J. Biodivers. Conservation 8(3): 24-31 ISSN: 2457-0761 (online)
2024 http://www.aprfjournal.in

Original Paper

Assessment and Characterization of Plastic Pollution in two Coastal sites in Lagos Nigeria: Implications for Ecological Restoration and Public Awareness

Ebelechukwu Franklin Chinazor

University of Lagos, Nigeria
E-mail: Kwissfranklin@gmail.com

Article Details: Received: 2024-06-25 | Accepted: 2024-07-15 | Available online: 2024-07-22

Abstract: Plastics, derived from oil or gas, are widely used synthetic organic polymers. The excessive use of plastics has led to a global issue of marine litter, posing a significant threat to marine animals and coastal environments. This study aimed to assess and characterize plastics found at two coastal sites in Lagos (Ilaje and Makoko). The investigation included determining the composition of different plastic types and gathering perceptions of the two sites regarding plastic usage and impact. The findings revealed that polyamides (nylons) accounted for 43% of the plastics audited, while other types such as PET, HDPE, PVC, LDPE, PP, and PS had varying percentages. At the Makoko site, nylons were the most prevalent, whereas at Ilaje, PET dominated. The differences in plastic composition between the sites could be attributed to the popularity and accessibility of sachet water bags, which are generally consumed by households year-round compared to other sources of plastic. These results highlight the urgent need to raise public awareness about the environmental impacts of plastics, as the attitudes of Makoko residents reflect a lack of understanding concerning plastic waste and its appropriate management, emphasizing the significance of addressing these issues in line with the UN Agenda for ecosystem restoration.

Keywords: Coastal pollution, Plastic, Synthetic Organic Polymer, Biodiversity Conservation, Public Awareness, Marine litters

Introduction

The world's population is congregating closer to the coasts, working, living, and taking vacations, and they are also directly witnessing the biggest and most spectacular plastic waste wave in history. Ten years into this century, the amount of plastic manufactured will surpass that of the previous century combined. There are many different kinds and forms of plastic pollution, but it generally refers to the buildup of plastic items in the environment that negatively impacts human health or wildlife habitat (Reddy et al., 2014). A negative impact on lands, waterways, and oceans can result from plastic waste. Since plastics are widely utilized by people and are reasonably priced and long-lasting, there is a strong

correlation between plastic pollution and these factors. (Reddy et al., 2014). Materials and products classified as plastics are composed of various high molecular mass polymers (Babayemi et al., 2018). Because of their low cost, minimal maintenance, low weight, and ease of production, they have many uses across time and space. The amount of plastic used in a wide variety of items has increased dramatically in recent decades. From 1.5 million tons (Mt) year in 1950 to 245 Mt annually in 2008, this commodity's global production surged. It has been estimated that by 2050, the world's plastic production might triple (Green paper, 2013). The last 50 years have seen a 20-fold growth in its use, and the next 20 years should see another 20-fold increase. Glass, ceramics, metals, and wood are gradually being replaced by plastic in many items. The food, beverage, and other fast-moving consumer goods industries now use plastic packaging materials. Nevertheless, when plastics reach the end of their useful lives, they pose problems for the management of solid waste. Plastic waste management, and recycling in particular, is a global problem that is made worse in African nations with weak waste management infrastructure (Cooper, 2013).

