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KENYA Aquatica

A Scientific Journal of Kenya Marine and Fisheries Research Institute

KMFRI

Editorial

Editorial: Kenya Aquatica Journal Vol 10(1) – *A Showcase of KMFRI's Pioneering Research in Freshwater Ecosystems*

The latest edition of Kenya Aquatica Journal, Vol 10(1) showcases pioneering research by KMFRI scientists on Kenya's freshwater ecosystems. This edition, supported by KMFRI and WIOMSA, covers ecological, socio-economic, and environmental challenges, providing valuable insights into sustainable management practices.

One notable study investigates disease surveillance and antimicrobial resistance in fish from lacustrine caged farms, emphasizing responsible antibiotic use to maintain fish health. Another study explores the impact of organochlorine pesticides on macroinvertebrates in Lake ecosystems, advocating for Rhagovelia spp. as a bioindicator for pesticide monitoring across food webs.

Research on Lake Baringo's small-scale fishery assesses the catch and effort composition, stressing the need for regulatory enforcement to avoid overfishing and advocating for capacity building among stakeholders for sustainable management. Additionally, a study on wild fish kills in Lake Victoria focuses on eutrophication and pollution, recommending integrated watershed management to protect the lake's fisheries and local livelihoods.

A comprehensive study on Lake Elementaita – one of Kanya's flamingos' sanctuaries, combines water quality, fisheries studies, and community surveys, calling for integrated watershed management, conservation, and sustainable agriculture. Research on fisheries co-management in Lake Baringo highlights the importance of local community involvement and sustained achievements in ecosystem management, despite challenges in law enforcement.

An article on the socio-economic dynamics of Lake Victoria proposes establishing a regulatory framework incorporating citizen science to manage the lake's resources for long-term sustainability. Addressing plastic pollution in Lake Turkana, a study recommends waste management solutions, public awareness, and better enforcement of regulations to tackle the issue.

The journal also features research on antimicrobial resistance (AMR), with a review exploring Kenya's aquatic biodiversity for potential novel antimicrobial agents. A genetic research study evaluates freshwater fish populations, identifying gaps and proposing future directions for conservation and management.

Lastly, the journal presents an evaluation of fish market dynamics in Lake Naivasha, recommending infrastructure development like fish markets and hatcheries to support the region's fishery sector.

This edition of Kenya Aquatica Journal provides crucial insights into Kenya's freshwater ecosystems, covering a wide range of research on sustainable management, environmental challenges, and the socio-economic factors influencing aquatic resources. The research highlights KMFRI's ongoing contributions to understanding and addressing these issues, fostering a deeper understanding of Kenya's aquatic biodiversity.

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About Kenya Aquatica

Kenya Aquatica is the Scientific Journal of the Kenya Marine and Fisheries Research Institute (KMFRI). The aim of the Journal is to provide an avenue for KMFRI researchers and partners to disseminate knowledge generated from research conducted in the aquatic environment of Kenya and resources therein and adjacent to it. This is in line with KMFRI's mandate to undertake research in "marine and freshwater fisheries, aquaculture, environmental and ecological studies, and marine research including chemical and physical oceanography", in order to provide sci entific data and information for sustainable development of the Blue Economy.

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Submitting Articles

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Featured front cover picture: Researcher sampling surface plankton in the Kerio River inlet to Lake Turkana. (Photo credit: Mr. John Malala)

Featured back cover picture: Chair of KMFRI Board of Management Amb. Dr. Wenwa Akinyi Odinga Oranga (seated middle), on her right, Ag. KMFRI CEO Dr. James Mwaluma, flanked by KMFRI Heads of Sections: Front (L-R) Dr. Victoria Tarus, Ms Caroline Mukiira, Dr. Jacob Ochiewo, Dr. Irene Githaiga, Mr. Abraham Kagwima. Back (L—R) Mr. Paul Waluba, Ms Jane Kiguta, Dr. Gladys Okemwa, Dr. Eric Okuku, Dr. Joseph Kamau, Mr. Isaac Kojo, Ms Joan Karanja, Mr. Milton Apollo. (Photo credit KMFRI)

Research Vessel MV Mtafiti in the background

Assessment of the plastic pollution levels along Ferguson's Gulf, Lake Turkana

Maurice Obiero[1*], John Malala[1], Casianes Olilo[1], Chadwick Bironga[1], Jonathan Ekiru[1], Cyprian Odoli[2], Christopher Mulanda Aura[3]

[1]Kenya Marine and Fisheries Research Institute, Turkana Station, P.O. Box 205-30500, Lodwar, Kenya

[2]Kenya Marine and Fisheries Research Institute, Baringo Station, P.O. Box 31-30406, Kambi ya Samaki, Kenya

[3]Kenya Marine and Fisheries Research Institute, Kisumu Centre, P.O. Box 1881-40100, Kisumu, Kenya

