MICROPLASTICS POLLUTION IN COASTAL NEARSHORE SURFACE WATERS OF VANGA, MOMBASA, MALINDI AND LAMU, KENYA

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FINAL REPORT

By

Charles Mitto Kosore

SUMMARY

Plastic production has been increasing rapidly and became a potential threat to the marine environment, where they degrade to become brittle enough to fall apart into fragments and microsized plastics, typically not visible to the naked eye, called microplastics (MPs), with size range of ≥ 1 µm - 5 mm. Because of their size, MPs are available to a broad range of organisms and have already been shown to be ingested by several species. The ingestion of MPs by species at the base of the food web causes human food safety concerns as little is known about their effects and transfer across trophic levels. This study was to assess MPs abundance and composition in Kenya's coastal nearshore waters during north east monsoon (NEM) and south east monsoon (SEM) seasons respectively in order to capture the seasonal variations in distribution of MPs and inform of the possibility of MPs pollution entering the food chain, and lead to threats on communities' health due to consumption of contaminated seafood. Surface water MPs were collected in Vanga, Mombasa, Malindi and Lamu areas as a representation of South coast, Mombasa and North coast of Kenya's coastal nearshore waters, based on fishing, recreation, and industrial activities, as well as municipal effluents into these areas. The results showed a widely varied distribution of MPs between the two seasons, with the overall highest abundances of MPs being found SEM, where surface runoff from land due to rains as well as effluents from the major towns. The abundances were quite high compared to other parts of the world. This has provided a baseline data for MPs, showing that population, anthropogenic activities and seasonal variations play key roles in influencing MPs pollution and gives environmentally realistic abundances and composition that biota, especially seafood, are exposed to in the Kenya's marine natural environment, as well an opportunity for further studies of MPs in our coastal sea surface waters, sediments and biota, in combination with environmental factors.

1. INTRODUCTION

Plastic production has been increasing rapidly and became a potential threat to the marine environment. Plastic production in a wide variety of products reached 335 million tons worldwide and is estimated to have an upward trend of 1.5- 2.5% on 2017 and 2018. High consumption of plastics exceeds the recycle rates. Most of the plastic packages are not recycled, only 14% plastics package collected for recycling, 40% of which go to landfill, 32% leaks to the environment including marine ecosystem and the other 14% plastics wastes incinerated and/or used as energy recovery. Recent studies indicate that plastic debris in the ocean is between 7,000 and 250,000 metric tons. This prevailing condition is enough to notice that plastics have been a new potential threat to the environment (Cordova, et al., 2018).

Polymer degradation is a sequence of chemical changes that drastically reduce the average molecular weight and mechanical integrity of the polymer, mostly modulated by reactions like photo- and thermal-oxidation, hydrolysis and biodegradation mediated by microbial activity. Degradation rate can vary according to polymer typology, presence of chemical additives, oxygen availability to the system, environmental temperature. Compared to beaches, where temperature may raise up to 40°C in summer, plastic weathering is markedly slower in colder seawater and marine sediments. Coupled with physical abrasion, such as wave action and sand grinding, degradation leads to embrittlement and fragmentation. Extensively degraded plastics become brittle enough to fall apart into powdery fragments and microsized plastics, typically not visible to the naked eye, called MPs (Kazmiruk, et al., 2018). Based on the size, plastic particles in the marine environment MPs are categorized into megaplastics (≥ 1 m), macroplastics (≥ 2.5 cm - 1 m), mesoplastics (≥ 1 mm - 2.5 cm), MPs (≥ 1 μm - 1 mm) and nanoplastics (≤ 1 μm) (GESAMP 2015). However, < 5 mm sized plastics are categorized as MPs and depending on their origin, can be divided into two groups: primary, virgin granules originally constructed to be of microscopic size and used to produce macroplastics and secondary, originating from the degradation of macroplastics (Kazmiruk, et al., 2018).

Because of their size MPs are available to a broad range of organisms and have already been shown to be ingested by several species. The ingestion of MPs by species at the base of the food web causes human food safety concerns as little is known about their effects and transfer across trophic levels. Moreover, plastics can leach toxic additives and accumulate persistent organic pollutants (POPs) while residing in the marine environment (Maes, et al., 2017). The aim of this study was to assess MPs abundance and composition in Kenya's coastal nearshore waters during NEM and SEM seasons respectively in order to capture the seasonal variations in distribution of MPs and inform of the possibility of MPs pollution to the food chain, and lead to threats on communities' health due to consumption of contaminated seafood.