Literature Review

Plastic waste has the potential to be recovered and recycled (Wang et al., 2015). But the amount of plastics being disposed of in landfills and dumpsites is larger than ever, and recycling is not keeping up with the rate at which virgin plastics are manufactured (Merrington, 2017). Recyclable polymers are quite rare (Garcia, 2016). Low plastic recycling and recovery rates are found in African nations. Babayemi et al. (2015) state that waste plastics may also contain dangerous materials, which would restrict the amount of material that may be recycled. Volatile organic compound emissions during recycling in recycling workshops can present both short-term and long-term health hazards (He Z et al., 2017). Endocrine-disrupting substances like phthalates are present in a wide variety of polymers. The amount of maritime debris is always increasing. According to recent studies, there will be 250 times more garbage on some beaches in ten years than there is now (Kako et al., 2014). The vast majority of garbage comes from sources on land. A greater portion of marine litter is made up of plastic, which is a major and expanding global environmental concern (Dussud et al., 2017). 6.1 billion tons of plastic have been manufactured worldwide; 10% of this is predicted to end up permanently deposited in the world's oceans (Wichels et al., 2017). In 2010, 188 coastal countries are projected to have generated 275 Mt of plastic garbage, of which 4.8 to 12.7 Mt entered the ocean, with 0.25 to 1.00 Mt coming from Land. One of the main issues facing Africa and other developing nations is the inadequate management of solid waste, which is also a major contributor to the pollution caused by plastics (Babayemi and Dauda, 2009). Inadequate technological capacity and inefficient trash collecting systems provide issues for the region. Because Nigeria lacks source separation for solid waste, a greater percentage of waste plastic and other polymers wind up at dumpsites among other disposed of wastes. Recycling is a recommended method of managing plastic, and it is being used in this area to some degree. Apart from the restricted technological capability for recycling, there exists a possibility of dangerous compounds contaminating recycled plastic (Babayemi et al., 2016). Open burning and landfill fires, which discharge pollutants into the air, are used to dispose of polymers that do not find their way into the recycling stream. A further portion of plastic waste ends up in rivers and streams (Babayemi et al., 2017). In Nigeria, sufficient data on plastic/polymer quantities and categories are required to enhance plastic

management and provide suitable and productive policies and incentives. Rivers are a source of marine litter, according to recent studies, and Nigeria is sixth in the world for the release of plastic marine litter (Rech et al., 2014). As a result, emerging nations like Nigeria urgently need to manage waste plastics more effectively.

Materials and Methods

Two communities in Bariga, the Makoko community and the Ilaje community, were the study's primary focus areas upstream of the Lagos Lagoon.

Makoko Community

Makoko is a riverbank community in the Yaba local government area of mainland Lagos, located at latitude 6°29'46.06"N and longitude 3°23'34.69"E. The Third Mainland Bridge borders it to the south, the Lagos Lagoon to the east, Ebute-Meta to the west, and Iwaya and the University of Lagos to the north. Originally settled by the Ilajes and Eguns in the early nineteenth century, Makoko is also home to a small number of Yorubas, Igbos, and other ethnic groups. With an estimated population of 100,000, the municipality has several obstacles, especially heavy floods during the wet season due to its partially waterlogged topography. According to studies, Makoko serves as a haven for migrants from different coastal towns in Africa, such as those in the Niger Delta, Benin, Togo, and Ghana. The main industries in the area for its citizens are trading and fishing. Serious environmental and infrastructure problems plague the town, including limited access to necessities like homes, schools, healthcare facilities, and roadways. Most of the homes are made of fragile materials, which increases the community's susceptibility. The socioeconomic makeup of the population and the surrounding environment draw attention to the difficulties experienced by the urban poor, who have little ability to change their situation. Health hazards and environmental degradation are exacerbated by inadequate housing and basic amenities including waste management, potable water, sanitation, and overcrowding.

