Marine Policy 96 (2018) 256–263

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Challenges and emerging solutions to the land-based plastic waste issue in Africa

Jenna Jambeck[a], Britta Denise Hardesty[b,*], Amy L. Brooks[a], Tessa Friend[c], Kristian Teleki[c], Joan Fabres[d], Yannick Beaudoin[d], Abou Bamba[e], Julius Francis[f], Anthony J. Ribbink[g], Tatjana Baleta[g], Hindrik Bouwman[h], Jonathan Knox[i], Chris Wilcox[b]

[a] Center for Circular Materials Management and College of Engineering, University of Georgia, United States of America
[b] CSIRO Oceans and Atmosphere, Hobart, Tasmania, Australia
[c] Prince of Wales's International Sustainability Unit, Clarence House, London SW1A1BA, United Kingdom
[d] GRID-Arendal, P.O. Box 183, N-4802 Arendal, Norway
[e] Abidjan Convention, Ecosystem Division, UN Environment, Côte d'Ivoire, Abidjan - II Plateaux-Vallon, Rue Harris Memel Foteh, 01 BP 1747 Abj 01, Côte d'Ivoire
[f] Western Indian Ocean Marine Science Association (WIOMSA), University of Dar es Salaam, P. O. Box 3298, Zanzibar, United Republic of Tanzania
[g] Sustainable Seas Trust, P.O. Box 77, Kenton 6191, South Africa
[h] Research Unit: Environmental Sciences and Management, North-West University, Potchefstroom, South Africa
[i] Fauna & Flora International, The David Attenborough Building, Pembroke Street, Cambridge CB2 3QZ, UK

ARTICLE INFO

Keywords:
Circular economy
Economic development
Governance
Plastics production
Waste management

ABSTRACT

In recent years, there has been a tremendous increase in work that focuses on the amount and types of waste entering the marine environment from multiple geographies around the world. To date, however, there are few reports about the scale of waste entering the coastal and oceanic waters around Africa. To address this knowledge gap, existing information was collated on waste mismanagement that can become marine debris in Africa at the continental scale. This paper focuses on identifying sources and seeking solutions to waste mismanagement. Stories are shared about opportunities that have arisen and solutions that are taking place in several countries around Africa. Finally, impediments to success are discussed and sectors are described where investments can be made to significantly reduce this growing global problem.

1. Introduction

Plastic has been found on the remotest of beaches; afloat in the middle of the ocean; frozen within polar ice; building up on the sea floor; and inside marine animals and sea birds. Global cumulative production of plastic since 1950 equals 8.3 billion metric tons, with half of that being produced in the past 13 years and projected to increase in the future [1]. In fact, this manufactured material is now recognised as being one of the most noticeable pollutants affecting the ocean worldwide [2].

Recent studies have suggested that the ocean receives an estimated 8 million metric tonnes of plastic waste per year [3]. As plastic remains in the environment for hundreds of years, the trillions of plastic pieces accumulating in the ocean form part of a global pollution issue that affects all coastal countries [4]. In parallel with this stark reality, levels of awareness of this issue have grown alongside a global consensus that action must be taken to stem the flow of plastic entering the ocean.

Ecological, economic, and aesthetic damage are also associated with marine debris and especially plastic debris. Plastic waste in our ocean results in harm to wildlife [5,6, 7, 8], with nearly 700 species known to interact with anthropogenic debris [6]. While the population level impacts associated with plastic impacts on marine fauna are not well quantified across multiple taxa [5], there is still ample cause for concern. Floating plastic also provides habitat for the transport of invasive species [9], can be a navigation hazard [10], and can result in significant losses in tourism revenue, as has been reported in California [11] and Korea [12] al.,.

