Troubled water: Tracing the plastic tide on Sierra Leones beaches

Supplementary Information

Stephanie Lavelle1, Fiona Preston-Whyte1, Paul A. Lamin2, Salieu Kabba Sankoh3, Isha Timbo2, Thomas Maes1

1 GRID-Arendal, Teaterplassen 3, 4836 Arendal, Norway

2 Environment Protection Agency, 92 Dundas Street, Freetown, Sierra Leone

3 Institute of Marine Biology and Oceanography, Department of Biological Sciences, Fourah Bay College, University of Sierra Leone

**SI 1:**

### Site selection – Part 1: dynamics of Sierra Leone’s coastline

#### Ecology

Ten major rivers flow in a south-westerly direction from the Coastal Plains and dense mangrove forest areas (figure 1), where they meander into a series of channels, tributaries, lagoons and swamps before forming estuaries (Bird, 2010). Coastal waters are often turbid and observations have shown that the numerous small estuaries fringing the coastline contribute significant sediment load, which may lead to rapid shoreline accretion in some areas (Anthony, 2004; Capo et al., 2006).

#### Coastal habitat:

Possibly due to the sheltered nature of this coast, coupled with differences in development, the perception of the problem of marine pollution varies along the shoreline ranging from hotspots to almost insignificant (Environment Protection Agency, 2015). Sierra Leone’s flat and sheltered coast is dominated by mangroves (notably *Rhizophora* spp.) and mudflats (Anthony, 2006). However, there are also many stretches of sandy beach along the country’s coastline, which is estimated to be over 500 km (CLISS, 2016).

Freetown is a major port city on the Atlantic Ocean. It is situated on the world’s third largest natural harbour (Bird, 2010), south of which is the Western Area National Park, famous for its pristine rainforest, mountains and beaches across the Freetown Peninsula. This area hosts a mixture of headlands and beach compartments comprising medium to fine quartz sand that demonstrate a balanced seasonality between deposition and erosion (Bird, 2010).

#### Meteorology and Oceanography

The meteorology and oceoanographic profile of Sierra Leone’s coastline was also important when considering site selection and temporal aspects of data collection. Situated on the coast of West Africa, on the Atlantic Ocean’s periphery, most of Sierra Leone is classified as having a ‘tropical monsoon’ climate, receiving more rainfall than any other country in the region (CLISS, 2016; Jackson, 2018) (figure 1). The strong summer monsoon (May to October) is followed by a dry season (November to April) (Anuforom, 2007). There is a south-north gradient of decreasing rainfall and duration of the wet season caused by the interaction of the Atlantic Ocean and Saharan Desert air masses (the Harmattan wind flow) (figure 1). Annual rainfall ranges from 1,900 mm in the northwest to over 4,000 mm on the coast (Wadsworth et al., 2019) (figure 1). Freetown has a mean annual rainfall of 3,434 mm.

The seasonal interaction of air masses also impacts the country’s currents (figure 1). The eastward Guinea Current is seasonally dynamic and receives input from the Canary and Northern Equatorial counter currents. Although locally generated storms can occur during the wet season, the inshore marine environment in Sierra Leone has relatively low wave energy, occasionally receiving a weak swell from the North Atlantic in the dry season, but they are highly refracted, low waves with no fixed direction (Bird, 2010). The south-easterly coast towards Liberia is dominated by the south-westerly Atlantic swell (Bird, 2010). Consequently, some beaches demonstrate longshore drift of sand in a northerly direction, while others do in a southerly direction.