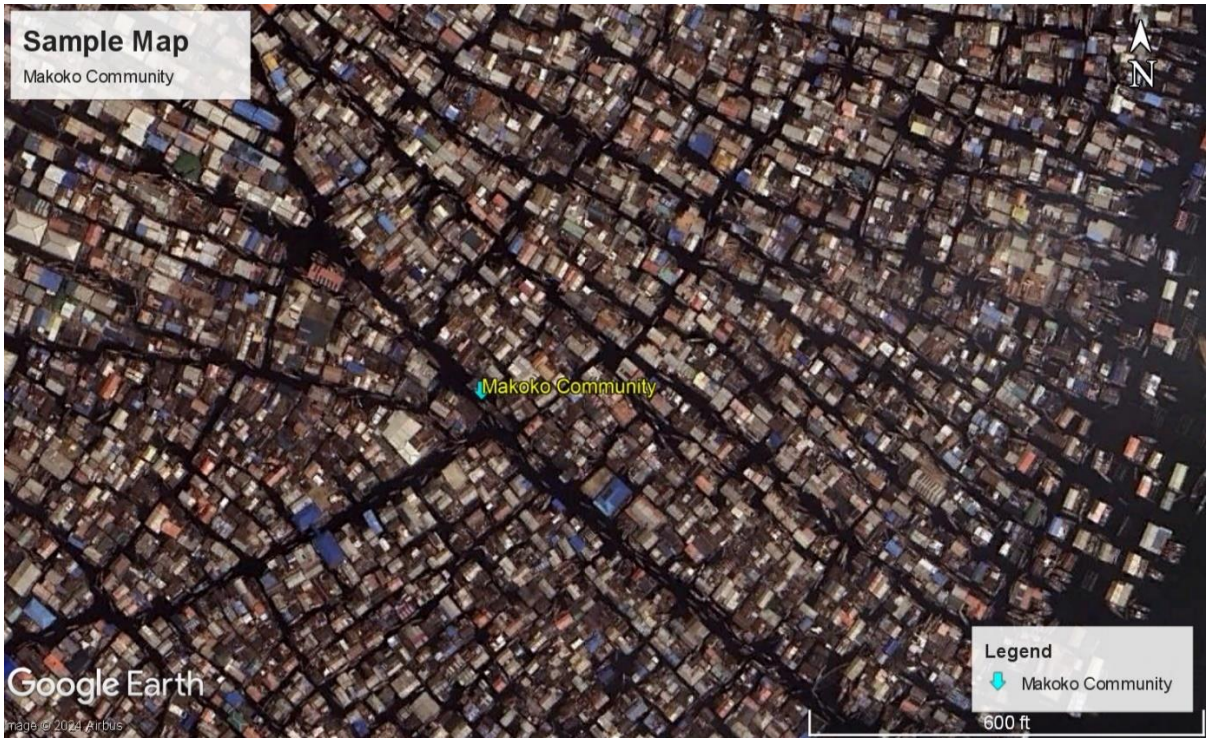

Figure 1: Sample Map showing Makoko Community

Figure 2: Sample Map showing Ilaje Community

Figure 1: Sample Map showing the two study sites

Ilaje (Bariga)

The research was conducted on Adedoyin Oshibanjo Street in Bariga, Lagos, which is roughly located at latitude N6°31'48.56761 and longitude E3°24'0.86576. In Lagos State, southwest Nigeria, there is a suburban neighborhood called Bariga that is part of the Somolu local government area. It shares boundaries with the Lagos Lagoon on the east, Mushin Local Government on the west, and the Lagos Mainland and Kosofe Local Government Areas on the north and south, respectively. There is a sizable Yoruba, Igbo, Hausa, and other ethnic group population in this varied community.

Sampling methods

The study utilized 1-kilogram trash bags to randomly collect various types of plastics from the Ilaje and Makoko communities. Over a five-day period at each location, four bags of plastics were gathered daily, resulting in a total of 792 plastics collected at Makoko and 708 at Ilaje. These plastics were subsequently sorted and categorized based on their types. In addition to physical samples, the study employed questionnaires distributed to neighbouring residents, with 200 questionnaires delivered in total (100 from each study site). The questionnaires aimed to gather information on the most used plastic products, people's disposal practices for these materials, and their awareness of plastic pollution and its environmental impacts. The collected questionnaire data was analysed using Microsoft Excel 2016. This analysis was instrumental in evaluating the quantity and types of plastics used, understanding the disposal methods employed by residents, and assessing the level of awareness regarding plastic pollution issues within the community. The combination of physical sampling and survey data provided comprehensive insights into plastic usage patterns, disposal behaviours, and community perceptions related to plastic pollution in both the Ilaje and Makoko neighbourhoods.

Plate 1: a) A section of Ilaje community before the exercise; b) Plastics waste collected after the exercise in Ilaje Community

Results

In the Makoko community study, respondents ranged in age from 13 to over 50, with the majority (91%) falling within the youth bracket of 13 to 40 years old. This demographic dominance highlights the significant presence of youth within the community, indicating their pivotal role in shaping its social and economic dynamics. Women constituted a higher proportion (60%) of the respondents, underscoring important considerations regarding gender dynamics within the community. This suggests potential gender-specific challenges or roles that women experience, warranting further exploration. The study also revealed that 85% of respondents had attained primary and secondary levels of education.

