Chapter 2
Marine Litter Sources and Distribution Pathways

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Summary Marine litter has been a global concern for many decades. It is important to understand marine litter sources and distribution pathways for the development of targeted and effective interventions and strategies. These have been relatively less researched on the African continent. This chapter focuses on (1) the sources of litter items from macro to nanoscale entering the marine environment and (2) the distribution and accumulation of these items within the environment, focusing on the African marine setting. Case studies are used to showcase specific examples and highlight knowledge/data gaps that need to be addressed within Africa. The potential pathways going forward are discussed and what may be expected in the future, in light of the challenges and successes examined.

Keywords Marine litter · Plastic pollution · Microplastics pollution · Monitoring

2.1 Introduction

Whilst marine litter has been a global concern for many decades. It has been relatively less researched on the African continent (Akindele and Alimba, 2021; Alimi et al., 2021). The majority of quantification studies took place in South Africa, dating back to the 1980s (Ryan, 1988). However, the global spotlight on this issue has seen more studies being conducted across the continent (Fig. 2.1a, b).

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2.2 Sources of Marine Litter

Marine and freshwater litter (e.g., plastics, ceramics, cloth, glass, metal, paper, rubber, wood) are evident throughout Africa (Chitaka & von Blottnitz, 2019, 2021; Dunlop et al., 2020; Ebere et al., 2019; Moss et al., 2021; Weideman et al., 2020a). The sheer volume littering coasts or floating down rivers highlights its prevalence and the predominance of and leakage from various sources in the region. Sources and release pathways can be linked to land-based or sea-based activities, with the former including municipal solid waste management, direct littering, wastewater and sludge release, agricultural activities, industrial production, harbour/port activities, and others (Fig. 2.2). Sea-based activities include the fishing industry and aquaculture sector and sea-based dumping from ships and off-shore platforms (Fig. 2.2).

2.2.1 Land-Based Sources

Municipal Solid Waste Management and Direct Littering

A major source of litter entering the environment in Africa results from the lack of adequate and appropriate solid waste management, which pervades every country of the continent (UNEP, 2018b). Municipal solid waste generation rates vary across Africa (Hoornweg & Bhada-Tata, 2012; Kaza et al., 2018), however, overall daily capita rates were considered to be 0.78 kg in 2012, compared to a global average of 1.2 kg per capita per day (UNEP, 2018b). Higher waste generation rates have been associated with some African island states (i.e., Seychelles, Mauritius, and Cabo Verde), which have been attributed to the tourism industry and a reliance on imported resources and associated packaging (Andriamahefazafy & Failler, 2021; Hoornweg & Bhada-Tata, 2012).

Increases in waste generation rates are driven by factors that include rapid population growth and urbanisation, a growing middle class with associated changing consumption habits, economic development, and global trade, which encourages imports of consumer goods into Africa (Jambeck et al., 2018). See Chap. 1 for further details on projections for Africa. Despite these projections, service delivery remains poor and is unlikely to improve at rates needed to support the populace. In Sub-Saharan Africa, for example, only about 44% collection rate of waste, on average, is achieved (Kaza et al., 2018). Waste collection and disposal methods are primarily crude. It is estimated that the treatment processes across the region are: open dumping and/or burning (69%), unspecified landfilling (12%), sanitary landfilling (11%), controlled landfilling (1%), and recycling (7%) (Kaza et al., 2018). 19 of the world's 50 biggest dumpsites are in Africa, with six located in Nigeria (UNEP, 2018b). Corresponding data for the North African sub-region alone are not readily available as the area is often combined with that for the

Middle East. In this regard, the Middle East and North Africa region had an estimated average waste generation rate of 0.81 kg per capita per day, which amounted to 129 million tonnes in 2016 (Kaza et al., 2018). The average collection rate was 82% for this combined region but varied significantly amongst the countries. Waste treatment in the region was estimated to be: open dumping (52%), unspecified landfilling (10%), sanitary landfilling (11%), controlled landfilling (14%), recycling (9%), and composting (4%) (Kaza et al., 2018). Waste management data from African Small Island Developing States (SIDS) is limited. However, it is well understood that due to lack of space and infrastructure and disposal sites near the marine environment, SIDS are often disproportionately affected by waste leakage into the environment (see Chap. 3 for more detail). This is often compounded by debris littering beaches brought by ocean currents and higher generation of waste by visiting tourists (UNEP, 2019).

Open spaces where solid waste has been dumped indiscriminately result in high leakage of hazardous and non-hazardous waste into drains and finally into rivers, lakes, and estuaries. The closer the source of mismanaged waste to river networks and coastal zones, the greater the chances of marine litter. Many populated inland cities are located on rivers' banks, which form a rich network of waterways that criss-cross the continent (Grid-Arendal, 2005; Lane et al., 2007; UNEP, 1999). Thus, Africa's inland rivers and estuaries may provide a pathway for a portion of land-derived litter to enter the sea (Lane et al., 2007; Moss et al., 2021; Naidoo & Glassom, 2019; Weideman et al., 2020c) (Fig. 1.1a). Africa has many densely populated coastal cities, of which several have been linked to large litter inputs to the marine environment (Ryan, 2020a, 2020b; Ryan et al., 2021). Lack of adequate affordable housing in Africa may be, for example, a source of litter entering nearby environments, especially as waste is often used as part of informal and temporary structures and shelters (GESAMP, 2019). The coupling between mismanaged waste and affordable housing needs to be investigated further, along with more work on the role coastal cities across Africa play as a source of litter to the surrounding marine environment.

Direct littering and dumping by households in parts of Africa, has also resulted in solid waste entering open drains, river watercourses, and coastal beaches. Beaches in most parts of the world, but especially those in many low-income countries, have been littered with waste by tourists and local persons involved in recreational activities (Lamprecht, 2013; Lane et al., 2007; Tsagbey et al., 2009; UNEP, 2019). Common items include drink bottles, water sachets, single-use food packaging, cigarette butts, and an array of miscellaneous materials. Many beaches in different parts of Africa have been recorded as frequently littered by tourists, especially during peak holiday months (Tsagbey et al., 2009) or specific sporting/entertainment events (Ahmed et al., 2008).

Once in the environment, larger plastic litter items are physically, biologically, and chemically broken down and degraded into secondary fragments/films/foams that include meso, micro, and nano sizes (Bond et al., 2018; Cooper & Corcoran, 2010). The most common polymers detected in African microplastic studies were polyethylene (PE) and polypropylene (PP) (Alimi et al., 2021; Mayoma et al., 2020;

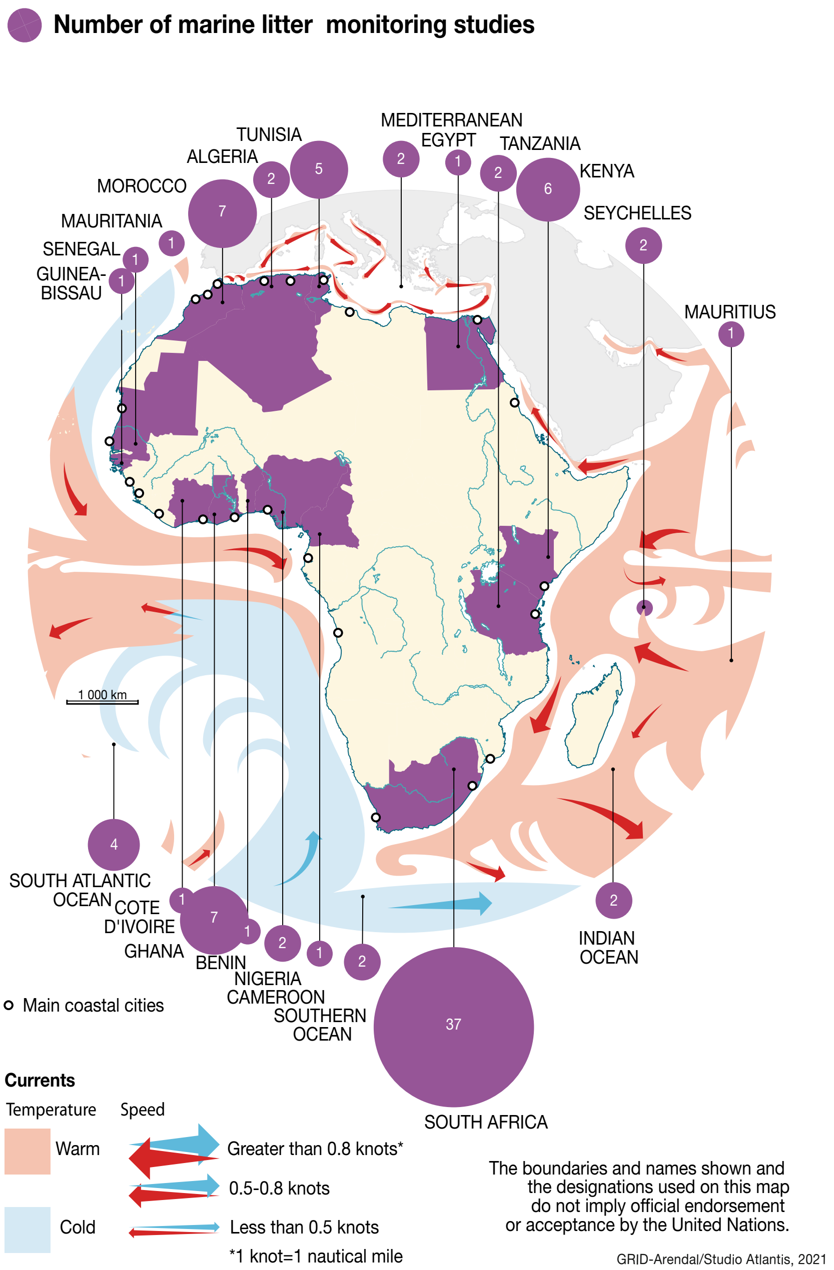
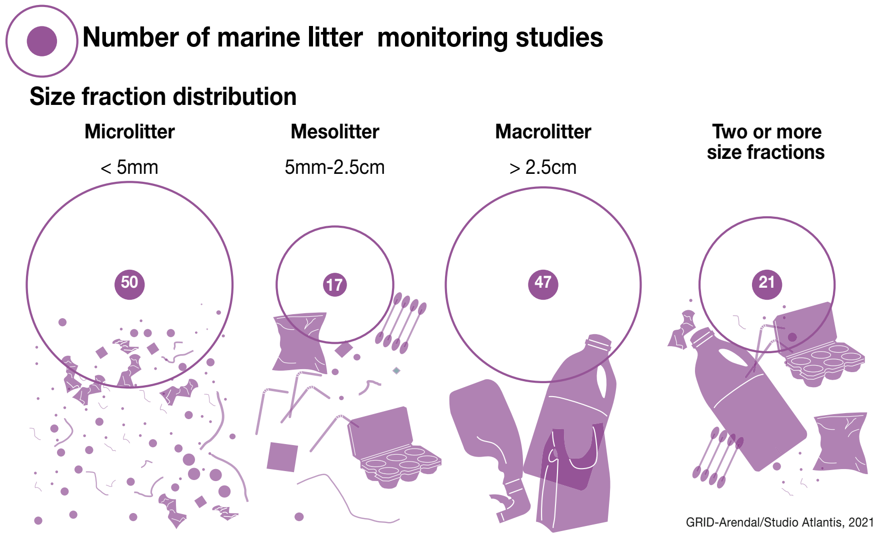


Fig. 2.1 **a** Total number of marine litter quantification studies published across Africa in peer-reviewed journals (excluding ingestion and entanglement studies, which are covered in Chap. 3). *As of December 2021, detailed list in Annex 2.1. **b** Total number of marine litter quantification studies, by size fractionate, published across Africa in peer-reviewed journals (excluding ingestion and entanglement studies, which are covered in Chap. 3). *As of December 2021, detailed list in Annex 2.1



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Missawi et al., 2020; Vetrimurugan et al., 2020; Wakkaf et al., 2020; Zayen et al., 2020), which are widely used in the packaging sector (PlasticsSA, 2018). More targeted studies are needed to investigate the role open or unmanaged dumpsites (Bundhoo, 2018; Nel et al., 2021) and incineration sites, where litter is managed through informal burning (Yang et al., 2021), play in microplastic generation and release. Especially, as these sites may become significant legacy sources, leaching microplastics to the surrounding environment long after site closure.

Wastewater and Sludge

Domestic and industrial wastewater is a well-recognised source of litter that may get deposited in marine environments (Conley et al., 2019; Freeman et al., 2020; GESAMP, 1991; Kay et al., 2018; Okoffo et al., 2019). Domestic and industrial wastewater serve as conduits for litter, which has been purposely dumped/flushed or originated from added products. Once discharged into streams and rivers (or in some countries directly into the marine environment), litter may be carried into the marine environment. In high-income countries with efficient processing plants, the impact of wastewater discharge on the marine environment is usually mitigated by pre-treatment purification steps (biological, chemical, and mechanical). However, whilst such wastewater treatment plants (WWTPs) may remove most macrolitter and a relatively large portion of microlitter, the smaller (<100 µm) litter fractions remain in the effluent, subsequently entering aquatic environments through discharge (Conley et al., 2019; Iyare et al., 2020; Talvitie et al., 2017). Additionally, although microlitter may get removed before the effluent is discharged into aquatic

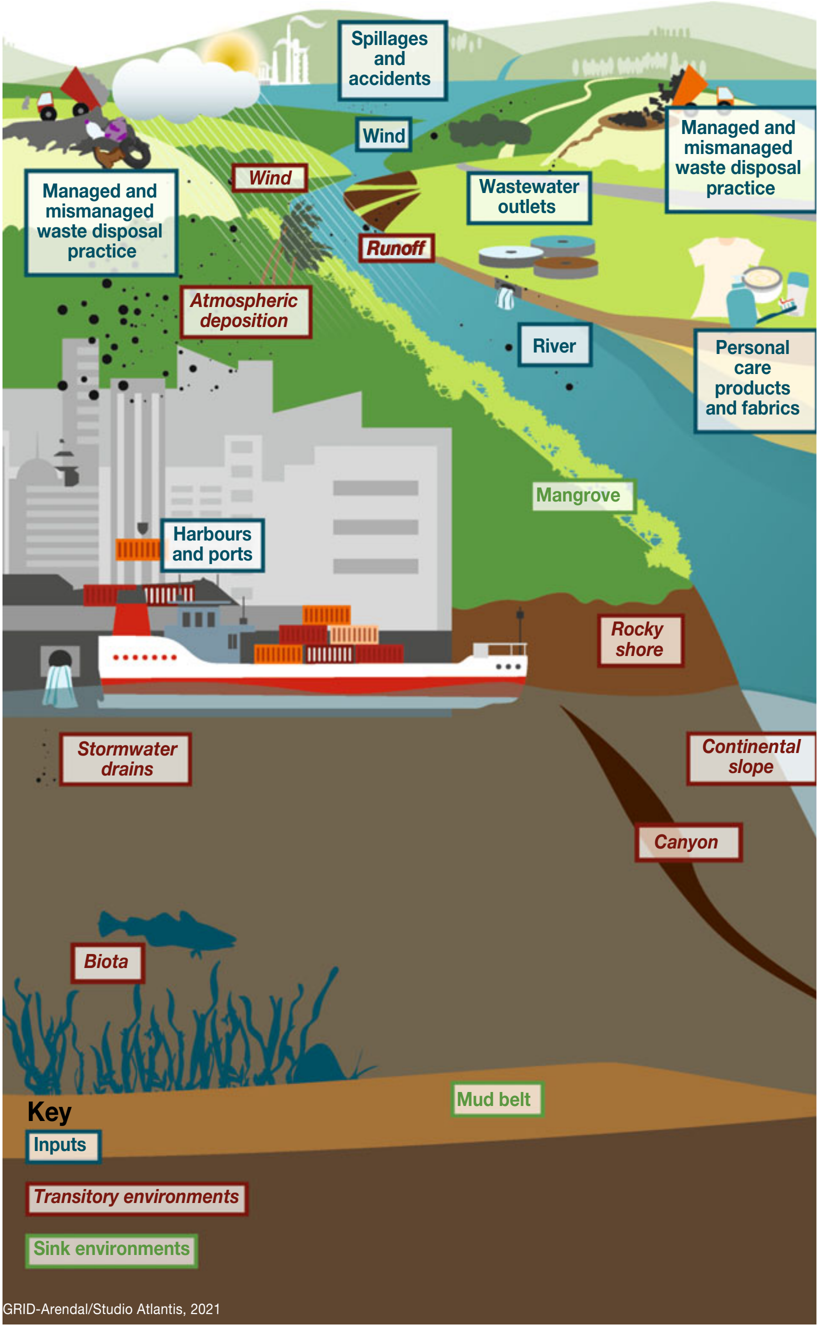
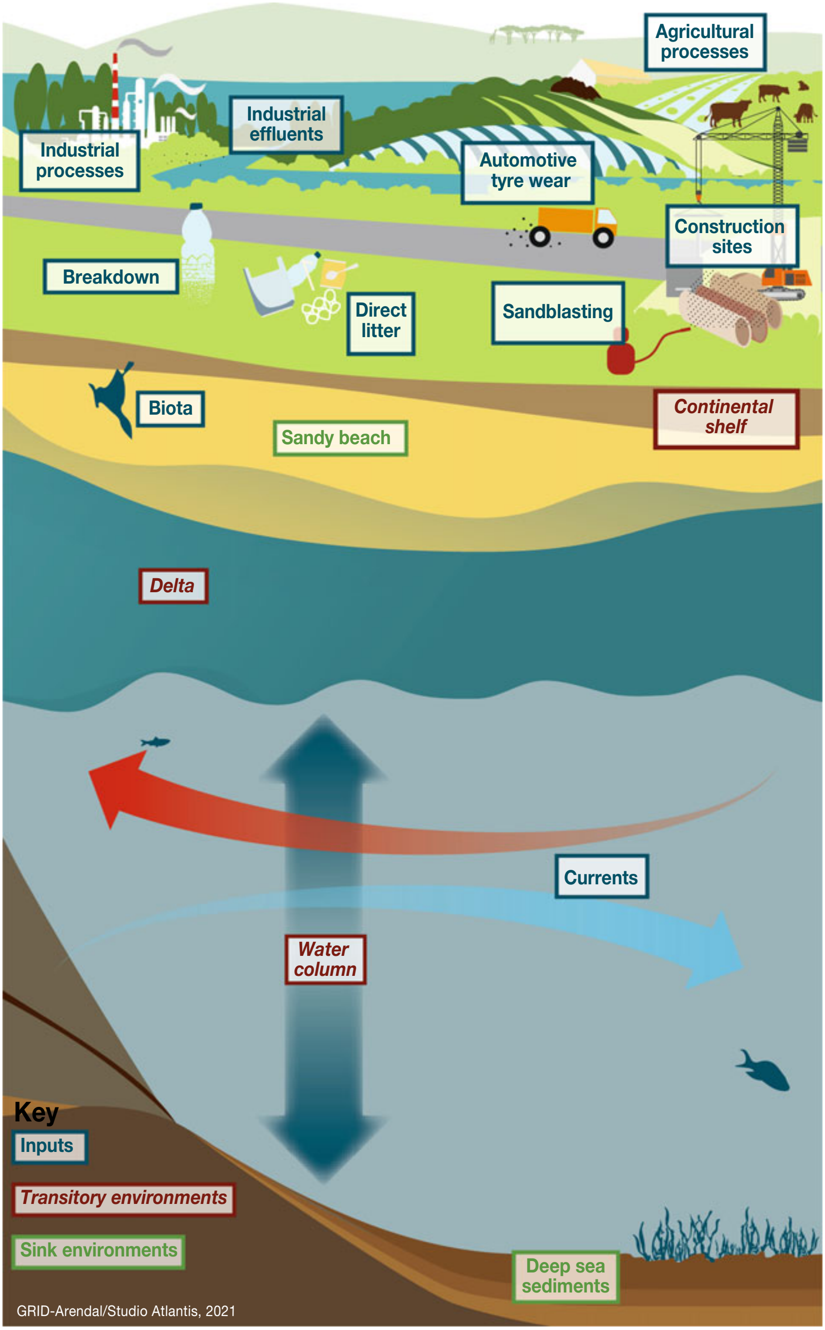


Fig. 2.2 Sources, pathways, and sinks of marine litter from macro- to micro-sized items



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environments, evidence shows that contaminated sludge/biosolids are spread over terrestrial and agricultural land (De Falco et al., 2019; Mahon et al., 2017; Okoffo et al., 2020) which then leach microlitter during runoff events (Okoffo et al., 2019). The release of raw/untreated sewage directly into the ocean is an additional source of marine litter. Domestic and industrial wastewater in Africa may be an understudied yet a significant source for all sizes of litter, this is detailed in Box 2.1.

Box 2.1: Domestic and Industrial Wastewater as an Understudied Source for Litter from Macro to Nano

Domestic and industrial wastewater are potential sources of marine litter. An investigation of macrolitter flows in three WWTPs in Cape Town, South Africa, found cotton bud sticks in the discharged effluent, which passed through the primary screens designed to trap debris (Chitaka, 2020). Investigations conducted by Nel et al. (2018) and Dalu et al. (2021) of river sediments upstream and downstream of WWTP effluent discharges in South Africa suggested that WWTPs are point-sources for microplastics and microfibres. Research in the Bizerte Lagoon, Tunisia, and the adjacent coastline identified microplastic hotspots potentially linked to wastewater facilities (Wakkaf et al., 2020).

