Research article

Characterisation of litter and their deposition at the banks of coastal lagoons in Ghana

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ABSTRACT

Coastal lagoons near shores of the marine environment are transitional zones that accumulate litter in transit to the oceans. In view of this, it is important that the dynamics of lagoon litter accumulation are well understood to inform waste control and sustainable management of the coastal environment. The present study assessed the spatio-temporal distribution of lagoon litter along the eastern coast of Ghana, taking a critical look at the abundance and diversity of lagoon litter. Five coastal lagoons were studied: the Kpeshie, Mukwei and Sakumo II lagoons (in urban locations) and the Gao and Keta lagoons (in non-urban locations). Site specific litter abundance (number of items) along the banks of the lagoons ranged between 842 and 8,243 items/month at a deposition rate of 0.71 items/m²/month. Plastic litter was by far the most abundant and diverse litter fraction. Generally, lagoons at urbanised areas of the coast were found to accumulate more litter than those located at non-urbanized areas. Other key factors that affected the accumulation of lagoon litter included proximity to communities, rainfall and the use of lagoons for recreational and religious activities. The results provided baseline data for lagoon waste management in the coastal environment in Ghana and other West African countries that share similar coastal characteristics.

1. Introduction

Marine ecosystems are defined as complex range of physical, chemical and geological variations in tandem with different habitats that range from highly productive near shore regions that extend to the deep-sea floor inhabited by highly specialized organisms (EEA, 2010). Coastal lagoons near shores of the marine environment are transitional zones that accumulate litter in transit to the oceans. They are among the most sensitive ecosystems particularly subjected to direct human impacts such as overexploitation of their resources, pollution and various forms of environmental degradation (EEA, 2000; Pérez Ruzaffa et al., 2011). Lagoon-ocean interactions resulting from the frequent formation and breakage of sand bars provides an avenue for the flow of litter to and from the sea. About 6.4 million tons of marine debris is estimated to enter the seas annually (UNEP, 2005) through this interaction. Litter accumulation in the marine environment poses significant threat to marine mammals, other biota and users. Stranded litter, for example, can entangle marine mammals, restrict their movement, affect their ability to catch food and escape from predators. It can also cause exhaustion and lacerations that might finally result in their drowning (Houser, 2021). Thus, solid waste pollution is a major environmental problem that is continually plaguing coastal lagoons and gradually bringing them to a state of disrepair (see Table 1).

Seabirds tend to mistake bottle tops and lids for food and ingest them thereby resulting in starvation and sometimes death (Wemer et al., 2016). Litter serves as a medium for the introduction and transfer of toxic substances into marine environments. It transfers non-native invasive species to a particular marine ecosystem (UNEP, 2005; Allsopp et al., 2006). Barnes and Milner (2005) have found invasive barnacle species Elminius modestus on plastics on the shoreline of the Shetland Islands and Mouat et al. (2010) have also explained the adaption of these alien species to the changing environmental conditions of a place to the slow movement of marine litter in the marine environment as it gives enough time for the alien species to adjust. Other destructive effects of litter in marine environments include incidences of “ghost fishing” by derelict fishing gears such as traps, pots and nets which continue to trap fishes for long periods (Mouat et al., 2010). Thus, such abandoned gears in the marine environment never end fishing. Sheavly (2005) describes this
untargeted fishing mechanism as perpetual “killing machines”. This situation undermines fisheries management and threatens marine life (OSPAR, 2009; STAP, 2011).

Litter in lagoon environments also hinders the perching abilities of both resident and migratory birds and denies them of benthic organisms, which they depend on as food. Plastic carrier bags that hang on mangroves produce peculiar sounds by wind action and greatly disturb the foraging of birds (Singh et al., 2013). Litter also reduces the aesthetic appeal of the marine environment and strips it off the tourism potential coastal communities stand to gain (Tudor and Williams, 2003). Litter is also hazardous to human as items like broken pieces of glass, rusty metallic objects and other sharp plastic materials can injure users of beaches and lagoons (Wemer et al., 2016; Cheshire et al., 2009). As more litter is disposed into the marine environment, there is an increased risk of deleterious effect on the biophysical characteristics of the marine environment. The volume of litter in the marine environment is not only inversely related to its geographical distance from heavily populated centers but also directly related to the number of users (Asensio-Montesenos et al., 2021).

