The impacts of COVID-19 pandemic on marine litter pollution along the Kenyan Coast: A synthesis after 100 days following the first reported case in Kenya

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ABSTRACT

The contribution of COVID-19 pandemic to marine litter pollution was studied in Mombasa, Kilifi, and Kwale counties of Kenya, in June 2020 (100 days following the first confirmed case in Kenya). Standing stock surveys were conducted in 14 streets and 21 beaches while 157 transects were surveyed for floating litter. COVID-19 related items contributed up to 16.5% of the total litter encountered along the streets. The urban beaches (Mkomani and Nyali) had the highest quantities of COVID-19 related items (55.1% and 2.6% respectively) attributable to the ability to purchase single-use products and lifestyle. Most of the recreational beaches had no COVID-19 related products which could be attributed to the presidential directive on beach closure as a COVID-19 contingency measure. No COVID-19 related litter was found in the floating litter. Generally, beach closure and cessation of movement reduced the amount of litter that leaked to the marine environment.

1. Introduction

Coronaviruses are enveloped, gram-positive single-stranded large RNA viruses belonging to the family *Coronaviridae* and existing in alpha-, beta-, gamma- and delta- subfamilies (Ahn et al., 2020; Velavan and Meyer, 2020). These subfamilies have been traced to originate from bats (alpha- and beta), birds, and pigs (gamma- and delta). SARS-CoV-2 belonging to the beta-coronaviruses subfamily, succeeded in jumping species from animals to humans in Huanan seafood market in Wuhan, China, manifesting clinically as pneumonia (Joseph and Fagbami, 2020; Liu et al., 2020).

The first case of the new respiratory disease-causing pneumonia was reported in Wuhan, Hubei Province, China in December 2019 and had the potential to generate explosive outbreaks in confined settings and across the borders following human mobility patterns. The disease caused by the novel coronavirus became known as "2019-nCoV" and later renamed Coronavirus disease 2019 (COVID-19) by the World Health Organization, WHO (Ahn et al., 2020). WHO Emergency Committee declared it as a global health emergency on 30th January 2020, following its rapid spread in China and internationally in the preceding months of its first detection (Velavan and Meyer, 2020). WHO subsequently declared COVID-19 a pandemic on 11th March 2020 following its spread to more than 114 countries with nearly 120,000 cases detected (Silva et al., 2020). As of mid-April 2020, more than 1.8 million cases were confirmed and a rising trend was observed largely due to low awareness on the novel virus, poor detection techniques, and delays in the implementation of interventions. It was particularly predicted that the outbreak would be worse in African countries due to the prevailing factors such as poor socioeconomic status, poor health systems, low testing efficiency, and the onset of the dry season (Zhao et al., 2020).

Africa was expected to be at a higher risk of infection due to her densely populated communities and the communicable nature of COVID-19 Kenya, among other African nations, was prioritized for monitoring by WHO due to her close links with the disease epicenter, inadequate and insufficient capacity among other challenges (Velavan

and Meyer, 2020). The first case in Africa was reported in Egypt on 15th February 2020 while the first case in Kenya was reported in Nairobi on 12th March 2020 by the Ministry of Health (Aluga, 2020). Kenya promptly put in place several precautionary contingency measures since February 2020 to mitigate the pandemic in its early stages. These measures included: the use of Personal Protective Equipment (PPE) such as face masks to limit the spread of COVID-19; use of surgical gloves for the protection against surfaces or items contaminated with the virus; use of alcohol-based sanitizers for disinfecting hands or surfaces and use of soaps for handwashing (NEMA, 2020; MOH, 2020a). Additional pre-scribed measures included the observance of social distancing, working from home, staying at home and avoiding congregation, maintaining good respiratory hygiene while coughing and sneezing, travel re-strictions, provision of hand sanitizers, and handwashing in public places by proprietors and in public transport among other measures (Aluga, 2020; MOH, 2020a).

COVID-19 has arguably underscored the importance of single-use plastic especially in the management of the virus (Schlegel, 2020) and as a safe alternative for many applications despite its environmental liability in most other applications (Klemeš et al., 2020). Single-use masks contain plastic polymers such as polypropylene, polyurethane, and polyacrylonitrile; gloves are made of latex rubber which contains some chemical additives (Tamir, 2019). The other COVID-19 related products contain plastic polymers and plastic packaging materials that ultimately accumulate in the environment and degrade into microplastic pieces (Silva et al., 2020).

Generally, the progression of the pandemic has created an upsurge in demand for PPE both for frontline healthcare workers and the general public. The global monthly demand by healthcare workers alone was estimated at 89 million medical masks, 76 million gloves, and 1.6 million goggles (WHO, 2020). In China, for example, mask production increased significantly with 200 million face masks produced per day in June 2020 which was more than twenty times the amount produced at the beginning of February 2020 (Aragaw, 2020). The increase in de-mand for PPE was accompanied by an increase in post-consumer PPE waste. For instance, Wuhan hospitals generated a daily average of 240 tons of medical waste, representing nearly a 480% increase. Usage by the public is unquantified globally but may far exceed the demand by healthcare workers, for instance, there has been an increase in garbage from PPE such as masks and gloves in the USA (Calma, 2020). Although single-use PPEs have been regarded as effective in the fight against COVID-19, there are rising environmental concerns about their contri-bution to the plastic waste that is leaking to the environment (Edmond, 2020; Mukhopadhyay, 2020; Winters, 2020).