#### Site selection – Part 3: Waste management in Sierra Leone

The MSW and population profile of Sierra Leone are important factors to consider when selection site and analysing data. The issue of waste has been growing in Freetown in alignment with population growth for over two decades, contributing to some of the most detrimental impacts to human and environmental health in Sierra Leone (Sood, 2004). There is limited capacity or legislative power to manage the increasing volumes of waste produced (Sankoh, 2013). Subsequently, individuals and private-sector businesses improperly dispose of waste, the majority of which gets dumped on the streets, in waterways and burned to make more room at dump sites, creating a heavy burden of toxic emissions (Sankoh, 2013; Sood, 2004). In the Western Area Urban District, two main dump sites are in use (Granville Brook dumpsite in the east and Kingtom dumpsite in the west), both of which are severely inadequate (Sankoh, 2013). These sites reached capacity over 20 years ago and visibly leach into the Atlantic Ocean (Sood, 2004). The Waste Atlas recognises the Granville Brook site, located in the Western Area district of Freetown on the mouth of the Rokel river estuary, as one of the 50 biggest informal landfill sites in the world, estimated to retain between 2.3-3.3 million Mt of waste a decade ago (Waste Atlas, 2014). The number of smaller informal waste sites have not yet been documented. Furthermore, medical, toxic and hazardous wastes have historically been disposed of with regular waste (Sood, 2004).

The main sources of waste in Freetown have previously been identified as predominantly from households and markets, but industrial, commercial, institutional, municipal services, process wastes (e.g. slag, mineral tailings) and agriculture sources are also of concern (Sood, 2004). Finance is an inherent challenge for managing these wastes (Sood, 2004). A recent draft report by the World Bank assessed the socioeconomics of 8 out of 16 districts in Sierra Leone (World Bank, 2021). Some of these assessments (illustrated in SI 9) report the relative amount of waste collected or disposed in government bins and access to clean water and sanitation. Freetown, where around 14 % of the population resides, has some of the most developed facilities and infrastructure. With the investment and development of waste management companies, waste collection in the Western Area Urban District is thought to have increased in the last 20 years (Sood, 2004; World Bank, 2021). Despite these progressions, population growth continues to outpace the capacity of waste management systems. MSW generation estimates are limited for Sierra Leone, but 329,960 Mt year-1 is one estimate from around ten years ago (Sood, 2004), which has nearly doubled according to a more recent estimate of 610,222 Mt year-1 (Abidjan Convention and GRID-Arendal, 2020). Recycling rates are low in the region, with only 6.6 % estimated to be sent for recycling in Sub-Saharan Africa (Kaza et al., 2018). As such, garbage in Sierra Leone can still be seen everywhere and illegal dumping, open-burning, and waste leakages are still a considerable challenge (UNEP, 2018). Overall, Sierra Leone has significant data gaps regarding MSW and to date has no marine litter monitoring data.

### Site selection – Part 3: specific sites

At each location, the survey area was well defined by the water line at low tide, the first high tide line and the back of the beach, which was composed of shrubs, grass or trees. The tidal range of all sites is between 0.81-2.57 m. All sites have regular year-round use with up to 100 visitors a day, except Kent, a private beach that is only used seasonally.

Based on expert judgement and local knowledge, site selection also considered the accumulation nature of the beaches i.e., whether they are naturally incremating or depleting beaches. Different coastal environments have different plastic trapping (Harris et al., 2021), therefore depleting beaches were excluded from site selection.

#### Bailor

Bailor beach is situated around 35 km north of Freetown in the Port Loko District (4,668 km2), which has an estimated population of 528,032 (113 km-2) (Sierra Leone Statistics, 2015). Bailor beach sits on the outer edge of a wide estuary mouth, where the Great Scarcies and Little Scarcies Rivers, along with their tributaries, meet. These rivers travel 257 km through Sierra Leone, flowing through dense mangrove ecosystems and areas that have been extensively cleared for rice farming (Britannica, n.d.). Three main towns sit along the river, collecting the rice and transporting it along the coast to Freetown via the river mouth, where fishing and salt preparation are also important occupations (Britannica, n.d.)

#### Tintafor

Tintafor beach is also in the Port Loko District and situated around 15 km north of Freetown. Both Tintafor and Freetown overlook Sierra Leone harbour on the mouth of the country's largest river, The Rokel (Mondal et al., 2018). The estuary is also known as the Sierra Leone River, where the Rokel is joined by the Bankasoka River and extends around 30-40 km towards the Atlantic. The source of the Rokel River can be found in the Loma Mountains, around 250 km northeast of the estuary mouth. The mean spring tidal range of Freetown harbour is 2.8 m (Bird, 2010).