***Corresponding Author:** mobiero69@gmail.com, +254719517205

Abstract

Plastic pollution is the accumulation of plastic objects and particles in the environment that has an adverse effect on humans, wildlife and their habitats. The present study aimed at assessing the level of plastic pollution along Ferguson's Gulf in Lake Turkana. Five sampling sites, namely Daraja, Namakat, Namkuse, Kenya Oil and Longe'ch were selected. Random sampling was done using 100 m^2 quadrats to quantify and identify the plastic debris that occur at the sites due to human settlement, fishing and other anthropogenic activities. Results showed that Daraja had the highest proportion of plastics at 28%, while Namkuse was least affected at 6%. With plastics categorized as polyethylene terephthalate (PETE), high density polyethylene (HDPE), polyvinyl chloride (PVC or Vinyl), low density polyethylene (LDPE), polypropylene (PP), polystyrene (PS or Styrofoam) and others, PETE was the most abundant at 45% while PS and PVC was the least abundant (3%). Higher plastic density (2 debris m^{-2}) was observed in Daraja and Namakat compared to Kenya Oil and Longe'ch (1 plastic debris m^{-2}). Daraja was therefore considered a plastic pollution hotspot in comparison to the rest of the sites. Recommendations proposed include the provision of waste bins, capacity building or sensitization forums on the negative impacts of plastic pollution and enforcement of relevant regulations by the National Environment Management Authority (NEMA). Otherwise, plastic pollution could adversely impact aquatic life inhabiting Ferguson's Gulf.

Keywords: plastic pollution, anthropogenic, debris, Ferguson's Gulf, Lake Turkana

Introduction

The accumulation of plastic objects and particles (e.g., plastic bottles, bags and microbeads) in the environment that adversely affects humans, wildlife and their habitat is considered plastic pollution (Carpenter *et al.,* 1972). Plastic pollution is ubiquitous, from deserts to farms, from mountain tops to the deep ocean, in Arctic snow and in tropical landfills (Borrelle *et al.,* 2020). Reports of plastic debris in the marine environment date back to half a century ago (Carpenter *et al.*, 1972). A number of reports indicate that plastic pollution poses significant threats on aquatic life, ecosystems, and human health (Derraik, 2002; Rochman *et al.,* 2015; Conchubhair *et al.,* 2019). It is estimated that 9.2 billion tonnes of plastic were produced between 1950 and 2017 (Borrelle *et al.,* 2020), with more than half this volume having been produced from 2004.

Plastics pollutants are categorized by size as micro-, meso-, or macro- debris (Borrelle *et al.,* 2020). Within these three categories, there are seven main types of plastics viz., polyethylene terephthalate (PET or PETE), high density polyethylene (HDPE), polyvinyl chloride (PVC or Vinyl), low density polyethylene (LDPE), polypropylene (PP), polystyrene (PS or Styrofoam) and other types of plastic . Plastics are inexpensive and durable, making them very adaptable for different uses, thus, manufacturers choose to use plastic over other materials. However, the chemical structure of most plastics renders them resistant to many natural processes of degradation and as a result they are slow to degrade (Lau *et al.,* 2020). These two major factors contribute to the accumulation of large volumes of plastic in environment as mismanaged waste and the subsequent long-term persistence of plastic debris in the environment.

It is reported that plastic pollution is on an increasing trend and will continue to increase, even in some of the most optimistic future scenarios of plastic waste reduction (Borelle *et al.,* 2020). Estimates of global emissions of plastic waste to rivers, lakes, and the ocean range from 9 to 23 million mt year^{-1}, with a similar amount emitted into the terrestrial environment, ranging from 13 to 25 million mt year^{-1} as of 2016 (Borelle *et al.,* 2020). According to Geyer et al. (2017), only 9% of all plastics ever made are recycled. Plastic pollution occurs as accumulated waste, accumulated marine litter, fragments or microparticles of plastics and non-biodegradable fishing nets which continue to trap wildlife, causing the death of animals by ingestion of plastic objects and finally, the introduction of microplastics and microbeads of plastics from cosmetic and body care products (Borelle *et al.,* 2020).

Plastics contribute to approximately 10% of discarded waste. Many kinds of plastics exist depending on their precursors and the method for their polymerization. Depending on their chemical composition, plastics and resins have varying properties related to contaminant absorption and adsorption. Polymer degradation takes much longer as a result of saline environments and the cooling effect of the sea, factors that contribute to the persistence of plastic debris in certain environments (Barnes *et al.,* 1998). However, The Environmental Report (UNEP, 2021) indicated that plastics in the ocean decompose faster than was once thought, due to exposure to sun, rain, and other environmental conditions, resulting in the release of toxic chemicals such as bisphenol. It is estimated that a foam plastic cup takes 50 years, a plastic beverage holder takes 400 years, a disposable nappy takes 450 years, and a fishing line takes 600 years to degrade.