The persistence of the pandemic globally has shifted the priority to people's health with little focus on the impact of the virus on the envi-ronment. The first studies pointed out the indirect impact on the envi-ronment i.e. reduction of particulate matter ($PM_{2.5}$) and NO_2 concentrations in China (Yuan et al., 2020); drop in greenhouse gas (GHG) emissions in France, Germany, Spain, and Italy (Global Carbon Project, 2020) and cleaner beaches due to reduced waste generation by tourism activities in Acapulco, Barcelona and Salinas beaches (Zam-brano-Monserrate et al., 2020). Whereas these studies pointed out the positive effect of COVID-19 such as ecosystems recovery from air and water pollution, depletion of groundwater level, and other issues caused by human activities (Chakraborty and Maity, 2020), the pandemic has also elicited negative indirect effects, for example, the suspension of bans on single-use plastics and recycling programs in the USA due to concerns about the risk of spreading the virus in recycling centers. Some countries have also imposed restrictions prohibiting infected persons from direct waste handling/separation to protect the waste recyclers. These measures have reduced recycling and promoted the mixing of medical waste such as contaminated masks, gloves, used or expired medications with domestic waste (Silva et al., 2020; Zambrano-Mon-serrate et al., 2020). The pandemic has further favored a shift to single-use plastics for safety and hygiene reasons as well as an upsurge in take-away packaging and online shopping.

In general, several countries have experienced a significant increase in the discarded PPE items occasioned by their mandatory use and increased demand resulting in mismanagement due to incorrect disposal in public places and the natural environment (Silva et al., 2020). In Kenya, the production of fabric non-surgical masks by textile factories and tailors is on the rise for those who cannot afford the single-use masks. This follows a government directive to wear masks in public places (Arakpogun et al., 2020). This initiative has enabled the country to fill in the gap in the demand and supply of surgical masks. About 60% of clothing materials used for fabric masks contain plastic, which in-cludes polyester, acrylic, and nylon textiles (UNEP, 2019). These plastics pose a significant threat to marine life in the form of microfibers that may be ingested and cause the biomagnification of toxins at higher levels of the food chain (UNEP, 2019). The face masks can also degrade into smaller particles usually less than 5 mm due to various environ-mental conditions (Schmidt et al., 2018). These particles can persist in the environment and continue to pose risk to human health and the environment by harboring infectious pathogens and polluting land and marine ecosystems (NEMA, 2020).

In foresight of the potential risk of spreading the infection through discarded PPE and to control environmental pollution, the National Environment Management Authority (NEMA), Kenya's principal Agency on environmental protection and conservation, developed guidelines for sound management of COVID-19 related waste. The guidelines outline comprehensive ways to manage COVID-19 related waste at the public, community, and household levels as well as those generated in the treatment and quarantine of COVID -19 patients (NEMA, 2020). Despite the issuance of these guidelines, wastes related to the pandemic including disposable and reusable masks, gloves, soap wrappers, wet wipes, liquid hand wash, and alcohol-based sanitizer bottles are often mismanaged and are now becoming common on the streets, beaches, and dumpsites in Kenya. Mombasa metro area has a population of 1,296,000 people (KNBS, 2019). It is estimated that over 1.3 million disposable masks are used in Mombasa daily assuming that each indi-vidual utilizes one disposable mask per day. This translates to about 16 million masks used annually, putting a strain on the already existing ineffective waste management system.

Previous studies by Okuku et al. (2020a) on marine litter pollution along the Kenya coast reported that most beach litter originated from land sources and were mainly dominated by plastics (11.15 ± 4.49 items m^{-1} day^{-1}). Currently PPE and sanitizing waste comprise less than 1% of the total waste in Kenya (Koome and Paffenholz, 2020). However, with the growing number of COVID-19 cases and lack of proper waste management strategies in place, it is expected that there will be an in-crease in PPE, sanitizer bottles, wet wipes, and other COVID-19 related waste loads on the streets, beaches, and other accessible public places (Kalina and Tilley, 2020). The directives on beach closure effected on 15th March 2020 in Mombasa and cessation of movement into and out of three coastal counties, (Kilifi, Mombasa, and Kwale) on 16th April 2020 (National Emergency Response Committee on Corona Virus, 2020) was therefore expected to reduce beach litter loads significantly. How-ever, litter can still be transported to the waterways (if not disposed of appropriately) through surface runoff; particularly in the Kenyan coastal counties where consistent and sustainable waste disposal is still a chal-lenge. Whereas medical facilities are equipped to deal with bio-hazardous waste, proper disposal of PPE from households is still a major concern.

June 19th, 2020 marked 100 days since the first case was reported in Kenya with 2705 active cases, 4374 total cases, and 119 deaths (MOH, 2020b). This paper explores the contribution of COVID-19 related litter to the litter stream in the streets, beaches, and in the coastal areas after 100 days since the disease was first reported in Kenya by describing their composition, quantities, and distribution.

