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Assessing Marine Litter Pollution and Ecotourists Dynamics along Lagos Coastline Beaches: Sources, Composition, and Impacts

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ABSTRACT

A study assessing the environmental quality of six beaches along the Lagos coastline (Atican, Alpha, Elegushi, Narval, Oniru, and Takwa) was conducted from November 2021 to February 2022. The research focused on litter abundance, composition, and tourist population. A total of 12,968 litter items were recorded, revealing significant spatial and temporal variations in litter abundance. The average litter composition per 100 meters included: Plastic: 163.91 ± 20.66, Rubber: 57.00 ± 7.38, Styrofoam: 125.33 ± 26.03, Cloth: 22.83 ± 5.08, Glass/Ceramic: 44.75 ± 4.28, Metals: 67.16 ± 9.28, Paper: 33.66 ± 2.79, Wood: 23.41 ± 5.86, Fruits: 14.91 ± 5.01, and Nets: 10.16 ± 2.80. ANOVA analysis indicated significant differences in litter abundance among beaches, except for metals and paper, suggesting regular dumping by tourists or litter washed ashore by currents. The dominant litter types were plastic (29%), styrofoam (22.25%), metal (12%), and rubber (10%). Principal Component Analysis revealed that styrofoam and plastic significantly influenced litter composition across the beaches, likely due to poor waste management and coastal erosion. Elegushi Beach recorded the third-highest litter occurrence (1,769 items), followed by Oniru (2,589) and Narval (439). Cluster analysis grouped Narval, Oniru, and Elegushi, indicating similar litter sources and activities. The Shannon diversity indices ranged from 1.72 to 1.95, with Takwa having the highest and Oniru the lowest values. Narval Beach attracted 32.7% of total visitors and accounted for 33.2% of litter, making it the most frequented beach. The prevalence of plastic and styrofoam suggests these materials are commonly used by tourists and easily transported to the beach. To mitigate marine litter along the Lagos coastline, stakeholders should enhance waste management infrastructure and promote eco-friendly practices among tourists and local businesses.

Keywords: *Beach litter; environmental quality; plastic waste; tourism impact; waste management; public awareness.*

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1.0 INTRODUCTION

Worldwide reports of the detrimental effects of litter are rising [1]. It is a major issue arising from environmental concerns in the twenty-first century [2]. Critical secluded environments, such as Polar regions, the ocean's deep floors, litter have been evident, [3-4]. According to ref [5], approximately 80% of the trash that enters the water comes from the land. Flowing by rivers, unlawful dumping, left on beaches by tourists, and dumped into the sea by ships and offshore connections are examples of marine-based springs, [6-7]. Travel and tourism are the two global industries that are expanding the fastest [8-9]. In 2017, receipts grew by 5%, bringing the total earnings in the destinations to US$1340 billion worldwide, according to previous works of [9]. By 2030, it is predicted that 1.8 billion people will be traveling internationally, [4]. The beaches are Earth's most dynamic habitats, according to ref [10-11]. Beaches sustain biodiversity, as well as organisms that are rare to other environments.

Numerous different types of organisms, including bacteria, protozoans, microalgae, and microbenthic invertebrates, can be found in the intertidal zones of beaches [12]. Several hundred different invertebrate species can coexist on a single beach, [13]. Beaches are strategic suppliers to ecosystem services such as pollination, soil formation, raw materials, and land use opportunities. According to ref [12], these facilities are inventive in improving the socioenvironmental usage of this unique setting. Debris from marine is known to have a detrimental effect on industry aligned with tourism; few studies have specifically expressed these impacts [14]. Cleanliness is a vital characteristic for beach selection. In the Cape Metropolitan Region of South Africa, hundreds of millions of US dollars in annual tourism earnings could be lost due to marine debris [15]. Numerous problems are linked to the beach environment and litter, be it societal and economic ([16-17], health-related [18] or biological [19]. Numerous studies of the effects that this pollutant has on the tourism business are prompted by tourism-related debris [20-22]. Excessive trash from the sea can have negative aesthetic and financial effects, primarily by reducing tourism, coastal use, and recreation linked with water activities [22-23]. Environmentally sound beach conditions are a critical issue and a need for the growth of coastal tourism. Litter pollution on beaches is currently out of control and contributing to environmental damage [24]. A combination of uncleanliness, unhygienic circumstances, and low scenic qualities, litter causes unfavorable and rejective reactions from beachgoers at the socioeconomic discussion level, [25].