Of all the plastic discarded so far, 14% has been incinerated and less than 10% has been recycled (Barnes, 1998). In Lake Turkana, especially along the Ferguson's Gulf, there are a number of activities that involve the purchase and use of plastic products in the informal settlements. A number of small and micro enterprise activities serve the fisher communities inhabiting the area around the Gulf. These enterprises sell products that involve use of plastics or are plastic in nature. Water containers, sweet rappers and cold drink bottles are some common types the plastic waste generated from these products. Fishing gear, especially monofilament nets are also discarded everywhere. The scarcity of portable water has further exacerbated the situation, with most portable water containers being plastic. These factors contribute significantly to plastic pollution and hence the need to assess the level of their pollution in the study area.

The main objective of the present study was to assess the level of plastic pollution along the Ferguson's Gulf in Lake Turkana to provide information for sustainable management of the area. Specifically, the study intended:

i. to assess the major types of plastic pollution along Ferguson's Gulf;
ii. to quantify plastic pollutants along Ferguson's Gulf;
iii. to identify major plastic pollution hotspots along Ferguson's Gulf; and
iv. to determine the intensity of plastic pollution along Ferguson's Gulf.

Materials and methods

Study area

Lake Turkana, lies within the Great Rift Valley in Northern Kenya. The Lake is approximately 250 km long, with an elevation of about 360 m above sea level and a maximum depth of 120 m. It has a surface area of 7,500 km^2, making it the largest lake in Kenya. Ferguson's Gulf lies 3°30′ 51″ N, 35°0 54′ 58″ E within the mid-Western part of Lake Turkana. Its surface area fluctuates depending on Lake levels at any given time (Kolding, 1989). It is a major fishing ground and is completely surrounded by informal settlements where various activities, including small and medium enterprises are undertaken (Kolding, 1989).

In the current study, five sites were identified for sampling of plastic pollutants, i.e., Daraja, Namakat Namkuse, Kenya Oil, and Longe'ch. The five sites were situated in settlement areas with fishing activities being undertakes at the shore. Shopping stalls and kiosks for refreshments characterize the area. Entertainment joints like bars and whisky shops are available as well. All these activities use plastics containers in one way or another to sell the products.

The five sites were located at different points along the Ferguson's Gulf of Lake Turkana. Amenities like schools and churches were found in the vicinity of the Gulf and one ice making enterprise (Adili Hub Ltd) was operating at the vicinity of Longe'ch as a source for ice.

Data collection and analysis

Random sampling using a 10 m x 10 m (100 m^2) quadrat was done to quantify and identify the types of plastic in the selected sites. Each site was randomly sampled in triplicate by marking the quadrat area and collecting all types of plastic within the quadrats. The samples were placed in gunny bags and sorted according to the seven types of plastics as per the identification chart developed (Table 1).