In most African countries, wastewater management facilities are non-existent (AfDB/UNEP/Grid-Arendal, 2020). Where they exist, they are mostly aging, inadequate, dis-used, or derelict due to high maintenance and replacement costs (Nikiema et al., 2013). Inadequate provisions for sanitation are a significant problem for most African urban, peri-urban, and rural communities. In most African countries, 72–92% of wastewater was untreated in 2015 (WWAP, 2017). Domestic wastewater from households, hospitals, academic institutions, government offices, etc., is rarely discharged into sewers. Instead, most households discharge directly into soak-away pits that contaminate groundwater or open land and public drainage gutters, contaminating rivers, streams, and ultimately marine environments (AfDB/UNEP/Grid-Arendal, 2020; Mafuta et al., 2018; Wang et al., 2014). In some coastal cities, sewage is directly discharged into the sea. SIDS are no exception. Although many households are provided with a supply of water, a wastewater collection/connection is far less common within SIDS (UNEP, 2019). More research needs to be conducted across Africa to assess how the lack of services and poor maintenance of wastewater infrastructure results in the release of all sizes of litter to the natural environment. Thus, allowing us to inform which mitigation methods to prioritise and importantly, which solutions have been effective (Image 2.1).

Image 2.1 Evidence of debris in the **a** dissolved air flotation tank and **b** effluent of a Cape Town WWTP (Chitaka, 2020)

Domestic and industrial wastewater may contain primary microplastics, intentionally incorporated into some products. For example, 'microbeads' made from polyurethane (PU) spheres or PE particles are found in a range of personal care and cosmetic products (Amec Foster Wheeler Environment & Infrastructure UK Limited, 2017; UNEP, 2015). This type of contaminant has gained attention across the globe as a result of the 'Beat the Microbead' campaign (Dauvergne, 2018), which highlighted how these products can get released into the environment via wastewater systems. Microplastics may also be intentionally added to or used in the production of paints/coatings, detergents, slow- and controlled-release fertilisers, and industrial abrasives, and depending on the product, will get released into the environment via wastewater, leaching, and/or stormwater runoff (Amec Foster Wheeler Environment & Infrastructure UK Limited, 2017). Although very high concentrations of microbeads have been recorded within some aquatic environments, for example in sediment from the St. Lawrence River, Canada (10^3 microbeads L^{-1}; Castaneda et al., 2014) and throughout the Irwell and Mersey catchments in the United Kingdom (<70,000 microbeads kg^{-1}; Hurley et al., 2018), similar hotspots have not been detected in Africa. Microbeads associated with personal care products range in size, shape, and colour (Cheung & Fok, 2017). White granule-like PE fragments in face washes may be more challenging to detect than brightly coloured (blue and green) spherical beads found in other cosmetic products (Nel et al., 2019). This difference in detection may result in some microbead granules being overlooked. Regardless, the potential for contamination is apparent, resulting in several countries banning their use in rinse-off products (Guerranti et al., 2019). However, no African country has banned the inclusion of plastic particles in cosmetic products, though discussions have occurred, and some industries (such as the South African cosmetics industry) have implemented some voluntary initiatives to replace microbeads with other materials (Verster & Bouwman, 2020).

Synthetic and natural microfibres can enter the environment as a result of industrial activities (textile factories), individual consumer activities (washing of clothes by hand or using household/communal machines), and wastewater management (sewage effluent, sewage sludge) (Mishra et al., 2019). Marine microplastic studies in South Africa (De Villiers, 2018, 2019; Nel & Froneman, 2015; Nel et al., 2017) and Tunisia (Wakkaf et al., 2020) found microfibres were the most dominant type of microlitter detected. However, by mass of debris they account for <0.01% (Ryan et al., 2020d). Researchers have suggested that microfibres should be classed as their own contaminant independent of 'microplastics'. Anthropogenic fibres recorded in the environment can be plastic in origin. Washing synthetic textile materials has been shown to release large amounts of microfibres into wastewater (Browne et al., 2020; De Falco et al., 2019, 2020). Microfibres can also be natural/non-plastic in origin e.g., cotton, viscose, linen, jute, kenaf, hemp (Suaria et al., 2020a) or synthetic in origin but made from natural sources of regenerated cellulose e.g., rayon (Kanhai et al., 2017). Reports have suggested microplastic and microfibre removal rates of ~90% for treated wastewater, however the combined global release of microlitter annually from untreated effluent has been estimated at 3.85×10^{16} (Pedrotti et al., 2021; Uddin et al., 2020). The largely untreated domestic wastewater that pollutes local streams and rivers in Africa may be expected to be loaded with an abundance of these particles.

Microplastic pollution is expected in industrial wastewaters/drainage, either through intentional industrial processes or as accidental leakage from industries manufacturing items that utilise primary microplastics or process pristine/recycled plastic products (Karlsson et al., 2018). Unfortunately, data on microplastic/microfibre abundance and distribution in industrial wastewaters/drainage is scarce in Africa and globally. However, Zhou et al. (2020b) and Chan et al. (2021) both recorded high levels of pollution (~300/500 microfibres L^{-1}) originating from textile processing factories in China.

Pre-production pellets are another primary microplastic. They have been recorded on beaches in Africa since the 1980s (International Pellet Watch, 2021; Ryan & Moloney, 1990). They have been attributed to unintentional factory and transportation leakage (Boucher & Friot, 2017; Karlsson et al., 2018). Pellets in the marine environment have often been associated with urbanisation and industrialisation centres (Hosoda et al., 2014; Naidoo et al., 2015; Ryan & Moloney, 1990; Ryan et al., 2018). However high concentrations have also been located in more rural locations due to historical deposits resulting from long-range transport carrying high densities of pellets from urban centres (Ryan et al., 2018). For example, in South Africa, pellet deposits are seen at 16 mile Beach in the West Coast National Park and Woody Cape at the east end of Algoa Bay (Ryan et al., 2012, 2018). To combat this specific type of contamination the 'Operation Clean Sweep' campaign has been adopted by plastic producers and converters worldwide (American Chemistry Council, 2021). In Africa, the Egyptian Plastic Exporters and Manufacturers Association, Ghana Plastics Manufacturers Association and Plastics SA have pledged to follow best practice guidelines outlined by the campaign to minimise pellet, flake and powder loss from the plastic industry.

Harbour and Port Activities

Globally, shipping activities are associated with generating large quantities of wastes onboard. At the same time, ports and harbour activities may also generate wastes close to the sea (APWC, 2020; IMO, 1973/1978; Mobilik et al., 2016). Wastes from both sources can contribute to the marine litter problem. Two international conventions, The London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (IMO, 1972), and the MARPOL (1973/1978) Convention for the Prevention of Pollution from Ships (IMO, 1973/1978) have been designed to ensure that ship-sourced wastes are not dumped into the open ocean, but are provided with adequate ports reception facilities for the safe and efficient discharge and treatment of the wastes. In particular, Annex V (Pollution by Garbage from Ships) to the MARPOL convention, which came into force in 1989, specifically bans the dumping of persistent wastes, including plastics, at sea, and requests for countries to operate adequate ports reception facilities that should include garbage reception boats, ships and vehicles, garbage treatment facilities and adequate communication services, amongst others.

Parties and signatories to the MARPOL convention have been provided with adequate guidelines for operating sustainable and efficient national port reception facilities and guidance for ships to practice good housekeeping onboard (Hwang, 2020; IMO, 2013, 2014, 2016; Wallace & Coe, 1998). Unfortunately, whilst in most high-income countries, national ports authorities provide efficient port reception facilities (Argüello, 2020; NOWPAP, 2009; Øhlenschlæger et al., 2013), the same cannot be said of most seaports in Africa. African seaports have been characterised by their inability to provide adequate and sustainable infrastructure and suffer from generally poor management to address the issues of Annex V of the MARPOL Convention. Although the exact amounts of marine litter derived from port and harbour activities have not been quantified yet in Africa, the few available studies on the status of reception facilities at some national ports underscore the need for improvement. For example, several studies examining facilities at the Apapa Port and the TinCan Island Port of Lagos, Nigeria (Onwuegbuchunam et al., 2017a, 2017b; Osaloni, 2019; Peters & Marvis, 2019) have identified the need for improvements to meet MARPOL Convention requirements. In South Africa, a detailed audit of eight major ports, in Durban, Richards Bay, Cape Town, Saldanha, Ngqura, Port Elizabeth, East London and Mossel Bay, and eleven smaller ones (APWC, 2020) found that it was challenging to get a clear picture of the management of ship-generated waste received at commercial ports. Port-generated waste was well managed and regulated, but ship-generated waste had much lower levels of control. A study of ports in the Mediterranean region, including those of Algeria, Egypt, Morocco, Tunisia, and Libya (REMPEC, 2005), also highlighted the need for considerable improvement of port reception facilities in the African countries of that region. The story is not much different in the East African region (Lane et al., 2007).

Various port activities have also been linked with the unintentional release of microplastics into the environment. In 2017 an accidental spill occurred in Durban Harbour, South Africa, wherein two containers carrying PE pellets broke open after falling off a vessel. This resulted in the rapid and widespread distribution of pellets across the South African coastline (Schumann et al., 2019). Although clean-up campaigns were initiated about 82% of the pellets lost were never recovered (Schumann et al., 2019), probably due to seepage into the south Atlantic and the Indian Oceans via dominant ocean currents (Collins & Hermes, 2019) (Fig. 1.1a). Hull scrapings and marine coatings have also been identified as sources of marine microlitter as a result of harbour and port activities (Dibke et al., 2021). Interestingly, Preston-Whyte et al. (2021) suggested harbour/port dredge spoils that may get dumped in nearby coastal zones may be an important and understudied source of microplastics to the marine environment. This is especially important as many harbours in Africa are associated with high microplastic concentrations and a more diverse suite of microplastic particles (Chouchene et al., 2019; Naidoo et al., 2015; Nel et al., 2017; Shabaka et al., 2019). Harbour sediments are also highly contaminated with persistent organic pollutants (POPs), metals, and a whole range of other hazardous substances that have been shown to sorb to microplastics (Torres et al., 2021). Please refer to Chap. 1 for details on these other chemical pollutants.

2.2.2 Sea-Based Sources

Shipping Industry

As mentioned in the previous section, the shipping industry is a significant contributor to marine pollution including, dumping hazardous and general waste (Ryan et al., 2019). A long-term study of bottles washing ashore of Inaccessible Island in the South Atlantic Ocean found an increase in the debris of Asian origin; this suggested that dumping from ships played a significant role in marine pollution in that region (Ryan et al., 2019). Additionally, Ryan (2020a) investigated the origin of plastic bottles stranded on nine Kenyan beaches and concluded that most bottles in urban areas were from local sources. The presence of newly manufactured Polyethylene terephthalate (PET) bottles from China implied ship derived waste is still an important component. Further evidence of ship-based waste was observed in South Africa, wherein foreign bottles accounted for up to 74% on some beaches (Ryan et al., 2021).

Fishing and Aquaculture Industry

A meta-analysis of 68 publications estimated that annual losses of fishing nets, traps, and lines are around 6%, 9%, and 29%, respectively (Richardson et al., 2019). An analysis of the Great Pacific Garbage Patch estimated that fishing nets accounted for 46% of the mass of all plastics (Lebreton et al., 2018) whilst fishing related debris was commonly observed on the seabed across all areas of the West European coastal shelves (Maes et al., 2018).

In Africa, fishing gear has also been found to be a major contributor to marine litter from coastal to oceanic waters (Alshawafi et al., 2017; Loulad et al., 2017; Ryan, 2014; Scheren et al., 2002) and on the seabed (Ryan et al., 2020c; Woodall et al., 2015). In Morocco, plastic fishing gear accounted for 94% by number of all collected plastic items on the seafloor (Loulad et al., 2017). Whereas, in South Africa, fishery waste accounted for 22% by number and 73% by mass (Ryan et al., 2020c). In cases where fishing gear has been located close to shore, this is mainly related to small-scale fishing operations. Cardoso and Caldeira (2021) investigated the source of plastic pollution found on the Macaronesian Islands. They concluded that the high proportion of fishing gear littering Cabo Verde (Aguilera et al., 2018) originates predominantly from activities off Western Sahara, Mauritanian and Senegalese coasts, with the east coast of North America a secondary source (Cardoso & Caldeira, 2021).

Aquaculture has also been identified as a potential source of plastic into the marine environment through discarded or lost gear (e.g., polyvinyl chloride (PVC) tubes, nets, and cages) as a result of mismanagement and/or accidental losses during extreme weather events (Huntington, 2019). Aquaculture is also a potential source of microplastics leakage resulting from the fragmentation of plastic gear over time and contaminated fishmeal (Lusher et al., 2017; Thiele et al., 2021; Zhou et al., 2020a). The extent to which aquaculture contributes to marine pollution has not been a research focus in Africa, which may be attributed to the industry's small size (see details in Chap. 1). However, as African aquaculture is projected to increase (see Chap. 1, Fig. 1.2a, b), this could be an increasing source of marine litter.

Oil and Gas Industry

There is global concern about the contribution of the oil and gas industry to plastic pollution, especially at sea (Ahmed et al., 2021). Studies are limited however, a case study from the Norwegian continental shelf found higher microplastic concentrations in both sediment and tube-dwelling polychaete worms near offshore oil and gas installations compared to more remote reference sites (Knutsen et al., 2020). The European Union has recently commissioned studies on identifying all material inputs and activities of this industry that may contribute to the environmental burden of microplastics. It is already well known that microplastics are used in the following applications in the oil and gas sector: cement additives and loss circulation material for drilling, wax inhibitors in production, and crosslinking chemicals in pipelines (Amec Foster Wheeler Environment & Infrastructure UK Limited, 2017). Mega and macroplastic leakage from the oil and gas industry is unquantified. Current Oil-producing, coastal African countries (Algeria, Angola, Republic of Congo, Egypt, Equatorial Guinea, Gabon, Libya, Nigeria, and recently Ghana) often have offshore, and coast-based oil industry installations and are liable to release plastics of all sizes into the marine environment. Though oil production is currently concentrated on the north and west coasts of Africa, oil fields, which may be exploited in the future, do exist on the east coast. Gas-producing coastal countries occur all around Africa and are also liable to release plastics of all sizes into the marine environment. However, studies and data quantifying releases from this industry have been sparse despite this knowledge, in Africa and globally.

2.3 Abundance and Distribution of Marine Litter

The abundance, accumulation rates, and characteristics of marine litter can be investigated in different environmental compartments (shorelines, in coastal waters, and the open ocean from the surface to the seabed) using various methods. Watercourses (e.g., rivers, stormwater drains, and WWTP outlets) are also an area of interest as they provide a conduit for litter transportation into the marine environment. Fluxes between compartments are dynamic, and sinks can become sources to other areas and vice versa depending on various abiotic and biotic processes. As such, it is important to understand these fluxes between land and sea, from rivers, estuaries, and the nearshore surface water to the deep sea, to interpret data trends accurately. More importantly, Ryan et al. (2020b) suggest that when monitoring the effectiveness of mitigation measures, sites close to sources are better as they give a more rapid and accurate measure.

Models used to estimate current, and future risk scenarios predict flow and accumulation. These are often associated with high levels of uncertainty, especially due to an incomplete understanding of marine litter inputs and distribution processes and limited and incomparable datasets (Lebreton et al., 2017; Schmidt et al., 2017). A good demonstration of the uncertainty associated with estimating plastic flows into the marine environment is the case of South Africa. Based on estimates of total waste production and proportion of mismanaged waste, Jambeck et al. (2015) estimated that 90,000–250,000 tonnes of plastic flowed into the ocean from South Africa during 2010. A subsequent estimate by Verster and Bouwman (2020), using more robust data, put forth a more conservative range of 15,000–40,000 tonnes per year, highlighting that the amount of plastic flowing into the environment, though less, is still a point of concern. This last estimate was better aligned with observed amounts of plastic washing up on beaches (Weideman et al., 2020b). Global studies using a Lagrangian model have attempted to estimate marine litter hotspots, suggesting the Mediterranean Sea and the coastal zone around southern Africa as regions of concern (Eriksen et al., 2014; Lebreton et al., 2012; Van Sebille et al., 2015). Models can also assist with where litter has originated. For example, Van Der Mheen et al. (2020) investigated the distribution patterns of particles released into the Northern Indian Ocean (NIO). They suggested that depending on the particle beaching probability, the east coast of Africa and many SIDs can be severely affected by pollution released by countries in south-east Asia. This is supported by direct evidence of long-distance drift of high-density-PE bottles and lids, mainly from Indonesia, found on beaches in Kenya, South Africa, and various western Indian Ocean (WIO) island states (Duhec et al., 2015; Ryan, 2020a; Ryan et al., 2021).

2.3.1 Rivers

Freshwater environments are also contaminated with litter, with rivers considered a major pathway for land-based litter to enter the marine environment (Schmidt et al., 2017; Van Calcar & Van Emmerik, 2019). River basins can also retain high levels of litter (buried beneath sediment, trapped along rocky outcrops and vegetated areas), particularly during low-flow conditions. There have been a handful of studies in Africa looking at macrolitter associated with rivers. In South Africa, visual observations of litter flowing down three rivers into Algoa Bay estimated discharge rates of 22–1500 items day^{-1} (Moss et al., 2021). Weideman et al. (2020c) investigated the long-distance transport of litter within the Orange-Vaal River system and found limited downstream distribution, with macrolitter often linked to local sources. Ryan and Perold (2021) showed limited debris dispersion from a river into the ocean, with deposition concentrated on beaches within 1 km of the river mouth. They also observed the litter exchange between the sea and the river, with marine litter, found up to 1.2 km inland. Rivers also can be long-term sinks for litter (Ryan & Perold, 2021; Tramoy et al., 2020) however, this is dependent on climatic and hydrological conditions within the catchment. For more information on monitoring litter in rivers and lakes, please see the UNEP (2020) report on harmonised approaches.

Rivers as a major transportation pathway for litter has made it a key point of focus for intervention efforts. Several catchment litter management options exist (Armitage & Rooseboom, 2000), using river booms as a popular intervention method (Box 2.2).

Box 2.2: The Litterboom Project, South Africa

Interception booms made of sun-proof high-density PE have been placed in series across several inland rivers in Durban and Cape Town, collecting a minimum of 14,000 kg per site annually. The litter booms are designed to float on the water's surface, catching floating plastic and other debris as they move downstream, bound for the open ocean. The booms are placed at an angle to ensure waste flows towards the most accessible bank for easier and safer collection. Litter is recycled where possible or landfilled. Litter booms are easy to maintain for teams in the community and very effective when cleared daily. However, retention can be poor when flow rates are high, for example during rainfall events. Such projects have been useful also for raising community awareness on the impact of indiscriminate disposal and littering. In addition, the collected waste data can be used to inform city-wide efforts to stop ocean-bound plastics (Image 2.2).

Image 2.2 The Litterboom Project (Photo Credit). The initiative is credited to the partnership of The Litterboom Project (TLC) with Parley, the City of Cape Town and Pristine Earth Collective

Micro and nano-plastic and fibre abundances have also been assessed in some freshwater rivers across the continent (Alimi et al., 2021), with most studies in South Africa (Dahms et al., 2020; Dalu et al., 2021; Nel et al., 2018) and Nigeria (Adeogun et al., 2020; Akindele et al., 2019; Ebere et al., 2019; Oni et al., 2020). Microplastics were generally partitioned into the water, river bed/bank sediment, and biota. They were characterised to be mostly derived from PE, PP, PU, polystyrene (PS), and polyester materials (Alimi et al., 2021).

Microplastic abundance in inland freshwater systems across the continent is very varied. For the Bloukrans River system in the Eastern Cape of South Africa, Nel et al. (2018) found sediment microplastic concentrations were less in summer (6.3 ± 4.3 particles kg^{-1}) than in winter (160 ± 140 particles kg^{-1}). In Tunisia, Toumi et al. (2019) investigated the sediments of the Bizerte Lagoon and surrounding areas and found 2340–6920 particles kg^{-1} in streams, and 3000–18,000 particles kg^{-1} in the lagoon. For Lake Victoria, Egressa et al. (2020) found 0.02–2.19 particles m^{-3} in the water. For the same lake, in Kenya, Migwi et al. (2020) found 1.56–5.38 particles m^{-3} in the water. Concentrations are often difficult to compare directly due to different authors' variable sampling and analysis methodologies with no standard or harmonised approach available to date.

What drives microplastic distribution, immobilisation and remobilisation, and burial in freshwater systems is still understudied. Depending on various in-stream abiotic and biotic processes, these particles may become temporarily immobilised within riverbed sediments and other in-stream features or float freely within the water column (Drummond et al., 2020; Krause et al., 2021). Floating particles may get distributed further downstream, eventually discharging into the marine environment (Besseling et al., 2017; Drummond et al., 2020; Schmidt et al., 2017; Siegfried et al., 2017). Overall, there are data gaps regarding the extent African rivers contribute litter to marine ecosystems, whether this contribution varies seasonally and how future scenarios may change with the changing climate.

Other data gaps surround where the potentially vulnerable ecosystems are due to litter accumulation. Wetlands, for example, may be potential sinks for both land- and sea-derived litter (Ryan & Perold, 2021). An assessment of macrolitter in two mangrove forests in Mauritius observed mean densities of 0.46 ± 0.24 and 0.24 ± 0.22 items m^{-2} (Seeruttun et al., 2021). Additionally, microplastics have been detected in South African mangroves at densities ranging from 18.5 ± 34.4 per 500 g (St. Lucia) to 143.5 ± 93.0 per 500 g (Isipingo estuary) for sediment samples (Govender et al., 2020). Microplastics in water, sediment, and biota were also found associated with the coastal wetland of Sakumo II Lagoon in Ghana (Kanhai et al., 2017). Mangroves situated within 20 km of river mouths are more vulnerable to plastic pollution due to their potential to trap receiving litter (Harris et al., 2021). However, the extent these regions play as litter traps has not yet been established empirically.