Various factors, including tourism, fishing, swimming, maritime traffic, and waterborne aquatic activities, can lead to the buildup of macroplastics and microplastics on sandy beaches worldwide [26-28]. Sea beaches are the most vulnerable locations where land-based plastic garbage enters coastal waterways because of the rising effects of tidal fluctuations and human activity. Determining the amount, nature, and sources of plastic trash requires extensive worldwide monitoring of coastal plastic debris [29-30]. Cigarette butts (CBs) have been discovered on beaches and have been a subject of intensive research worldwide, in addition to plastics [31]. Cellulose acetate makes up CBs toxicology research, and has shown that plants and animals are harmed by extracted natural microparticles, including the cellulose fibers found in clothing, toiletries, and cigarette filters, which are harmful to both plants and animals [32-33]. Litters registered on the beach's line is enough factor for non-visit or low response [12, 32].

The study focused on three main objectives: (i) to quantify, characterize, and map the distribution of marine debris across six beaches in Lagos; (ii) to evaluate the relationship between various types of litter present at the sampled beaches; and (iii) to assess tourist visitation rates at each beach.

2.0 Study area

Takwa beach, 6.4018ºN-3.3954ºE, Narval beach, 6.4227ºN-3.4427, Oniru beach, 6.4226ºN-3.4422ºE, Atican beach, 6.4247ºN-3.5971ºE, Eleghusi 6.4219 ºN-3.4896 ºE and Alpha beach, 6.4229ºN-3.5228ºE are the six beaches that are located in the six separate communities in Lagos state, Southwest Nigeria (Fig.1). Given that the beaches are all situated in highly developed areas of Lagos State, Nigeria, and that nearby infrastructure makes them urban beaches, they are all categorized as such. Water from the Lagos lagoon and other streams that drained into the Atlantic Ocean was poured into them.

Marine debris was gathered from these six beaches (Alpha, Atican, Eleghusi, Narval, Oniru, and Takwa Beach). They were chosen using the standards set forth by ref [34-35]; they were dominated by coarse to medium sand, and are linked to the ocean, and accessible. The length ranges between 100 meters and 1 km, and are devoid of any built structures. Every beach had its orientation toward the west, proximity to the cities, with in-built social amenities such as: hotels, clubs, resorts and schools.

Figure 1: The Study area's map showing sampling stations. Source: Ecological Beach survey (2021-2022)

3.0 Materials and Methods

Beach surveys were conducted across six beaches along the Atlantic coast of Lagos State, Nigeria, from November 2021 to February 2022. Marine litter data collected at each beach were analyzed using descriptive statistics, correlation analysis, ANOVA at a significance level of $\alpha_{0.05}$, and classification-clustering (UPGMA method). Additionally, Shannon-Weiner's diversity index (H'), evenness (E), and equitability index (J) were calculated. To identify patterns and similarities among the sites, as well as relationships between litter categories based on their relative abundance, the data underwent Principal Component Analysis and Cluster Analysis [36].

Ward's approach using Squared Euclidean distance was used to do Hierarchical Cluster Analysis (CA), both with and without standardized variables (categories). In the analysis of non-standardized data, categories are weighted according to their respective numerical values. Therefore, compared to those with low occurrences, those with large abundance at locations have a significant impact on derived clusters. Categories with relatively low and high occurrences contribute equally since standardized data weights them based on a common mean value. Correlation coefficients, which implicitly normalize all variables, were employed in the cluster analysis of the categories.