Current estimates of the volume and weight of plastic entering the ocean from land have been generally based on the following indicators: (i) waste generation per capita, (ii) proportion of waste that is plastic

* Corresponding author.
E-mail addresses: jjambeck@engr.uga.edu (J. Jambeck), Denise.Hardesty@csiro.au (B.D. Hardesty), abrooks@engr.uga.edu (A.L. Brooks), tessa.friend@royal.gsx.gov.uk (T. Friend), kristian.teleki@royal.gsx.gov.uk (K. Teleki), Joan.Fabres@grida.no (J. Fabres), Yannick.Beaudoin@grida.no (Y. Beaudoin), abou.bamba@unenvironment.org (A. Bamba), julius@wiomsa.org (J. Francis), a.ribbink@sst.org.za (A.J. Ribbink), t.baleta@sst.org.za (T. Baleta), henk.bouwman@nwu.ac.za (H. Bouwman), jonathan.knox@fauna-flora.org (J. Knox), Chris.Wilcox@csiro.au (C. Wilcox).

https://doi.org/10.1016/j.marpol.2017.10.041
Received 6 August 2017; Received in revised form 18 October 2017; Accepted 27 October 2017
Available online 02 December 2017
0308-597X/

and (iii) percentage of waste that is mismanaged. Calculations using globally available data at the time have shown that rapidly developing economies (e.g., Southeast Asia) that have not been able to keep pace with solid waste management infrastructure can contribute significantly to marine debris [3]. However, data has been challenging to access on this subject and with even less available data available from the majority of countries in Africa, the amount of mismanaged waste in this region is more difficult to estimate with accuracy. Plastics have been used in Africa since the late 1950s, long before adequate recycling policies were in place. Hence, a significant portion of this durable material is likely to still remain in the environment.

This knowledge gap is addressed for the continent with the largest population growth globally [13]. The best available information are used to make an estimate of likely sources of marine waste in Africa. We also focused on quantifying the scale of the problem, identifying much-needed solutions and opportunities for investments. Finally, several successful interventions that are currently being employed to reduce the problem before it reaches the ocean are discussed.

2. A continental overview of Africa

Africa is experiencing unprecedented population growth with predictions that it will add 1.3 billion people to the planet by 2050 [13]. This is the equivalent of 3.5 million more people per month, or 80 additional people per minute, thus making Africa the biggest contributor to the future global population growth [13]. Furthermore, the highest rates of population growth and urbanisation are expected in the coastal zone with an estimated 49 million more people in low elevation coastal flood plains by 2060 [14]. Alongside this rapid rate of urbanisation, Africa's growing middle class is creating large consumer markets for plastic goods and those packaged in plastic with supermarkets now replacing informal shops and markets [15]. Eighty percent of the continent's GDP is concentrated in just 11 African countries (Nigeria, South Africa, Egypt, Algeria, Angola, Morocco, Sudan, Tunisia, Kenya, Ghana and Libya) - all of which are have prominent coastlines [15].

Similar to the expanding coastal populations in Africa, there are an increasing number of people, in high densities, living short distances from river systems (Fig. 1). For example, the population density of the Nile Delta is 1000 people per square kilometre which is much higher than the global average for coastal areas (80 people per square kilometre) [16]. The extensive river basins of the Niger, Congo, Zambezi and the Nile contain some of the largest cities in the world and empty a significant volume of freshwater into the Atlantic Ocean, Indian Ocean and Mediterranean Sea. A lack of adequate waste management infrastructure in these areas also means that these rivers are likely to transport a large quantity of land-based waste, including plastic pollution, as they make their way to the ocean [17].

While land-based sources of waste entering the ocean are significant, mismanaged waste resulting from Africa's shipping and maritime activities such as aquaculture and fishing also enters the ocean. Abandoned, lost or otherwise discarded fishing gear contributes an estimated additional 640,000 t of marine debris globally [18]. Similarly, studies have shown that polystyrene buoys used in aquaculture can result in large amounts of plastic debris ending up in the ocean and washed up on beaches [19, 20]. One study from a South Korean beach in close proximity to an aquaculture farm found that polystyrene particles from aquaculture contributed 95% of all plastic debris encountered [19]. With over 12 million people engaged in Africa's fisheries sector [21], plastic pollution from this sector alone is likely to be a non-trivial factor in African waters. Furthermore, given that subsistence fishing is significant in African countries and the proportion of protein intake from fish is high (i.e. 50% in Mozambique, 60% in Sierra Leone and Ghana, and 70% in Tanzania) [22], marine debris represents a potential threat to food security, economic development, the viability of the marine ecosystems and establishment of a vibrant and productive 'blue economy' (the term used to describe the concept of sustainable use of the ocean's resources for continued growth, economic benefit, and improved livelihoods whilst ensuring marine ecosystem health and persistence) [22].