2. MATERIALS AND METHODS

2.1. Study Area

Surface water MPs were collected in transects at selected areas in Vanga (at open sea and around the landing site), Mombasa (at Mtwapa creek, Mombasa Marine Park area, off Nyali beach hotel and Tudor creek), Malindi (off Malindi public beach and Malindi marine park) and Lamu (at Ras Kitau-Shela areas and adjacent to Lamu town) as a representation of South coast, Mombasa and North coast of Kenya's coastal nearshore waters. The criteria of selection were based on fishing, recreation, and industrial activities, as well as municipal effluents.

2.2. Surface water sampling

Surface water MPs were collected during NEM and SEM seasons respectively in order to capture the seasonal variations in distribution of MPs. A manta net (Figure 2) of a 2 m long 300 µm mesh size net, with a rectangular opening of 14.5 cm × 29.5 cm and 26.5 cm × 10.5 cm cylindrical collecting cod end of 300 µm mesh-size was used for sample collection at a speed of 2 – 3 knots for 20mins. The samples were sieved in filtered sea-water through a 125 µm mesh-size sieve and preserved in 70% ethanol according to Kovač Viršek, et al., 2016 until analysis. However, samples were not collected in Lamu during SEM due to heavy floods that came with heavy rains in the area.

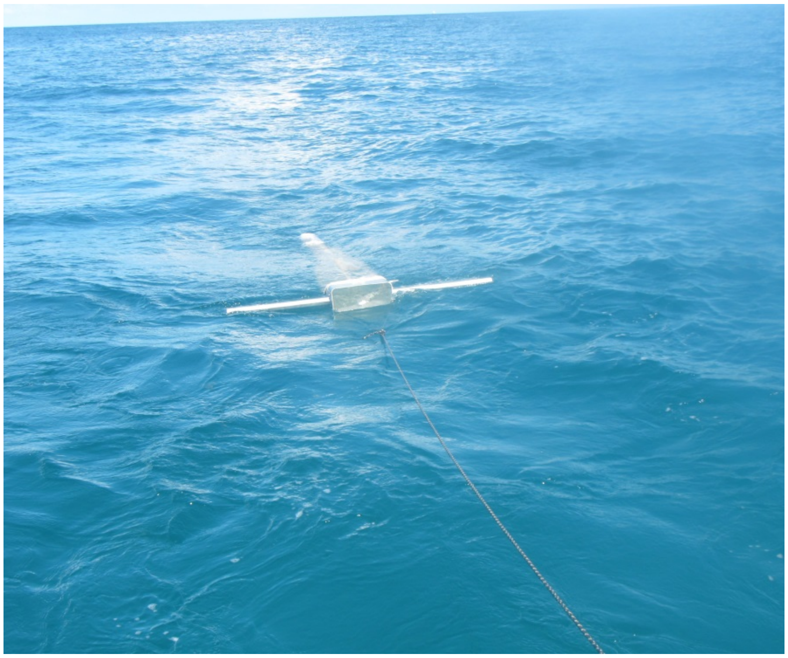

Figure 2: Manta net trawls during collection of surface water MPs

2.3.Microplastics sorting

Microplastic particles were visually sorted and characterized using an Leica dissecting microscope equipped Leica camera into colour, type (Gago *et al.*, 2018) and size (Kovač Viršek, et al., 2016). Volumetric concentrations of microplastic were calculated in m^{-3} by multiplying the number of microplastic particles by manta trawl opening area by transect length (Gewert, et al., 2017).

3. RESULTS AND DISCUSION

3.1.Microplastics abundances

Total abundance of MPs in all the study areas during NEM and SEM ranged from 83 – 8266 and 126 – 12,256 MPs m^{-3} respectively (Figure 3), with a mean of 3228 MPs m^{-3}. The highest microplastic abundances were found in Mombasa (12,256 MPs m^{-3}) during SEM, where runoff and effluents from the from the heavy rains are expected to be the main source, followed by Malindi again during SEM due to the input from River Sabaki through the rains. The results indicate that heavy rains during SEM play crucial role in the input of MPs into the ocean through runoff and river Sabaki.