3.01 Field study

Guidelines from ref [37-38], and ref [22, 38] were followed in the survey's methodology. Litter was discovered along a 100 m wide area that was 50 m on either side of an entry point that was typically in the middle of the beach (Fig.1 to Fig.3). Four stations were randomly created on the coastline to represent replicates and to determine variation of debris within the shoreline. Four surveys were conducted on each beach between November and December 2021, and January and February 2022, to present over 75% of the holiday period. The number of objects per unit of beach length was used to measure the amount of litter. According to its composition and amount, marine debris was recognized and grouped into key classes, including plastic, foamed plastics/styro foam, fabric, glass and ceramic, metal, paper, rubber, wood, fruit, and other materials [38-39]. The sources of marine litters were classified into six major groups, five out six groups stated according to Ocean Conservancy [40]

(I) shoreline and recreational activities (e.g. bottles, caps, toys, cans etc), (ii) smoking-related activities (such as lighters, cigarette butts), (ii) boat/fishing/farming activities (bouys, nets, fishing lines) (iv) dumping activities, (v) medical/personal hygiene (e.g syringes, hang gloves, face mask) except, and (vi) Religious activities, (fruits, palm, ceramics, candles, plastic kegs). The second part of the survey focused on the population count of visitors to the beaches namely beach users' Population frequency [41-42].

During the sampling and collection of coastal litter and marine debris across six Lagos beaches (Atican, Alpha, Elegushi, Narval, Oniru, and Takwa), we gathered bags filled with plastic bottles (Fig.2), mixed litter pushed to the shoreline by waves and tides (Fig.3), fragments of Styrofoam (Fig.3), floating debris such as fragmented plastics, nylon bags, and wood (Fig.4). These litters were sampled, packed and weighed as representative marine debris at the sampling stations (Fig.5).

Figure1: Bags containing plastic bottles of counted litter

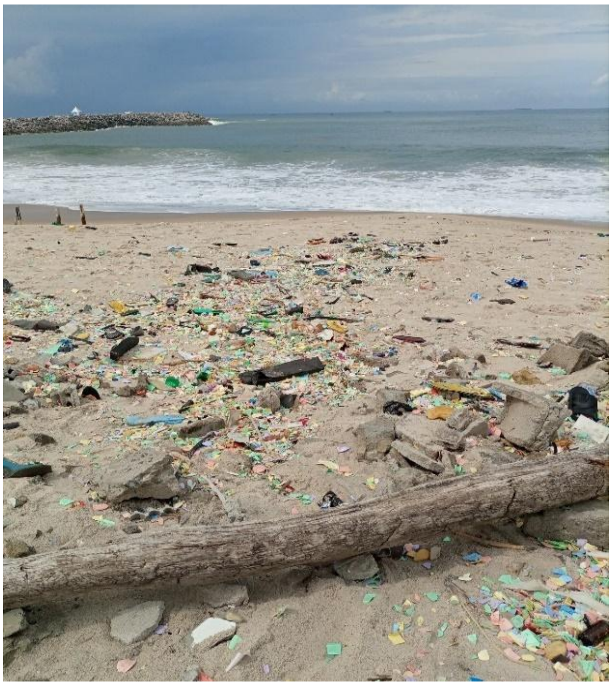

Figure 2: Mixed litters pushed to the shoreline by the wave and tide

Figure 3: Fragments of Styrofoam on the beach

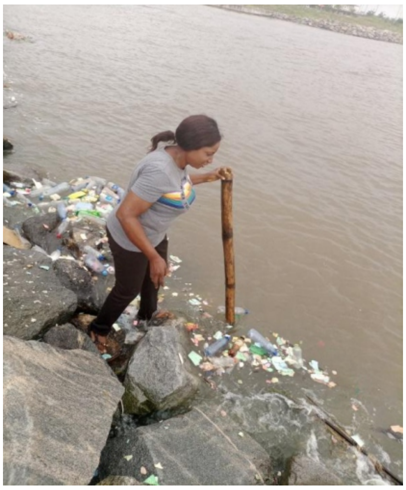

Figure 4: Floating litter (Fragment plastics, nylon bags, styrofoam, wood, papers) being washed across the stone barriers to the shoreline

Figure 5: Weighed litter collected during the sampling exercise

4.0 RESULTS AND DISCUSSION

A total of 12,968 items of beach litter were encountered at all sites during the four periods of sampling (Table 1). Statistics showed substantially significant differences in both the regional and temporal variations in beach litter abundance (Fig.6). Elegushi had the third-highest occurrence of litter (1769), preceded by Oniru (2589) and the highest was found in Narval Beach (4309). This study corroborates the previous work of Ayo-Dada et al [43], who reported Narval beach as a distinct beach with overcrowded tourist visitors, with characteristics of poor environmental sanitation. The ranking of the litter occurrence from items collected ranged from 1,269 to 218 items from Narval Beach (Station 1) to Atican Beach (Station 4), respectively. The highest percentage of litter group ranged from plastic (29%), styrofoam (22.25%), metals (11.92%), while the least was nets (1.80%).