Plate 2: Field survey in study areas

This statistic calls for a critical assessment of the community's literacy rates and underscores its implications for individual empowerment, economic participation, and overall community development. Regarding age distribution within the study site, 45% of respondents were aged 13-20, followed by 25% aged 31-40, with no participants over 50 years old. This demographic breakdown offers insights into the community's age structure and demographic trends, emphasizing a concentration of youth and young adults within the study population. In the Ilaje community, there were two distinct scenarios observed in the survey. In one instance, female respondents outnumbered male respondents, comprising 60% of the total, while males constituted 40%. Additionally, 55% of all respondents had completed secondary education. In another scenario within the same community, the majority of respondents were male, accounting for 65% of the total participants. The literacy level was similar to the previous scenario, with a significant portion having attained secondary education. The age distribution showed 45% of respondents in the 13-20 age group and 20% in the 31-40 age group. These findings illustrate variability within the community, reflecting different gender compositions and age distributions in the surveyed populations as shown in (Table 1).

Table 1: Demography of the sampled respondents

Questionnaire Parameters	**Makoko Community**	**No of Response**	**Percentage (%)**	**Ilaje Community**	**No of Response**	**Percentage (%)**
Age	13-20	45	45.0	13-20	45	45
	21-30	21	21.0	21-30	25	25
	31-40	25	25.0	31-40	20	20
	41-50	9	9.0	41-50	10	10
	51and above	0	0	51 and above	0	0
Sex of Respondents	Male	40	40.0	Male	65	65
	Female	60	60.0	Female	35	35

Educational qualification	Primary level	30	30.0	Primary level	35	35
	Secondary level	55	55.0	Secondary level	50	50
	Tertiary level	10	10.0	Tertiary level	10	10
	Graduate	5	5.0	Graduate	5	5.0

Responses on Plastics use and disposal

In the Makoko community, the most used plastic material is nylons, which account for approximately 48% of total plastic usage. This is followed by plastic bottles at 36%. Plastic cups, plastic buckets, and plastic spoons have lower percentages, with 8%, 6%, and 2% respectively. On the other hand, in the Ilaje community, plastic bottles are the predominant plastic material, comprising approximately 62% of total plastic usage. Nylons follow at 30%. Plastic cups, plastic buckets, and plastic spoons each have a similar low percentage of 6%. plastic bottles and nylons being the most prevalent types, albeit in varying proportions across the two locations as shown in (Table 2).

Table 2: Responses of the most used plastics at Makoko and Ilaje

	Makoko		**Ilaje Bariga**	
Most used plastic material	**Frequency**	**Percentage (%)**	**Frequency**	**Percentage (%)**
Plastic bottle	36	36.0	62	62
Plastic cup	8	8.0	-	-
Plastic bucket	6	6.0	6	6
Plastic spoon	2	2.0	6	6
Nylons	48	48.0	30	30
Total	**100**		**100**	

24% of residents in Makoko recycle and reuse their plastic products, whereas 26% of people in the town dispose of their rubbish by tossing it into bins. The shocking truth is that 52% of respondents acknowledge carelessly discarding their waste on the floor after use. Surprisingly, none of the respondents burn the plastic waste they produce. When it comes to the disposal of plastic garbage, only sixteen percent of people in the Ilaje community choose to reuse their plastic objects, whereas forty-seven percent of people trash it into bins. Still, 37% of participants admit to leaving their waste on the floor after using something. Like Makoko, none of the Ilaje respondents said they ever burn their plastic debris (Table 3).

Table 3: Responses on mode of Plastics Disposal at Makoko

	Makoko community		**Ilaje community**	
Method of disposal	**Frequency**	**Percentage (%)**	**Frequency**	**Percentage (%)**

Throw into the bin	26	26	47	47
Reuse and Re-cycle	22	22	16	16
Throw on the floor (litter)	52	52	37	37
Burn	0	0	_	_
Total	**100**		**100**	

Issues considered to be of Environmental threat facing the study area by the respondents

Data analysis conducted in the Makoko community shows that 54% of respondents think that the main problem with plastic usage is that it creates litter, while 24% think that it takes up space in landfills. Of these, only 6% believe it to be related to animal deaths, while 16% do not think it poses a serious concern. In the Ilaje neighborhood, however, a greater proportion—65%—identifies the production of litter as the main issue related to plastic use, with 20% mentioning its effect on landfill space. Merely 5% of participants associate plastic usage with animal fatalities, while 10% do not consider it to be a hazard at all (Table 4).