2. Methodology

The surveys were carried out in June 2020. The surveys covered beaches in urban and remote areas (Table 1). The study scope consisted of street, beach, and floating litter surveys. All the litter was collected and grouped as COVID-19 related and other categories which were non-COVID-19 (plastic, rubber, paper, processed wood, building and construction materials, marine and fishing gear, clothing, glass, foam, metal, hygiene products e.g. diapers, condoms and others). Litter items considered as COVID-19 related included masks, gloves, sanitizer containers, soap wrappers, wet wipes, and liquid hand wash bottles.

2.1. Street survey

Street surveys were carried out in the major streets connecting or adjacent to the surveyed beaches (Table 1) to determine the relationship between the COVID-19 related litter on the streets, beaches, and floating on the ocean. A distance between 200 m and 2000 m (depending on the length of the street) was surveyed for marine litter, with special attention to COVID-19 related litter. Litter was picked from a width of 2 m on both sides of the street (and not on the main street). All items were cleaned, characterized, counted, weighed, and the information recorded.

2.2. Beach survey

Standing stock surveys on the beaches (Fig. 1) were carried out with the main focus on COVID-19 related waste. The start and endpoints for the surveyed sections were geo-referenced using Garmin GPS Map 2S. The surveys traversed the entire width of the beaches from the edge of water up to 2 m into the vegetation or the wall at the back of the beach. The length of the sampled beach sections ranged between 50 m and 300 m depending on the length of the beach and the amount of litter encountered at the time of the survey (Table 2).

All macro litter (>25 mm) were collected following a parallel walking pattern from the water edge to the vegetation line or back of the beach. All the collected litter was thoroughly cleaned of trapped sand on the folds of the litter and stored in woven refuse bags for analysis. Litter items containing unknown substances were counted, characterized and the weights in our inventory list were used. Sorting and analysis were centrally executed by well-trained volunteers under the close supervision of senior scientists as a quality control measure. Litter counting and weighing were done per item type (such as lollipop sticks, diapers, bottles, etc.). The items were classified as COVID-19 related and others including; plastic, rubber, paper, processed wood, building and construction materials, marine and fishing gear, clothing, glass, foam, metal, hygiene objects, and other objects.

2.3. Floating litter survey

Floating litter visual surveys were done concurrently with surface trawl surveys. Two observers seated on both sides of the boat observed and recorded macro plastics seen within 5 m bands. The start and end time, together with geo-referenced locations were noted. Floating litter trawl surveys were carried out using a 300 μm mesh sized Manta trawl net fitted with a flow meter. Trawl transects were geo-referenced using Garmin GPS Map 2S as described by Dris et al. (2015). Line transects were conducted collecting triplicate samples from every station. The manta net was secured towards the edge of a horizontally mounted pole to avoid collecting disturbed marine litter by the boat engine. The manta net was deployed depending on the direction of the prevailing waves while ensuring that the hood of the trawl net rode on the water surface to capture and deflect waves into the net at approximately 2 knots (Setälä et al., 2016). The net was retrieved after every 15 min and the collected samples put in a clean bucket where the large seaweeds were washed and removed from the samples. The remaining samples were preserved with 70% ethanol, kept in tightly closed glass containers, and transported to the laboratory for analysis.

In the laboratory, samples were sorted in trays by three people who worked alternately on each sample for 15 min each. Observers picked any visible litter item using a tweezer, placed them in a petri dish, and recorded: date of sample collection, transect code, the litter type, and count in datasheets. The litter was categorized as COVID-19 related, soft plastics, foam and Styrofoam, fiber and plastic line, and hard plastic. Thereafter, the results were tallied and entered into a Microsoft® Excel database for further analysis.

The density of litter items was obtained using the formula:

$$C = n/a$$

where: C = density of debris items per km^2

n = number of debris items observed

a = area trawled (km^2) = [net mouth width × d]

d = distance travelled = (flow meter final- flow meter initial) × correction factor

3. Results and discussion

3.1. Street litter surveys

The density of COVID-19 related litter items encountered on the surveyed streets were in the order of Nyali > Mkomani > Pirates > Gazi > Mtwapa/Coppacabbana > Forty Thieves > Shariani/Kuruwitu while the rest of the sampled streets (Warm sea sand, Jacaranda beach road, Malindi Jetty and Tiwi) had densities of less than 0.01 items m^{-1} (Fig. 2). Mombasa County (Nyali, Mkomani, and Pirates) reported the highest number of COVID-19 related litter items compared to Kilifi and

Table 1
The surveyed streets of the adjacent beaches in the Kenyan North and South coast, 100 days after the first COVID-19 reported case in Kenya.