#### Kent

Kent beach is located around 35 km south of Freetown on the southwestern coast of the Western Area Peninsula Park, a protected area that is an important biodiversity hotspot in the country. This National Park is tentative to become a UNESCO World Heritage Site and attracts tourists. It hosts rainforests that are 60 % pristine and home to 80-90 % of Sierra Leone's terrestrial wildlife (UNESCO, 2012). The Western Area rural district has an estimated population of 444,270 (density 810 km-2) in an area of 210 km2 (Sierra Leone Statistics, 2015).

#### Chepo

Chepo beach is around 95 km south of Freetown, located on the Atlantic coast of Sherbro Island (600 km2), which is separated from the mainland by the Sherbro River and Sherbro Strait. Rice cultivation and fishing are the main economic activities on the island (Britannica, n.d.), which has an estimated population of 30,000 and sits within the Bonthe District (3,468 km2) that has an estimated population of 200,781 (57.9 km-2) (Sierra, Leone Statistics, 2015). The surrounding shallows harbour ecologically important seagrass beds (Sidi Cheikh et al., 2023). In addition, the endangered leatherback turtle, *Dermochelys coriacea*, is among five turtle species found in Sierra Leone and Sherbro Island is an important nesting site (Fretey et al., 2007).

**SI 2:**

### Survey Approach

Figure 1 illustrates the survey approach, which measures above and below the high tide line in two separate compartments. The exact distance monitored parallel to the water's edge and shown in figure 1 is 100 m, in alignment with the OSPAR methodology (Wenneker and Oosterbaan, 2010). Surveys were conducted monthly, 4-6 hours after high tide, with 2-6 surveyors traversing the survey area collecting litter items.



Figure 1: Diagram showing the combined methodologies (adjusted from Meakins et al., (2022)).

On each of the four survey sites, a 100 m long transect parallel to the water’s edge and centred along a visible high tide line outlined a sampling unit. The sampling unit was defined by the water’s edge and the vegetation at the back of the beach, with sub-sampling units defined as below and above the high tide line.

Litter collected on the high tide line was collected within the above high tide zone (supratidal) in line with Binetti et al., (2020) and Silburn et al., (2022). This is not recommended for future surveys. This data should either be collected within the below high tide zone or (intertidal) or data should only be collected from the water’s edge to back of the beach as one zone.

Within these sampling units, all macrolitter (>2.5 cm) was collected, separated based on material type and categories. Litter counts and dry weights (DW) were recorded on dedicated survey sheets *in situ* and input to an excel metadata file by a single survey lead. Spatial variation of survey sites was provided through GPS coordinates, detailed metadata and photographic material defining the area.

### Data analysis

Data cleaning and quality assurance checks were completed for all datasheets. Following quality assurance of datasheets, data were analysed using Microsoft Excel, R and Tableau Public, a free statistical analysis and data visualisation software available online.

Parametric and non-parametric statistics were performed to analyse the spatiotemporal trends of litter counts and weights. Variance of data was assessed using Levene's test for homogeneity of variances and normality was assessed using the Shapiro-Wilk test. A subsequent Analysis of Variance (ANOVA), *T*-test, *F*-test or Welch test was performed. Appropriate Tukey or Games-Howell multiple comparison *post hoc* tests were also used to evaluate the hypotheses of interest.

Agglomerative Hierarchical Clustering (AHC) and Principal Component Analysis (PCA) were applied to visualise and interpret similarities and dissimilarities in the abundance of litter categories. Analyses were performed using the Ward method with Euclidean distances as measures of the proximity of litter material categories for counts and weights, producing groups of survey sites based on litter abundances. Principal Component Analysis (PCA) was also performed to interpret relationships between survey sites, season and litter categories.