Table 4: Responses on biggest concern of plastics pollution at Makoko

	Makoko community		**Ilaje Community**	
Concerns	**Frequency**	**Percentage (%)**	**Frequency**	**Percentage (%)**
It Creates Litter Problem	54	54	65	65
It Uses Space in Land Fills	24	24	20	20
It Can Make Animals Die	6	6	5	5
It Is Not a Problem (Threat)	16	16	10	10
Total	**100**		**100**	

Table 5 shows that the majority of respondents in the Makoko area, or 77% of them, do not believe that plastics can cause aquatic species to become entangled or suffocated and eventually die. On the other hand, just 23% of respondents think that plastics might endanger the marine life in Makoko. Similarly, in the Ilaje region, 29% disagree with 71% of respondents who do not think plastics can harm aquatic organisms by entangling and suffocating them.

Table 5: Perception on Effect of Plastic Debris on Aquatic Organisms

Can plastic debris cause entanglement? and kill marine organisms	**Frequency of Response (s)**	**Percentage (%)**	**Frequency of Response (s)**	**Percentage (%)**
Strongly agree	13	13	14	14
Agree	10	10	15	15
Disagree	47	47	57	57

Strongly disagree	30	30	I4	14
Total	**10**	**100**	**100**	**100**

The majority of people, approximately 92%, are unaware of how much plastic they produce annually, although 8% are aware of this information; In this study location, approximately 62% of respondents are unaware of the harm that plastic poses to the environment, whereas the remaining 28% are knowledgeable of these impacts; While 67% of people did not support waste management organizations like LAWMA coming to clean up the rubbish, 33% of people agreed; The government should be in charge of reducing the amount of plastic garbage in the environment, according to the majority of respondents (94%) and the remaining 6% who disagree; Of the participants, Less than half of respondents—28% agree to local initiatives, while 72% disagree admitted that they prefer to use alternatives such paper bags (54%), while 46% prefer to use plastic bags (Table 6).

Table 6: Responses to the questionnaire as regards to plastics waste management

Questions	**Yes (%)**	**No (%)**	**Yes (%)**	**No (%)**
Are you aware of how much plastic you generate in a year?	8	92	14	86
Are you aware of the environmental effects' plastic is causing in the world?	28	62	23	56
Is there a local plastic recycling scheme in your area?	22	78	36	64
Do any waste management authority come to do sanitation here?	33	67	90	10
Do you think government should be responsible` to help reduce plastic waste?	94	6	64	36
Do you prefer to use alternatives such as paper bags?	54	46	69	31
Any campaign to reduce plastic pollution in your area?	28	72	15	86

Distribution and Comparison of plastics types in both study sites

Figure 4 illustrates the distribution of various types of plastics found at both sites. The majority of the plastics are made up of polyethylene terephthalate (PET), which constitutes 49% of the total. This is followed by polyamide (PA) at 26%, and polypropylene (PP) at 10%. Polystyrene (PS) accounts for 4%, while the remaining plastics, categorized as 'others,' make up 2% of the total.