| County	Street	Adjacent beach	Classification	Street distance (m)	Start coordinates	End coordinates
Kwale	Diani Road	Tradewinds	Urban	600	−4.362079, 39.557954	−4.357942, 39.559079
	Msambweni street	Msambweni	Remote	1000	−4.480066, 39.481477	−4.475736, 39.483200
	Gazi street	Gazi	Remote	200	−4.424490, 39.504370	−4.420330, 39.598830
	Jacaranda beach road	Jacaranda	Urban	700	−4.280980, 39.595290	−3.350900, 39.598830
	Tiwi street	Tiwi	Urban	200	−4.250510, 39.597580	−4.247870, 39.598550
Kilifi	Mombasa-Malindi Highway	Kuruwitu	Urban	600	−3.806130, 39.832523	−3.804850, 39.833026
	Maua Watamu road	Watamu	Urban	700	−3.349120, 40.020850	−3.350900, 40.018710
	Mtwapa/Coppacabbana	CoppaCabbana	Urban	600	−3.950909, 39.751921	−3.953489, 39.748015
	Jetty Malindi road	Malindi	Urban	600	−3.221170, 40.126530	−3.233290, 40.127370
	Kiwandani street	Baobab	Urban	2000	−3.626922, 39.871782	−3.626922, 39.873276
Mombasa	Silos road	Mkomani	Urban	200	−4.055650, 39.682931	−4.059582, 39.685198
	Greenwood street	Kenyatta	Urban	250	−4.058220, 39.689820	−4.047990, 39.703190
	Beach road	Nyali	Urban	300	−4.047206 39.703178	−4.047199, 39.703190
	Mombasa-Malindi Highway	Pirates	Urban	300	−4.004790, 39.724792	−4.007170, 39.723621
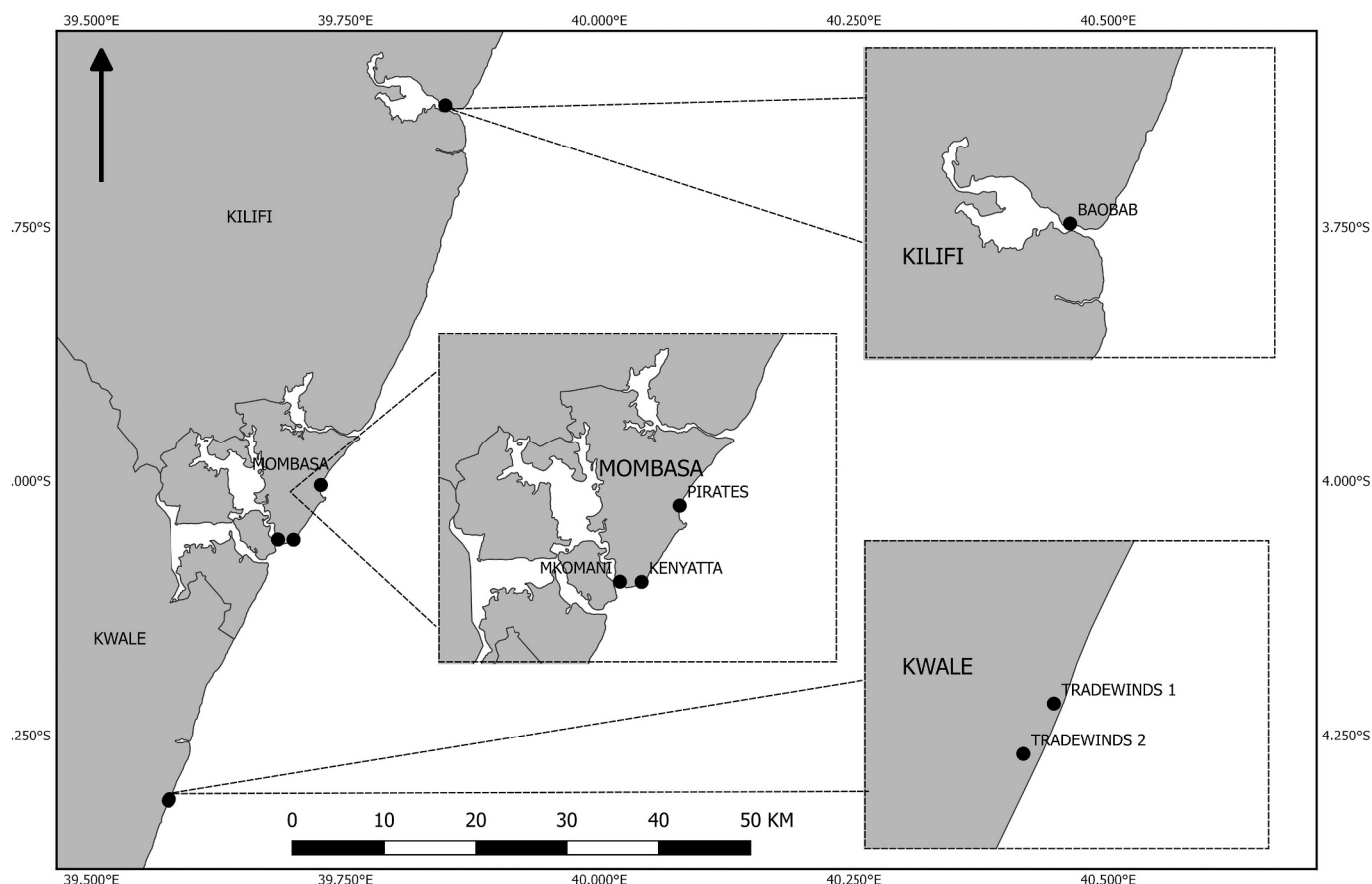
Fig. 1. Map showing the surveyed beaches in the Kilifi, Mombasa and Kwale Counties in June 2020.

Table 2
The surveyed beaches in the Kenyan coast, 100 days after the first COVID-19 reported case in Kenya.