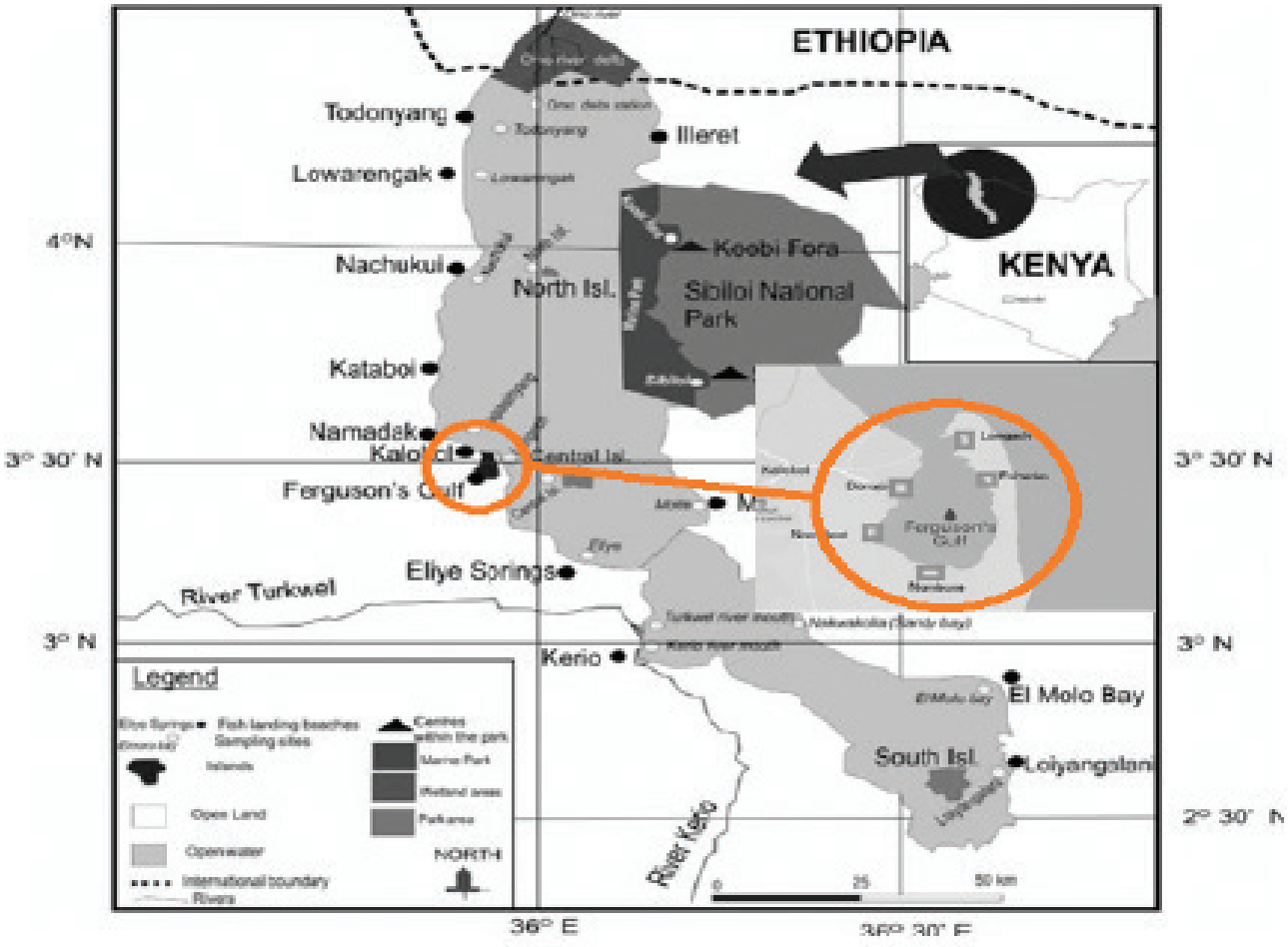

Figure 1. Map of Lake Turkana showing the study area (Source: Authors).

Table 1. Identification chart developed to characterize the samples collected based on the type of plastic.

Type of plastic	Sample type
Polyethylene terephthalate (PET or PETE)	Included soft drink bottles, drinking water bottles and cooking oil containers
High density polyethylene (HDPE)	Included milk jugs, laundry detergent bottles, cleaning solution bottles, shampoo bottles and conditioner bottles
Polyvinyl chloride (PVC or Vinyl)	Included cling wrap and piping (for plumbing)
Low Density Polyethylene (LDPE)	Included shopping bags and squeeze bottles
Polypropylene (PP)	Included drinking straws, medicine bottles and condiment bottles
Polystyrene (PS or Styrofoam)	Included clam-shell take out packaging and Styrofoam plastics
Other plastic forms	All other types of plastic waste

For each quadrat, the data were inserted in a pre-designed form, capturing the sample type and respective type of plastic collected at each of the five sampling sites. The data was subsequently entered Ms Excel spreadsheets and analyzed using the same application. Descriptive statistical analysis was done and the results mainly presented in graphs, tables and pie charts.

Results and discussion

Major types of plastic pollution

The major plastic type observed in the sampling sites was PETE, consisting of drinking bottles, bottled water containers and cooking oil bottles, totaling to 892 pieces (Table 2). Hot weather encourages use of drinking water in plenty, including use of juice and other food stuffs packaged in plastic containers. Most of the kiosks and shops store a lot of drinks and water bottles which are used and then scattered everywhere because there are no waste disposal bins or designated wastes disposal sites.

The second most abundant plastic type was LDPE, consisting of shopping bags and squeeze bottles. Shopping bags present a significant environmental concern owing the comparatively high frequency of utilization for shopping activities. The bags are predominantly single-use and rarely reused, resulting in their high accumulation as pollutants as a result of poor waste management practices.

The third category of plastics observed was the type of plastics categorized as other types, consisting mainly of monofilament nets dumped by the shore. The plastics pose a great danger to aquatic life, especially through ghost fishing and ingestion of microplastics. This is due to the disposal of fishing nets are at the beach, without any regard to the potential impacts on biodiversity. Limited access to portable water also contributes significantly to the use of drinking water packaged in plastic bottles, which further contributes to the rampant pollution in the study area.