The average values of beach litter were plastic 163.91 ± 20.66, Rubber 57.00 ± 7.38, styrofoam 125.33 ± 26.03, cloth 22.83 ± 5.08, glass /ceramic 44.75 ± 4.28, metal 67.16 ± 9.28, paper 33.66 ± 2.79, wood 23.41 ± 5.86, fruit 14.91 ± 5.01, net 10.16 ± 2.80 items per 100m.

Total abundance by beach indicated that Narval Beach has the most pollution from trash, made up of 4309 items, and Atican Beach has the least beach litter with 929 items per 100m. Significant variations in debris abundance were registered for all the beaches, except the group belonging to metal and paper. Plastic litter had the highest percentage of 29% of the total litter, ranking highest with the population of all visitors to the beaches (Figure 3). Narval Beach recorded the highest litter number, ranging from the nine groups 4309, and made up 33% of the total litter (Table 1). Table 1 showed that the mean values of all litter recorded on the beach had the highest value among the other five beaches. Distinctly Narval Beach also had the highest number of visitors, making it directly proportional to the number of litters. The correlation (table 2) showed a strong, significant correlation of plastic with Styrofoam, cloth, paper, fruit, and wood, which is indication of relatively from same source, likely from recreational and tourism activities by tourists. The heterogeneity diversity of marine litter (Table 3) ranged from Shannon Weiner (H), Evennes (E), Equitability (J); Takwa had the highest values (H=1.93; E=0.78; J=0.89) while Oniru had lowest values (H=1.72; E=0.62, J=0.62). Equitability indices across the beaches ranged from 0.78 to 0.89, Evenness was between 0.62 to 0.78, the litter diversity showed average stability during the period of sampling.

Table 1: Mean value Variation of Litter and Population Frequency across the six beaches

	Atican	Alpha	Elegushi	Narval	Oniru	Takwa	P value	
Plastic	47.50 ±6.61	126.75±38.82	155.50±41.91	296.25±19.95	225.00±48.94	132.50±33.57	<0.05	
Rubber	13.2500±2.68	102.5000±17.96	29.7500±7.19	88.7500±5.54	53.2500±8.64	54.5000±10.21	<0.05	
Styro foam	69.50±7.14	48.50±7.93	66.25±9.64	351.25±45.20	170.25±70.07	46.25±8.50	<0.05	
Cloth	6.75±1.37	5.00±1.29	10.00±2.85	70.50±7.90	32.25±5.75	12.50±3.79	<0.05	
Glass and Ceramic	37.00±11.14	49.25±7.28	39.50±6.71	78.50±5.29	36.00±5.27	28.25±5.96	<0.05	
Metal	27.00±5.32	56.50±11.65	99.75±21.32	76.00±8.01	92.50±44.55	51.25±6.68	>0.05	
Paper	23.75±3.83	33.50±7.72	27.50±6.61	38.00±5.30	43.25±8.53	36.00±7.52	>0.05	
Wood	8.75±3.11	3.75±0.75	16.25±1.75	80.00±15.13	13.75±2.39	18.00±3.13	<0.05	
Fruit	4.50±2.10	2.00±0.81	2.75±1.10	67.50±5.95	6.75±1.79	6.00±0.91	<0.05	
Nets	1.0000±0.40	13.0000±7.52	5.0000±0.40	1.0000±0.57	6.5000±1.19	34.5000±5.72	<0.05	
Population/Visitation	185.5000±73.75	90.0000±21.31	312.5000±85.08	462.5000±48.41	342.5000±152.93	225.0000±77.72	>0.05	

Mean ± Standard Error per 100m. P<0.05= Significant Difference; P>0.05= Non-Significant Difference

Table 2: Correlation of different Marine litter groups, Population of tourists, and the stations