### **SI 3:**

### Beach litter estimates for all surveys reporting items per unit length of beach and items per unit area:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Site** | **Month** | **Total items 100m-1** | **Items m-2** | **Total weight (g) 100m-1** | **Total weight (g) m-2** |
| Kent | June | 1271 | 0.33 | 10945 | 2.88 |
| Tintafor | June | 2965 | 0.93 | 80106 | 25.03 |
| Chepo | June | 1512 | 0.47 | 26525.5 | 8.29 |
| Bailor | June | 5614 | 0.56 | 157128.08 | 15.71 |
| Kent | July | 621 | 0.16 | 15368.01 | 3.94 |
| Tintafor | July | 3634 | 1.14 | 105173 | 32.87 |
| Chepo | July | 1226 | 0.36 | 16118 | 4.74 |
| Bailor | July | 1725 | 0.18 | 17647 | 1.88 |
| Kent | August | 177 | 0.05 | 3530 | 0.91 |
| Tintafor | August | 5187 | 1.62 | 120508 | 37.66 |
| Chepo | August | 2610 | 0.84 | 25395 | 8.19 |
| Bailor | August | 2255 | 0.24 | 55783 | 5.93 |
| Kent | September | 413 | 0.11 | 8479 | 2.23 |
| Tintafor | September | 3017 | 0.94 | 56513 | 17.66 |
| Chepo | September | 558 | 0.17 | 3496 | 1.09 |
| Bailor | September | 3776 | 0.38 | 46904 | 4.69 |
| Kent | October | 320 | 0.08 | 3614 | 0.95 |
| Tintafor | October | 4054 | 1.27 | 73300 | 22.91 |
| Chepo | October | 838 | 0.26 | 4489 | 1.40 |
| Bailor | October | 1281 | 0.13 | 24531 | 2.45 |
| Kent | November | 131 | 0.04 | 2586 | 0.81 |
| Tintafor | November | 1254 | 0.39 | 12198 | 3.81 |
| Chepo | November | 670 | 0.07 | 3418 | 0.35 |
| Bailor | November | 1058 | 0.11 | 8277 | 0.83 |
| Kent | December | 1192 | 0.31 | 14592 | 3.84 |
| Tintafor | December | 7421 | 2.32 | 122356 | 38.24 |
| Chepo | December | 1073 | 0.34 | 7977 | 2.49 |
| Bailor | December | 1223 | 0.12 | 18202.1 | 1.82 |
| Kent | January | 1505 | 0.39 | 21924 | 5.62 |
| Tintafor | January | 3812 | 1.19 | 59027 | 18.45 |
| Chepo | January | 363 | 0.11 | 1104 | 0.35 |
| Bailor | January | 1197 | 0.12 | 15843 | 1.58 |
| Kent | February | 485 | 0.12 | 9540 | 2.45 |
| Tintafor | February | 2010 | 0.63 | 29061 | 9.08 |
| Chepo | February | 325 | 0.10 | 597.7 | 0.19 |
| Bailor | February | 472 | 0.05 | 4276 | 0.43 |
| Kent | March | 184 | 0.05 | 1824 | 0.47 |
| Tintafor | March | 2239 | 0.70 | 30705 | 9.60 |
| Chepo | March | 505 | 0.16 | 4608 | 1.44 |
| Bailor | March | 641 | 0.06 | 5191 | 0.52 |
| Kent | April | 100 | 0.03 | 797 | 0.20 |
| Tintafor | April | 989 | 0.31 | 11200 | 3.50 |
| Chepo | April | 467 | 0.15 | 1715 | 0.54 |
| Bailor | April | 531 | 0.05 | 3485 | 0.35 |
|  |  |  |  |  |  |
| **Mean** |  | 1656.84 | 0.41 | 28319.46 | 7.01 |
| **SD** |   | 1639.02 | 0.48 | 37481.45 | 10.09 |