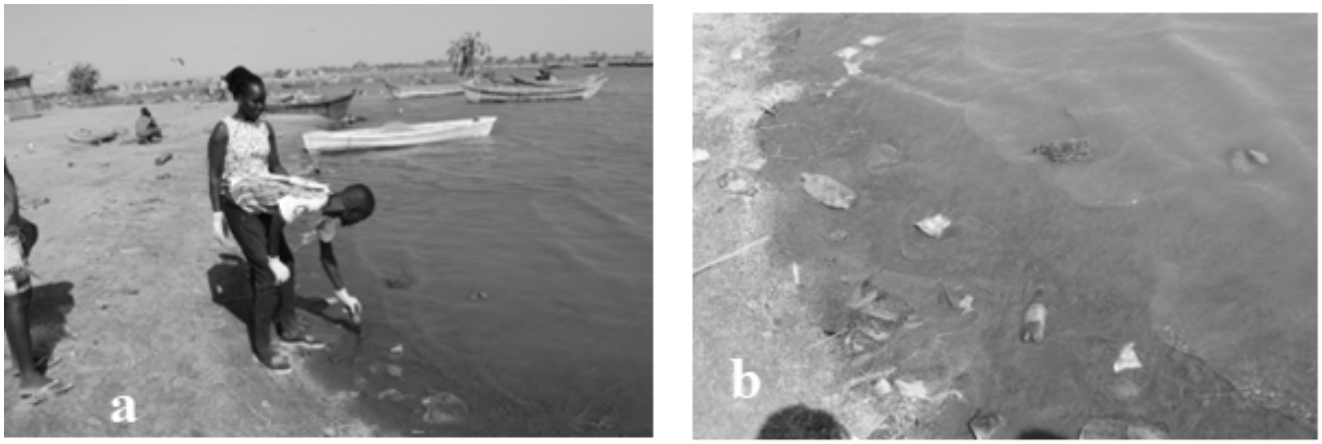

Figure 2. Plastic waste accumulation at the land-water interface along Ferguson's Gulf (Source: Authors).

Table 2. Number of plastic types at various sampling sites along Ferguson's Gulf in Lake Turkana. PETE: polyethylene terephthalate, HDPE: high density polyethylene, PVC: polyvinyl chloride, LDPE: low density polyethylene, PP: polypropylene, PS: polystyrene (styrofoam).

	Daraja	Namakat	Namkuse	Kenya Oil	Longe'ch	Total
PETE	346	224	58	152	112	892
HDPE	16	36	21	43	5	121
PVC	2	3	15	22	11	53
LDPE	51	22	23	217	192	505
PP	64	39	1	3	1	108
PS	26	29	0	1	6	62
Other types of plastics	47	101	13	12	64	237
Total	552	454	131	450	391	1978
% Composition	28	23	6	23	20	100

The least amongst the plastic types was the PVC. This was attributed to the fact that piping has not been scaled up in the study area, as evidenced by limited water pipes and lack of houses with piped water. Each sampling site exhibited unique plastic type composition determined by the activities being practiced therein.

Daraja site

Results showed that Daraja had the highest plastic composition out of the five sampling sites at 28% (Table 2). This could be attributed to the lack of portable water in Daraja. Majority of the residents prefer using bottled drinking water since water sourced from the Lake is mainly used for cooking and household chores. This contributes highly to plastic pollution in the site. Another source of plastic pollutants are the cooking oil containers. Deep frying is a major fish processing method in this area. The cooking oil used for this method of fish processing is sold in plastic containers, some of which are not recycled. The plastic waste is littered everywhere causing major plastic pollution in the area. Other major sources are travelers and traders who use plastic containers for either selling their products or purchase products packaged in plastic. Some of these containers are left to litter in the area, contributing to high plastic pollution. Fresh fruits and vegetables are wrapped in plastic bags which are also discarded anywhere in the area after use. Environmental factors, such as strong winds, facilitate the dispersal of accumulated litter from the lake shore throughout the study area. The confluence of these anthropogenic activities and inadequate solid waste management infrastructure has rendered Daraja a critical hotspot for plastic pollution within the Gulf region.

Namakat site

Namakat recorded the second highest proportion of plastic pollutants, accounting for 23% of the plastics samples collected. The site also recorded a comparatively higher number of PETE plastic types. This was attributed to lack of portable water, necessitating the purchase of bottled drinking water. The hot weather in the region further increases the consumption rate of drinking water.

Kenya Oil site

This sampling site contributed 23% of the plastics sampled. Unlike Daraja, where PETE was the dominant type of plastic, Kenya Oil was dominated by LDPE pollutants, indicating high usage of shopping bags and squeeze bottles.

Longe'ch site

Longe'ch sampling site accounted for 20% plastic samples collected. Similar to Kenya Oil site, shopping bags and squeeze bottles were higher in number than the other plastic types, thus LDPE plastic was the major pollutant at this site.

Namkuse

This site had a unique characteristic in terms of plastic pollution, contributing only 6% of the plastics sampled. All plastic types were few in comparison to other sampled sites, a factor that could be attributed to the low population level in the area. The community in the area has settled in farther away from the beach, resulting in reduced use of plastics at the shore.