	Plastic	Rubber	Styrofoam	Cloth	Glass	Metal	Paper	Wood	Fruit	Nets	Popula	ST
Plastic												
Rubber	0.25											
Styrofoam	0.73**	0.36										
Cloth	0.62**	0.28	0.70**									
Glass	0.45*	0.37	0.59**	0.66**								
Metal	0.21	0.22	0.36	0.16	0.27							
Paper	0.57**	0.08	0.31	0.23	0.15	0.10						
Wood	0.61**	0.35	0.80**	0.75**	0.55**	0.07	0.16					
Fruit	0.59**	0.37	0.78**	0.91**	0.74**	0.15	0.175	0.84**				
Nets	-0.15	0.15	-0.38	-0.26	-0.37	-0.11	0.16	-0.22	-0.29			
Population	0.29	0.03	0.31	0.57**	0.26	-0.07	0.13	0.51*	0.45*	-0.16		
ST	0.42*	0.16	0.21	0.34	-0.11	0.23	0.37	0.24	0.18	0.52**	0.28	

***. Correlation is significant at the 0.01 level*
**. Correlation is significant at the 0.05 level*

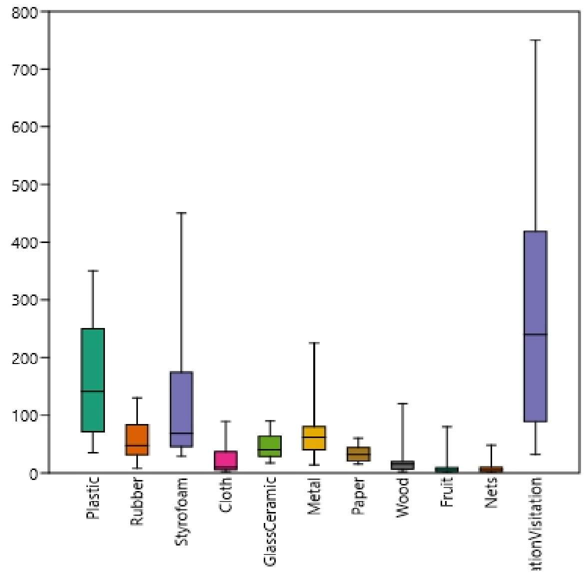

Figure 6: The box plot mean-value of the different groups of litter and visitors populations across the Beaches

4.1 Diversity Indices of the Litter across the Beaches

A wide variety of litter types may also have an indirect effect on aquatic biodiversity by lowering the biological quality of the water body and posing risks (such as ingesting plastics or becoming entangled in fishing nets). The beaches' Shannon diversity indices (Table 3) ranged from 1.72 to 1.95, with Takwa and Oniru beaches having the greatest and lowest values, respectively. The ranges were classified as moderately spread litter pollution on the beach, which implies that a particular activity or source may be in charge of the pollution (e.g., plastic from beach users, erosion, fishing gear, or recreational activities). Each beach's categorized litter had a high and equal distribution, according to the Evenness index.

Table 3: Diversity Indices of the Litter across the Beaches

	Atican	Alpha	Elegushi	Narval	Oniru	Takwa
Taxa	9	9	9	9	9	9
Individuals	929	1743	1769	4309	2589	1629
Dominance (D)	0.18	0.19	0.21	0.20	0.23	0.17
Simpson (S)	0.82	0.81	0.79	0.79	0.77	0.83
Shannon (H)	1.85	1.83	1.76	1.80	1.72	1.95
Evenness (E)	0.71	0.69	0.65	0.67	0.62	0.78
Margalef richness (R)	1.17	1.07	1.07	0.96	1.02	1.08
Equitability (J)	0.84	0.83	0.80	0.82	0.78	0.89

4.2 Cluster classification of the stations across the beaches

Hierarchical Clustering Analysis

The Hierarchical Clustering Analysis is represented (Figure 7); Group 1: This group is composed of five beaches (Atican, Alpha, Elegushi, Oniru, Takwa), all the beaches in group contributed 58.2% of the total litter. Group 2; consists of three beaches (Narval, Oniru, and Eleghusi), 48.2% of the litter contribution was from this group. The clusters showed the characteristics of the beaches in the same group. Narval beach was an exceptional difference from all the other beaches according to the Hierarchical classification.