The increasing trend in per capita consumption, urbanisation, and population growth is concerning when combined with a lack of sufficient infrastructure to manage the increased waste generation. Plastic waste presents not only an environmental issue for African countries but also a major socio-economic development challenge which impacts biodiversity, infrastructure, tourism and fisheries livelihoods. The lack of clean drinking water only exacerbates the problem, as in many city centers, even drinking water is packaged in single use sachets and plastic bags [23]. The projected growth and "business-as-usual" scenarios of mismanaged plastic waste present a significant risk to human health, the environment and the economy. For example, in the Ghanaian capital of Accra, plastic bags and other plastic consumer goods accumulated in waterways and clogged drains during heavy rains in 2015. These plastic products caused a significant flooding event in which at least 150 people died and millions of dollars of damage occurred [24]. In response to the environmental and health threat posed by plastic bags, more than 20 countries on the African continent have now put bag bans and taxes in place [25] (Fig. 2). However, appropriate enforcement mechanisms remain a challenge. Furthermore, improperly disposed waste on land may also contribute to the spread of disease by providing standing water for mosquitoes to use as breeding grounds. This can enable the spread of diseases such as Zika virus, Dengue fever, malaria and Chikungunya [26].

Although the data is patchy, a recent study estimates the quantity of mismanaged plastic waste available to enter the ocean from each of Africa's coastal and island countries [3]. Of particular relevance are Egypt, Nigeria, South Africa, Algeria and Morocco which are estimated to be among the top 20 countries around the world contributing to marine debris each year (see Fig. 3 for an estimate of the quantities of mismanaged plastic waste available to enter the ocean for 2010 and without any changes ("business as usual"), the estimated quantities of land-based waste entering the ocean by 2025). Based on the best available country-level data (from [3]), the total mismanaged plastic waste (out of 32 million metric tons globally) for the continent is estimated at 4.4 million metric tons in 2010. This could be as high as 10.5 million metric tons in 2025 if nothing changes to deliberately reduce the flow of land-based plastics to the ocean (Fig. 3).

3. Drivers, sources and movement of marine debris

Plastic and microplastic has recently been documented in and around the African continent [27]. Waste or debris can end up in the environment through a variety of pathways and as such there are often clear patterns between plastic in the marine environment and plastic waste from nearby sites. With the majority of studies on the drivers, sources and movement of debris having been conducted outside of Africa, there is a significant lack of survey data from this region. However, these patterns can be used to create models that predict the amount of waste at un-surveyed sites. As such, the information from other international studies can provide a basis for inferring contexts where the amounts are particularly high and concerted action and investment have maximum effect.

Global analyses have identified a number of variables that affect waste loads, including weather-related variables (e.g. wind force, water flows), socioeconomic factors, population density and accessibility to a particular location[28]. Studies have shown that the primary pathway for waste entering the ocean includes human movement and behaviour (littering or dropping items), vehicular transport, wind and water (i.e. along rivers, creeks, streams and stormwater outfalls)[28]. Studies have also found that human deposition was by far the most important factor in determining the debris load at a site [28]. Accordingly, it has been argued that the three strongest predictors of debris at a site had to do with economic wealth and social disadvantage in the population near