Studies on marine litter in Ghana and across the globe are skewed to the beaches. Thus, there is currently a dearth of knowledge on the composition, abundance, and diversity of litter on banks of lagoons, especially in tropical environments. The aim of this study was to characterize lagoon litter in Ghana and assess the factors that may influence litter composition, abundance, and diversity. This study provides baseline information on the deposition of litter on the banks of coastal lagoons in Ghana. The data are useful for lagoon solid waste management in Ghana and other West African countries that share similar coastal characteristics.

2. Material and methods

2.1. Study area

The study was undertaken along the banks of five lagoons located on the eastern coast of Ghana. The socio-economic and ecological importance, as well as how easy the lagoons could be accessed were primary factors considered in the selection of sampling sites. The availability of a maximum shore length of about 100 m was also key in the selection of the sampling sites (Cheshire et al., 2009; Lippiatt et al., 2013). The five sampling sites namely Kpeshie, Mukwei and Sakumo II lagoons are located at the western end of the eastern coast of Ghana, whereas the Gao and Keta lagoons are located more to the eastern portion of the coast of Ghana.

Table 1. Litter abundance at the banks of some coastal lagoons in Ghana over a 6-months period.

| Site       | Proximity of lagoon to Urban centre | Overall litter count (abundance) |
|------------|-----------------------------------|--------------------------------|
| Kpeshie    | Close proximity                    | 49457                           |
| Mukwei     | Close proximity                    | 18928                           |
| Gao        | Remote                            | 16143                           |
| Sakumo II  | Close proximity                    | 16899                           |
| Keta       | Remote                            | 5052                            |

The data are useful for lagoon solid waste management in Ghana and other West African countries that share similar coastal characteristics.

Figure 1. Map of Ghana showing the eastern coast. The green dots show the sampling sites.
Ghana. The Keta lagoon complex is located at the extreme end of the eastern coast (Figure 1).

The lagoons were classified as "urbanized" and "non-urbanized" according to their proximity to a major urban center or outskirts of rural and municipal area. Kpeshie, Mukwei and Sakumo II were considered ‘urbanized’, whereas Gao and Keta lagoons were categorized as non-urbanized.

The selected lagoons were all major fishing sites to communities around them and served as nursing grounds for fishes (Entsu-Mensah et al., 2000). The Sakumo II and the Keta lagoons, for instance, are designated as wetlands of international importance especially as water-fowl habitats (RAMSAR sites). The Kpeshie lagoon receives freshwater from its northern and eastern portions, but all these input channels have been flooded with waste, thereby restricting the flow of freshwater into it. It has a well-developed sandy bar that attracts tourist all year round, particularly during festive seasons notably during public holidays. The Mukwei lagoon receives its water inflow from two main freshwater sources—one from its eastern side and the other from its western side and empties into the sea through a narrow strip, which opens significantly during high tides. Its adjoining beach is a popular recreation site that also usually gets very busy during festive occasions and holidays. It also serves as a spiritual ground for some worshippers. The Sakumo II lagoon is a wide flat plain with freshwater marshes. It covers an area of about 1 km² in the dry season (Mid-November –April). It is normally inundated during the wet season when its surface area increases significantly to about 10 km² with floodwaters. It hosts at least thirteen (13) fish species belonging to thirteen (13) genera and eight (8) families including Sarotherodon melanotheron (Black-Chin Tilapia), which constitutes about 97% of the fish population (Klak et al., 2012). The Lagoon is separated from the sea by an eroding sand bar and opens into the sea through artificial conduit points constructed with culverts that lie underneath a road. It is one of five coastal RAMSAR sites in Ghana and is also home to many bird species. Two principal sub-drainage basins recharge it; one of which lies to its western part and the other to its northern part. The Gao lagoon receives freshwater inflow both from its north and occasional storm flood water from its eastern side. Like the Mukwei lagoon, its sand bar is bridged at the western corner to the sea and also serves as a sandy beach for beachgoers. The southern part of the lagoon is shallow and completely exposed during low tides thereby depositing much of the litter in its containment on its banks, while the northern part is relatively deep and remains loaded with litter at all times. The Keta Lagoon complex is the largest lagoon in the West African sub-region and is also a designated RAMSAR site-wetlands internationally recognized as habitats for waterfowls. Cast net, bottle traps, gill net, drag net and rope fishing are popular fishing gears deployed for fishing by the indigenes of the area for their fishery expedition (Entsu-Mensah et al., 2000).