The scree plot (Figure 8) shows that the first two principal components are significant for the variation among the stations (beaches) based on their litter compositions. This is because the plot starts to flatten out at the third component. Approximately 63.2% variation among the beach stations based on their litter composition is explained by the first two principal components. Oniru and Narval stations cluster while the remaining beach stations clustered together according to their litter composition. The Cluster analysis (Figure 9) potentially states that variables such as litter source and abundance are related to sources and classification of the beach as Urban beaches. There is a strong positive relationship between plastic and Styrofoam abundance on the beach, whilst the other litter, such as metal, glass, cloth, fruit, and wood, had a close relationship. The first two axes explained (Figure 9) that 89.8% of the variance of different marine litter can be explained by variation in the beaches. The hierarchy tree showed two groups of clusters (Figure 9), confirming the strong connectivity between the Styrofoam and plastic cluster, while the other litters had clustered together. The PCA ordination bi-plot diagram (Fig.10) indicated that all the marine litter groups identified on the coastline (plastic, styrofoam, rubber, paper, wood, net, fruit, cloth, metal, and glass) were identified as the constrained variables. Styrofoam and plastic had the highest positive scores on axis 2 (0.75 and 0.55) and positively influenced Oniru, Narval, Takwa, Alpha, Atican, and Elegushi beaches.

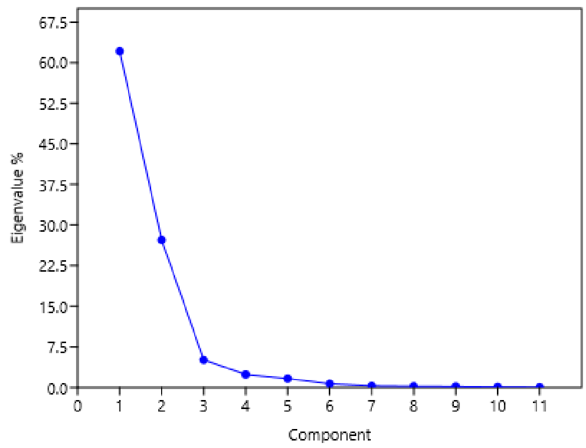

Figure 8: Scree plot of the beaches and litter

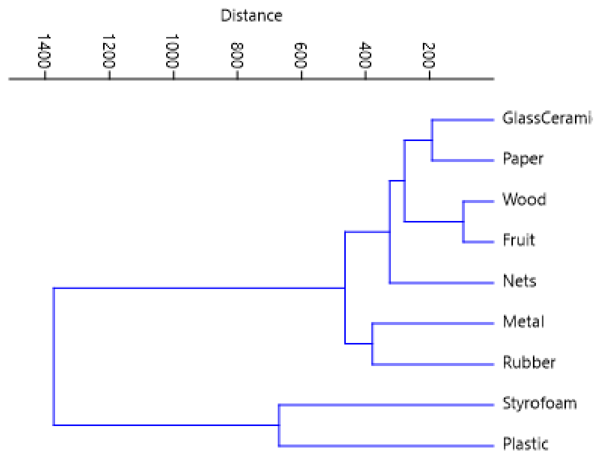

Figure 9: Hierarchical cluster Analysis (litters' category relationship)

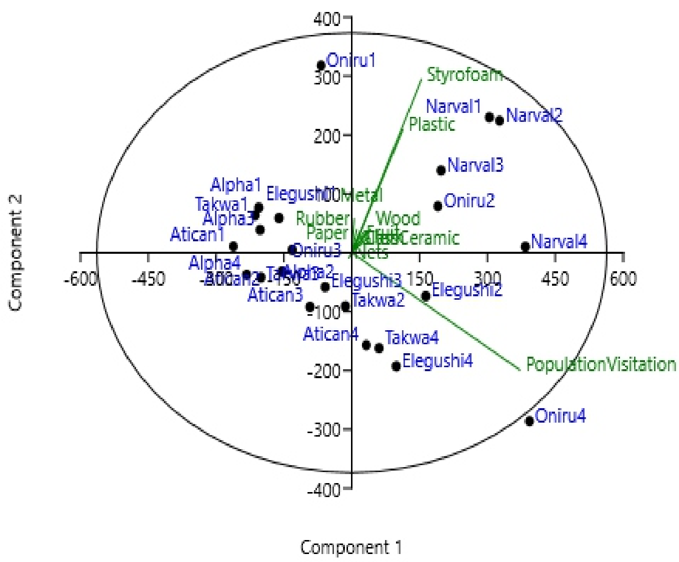

Figure 10: Principal component analysis of the litter and the sampling station across the six beaches