**SI 4:**

#### Games-Howell multiple comparisons tests for count and weight data between sites:

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| --- |
| **Games-Howell Multiple Comparisons Test: Counts** |
|   |   |   |   |   | 95% Confidence Interval |
| **Beach (I)** | **Beach (J)** | **Mean Difference (I-J)** | **Std. Error** | **Sig.** | **Lower Bound** | **Upper Bound** |
| Tintafor | Bailor | 1528.09 | 731.65 | 0.192 | -524.03 | 3580.21 |
| Chepo | 2403.18 | 592.01 | 0.007 | 658.74 | 4147.63 |
| Kent | 2743.91 | 576.45 | 0.003 | 1021.36 | 4466.46 |
| Bailor | Tintafor | -1528.09 | 731.65 | 0.192 | -3580.21 | 524.03 |
| Chepo | 875.09 | 517.54 | 0.365 | -635.55 | 2385.73 |
| Kent | 1215.82 | 499.66 | 0.123 | -266.91 | 2698.54 |
| Chepo | Tintafor | -2403.18 | 592.01 | 0.007 | -4147.63 | -658.74 |
| Bailor | -875.09 | 517.54 | 0.365 | -2385.73 | 635.55 |
| Kent | 340.73 | 254.6 | 0.551 | -376.82 | 1058.27 |
| Kent | Tintafor | -2743.91 | 576.45 | 0.003 | -4466.46 | -1021.36 |
| Bailor | -1215.82 | 499.66 | 0.123 | -2698.54 | 266.91 |
| Chepo | -340.73 | 254.6 | 0.551 | -1058.27 | 376.82 |

|  |
| --- |
| **Games-Howell Multiple Comparisons Test: Weights** |
|   |   |   |   |   | 95% Confidence Interval |
| **Beach (I)** | **Beach (J)** | **Mean Difference (I-J)** | **Std. Error** | **Sig.** | **Lower Bound** | **Upper Bound** |
| Tintafor | Bailor | 31245.44 | 18204.56 | 0.342 | -19750.98 | 82241.86 |
| Chepo | 55047.62 | 12558.79 | 0.005 | 17311.58 | 92783.66 |
| Kent | 55251.64 | 12393.15 | 0.005 | 17697.21 | 92806.07 |
| Bailor | Tintafor | -31245.44 | 18204.56 | 0.342 | -82241.86 | 19750.98 |
| Chepo | 23802.18 | 13794.71 | 0.357 | -17769.2 | 65373.56 |
| Kent | 24006.2 | 13644.09 | 0.344 | -17406.38 | 65418.77 |
| Chepo | Tintafor | -55047.62 | 12558.79 | 0.005 | -92783.66 | -17311.58 |
| Bailor | -23802.18 | 13794.71 | 0.357 | -65373.56 | 17769.2 |
| Kent | 204.02 | 3532.45 | 1 | -9778.47 | 10186.51 |
| Kent | Tintafor | -55251.64 | 12393.15 | 0.005 | -92806.07 | -17697.21 |
| Bailor | -24006.2 | 13644.09 | 0.344 | -65418.77 | 17406.38 |
| Chepo | -204.02 | 3532.45 | 1 | -10186.51 | 9778.47 |