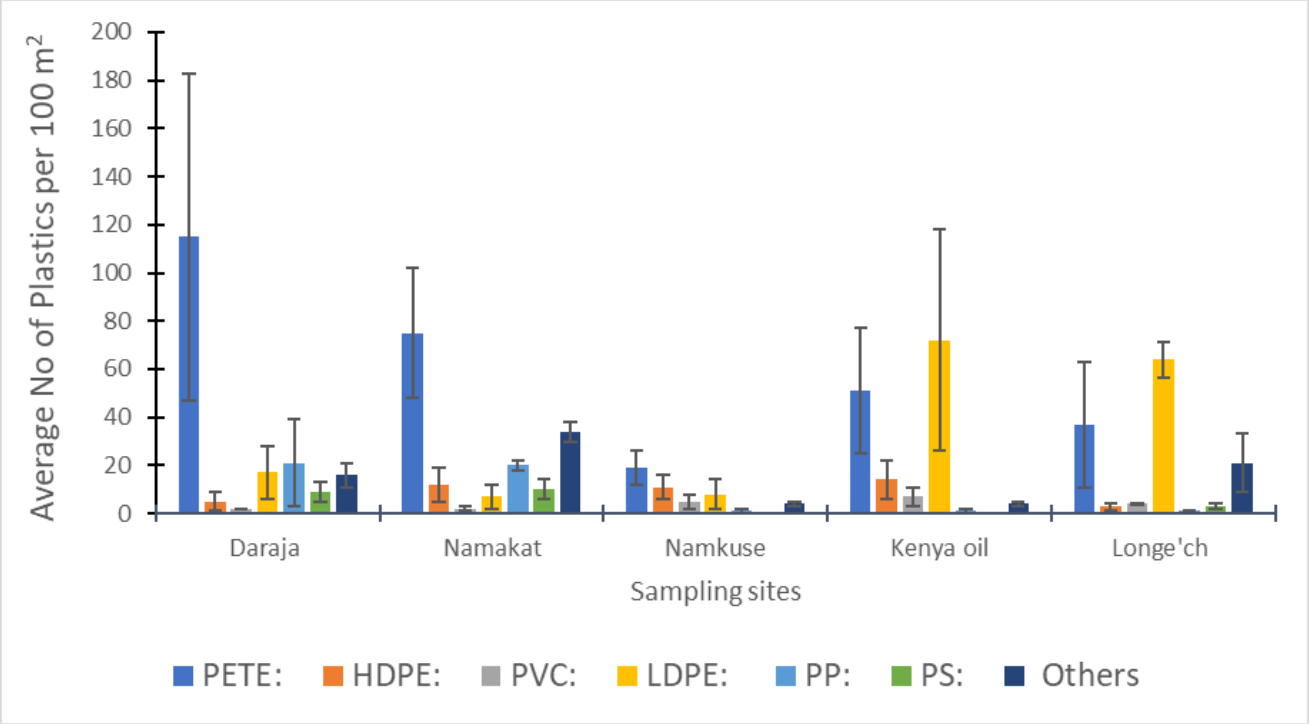

Figure 3. Average number of plastic types per quadrat in various sites along Ferguson's Gulf, Lake Turkana.

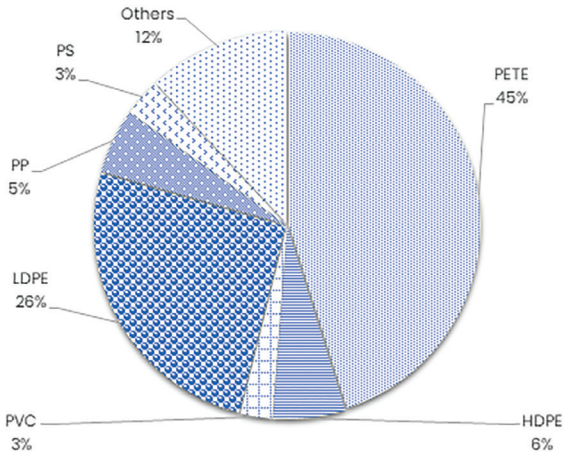

Figure 4. Percentage composition of different plastic along the Ferguson's Gulf, Lake Turkana. PETE: polyethylene terephthalate, HDPE: high density polyethylene, PVC: polyvinyl chloride, LDPE: low density polyethylene, PP: polypropylene, PS: polystyrene (styrofoam).

The results in Figure 4 show the average quantity of plastics in each quadrat in various sampling sites. Daraja sampling exhibited an average value of 115 ± 68 plastics for PETE with the rest of plastic types indicating values below 25 pieces. However, the variation in the number of plastic pollutants in collected in each quadrat was high meaning that different parts of Daraja had significantly different plastic quantity within the same site. It was also noted that Daraja leads in all sampling sites in the quantity of PETE plastic type followed by Namakat (75 ± 27) and Kenya Oil (51 ± 26) respectively. However, Kenya Oil took lead in low-density polyethylene (72 ± 46) followed by Longe'ch (64 ± 7) and Daraja (17 ± 11), respectively.

