waste generation load of the population. The behavioral pattern clearly indicates the participative growth of transect 1, also in the kiosk area in the high summer season.

In transect 2, there is a gradual slope along its length, with part of the length shaded by coconut trees and an inviting commercial structure with many tables and chairs, vendors and music from the kiosks. Transect 1, however, has a smaller strip of sand, with a steeper slope near the water line and less vendor activity, restricting the most frequent users and giving preference to the use of services from the kiosks located on this portion of the beach.

Results indicates the need for the third-party company to increase the daily frequency of cleaning during the high summer season, showing the greater efficacy in the removal of wastes, including wastes with lower mass and volume, as these types of solid waste are very significant and seldom collected by those responsible for cleaning.

D.Classification by Composition of Beach Waste in the Curva da Jurema Beach

Although some types of waste are not as representative in terms of number of items, they have a participation in waste mass. The "cigarette butts" due to their small size and color and the fact that they are easily camouflaged in the sand, cigarette butts are rarely collected, which makes them prone to accumulation, increasing the levels of beach contamination. Not only the butts but also disposables such as straws and popsicle sticks that are commonly buried in the sand by beach users are difficult to see and collect. These types of waste include "plastic bags" which are a light material, but when covered with sand their weight increases, even more so if the material is wet, as was the case with "paper/cardboard" [15].

In agreement with that reported by [3], which relates to the waste accumulation during the bathing season due to the low efficiency of the daily mechanical cleaning procedure for collecting small-sized waste, particularly cigarette butts.

An important fact that must also be emphasized relates to the near absence of aluminum cans during the sampling. Although the consumption of beer and soda in this type of container is widespread across the beach, the low presence of aluminum cans as a component of litter is most likely because the aluminum cans are efficiently collected by recycling collectors [17] because Brazil has a promising market for this type of activity, which justifies its position as the country that recycles the most aluminum in the world [2].

After grouping the items with the same raw material, plastic wastes (all types) were the most common type of solid waste found in the area sampled, representing 51.4% of the total number of items, as shown in Table V.

TABLE V
NUMBER OF ITEMS IN LOW SEASON AND HIGH SUMMER SEASON CLASSIFIED BY RAW MATERIAL (CURVA DA JUREMA BEACH, BRAZIL)

Raw material	Low season						High summer season						General	
	C1	C2	C3	C4	Total	%	C1	C2	C3	C4	Total	%	Total	%
Plastic Film	191	147	330	81	749	36.7	89	183	205	181	658	28.5	1407	32.3
Soft Plastic	40	58	75	27	196	9.6	46	84	59	73	261	11.3	457	10.5
Hard Plastic	41	62	64	23	190	9.3	37	57	49	42	184	8.0	374	8.6
Paper/ Cardboard	62	180	165	116	523	25.6	84	66	192	248	590	25.5	1113	25.6
Metal	9	15	9	1	34	1.7	2	13	10	4	17	0.7	51	1.2
Glass	0	0	9	0	9	0.4	1	0	1	0	2	0.1	11	0.3
Rubber	3	8	8	0	19	0.9	1	4	2	1	5	0.2	24	0.6
Organic	10	4	6	2	22	1.1	13	22	28	21	84	3.6	106	2.4
Wood	65	83	60	36	244	12.0	65	102	133	164	456	19.7	700	16.1
Others	11	21	12	5	53	2.6	1	10	12	7	55	2.4	108	2.5
Sum of Items	432	578	738	291	2039	100	339	541	691	741	2312	100	4351	100

C1: 1st campaign, C2: 2nd campaign, C3: 3rd campaign, C4: 4th campaign

Regarding classification by type of waste (Table V), the most numerous items in both sampling periods was "plastic film", representing 32.3% of the total. The representativeness of the solid waste extends also to the volume collected and the mass in the high summer season. Reference [13] in a study of the marshes and beaches of coastal Georgia found concentrations variable of plastic debris in both inaccessible areas and highly visited beaches. Different results are presented in a study performed by [18] that quantified beach litter in Monterey Bay, CA, and styrofoam is currently the most common type of beach litter, comprising 41% of items found, but as most of styrofoam was broken-up (5 mm–5 cm), it was impossible to identify the source from these fragments. Reference [18] also found unexpected items as fertilizer pellets in the beach litter in Monterey Bay, CA.