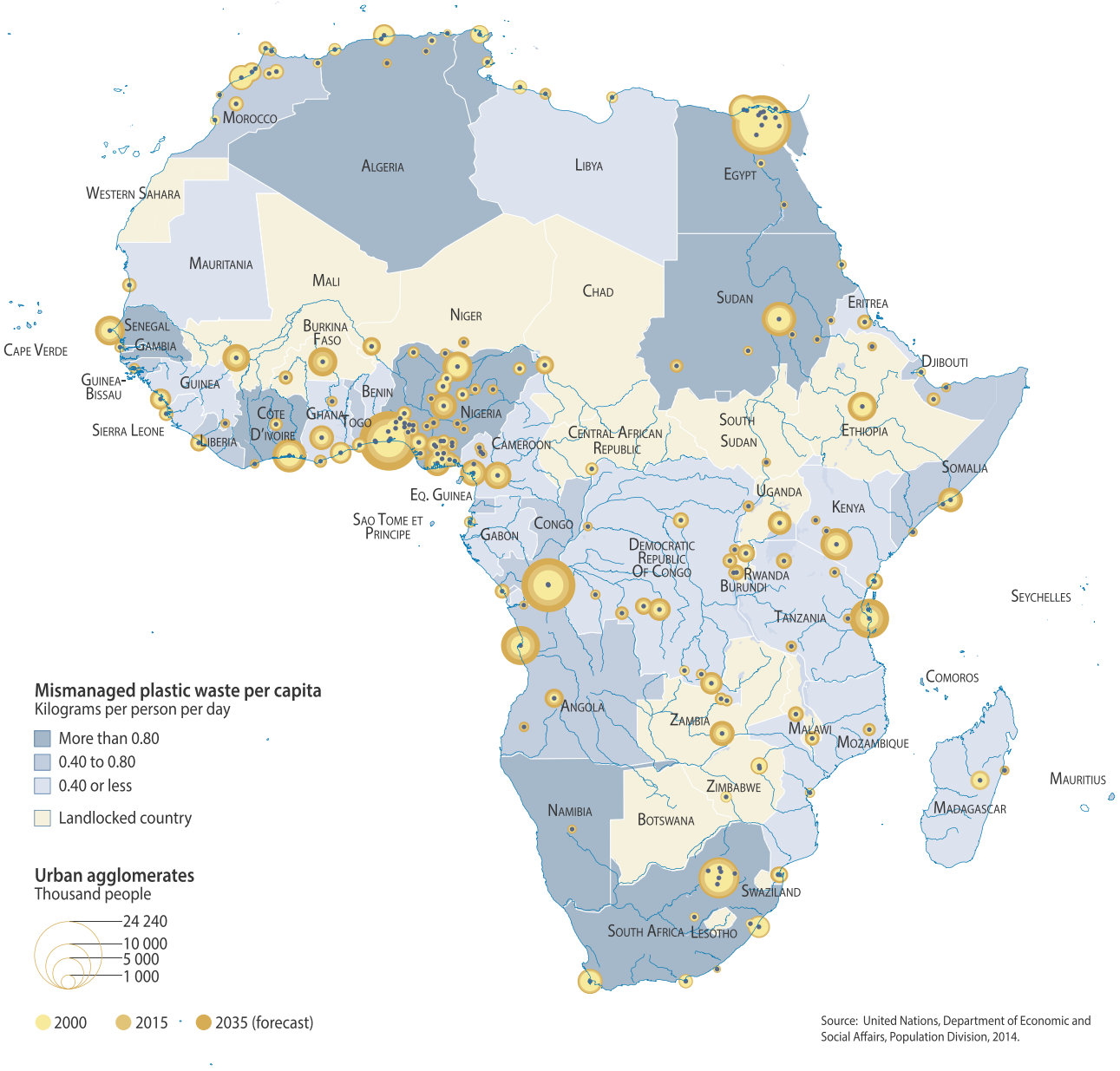

Fig. 1. Waste generation rates and urban population centers in Africa.

the site making it critical to target particular population segments when identifying intervention points [28]. While improper waste disposal is a key driver of the amount of debris at a site, transport by wind and water are also important. Areas downwind and downstream act as sinks, accumulating debris from other sites.

Models predicting waste loads and flows not only provide a useful way of estimating sources of marine debris, but can also inform mitigation and management strategies. Given the important role that waterways play in transporting waste, debris traps in surface, stormwater and wastewater systems are a useful intervention. Using models to anticipate the load that would be expected given the location of the trap, it is possible to identify where to best allocate funds and staff time in installing and maintaining such infrastructure to maximise efficiency. Given the likelihood for transport along rivers, creeks and streams to the marine environment, reducing loads in watercourses is a vital action. To better understand the dynamics of waste in Africa, geographically-relevant studies on the drivers, sources and pathways of marine debris from across the continent are also needed.

4. Current governance instruments that address marine debris

Due to the varied sources, pathways and persistence of plastic debris in the marine environment, there are a myriad of environmental regulations with a bearing on how to address this issue. These range from global generic instruments on marine environmental protection and pollution, to regional marine debris action plans and specific product bans at the national or municipal level [29].

In Africa, the most common policy at country level currently is the ban or taxes on plastic bags. Mauritania was the first country to adopt such a policy. This policy followed the loss of up to 70% of livestock to plastic ingestion [30]. Today, a number of other countries in Africa have adopted similar bans including Senegal, Côte d'ivoire, Mali, Ghana, Kenya, Ethiopia, Malawi, Mauritius, Zanzibar (Tanzania) and Uganda. Both Cameroon and South Africa have adopted taxes (Fig. 2).