Relative composition of plastic types along Ferguson's Gulf, Lake Turkana

Results illustrated in Figure 5 indicate that 45% of plastic pollution in the Ferguson's Gulf is caused by PETE plastic type. This was followed by LDPE at 26%. The least type of plastic pollutant in the Gulf is PVC and PS, with a composition of only 3% respectively. Use of bottled drinks, water bottle and cooking oil with no major management of the same therefore pause a major threat to this environment especially to aquatic resources (fish and other aquatic animals) in the Gulf.

The need for waste management through a centralized disposal site and creation of awareness on proper handling of plastic waste is are highly recommended as immediate interventions to reduce the scale of plastic pollution. As shown in Figure 5d, the plastic further dispersed by wind and accumulate next to the shore posing a significant threat to water quality and ultimately to aquatic life.

Figure 5. Some of the plastic waste at Daraja landing site (Natirae BMU) along Ferguson's Gulf, Lake Turkana (Source: Authors)**.**

Discarded fishing gear should to be removed from the water and away from the shore for proper disposal. Beach Management Units (BMUs), the fisher community and other stakeholders require to be responsive to this problem and come up with effective ways to deal with it for sustainable management towards a clean and healthy environment.

Pollution hotspots in Ferguson's Gulf

The results show that Daraja is the most affected site in terms of plastic pollution (Fig. 7). This could be attributed to its proximity with Kalokol, a major shopping center with a comparatively high population. Most of the people operating at Daraja live in Kalokol and contribute to the introduction of plastic in form of shopping

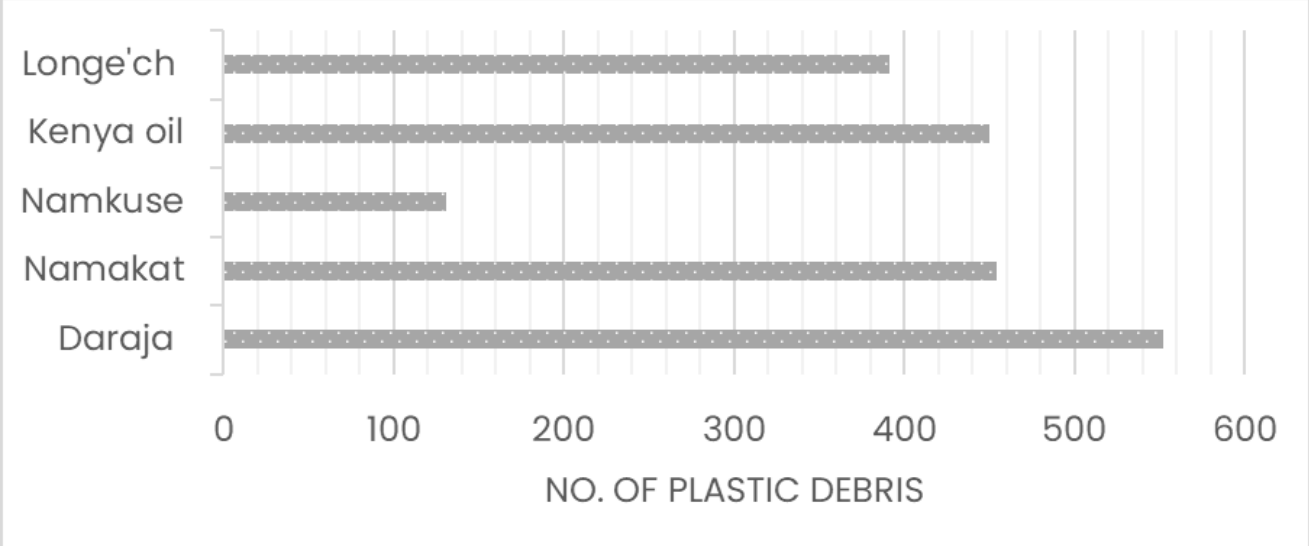

Figure 6. Number of plastic debris collected at different sampling sites along Ferguson's Gulf, Lake Turkana.

bags, drinking water bottles and oil containers to the site. Most these single-use plastic containers are dumped at the site, ultimately leading to high plastic waste at the beach. Secondly, Daraja is easily accessible by visitors and frequent traders from other locations who purchase fish while on transit to distant markets. Most of these visitors carry drinking water and other bottled drinks for use at the beach. These factors make Daraja site a hotspot in terms of plastic pollution.

Daraja site is closely followed by Namakat and Kenya Oil respectively. Owing to the gradual increase in the water levels of Lake Turkana, people inhabiting the Gulf have been relocating to settle in higher ground. This has resulted in an increase in the population of Namakat and Kenya Oil, which has contributed to a the increased use of plastic products such as shopping bags and consumables packaged using plastic containers such as cooking oil, bottled drinks and drinking water. These factors led to increased plastic debris in the area in question. Longe'ch as well bears the same problem of high plastic pollution. Most of the fishers and traders prefer settling here due to high fishing activity, thus, the use of plastic containers and plastic-wrapped products is eminent. Namkuse was found to be the least affected amongst the sites sampled, which is attributable to the sparse population density in the area.