On the other hand, [3] calls attention to recycling procedures that should be facilitated, since 49.4% of the total amount of waste generated on the beaches in Catalan Coast is composed of recyclable materials (plastic, wrapping, beverage containers, glass and paper).

The study on Curva da Jurema Beach showed values similar to studies conducted on other beaches in Brazil and around the world, demonstrating the high occurrence of plastics, as shown in Table VI.

TABLE VI
PERCENTAGE OF PLASTICS IN RELATION TO OTHER LITTER ITEMS IN BRAZIL AND OTHER REGIONS OF THE WORLD [2]

Local	Year of study	Plastic (%)	Reference
Island of St. Lucia (Caribbean)	1991-1992	51.3%	[7]
Island of Dominica (Caribbean)	1991-1992	35.9%	[7]
Curaçao (Caribbean)	1992-1993	64.2%	[9]
Beaches in South Africa	1994-1995	83.4%	[16]
Cassino Beach, RS (Brazil)	1996-1997	52%	[19]
Tamandaré Beach, PE (Brazil)	2001-2002	>80%	[2]
Catalan Coast	2004	26%-35%	[3]
La Pleasure Beach, Ghana	2006	53%	[20]
Korle Beach, Ghana	2006	66%	[20]
Curva da Jurema Beach, ES (Brazil)	2011-2012	51.4%	This study

The beach is an environment susceptible to receipt of wastes from various sources. The inefficacy or lack of solid waste management systems in coastal cities also contributes to the entry of litter into marine and coastal environments [10].

Curva da Jurema Beach is generally not very different from the other regions studied when the subject is beach wastes, as can be seen in Table VI. The total number of “plastic packaging” items represented half of all of the debris collected, confirming what was already stated by other authors. This type of solid waste is today one of the five largest priorities for permanent monitoring on a global level [2].

Plastic is extremely persistent and major dangers associated include ingestion by and entanglement of vertebrates (seals, seabirds and turtles) besides economic losses when tourist beaches are persistently contaminated.

Plastics found on beaches are highly resistant to biodegradation due to their polymeric structure and the primary degradation processes are photo-degradation, chemical oxidation and physical abrasion which promote the formation of plastic debris that can be found on beaches and in rivers flowing into the ocean [13].

According to [3], it has been demonstrated that beach cleaning operations are in some cases just a temporary solution since a part of litter (46%) returns to the beach within one year, which indicates that environmental education has an important weight in the issue of beach waste.

The beach waste management in some countries should have prevented most of the litter from entering the marine environment, yet its influence has seldom been discussed in the literature [14].

V. CONCLUSIONS

The results from the environmental indicators of beach wastes on Curva da Jurema Beach confirm the influence of seasonal variation, especially due to the seasons of the year, indicating an increase of 13% in solid waste generation during the high summer season compared to the low season in the quantification of items collected. This value could be even higher in the high summer season if it were not for the increased frequency of daily cleaning in the summer.

Regarding the local variation of solid waste on the beach, in the low season, transect 3 showed higher values compared to the other transects and in the high summer season, transect 2 showed considerably higher data. This increase in transect 2 is likely due to the available infrastructure and the physical characteristics of this section. Additionally, in all of the periods, plastics were indisputably the most common type of waste, due to the large number of items (51.4%) and the volume generated (68%).

According to the classification of contamination suggested by [11], transect 3 in the low season and transect 2 in the high summer season are classified as type D: they are heavily contaminated by the accumulation of solid wastes. The contribution of beachgoers to the generation of this type of pollutant on the waterfront, where tourism is intense, results in an elevated production of wastes during the summer. Solid waste generation by users is extremely significant and can be reduced.

Reactive/emergency measures such as public waste collection and making an appropriate allocation of the solid waste are clearly essential to reduce solid wastes in the beach environment. However, when these measures are not accompanied by preventive attitudes, the management system does not function effectively.

The implementation of permanent environmental education programs both in schools and on the beach (and in other public places) that are embraced by the population represents preventive measures that avoid the generation of solid wastes, founded on raising awareness and the consequent change in the posture of the citizens to achieve the principles of sustainability.

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