2.3.2 Urban Drainage Systems

Few studies have been conducted on urban drainage systems in Africa, including stormwater drains and sewage outlets. Stormwater runoff resulting from rainfall events carries litter from many sources (Image 2.3), flushing debris into streams, rivers, and ultimately the sea. When stormwater occurs around coastal areas, beach litter may be directly washed into the sea. Most of Sub-Saharan Africa experiences stormwater events during the rainy seasons. In South Africa, Arnold and Ryan (1999) quantified urban stormwater runoff in Cape Town, observing macrolitter fluxes of 7–731 items ha^{-1} day^{-1}. Twenty years later, Weideman et al. (2020a), repeated the study finding little change with fluxes of 5–576 items ha^{-1} day^{-1}.

Stormwater also carries microlitter deposited from a variety of sources, including fragmented solid waste, city dust, tyre and road wear particles, paint chips, and other industrial and agricultural emissions (Boucher & Friot, 2017; Horton & Dixon, 2018;

Image 2.3 Stormwater drain discharge from Cape Town, South Africa (Photo Credit: T.Y. Chitaka) and stormwater debris deposited at the drainage entrance into the Sierra Leone River in Freetown (Photo Credit: S.K. Sankoh)

Liu et al., 2019; Pramanik et al., 2020). Stormwater runoff was considered a major pathway for microlitter to enter aquatic environments and has been shown as an important point source in Durban Harbour, South Africa (Preston-Whyte et al., 2021). Particles released from tyres, and brake pads constitute a major global source of microplastic contamination (Järlskog et al., 2020; Klöckner et al., 2020; Knight et al., 2020; Kole et al., 2017). Evangeliou et al. (2020) estimated that about 64,000 tonnes per year of tyre wear and brake wear particles are directly transported globally through rivers into the ocean, whilst about 140,000 tonnes per year are carried through long-range transport in the atmosphere and deposited into the sea. However, current extraction and spectroscopic techniques used to isolate and identify microplastics are often inadequate for tyre and road wear particle detection (Baensch-Baltruschat et al., 2020). Another source may come from the use of plastic waste in construction and infrastructure, such as roads, that may release plastic fragments over time (Appiah et al., 2017). With the growing economy of many African countries and the significant rise in the number of automobiles in use, some African cities are likely contributing significantly to the local contamination of the environment by microplastics from tyre and brake pad wear.

Runoff from agricultural land may be another pathway by which microlitter enters aquatic environments. Agricultural land may receive microlitter from the degradation of shade cloth, the application of contaminated sewage sludge or biosolids, use of slow-release plastic-encapsulated fertilisers, plastic mulch film, polymer coasted seeds, contaminated irrigation water, and from direct atmospheric deposition to farmland (Katsumi et al., 2021; Okoffo et al., 2021; Qi et al., 2020; Weithmann et al., 2018). Runoff can transport microplastics from farmlands into drainage systems and river courses. Wind can also mobilise soil-deposited microplastics into the atmosphere (Dris et al., 2016; Zhang et al., 2020), which can be especially important in arid zones such as the Sahara Desert where stormwater events are rare, and the wind frequently generates sandstorms that may be transported far beyond the immediate region.

2.3.3 Beaches

Beach litter surveys are the most common monitoring employed in the marine environment. Data gathered are often used to provide initial insight into the composition and quantity of marine litter and to infer the source. Most beach surveys in Africa have been conducted in South Africa, accounting for about 40% of all published studies (Table 2.1). However, the last 20 years have seen studies conducted in Algeria, Ghana, Guinea-Bissau, Kenya, Mauritania, Morocco, Nigeria, Seychelles, Tanzania, and Tunisia.

Beach litter surveys, using a transect or quadrats, are popular for two reasons; beaches are more accessible than other compartments (e.g., rocky shores, deep-sea, and open ocean) and require fewer resources (Barnardo & Ribbink, 2020, Annex 2.2). Furthermore, beach litter surveys also contribute to awareness-raising

Table 2.1 Review of observed litter densities across various beaches in Africa for different size fractions (macro, meso, and micro)

Country	Source	Survey date	Survey type	Material type	Size fraction	Observed density	Site #
Algeria	Tata et al. (2020)	2017/2018	Standing stock	Plastic	Micro and macro	649 ± 184 and 183 ± 27.32 kg^{-1} dry sediment	4
	Taïbi et al. (2021)	2017	Standing stock	Plastic	Micro and macro	7.6 ± 18.8 and 66 ± 107 items m^{-2} sediment	9
Ghana	Nunoo and Quayson (2003)	2002	Weekly accumulation	All	Macro	698 ± 62.99 and 876 ± 79.93 items 1000 m^{-2} week 7253 ± 618 and 5951 ± 783 g 1000 m^{-2} week	2
Bijagós archipelago, Guinea-Bissau	Lourenço et al. (2017)	2013/2015	Standing stock	Fibres	Micro	2.7 ± 3.27 fibres ml^{-1}	1
Kenya	Okuku et al. (2020a)	2019	Standing stock	All	Meso	68–613.6 items m^{-2}	23
	Okuku et al. (2020b)	2019	Daily accumulation	All	Macro	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}	6
	Okuku et al. (2021b)	2019–2020	Standing stock	All	Macro	0.091–0.736 items m^{-2}	1
Mauritania	Lourenço et al. (2017)	2013/2015	Standing stock	Fibres	Micro	4.3 ± 4.90 fibres ml^{-1}	1
Morocco	Velez et al. (2019)	Unknown	Standing stock	Plastic	Micro	Mean: 336 particles m^{-2}	
			Standing stock	All	Macro	0.81 ± 0.56–12.48 ± 4.35 items 5 m^{-1}	4
	Nachite et al. (2019)	2015–2017	Standing stock	All	Macro	126 ± 54.4–821 ± 306 items 100 m^{-1} 0.011 ± 0.005–0.103 ± 0.038 g m^{-2}	14
	Haddout et al. (2021)	2020	Standing stock	Plastic	Micro	10–300 particles kg^{-1} sediment	18

(continued)

Table 2.1 (continued)

Country	Source	Survey date	Survey type	Material type	Size fraction	Observed density	Site #
Nigeria	Ilechukwu et al. (2019)	2018	Standing stock	Plastic	Micro	170 ± 21–121 ± 38 items 50 g^{-1} dry sediment	4
	Fred-Ahmadu et al. (2020)	2018–2019	Standing stock	Plastic	Micro	3.6 ± 3.5–173 ± 21.3 particles kg^{-1} sediment	5
Seychelles	Dunlop et al. (2020)	2003–2019	Daily accumulation rate	All	All	0.0010–0.0415 items m^{-1} day^{-1}	1
South Africa	Ryan and Moloney (1990)	1984	Standing stock	All	Micro	491 particles m^{-1}	52
					Macro	1.09 items m^{-1}	
		1989			Micro	678 particles m^{-1}	
					Macro	2.99 items m^{-1}	
	Madzena and Lasiak (1997)	1994	Standing stock	All	All	19.6–72.5 items m^{-1} 42.8–164.1 g m^{-1}	6
		1994–1995	Monthly accumulation			1.4–9.8 items m^{-1} $month^{-1}$ 3.4–25.0 g m^{-1} $month^{-1}$	
	Ryan et al. (2014a)	1994	Daily accumulation	All	Macro	1.55 and 0.35 items m^{-1} day^{-1}	2
			Weekly accumulation			0.46 and 0.16 items m^{-1} day^{-1}	
		1995	Daily accumulation			2.87 and 1.30 items m^{-1} day^{-1}	
			Weekly accumulation			0.93 and 0.62 items m^{-1} day^{-1}	

(continued)

Table 2.1 (continued)

Country	Source	Survey date	Survey type	Material type	Size fraction	Observed density	Site #
		2012	Daily accumulation			14.58 and 2.04 items m^{-1} day^{-1}	
			Weekly accumulation			5.47 and 0.63 items m^{-1} day^{-1}	
	Nel and Froneman (2015)	2014	Standing stock	Plastic	Micro	689 ± 348–3308 ± 1449 particles m^{-2} sediment	21
	Ryan et al. (2018)	2015	Standing stock	All	Meso	708 items m^{-1}	82
	Nel et al. (2017)	2016	Standing stock	Plastic	Micro	86.67 ± 48.68–755 ± 393 particles m^{-2}	13
	De Villiers (2018)	2016	Standing stock	Fibres	Micro	4–772 fibres dm^{-3} sediment	175
		2017				0–797 fibres dm^{-3} sediment	175
	Chitaka (2020)	2017	Daily accumulation	All	Macro	37.8–2962 items 100 m^{-1} day^{-1} 189–4430 g 100 m^{-1} day^{-1}	5
		2018–19			Macro	305–2082 items 100 m^{-1} day^{-1} 557–3799 g 100 m^{-1} day^{-1}	
	Ryan et al. (2020d)	2008	Standing stock	All	Macro	Surface: 11.8 items m^{-1}, 249 g m^{-1} Buried: 123.2 items m^{-1}, 149.0 g m^{-1}	1
		2010	Standing stock	All	Macro	Surface: 14.6 items m^{-1}, 227 g m^{-1} Buried: 92.8 items m^{-1}, 77.7 g m^{-1}	
				All	Meso	444 items m^{-1} 9.1 g m^{-1}	

(continued)

Table 2.1 (continued)

Country	Source	Survey date	Survey type	Material type	Size fraction	Observed density	Site #
		2017	Standing stock	Fibres	Micro	Surface: 60×10^3 fibres m^{-1}, 12.4 mg m^{-1} Buried: 128×10^3 fibres m^{-1}, 47.5 mg m^{-1}	
	Weideman et al. (2020b)	2019	Monthly accumulation rate	All	Macro	2.3 ± 0.8 items m^{-1} $month^{-1}$ 8.5 ± 8.8 g m^{-1} $month^{-1}$	1
		2020	Daily accumulation rate			0.4 ± 0.3 items 100 m^{-1} day 8.3 ± 20.4 g 100 m^{-1} day^{-1}	2
Tanzania	Mayoma et al. (2020)	–	Standing stock	Plastic	Micro	15 ± 4–2972 ± 238 particles kg^{-1} dry weight	18
	Maione (2021)	2018	Standing stock	Plastic	Macro	46.8–89.7 kg	4
Tunisia	Abidli et al. (2018)	2017	Standing stock	Plastic	Micro	141 ± 25.98 and 461 ± 29.74 items kg^{-1} dry weight	5
	Missawi et al. (2020)	2018	Standing stock	Plastic	Micro	129–606 items kg^{-1} sediment	8

and positive behaviour change of those involved (Nelms et al., 2017). There are two general methods; standing stock surveys or accumulation rate surveys, with the latter currently only conducted for macrolitter. Standing stock surveys report the amount of litter at a specific period in time whilst the latter reports the accumulation rate of litter in a given area and can be used as a proxy for litter abundance in adjacent coastal waters subject to inputs from direct littering or exhumation (Cheshire et al., 2009; Ryan et al., 2009). When interpreting the results of beach surveys, it is important to consider the limitations of each method (see Annex 2.2 for further details). Macrolitter monitoring at beaches might be useful to determine the most prevalent items and subsequent actions, for comparable monitoring of status and trends of beach litter across countries and regions. It is also recommended to focus on the larger microplastic fraction (2–5 mm) as a potential legacy contaminant concentrations are likely to increase in the future (Chubarenko et al., 2020; Haseler et al., 2018).

Long-term longitudinal studies of standing stocks may provide indications of gross changes in the types and abundance of litter, as well as distribution patterns (Ryan et al., 2009). For example, Ryan et al. (2018) used a series of surveys conducted across South Africa in 1994, 2005, and 2015 to investigate mesoplastic distribution patterns, concluding that they mostly derive from local, land-based sources. In addition, there was no significant change in mesoplastic abundance over the years. In Kenya, Okuku et al. (2021b) employed standing stock surveys to investigate the influence of monsoons on the abundance and distribution of macrolitter in Mkomani Beach; the results indicated that monsoons influenced both litter abundance and composition.

Accumulation rates are highly site-specific, with variability across beaches and within beaches (Table 2.1). In 2019, accumulation rates of 3.8 $\pm$ 3.1–24.9 $\pm$ 19.1 items m^{-1} day^{-1} were observed in Kenya (Okuku et al., 2020b), whilst 0.0255 $\pm$ 0.0086 items m^{-1} day^{-1} were observed on Cousine Island, Seychelles (Dunlop et al., 2020) and 0.403 $\pm$ 0.061–0.853 $\pm$ 0.085 items m^{-1} day^{-1} in South Africa (Chitaka & von Blottnitz, 2019). Limited long-term studies investigating litter fluxes have been conducted. In South Africa, Ryan et al. (2014a) conducted daily and weekly accumulation rate surveys over two beaches in 1994, 1995, and 2012, during which a significant increase was observed in litter loads over time. On Cousine Island, Seychelles, Dunlop et al. (2020) conducted what is arguably the longest temporal study of litter fluxes in Africa, conducting 40 surveys from 2003 to 2019 along the same beach, significant increase in litter was observed over time.

To fully appreciate the extent of the marine litter problem, it is important to relate it to waste generation. A study in Cape Town, South Africa, estimated the proportion of products that leaked into the marine environment in 2017. It was found that items associated with food consumed on the go were more prone to leakage (Chitaka & von Blottnitz, 2021). The estimates were based on beach accumulation rates as a proxy for litter flows into the ocean, coupled with waste generation rates. Whilst uncertainty is associated with such estimates, it is important to note the differences in leakage rates for specific product items (Fig. 2.3).

2.3.4 Coastal and Oceanic Waters

Marine litter has been detected in coastal and oceanic waters off the African coast. However, the presence of marine litter in the ocean remains one of the most understudied compartments from an African perspective, as illustrated in Fig. 2.1a, b.

Seabed trawls conducted in the Mediterranean Sea, off the coast of Morocco, found total macrolitter densities ranging from 0 to 1768 ± 298 kg km^{-2} at depths up to 266 m (Loulad et al., 2017). Off the South African coast, only 17% of 235 trawls contained litter with an average density of 3.4 items km^{-2}. Most litter was located at depths greater than 200 m (Ryan et al., 2020c). From 2012 to 2015, Loulad et al. (2019) conducted sea trawl surveys in the Mediterranean Sea and observed mean densities of 26 ± 68–80 ± 133 kg km^{-2}, most of which was located closer to the coast. Visual surveys conducted in the South Atlantic Ocean in 2013 observed a decrease in macrolitter density as distance increased from the coast of Cape Town (Ryan, 2014). Furthermore, the survey offered the first evidence of a South Atlantic 'garbage patch'. Subsequent surveys provided further evidence to support the dispersion and accumulation of litter into this gyre (Ryan et al., 2014b).

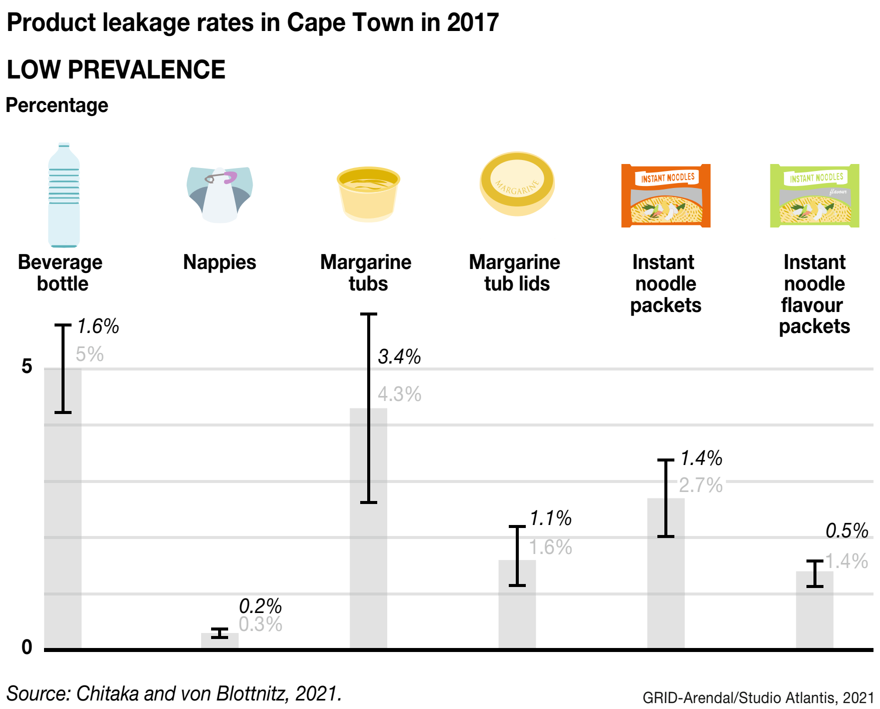

Fig. 2.3 Looking at the big picture: product-specific leakage rates

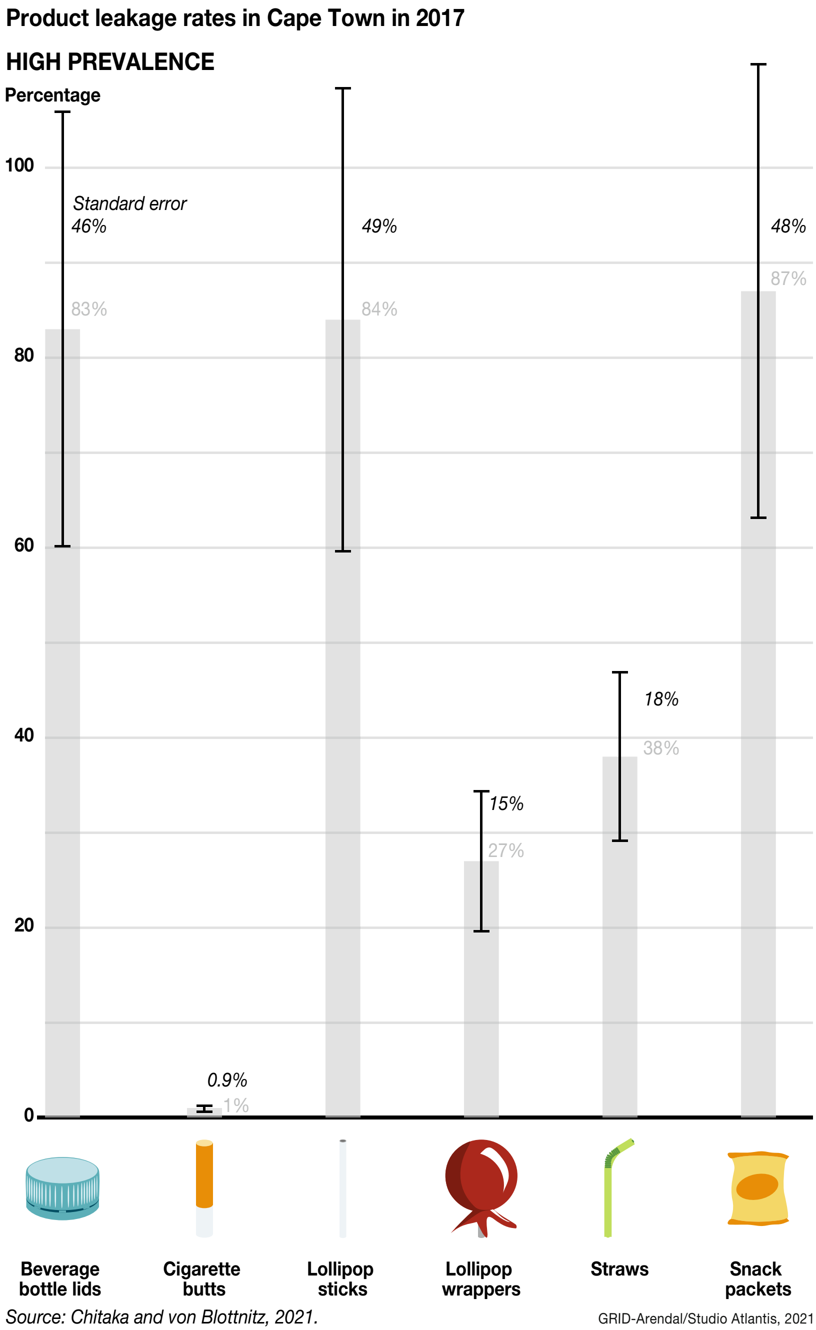

Fig. 2.3 (continued)

Microplastics collected using neuston nets in the open ocean have been predominately made of PE, with higher concentrations closer to the coast (Suaria et al., 2020b; Vilakati et al., 2020). Fibrous microlitter (rayon and polyester) have been detected in seabed sediment south of Madagascar (Woodall et al., 2015). Seabed cores have also been helpful in demonstrating the increase in microplastics in recent years. An example from Durban Harbour in South Africa shows higher concentrations associated with more recent sediment deposits (Matsuguma et al., 2017).

2.4 Litter Characteristics

Internationally, plastic has been found to be a significant contributor to marine litter, and this is the same case in Africa. Assessments of macrolitter have observed plastic proportions ranging up to 99% of collected items by number. In the open ocean, fishing gear makes up a relatively higher proportion than is observed closer to land (Loulad et al., 2017; Ryan et al., 2014b). Moreover, areas with a lot of fishing activity are found to have large proportions of fishing-related litter (Loulad et al., 2017; Ryan et al., 2020d; Scheren et al., 2002). Packaging is often found to be a major contributor across compartments, including rivers (Moss et al., 2021; Weideman et al., 2020c), beaches (Chitaka & von Blottnitz, 2019; Fazey & Ryan, 2016b; Okuku et al., 2020b, 2021b; Van Dyck et al., 2016), as well as coastal and oceanic waters (Ryan, 2014). Most of the packaging is single-use and related to food and beverages, including snack packets, bottles, lids/caps, and sweet wrappers. Common polymer types used to manufacture these items include PE, PP, and PET (PlasticsSA, 2018). Multilayer packaging containing combinations of plastic, paper, or various plastics is also employed particularly for snack packets. However, it must be remembered that the extent to which these items contribute to marine litter is influenced by a variety of factors including consumption rates, consumer behaviours, and solid waste management infrastructure and practices; which vary across the continent (see Boxes 2.3 and 2.4) (Marais & Armitage, 2004; Okuku et al., 2020b; UNEP, 2018a; Weideman et al., 2020b).