2.2. Study design

The litter survey was conducted for a period of six continuous months from July to December 2016. Different approaches have been adopted by several studies for litter surveys. Whereas some have focused only on freshly deposited debris, others have concentrated on accumulated debris in addition (Asensio-Montesinos et al., 2021). In this survey, all visible litter found within the established 100 by 50 m transect that lie parallel to the lower water mark of each lagoon and extending to the vegetation cover or dune in any new month of sampling were collected. These areas were then closely monitored over the sampling period by an average of 5 trained volunteers. They lined up at one end of the 50 m side of the transect with approximately 2 m intervals between them and then walked slowly along the 100 m stretch parallel to the lagoon water mark and collected every visible litter on their course. The team then repeated the walking and collection pattern in a reversed direction towards the tip of the vegetation cover or dune until the entire transect was completely covered and every litter collected from the 100 × 50 m transect. All litter collected were taken away from the sampling site, counted and weighed.

The collected litter was then classified according to their material composition and grouped under the eight categories as prescribed by Oslo-Paris (OSPAR) Convention for the protection of marine environment of the North-East Atlantic classification list (OSPAR, 2010). They included plastics, metallic objects, fabrics, papers, glasses, plant materials, polystyrenes and ropes/nets. Unclassified items were grouped under "others" category. After classification, the litter was conveyed to the nearest municipal or rural waste management sites for proper disposal to avoid double counting at subsequent visits. Thus at any particular month, it was only freshly accumulated litter that was collected for analysis.

The composition, abundance and diversity of lagoon litter pollution at each site were determined. Litter composition is what the litter is made up of; litter abundance implies the total number of individual litter encountered; while litter diversity implies the variety of litter in the litter waste stream. A data sheet predesigned in accordance with the OSPAR (2010) classification scheme of eight main groupings was used to categorize the litter found. The overall abundance of each broad litter category was then determined by summing up the sub-totals of individual litter within that category. The data sheet was also useful in determining the litter diversity by the number of the different types of litter counted under the broad litter classification by OSPAR (2010) and by the further count of the respective different litter types under a given litter category.

2.3. Statistical analysis

The unit of analysis was the litter, and it was expressed in both number of items that were counted (litter abundance), and the corresponding weight (kg) of each category of items. The monthly variation in litter abundance at each site was compared using ANOVA. The litter abundance was also compared across sites using ANOVA. Differences resulting in p < 0.05 were considered statistically significant. Trends in litter streams across sites were evaluated with a scatter plot. All the analyses were done with Microsoft Excel. Normality of data was checked using Shapiro-Wilks test and the data was found to have a normal distribution.