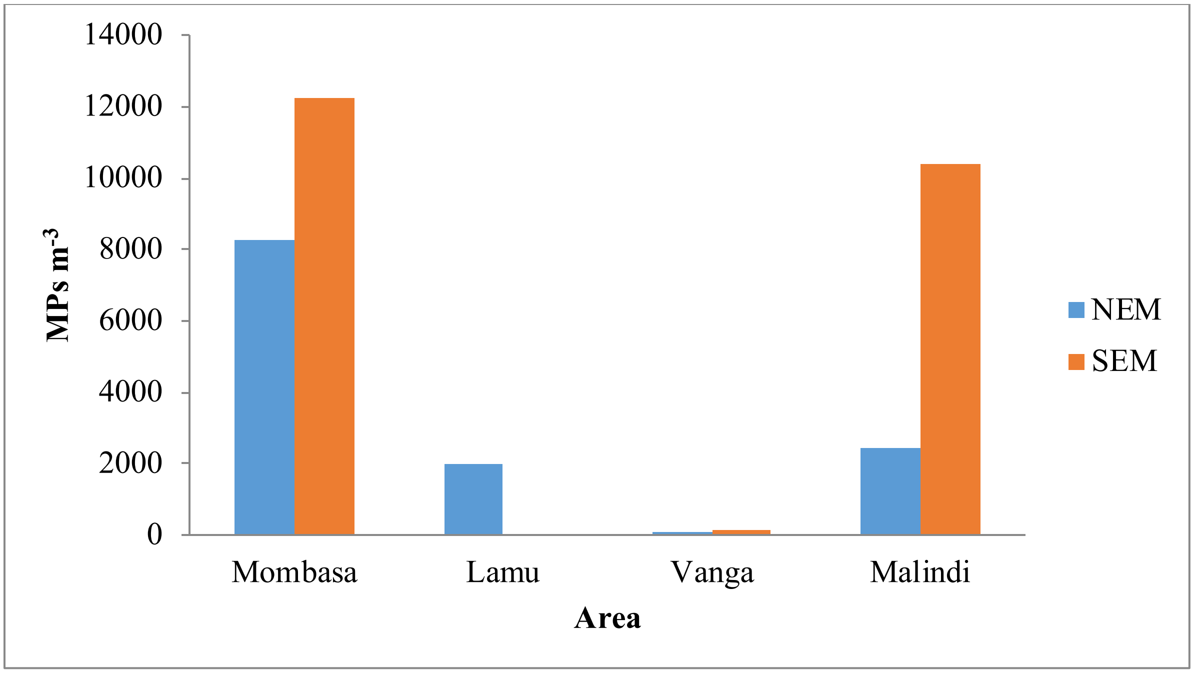

Figure 3: Total abundance of MPs in coastal nearshore waters of Vanga, Mombasa, Malindi and Lamu during NEM and SEM seasons

Higher abundances of MPs were found at possible point sources during NEM, and Point and diffuse sources combined during SEM. In Mombasa, Tudor creek recorded higher abundances due shipping activities at old port, discharge from Coast General Hospital, rain runoff from Kongowea market and Muoroto slums, and Mikindani sewage effluent. Malindi seems to be impacted mostly by river Sabaki outflows and a bit of tourism, in which the abundance ie enhanced by the rains during SEM. Lamu is impacted mostly by boat activities and a bit of tourism during NEM and runoff from the town during SEM, while fishing activities, as well as well as runoff from the village could be responsible for the MPs abundances recorded in Vanga. Similar observations were reported by Gewert, et al., (2017). The mean abundance recorded in Vanga, Mombasa, Malindi and Lamu led to the concern that these areas are highly impacted given that their total MPs abundances are about 600 times higher than (5.26 MPs m^{-3}) recorded in Stockholm Archipelago (Gewert, et al., 2017).

3.2. Microplastics Colour composition

The MPs were sorted into white, blue, black, red, green, transparent and others (brown, yellow, grey, pink, purple) according to Gago, et al., (2018). White coloured MPs were predominant during NEM and SEM with 106 and 182 particles respectively. Transparent particles were the highest during SEM with 184 particles, followed by white (182) and blue (103). The lowest colour green with 4 particles during SEM. The predominance of white coloured MPs were also reported by Gewert, et al., (2017) in Stockholm Archipelago. The number of coloured MPs varied considerably among the study areas (Table 1), with Mombasa recording the highest total number of coloured particles with 381 particles, followed by Malindi (240). The difference in number of coloured MPs could be reflecting the different uses of plastics and sources into the Kenya's coastal nearshore waters of Vanga, Mombasa, Malindi and Lamu.

Table 1: Total number of microplastic colours in the study areas

Area	Black		White		Green		Red		Blue		Transparent		Others	
	NEM	*SEM*	*NEM*	*SEM*	*NEM*	*SEM*	*NEM*	*SEM*	*NEM*	*SEM*	*NEM*	*SEM*	*NEM*	*SEM*
Mombasa	6	3	75	112	2	NIL	3	11	27	44	26	30	19	23
Lamu	0	-	5	-	1	-	NIL	-	8	-	3	-	1	-
Vanga	4	1	16	24	NIL	5	1	3	2	7	NIL	3	NIL	NIL
Malindi	1	3	10	12	6	10	NIL	2	9	17	7	143	4	16
TOTAL	**11**	**14**	**106**	**182**	**9**	**15**	**4**	**25**	**46**	**103**	**36**	**184**	**24**	**44**

3.3.Microplastic Types

Microplastic particles were categorized into five different types, i.e., fragments, fibers, films, foams and pellets. The most common types were fragments with 81 and 203 particles during NEM and SEM respectively, followed by transparent (182), and fibers (103) in SEM, although slightly higher fibers (41) than transparent (32) were recorded in NEM. Majority of the microplastic types were found in Mombasa, followed by Malindi (Table 2).