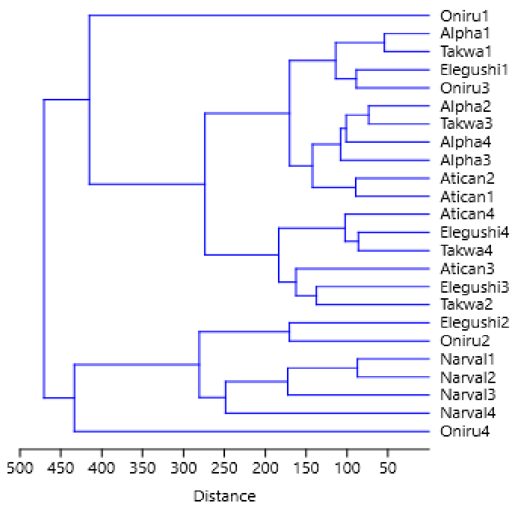

Figure 7: Cluster Analysis (Beach relationship category)

4.3 Population of Visitors and Marine Litter in the study area

The population's summation of visits to the six beaches during the four-sampling survey was 7634; 57% of the total population was male (4351), and 43% was female (3282) (Fig.11). The population of male visitors was higher in all the beaches except Narval and Oniru beaches. The highest population was recorded in Narval beach (32.7%), Elegushi beach had the second highest value (21%), and the least value was registered in Apha beach (7.2%). Narval beach contributed 33.3% of the total marine litter (Fig.12). The Population is relatively proportionate to the percentage of litter generated on the beach.

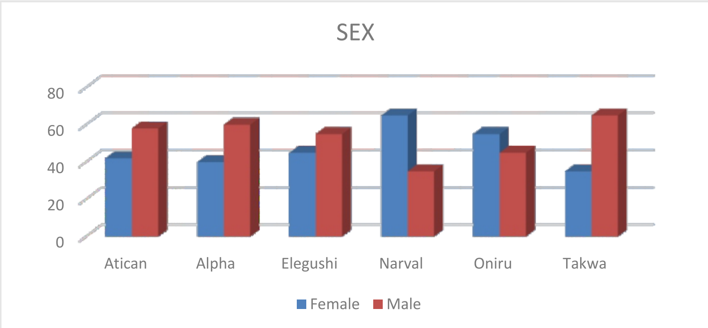

Figure 11: Bar chart plot of the sex ratio of visitors

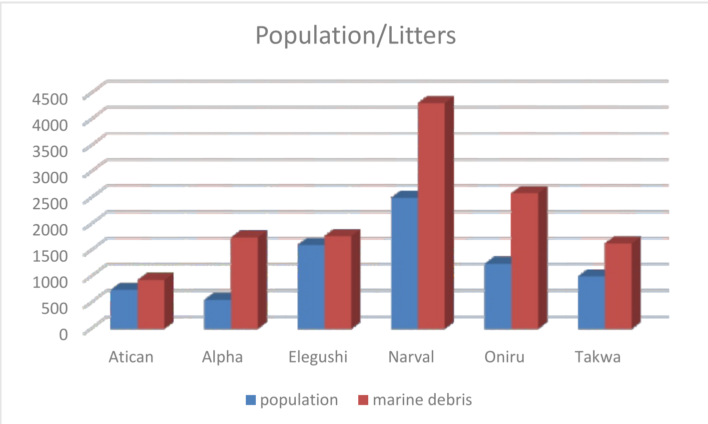

Figure 12: Bar chart plot of Population of Visitors and Marine Litter

4.4 Sources, Composition, and Impacts of the Study

The survey conducted across six beaches along the Atlantic coastline of Lagos highlighted a significant presence of marine litter, attributed to both human activities and natural processes. This aligns with previous studies by Gregory [44], and Hirai et al [45], which indicate that mobile pollutants are not confined by distance or protected area status. The most prevalent types of marine litter identified on these beaches were plastic and styrofoam, widely recognized as the dominant forms of litter globally [35, 39]. Common plastic items collected included polystyrene (nylon bags), plates, plastic bottle caps, cutlery, plastic bottles, slippers, shoes, flip-flops, kegs, and sacks. These materials, which are deeply entrenched in daily human activities, pose significant challenges due to their slow decomposition in marine environments [46].