3. Results

3.1. Lagoon litter abundance in Ghana

Kpeshie lagoon recorded the highest litter abundance over the 6 months study period (49,457 items), which weighed 2117 kg. It also constituted 46.44% of the overall abundance and 42.8% of the total mass. Mukwei lagoon accumulated the next highest abundance of litter (18,928 items) constituting 17.78% of the total litter abundance and 14.76% (730 kg) of the total mass. Total litter abundance at the Sakumo II lagoon (16,899 items) represented the third highest for the study and accounted for 15.87% of the overall litter abundance. The litter mass at Sakumo II lagoon however represented 24.25% (1200 kg) of the total mass of litter in this study. Gao lagoon recorded 16143 items (15.16%) of the overall litter abundance accounting for 16.17% (800 kg) of the total mass, whiles Keta lagoon recorded the lowest litter abundance of 5,052 items (4.74%) and formed 2.02% (100 kg) of the overall mass. Lagoons found closer to urban centers (such as Kpeshie, Mukwei and Sakumo II lagoons) accounted for 85,284 items (4047 kg) of the overall litter accumulation, while those found at non-urbanized centers (Gao and Keta lagoons) accumulated 21,195 items (900 kg) of the overall litter.

3.2. Lagoon litter accumulation and monthly variation

The study revealed that there was no statistically significant difference in temporal litter abundance during the study period (p = 0.44). However, the range of litter deposition per square meter across sites showed a consistent decreasing trend from the west towards the eastern coast. Litter deposition rate ranged from 0.17 to 1.65 m²/month with an
average of 0.71 m²/month (Figure 2). Litter abundance per 5000 m² for each site were as follows, 8,243 at Kpeshie, 3,155 at Mukwei, 2,817 at Sakumo II, 2,690 at Gao and 842 at the Keta lagoon (Figure 3).

The litter abundance was variable among the various months of sampling (Figure 3). The highest litter abundance of 35,808 items (weighing approximately 2290 kg) was recorded in July 2016 and the least abundance of 7,377 items (weighing 311 kg) was recorded in December 2016. In between those two months, litter abundance increased progressively from 10,739 items (weighing 271 kg) in August to 20,808 items (weighing 1006 kg) in November (Figure 3).

The litter composition (stream) across lagoons in Ghana consisted mainly of fabrics, glass, metals, paper, plant debris, plastics (mostly polyethylene terephthalate (PET), low-density polyethylene (LDPE) and high-density polyethylene (HDPE)), polystyrene, rope/net and other materials. Although there were site specific variations in the litter stream, the plastic component clearly dominated at all the sites (Figure 4). Fabric, plant debris and polystyrene were also generally quite evident across several sites, except Keta lagoon. Glass and metals were quite noticeable at the Mukwei lagoon site. Site-specific distribution of the various litter fractions indicated that the highest amount of plastics, averagely 6142 items/month, occurred in the Kpeshie lagoon, while the least occurred in Keta lagoon at an average amount of 731 items/month. It also emerged that all the litter fractions, except rope/net and others, decreased progressively (reflected in strong r² values for several of the components, especially plastic, polystyrene, plant debris and metals) at lagoon banks in an eastward direction from urbanized areas (Kpeshie, Mukwei and Sakumo II) to non-urbanized communities (Gao and Keta) of Ghana (Figure 5).

Across the various lagoon sites, the average mass (kg) of litter fractions per month ranged as follows: fabric (3.6–112.4), glass (0.3–83.1), metal (0.6–5.4), paper (0.4–1.7), plastic (41.7–265.9), plant materials (0.7–40.1), polystyrene (0.1–6.1) and rope/net (0.03–1.0). The mass of other non-categorized items collectively ranged between 0.2 and 6.2 kg per month across the lagoon sites. Except for plastic and rope/net, the number of items of the various litter fractions correlated well with mass (Figure 6).

### 3.3. Lagoon litter diversity

The litter diversity was quite consistent across lagoon sites, with plastic litter constituting close to 50% of mean litter diversity (Figure 7).