County	Beach	Classification	Surveyed length	Start coordinates	End coordinates
	Shimoni	Urban	200	−4.647923, 39.381584	−4.647863, 39.379885
	Vanga	Remote	100	−4.660243, 39.219861	−4.649489, 39.220029
	Msambweni	Urban	200	−4.488307, 39.477630	−4.486038, 39.479102
	Tradewinds	Urban	300	−4.107223, 39.667940	−4.106898, 39.660100
	Forty Thieves	Urban	300	−4.313651, 39.578738	−4.311114, 39.579633
	Gazi	Remote	150	−44,288,880,39.512021	−4.427691, 39.512676
	Wasini	Remote	50	−4.658381, 39.366673	−4.658152, 39.366282
	Jacaranda	Urban	250	−4.262491, 39.598656	−4.262528, 39.598400
	Tiwi	Urban	300	−4.251210, 39.601787	−4.251766, 39.601787
	Gazi- Board walk	Remote	75	−4.421008, 39.512004	−4.421026, 39.512055
	Mkwiro-Wasini	Remote	100	−4.662059, 39.394928	−4.661734, 39.395471
Kwale	Shelly beach	Urban	300	−4.303749, 39.583389	−4.303591, 39.583074
	Turtle Bay	Urban	150	−3.364462, 40.004210	−3.363450, 10.005135
	Coppacabbana	Urban	100	−3.956061, 39.756594	−3.955449, 39.757267
	Kuruwitu	Urban	150	−3.807325, 39.832204	3.808544, 39.831651
	Warm Sea Sand	Urban	200	−4.367424, 39.559189	−4.365801, 39.559866
	Baobab	Urban	300	−3.629544, 39.871958	−3.627231, 39.873355
	Scorpio	Urban	150	−3.229073, 40.128781	−3.227740, 40.129057
	Kwa Ngala	Remote	150	−3.580259, 39.896074	−3.578715, 39.896848
	Maua Watamu	Urban	250	−3.351142, 40.024584	−3.353883, 40.023762
Kilifi	Malindi Jetty	Urban	250	−3.216925, 40.126392	−3.214828, 40.125210

Kwale counties. Most people in Mombasa County were observing guidelines set by the Kenya Ministry of Health after the county was ranked second, countrywide, following Nairobi County that had recorded high numbers of COVID-19 cases in Kenya (MOH, 2020b). When COVID-19 epidemic was declared a national disaster, there was heightened public health awareness which resulted in the large use of PPE and sanitizing resources; especially single-use disposable masks, with little effort put on environmental awareness on proper disposal of generated waste (Silva et al., 2020). The majority of the COVID-19 related litter items found on the streets of Mkomani and Nyali were wet wipes and single-use masks.

In comparison, a study was done by Ouhsine et al. (2020) in central Morocco found an increase in PPE (masks and gloves) during the COVID-19 lockdown while a study by Fadare and Okoffo (2020) reported the presence of face masks along a highway and drainage in Ile-Ife, Nigeria. Single-use masks were similarly encountered in parks and along the
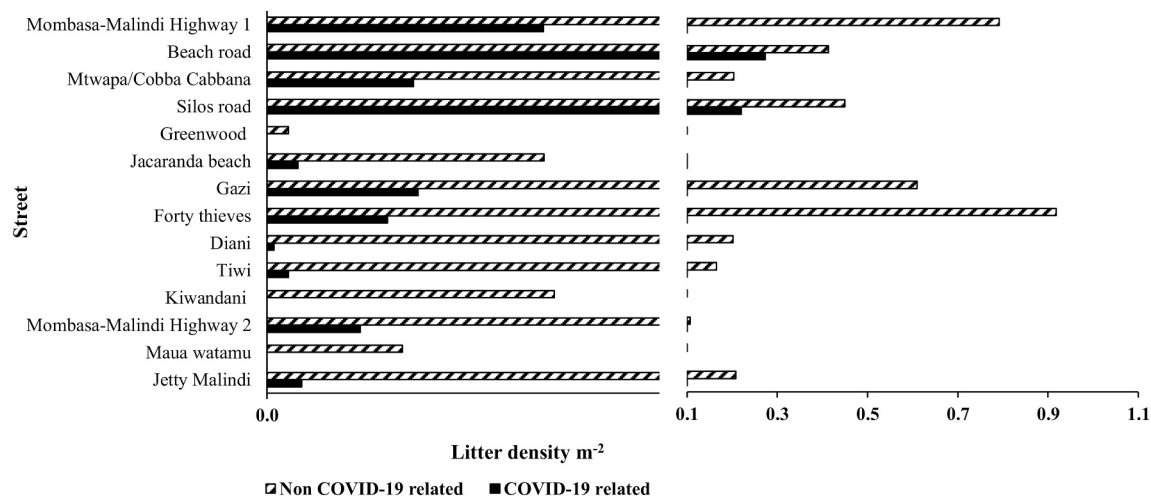
Fig. 2. The composition of litter items encountered during the street surveys. Mombasa- Malindi Highway 1 (Mombasa County) and Mombasa- Malindi Highway 2 (Kilifi County).

roads in the USA and Hong Kong (Mukhopadhyay, 2020; Winters, 2020).

Low densities of COVID-19 related litter items in relatively remote areas reported in a survey of 31 provinces in China were similarly observed during this study. This observation could be due to rural residents not strictly adhering to COVID-19 preventive measures as much as urban area residents (Chen and Chen, 2020) since the spread of COVID-19 in sparsely populated areas is lower than in urban areas (Diop et al., 2020). This can also be attributed to the preference and reliance on affordable reusable cloth masks and bar soaps for handwashing compared to the higher-end cleansing products common in urban areas. The government has promoted investment in innovative ways through which the demand for face masks has been met locally i.e. manufacture of fabric masks. Since then, there has been a surge in their numbers due to their accessibility affordability and they can be reused over time contrary to the single-use masks (Aloui-Zarrouk et al., 2020).