Box 2.3: The Scourge of Water Sachets in West Africa

For several decades, the West Africa sub-region has been bedevilled by a special form of plastic waste—sachets used for packaging water, which now serves most people with a safe source of drinking water. It began as an initiative by a local entrepreneur in Nigeria in the 1990s and has grown into a lucrative business throughout West Africa. Its rapid growth stems from the failure of governments to provide clean and safe potable water and sanitation (GIZ, 2019; Stoler, 2017; Thomas et al., 2020; WWAP, 2015).

The water is packed into low-density-PE sachets holding 300–500 ml. National regulations on the production, use, and management of waste derived from this product are largely disregarded by manufacturers and consumers and are not enforced (Vapnek & Williams, 2017). A 'use and throw away' culture generally still prevails in the region, resulting in massive littering of street corners, open drains, and streams and rivers. Water sachets are amongst the top contributors to beach litter in Ghana (Nunoo & Quayson, 2003; Tsagbey et al., 2009) and Nigeria (Ebere et al., 2019).

Polymer identification is a very important step in meso and microplastic research as it is used to infer the most likely source/origin, as well as suggest associated risk/hazard. As the source is easier to infer when litter is larger, polymer identification techniques are not regularly employed during macrolitter studies. The lack of spectroscopy equipment hinders the African continents ability to identify polymers (Akindele & Alimba, 2021; Alimi et al., 2021; Nel et al., 2021). In South Africa, the application of the rapid screening technique using a fluorescent dye (Nile Red) (Maes et al., 2017) has proved to be a cost-effective solution for the large scale monitoring of microplastics in marine sediment, water, and fish (Bakir et al., 2020; Preston-Whyte et al., 2021). Shabaka et al. (2019) used differential scanning calorimetry (DSC) to detect a wide range of polymers in Eastern Harbour, Egypt; detecting PP, polyethylene vinyl acetate (PEVA), acrylonitrile butadiene, PS, and polytetrafluoroethylene. There also appears to be capacity using Attenuated Total Reflection-Fourier Transform Infrared (ATR-FTIR) Spectroscopy for the identification of particles > 300 μm (Nel et al., 2021). However, it would be pertinent to build capacity for polymer identification < 300 μm, given that this size range is often linked to increased uptake (Chap. 3).

2.4.1 Factors Influencing Litter Characteristics, Abundance, and Distribution

Several factors have been identified to determine the characteristics, abundance, and distribution of litter in the marine environment. These include, but are not limited to:

- Catchment area characteristics and drainage systems
- Development status and income levels of residents
- Climatic condition (wind, rainfall amount, and flood events)
- Coastal hydrodynamics and ocean currents
- Physical and chemical characteristics of the litter materials.

Catchment Area Characteristics and Drainage System

Once litter is in the marine environment, several processes can influence characteristics, abundance, distribution, and fate. Catchment area characteristics (land-use cover, population density) have influenced litter. In South Africa, Arnold and Ryan (1999) and Weideman et al. (2020a) conducted studies quantifying macrolitter discharges from the same three catchment areas (residential, industrial, and mixed commercial/residential) during wetter months in 1996 and 2018–2019. In both cases, macrolitter was most abundant in the industrial area, with the least in the residential area. In general, remote locations are associated with lower macrolitter abundance than those in densely populated areas (Nachite et al., 2019; Okuku et al., 2020b; Ryan, 2020a; Seeruttun et al., 2021). Nevertheless, some remote beaches away from industrial/urban centres have been found to have relatively high litter loads, which suggest long-range transportation does occur (Aguilera et al., 2018; Dunlop et al., 2020; Ryan et al., 2019). In addition, a study by Ryan et al. (2021) found that standing stocks at remote beaches had lower bottle loads than urban beaches but higher loads than semi-urban beaches; this was attributed to the lower inputs of semi-urban beaches vs urban, coupled with greater cleaning efforts at semi-urban beaches than remote beaches.

Development Status and Income Levels of Residents

Some studies have suggested an inverse relationship between income level and macrolitter abundance. A study of debris in stormwater drains in South Africa found higher macrolitter loads in low-income areas, which was attributed to the poor waste removal services available (Marais & Armitage, 2004). A similar relationship was suggested by accumulation surveys of five beaches conducted in Cape Town, wherein a beach in a low-income area was associated with relatively high macrolitter loads (Chitaka & von Blottnitz, 2019).

Climatic Condition (Wind, Rainfall Amount, and Flood Events)

Litter distribution is influenced by climatic conditions such as wind and rain. Rainfall and flood events can increase litter fluxes from watercourses and waterways as accumulated litter is flushed out of the system (Chitaka & von Blottnitz, 2021; Nunoo & Quayson, 2003; Okuku et al., 2020b; Ryan & Perold, 2021). Wind strength and direction have also influenced litter distribution and deposition (Okuku et al., 2021b; Ryan & Perold, 2021).

Coastal Hydrodynamics and Ocean Currents

Ocean currents play a vital role in transporting and distributing litter within the marine environment (Collins & Hermes, 2019; Van Sebille et al., 2015). Trawl surveys have observed variations in litter density according to water depth (Loulad et al., 2017, 2019; Ryan et al., 2020c). There are no clear correlation indicating if this variation is direct (lower depth, less litter) or inverse (lower depth, more litter) variation. Litter distribution within the ocean is also influenced by geomorphology and hydrodynamics (Loulad et al., 2019), additionally, ocean currents influence the deposition of litter on coastlines (Collins & Hermes, 2019; Ryan, 2020b). A study conducted by Chitaka and von Blottnitz (2019) suggested preferential deposition of litter in Table Bay (South Africa) which was attributed to water movements. Further studies on litter deposition along South African coastlines have also suggested that water movements significantly influence the distribution and stranding of litter items (Fazey & Ryan, 2016a, 2016b; Ryan & Perold, 2021). Microplastic distribution and their fate are influenced by ocean currents (Collins & Hermes, 2019; Schumann et al., 2019), biofouling and inclusion within sinking marine snow (Kooi et al., 2017), sequestration along deep-sea canyons (Pohl et al., 2020) and fluxes to the atmosphere via sea breeze (Allen et al., 2020).

Physical Characteristics of the Litter Materials

The physical characteristics of an item also influence distribution of litter. Fazey and Ryan (2016a, 2016b) found that size and buoyancy influence debris dispersal, with smaller and less buoyant items observed to disperse over shorter distances. Biofouling was also found to play a role in distribution by decreasing the buoyancy of items (Fazey & Ryan, 2016a). Furthermore, Weideman et al. (2020b) found that rigid plastics were less likely to be deposited and trapped along rocky shorelines, whilst flexible packaging was prone to entrapment in weeds and rocks.

Similar to larger litter items, microplastic distribution is linked to particle size and shape, polymer type, density, surface characteristics, and degradation rates, to name a few. These factors may affect which types of particles the marine environment receives through river inputs. Weideman et al. (2020c) found that fibres were present across the Orange-Vaal river basin but concentrated in the lower reaches. At the same time large plastics and fragments were more closely linked to urban settlements. Chouchene et al. (2019) recorded features indicative of weathering (i.e., pits, fractures, grooves, cracks, and scratches) associated with PE and PP microplastics from Sidi Mansour Harbour sediment samples in Tunisia. There is a need to understand how factors, such as weathering, influence the transport and fate of microplastics. Changes to plastics (bites on bottles, biofouling) can also be used as an indicator of the length of time plastic litter has been at sea and potentially travelled (Ryan, 2020a; Ryan et al., 2021).

Fibres appear more homogenously distributed within the environment (Barrows et al., 2018; Ryan et al., 2020d; Weideman et al., 2019, 2020c). This may reflect their multiple entry points, for example, point sources through WWTP effluent, and diffuse sources via atmospheric deposition and through the spread of sewage sludge or biosolids on agricultural land. Alternatively, fibres may be more widely distributed, especially as their large surface area to volume ratio may lead to reduced settling rates compared to other microplastic shapes (Hoellein et al., 2019; Khatmullina & Isachenko, 2017). More research is needed to corroborate this assumption, using controlled lab-based experiments, such as artificial flumes which can test hydrodynamic scenarios. Visual bias may also lead to conspicuous fibres being detected more frequently than other microlitter types however, few studies have tested this empirically. Nevertheless, it is important for researchers to understand what type of microplastics are being transported down rivers to the marine environment and in what ‘condition’; as they have likely undergone a series of immobilisation and remobilisation events changing their physical and chemical characteristics that in turn will change how they behave in the estuarine and marine environment as they are no longer ‘pristine’. Understanding these processes within the global, let alone the African context is still in its infancy.

Some microplastics and microfibres emitted from different sources are present and suspended in the atmosphere (Dris et al., 2016) and liable to long-range transport to remote places, including parts of Africa (Evangeliou et al., 2020; González-Pleiter et al., 2021; Wright et al., 2020; Zhang et al., 2020). However, no data is published for Africa regarding atmospheric contamination by microplastics and microfibres. Microplastics get deposited onto soil surfaces by gravitational settling and rainout/washout processes during wet precipitation events (Brahney et al., 2020). This is an substantial gap to fill, especially considering atmospheric deposition may be a major diffuse source for aquatic and terrestrial environments (Wright et al., 2020; Zhang et al., 2020).

Box 2.4: Litter and the COVID-19 Pandemic

The COVID-19 pandemic highlighted the usefulness of plastic in our society in the form of Personal Protective Equipment. Unfortunately, the increased consumption of single-use plastics and their improper disposal raised concerns about the impacts on the environment. In Kenya, Okuku et al. (2021a) found that COVID-19 related litter, including masks, gloves, soap wrappers, wet wipes as well as liquid hand wash and sanitiser bottles, were observed along 11 of 14 streets 10-days after the first confirmed COVID-19 case in the country, contributing up to 17% of waste items. In comparison, in South Africa, relatively low amounts of COVID-19 related litter were observed during daily accumulation surveys of urban streets, contributing less than 1% (Ryan et al., 2020a). On Kenyan beaches, COVID-19 litter densities of up to 5.6×10^{-2} items m^{-2} were observed (Okuku et al., 2021a). Interestingly, higher densities were observed at remote beaches, attributed to less compliance with Government instructions to close beaches. This complements findings by Ryan et al. (2020a), who found approximately three times as much litter during less restricted periods of national lockdown compared to periods where movement was strictly monitored. Additionally, the potential of masks as a source of microplastics has been suggested by some researchers (Fadare & Okoffo, 2020; Shruti et al., 2020).

2.5 Key Messages and Future Directions

This chapter demonstrates that current published studies are isolated to a few selected countries. Thus, there is a need for more coordinated research efforts, using harmonised approaches, across Africa. Specifically, it is important to develop baseline datasets which when combined with long-term monitoring studies at the same locales, will enable countries to measure change and mitigation effectiveness. This can only be realised through investment in capacity across the continent, especially equipment and expertise at the smaller size fractions of plastic pollution (micro and nano), which may have legacy impacts.

Knowledge of the pathways and sources for litter release in the environment can facilitate concentrated mitigation efforts and aid in the accurate interpretation of monitoring datasets in the future. There is a need for more field studies quantifying litter inputs, across all size ranges, from various sources. For example, WWTPs are an understudied source of plastics into the environment in Africa, whilst landfill and incineration sites may be important legacy sources in the future if not contained effectively. Rivers are a pathway for the transportation and transformation of plastics however, understanding the role small and larger systems play in retaining plastics is also important for risk-based assessments, clean-up efforts, and interpretation of downstream trends. This will require inter-African collaboration, especially as many rivers are transboundary. Many large and important rivers in Africa, i.e., the Nile, Congo, Niger, Zambezi, and Senegal, have not been extensively studied.

More studies looking at distribution and burial drivers, and underlying fragmentation processes are required. This will enable a deeper understanding of the results of monitoring studies such as beach surveys. For example, the need to assess the role seasonality plays in litter distribution and burial. Hurley et al. (2018) showed that seasonal changes in catchment hydrology could redistribute microlitter hotspots. This needs to be done across the continent as wet and dry seasons will be regionally relevant and can vary significantly within countries and across the continent. This is especially important as climate change is expected to alter the duration and intensity of various climatic events that could change how litter is immobilised and remobilised in the environment. Other aspects such as the occurrence/degree of biofouling and fragmentation of litter and the hetero-aggregation of micro and nano-plastics may vary with the different current and future climatic conditions found across Africa.

Models looking at how litter gets distributed from urban-industrial centres around Africa or the numerous rivers discharging into the marine environment are important in understanding marine pollution. However, this can only be achieved through various actions such as;

- Hosting workshops whereby researchers working on in situ data collection and those who need data for model validation are gathered to discuss what is required for models versus what is available/achievable.
- The development of an open access database on plastic pollution abundance/loads specific to the African continent.
- Capacity building for more modelling expertise in Africa.

Whilst research is essential to developing an understanding of plastic pollution; this is not to imply that countries should postpone developing strategies to mitigate litter inputs. It is also vital to understand the drivers of littering and inappropriate waste management (with a view to more effectively changing adverse behaviours). We know there is a problem, and efforts should be made to mitigate it by developing product targeted interventions taking into account the leakage propensities of different items (Fig. 2.3a, b). Thus, combining accumulation rate studies with waste generation rates to get a fuller picture of leakage rates into the environment should be encouraged.

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Annex 2.1: Marine Litter Quantification Studies Published Across Africa in Peer-Reviewed Journals as of December 2021

Country	Total number of studies	Citations
Ghana	7	Scheren et al. (2002), Nunoo and Quayson (2003), Tsagbey et al. (2009), Hosoda et al. (2014), Van Dyck et al. (2016), Chico-Ortiz et al. (2020), Gbogbo et al. (2020)
Cote D'Ivoire	1	Scheren et al. (2002)

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Country	Total number of studies	Citations
Benin	1	Scheren et al. (2002)
Cameroon	1	Scheren et al. (2002)
Nigeria	2	Scheren et al. (2002), Ebere et al., (2019)
Kenya	6	Kosore et al. (2018), Ryan (2020a), Okuku et al. (2020a, 2020b, 2021a, 2021b)
Cousine Island, Seychelles	1	Dunlop et al. (2020)
Alphonse Island, Seychelles	1	Duhec et al. (2015)
Mauritius	1	Seeruttun et al. (2021)
Morocco	7	Alshawafi et al. (2017), Loulad et al. (2017), Maziane et al. (2018), Nachite et al. (2019), Velez et al. (2019), Mghili et al. (2020), Haddout et al. (2021)
South Africa	37	Ryan (1988, 2015, 2020b), Ryan and Moloney (1990), Madzena and Lasiak (1997), Ryan et al. (2014a, 2018, 2020a, 2020b, 2020c, 2020d, 2021), Naidoo et al. (2015), Nel and Froneman (2015), Fazey and Ryan (2016), Matsuguma et al. (2017), Nel et al. (2017, 2018, 2021), De Villiers (2018, 2019), Chitaka and von Blottnitz (2019), Collins and Hermes (2019), Naidoo and Glassom (2019), Schumann et al. (2019), Weideman et al. (2019, 2020a, 2020b, 2020c), Govender et al. (2020), Iroegbu et al. (2020), Vetrimurugan et al. (2020), Verster and Bouwman (2020), Vilakati et al. (2020), Moss et al. (2021), Preston-Whyte et al. (2021), Ryan and Perold (2021)
Algeria	2	Mankou-Haddadi et al. (2021), Taïbi et al. (2021)
Tunisia	5	Chouchene et al. (2019, 2020), Missawi et al. (2020), Wakkaf et al. (2020), Zayen et al. (2020)
Tanzania	2	Mayoma et al. (2020), Maione (2021)
Egypt	1	Shabaka et al. (2019)
Mauritania	1	Lourenço et al. (2017)
Guinea-Bissau	1	Lourenço et al. (2017)
Senegal	1	Tavares et al. (2020)
Atlantic Ocean	4	Ryan (2014), Kanhai et al. (2017), Ryan et al. (2019, 2020b)

(continued)

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Country	Total number of studies	Citations
Southern Ocean	2	Ryan et al. (2014b), Suaria et al. (2020)
Mediterranean	2	Cózar et al. (2015), Cincinelli et al. (2019)
Indian Ocean	2	Woodall et al. (2014), Connan et al. (2021)

References for Annex 2.1

Alshawafi, A., Analla, M., Alwashali, E., & Aksissou, M. (2017). Assessment of marine debris on the coastal wetland of Martil in the North-East of Morocco. *Marine Pollution Bulletin, 117*, 302–310. https://doi.org/10.1016/j.marpolbul.2017.01.079

Chico-Ortiz, N., Mahu, E., Crane, R., Gordon, C., & Marchant, R. (2020). Microplastics in Ghanaian coastal lagoon sediments: Their occurrence and spatial distribution. *Regional Studies in Marine Science, 40*, 101509. https://doi.org/10.1016/j.rsma.2020.101509

Chitaka, T. Y., & von Blottnitz, H. (2019). Accumulation and characteristics of plastic debris along five beaches in Cape Town. *Marine Pollution Bulletin, 138*. https://doi.org/10.1016/j.marpolbul.2018.11.065

Chouchene, K., da Costa, J. P., Wali, A., Girão, A. V., Hentati, O., Duarte, A. C., et al. (2019). Microplastic pollution in the sediments of Sidi Mansour Harbor in Southeast Tunisia. *Marine Pollution Bulletin, 146*, 92–99. https://doi.org/10.1016/j.marpolbul.2019.06.004

Chouchene, K., Rocha-Santos, T., & Ksibi, M. (2020). Types, occurrence, and distribution of microplastics and metals contamination in sediments from south west of Kerkennah archipelago, Tunisia. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-020-09938-z

Cincinelli, A., Martellini, T., Guerranti, C., Scopetani, C., Chelazzi, D., & Giarrizzo, T. (2019). A potpourri of microplastics in the sea surface and water column of the Mediterranean Sea. *TrAC—Trends in Analytical Chemistry, 110*, 321–326. https://doi.org/10.1016/j.trac.2018.10.026

Collins, C., & Hermes, J. C. (2019). Modelling the accumulation and transport of floating marine micro-plastics around South Africa. *Marine Pollution Bulletin, 139*, 46–58. https://doi.org/10.1016/j.marpolbul.2018.12.028

Connan, M., Perold, V., Dilley, B. J., Barbraud, C., Cherel, Y., & Ryan, G. (2021). The Indian Ocean 'garbage patch': Empirical evidence from floating macro-litter. *Marine Pollution Bulletin, 169*. https://doi.org/10.1016/j.marpolbul.2021.112559

Cózar, A., Sanz-Martín, M., Martí, E., González-Gordillo, J. I., Ubeda, B., Gálvez, J. Á., et al. (2015). Plastic accumulation in the Mediterranean Sea. *PLOS One, 10*, 1–12. https://doi.org/10.1371/journal.pone.0121762

De Villiers, S. (2018). Quantification of microfibre levels in South Africa's beach sediments, and evaluation of spatial and temporal variability from 2016 to 2017. *Marine Pollution Bulletin, 135*, 481–489. https://doi.org/10.1016/j.marpolbul.2018.07.058

De Villiers, S. (2019). Microfibre pollution hotspots in river sediments adjacent to South Africa's coastline. *Water SA, 45*, 97–102. https://doi.org/10.4314/wsa.v45i1.11

Duhec, A. V., Jeanne, R. F., Maximenko, N., & Hafner, J. (2015). Composition and potential origin of marine debris stranded in the Western Indian Ocean on remote Alphonse Island, Seychelles. *Marine Pollution Bulletin, 96*, 76–86. https://doi.org/10.1016/j.marpolbul.2015.05.042

Dunlop, S. W., Dunlop, B. J., & Brown, M. (2020). Plastic pollution in paradise: Daily accumulation rates of marine litter on Cousine Island, Seychelles. *Marine Pollution Bulletin, 151*, 110803. https://doi.org/10.1016/j.marpolbul.2019.110803

Ebere, E. C., Wirnkor, V. A., Ngozi, V. E., & Chukwuemeka, I. S. (2019). Macrodebris and microplastics pollution in Nigeria: First report on abundance, distribution and composition. *Environmental Analysis, Health and Toxicology, 34*, e2019012. https://doi.org/10.5620/eaht.e2019012

Fazey, F. M. C., & Ryan, P. G. (2016). Debris size and buoyancy influence the dispersal distance of stranded litter. *Marine Pollution Bulletin, 110*, 371–377. https://doi.org/10.1016/j.marpolbul.2016.06.039

Gbogbo, F., Takyi, J. B., Billah, M. K., & Ewool, J. (2020). Analysis of microplastics in wetland samples from coastal Ghana using the Rose Bengal stain. *Environmental Monitoring and Assessment, 192*. https://doi.org/10.1007/s10661-020-8175-8

Govender, J., Naidoo, T., Rajkaran, A., Cebekhulu, S., Bhugeloo, A., & Sershen (2020). Towards characterising microplastic abundance, typology and retention in Mangrove-dominated estuaries. *Water, 12*, 2802. https://doi.org/10.3390/w12102802

Haddout, S., Gimiliani, G. T., Priya, K. L., Hoguane, A. M., Casila, J. C. C., & Ljubenkov, I. (2021). Microplastics in surface waters and sediments in the Sebou Estuary and Atlantic Coast, Morocco. *Analytical Letters,* 1–13. https://doi.org/10.1080/00032719.2021.1924767

Hosoda, J., Ofosu-Anim, J., Sabi, E. B., Akita, L. G., Onwona-Agyeman, S., Yamashita, R., et al. (2014). Monitoring of organic micropollutants in Ghana by combination of pellet watch with sediment analysis: E-waste as a source of PCBs. *Marine Pollution Bulletin, 86*, 575–581. https://doi.org/10.1016/j.marpolbul.2014.06.008

Iroegbu, A. O. C., Sadiku, R. E., Ray, S. S., & Hamam, Y. (2020). Plastics in municipal drinking water and wastewater treatment plant effluents: Challenges and opportunities for South Africa—A review. *Environmental Science and Pollution Research, 27*, 12953–12966. https://doi.org/10.1007/s11356-020-08194-5

Kanhai, L. D. K., Officer, R., Lyashevsha, O., Thompson, R. C., & O'Connor, I. (2017). Microplastic abundance, distribution and composition along a latitudinal gradient in the Atlantic Ocean. *Marine Pollution Bulletin, 115*(1), 307–314. https://doi.org/10.1016/j.marpolbul.2016.12.025

Kosore, C., Ojwang, L., Maghanga, J., Kamau, J., Kimeli, A., Omukoto, J., et al. (2018). Occurrence and ingestion of microplastics by zooplankton in Kenya's marine environment: First documented evidence. *African Journal of Marine Science, 40*, 225–234. https://doi.org/10.2989/1814232X.2018.1492969.