The UN 2030 Agenda for Sustainable Development (SDG) addresses marine debris and pollution through Goal 14 (target 14.1), with a particular focus on sources from land-based activities. Similarly, goals 6, 11 and 12 target untreated wastewater (6.3), municipal and other

Fig. 2. Plastic Waste Generation rates and Projects addressing waste management in Africa and Plastic Bag Policies.

waste management (11.6), environmentally sound management of chemicals and wastes throughout their life cycle (12.4), and overall waste reduction (12.5). In addition, SDG 15 (target 15.1) focuses on preventing land degradation and biodiversity loss through the conservation and restoration of terrestrial and inland freshwater ecosystems of which identification and management of terrestrial waste sinks forms an important part. Goals 3 and 13 encompass the health impacts of open waste burning where infrastructure does not exist and the climate change impact of excess methane and carbon dioxide production from poorly managed waste sites. It has been estimated that within ten years, dumpsites could be responsible for up to 10% of anthropogenic greenhouse gases [31]. As such, effective waste management is a cross-cutting issue related to a large proportion of the goals set under the United Nation's Sustainable Development Agenda.

In terms of global regulatory instruments, all African coastal states (with the exception of Eritrea and Libya) are parties to the United Nations Convention of the Law of the Sea (UNCLOS). This global, legally binding instrument regulates activities carried out in the ocean and requires states to take measures that prevent, reduce and control pollution of the marine environment. In addition to UNCLOS there are other multilateral environment agreements of global scope such as The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78); the London Convention and Protocol addressing dumping of waste at sea; the Basel, Rotterdam, and Stockholm Conventions dealing with hazardous substances; and the Conventions on Migratory Species and on Biological Diversity that include provisions to prevent the harmful impact of marine plastic debris and microplastics.

The four African Regional Seas Conventions and Action Plans (RSCAPs) including the Barcelona Convention (Mediterranean), the Abidjan Convention (West Africa), the Nairobi Convention (Eastern Africa and the Island States) and PERSGA (Red Sea and Gulf of Aden) are instrumental in encouraging regional cooperation and coordination among countries sharing common resources along their coastlines.