Plastic density along Ferguson's Gulf

The findings of the present study indicated that Daraja and Namakat had an average density of 2 plastics m^{-2}; while at Kenya Oil and Longe'ch the average density was 1 plastic m^{-2} (Fig. 7). Namkuse on the other had indicated that one could easily miss getting a plastic in 1 m^2 area of the site. The intensity of 2 plastics per m^{-2} in Daraja and Namakat indicates higher pollution potential in the two sites compared to the others.

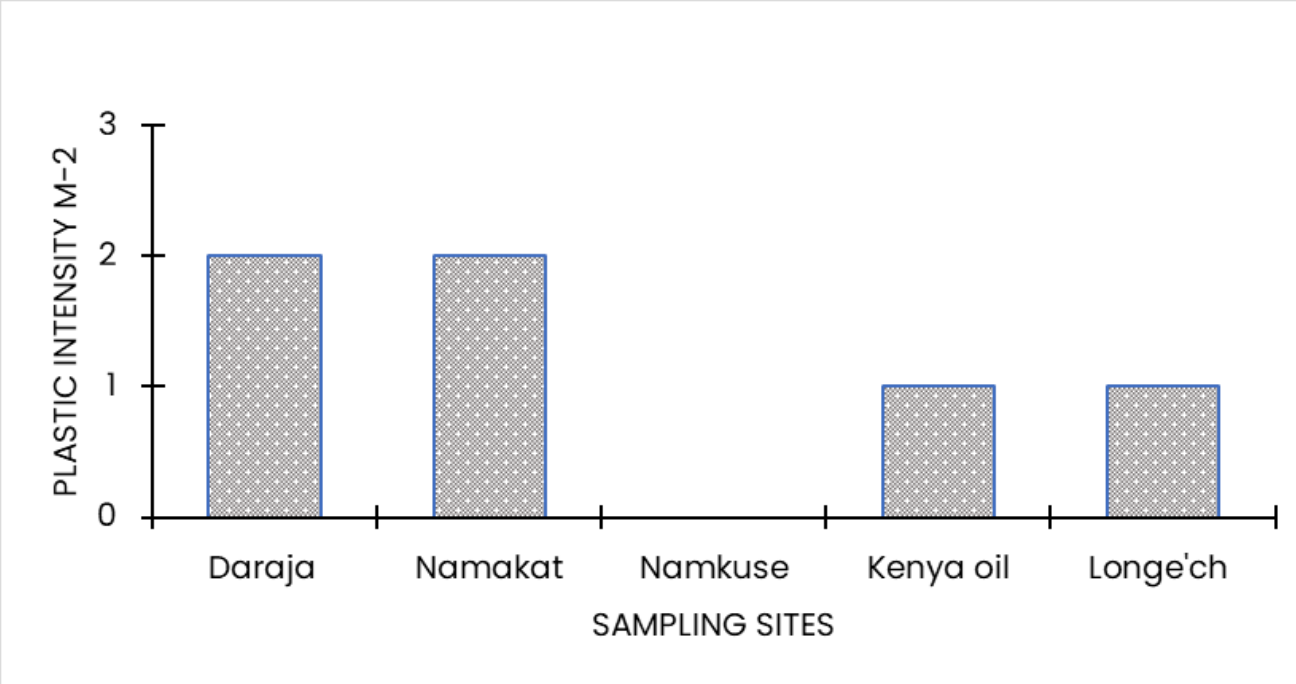

Figure 7. Density of plastic debris in various sampling sites along Ferguson's Gulf Lake Turkana.

Conclusion and recommendations

Ferguson's Gulf exhibited high level of plastic pollution that requires proper management. Daraja had the highest level of plastic pollution, followed by Namakat, Kenya Oil and Longe'ch, respectively.

Polyethylene terephthalate (PETE) e.g., beverage, water and cooking oil bottles consituted the bulk of the plastic pollutants in the Ferguson's Gulf. Low density polyethylene (LDPE) such as shopping bags and squeeze bottles were the second highest plastic pollutants, with Longe'ch and Kenya Oil sites taking the lead in this plastic type. Lack of proper management of the plastic waste along Ferguson's Gulf pose a significant threat to aquatic life in the study area.

There is need to establish solid waste collection points in the area to contain the spread of plastics to the Lake and adjacent environment. Beach Management Units, in collaboration with the County Government should come up with ways of managing plastic wastes in the respective beaches to reduce this plastic menace at the respective sites The enforcement of NEMA regulations banning the use of single-use plastic bags is to ensure the long-term reduction of plastic pollution. Capacity building and sensitization of all stakeholders should be undertaken on a consistent basis to encourage responsible use and disposal of plastics.

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