Loulad, S., Houssa, R., Rhinane, H., Boumaaz, A., & Benazzouz, A. (2017). Spatial distribution of marine debris on the seafloor of Moroccan waters. *Marine Pollution Bulletin, 124*, 303–313. https://doi.org/10.1016/j.marpolbul.2017.07.022

Lourenço, P. M., Serra-Gonçalves, C., Ferreira, J. L., Catry, T., & Granadeiro, J. P. (2017). Plastic and other microfibers in sediments, macroinvertebrates and shorebirds from three intertidal wetlands of southern Europe and West Africa. *Environmental Pollution, 231*, 123–133. https://doi.org/10.1016/j.envpol.2017.07.103

Madzena, A., & Lasiak, T. (1997). Spatial and temporal variations in beach litter on the Transkei coast of South Africa. *Marine Pollution Bulletin, 34*, 900–907. https://doi.org/10.1016/S0025-326X(97)00052-0

Maione, C. (2021). Quantifying plastics waste accumulations on coastal tourism sites in Zanzibar, Tanzania. *Marine Pollution Bulletin, 168*, 112418. https://doi.org/10.1016/j.marpolbul.2021.112418

Mankou-Haddadi, N., Bachir-bey, M., Galgani, F., Mokrane, K., & Sidi, H. (2021). Benthic marine litter in the coastal zone of Bejaia (Algeria) as indicators of anthropogenic pollution. *Marine Pollution Bulletin, 170*, 112634. https://doi.org/10.1016/j.marpolbul.2021.112634

Matsuguma, Y., Takada, H., Kumata, H., Kanke, H., Sakurai, S., Suzuki, T., et al. (2017). Microplastics in sediment cores from Asia and Africa as indicators of temporal trends in plastic pollution. *Archives of Environmental Contamination and Toxicology, 73*, 230–239. https://doi.org/10.1007/s00244-017-0414-9

Mayoma, B. S., Sørensen, C., Shashoua, Y., & Khan, F. R. (2020). Microplastics in beach sediments and cockles (*Anadara antiquata*) along the Tanzanian coastline. *Bulletin of Environmental Contamination and Toxicology, 105*, 513–521. https://doi.org/10.1007/s00128-020-02991-x

Maziane, F., Nachite, D., & Anfuso, G. (2018). Artificial polymer materials debris characteristics along the Moroccan Mediterranean coast. *Marine Pollution Bulletin, 128*, 1–7. https://doi.org/10.1016/j.marpolbul.2017.12.067

Mghili, B., Analla, M., Aksissou, M., & Aissa, C. (2020). Marine debris in Moroccan Mediterranean beaches: An assessment of their abundance, composition and sources. *Marine Pollution Bulletin, 160*, 111692. https://doi.org/10.1016/j.marpolbul.2020.111692

Missawi, O., Bousserrhine, N., Belbekhouche, S., Zitouni, N., Alphonse, V., Boughattas, I., et al. (2020). Abundance and distribution of small microplastics ($\leq 3\ \mu m$) in sediments and seaworms from the Southern Mediterranean coasts and characterisation of their potential harmful effects. *Environmental Pollution, 263*, 114634. https://doi.org/10.1016/j.envpol.2020.114634

Moss, K., Allen, D., González-Fernández, D., & Allen, S. (2021). Filling in the knowledge gap: Observing macroplastic litter in South Africa's rivers. *Marine Pollution Bulletin, 162*. https://doi.org/10.1016/j.marpolbul.2020.111876

Nachite, D., Maziane, F., Anfuso, G., & Williams, A. T. (2019). Spatial and temporal variations of litter at the Mediterranean beaches of Morocco mainly due to beach users. *Ocean & Coastal Management, 179*, 104846. https://doi.org/10.1016/j.ocecoaman.2019.104846

Naidoo, T., & Glassom, D. (2019). Sea-surface microplastic concentrations along the coastal shelf of KwaZulu–Natal, South Africa. *Marine Pollution Bulletin, 149*, 110514. https://doi.org/10.1016/j.marpolbul.2019.110514

Naidoo, T., Glassom, D., & Smit, A. J. (2015). Plastic pollution in five urban estuaries of KwaZulu-Natal, South Africa. *Marine Pollution Bulletin, 101*, 473–480. https://doi.org/10.1016/j.marpolbul.2015.09.044

Nel, H. A., Chetwynd, A. J., Kelly, C. A., Stark, C., Valsami-Jones, E., Krause, S., et al. (2021). An untargeted thermogravimetric analysis-Fourier transform infrared-gas chromatography–mass spectrometry approach for plastic polymer identification. *Environmental Science & Technology, 55*(13), 8721–8729. https://doi.org/10.1021/acs.jpca.1c07162

Nel, H. A., Dalu, T., & Wasserman, R. J. (2018). Sinks and sources: Assessing microplastic abundance in river sediment and deposit feeders in an Austral temperate urban river system. *Science of the Total Environment, 612*, 950–956. https://doi.org/10.1016/j.scitotenv.2017.08.298

Nel, H. A., & Froneman, P. W. (2015). A quantitative analysis of microplastic pollution along the south-eastern coastline of South Africa. *Marine Pollution Bulletin, 101*, 274–279. https://doi.org/10.1016/j.marpolbul.2015.09.043

Nel, H. A., Hean, J. W., Noundou, X. S., & Froneman, P. W. (2017). Do microplastic loads reflect the population demographics along the southern African coastline? *Marine Pollution Bulletin, 115*, 115–119. https://doi.org/10.1016/j.marpolbul.2016.11.056

Nunoo, F. K. E., & Quayson, E. (2003). Towards management of litter accumulation—Case study of two beaches in Accra, Ghana. *Journal of the Ghana Science Association, 5*, 145–155.

Okuku, E. O., Kiteresi, L. I., Owato, G., Mwalugha, C., Omire, J., Mbuche, M., et al. (2020a). Baseline meso-litter pollution in selected coastal beaches of Kenya: Where do we concentrate our intervention efforts? *Marine Pollution Bulletin, 158*, 111420. https://doi.org/10.1016/j.marpolbul.2020.111420

Okuku, E. O., Kiteresi, L. I., Owato, G., Mwalugha, C., Omire, J., Otieno, K., et al. (2020b). Marine macro-litter composition and distribution along the Kenyan Coast: The first-ever documented study. *Marine Pollution Bulletin, 159*, 111497. https://doi.org/10.1016/j.marpolbul.2020.111497

Okuku, E., Kiteresi, L., Owato, G., Otieno, K., Mwalugha, C., Mbuche, M., et al. (2021a). 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. *Marine Pollution Bulletin, 162*, 111840. https://doi.org/10.1016/j.marpolbul.2020.111840

Okuku, E. O., Kiteresi, L., Owato, G., Otieno, K., Omire, J., Kombo, M. M., et al. (2021b). Temporal trends of marine litter in a tropical recreational beach: A case study of Mkomani beach, Kenya. *Marine Pollution Bulletin, 167*, 112273. https://doi.org/10.1016/j.marpolbul.2021.112273

Preston-Whyte, F., Silburn, B., Meakins, B., Bakir, A., Pillay, K., Worship, M., et al. (2021). Meso- and microplastics monitoring in harbour environments: A case study for the Port of Durban, South Africa. *Marine Pollution Bulletin, 163*, 111948. https://doi.org/10.1016/j.marpolbul.2020.111948

Ryan, P. G. (1988). The characteristics and distribution of plastic particles at the sea-surface off the southwestern Cape Province, South Africa. *Marine Environmental Research, 25*(4), 249–273.

Ryan, P. G. (2014). Litter survey detects the South Atlantic "garbage patch". *Marine Pollution Bulletin, 79*, 220–224. https://doi.org/10.1016/j.marpolbul.2013.12.010

Ryan, P. G. (2015). Does size and buoyancy affect the long-distance transport of floating debris? *Environmental Research Letters, 10*. https://doi.org/10.1088/1748-9326/10/8/084019

Ryan, P. G. (2020a). Land or sea? What bottles tell us about the origins of beach litter in Kenya. *Waste Management, 116*, 49–57. https://doi.org/10.1016/j.wasman.2020.07.044

Ryan, P. G. (2020b). The transport and fate of marine plastics in South Africa and adjacent oceans. *South African Journal of Science, 116*, 1–9. https://doi.org/10.17159/sajs.2020/7677

Ryan, P. G., Dilley, B. J., Ronconi, R. A., & Connan, M. (2019). Rapid increase in Asian bottles in the South Atlantic Ocean indicates major debris inputs from ships. *Proceedings of the National Academy of Sciences,* 1–6. https://doi.org/10.1073/pnas.1909816116

Ryan, P. G., Lamprecht, A., Swanepoel, D., & Moloney, C. L. (2014a). The effect of fine-scale sampling frequency on estimates of beach litter accumulation. *Marine Pollution Bulletin, 88*, 249–254. https://doi.org/10.1016/j.marpolbul.2014.08.036

Ryan, P. G., & Moloney, C. L. (1990). Plastic and other artefacts on South African beaches: Temporal trends in abundance and composition. *South African Journal of Science, 86*, 450–452.

Ryan, P. G., Musker, S., & Rink, A. (2014b). Low densities of drifting litter in the African sector of the Southern Ocean. *Marine Pollution Bulletin, 89*, 16–19. https://doi.org/10.1016/j.marpolbul.2014.10.043

Ryan, P. G., & Perold, V. (2021). Limited dispersal of riverine litter onto nearby beaches during rainfall events. *Estuarine, Coastal and Shelf Science, 251*, 107186. https://doi.org/10.1016/j.ecss.2021.107186

Ryan, P. G., Perold, V., Osborne, A., & Moloney, C. L. (2018). Consistent patterns of debris on South African beaches indicate that industrial pellets and other mesoplastic items mostly derive from local sources. *Environmental Pollution, 238*, 1008–1016. https://doi.org/10.1016/j.envpol.2018.02.017

Ryan, P. G., Pichegru, L., Perold, V., & Moloney, C. L. (2020a). Monitoring marine plastics—Will we know if we are making a difference? *South African Journal of Science, 116*, 1–9. https://doi.org/10.17159/sajs.2020/7678

Ryan, P. G., Suaria, G., Perold, V., Pierucci, A., Bornman, T. G., & Aliani, S. (2020b). Sampling microfibres at the sea surface: The effects of mesh size, sample volume and water depth. *Environmental Pollution, 258*, 113413. https://doi.org/10.1016/j.envpol.2019.113413

Ryan, P. G., Weideman, E. A., Perold, V., Durholtz, D., & Fairweather, T. P. (2020c). A trawl survey of seafloor macrolitter on the South African continental shelf. *Marine Pollution Bulletin, 150*, 110741. https://doi.org/10.1016/j.marpolbul.2019.110741

Ryan, P. G., Weideman, E. A., Perold, V., & Moloney, C. L. (2020d). Toward balancing the budget: Surface macro-plastics dominate the mass of particulate pollution stranded on beaches. *Frontiers in Marine Science, 7*, 1–14. https://doi.org/10.3389/fmars.2020.575395

Ryan, P. G., Weideman, E. A., Perold, V., Hofmeyr, G., & Connan, M. (2021). Message in a bottle: Assessing the sources and origins of beach litter to tackle marine pollution. *Environmental Pollution, 288*, 117729. https://doi.org/10.1016/j.envpol.2021.117729

Scheren, P. A., Ibe, A. C., Janssen, F. J., & Lemmens, A. M. (2002). Environmental pollution in the Gulf of Guinea—A regional approach. *Marine Pollution Bulletin, 44*, 633–641. https://doi.org/10.1016/S0025-326X(01)00305-8

Schumann, E. H., Fiona MacKay, C., & Strydom, N. A. (2019). Nurdle drifters around South Africa as indicators of ocean structures and dispersion. *South African Journal of Science, 115*, 1–9. https://doi.org/10.17159/sajs.2019/5372

Seeruttun, L. D., Raghbor, P., & Appadoo, C. (2021). First assessment of anthropogenic marine debris in mangrove forests of Mauritius, a small oceanic island. *Marine Pollution Bulletin, 164*, 112019. https://doi.org/10.1016/j.marpolbul.2021.112019

Shabaka, S. H., Ghobashy, M., & Marey, R. S. (2019). Identification of marine microplastics in Eastern Harbor, Mediterranean Coast of Egypt, using differential scanning calorimetry. *Marine Pollution Bulletin, 142*, 494–503. https://doi.org/10.1016/j.marpolbul.2019.03.062

Suaria, G., et al. (2020). Floating macro- and microplastics around the Southern Ocean: Results from the Antarctic circumnavigation expedition. *Environment International, 136*, 105494.

Taïbi, N. E., Bentaallah, M. E. A., Alomar, C., Compa, M., & Deudero, S. (2021). Micro- and macro-plastics in beach sediment of the Algerian western coast: First data on distribution, characterization, and source. *Marine Pollution Bulletin, 165*, 112168. https://doi.org/10.1016/j.marpolbul.2021.112168

Tavares, D. C., Moura, J. F., Ceesay, A., & Merico, A. (2020). Density and composition of surface and buried plastic debris in beaches of Senegal. *Science of the Total Environment, 737*, 139633. https://doi.org/10.1016/j.scitotenv.2020.139633

Tsagbey, S. A., Mensah, A. M., & Nunoo, F. K. E. (2009). Influence of tourist pressure on beach litter and microbial quality—Case study of two beach resorts in Ghana. *West African Journal of Applied Ecology, 15*. https://doi.org/10.4314/wajae.v15i1.49423

Van Dyck, I. P., Nunoo, F. K. E., & Lawson, E. T. (2016). An empirical assessment of marine debris, seawater quality and littering in Ghana. *Journal of Geoscience and Environment Protection, 04*, 21–36. https://doi.org/10.4236/gep.2016.45003

Velez, N., Zardi, G. I., Lo Savio, R., McQuaid, C. D., Valbusa, U., Sabour, B., et al. (2019). A baseline assessment of beach macrolitter and microplastics along northeastern Atlantic shores. *Marine Pollution Bulletin, 149*, 110649. https://doi.org/10.1016/j.marpolbul.2019.110649

Verster, C., & Bouwman, H. (2020). Land-based sources and pathways of marine plastics in a South African context. *South African Journal of Science, 116*, 1–9. https://doi.org/10.17159/sajs.2020/7700

Vetrimurugan, E., Jonathan, M. P., Sarkar, S. K., Rodríguez-González, F., Roy, P. D., Velumani, S., et al. (2020). Occurrence, distribution and provenance of micro plastics: A large scale quantitative analysis of beach sediments from southeastern coast of South Africa. *Science of the Total Environment, 746*, 141103. https://doi.org/10.1016/j.scitotenv.2020.141103

Vilakati, B., Sivasankar, V., Mamba, B. B., Omine, K., & Msagati, T. A. M. (2020). Characterization of plastic micro particles in the Atlantic Ocean seashore of Cape Town, South Africa and mass spectrometry analysis of pyrolyzate products. *Environmental Pollution, 265*, 114859. https://doi.org/10.1016/j.envpol.2020.114859

Wakkaf, T., El Zrelli, R., Kedzierski, M., Balti, R., Shaiek, M., Mansour, L., et al. (2020). Characterization of microplastics in the surface waters of an urban lagoon (Bizerte lagoon, Southern Mediterranean Sea): Composition, density, distribution, and influence of environmental factors. *Marine Pollution Bulletin, 160*, 111625. https://doi.org/10.1016/j.marpolbul.2020.111625

Weideman, E. A., Perold, V., Arnold, G., & Ryan, P. G. (2020a). Quantifying changes in litter loads in urban stormwater run-off from Cape Town, South Africa, over the last two decades. *Science of the Total Environment, 724*, 138310. https://doi.org/10.1016/j.scitotenv.2020.138310

Weideman, E. A., Perold, V., Omardien, A., Smyth, L. K., & Ryan, P. G. (2020b). Quantifying temporal trends in anthropogenic litter in a rocky intertidal habitat. *Marine Pollution Bulletin, 160*, 111543. https://doi.org/10.1016/j.marpolbul.2020.111543

Weideman, E. A., Perold, V., & Ryan, P. G. (2020c). Limited long-distance transport of plastic pollution by the Orange-Vaal River system, South Africa. *Science of the Total Environment, 727*, 138653. https://doi.org/10.1016/j.scitotenv.2020.138653

Weideman, E. A., Perold, V., & Ryan, P. G. (2019). Little evidence that dams in the Orange–Vaal River system trap floating microplastics or microfibres. *Marine Pollution Bulletin, 149*, 110664. https://doi.org/10.1016/j.marpolbul.2019.110664

Woodall, L. C., Sanchez-Vidal, A., Canals, M., Paterson, G. L. J., Coppock, R., Sleight, V., et al. The deep sea is a major sink for microplastic debris. *Royal Society Open Science, 1*(4), 140317. https://doi.org/10.1098/rsos.140317

Zayen, A., Sayadi, S., Chevalier, C., Boukthir, M., Ben Ismail, S., & Tedetti, M. (2020). Microplastics in surface waters of the Gulf of Gabes, southern Mediterranean Sea: Distribution, composition and influence of hydrodynamics. *Estuarine, Coastal and Shelf Science, 242*, 106832. https://doi.org/10.1016/j.ecss.2020.106832

Annex 2.2: Marine Litter Monitoring

Marine litter monitoring can be conducted for a number of reasons including changes in abundance and compositions of litter from different sources or in different compartments as well as assessing the effectiveness of mitigation efforts (Ryan et al., 2020). Beach surveys are a common method for monitoring marine litter due to the accessibility of the beaches compared to the open ocean or sea bed. Furthermore, relatively less equipment is required; personal protective equipment is required for participants, receptacles for collecting the litter and sieves for collecting small size fractions. They often focus on macrolitter, due to the difficulty associated with sampling smaller size fractions. Thus, the accessibility of this method makes it an attractive option for initial investigations into marine litter.

In general, either standing stock assessments or accumulation rate surveys are used. The former reports the amount of litter at a specific period in time whilst the latter reports the accumulation rate of litter in a given area. Both methods provide information on the abundance and characteristics of litter. Furthermore, accumulation rate surveys can be used to better understand litter fluxes between compartments (Cheshire et al., 2009; Ryan et al., 2009), whilst simultaneously giving a better reflection of overall standing stock associated with that location. For more details on monitoring refer to Barnardo and Ribbink (2020) and GESAMP (2019).

Standing stock surveys are popular as they are relatively less time intensive as they only require once-off sampling. However, as they provide a snapshot in time the information they provide with regards to marine litter is limited. More specifically, reported litter loads should be approached with caution as their representativeness and thus interpretation is constrained by the limited information regarding litter fluxes, distribution and deposition prior to the collection of litter. For example, an increase in standing stocks over fifty years can be attributed to a number of factors including an increase, decrease or even no change in litter washing ashore, turnover rates of different material types as well as beach cleaning efforts (Ryan et al., 2020). As such, the value of standing stock surveys lies in the litter composition observed rather than amounts.

Accumulation rate surveys are associated with greater investment in time and effort. They require an initial clean-up of the survey area followed by regular sampling of the newly arrived litter. Thus, they are better suited to macrolitter as it is difficult to ensure that smaller size fractions are completely collected during the initial clean-up (Ryan et al., 2020). Studies can be conducted at different intervals including, daily, weekly or monthly. However, observed fluxes are influenced by the chosen sampling frequency. A comparison of daily vs weekly sampling campaigns conducted by Ryan et al. (2014) found that daily surveys yielded 2.1–3.4 times more items than weekly, with observed masses 1.3–2.3 times greater. Furthermore, the study observed that low density items were associated with greater differences with polystyrene foam showing 4–5 times greater values during daily sampling. This demonstrated that different polymer types are associated with varying turnover rates, most likely linked to wind or perhaps to their buoyancy in the water column. In addition, observed accumulation rates can be influenced by water movements and climatic conditions including rain, wind strength and direction (Ryan et al., 2009). Other challenges include exhumation of buried litter either by tides, the weather or beach goers and cleaning efforts on the site (Ryan et al., 2020).