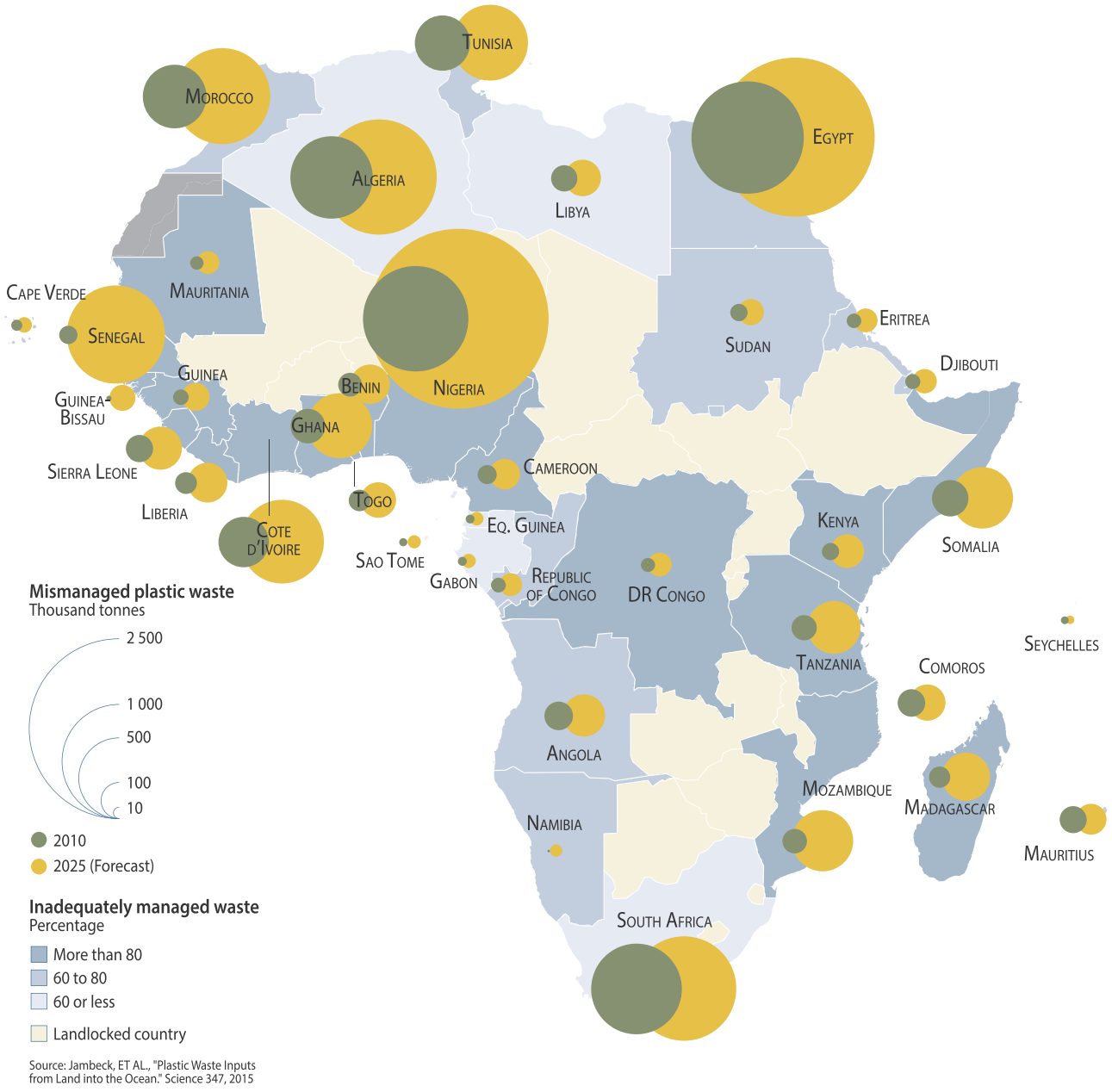

Fig. 3. Mismanaged plastic in Africa in thousands of tonnes as of 2010 (green circles) and projection of waste mismanagement forecast in 2025 given current practices (yellow circles). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Globally, the RSCAPs have pioneered the development of regional sea action plans on marine debris. For example, Mediterranean coastal states have recently adopted one of the most advanced regional instruments on marine debris with a strategic plan including legally binding measures. PERSGA, and the Abidjan and Nairobi Conventions, through the UNEP Regional Seas Programme have undertaken activities to evaluate the level of risk posed by litter and the effectiveness of future mitigation programs and strategies. The recent Abidjan Convention COP12/6 decision on the issue of marine waste highlights the importance of the subject for African countries.

In addition, the Convention on Biological Diversity Aichi Biodiversity Targets Global Biodiversity. Strategic Goal B explicitly recognises the threat of marine debris to wildlife (Target 8), "…of continuing or growing concern include plastics, in particular their impacts on marine ecosystems." As mentioned above, the tangible links between waste and biodiversity impacts are increasingly being documented. A key action to ensure progress towards Target 8 is the "reduction of marine debris". While recognised in the high level biodiversity frameworks, waste impacts are also visible at the species level with "at least 17% of species affected by [waste] entanglement and ingestion" listed as threatened or near threatened by the IUCN Red List [6].

National measures to reduce waste in the environment differ across Africa; however, there is still a significant need for a deeper understanding of these existing measures and the effectiveness of their implementation. The lack of proper national and regional policies to address the issue of marine litter represents a real obstacle for the implementation of blue economy principles in Africa and may jeopardize the effort initiated by government and development partners to achieve the Sustainable Development Goals (SDGs).

5. Solutions and innovation across Africa

Initiatives aimed at mitigating the flow of plastic into the ocean can

Fig. 4. Intervention points to mitigate the flow of plastic to the ocean (used with author permission; from [34]).

occur at various intervention points along the plastic value chain. These possible interventions include activities that reduce plastic production, provide innovative materials and product design, reduce waste generation, improve waste management, improve litter capture and reduce input concentrations to the ocean [32].