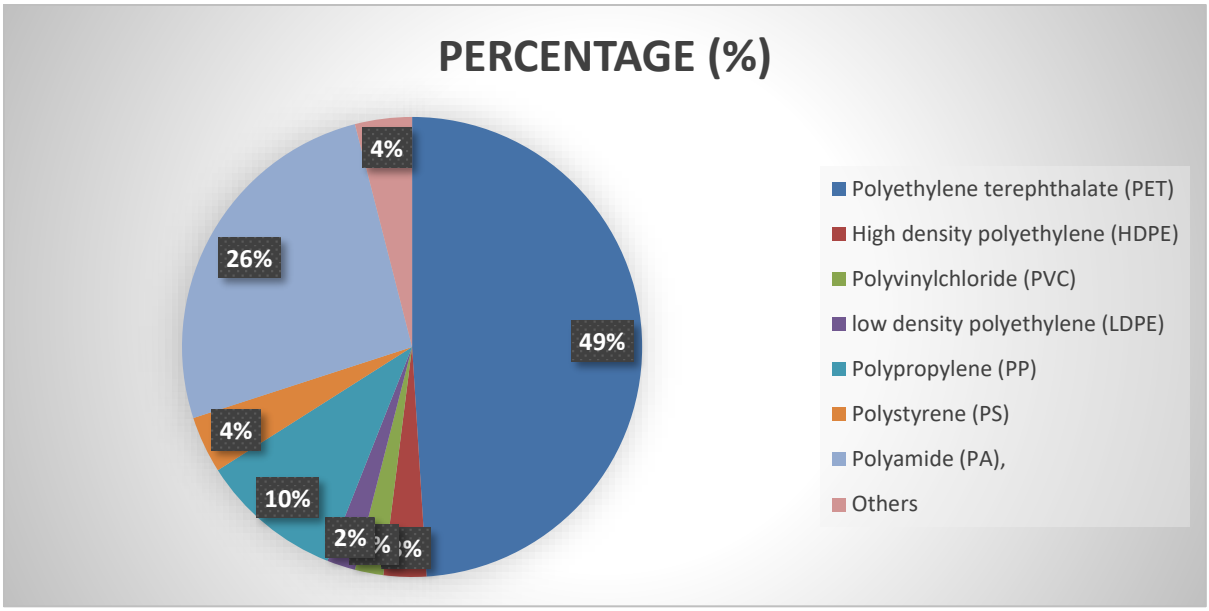

Figure 4: Showing the distribution of the total plastics found on the both sites

The distribution of different types of plastics at the two sites, Makoko and Ilaje, shows notable variations, as shown in Table 7 and Figure 5. At Ilaje, polyethylene terephthalate (PET) is the predominant plastic, constituting 66% of the total plastics found. In contrast, PET makes up only 30% of the plastics at Makoko. This indicates a significantly higher prevalence of PET in Ilaje compared to Makoko. High-density polyethylene (HDPE) is also more common in Ilaje, accounting for 5% of the plastics, whereas it represents only 2% in Makoko. Both sites show an equal presence of polyvinylchloride (PVC), with each site having 2% of this type of plastic. Low-density polyethylene (LDPE) is slightly more prevalent in Makoko at 2%, compared to 1% in Ilaje. Polypropylene (PP) has a fairly similar distribution at both sites, making up 10% of the plastics in Makoko and 9% in Ilaje. Polystyrene (PS) and polyamide (PA) distributions are not provided for Makoko, but for Ilaje, PS accounts for 6% and PA for 5%. The 'Others' category of plastics is significantly higher in Makoko at 43%, compared to only 6% in Ilaje. This suggests a greater diversity of less common plastics in Makoko. Ilaje has a higher concentration of PET and HDPE, whereas Makoko has a much larger proportion of miscellaneous other plastics, with similar levels of PP and PVC at both sites.

Table 7: Comparison of plastics types in both study sites

Brands	**Makoko (%)**	**Ilaje (%)**
Polyethylene terephthalate **(**PET)	30	66
High density polyethylene (HDPE)	2	5
Polyvinylchloride (PVC)	2	2
low density polyethylene (LDPE)	2	1
Polypropylene (PP)	10	9
Polystyrene (PS)	6	2
Polyamide (PA)	43	11
Others	5	4