Eleven out of fourteen streets surveyed recorded COVID-19 related litter as a result of improper disposal. This poses risks to the environment, by adding to the bulk plastics in the aquatic environment. Prata et al. (2020) similarly reported inappropriate disposal of PPE as the main contributing factor to litter pollution in several public places as well as in the natural environment. The litter on the streets is of concern given that they can be washed into water bodies through surface runoff thus adding to the number of macro-plastics in the ocean (Fadare and Okoffo, 2020). For instance, wet wipes are a source of white microplastic fibers in the marine environment that may enter the food chain and act as a vector for potentially harmful contaminants (Galafassi et al., 2019; Zhao et al., 2018; Thompson et al., 2004).

Among the COVID-19 related litter, sanitizer and detergent hand wash bottles that were recorded during the survey were perceived to be as a result of their use as a preventive measure to curb the pandemic. A report from global hand sanitizers on impacts of COVID-19 analysis forecast 2019–2020 reported an increase from 1.35 billion before COVID-19 to 1.87 billion during COVID-19 (Fortune Business Insights, 2020). These items are similarly a potential risk to the marine environment and human health (Geissen et al., 2015) since they have a low biodegradation rate (Ammala, 2013).

Generally, the waste from responses to disasters has not been discussed with regards to waste management but is lightly discussed in disaster relief and logistics literature (Kalina and Tilley, 2020). Moreover, little scholarly attention has been directed to sustainable and hygienic management of infectious waste (Brown and Milke, 2016; Zhang et al., 2016). Safe management of domestic waste could be critical during the COVID-19 pandemic, since domestic medical waste such as

masks, gloves, due to self-medication at home can easily be mixed with domestic waste and leak into the environment (Zambrano-Monserrate et al., 2020).

3.2. Beach standing stock

Generally, COVID-19 related items were encountered in low densities (0.1 items m^{-2}) representing 0.43% of the total litter items (Fig. 3, Supplementary S1–S6) The low densities could be attributed to the closure of beaches for recreational purposes and cessation of movement into the three counties which hindered both domestic and foreign tourism. Zambrano-Monserrate et al. (2020) similarly concluded that reduced touristic activities, as a result of the social distancing measures had caused a notable change in the appearance of many beaches in the world. Beaches such as Acapulco (Mexico), Barcelona (Spain), and Salinas (Ecuador) were cleaner with crystal clear waters. Ormaza-Gonzalez and Castro-Rodas (2020) also reported cleaner beaches in a study carried out in Ecuador which was attributed to confinement and social distancing measures set by the government during the COVID-19 pandemic season. This positive observation was despite the reported increase in use and existence of PPE such as face masks, gloves in over 50 countries including Ecuador, Austria, Venezuela, Morocco, Argentina, Spain, Portugal (Ormaza-Gonzalez and Castro-Rodas, 2020; Zambrano-Monserrate et al., 2020).

During the study, 18 out of the 24 surveyed beaches along the Kenya coast had COVID-19 related litter items in the order: Mkomani > Copacabana > Kuruwitu > Vanga > Turtle Bay > Msambweni > Nyali > Kwa Ngala > Kenyatta > Tiwi > Malindi Jetty > Shelly > Pirates > Tradewinds > Maua Watamu beach, while the remaining beaches (Gazi, Gazi Boardwalk, Baobab, Jacaranda, Mkwiro, Forty Thieves, Scorpio, Shimoni, Warm Sea sand and Wasini beaches) had less than 1.0×10^{-4} items m^{-2} (Fig. 3). The existence of these items in the beaches could be attributed to illegal beach visitation and runoff from the streets that transport improperly disposed PPE and other COVID-19 related wastes as also reported in Portugal by Silva et al. (2020).