While the examples in this section primarily relate to intervention on solid waste management (Fig. 2), other actions should be implemented upstream and downstream. There is a growing global consensus emerging on the urgent need to shift from today's linear take-make-dispose model, to a more circular approach. Under a 'circular economy' approach, plastic items are designed to be reused or recycled [33]. This approach is resulting in a new suite of solutions. Such actions can be informed by an assessment of solid waste and management and leakage from systems. Most importantly, these actions can be integrated with each other along an entire continuum of possible solutions (Fig. 4). Responsibility for these actions can be shared by industry, government, and citizens.

Africa's densely populated residential areas provide significant challenges to solid waste management, especially where infrastructure is lacking. In Nigeria, Wecyclers and Recycle Points have partnered with the Lagos Waste Management Authority (LWMA) to collect recyclable waste items (e.g., plastic bottles and bags, cans, glass bottles, paper and cartons) directly from consumers providing much needed collection and sorting services. They incentivise clients to collect and sort their used recyclable waste at home by exchanging it for points which can later be redeemed for household items, food, or cell phone minutes. These initiatives not only provide jobs to Lagos residents and the opportunity to turn their waste into value, but sorted waste can then be sold to larger recycling facilities [35]. TakaTaka Solutions operates similarly in Nairobi, Kenya. Serving both residential and commercial clients they manage post-consumer waste by asking clients to separate waste into organic and inorganic fractions for collection. The organic waste is used to create high-quality compost which is sold to local farmers. All inorganic waste is further sorted and either sold to recycling industries or used to create tumblers out of recycled bottles. As a result of their efficient operation, TakaTaka Solutions collects 10 t of waste per day and recycles up to 95% of the waste collected [36]. USE-IT in South Africa, a Non-Profit Organisation, is working on a holistic approach to solid waste management through several recycling programs and the eThekwini Waste Materials Recovery Industry Development Center [37].

Within Africa, there are also several groups specifically focused on plastic waste management. Proplast began in 1997 in Senegal by 14 women to collect and processes plastic waste. Proplast now employs 100 women and processes 1500 metric tons of plastic per year turning it into granulated plastic sold to local plastic processing companies. New public kiosk drop-off centers allow for more public access to recycling in Dakar [38]. Polyco, and industry group in South Africa, has several projects around the country outlined on their website [39]. One of the newest projects is Pack-a-ching, a mobile kiosk where citizens can take their polyethylene plastic for compacting and recycling to get a cash card loaded with money. The goal of the mobile kiosk is to provide the opportunity for people in informal settlements to both manage their waste and get cash for it. Other goals include education and local community funding, along with a growth of corporate partners [40].

Across Africa there are a number of initiatives turning plastic waste into valuable retail opportunities. For example, SoleRebels in Ethiopia uses recycled tires and traditional Ethiopian hand-loom techniques to create fashionable fairtrade footwear whilst providing workers four-times the local minimum wage [41]. Similarly, Ocean Sole in Kenya collects over 400,000 plastic flip flops from dumpsites, waterways, and the ocean every year. These are recycled into art as part of a global awareness campaign on the importance of a clean ocean to both humans and marine life [42]. All Women Recycling is a women-empowerment initiative in South Africa that upcycles plastic bottles to make the Kliketyklikbox™, now sold worldwide. This initiative upcycled over 500,000 plastic bottles in 2016 while providing a safe place for women from marginalized backgrounds to develop skills [43]. Also in South Africa, Repurpose Schoolbags creates schoolbags from plastic bags and billboard materials providing bags to schoolchildren in need. These bags are outfitted with a portable solar panel that can be used as a desk lamp at night for children's homework and reading [44].

Technology, especially mobile technology, can facilitate data collection and innovation in the plastic pollution solution space. For example, Ecopost in Nairobi, Kenya uses a waste management app that encourages residents and businesses to collect and sort their waste in return for points that can be redeemed for products. Ecopost collects both plastic waste and agricultural waste (e.g. rice husks, wheat bran, sawdust) to create plastic lumber that can be used for fencing. This helps to reduce deforestation while creating jobs for local citizens, as well as providing a way for residents to gain value from their waste [45]. Although some of these programs and waste streams are niche or local solutions at the moment, the ideas and products can capture people's interest. They also are working successfully as a communication tool to raise awareness and mobilise funding for addressing this issue. Depending on the model, the enterprises are either able to provide full-time employment, casual jobs or supplementary income to enhance local livelihoods.