**SI 5:**

### Most abundant materials and items during wet and dry season:

#### PCA skree and vector plots for litter material categories for a) counts and b) weights, grouped by season:

1. **b.**



#### Ten most abundant litter items for a) counts and b) weights, grouped by season:

**a.**



**b.**



**SI 6:**

#### Weather and wind conditions during surveys:

|  |  |  |  |
| --- | --- | --- | --- |
| **Site** | **Month** | **Weather during survey** | **Wind during survey** |
| Kent | June | Clear | Calm |
| Tintafor | June | Heavy rain | Moderate breeze (10-25km/h) |
| Chepo | June | Clear | Calm |
| Bailor | June | Heavy rain | Moderate breeze (10-25km/h) |
| Kent | July | Clear | Moderate breeze (10-25km/h) |
| Tintafor | July | Heavy rain | Moderate breeze (10-25km/h) |
| Chepo | July | Drizzle | Calm |
| Bailor | July | Clear | Light breeze (10Km/h) |
| Kent | August | Clear | Light breeze (10Km/h) |
| Tintafor | August | Clear | Calm |
| Chepo | August | Clear | Calm |
| Bailor | August | Clear | Light breeze (10Km/h) |
| Kent | September | Clear | Calm |
| Tintafor | September | Heavy rain | Light breeze (10Km/h) |
| Chepo | September | Clear | Calm |
| Bailor | September | Clear | Calm |
| Kent | October | Clear | Light breeze (10Km/h) |
| Tintafor | October | Clear | Calm |
| Chepo | October | Clear | Calm |
| Bailor | October | Heavy rain | Moderate breeze (10-25km/h) |
| Kent | November | Clear | Light breeze (10Km/h) |
| Tintafor | November | Clear | Calm |
| Chepo | November | Clear | Calm |
| Bailor | November | Clear | Calm |
| Kent | December | Clear | Calm |
| Tintafor | December | Clear | Moderate breeze (10-25km/h) |
| Chepo | December | Clear | Light breeze (10Km/h) |
| Bailor | December | Clear | Light breeze (10Km/h) |
| Kent | January | Clear | Calm |
| Tintafor | January | Clear | Calm |
| Chepo | January | Clear | Calm |
| Bailor | January | Clear | Calm |
| Kent | February | Clear | Calm |
| Tintafor | February | Clear | Calm |
| Chepo | February | Clear | Calm |
| Bailor | February | Clear | Calm |
| Kent | March | Clear | Calm |
| Tintafor | March | Clear | Calm |
| Chepo | March | Clear | Calm |
| Bailor | March | Clear | Calm |
| Kent | April | Clear | Calm |
| Tintafor | April | Clear | Calm |
| Chepo | April | Clear | Calm |
| Bailor | April | Clear | Calm |
|  |  |  |  |
|  |  |  |  |