Mkomani, an urban beach in Mombasa County located near the mouth of Tudor creek, had the highest density of COVID-19 related litter items (Fig. 3). This is potentially due to the beaching of seaborne litter discharged into the creek through runoff from Nguu Tatu, new Mombasa solid waste dumpsite, (Hamid, 2017), runoff from Mombasa town through the storm drains as well as litter input from Kombeni and Tsalu rivers flow into the creek. Similar studies by Asensio-Montesinos et al. (2020) found that beaches located close to the mouth of a river had more diverse litter, and wastewater and surface runoff deposit hygiene
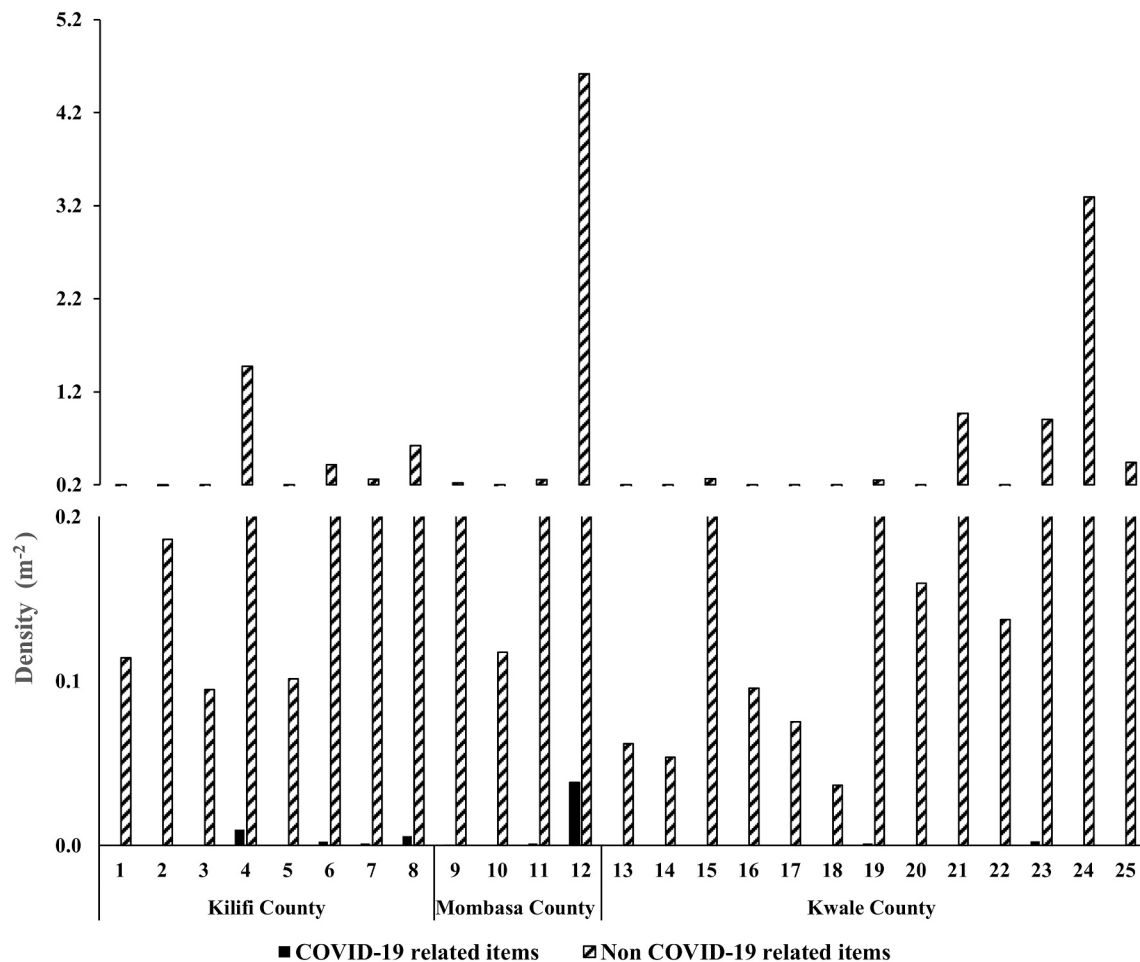
Fig. 3. Densities of COVID-19 and non- COVID-19 related litter in the surveyed beaches. 1 (Jetty Malindi), 2 (Scorpio Malindi), 3 (Baobab), 4 (Coppacabbana), 5 (Maua Watamu), 6 (Turtle Bay), 7 (Kwa Ngala), 8 (Kuruwitu), 9 (Kenyatta), 10 (Pirates), 11 (Nyali), 12 (Mkomani), 13 (Jacaranda), 14 (Forty Thieves), 15 (Gazi), 16 (Gazi- Board walk), 17 (Shelly beach), 18 (Tiwi), 19 (Msambweni), 20 (Tradewinds), 21 (Shimoni), 22 (Warm Sea Sand), 23 (Vanga), 24 (Wasini) and 25 (Mkwiro-Wasini).

products like earbuds, wet wipes, and condoms, with numbers increasing disproportionately after heavy rain events. Additionally, the position of Mkomani beach in Tudor creek could further facilitate the deposition of litter ashore (Okuku et al., 2020a; Okuku et al., 2020b; Liubartseva et al., 2019). Notably, recreational beaches in urban areas of Mombasa (Pirates, Nyali) that are frequented by visitors all year-round had low densities of COVID-19 related litter.

Densities of COVID-19 related litter items in urban beaches ranged between 0.00 and 3.8×10^{-2} items m^{-2} whereas in remote beaches ranges were from 0.00 to 5.6×10^{-2} items m^{-2} (Fig. 3). The higher densities in remote beaches could be partly attributed to the differences in compliance with the Government of Kenya directive on the closure of public beaches (National Emergency Response Committee on Corona-virus, 2020). People in rural areas tend to adhere less to the directive. It was noted that there were still beachgoers and activities (e.g. swimming and sports) ongoing in Msambweni and Kuruwitu beaches during the survey, despite the Government directive on beach closure. Similar findings of non-adherence to directives were also observed in China by Chen and Chen (2020). The encounter of COVID-19 related items in remote beaches has similarly been reported by Oceans Asia (2020) in a 100 m stretch in the remote Soko islands beach, Hong Kong. Large quantities of latex gloves, face masks, and bottles of hand sanitizer were also encountered in the Mediterranean Sea (Konyn, 2020). No COVID-19 related litter was reported in Baobab, Shimoni, and Warm Sea sand beaches (Fig. 3).