References for Annex 2.2

Barnardo, T., & Ribbink, A. J. (2020). *African marine litter monitoring manual*. African Marine Waste Network, Sustainable Seas Trust, Port Elizabeth. https://www.wiomsa.org/wp-content/uploads/2020/07/African-Marine-Litter-Monitoring-Manual_Final.pdf

Cheshire, A. C., Adler, E., Barbière, J., Cohen, Y., Evans, S., Jarayabhand, S., et al. (2009). *UNEP/IOC guidelines on survey and monitoring of marine litter* [UNEP Regional Seas Reports and Studies, No. 186; IOC Technical Series]. https://wedocs.unep.org/xmlui/bitstream/handle/20.500.11822/13604/rsrs186.pdf?sequence=1

GESAMP. (2019). *Guidelines or the monitoring and assessment of plastic litter and microplastics in the ocean.* IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. http://www.gesamp.org/publications/guidelines-for-the-monitoring-and-assessment-of-plastic-litter-in-the-ocean

Ryan, P. G., Lamprecht, A., Swanepoel, D., & Moloney, C. L. (2014). The effect of fine-scale sampling frequency on estimates of beach litter accumulation. *Marine Pollution Bulletin, 88*, 249–254. https://doi.org/10.1016/j.marpolbul.2014.08.036

Ryan, P. G., Moore, C. J., Van Franeker, J. A., & Moloney, C. L. (2009). Monitoring the abundance of plastic debris in the marine environment. *Philosophical Transactions of the Royal Society B-Biological Sciences, 364*, 1999–2012. https://doi.org/10.1098/rstb.2008.0207

Ryan, P. G., Maclean, K., & Weideman, E. A. (2020a). The impact of the COVID-19 lockdown on urban street litter in South Africa. *Environmental Processes, 7*, 1303–1312. https://doi.org/10.1007/s40710-020-00472-1

Ryan, P. G., Pichegru, L., Perold, V., & Moloney, C. L. (2020b). Monitoring marine plastics—Will we know if we are making a difference? *South African Journal of Science, 116*, 58–66. https://sajs.co.za/article/view/7678/9944

Ryan, P. G., Weideman, E. A., Perold, V., Durholtz, D., & Fairweather, T. P. (2020c). A trawl survey of seafloor macrolitter on the South African continental shelf. *Marine Pollution Bulletin, 150*, 6. https://doi.org/10.1016/j.marpolbul.2019.110741

Ryan, P. G., Weideman, E. A., Perold, V., & Moloney, C. L. (2020d). Toward balancing the budget: Surface macro-plastics dominate the mass of particulate pollution stranded on beaches. *Frontiers in Marine Science, 7*, 14. https://doi.org/10.3389/fmars.2020.575395

References

Abidli, S., Antunes, J. C., Ferreira, J. L., Lahbib, Y., Sobral, P., & Trigui El Menif, N. (2018). Microplastics in sediments from the littoral zone of the north Tunisian coast (Mediterranean Sea). *Estuarine, Coastal and Shelf Science, 205*, 1–9. https://doi.org/10.1016/j.ecss.2018.03.006

Adeogun, A. O., Ibor, O. R., Khan, E. A., Chukwuka, A. V., Omogbemi, E. D., & Arukwe, A. (2020). Detection and occurrence of microplastics in the stomach of commercial fish species from a municipal water supply lake in southwestern Nigeria. *Environmental Science and Pollution Research, 27*, 31035–31045. https://doi.org/10.1007/s11356-020-09031-5

AfDB/UNEP/GRID-Arendal. (2020). *Sanitation and wastewater atlas of Africa.* AfDB/UNEP/Grid-Arendal. https://www.grida.no/publications/471

Aguilera, M., Medina-Suárez, M., Pinós, J., Liria-Loza, A., & Benejam, L. (2018). Marine debris as a barrier: Assessing the impacts on sea turtle hatchlings on their way to the ocean. *Marine Pollution Bulletin, 137*, 481–487. https://doi.org/10.1016/j.marpolbul.2018.10.054

Ahmed, F., Moodley, V., & Sookrajh, R. (2008). The environmental impacts of beach sport tourism events: A case study of the Mr Price Pro surfing event, Durban, South Africa. *Africa Insight, 38*, 73–85. https://www.cabdirect.org/cabdirect/abstract/20093084848

Ahmed, M. B., Rahman, M. S., Alom, J., Hasan, M. D. S., Johir, M. A. H., & Mondal, M. I. H. (2021). Microplastic particles in the aquatic environment: A systematic review. *Science of the Total Environment, 775*, 145793. https://doi.org/10.1016/j.scitotenv.2021.145793

Akindele, E. O., & Alimba, C. G. (2021). Plastic pollution threat in Africa: Current status and implications for aquatic ecosystem health. *Environmental Science and Pollution Research, 28*, 7636–7651. https://doi.org/10.1007/s11356-020-11736-6

Akindele, E. O., Ehlers, S. M., & Koop, J. H. E. (2019). First empirical study of freshwater microplastics in West Africa using gastropods from Nigeria as bioindicators. *Limnologica, 78*, 9. https://agris.fao.org/agris-search/search.do?recordID=US201900446650

Alimi, O. S., Fadare, O. O., & Okoffo, E. D. (2021). Microplastics in African ecosystems: Current knowledge, abundance, associated contaminants, techniques, and research needs. *Science of the Total Environment, 755*, 142422. https://doi.org/10.1016/j.scitotenv.2020.142422

Allen, S., Allen, D., Moss, K., Le Roux, G., Phoenix, V. R., & Sonke, J. E. (2020). Examination of the ocean as a source for atmospheric microplastics. *PLOS One, 15*, e0232746. https://doi.org/10.1371/journal.pone.0232746

Alshawafi, A., Analla, M., Alwashali, E., & Aksissou, M. (2017). Assessment of marine debris on the coastal wetland of Martil in the North-East of Morocco. *Marine Pollution Bulletin, 117*, 302–310. https://doi.org/10.1016/j.marpolbul.2017.01.079

Amec Foster Wheeler Environment & Infrastructure Uk Limited. (2017). *Intentionally added microplastics in products*. https://ec.europa.eu/environment/chemicals/reach/pdf/39168%20Intentionally%20added%20microplastics%20-%20Final%20report%2020171020.pdf

American Chemistry Council. (2021). https://www.opcleansweep.org/about/

Andriamahefazafy, M., & Failler, P. (2021). Towards a circular economy for African Islands: An analysis of existing baselines and strategies. *Circular Economy and Sustainability*. https://doi.org/10.1007/s43615-021-00059-4

Appiah, J. K., Berko-Boateng, V. N., & Tagbor, T. A. (2017). Use of waste plastic materials for road construction in Ghana. *Case Studies in Construction Materials, 6*, 1–7. https://doi.org/10.1016/j.cscm.2016.11.001

APWC. (2020). *Port reception waste facilities audit*. The Commonwealth Litter Programme. APWC (Asia Pacific Waste Consultants). https://www.cefas.co.uk/clip/resources/reports/africa-clip-reports/port-reception-waste-facilities-audit-south-africa-apwc/

Argüello, G. (2020). Environmentally sound management of ship wastes: Challenges and opportunities for European ports. *Journal of Shipping and Trade, 5*, 12. https://doi.org/10.1186/s41072-020-00068-w

Armitage, N., & Rooseboom, A. (2000). The removal of urban litter from stormwater conduits and streams: Paper 1—The quantities involved and catchment litter management options. *Water SA, 26*. https://www.researchgate.net/publication/267260648_The_removal_of_urban_litter_from_stormwater_conduits_and_streams_Paper_1_-The_quantities_involved_and_catchment_litter_management_options

Arnold, G., & Ryan, P. G. (1999). Marine litter originating from Cape Town's residential, commercial, and industrial areas: The stormwater connection.

Baensch-Baltruschat, B., Kocher, B., Stock, F., & Reifferscheid, G. (2020). Tyre and road wear particles (TRWP)—A review of generation, properties, emissions, human health risk, ecotoxicity, and fate in the environment. *Science of the Total Environment, 733*, 137823. https://doi.org/10.1016/j.scitotenv.2020.137823

Bakir, A., van der Lingen, C. D., Preston-Whyte, F., Bali, A., Geja, Y., Barry, J., Mdazuka, Y., Mooi, G., Doran, D., Tooley, F., Harmer, R., Maes, T. (2020). Microplastics in commercially important small pelagic fish species from South Africa. *Frontiers in Marine Science*, *7*, 910. https://doi.org/10.3389/fmars.2020.574663

Barnardo, T., & Ribbink, A. J. (2020). *African marine litter monitoring manual*. African Marine Waste Network, Sustainable Seas Trust. https://repository.oceanbestpractices.org/handle/11329/1420

Barrows, A. P. W., Christiansen, K. S., Bode, E. T., & Hoellein, T. J. (2018). A watershed-scale, citizen science approach to quantifying microplastic concentration in a mixed land-use river. *Water Research, 147*, 382–392. https://doi.org/10.1016/j.watres.2018.10.013

Besseling, E., Quik, J. T. K., Sun, M., & Koelmans, A. A. (2017). Fate of nano- and microplastic in freshwater systems: A modeling study. *Environmental Pollution, 220*, 540–548. https://doi.org/10.1016/j.envpol.2016.10.001

Bond, T., Ferrandiz-Mas, V., Felipe-Sotelo, M., & Van Sebille, E. (2018). The occurrence and degradation of aquatic plastic litter based on polymer physicochemical properties: A review. *Critical Reviews in Environmental Science and Technology, 48*, 685–722. https://doi.org/10.1080/10643389.2018.1483155

Boucher, J., & Friot, D. (2017). *Primary microplastics in the oceans: A global evaluation of sources*. IUCN. https://portals.iucn.org/library/sites/library/files/documents/2017-002-En.pdf

Brahney, J., Hallerud, M., Heim, E., Hahnenberger, M., & Sukumaran, S. (2020). Plastic rain in protected areas of the United States. *Science, 368*, 1257–1260. https://doi.org/10.1126/science.aaz5819

Browne, M. A., Ros, M., & Johnston, E. L. (2020). Pore-size and polymer affect the ability of filters for washing-machines to reduce domestic emissions of fibres to sewage. *PLOS One, 15*, e0234248. https://doi.org/10.1371/journal.pone.0234248

Bundhoo, Z. M. A. (2018). Solid waste management in least developed countries: Current status and challenges faced. *Journal of Material Cycles and Waste Management, 20*, 1867–1877. https://doi.org/10.1007/s10163-018-0728-3

Cardoso, C., & Caldeira, R. M. A. (2021). Modeling the exposure of the Macaronesia Islands (NE Atlantic) to marine plastic pollution. *Frontiers in Marine Science, 8*. https://doi.org/10.3389/fmars.2021.653502

Castaneda, R. A., Avlijas, S., Simard, M. A., & Ricciardi, A. (2014). Microplastic pollution in St. Lawrence River sediments. *Canadian Journal of Fisheries and Aquatic Sciences, 71*, 1767–1771. https://doi.org/10.1139/cjfas-2014-0281

Chan, C. K. M., Park, C., Chan, K. M., Mak, D. C. W., Fang, J. K. H., & Mitrano, D. M. (2021). Microplastic fibre releases from industrial wastewater effluent: A textile wet-processing mill in China. *Environmental Chemistry*. https://doi.org/10.1071/EN20143

Cheshire, A. C., Adler, E., Barbière, J., Cohen, Y., Evans, S., Jarayabhand, S., et al. (2009). *UNEP/IOC guidelines on survey and monitoring of marine litter* [UNEP Regional Seas Reports and Studies, No. 186; IOC Technical Series]. https://wedocs.unep.org/xmlui/bitstream/handle/20.500.11822/13604/rsrs186.pdf?sequence=1

Cheung, P. K., & Fok, L. (2017). Characterisation of plastic microbeads in facial scrubs and their estimated emissions in Mainland China. *Water Research, 122*, 53–61. https://doi.org/10.1016/j.watres.2017.05.053

Chitaka, T. Y. (2020). *Inclusion of leakage into life cycle management of products involving plastic as a material choice*. Faculty of Engineering and the Built Environment, Department of Chemical Engineering. http://hdl.handle.net/11427/32574

Chitaka, T. Y., & Von Blottnitz, H. (2019). Accumulation and characteristics of plastic debris along five beaches in Cape Town. *Marine Pollution Bulletin, 138*, 451–457. https://doi.org/10.1016/j.marpolbul.2018.11.065

Chitaka, T. Y., & Von Blottnitz, H. (2021). Development of a method for estimating product-specific leakage propensity and its inclusion into the life cycle management of plastic products. *The International Journal of Life Cycle Assessment*. https://doi.org/10.1007/s11367-021-01905-1

Chouchene, K., Da Costa, J. P., Wali, A., Girão, A. V., Hentati, O., Duarte, A. C., et al. (2019). Microplastic pollution in the sediments of Sidi Mansour Harbor in Southeast Tunisia. *Marine Pollution Bulletin, 146*, 92–99. https://doi.org/10.1016/j.marpolbul.2019.06.004

Chubarenko, I., Esiukova, E., Khatmullina, L., Lobchuk, O., Grave, A., Kileso, A., Haseler, M. (2020). From macro to micro, from patchy to uniform: Analyzing plastic contamination along and across a sandy tide-less coast. *Marine Pollution Bulletin, 156*. https://doi.org/10.1016/j.marpolbul.2020.111198

Collins, C., & Hermes, J. C. (2019). Modelling the accumulation and transport of floating marine micro-plastics around South Africa. *Marine Pollution Bulletin, 139*, 46–58. https://doi.org/10.1016/j.marpolbul.2018.12.028

Conley, K., Clum, A., Deepe, J., Lane, H., & Beckingham, B. (2019). Wastewater treatment plants as a source of microplastics to an urban estuary: Removal efficiencies and loading per capita over one year. *Water Research X, 3*, 100030. https://doi.org/10.1016/j.wroa.2019.100030

Cooper, D. A., & Corcoran, P. L. (2010). Effects of mechanical and chemical processes on the degradation of plastic beach debris on the island of Kauai, Hawaii. *Marine Pollution Bulletin, 60*, 650–654. https://doi.org/10.1016/j.marpolbul.2009.12.026

Dahms, H. T. J., Van Rensburg, G. J., & Greenfield, R. (2020). The microplastic profile of an urban African stream. *Science of the Total Environment, 731*, 138893. https://doi.org/10.1016/j.scitotenv.2020.138893

Dalu, T., Banda, T., Mutshekwa, T., Munyai, L. F., & Cuthbert, R. N. (2021). Effects of urbanisation and a wastewater treatment plant on microplastic densities along a subtropical river system. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-021-13185-1

Dauvergne, P. (2018). The power of environmental norms: Marine plastic pollution and the politics of microbeads. *Environmental Politics, 27*, 579–597. https://doi.org/10.1080/09644016.2018.1449090

De Falco, F., Cocca, M., Avella, M., & Thompson, R. C. (2020). Microfiber release to water, via laundering, and to air, via everyday use: A comparison between polyester clothing with differing textile parameters. *Environmental Science & Technology, 54*, 3288–3296. https://doi.org/10.1021/acs.est.9b06892

De Falco, F., Di Pace, E., Cocca, M., & Avella, M. (2019). The contribution of washing processes of synthetic clothes to microplastic pollution. *Scientific Reports, 9*, 6633. https://doi.org/10.1038/s41598-019-43023-x

De Villiers, S. (2018). Quantification of microfibre levels in South Africa's beach sediments, and evaluation of spatial and temporal variability from 2016 to 2017. *Marine Pollution Bulletin, 135*, 481–489. https://doi.org/10.1016/j.marpolbul.2018.07.058

De Villiers, S. (2019). Microfibre pollution hotspots in river sediments adjacent to South Africa's coastline. *Water SA, 45*, 97–102. https://doi.org/10.4314/wsa.v45i1.11

Dibke, C., Fischer, M., & Scholz-Böttcher, B. M. (2021). Microplastic mass concentrations and distribution in German bight waters by pyrolysis-gas chromatography–mass spectrometry/thermochemolysis reveal potential impact of marine coatings: Do ships leave skid marks? *Environmental Science & Technology, 55*, 2285–2295. https://doi.org/10.1021/acs.est.0c04522

Dris, R., Gasperi, J., Saad, M., Mirande, C., & Tassin, B. (2016). Synthetic fibers in atmospheric fallout: A source of microplastics in the environment? *Marine Pollution Bulletin, 104*, 290–293. https://doi.org/10.1016/j.marpolbul.2016.01.006

Drummond, J. D., Nel, H. A., Packman, A. I., & Krause, S. (2020). Significance of hyporheic exchange for predicting microplastic fate in rivers. *Environmental Science & Technology Letters, 7*, 727–732. https://doi.org/10.1021/acs.estlett.0c00595

Duhec, A. V., Jeanne, R. F., Maximenko, N., & Hafner, J. (2015). Composition and potential origin of marine debris stranded in the Western Indian Ocean on remote Alphonse Island, Seychelles. *Marine Pollution Bulletin, 96*, 76–86. https://doi.org/10.1016/j.marpolbul.2015.05.042

Dunlop, S. W., Dunlop, B. J., & Brown, M. (2020). Plastic pollution in paradise: Daily accumulation rates of marine litter on Cousine Island, Seychelles. *Marine Pollution Bulletin, 151*, 110803. https://doi.org/10.1016/j.marpolbul.2019.110803

Ebere, E. C., Wirnkor, V. A., Ngozi, V. E., & Chukwuemeka, I. S. (2019). Macrodebris and microplastics pollution in Nigeria: First report on abundance, distribution and composition. *Environmental Analysis, Health and Toxicology, 34*, e2019012. https://doi.org/10.5620/eaht.e2019012

Egressa, R., Nankabirwa, A., Ocaya, H., & Pabire, W. G. (2020). Microplastic pollution in surface water of Lake Victoria. *Science of the Total Environment, 741*, 140201. https://doi.org/10.1016/j.scitotenv.2020.140201

Eriksen, M., Lebreton, L. C. M., Carson, H. S., Thiel, M., Moore, C. J., Borerro, J. C., Galgani, F., et al. (2014). Plastic pollution in the world's oceans: More than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. *PLOS One, 9*, e111913. https://doi.org/10.1371/journal.pone.0111913

Evangeliou, N., Grythe, H., Klimont, Z., Heyes, C., Eckhardt, S., Lopez-Aparicio, S., et al. (2020). Atmospheric transport is a major pathway of microplastics to remote regions. *Nature Communications, 11*, 3381. https://doi.org/10.1038/s41467-020-17201-9

Fadare, O. O., & Okoffo, E. D. (2020). Covid-19 face masks: A potential source of microplastic fibers in the environment. *The Science of the Total Environment, 737*, 140279–140279. https://doi.org/10.1016/j.scitotenv.2020.140279

Fazey, F. M. C., & Ryan, P. G. (2016a). Biofouling on buoyant marine plastics: An experimental study into the effect of size on surface longevity. *Environmental Pollution, 210*, 354–360. https://doi.org/10.1016/j.envpol.2016.01.026

Fazey, F. M. C., & Ryan, P. G. (2016b). Debris size and buoyancy influence the dispersal distance of stranded litter. *Marine Pollution Bulletin, 110*, 371–377. https://doi.org/10.1016/j.marpolbul.2016.06.039

Fred-Ahmadu, O. H., Ayejuyo, O. O., & Benson, N. U. (2020). Microplastics distribution and characterization in epipsammic sediments of tropical Atlantic Ocean, Nigeria. *Regional Studies in Marine Science, 38*, 101365. https://doi.org/10.1016/j.rsma.2020.101365

Freeman, S., Booth, A. M., Sabbah, I., Tiller, R., Dierking, J., Klun, K., et al. (2020). Between source and sea: The role of wastewater treatment in reducing marine microplastics. *Journal of Environmental Management, 266*, 110642. https://doi.org/10.1016/j.jenvman.2020.110642

GESAMP. (1991). *The state of marine environment. Group of experts on the scientific aspects of marine pollution*. http://www.gesamp.org/publications/the-state-of-the-marine-environment

GESAMP. (2019). *Guidelines or the monitoring and assessment of plastic litter and microplastics in the ocean*. IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. http://www.gesamp.org/publications/guidelines-for-the-monitoring-and-assessment-of-plastic-litter-in-the-ocean

GIZ. (2019). *Access to water and sanitation in Sub-Saharan Africa: Review of sector reforms and investments—Key findings to inform future support to sector development. Part 1. Synthesis report*. https://www.oecd.org/water/GIZ_2018_Access_Study_Part%20I_Synthesis_Report.pdf

González-Pleiter, M., Edo, C., Aguilera, Á., Viúdez-Moreiras, D., Pulido-Reyes, G., González-Toril, E., et al. (2021). Occurrence and transport of microplastics sampled within and above the planetary boundary layer. *Science of the Total Environment, 761*, 143213. https://doi.org/10.1016/j.scitotenv.2020.143213

Govender, J., Naidoo, T., Rajkaran, A., Cebekhulu, S., Bhugeloo, A., & Sershen. (2020). Towards characterising microplastic abundance, typology and retention in mangrove-dominated estuaries. *Water, 12*. https://doi.org/10.3390/w12102802

GRID-Arendal. (2005). *Vital water graphics: Major river basins of Africa*. https://www.grida.no/resources/5774

Guerranti, C., Martellini, T., Perra, G., Scopetani, C., Cincinelli, A. (2019). Microplastics in cosmetics: Environmental issues and needs for global bans. *Environmental Toxicology and Pharmacology*, *68*, 75–79. https://doi.org/10.1016/j.etap.2019.03.007

Haddout, S., Gimiliani, G. T., Priya, K. L., Hoguane, A. M., Casila, J. C. C., & Ljubenkov, I. (2021). Microplastics in surface waters and sediments in the Sebou Estuary and Atlantic Coast, Morocco. *Analytical Letters,* 1–13. https://doi.org/10.1080/00032719.2021.1924767

Harris, P. T., Westerveld, L., Nyberg, B., Maes, T., Macmillan-Lawler, M., & Appelquist, L. R. (2021). Exposure of coastal environments to river-sourced plastic pollution. *Science of the Total Environment, 769*, 145222. https://doi.org/10.1016/j.scitotenv.2021.145222

Haseler, M., Schernewski, G., Balciunas, A., Sabaliauskaite, V. (2018). Monitoring methods for large micro- and meso-litter and applications at Baltic beaches. *The Journal of Coastal Conservation*, *22*, 27–50. https://doi.org/10.1007/s11852-017-0497-5

Hoellein, T. J., Shogren, A. J., Tank, J. L., Risteca, P., & Kelly, J. J. (2019). Microplastic deposition velocity in streams follows patterns for naturally occurring allochthonous particles. *Scientific Reports, 9*, 3740. https://doi.org/10.1038/s41598-019-40126-3