**SI 7:**

#### Overview of peer-reviewed macrolitter studies across Africa 2003-2022:

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Country** | **Author** | **Survey type** | **Site #** | **Site detail** | **Survey duration** | **Size class** | **Method** | **Observed density**  | **Top items** | **Potential pathways and sources** | **Potential solutions** |
| **Sierra Leone** | Present study | Standing stock | 4 | 2 urban sites and 2 rural sites | June 2021-April 2022 | >2.5cm | 100m between water's edge and highest strandline | 1656.84± 1639.02 items 100m-1 or 0.41± 0.48 items m-2 and 28319.46± 37481.45kg 100m-1 or 7.01± 10.09kg m-2 | Plastic bottles, plastic water sachets, caps/lids, flip flops and shoes | Monsoons influence temporal abundance, suggesting riverine input from land-based sources, as well as beach tourism, as main sources |  |
| Ghana | Nunoo and Quayson (2003) | Weekly accumulation | 4 | Tourism sites | 16 weeks November 2012 - February 2013 | Not detailed | Sampling area of 1000m2 (10m x 100m) at each site between low tide mark and zone of vegetation, parallel to the water's edge | 698± 62.99 and 876± 79.93 items 1000m-2 week-1; 7253± 618 and 5951± 783g 1000m-2 week-1 | 93% from land-based sources | A social survey revealed littering beach users as the main source of litter generation | Intensive education, continuous monitoring and enforcement of appropriate policy incentives |
| Kenya | Okuku et al. (2020) | Daily accumulation | 6 | Tourism sites, no beach cleaning during survey | June-November 2019, 10 consecutive days per site | >2.5cm | Densities per unit length of beach, wet zone from water’s edge up to and including strandline and dry section from line to 2m into the vegetation at the back/foot of construction | 3.8± 3.1-24.9± 19.1 items m-1 day-1; 0.31± 0.2-0.04± 0.02 g m-1 day-1 [1.53±1.23 and 11.46±7.72 (for dry zones) and 2.69±2.13 and 8.93±7.87 items m-1day-1 (for wet zones)] | Plastic food packaging, bottles, personal care products and foam, PET bottles (171 different brands) | Local products contributed 88% of litter, higher manufacturer contribution near distribution stores and bottling plants | Local solution to waste management e.g., local waste receptors and awareness against littering, as well as brand responsibility through e.g., return program, cleaning product that has leaked, polluter pays principle |
| Okuku et al. (2021) | Standing stock | 1 | Tourism site, 13,048 m−2, located along Tudor creek | Monthly May-July Oct 2019, Feb-March 2020  | >2.5cm | 6 surveys of entire beach to determine the influence of the monsoon, between sea and back of beach vegetation/wall | 0.091-0.736 items m-2; mean of 0.383 ± 0.260 items m−2  | Foam and plastic fragments, PET bottles, food packaging, lollipop sticks, caps/lids, earbuds, rubber fragments, ropes, straws, foreign products | Monsoons influence temporal, diversity, richness and evenness of stranded litter, 316 brand from identifiable litter, mostly Kenyan origin | Further studies to understand the role of the monsoon, locally based solutions e.g., EPR and polluter pays principles, waste receptor facilities, advocacy for changing littering attitudes |
| South Africa | Chitaka (2020) | Daily accumulation | 5 | Tourism sites, various levels of cleaning activity | 5-10 days per site during Aug-Oct 2017 (winter to spring) | >2cm | 100m between water's edge and highest strandline | 36-2961 items 100m-1 day-1; 189-4430 g 100m-1 day-1 | Beverage bottle lids, snack packets, plastic fragments | Easy to litter and high leakage rate items | Mitigation approach could reduce up to 50% of litter in Cape Town |
| Chitaka (2020) | Daily accumulation | 5 | Tourism sites, various levels of cleaning activity | 5-10 days per site during Dec-Jan 2018-2019 (summer) | >2cm | 100m between water's edge and highest strandline | 305-2082 items 100 m-1 day-1; 557-3799g 100-1 day-1 | Beverage bottle lids, polystyrene food containers, sweet wrappers, snack packets and straws | Easy to litter and high leakage rate items | Strategies focused on sustainable design as opposed to plastic pollution mitigation, need to integrate leakage rates in LCA |
| Ryan (2020) | Standing stock | 1 | 16-mile remote beach cleaned 1-2 times a year | Summer 2008 | >1cm | 8 x 1 m and 4 x 50m transects across 500m, width of beach to above the storm strandline | Surface: 11.8 items m-1; 249 g m-1; Buried: 123.2 items m-1, 149 g m-1 | Bottles, lids/caps, straws, cigarette butts | Significant correlations between the number and mass of macro-litter items on the surface and buried |  n/a |
|   | Standing stock | 1 | 16-mile remote beach cleaned 1-2 times a year | Summer 2010 | >1cm | 8 x 1 m and 4 x 50m transects across 500m, width of beach to above the storm strandline | Surface: 14.6 items m-1, 227 g m-1; Buried: 92.8 items m-1, 77.7 g m-1 | Bottles, lids/caps, straws, cigarette butts | Significant correlations between the number and mass of macro-litter items on the surface and buried |  n/a |
| Ryan (2021) | Standing stock | 1 |  2.4km beach around mouth of estuary | 60 days April-July 2020 (winter/rainy season) | >1cm  | 400m at either end of the beach, only small selection of common items recorded at item level and broken items recorded as 0.5 | Core items: 0.2 to 19.9 items·100 m−1 d−1 | Drinking bottle lids/caps, cigarette butts, bottles, lollipop sticks | Large deposition from rivers on beaches near estuary mouth | Cleaning beaches around river mouths, especially after rain events, will help reduce leakage into the marine environment |
| Ryan (2021) | Standing stock | 32 | Beaches on east and west coast and one offshore island | June 2019-Sept 2020 | Plastic container/bottle items only | Bottle and SUP survey of 145km shoreline | 8-450 bottles km-1 | Drinking bottles, food packaging, cosmetic containers, shipping canisters | Locally manufactured bottles near urban centres, up to 74% foreign on remote beaches from dumping and longshore drift | Need sound understanding of sources, reduce leakages from sea and land-based sources |
| Weidemann (2020) | Monthly accumulation | 1 | Rocky shore in False Bay | Monthly May 2015-March 2018; July-Sept 2019 | Not detailed | 39 sampling events of 125m of rocky shore from the strandline to the water's edge | 2.4±1.7 items m-1 month-1; 24.9±82.6 g m-1 month | Plastics 71% by count but only 31% by mass; disposable bags, packets, straws and food packaging  | Rocky shores trapped more bags/packets, but less rigid plastics. Loads peaked after seasonal rains, suggesting most litter comes from local land-based sources  | Although routine monitoring of rocky shore litter is not recommended for tracking litter at sea, it can provide novel insights into litter dynamics. |
|   | Monthly accumulation | 1 | Sandy shore in False Bay | July-September 2019 | Not detailed | 400m long sandy beach, from the water's edge to the back of the beach | 2.3± 0.3 items m-1 month-1; 3.6± 48.0g m-1 month-1 | Food packaging, cotton buds and straws, but rope and fishing gear larger proportion by mass | Rigid packaging items such as bottles/tubs and lids/lid rings made up a larger proportion of sandy beach litter by mass | n/a  |
| Tanzania | Maione (2021) | Standing stock | 4 | Coastal tourism sites | 27-29 June 2018 | >2.5cm | 2-4 transects with 10x20m area perpendicular to the water's edge | Mean weight of 74.2kg/site (46.8-89.7kg) | Bottles, tableware, food packaging, bags | Contributions largely from sectors of Zanzibar's economy, mainly tourism, but also residential households, building and construction and commercial sector | Data can inform decisions on beach and coastal management, while future research could investigate litter management strategies and advance solutions at a manageable scale |