### 4. Discussion

Site specific litter abundance (number of items) deposited along the banks of the lagoons ranged between 842 and 8,243 items per month, with an average abundance of 3549 items, collectively weighing approximately 167 kg. Considering that each site had a transect of 5000
m², the rate of litter deposition at the banks of a lagoon in Ghana was estimated at 0.71 items/m²/month. In terms of weight, the lagoon litter massed up at a rate of 0.033 kg/m²/month. This does not only support suggestions from other studies that the quantum of litter accumulation in marine environment is unacceptable (Derraik, 2002; Gregory, 2009), it also gives an indication of increasing trend in litter deposition on the coast of Ghana. Thus, the continuous deposition of litter on the banks of coastal lagoons may lead to the collapse of this functional unit in Ghana if the situation continues unchecked. The mean litter deposition across all the sites decreased steadily from the urbanized areas in the capital city of Accra to the non-urbanized eastern coastal end of the country, in the order Kpeshie > Mukwei > Sakumo II > Gao > Keta lagoon. This observation resonates with earlier findings that lagoons in non-urbanized areas where population densities were smaller tended to accumulate lower volumes of litter than in urbanized areas (Slavin et al., 2012). Monthly abundance of litter followed the order July > November > October > September > August > December. High litter deposition observed at all the sampling sites in July and in October could be associated with raining seasons in the country during which runoffs and floods from the poorly managed municipal dumpsites drain into the

![Figure 4. The composition and variety of litter in various lagoons in Ghana.](image-url)
lagoons. Rainfall in Ghana is bimodal, with a major peak in June and a minor peak in October (https://www.weather-atlas.com/en/ghana/accura-climate). Thus, it appeared that as the rains peaked in June and October, it washed a lot of litter by runoff from adjoining communities into the lagoons causing a mass up of litter at the lagoon banks in the following months of July and November, respectively. This may explain why July and November were the leading months regarding lagoon litter abundance. Generally, there was a direct relationship between the proximity of a lagoon to a settlement and the abundance of litter collected at its banks.

Like other beach litter surveys (Golik and Gertner, 1992; Corbin and Singh, 1993), this study confirmed the dominance of plastic litter at all sites (Figure 4). But the abundance of the plastic litter, as well as all the other litter fractions, except rope/net and others that were non-categorized, decreased progressively as one traversed from the urbanized lagoons (Kpeshie, Mukwei, Sakumo II) to the non-urban located lagoon at Gao and Keta (Figure 5). Obviously, proximity to urbanized communities exposes the urban located lagoons to diverse litter fractions. On the other hand, it was observed that rope/net litter fraction relatively increased at the rural Keta lagoon. This may be attributed to increased indigenous style of fishing by the rural folks that tend to leave rope and net debris in the water. The abundance of plastic and rope/net litter did not correlate with the mass of these fractions (Figure 6). This suggests high diversity with varied mass of the plastic and rope/net litter, such that it is difficult to use the mass of these litter categories to predict their abundance.

The dominant use of plastic materials in adjoining communities, particularly for packaging, wrapping purposes and as containers for drinking water, influenced the abundance of plastic litter fraction (Allsopp et al., 2006). The complete shift from glass to plastics for bottling almost all beverages and water by distilleries and bottling companies in Ghana also accounted for the huge plastic litter dominance across time and space in this study (Fobil and Hogarth, 2006). The most prevalent types of plastic litter at the Kpeshie lagoon site for instance were plastic bottles, sachet water wrappers (SWW), sweet/crisp wrappers (SCWP), plastic packaging bags (PPB) and disposable cups. Those found to be widespread at the Mukwei lagoon site were SWW, plastic bottles; carrier bag polythene strands (CBPS), SCWP and disposable cups. Again, plastic bottles and SWW were most ubiquitous on the banks of the Sakumo II lagoon. At the Gao lagoon site, similar types of plastic debris such as plastic bottles, SWW and CBPS were most common. Sachet water wrappers, CBPS and PPB were widespread among the plastic litter collected at the Keta lagoon site.