Hoornweg, D., & Bhada-Tata, P. (2012). *What a waste: A global review of solid waste management*. World Bank. https://openknowledge.worldbank.org/handle/10986/17388

Horton, A. A., & Dixon, S. J. (2018). Microplastics: An introduction to environmental transport processes. *WIREs Water, 5*, e1268. https://doi.org/10.1002/wat2.1268

Hosoda, J., Ofosu-Anim, J., Sabi, E. B., Akita, L. G., Onwona-Agyeman, S., Yamashita, R., et al. (2014). Monitoring of organic micropollutants in Ghana by combination of pellet watch with sediment analysis: E-waste as a source of PCBs. *Marine Pollution Bulletin, 86*, 575–581. https://doi.org/10.1016/j.marpolbul.2014.06.008

Huntington, T. (2019). *Marine litter and aquaculture gear—White paper*. Report produced by Poseidon Aquatic Resources Management Ltd for the Aquaculture Stewardship Council. https://www.asc-aqua.org/wp-content/uploads/2019/11/ASC_Marine-Litter-and-Aquaculture-Gear-November-2019.pdf

Hurley, R., Woodward, J., & Rothwell, J. J. (2018). Microplastic contamination of river beds significantly reduced by catchment-wide flooding. *Nature Geoscience, 11*, 251–257. https://doi.org/10.1038/s41561-018-0080-1

Hwang, D.-J. (2020). The IMO action plan to address marine plastic litter from ships and its follow-up timeline. *Journal of International Maritime Safety, Environmental Affairs, and Shipping, 4*(2), 32–39. https://doi.org/10.1080/25725084.2020.1779428

Ilechukwu, I., Ndukwe, G., Mgbemena, N., & Akandu, A. (2019). Occurrence of microplastics in surface sediments of beaches in Lagos, Nigeria. *European Chemical Bulletin, 8*, 371. https://doi.org/10.17628/ecb.2019.8.371-375

IMO. (1972). *Convention on the prevention of marine pollution by dumping of wastes and other matter (London Convention).* IMO (International Maritime Organisation). https://www.imo.org/en/OurWork/Environment/Pages/London-Convention-Protocol.aspx

IMO. (1973/1978). *The international convention for the prevention of pollution from ships (marine pollution), 1973 as modified by the protocol of 1978.* https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx

IMO. (2013). *Guide to good practice for port reception facility providers and users.* MEPC 671/Rev.1. http://www.mantamaritime.com/downloads/flag_news/MEPC.1_Circ.671_Rev.1.pdf

IMO. (2014). *Inadequacy of reception facilities: Revision of the IMO comprehensive manual on port reception facilities.* MEPC 67/11. http://www.basel.int/Portals/4/download.aspx?d=2014-MEPC-67-11.pdf

IMO. (2016). *Amendments to the Annex of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the protocol of 1978 relating thereto: Amendments to MARPOL Annex V. (HME substances and form of garbage record book).* Resolution Mepc.277(70). https://www.gard.no/Content/25062772/MEPC.277(70).pdf

International Pellet Watch. (2021). http://pelletwatch.org/

Iyare, P. U., Ouki, S. K., & Bond, T. (2020). Microplastics removal in wastewater treatment plants: A review. *Environmental Science: Water Research & Technology, 6*, 2664–2675. https://doi.org/10.1039/D0EW00397B

Jambeck, J., Hardesty, B. D., Brooks, A. L., Friend, T., Teleki, K., Fabres, J., et al. (2018). Challenges and emerging solutions to the land-based plastic waste issue in Africa. *Marine Policy, 96*, 256–263. https://doi.org/10.1016/j.marpol.2017.10.041

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., et al. (2015). Plastic waste inputs from land into the ocean. *Science, 347*, 768–771. https://doi.org/10.1126/science.1260352

Järlskog, I., Strömvall, A.-M., Magnusson, K., Gustafsson, M., Polukarova, M., Galfi, H., et al. (2020). Occurrence of tire and bitumen wear microplastics on urban streets and in sweepsand and washwater. *Science of the Total Environment, 729*, 138950. https://doi.org/10.1016/j.scitotenv.2020.138950

Kanhai, L. D. K., Officer, R., Lyashevska, O., Thompson, R. C., & O'Connor, I. (2017). Microplastic abundance, distribution and composition along a latitudinal gradient in the Atlantic Ocean. *Marine Pollution Bulletin, 115*, 307–314. https://doi.org/10.1016/j.marpolbul.2016.12.025

Karlsson, T. M., Arneborg, L., Broström, G., Almroth, B. C., Gipperth, L., & Hassellöv, M. (2018). The unaccountability case of plastic pellet pollution. *Marine Pollution Bulletin, 129*, 52–60. https://doi.org/10.1016/j.marpolbul.2018.01.041

Katsumi, N., Kusube, T., Nagao, S., & Okochi, H. (2021). Accumulation of microcapsules derived from coated fertilizer in paddy fields. *Chemosphere, 267*, 10. https://doi.org/10.1016/j.chemosphere.2020.129185

Kay, P., Hiscoe, R., Moberley, I., Bajic, L., & Mckenna, N. (2018). Wastewater treatment plants as a source of microplastics in river catchments. *Environmental Science and Pollution Research, 25*, 20264–20267. https://doi.org/10.1007/s11356-018-2070-7

Kaza, S., Yao, L. C., Bhada-Tata, P., & Van Woerden, F. (2018). *What a waste 2.0: A global snapshot of solid waste management to 2050*. World Bank. https://openknowledge.worldbank.org/handle/10986/30317

Khatmullina, L., & Isachenko, I. (2017). Settling velocity of microplastic particles of regular shapes. *Marine Pollution Bulletin, 114*, 871–880. https://doi.org/10.1016/j.marpolbul.2016.11.024

Klöckner, P., Seiwert, B., Eisentraut, P., Braun, U., Reemtsma, T., & Wagner, S. (2020). Characterization of tire and road wear particles from road runoff indicates highly dynamic particle properties. *Water Research, 185*, 116262. https://doi.org/10.1016/j.watres.2020.116262

Knight, L. J., Parker-Jurd, F. N. F., Al-Sid-Cheikh, M., & Thompson, R. C. (2020). Tyre wear particles: An abundant yet widely unreported microplastic? *Environmental Science and Pollution Research, 27*, 18345–18354. https://doi.org/10.1007/s11356-020-08187-4

Knutsen, H., Cyvin, J. B., Totland, C., Lilleeng, Ø., Wade, E. J., Castro, V., et al. (2020). Microplastic accumulation by tube-dwelling, suspension feeding polychaetes from the sediment surface: A case study from the Norwegian Continental Shelf. *Marine Environmental Research, 161*, 105073. https://doi.org/10.1016/j.marenvres.2020.105073

Kole, P. J., Löhr, A. J., Van Belleghem, F. G. A. J., & Ragas, A. M. J. (2017). Wear and tear of tyres: A stealthy source of microplastics in the environment. *International Journal of Environmental Research and Public Health, 14*, 1265. https://doi.org/10.3390/ijerph14101265

Kooi, M., Nes, E. H. V., Scheffer, M., & Koelmans, A. A. (2017). Ups and downs in the ocean: Effects of biofouling on vertical transport of microplastics. *Environmental Science & Technology, 51*, 7963–7971. https://doi.org/10.1021/acs.est.6b04702

Krause, S., Baranov, V., Nel, H. A., Drummond, J. D., Kukkola, A., Hoellein, T., et al. (2021). Gathering at the top? Environmental controls of microplastic uptake and biomagnification in freshwater food webs. *Environmental Pollution, 268*, 115750. https://doi.org/10.1016/j.envpol.2020.115750

Lamprecht, A. (2013). *The abundance, distribution and accumulation of plastic debris in Table Bay, Cape Town, South Africa*. University of Cape Town. Open UCT. https://open.uct.ac.za/handle/11427/6633

Lane, S., Ahamada, S., Gonzalves, C., Lukambuzi, L., Ochiewo, J., Pereira, M., et al. (2007). *Regional overview and assessment of marine litter related activities in the west Indian Ocean region*. United Nations Environment Programme. https://wedocs.unep.org/bitstream/handle/20.500.11822/8764/-A%20Regional%20Overview%20%26%20Assessment%20of%20Marine%20Litter%20Related%20Activities%20in%20the%20%20Western%20Indian%20Ocean%20Region-2007Regional_assessment_of_marine_litter_WIO_Region.PDF?sequence=3&isAllowed=y

Lebreton, L., Slat, B., Ferrari, F., Sainte-Rose, B., Aitken, J., Marthouse, R., et al. (2018). Evidence that the Great Pacific garbage patch is rapidly accumulating plastic. *Scientific Reports, 8*, 4666. https://doi.org/10.1038/s41598-018-22939-w

Lebreton, L. C. M., Greer, S. D., & Borrero, J. C. (2012). Numerical modelling of floating debris in the world's oceans. *Marine Pollution Bulletin, 64*, 653–661. https://doi.org/10.1016/j.marpolbul.2011.10.027

Lebreton, L. C. M., Van Der Zwet, J., Damsteeg, J.-W., Slat, B., Andrady, A., & Reisser, J. (2017). River plastic emissions to the world's oceans. *Nature Communications, 8*, 15611. https://doi.org/10.1038/ncomms15611

Liu, F., Olesen, K. B., Borregaard, A. R., & Vollertsen, J. (2019). Microplastics in urban and highway stormwater retention ponds. *Science of the Total Environment, 671*, 992–1000. https://doi.org/10.1016/j.scitotenv.2019.03.416

Loulad, S., Houssa, R., Ouamari, N. E., & Rhinane, H. (2019). Quantity and spatial distribution of seafloor marine debris in the Moroccan Mediterranean Sea. *Marine Pollution Bulletin, 139*, 163–173. https://doi.org/10.1016/j.marpolbul.2018.12.036

Loulad, S., Houssa, R., Rhinane, H., Boumaaz, A., & Benazzouz, A. (2017). Spatial distribution of marine debris on the seafloor of Moroccan waters. *Marine Pollution Bulletin, 124*, 303–313. https://doi.org/10.1016/j.marpolbul.2017.07.022

Lourenço, P. M., Serra-Gonçalves, C., Ferreira, J. L., Catry, T., & Granadeiro, J. P. (2017). Plastic and other microfibers in sediments, macroinvertebrates and shorebirds from three intertidal wetlands of southern Europe and west Africa. *Environmental Pollution, 231*, 123–133. https://doi.org/10.1016/j.envpol.2017.07.103

Lusher, A., Hollman, P., & Mendoza, J. (2017). Microplastics in fisheries and aquaculture: Status of knowledge on their occurrence and implications for aquatic organisms and food safety. https://www.fao.org/3/I7677E/I7677E.pdf

Madzena, A., & Lasiak, T. (1997). Spatial and temporal variations in beach litter on the Transkei coast of South Africa. *Marine Pollution Bulletin, 34*, 900–907. https://doi.org/10.1016/S0025-326X(97)00052-0

Maes, T., Jessop, R., Wellner, N., Haupt, K., Mayes, A. G. (2017). A rapid-screening approach to detect and quantify microplastics based on fluorescent tagging with Nile Red. *Scientific Reports, 7*, 44501.

Maes, T., Barry, J., Leslie, H. A., Vethaak, A. D., Nicolaus, E. E. M., Law, R. J., et al. (2018). Below the surface: Twenty-five years of seafloor litter monitoring in coastal seas of North West Europe (1992–2017). *Science of the Total Environment, 630*, 790–798. https://doi.org/10.1016/j.scitotenv.2018.02.245

Mafuta, C., Barnes, R., Plummer, L., & Westerveld, L. (2018). *Sanitation and wastewater in Africa.* GRID-Arendal. https://www.grida.no/publications/471

Mahon, A. M., O'Connell, B., Healy, M. G., O'Connor, I., Officer, R., Nash, R., et al. (2017). Microplastics in sewage sludge: Effects of treatment. *Environmental Science & Technology, 51*, 810–818. https://doi.org/10.1021/acs.est.6b04048

Maione, C. (2021). Quantifying plastics waste accumulations on coastal tourism sites in Zanzibar, Tanzania. *Marine Pollution Bulletin, 168*, 112418. https://doi.org/10.1016/j.marpolbul.2021.112418

Marais, M., & Armitage, N. (2004). The measurement and reduction of urban litter entering stormwater drainage systems: Paper 2—Strategies for reducing the litter in the stormwater drainage systems. *Water SA, 30*, 483–492. https://doi.org/10.4314/wsa.v30i4.5100

Matsuguma, Y., Takada, H., Kumata, H., Kanke, H., Sakurai, S., Suzuki, T., et al. (2017). Microplastics in sediment cores from Asia and Africa as indicators of temporal trends in plastic pollution. *Archives of Environmental Contamination and Toxicology, 73*, 230–239. https://doi.org/10.1007/s00244-017-0414-9

Mayoma, B. S., Sørensen, C., Shashoua, Y., & Khan, F. R. (2020). Microplastics in beach sediments and cockles (*Anadara antiquata*) along the Tanzanian coastline. *Bulletin of Environmental Contamination and Toxicology, 105*, 513–521. https://doi.org/10.1007/s00128-020-02991-x

Migwi, F. K., Ogunah, J. A., & Kiratu, J. M. (2020). Occurrence and spatial distribution of microplastics in the surface waters of Lake Naivasha, Kenya. *Environmental Toxicology and Chemistry, 39*, 765–774. https://doi.org/10.1002/etc.4677

Mishra, S., Rath, C. C., & Das, A. P. (2019). Marine microfiber pollution: A review on present status and future challenges. *Marine Pollution Bulletin, 140*, 188–197. https://doi.org/10.1016/j.marpolbul.2019.01.039

Missawi, O., Bousserrhine, N., Belbekhouche, S., Zitouni, N., Alphonse, V., Boughattas, I., et al. (2020). Abundance and distribution of small microplastics ($\leq 3\ \mu m$) in sediments and seaworms from the Southern Mediterranean coasts and characterisation of their potential harmful effects. *Environmental Pollution, 263*, 114634. https://doi.org/10.1016/j.envpol.2020.114634

Mobilik, J.-M., Ling, T.-Y., Husain, M.-L., & Hassan, R. (2016). Type and quantity of shipborne garbage at selected tropical beaches. *The Scientific World Journal, 2016*, 5126951. https://doi.org/10.1155/2016/5126951

Moss, K., Allen, D., González-Fernández, D., & Allen, S. (2021). Filling in the knowledge gap: Observing macroplastic litter in South Africa's rivers. *Marine Pollution Bulletin, 162*, 111876. https://doi.org/10.1016/j.marpolbul.2020.111876

Nachite, D., Maziane, F., Anfuso, G., & Williams, A. T. (2019). Spatial and temporal variations of litter at the Mediterranean beaches of Morocco mainly due to beach users. *Ocean & Coastal Management, 179*, 104846. https://doi.org/10.1016/j.ocecoaman.2019.104846

Naidoo, T., & Glassom, D. (2019). Sea-surface microplastic concentrations along the coastal shelf of KwaZulu-Natal, South Africa. *Marine Pollution Bulletin, 149*, 110514. https://doi.org/10.1016/j.marpolbul.2019.110514

Naidoo, T., Glassom, D., & Smit, A. J. (2015). Plastic pollution in five urban estuaries of KwaZulu-Natal, South Africa. *Marine Pollution Bulletin, 101*, 473–480. https://doi.org/10.1016/j.marpolbul.2015.09.044

Nel, H. A., Dalu, T., & Wasserman, R. J. (2018). Sinks and sources: Assessing microplastic abundance in river sediment and deposit feeders in an Austral temperate urban river system. *Science of the Total Environment, 612*, 950–956. https://doi.org/10.1016/j.scitotenv.2017.08.298

Nel, H. A., Dalu, T., Wasserman, R. J., & Hean, J. W. (2019). Colour and size influences plastic microbead underestimation, regardless of sediment grain size. *Science of the Total Environment, 655*, 567–570. https://doi.org/10.1016/j.scitotenv.2018.11.261

Nel, H. A., & Froneman, P. W. (2015). A quantitative analysis of microplastic pollution along the south-eastern coastline of South Africa. *Marine Pollution Bulletin, 101*, 274–279. https://doi.org/10.1016/j.marpolbul.2015.09.043

Nel, H. A., Hean, J. W., Noundou, X. S., & Froneman, P. W. (2017). Do microplastic loads reflect the population demographics along the southern African coastline? *Marine Pollution Bulletin, 115*, 115–119. https://doi.org/10.1016/j.marpolbul.2016.11.056

Nel, H. A., Naidoo, T., Akindele, E. O., Nhiwatiwa, T., Fadare, O. O., & Krause, S. (2021). Collaboration and infrastructure is needed to develop an African perspective on micro(nano)plastic pollution. *Environmental Research Letters, 16*, 021002. https://doi.org/10.1088/1748-9326/abdaeb

Nelms, S. E., Coombes, C., Foster, L. C., Galloway, T. S., Godley, B. J., Lindeque, P. K., Witt, M. J. (2017). Marine anthropogenic litter on British beaches: A 10-year nationwide assessment using citizen science data. *Science of the Total Environment*, *579*, 1399–1409. https://doi.org/10.1016/j.scitotenv.2016.11.137

Nikiema, J., Figoli, A., Weissenbacher, N., Langergraber, G., Marrot, B., & Moulin, P. (2013). Wastewater treatment practices in Africa—Experiences from seven countries. *Sustainable Sanitation Practice, 12*, 26–34. http://www.ecosan.at/ssp/selected-contributions-from-the-1st-waterbiotech-conference-9-11-oct-2012-cairo-egypt/SSP-14_Jan2013_26-34.pdf

NOWPAP. (2009). *Port reception facilities in the NOWPAP region.* NOWPAP (Northwest Pacific Action Plan). https://www.unep.org/nowpap/resources/toolkits-manuals-and-guides/port-reception-facilities-nowpap-region-2009

Nunoo, F. K. E., & Quayson, E. (2003). Towards management of litter accumulation—Case study of two beaches in Accra, Ghana. *Journal of the Ghana Science Association, 5*, 145–155. https://www.scirp.org/(S(i43dyn45teexjx455qlt3d2q))/reference/ReferencesPapers.aspx?ReferenceID=1752341

Øhlenschlæger, J. P., Newman, S., & Farmer, A. (2013). *Reducing ship generated marine litter—Recommendations to improve the EU port reception facilities directive*. International Institute for European Environmental Studies. http://minisites.ieep.eu/assets/1257/IEEP_2013_Reducing_ship_generated_marine_litter_-_recommendations_to_improve_the_PRF_Directive.pdf

Okoffo, E. D., O'Brien, S., O'Brien, J. W., Tscharke, B. J., & Thomas, K. V. (2019). Wastewater treatment plants as a source of plastics in the environment: A review of occurrence, methods for identification, quantification and fate. *Environmental Science: Water Research & Technology, 5*, 1908–1931. https://doi.org/10.1039/C9EW00428A

Okoffo, E. D., Tscharke, B. J., O'Brien, J. W., O'Brien, S., Ribeiro, F., Burrows, S. D., Choi, P. M., Wang, X., Mueller, J. F., & Thomas, K. V. (2020). Release of plastics to australian land from biosolids end-use. *Environmental Science & Technology*, *54*, 15132–15141. https://doi.org/10.1021/acs.est.0c05867

Okoffo, E. D., O'Brien, S., Ribeiro, F., Burrows, S. D., Toapanta, T., Rauert, C., et al. (2021). Plastic particles in soil: State of the knowledge on sources, occurrence and distribution, analytical methods and ecological impacts. *Environmental Science-Processes & Impacts, 23*, 240–274. https://doi.org/10.1039/D0EM00312C

Okuku, E., Kiteresi, L., Owato, G., Otieno, K., Mwalugha, C., Mbuche, M., et al. (2021a). 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. *Marine Pollution Bulletin, 162*, 111840. https://doi.org/10.1016/j.marpolbul.2020.111840

Okuku, E. O., Kiteresi, L., Owato, G., Otieno, K., Omire, J., Kombo, M. M., et al. (2021b). Temporal trends of marine litter in a tropical recreational beach: A case study of Mkomani beach, Kenya. *Marine Pollution Bulletin, 167*, 112273. https://doi.org/10.1016/j.marpolbul.2021.112273

Okuku, E. O., Kiteresi, L. I., Owato, G., Mwalugha, C., Omire, J., Mbuche, M., et al. (2020a). Baseline meso-litter pollution in selected coastal beaches of Kenya: Where do we concentrate our intervention efforts? *Marine Pollution Bulletin, 158*, 111420. https://doi.org/10.1016/j.marpolbul.2020.111420

Okuku, E. O., Kiteresi, L. I., Owato, G., Mwalugha, C., Omire, J., Otieno, K., et al. (2020b). Marine macro-litter composition and distribution along the Kenyan Coast: The first-ever documented study. *Marine Pollution Bulletin, 159*, 111497. https://doi.org/10.1016/j.marpolbul.2020.111497

Oni, B. A., Ayeni, A. O., Agboola, O., Oguntade, T., & Obanla, O. (2020). Comparing microplastics contaminants in (dry and raining) seasons for Ox-Bow Lake in Yenagoa, Nigeria. *Ecotoxicology and Environmental Safety, 198*, 8. https://doi.org/10.1016/j.ecoenv.2020.110656

Onwuegbuchunam, D. E., Ebe, T. E., Okoroji, L. I., & Essien, A. E. (2017a). An analysis of ship-source marine pollution in Nigeria seaports. *Journal of Marine Science and Engineering, 5*, 39. https://doi.org/10.3390/jmse5030039

Onwuegbuchunam, D. E., Ogwude, I. C., Ibe, C. C., & Emenike, G. C. (2017b). Framework for management and control of marine pollution in Nigeria seaports. *American Journal of Traffic and Transportation Engineering, 2*, 59–66. https://doi.org/10.11648/j.ajtte.20170205.11

Osaloni, O. S. (2019). *The legal regulation of port waste management in the United Kingdom and Nigeria: Comparative analysis of Southampton Port in the UK and Apapa Port in Nigeria* [PhD]. The University of Central Lancashire. https://www.semanticscholar.org/paper/The-legal-regulation-of-port-waste-management-in-%3A-Osaloni/9878d4de4f6fe1423d7b93d9e6012a37977e6338

Pedrotti, M. L., Petit, S., Eyheraguibel, B., Kerros, M. E., Elineau, A., Ghiglione, J. F., et al. (2021). Pollution by anthropogenic microfibers in north-west Mediterranean Sea and efficiency of microfiber removal by a wastewater treatment plant. *Science of the Total Environment, 758*, 144195. https://doi.org/10.1016/j.scitotenv.2020.144195

Peters, J. K., & Marvis, A. N. (2019). *Assessment of port reception facilities and waste management control in Nigeria: Case study: (Tin Can Island Port)* [World Maritime University Dissertations]. https://commons.wmu.se/cgi/viewcontent.cgi?article=2213&context=all_dissertations

PlasticsSA. (2018). *All about plastics*.