Table 2: Total number of microplastic types in the study areas

Area	**Fiber**		**Fragment**		**Pellet**		**Foam**		**Film**	
	NEM	*SEM*	*NEM*	*SEM*	*NEM*	*SEM*	*NEM*	*SEM*	*NEM*	*SEM*
Vanga	23	34	2	18	NIL	NIL	NIL	1	0	6
Mombasa	15	45	65	156	1	NIL	10	15	11	29
Malindi	2	24	8	29	NIL	NIL	NIL	3	18	147
Lamu	1	-	6	-	NIL	-	4	-	3	-
TOTAL	**41**	**103**	**81**	**203**	**1**	**0**	**14**	**19**	**32**	**182**

The pictures of particles shown in plates A – C indicate that sources could have been derived from degraded plastic liter/debris in and around the study areas according to Helm, (2017).

A

B

C

Plate **A** shows MPs particles from Tudor creek, **B**, from Malindi, and **C**, from Lamu.

3.4.Microplastics size categories

Three size categories were identified (Figure 2). The dominant size category was 2 – 5 mm during SEM, followed by 1-2mm during both NEM and SEM. The results show that Vanga, Mombasa, Malindi and Lamu coastal nearshore waters contained floating MPs, indicating that marine organisms living these areas may be exposed to MPs through ingestion and enter marine food chain, hence threaten human health through consumption of the contaminated seafood.

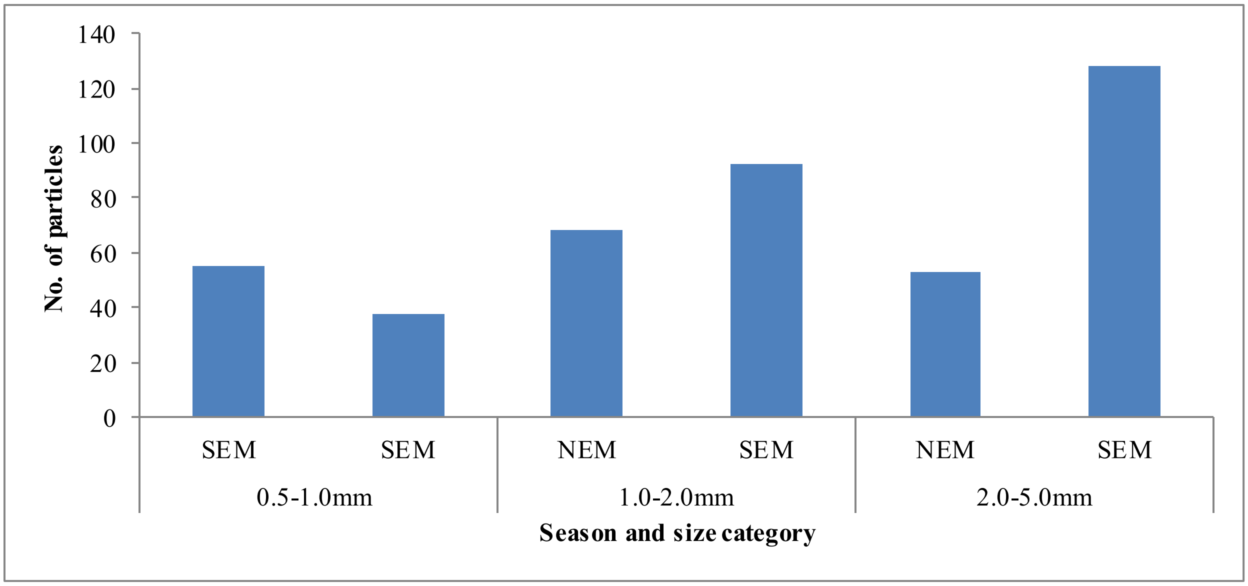

Figure 2: Size categories of a portion of microplastic particles in the study areas

CONCLUSIONS

The MPs were widely distributed in the study areas, with varied abundances, which are quite high, compared to other parts of the world, especially depending on the population and anthropogenic effluents. This study has provided a baseline information for MPs, showing that population, anthropogenic activities and seasonal variations play key roles in influencing microplastic pollution in Kenya's coastal nearshore waters. The results give environmentally realistic abundances, colours, types and sizes of MPs that biota, especially seafood and humans, can be exposed to in the Kenya's marine natural environment, and an opportunity for further studies of MPs in our coastal sea surface waters, sediments and biota, in combination with environmental factors.

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