3.3. Floating litter densities

3.3.1. Visual floating litter

A total of 150 litter items were observed floating in an area of 0.92 km^2 surveyed during the sampling period. The density of floating litter was higher in the areas adjacent to beaches of Kwale county (66 items km^{-2}) compared to the areas adjacent to the beaches of Kilifi county (86 items km^{-2}). There were no COVID-19 related items encountered. This could be attributed to their tendency to absorb water and float below the ocean surface or sink to the ocean floor where they are transported by water current and tidal movement (Oceans Asia, 2020; Fazey and Ryan, 2016). Genries (2020) and Ammendolia et al. (2020) reported PPE debris on the seafloor of the Mediterranean. Masks were also discovered underwater in the remote Soko islands bay beach, Hong Kong (Oceans Asia, 2020).

3.3.2. Floating Litter surface trawls

Generally, no COVID-19 related litter was captured during the sur-face trawl surveys, whereas the non-COVID-19 litter category had a density of 347,337 items km^{-2}. The non-COVID-19 related litter included soft plastic (126,236 items km^{-2}), hard plastic (137,950 items km^{-2}), and plastic line/fibers (82,109 items km^{-2}) were the most dominant among the litter items encountered, while foam and styrofoam (1042 items km^{-2}) were the least abundant (Fig. 4).

Floating litter in Kilifi county was higher (289,698 items km^{-2}) compared to Kwale county (75,922 items km^{-2}) and could be attributed
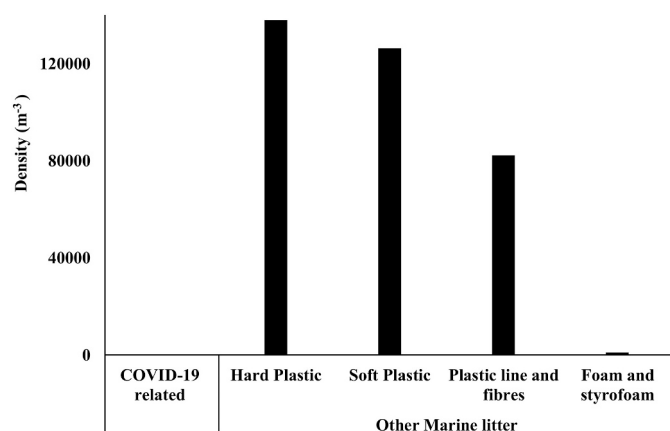
Fig. 4. Density of floating COVID-19 related litter and other litter category in Kilifi and Kwale counties.

to the litter input from the Athi-Galana-Sabaki river (Table 3). Athi-Galana-Sabaki river is the second largest coastal river along the Kenyan coast with a lot of activities upstream and in the wider catchment area encompassing Nairobi city and other major towns that discharge their waste into the river before ending up in the Indian Ocean. Lebreton et al. (2017) estimated that between 1.15 and 2.41 million tons of plastic currently flow from the global riverine system into the oceans annually. They further estimated that 7.8% of river inputs of plastics into the oceans come from Africa, with the Indian Ocean having the second-highest quantity of floating plastics (59,130 tons) after the North Pacific (96,400 tons) (Eriksen et al., 2014). Another major factor that may be contributing to higher floating litter counts in Kilifi County in comparison to Kwale County was the strong currents experienced during the South East Monsoon (SEM) that tend to transport litter towards the North. The contribution of the ocean currents as one of the factors that influence floating litter density in the ocean has been reported by Galgani et al. (2015). Other studies have documented large variations in the density of floating debris in coastal water although, little is understood of the influence of nearshore dynamics (Compa et al., 2020).

The highest litter density (35,466 items km^{-2}) in Kwale County was observed off Gazi beach (Table 3). This could be due to the high density of the mangrove forest that trap litter in the bay as well as litter input from Kidogoweni and Mkurumudzi River as reported in Vietnam and Thailand by Norris et al. (2017) and Horstman et al. (2014) respectively. The sheltered nature of Gazi bay, against wave action and ocean currents, may also lead to higher retention and harbor marine litter as reported in Cala d'Or, Mallorca Island by Compa et al. (2020) who documented higher retention of marine debris in small coves.

4. Conclusion

COVID-19 prevention measures that restricted people's movement; lockdown, curfew, beach closure, and travel restriction, led to a significant decrease in the amount of marine litter on the beaches. Indicating that targeted intervention on the beach can greatly help reduce marine litter pollution. Although higher amounts of COVID-19 related litter were found on the streets, it is expected that this litter will ultimately end in the ocean through surface runoff, thus proper waste management is encouraged for all litter classes with special emphasis to COVID-19 related ones.

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CRediT authorship contribution statement

E.O. Okuku: Conceptualization, Data curation, Funding acquisition,

Table 3
COVID-19 related litter and other Marine litter items distribution trawled on the surface waters adjacent to beaches in the Kenyan North and South coast, 100 days after the first COVID-19 reported case in Kenya.

County	Adjacent beach	COVID-19 related (items km^2)	Other Marine litter (items km^2)
Kilifi	Kilifi	0	215,484
	Kuruwitu	0	41,144
	Malindi	0	15,958
	Watamu	0	17,112
	Gazi	0	35,466
	Shimoni	0	30,971
	Tradewinds	0	8426
Kwale	Vanga	0	1060

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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