Pohl, F., Eggenhuisen, J. T., Kane, I. A., & Clare, M. A. (2020). Transport and burial of microplastics in deep-marine sediments by turbidity currents. *Environmental Science & Technology, 54*, 4180–4189. https://doi.org/10.1021/acs.est.9b07527

Pramanik, B. K., Roychand, R., Monira, S., Bhuiyan, M., & Jegatheesan, V. (2020). Fate of road-dust associated microplastics and per- and polyfluorinated substances in stormwater. *Process Safety and Environmental Protection, 144*, 236–241. https://doi.org/10.1016/j.psep.2020.07.020

Preston-Whyte, F., Silburn, B., Meakins, B., Bakir, A., Pillay, K., Worship, M., et al. (2021). Meso- and microplastics monitoring in harbour environments: A case study for the Port of Durban, South Africa. *Marine Pollution Bulletin, 163*, 111948. https://doi.org/10.1016/j.marpolbul.2020.111948

Qi, Y. L., Beriot, N., Gort, G., Lwanga, E. H., Gooren, H., Yang, X. M., et al. (2020). Impact of plastic mulch film debris on soil physicochemical and hydrological properties. *Environmental Pollution, 266*, 9. https://doi.org/10.1016/j.envpol.2020.115097

REMPEC. (2005). *Port reception facilities: A summary of REMPEC's activities in the Mediterranean region*. REMPEC (Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea). https://euroshore.com/sites/euroshore.com/files/downloads/port%20reception%20facilities%20final.pdf

Richardson, K., Hardesty, B. D., & Wilcox, C. (2019). Estimates of fishing gear loss rates at a global scale: A literature review and meta-analysis. *Fish and Fisheries, 20*, 1218–1231. https://doi.org/10.1111/faf.12407

Ryan, P. G. (1988). The characteristics and distribution of plastic particles at the sea-surface off the southwestern Cape Province, South Africa. *Marine Environmental Research, 25*, 249–273. https://doi.org/10.1016/0141-1136(88)90015-3

Ryan, P. G. (2014). Litter survey detects the South Atlantic 'garbage patch'. *Marine Pollution Bulletin, 79*, 220–224. https://doi.org/10.1016/j.marpolbul.2013.12.010

Ryan, P. G. (2020a). Land or sea? What bottles tell us about the origins of beach litter in Kenya. *Waste Management, 116*, 49–57. https://doi.org/10.1016/j.wasman.2020.07.044

Ryan, P. G. (2020b). The transport and fate of marine plastics in South Africa and adjacent oceans. *South African Journal of Science, 116*, 34–42.

Ryan, P. G., Bouwman, H., Moloney, C. L., Yuyama, M., & Takada, H. (2012). Long-term decreases in persistent organic pollutants in South African coastal waters detected from beached polyethylene pellets. *Marine Pollution Bulletin, 64*, 2756–2760. https://doi.org/10.1016/j.marpolbul.2012.09.013

Ryan, P. G., Dilley, B. J., Ronconi, R. A., & Connan, M. (2019). Rapid increase in Asian bottles in the South Atlantic Ocean indicates major debris inputs from ships. *Proceedings of the National Academy of Sciences, 116*, 20892–20897. https://doi.org/10.1073/pnas.1909816116

Ryan, P. G., Lamprecht, A., Swanepoel, D., & Moloney, C. L. (2014a). The effect of fine-scale sampling frequency on estimates of beach litter accumulation. *Marine Pollution Bulletin, 88*, 249–254. https://doi.org/10.1016/j.marpolbul.2014.08.036

Ryan, P. G., Maclean, K., & Weideman, E. A. (2020a). The impact of the COVID-19 lockdown on urban street litter in South Africa. *Environmental Processes, 7*, 1303–1312. https://doi.org/10.1007/s40710-020-00472-1

Ryan, P. G., & Moloney, C. L. (1990). Plastic and other artifacts on South-African beaches—Temporal trends in abundance and composition. *South African Journal of Science, 86*, 450–452. https://www.researchgate.net/publication/283507743_plastic_and_other_artefacts_on_South_African_beaches_temporal_trends_in_abundance_and_composition

Ryan, P. G., Moore, C. J., Van Franeker, J. A., & Moloney, C. L. (2009). Monitoring the abundance of plastic debris in the marine environment. *Philosophical Transactions of the Royal Society B-Biological Sciences, 364*, 1999–2012. https://doi.org/10.1098/rstb.2008.0207

Ryan, P. G., Musker, S., & Rink, A. (2014b). Low densities of drifting litter in the African sector of the Southern Ocean. *Marine Pollution Bulletin, 89*, 16–19. https://doi.org/10.1016/j.marpolbul.2014.10.043

Ryan, P. G., & Perold, V. (2021). Limited dispersal of riverine litter onto nearby beaches during rainfall events. *Estuarine, Coastal and Shelf Science, 251*, 107186. https://doi.org/10.1016/j.ecss.2021.107186

Ryan, P. G., Perold, V., Osborne, A., & Moloney, C. L. (2018). Consistent patterns of debris on South African beaches indicate that industrial pellets and other mesoplastic items mostly derive from local sources. *Environmental Pollution, 238*, 1008–1016. https://doi.org/10.1016/j.envpol.2018.02.017

Ryan, P. G., Pichegru, L., Perold, V., & Moloney, C. L. (2020b). Monitoring marine plastics—Will we know if we are making a difference? *South African Journal of Science, 116*, 58–66. https://sajs.co.za/article/view/7678/9944

Ryan, P. G., Weideman, E. A., Perold, V., Durholtz, D., & Fairweather, T. P. (2020c). A trawl survey of seafloor macrolitter on the South African continental shelf. *Marine Pollution Bulletin, 150*, 6. https://doi.org/10.1016/j.marpolbul.2019.110741

Ryan, P. G., Weideman, E. A., Perold, V., Hofmeyr, G., & Connan, M. (2021). Message in a bottle: Assessing the sources and origins of beach litter to tackle marine pollution. *Environmental Pollution, 288*, 117729. https://doi.org/10.1016/j.envpol.2021.117729

Ryan, P. G., Weideman, E. A., Perold, V., & Moloney, C. L. (2020d). Toward balancing the budget: Surface macro-plastics dominate the mass of particulate pollution stranded on beaches. *Frontiers in Marine Science, 7*, 14. https://doi.org/10.3389/fmars.2020.575395

Scheren, P. A., Ibe, A. C., Janssen, F. J., & Lemmens, A. M. (2002). Environmental pollution in the Gulf of Guinea—A regional approach. *Marine Pollution Bulletin, 44*, 633–641. https://doi.org/10.1016/s0025-326x(01)00305-8

Schmidt, C., Krauth, T., & Wagner, S. (2017). Export of plastic debris by rivers into the sea. *Environmental Science & Technology, 51*, 12246–12253. https://doi.org/10.1021/acs.est.7b02368

Schumann, E. H., Mackay, C. F., & Strydom, N. A. (2019). Nurdle drifters around South Africa as indicators of ocean structures and dispersion. *South African Journal of Science, 115*, 1–9. https://doi.org/10.17159/sajs.2019/5372

Seeruttun, L. D., Raghbor, P., & Appadoo, C. (2021). First assessment of anthropogenic marine debris in mangrove forests of Mauritius, a small oceanic island. *Marine Pollution Bulletin, 164*, 112019. https://doi.org/10.1016/j.marpolbul.2021.112019

Shabaka, S. H., Ghobashy, M., & Marey, R. S. (2019). Identification of marine microplastics in Eastern Harbor, Mediterranean Coast of Egypt, using differential scanning calorimetry. *Marine Pollution Bulletin, 142*, 494–503. https://doi.org/10.1016/j.marpolbul.2019.03.062

Shruti, V. C., Pérez-Guevara, F., Elizalde-Martínez, I., & Kutralam-Muniasamy, G. (2020). Reusable masks for COVID-19: A missing piece of the microplastic problem during the global health crisis. *Marine Pollution Bulletin, 161*, 111777–111777. https://doi.org/10.1016/j.marpolbul.2020.111777

Siegfried, M., Koelmans, A. A., Besseling, E., & Kroeze, C. (2017). Export of microplastics from land to sea. A modelling approach. *Water Research, 127*, 249–257. https://doi.org/10.1016/j.watres.2017.10.011

Stoler, J. (2017). From curiosity to commodity: A review of the evolution of sachet drinking water in West Africa. *Wires Water, 4*, e1206. https://doi.org/10.1002/wat2.1206

Suaria, G., Achtypi, A., Perold, V., Lee, J. R., Pierucci, A., Bornman, T. G., et al. (2020a). Microfibers in oceanic surface waters: A global characterization. *Science Advances, 6*, eaay8493. https://doi.org/10.1126/sciadv.aay8493

Suaria, G., Perold, V., Lee, J. R., Lebouard, F., Aliani, S., & Ryan, P. G. (2020b). Floating macro- and microplastics around the Southern Ocean: Results from the Antarctic circumnavigation expedition. *Environment International, 136*, 105494. https://doi.org/10.1016/j.envint.2020.105494

Taïbi, N.-E., Bentaallah, M. E. A., Alomar, C., Compa, M., & Deudero, S. (2021). Micro- and macro-plastics in beach sediment of the Algerian western coast: First data on distribution, characterization, and source. *Marine Pollution Bulletin, 165*, 112168. https://doi.org/10.1016/j.marpolbul.2021.112168

Talvitie, J., Mikola, A., Setälä, O., Heinonen, M., & Koistinen, A. (2017). How well is microlitter purified from wastewater?—A detailed study on the stepwise removal of microlitter in a tertiary level wastewater treatment plant. *Water Research, 109*, 164–172. https://doi.org/10.1016/j.watres.2016.11.046

Tata, T., Belabed, B. E., Bououdina, M., & Bellucci, S. (2020). Occurrence and characterization of surface sediment microplastics and litter from North African coasts of Mediterranean Sea: Preliminary research and first evidence. *Science of the Total Environment, 713*, 136664. https://doi.org/10.1016/j.scitotenv.2020.136664

Thiele, C. J., Hudson, M. D., Russell, A. E., Saluveer, M., & Sidaoui-Haddad, G. (2021). Microplastics in fish and fishmeal: An emerging environmental challenge? *Scientific Reports, 11*, 2045. https://doi.org/10.1038/s41598-021-81499-8

Thomas, M. L. H., Channon, A. A., Bain, R. E. S., Nyamai, M., & Wright, J. A. (2020). Household-reported availability of drinking water in Africa: A systematic review. *Water, 12*. https://doi.org/10.3390/w12092603

Torres, F. G., Dioses-Salinas, D. C., Pizarro-Ortega, C. I., & De-La-Torre, G. E. (2021). Sorption of chemical contaminants on degradable and non-degradable microplastics: Recent progress and research trends. *Science of the Total Environment, 757*, 143875. https://doi.org/10.1016/j.scitotenv.2020.143875

Toumi, H., Abidli, S., & Bejaoui, M. (2019). Microplastics in freshwater environment: The first evaluation in sediments from seven water streams surrounding the lagoon of Bizerte (Northern Tunisia). *Environmental Science and Pollution Research, 26*, 14673–14682. https://doi.org/10.1007/s11356-019-04695-0

Tramoy, R., Gasperi, J., Colasse, L., & Tassin, B. (2020). Transfer dynamic of macroplastics in estuaries—New insights from the Seine estuary: Part 1. Long term dynamic based on date-prints on stranded debris. *Marine Pollution Bulletin, 152*. https://doi.org/10.1016/j.marpolbul.2020.110894

Tsagbey, S. A., Mensah, A., & Nunoo, F. (2009). Influence of tourist pressure on beach litter and microbial quality—Case study of two beach resorts in Ghana. *West African Journal of Applied Ecology, 15*, 11–18. https://doi.org/10.4314/wajae.v15i1.49423

Uddin, S., Fowler, S. W., & Behbehani, M. (2020). An assessment of microplastic inputs into the aquatic environment from wastewater streams. *Marine Pollution Bulletin, 160*, 111538. https://doi.org/10.1016/j.marpolbul.2020.111538

UNEP. (1999). *Overview of land-based sources and activities affecting the marine, coastal and associated freshwater environment in the West and Central African Region* [UNEP Regional Seas Reports and Studies No. 171]. https://aquadocs.org/bitstream/handle/1834/800/UNEP171.pdf?sequence=1&isAllowed=y

UNEP. (2015). *Plastic in cosmetics*. https://wedocs.unep.org/handle/20.500.11822/21754

UNEP. (2018a). In P. Notten (Ed.). *Addressing marine plastics: A systemic approach—Stocktaking report*. United Nations Environment Programme. https://www.unep.org/resources/report/addressing-marine-plastics-systemic-approach-stocktaking-report

UNEP. (2018b). *Africa waste management outlook*. United Nations Environment Programme. https://wedocs.unep.org/handle/20.500.11822/25514

UNEP. (2019). *Small island developing states waste management outlook*. United Nations Environment Programme. https://www.unep.org/ietc/node/44

UNEP. (2020). *Monitoring plastics in rivers and lakes: Guidelines for the harmonization of methodologies*. https://wedocs.unep.org/bitstream/handle/20.500.11822/35405/MPRL.pdf

Van Calcar, C. J., & Van Emmerik, T. H. M. (2019). Abundance of plastic debris across European and Asian rivers. *Environmental Research Letters, 14*, 124051. https://doi.org/10.1088/1748-9326/ab5468

Van Der Mheen, M., Van Sebille, E., & Pattiaratchi, C. (2020). Beaching patterns of plastic debris along the Indian Ocean rim. *Ocean Science, 16*, 1317–1336. https://doi.org/10.5194/os-16-1317-2020

Van Dyck, I. P., Nunoo, F. K. E., & Lawson, E. T. (2016). An empirical assessment of marine debris, seawater quality and littering in Ghana. *Journal of Geoscience and Environment Protection, 04*, 21–36. https://doi.org/10.4236/gep.2016.45003

Van Sebille, E., Wilcox, C., Lebreton, L., Maximenko, N., Hardesty, B. D., Van Franeker, J. A., et al. (2015). A global inventory of small floating plastic debris. *Environmental Research Letters, 10*, 11. https://doi.org/10.1088/1748-9326/10/12/124006

Vapnek, J., & Williams, A. R. (2017). Regulating the packaged water industry in Africa: Challenges and recommendations, 20U. *Denver Water Law Review, 217*. https://repository.uchastings.edu/cgi/viewcontent.cgi?article=2631&context=faculty_scholarship

Velez, N., Zardi, G. I., Lo Savio, R., Mcquaid, C. D., Valbusa, U., Sabour, B., et al. (2019). A baseline assessment of beach macrolitter and microplastics along northeastern Atlantic shores. *Marine Pollution Bulletin, 149*, 110649. https://doi.org/10.1016/j.marpolbul.2019.110649

Verster, C., & Bouwman, H. (2020). Land-based sources and pathways of marine plastics in a South African context. *South African Journal of Science, 116*, 25–33. https://doi.org/10.17159/sajs.2020/7700

Vetrimurugan, E., Jonathan, M. P., Sarkar, S. K., Rodríguez-González, F., Roy, P. D., Velumani, S., et al. (2020). Occurrence, distribution and provenance of micro plastics: A large scale quantitative analysis of beach sediments from southeastern coast of South Africa. *Science of the Total Environment, 746*, 141103. https://doi.org/10.1016/j.scitotenv.2020.141103

Vilakati, B., Sivasankar, V., Mamba, B. B., Omine, K., & Msagati, T. A. M. (2020). Characterization of plastic micro particles in the Atlantic Ocean seashore of Cape Town, South Africa and mass spectrometry analysis of pyrolyzate products. *Environmental Pollution, 265*, 114859. https://doi.org/10.1016/j.envpol.2020.114859

Wakkaf, T., El Zrelli, R., Kedzierski, M., Balti, R., Shaiek, M., Mansour, L., et al. (2020). Characterization of microplastics in the surface waters of an urban lagoon (Bizerte lagoon, Southern Mediterranean Sea): Composition, density, distribution, and influence of environmental factors. *Marine Pollution Bulletin, 160*, 111625. https://doi.org/10.1016/j.marpolbul.2020.111625

Wallace, B., & Coe, J. M. (1998). *Guidelines for the provision of garbage reception facilities at ports under MARPOL Annex V*. NOAA Tech. Rep. U.S. Department of Commerce. https://aquadocs.org/handle/1834/20471?locale-attribute=en

Wang, H., Wang, T., Zhang, B., Li, F., Toure, B., Omosa, I. B., et al. (2014). Water and wastewater treatment in Africa—Current practices and challenges. *CLEAN—Soil, Air, Water, 42*, 1029–1035. https://doi.org/10.1002/clen.201300208

Weideman, E. A., Perold, V., Arnold, G., & Ryan, P. G. (2020a). Quantifying changes in litter loads in urban stormwater run-off from Cape Town, South Africa, over the last two decades. *Science of the Total Environment, 724*, 9. https://doi.org/10.1016/j.scitotenv.2020.138310

Weideman, E. A., Perold, V., Omardien, A., Smyth, L. K., & Ryan, P. G. (2020b). Quantifying temporal trends in anthropogenic litter in a rocky intertidal habitat. *Marine Pollution Bulletin, 160*, 10. https://doi.org/10.1016/j.marpolbul.2020.111543

Weideman, E. A., Perold, V., & Ryan, P. G. (2020c). Limited long-distance transport of plastic pollution by the Orange-Vaal River system, South Africa. *Science of the Total Environment, 727*, 11. https://doi.org/10.1016/j.scitotenv.2020.138653

Weideman, E. A., Perold, V., & Ryan, P. G. (2019). Little evidence that dams in the Orange-Vaal River system trap floating microplastics or microfibres. *Marine Pollution Bulletin, 149*, 110664. https://doi.org/10.1016/j.marpolbul.2019.110664

Weithmann, N., Moller, J. N., Loder, M. G. J., Piehl, S., Laforsch, C., & Freitag, R. (2018). Organic fertilizer as a vehicle for the entry of microplastic into the environment. *Science Advances, 4*, 7. https://doi.org/10.1126/sciadv.aap8060

Woodall, L. C., Robinson, L. F., Rogers, A. D., Narayanaswamy, B. E., & Paterson, G. L. J. (2015). Deep-sea litter: A comparison of seamounts, banks and a ridge in the Atlantic and Indian Oceans reveals both environmental and anthropogenic factors impact accumulation and composition. *Frontiers in Marine Science, 2*, 3. https://doi.org/10.3389/fmars.2015.00003

Wright, S. L., Ulke, J., Font, A., Chan, K. L. A., & Kelly, F. J. (2020). Atmospheric microplastic deposition in an urban environment and an evaluation of transport. *Environment International, 136*, 105411. https://doi.org/10.1016/j.envint.2019.105411

WWAP. (2015). *The United Nations world water development report 2015: Wastewater, the untapped resource*. United Nations World Water Assessment Programme. https://www.unwater.org/publications/world-water-development-report-2015/

WWAP. (2017). *The United Nations world water development report 2017: Wastewater, the untapped resource*. United Nations World Water Assessment Programme. https://wedocs.unep.org/handle/20.500.11822/20448

Yang, Z., Lü, F., Zhang, H., Wang, W., Shao, L., Ye, J., et al. (2021). Is incineration the terminator of plastics and microplastics? *Journal of Hazardous Materials, 401*, 123429. https://doi.org/10.1016/j.jhazmat.2020.123429

Zayen, A., Sayadi, S., Chevalier, C., Boukthir, M., Ben Ismail, S., & Tedetti, M. (2020). Microplastics in surface waters of the Gulf of Gabes, southern Mediterranean Sea: Distribution, composition and influence of hydrodynamics. *Estuarine, Coastal and Shelf Science, 242*, 106832. https://doi.org/10.1016/j.ecss.2020.106832

Zhang, Y., Kang, S., Allen, S., Allen, D., Gao, T., & Sillanpää, M. (2020). Atmospheric microplastics: A review on current status and perspectives. *Earth-Science Reviews, 203*, 103118. https://doi.org/10.1016/j.earscirev.2020.103118

Zhou, A., Zhang, Y., Xie, S., Chen, Y., Li, X., Wang, J., et al. (2020a). Microplastics and their potential effects on the aquaculture systems: A critical review. *Reviews in Aquaculture, 13*. https://doi.org/10.1111/raq.12496

Zhou, H., Zhou, L., & Ma, K. (2020b). Microfiber from textile dyeing and printing wastewater of a typical industrial park in China: Occurrence, removal and release. *Science of The Total Environment, 739*, 140329. https://doi.org/10.1016/j.scitotenv.2020.140329