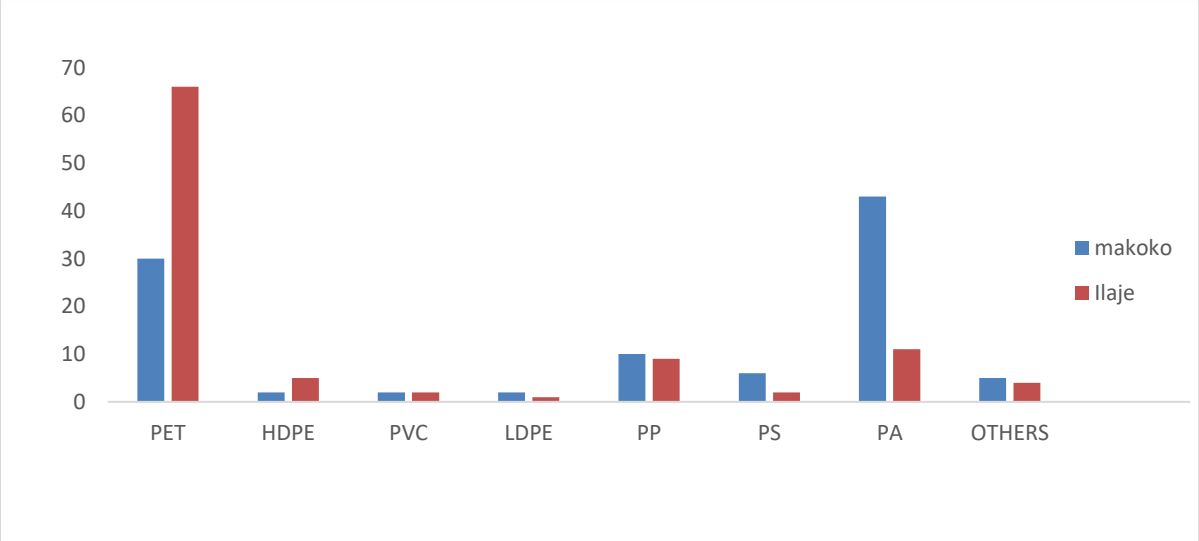

Figure 5: The comparative analysis of the two study sites

Discussions

The study revealed that Makoko community had a high prevalence of polyamide (nylon), which accounted for a significantly larger proportion of the plastic waste compared to other types such as PET, HDPE, PVC, LDPE, PP, and PS. This finding aligns with survey responses, indicating a widespread preference for nylon in the area. Additionally, a substantial majority of the respondents admitted to disposing of their plastic waste improperly, with over half littering their used plastics on the ground, contributing to the dominance of nylon waste in coastal litter. The preference for nylon is attributed to its use as wrappers and sachet water packaging, which are favoured for their affordability, cleanliness, and availability over alternatives like newspapers and natural leaves. This behaviour results in higher generation and improper disposal of nylon waste. The survey also highlighted a significant lack of awareness among the population regarding their plastic waste generation and its environmental impacts. Most respondents were unaware of the amount of plastic they produce annually and the adverse effects of plastic pollution, although there was a strong consensus that the government should be responsible for managing plastic waste. In contrast, the Ilaje community exhibited a different pattern, with PET being the most prevalent type of plastic waste, followed by other types in lower proportions. Plastic bottles were the most commonly used items, reflecting their dominance in the area's plastic waste. The disposal patterns in Ilaje were slightly better, with a higher percentage of respondents using waste bins compared to Makoko. However, a significant proportion still engaged in littering.These findings emphasize the urgent need for enhanced public awareness campaigns about the impacts of plastic pollution and the importance of proper waste management.

Conclusion and recommendation

Pollution has a profound and multifaceted impact on our resources, affecting them in ways that may not be immediately apparent. Despite being an inevitable consequence of our burgeoning population and advancing technology, its detrimental effects on resources are undeniable. Notably, pollution disrupts water quality, jeopardizing the well-being of aquatic ecosystems and hindering the sustainable utilization of water resources. However, with careful management, its adverse effects can be mitigated.

To address this pressing issue, these recommendations have been proposed:

Education plays a crucial role in raising awareness about pollution. By understanding its consequences, people can take proactive steps to prevent and mitigate its effects. Awareness campaigns and environmental education programs empower communities to adopt sustainable practices and reduce pollution. Initiatives like recycling plastics and installing barriers to prevent solid waste from entering ecosystems are essential measures. These actions not only reduce pollutants but also promote resource conservation and environmental stewardship. Recycling programs can turn waste into valuable resources, minimizing environmental impact. Embracing the Polluters' Pay Principle is a widely supported approach. This principle holds those responsible for pollution accountable for cleaning it up, either directly or indirectly. For example, policies that require consumers to pay for plastic grocery bags encourage recycling and waste reduction. This principle promotes accountability and ensures that pollution costs are not unfairly placed on society. Addressing pollution requires collective action and cooperation from all sectors of society. Government agencies, private companies, non-governmental organizations, and individuals must work together to implement effective pollution control measures. Collaborative efforts can lead to innovative solutions and shared responsibility in maintaining a clean and healthy environment. Ultimately, addressing pollution demands collective action and cooperation from all sectors of society. By working together towards a cleaner and safer environment, we can strive to make the world a better place for current and future generations to thrive.