The huge quantities of litter encountered on the banks of the Kpeshie lagoon suggests that it might be receiving litter from regular sources such as dumpsites located close to its periphery. Comparatively, the Kpeshie lagoon is the only site that also received regular recreational activities all year round due to its nearness to a National Trade Fair Center and popular beach resorts within its periphery. It is therefore not surprising that it accumulated such widely diverse and high volumes of litter monthly. Resorts centers and the communities around the Kpeshie lagoon can be cited as the main agents responsible for the high volumes of litter into the banks of the lagoon. The general lax in the enforcement of environmental regulations on littering and irresponsible solid waste disposal attitudes in the country does not only encourage poor solid waste disposal but also worsen the already unacceptable behaviors of people. This could account for the high volume of litter at the Kpeshie lagoon.

Glass litter was abundant at the banks of the Kpeshie, Mukwei and the Keta lagoons, while metallic litter were more on the banks of Mukwei, Sakumo II and the Gao lagoons. This presents a significant cause for concern as these debris could cause lacerations and pose safety threats to fisher folks and other users of the lagoon (Phillipp et al., 1994). Most of the glass litter types at the Mukwei and Kpeshie sites for instance, were mainly receptacles for liquor, medicines and fruit juices that have either been left there by beach goers or carried by runoff into the lagoon during floods. Glass litter at the Keta lagoon were predominantly broken liquor bottles that had been used as an indigenous fishing gear by the fisher folks (Entua-Mensah et al., 2000). The predominant use of liquor (mostly schnapps) for traditional religious activities around the lagoon can also be cited as the reason for the high abundance of glass on the banks of the Keta lagoon. These were litter left there by traditional worshippers after their worship activities around the lagoon.

The high litter load and diversity at the Mukwei lagoon could also be due to litter inflow from communities surrounding the lagoon and possibly from the activities of beach goers at a popular beach resort within its contiguous zone. It is therefore evident that when a lagoon is exposed to dumpsites, reclining sites and urbanized centers, it accumulates relatively high and diverse litter on its banks. The occurrence of litter categories such as fabric items, processed wood, polystyrene on the banks of almost all the lagoons also pose significant threat to biodiversity as they can cause smothering of benthic organisms (UNEP, 2005).
**Figure 6.** Litter abundance and corresponding mass of various fractions.

**Figure 7.** Pattern of litter diversity across some lagoon sites in Ghana.
There was high similarity in the monthly rate of litter deposition on the banks of all the lagoons studied. This is an indication that the possible sources of the litter around the lagoons were quite similar on monthly basis but varied from one lagoon to the other due to the differences in recreational and other social activities organized during holidays at the beaches where most of the lagoons are located (Golik and Gertner, 1992; Nunoo and Quayson, 2003).

5. Conclusion

Lagoon litter in Ghana was estimated to be deposited at a rate of 0.71 items/m²/month and mass rate of 0.033 kg/m²/month. The plastic litter abundance generally decreased from urban to rural communities. The most abundant litter fraction was plastic. The average abundance of the lagoon litter fractions was in the order plastic→polystyrene→fabric→plant debris→metal→glass→paper→others→rope/net. The plastic fraction was also the most diverse, given the several different plastic components that were retrieved. Litter abundance was relatively high in July and November, following peak rains in June and October, which washed a lot of litter by runoff from adjoining communities. The abundance of plastic and rope/net litter did not correlate with the mass of these fractions.

High diversity with varied mass of components of the plastic and rope/net litter made it difficult to use the mass of these fractions to predict their abundance.

It is recommended that management strategies for addressing the problem of litter accumulation on the banks of lagoons should be targeted at the retrieval of specific items such as plastic litter that dominate the entire litter categories around the respective lagoons especially for recycling purposes. This can be achieved by focusing the collection of these debris at the specific sources, activities or events that most likely results in the generation of those types of litter around the lagoons.

Declarations

Author contribution statement

Joseph T. Quarshie: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Daniel Nukpezah: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Elvis Nyarko: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Jonathan N. Hogarh: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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