NB: If quantified as items per unit area, litter loads in this study have a mean of 0.41 items m-2 (*SD* = 0.48), ranging from 0.15 items m-2 (*SD =* 0.13) at Kent to 1.04 items m-2 (*SD* = 0.64) at Tintafor, with a maximum of 2.32 items m-2 documented in December.

**SI 8:**

#### List of relevant regional policy frameworks and goals for West Africa:

|  |  |
| --- | --- |
| **Policy** | **Goals** |
| The United Nation’s Sustainable Development Goals (SDGs) | A global agenda to end poverty and environmental injustice. SDG 6 focuses on clean water and sanitation; Goal 12 aims to support sustainable production and consumption patterns and Goal 14 focuses on protecting the marine environment. |
| The United Nation’s Plastic Treaty | Development of a global strategy to prevent plastic pollution by 2024. |
| The African Union’s Agenda 2063 | A strategic framework to transform socioeconomics over the African continent, including a focus on sustainable development, waste management and sanitation, setting a 50% recycling targets for cities |
| The United Nations Environment Programme (UNEP) | A source of technical support, capacity building, policy guidance and financial support to help African countries improve waste management and sanitation. |
| The Basal Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal | This convention prohibits the imports of hazardous waste, including plastics unless they are cleaned, sorted into one polymer stream and destined for a certified recycling centre. |
| The Bamako Convention on the Ban of Import and Control of Hazardous Wastes within Africa | Another international treaty that focuses on hazardous waste management. |
| The Abidjan Convention | A treaty focused on the protection, management and development of the marine and coastal environment of the Atlantic. In 2017 member states adopted a ~~‘~~marine waste and integrated coastal and ocean management policy. |
| The Minamata Convention | An international treaty to protect human and environmental health from emissions of mercury and mercury compounds. |

**SI 9:**

#### Municipal Solid Waste collection, access to clean drinking water and toilet access (%) in Sierra Leone districts in Sierra Leone Districts (draft report, World Bank, 2021):