The analysis of litter sources was facilitated by categorizing the debris into nine distinct groups, reflecting the economic and human activities contributing to their presence. Each category highlights specific uses by various sectors before the materials are released into the coastal environment through targeted pathways [12, 37, 39]

The litter sampled from the beaches largely resulted from beachgoers, with litter originating from rivers, streams, and ocean routes characterized by buoyancy, which serves as a key indicator for identifying debris from these sources. Rech et al [31] noted that "prevailing buoyant" materials such as plastics, polystyrene, and synthetic wood are significant contributors to marine litter because these items drift and resist decomposition over extended distances.

Among the surveyed beaches, Narval Beach exhibited the highest percentage of litter, encompassing plastic, rubber, textiles, paper, biohazards, fish, apparel, and organic materials. These items can be classified as "short-term buoyant," as they drift with currents and require less time to sink and decompose, indicating that their sources are relatively close [12].

The role of tourists, residents, and beach users is critical, as their activities significantly contribute to litter accumulation, exacerbating environmental pollution. This observation corroborates findings from Rangel-Buitrago et al [12] regarding beaches in the Atlantico Department. Narval Beach was identified as the dirtiest among the six surveyed, primarily due to uncontrolled litter left behind by visitors [32, 46]. The overwhelming majority of litter collected was not associated with fishing activities, such as nets and ropes, but was instead attributed to recreational use, tourism, and improper waste disposal practices.

This study underscores the urgent need for improved waste management strategies and public awareness campaigns to mitigate the impacts of marine litter on the coastal environment, ensuring the sustainability of these valuable ecosystems along Lagos' Atlantic coastline.

5.0 CONCLUSION

The estimated marine litter recorded in this study, conducted from November 2021 to February 2022, totaled 12,968 items collected from six beaches. Plastics showed a significant correlation with five categories of litter: cloth, Styrofoam, wood, paper, and organic materials like fruit. Narval Beach exhibited the greatest diversity of litter, with distinct material types identified as primarily originating from recreational activities. This is likely due to its high visitor traffic and open beach policy, which allows beachgoers to bring food, drinks, and other items for their convenience during their stay.

The main sources of litter were linked to recreational and spiritual activities, while fishing-related debris was minimal, reflecting the limited fishing activities in these areas. The current survey provides valuable insights into the composition and abundance of litter along Lagos' Atlantic coastline, offering a basis for policy guidelines aimed at effective litter management in the region.

Additionally, various types of tourists, including resort visitors, campers, and recreational sightseers, were observed, with a notable emphasis on spiritual coastal tourism, which is prevalent in Lagos but often overlooked in other parts of the world. This form of tourism appears to be a significant contributor to marine litter.

To promote a cleaner environment and maintain pristine shorelines, stakeholders such as tourist operators, marine conservationists, and beach managers should implement awareness and educational programs focused on marine litter management for beachgoers.

To minimize the impact of marine litter as highlighted in the study, stakeholders should: (1) Implement Educational Programs by developing targeted awareness campaigns for beachgoers about the sources and impacts of marine litter, emphasizing responsible behavior during recreational activities. (2)

Enhance Waste Management Infrastructure by increasing the availability of waste disposal and recycling facilities at popular beaches to encourage proper litter disposal, and (3) Engage Local Communities by involving residents and businesses in beach clean-up initiatives and conservation efforts to foster a sense of ownership and responsibility for the coastal environment.

Overall, the research emphasizes the need for collective action in managing marine litter to ensure healthier and more sustainable coastal environments, and is closely aligned with Sustainable Development Goal 14: Life Below Water, as it addresses the significant issue of marine litter affecting the environmental quality of beaches along the Lagos coastline.

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