References

Acampora H, Deudero S and Alomar C. (2016). Marine litter in the Balearic Islands: Current situation and temporal trends. Marine Environmental Research. 120: 146-154.

Babayemi JO and Dauda KT. (2009). Evaluation of solid waste generation, categories and disposal options in developing countries: A case study of Nigeria. Journal of Applied Sciences and Environmental Management. 13(3): 83-88.

Babayemi JO, Kofoworola OF and Ilemobade AA. (2017). Strategies for sustainable urban and rural waste management in Nigeria. International Journal of Sustainable Development & World Ecology. 24(5): 418-426.

Babayemi JO, Ogundele LT and Dauda KT. (2015). Quantity and quality assessment of plastic wastes in selected dumpsites in Lagos, Nigeria. Advances in Recycling & Waste Management. 1(2): 1-6.

Babayemi JO, Oyelami AO and Badejo OT. (2016). Evaluation of recycling as a solid waste management option for Nigeria. International Journal of Environmental Protection and Policy. 4(2): 32-39.

Bergmann M, Mützel S, Primpke S, Tekman MB, Trachsel J, Gerdts G and White M. (2017). White and wonderful? Microplastics prevail in snow from the Alps to the Arctic. Science Advances. 3(8): e1701629.

Cooper J. (2013). Introduction to the revised edition of "Green Paper". In Waste and Want: A Social History of Trash (pp. 1-9). Bloomsbury Publishing USA.

Deudero S and Alomar C. (2015). Mediterranean marine biodiversity under threat: Reviewing influence of marine litter on species. Marine Pollution Bulletin. 98(1-2): 58-68.

Dussud C, Hudec C, George M, Fabre P, Higgs P, et al. (2017). Colonization of non-biodegradable and biodegradable plastics by marine microorganisms. Frontiers in Microbiology. 8: 1571-1671.

Garcia MT. (2016). Recycling and resource recovery. In Reference Module in Earth Systems and Environmental Sciences. Elsevier.

Green Paper. (2013). Plastics waste management in Nigeria: An integrated approach to solve the environmental challenge. United Nations Environment Programme.

Hahladakis JN, Velis CA, Weber R, Iacovidou E and Purnell P. (2018). An overview of chemical additives presents in plastics: Migration, release, fate and environmental impact during their use, disposal, and recycling. Journal of Hazardous Materials. 344: 179-199.

He Z, Wang J and Tong J. (2017). Health risks of volatile organic compounds emissions from the recycling of electronic waste: A systematic review. International Journal of Environmental Research and Public Health.14(1): 46-46.

Jambeck JR, Geyer R, Wilcox C, Siegler TR, Perryman M, Andrady A et al. (2015). Plastic waste inputs from land into the ocean. Science. 347(6223): 768-771.

Kako SI, Ismail SNS, Ismail MH, Pauzi N and Hanapi ND. (2014). A review on the impacts of microplastics on marine environment and biota. Journal of Biological Sciences. 14(2): 108-116.

Merrington A. (2017). The circular economy: A new opportunity for the UK resource management sector? Resources, Conservation and Recycling. 127: 107-108.

Pivnenko K, Eriksson E, Astrup TF and Vollertsen J. (2016). A critical review of procedures for sampling and analysis of microplastics in wastewater and solid waste. Waste Management. 51: 324-333.

Reddy MS, Basha S, Adimurthy S and Ramachandraiah G. (2014). Marine debris ingestion by albatrosses in the North Pacific Ocean. Marine Pollution Bulletin. 49(12): 865-869.

Shaw SD, Kannan K and Halbrook RS. (2010). Persistent organic pollutants including polychlorinated and polybrominated dibenzo-p-dioxins and dibenzofurans in landfill fires from the United States. Environmental Science & Technology. 44(1): 999-1005.

Wang Z, An X, Wang S and Li H. (2015). A review of municipal solid waste environmental standards with a focus on incineration residues. Journal of Environmental Management. 147: 9-18.

Wichels A, Biel SS, Gelderblom HR, Brinkhoff T, Muyzer G and Schütt C. (2017). Bacteriophage diversity in the North Sea. Applied and Environmental Microbiology. 73(20): 6730-6739.