6. The African Marine Waste Network

The marine environment is an important source of livelihoods, food security and economic development in the 38 African coastal and island countries. It is also of great importance to the rapidly growing interest in the blue economy. Given the potential for these opportunities to be undermined by pollution, it is critical that the issue and scale of marine debris is better understood, in order to manage and mitigate on a pan-African scale.

Land-based waste management in Africa undoubtedly requires African-led solutions. Given the transboundary nature of the problem, working within regional frameworks aimed at combatting marine debris will likely result in increased success. The African Marine Waste Network (AMWN), formed in 2016, draws together stakeholders in government, Intergovernmental Organisations, business (both large and small), academia and civil society and aims to coordinate cross-sectoral efforts in Africa from continental to local scales to better manage waste [46]. Establishment of the AMWN begins a collective approach that facilitates collaboration on this issue. The network also supports the further development of regional and national action plans. Such plans will need to take into close consideration the local context of this issue,

its current realities in Africa, and what barriers (e.g. lack of data) and opportunities (e.g. education and awareness raising) exist across Africa to address the issue of marine debris and other waste-related issues across the continent [46].

6.1. Data needs

The need to measure the extent, distribution and impacts of debris on land, along rivers, estuaries, on islands and along coastlines has been identified as a key knowledge gap. By identifying and quantifying the sources, sinks, flows and types of waste across Africa, a baseline upon which to build management and remedial strategies can be developed. Such a baseline would provide understanding of the source/sink dynamics of marine waste allowing identification of bottlenecks as well as temporary and long-term transitory sinks. This knowledge would also enable priority setting and the effective deployment of land-based, coastal, and marine waste monitoring and management strategies. In addition, a well-designed data collection effort can serve as a baseline for testing effectiveness of programs, and for reporting on the impact of current and new legal instruments such as bag bans as they come into effect.

To date, there have been individual and group-led efforts to collect data and collate information in various parts of Africa. Participants across many cities and regions participate in annual International Coastal Cleanup (ICC) events, coordinated by the Ocean Conservancy (https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/). For example, South Africa has participated in the ICC for 20 years. There are also efforts underway to collect data on microplastic marine debris in the Atlantic and Indian Oceans. This is taking place through a new research initiative which aims to map and identify floating plastic hotspots (the Nansen project coordinated by FAO).

Additional recommendations include collection of data at a continental scale as part of a global research effort, promoting collaboration between experts from Africa and elsewhere. Incorporating demographic, socioeconomic and ecological factors such as biodiversity conservation will be significant considerations to understand waste movement, drivers, and flows. Research efforts within Africa will benefit by applying a unified approach and sharing resources towards common goals. Consistency in data collection, management, storage, dissemination and exchange of experiences in an African context are further relevant considerations.

6.2. Education and awareness

Research has shown that education and awareness raising programs are correlated with reduced coastal debris [28] Hence, fast-tracking education and understanding to promote behavioural changes while creating a platform for sharing educational resources and best practices could prove beneficial towards reducing waste inputs to the environment. Education on-line and in schools, adapting programs from other continents to African cultures and conditions where appropriate, and adapting existing resources can help reduce litter inputs to the environment. Working with manufacturers, distributors and retailers to increase understanding of the impacts of plastic losses to the environment could also help to identify and reduce leakage points.

7. Conclusion

In light of the projected growth in economies, human population and plastic production, the African continent cannot be ignored on the issue of marine waste and plastic waste leakage into the ocean. Clearly there are opportunities for infrastructure advances aimed to help reduce plastic leakage into the environment. Given the ingenuity that arises from necessity, there will undoubtedly be numerous creative, collaborative approaches taken to tackle this growing environmental issue that has become the tragedy of the commons of the 21st century. Perhaps the land-based and marine waste crisis will provide a unique opportunity for jobs creation and associated poverty reduction, clean up campaigns and local environmental stewardship as well as tourism development. Reducing plastic waste before mismanagement occurs may also aid in the reduction of some diseases and help prevent flooding, particularly in urban areas. Furthermore, addressing the issue provides the occasion for policy reforms at national, sub-regional and continental levels.

References

[1] R. Geyer, J. Jambeck, K. Lavender Law, Production, use, and fate of all plastics ever made, Sci. Adv 3 (7) (19 2017), http://dx.doi.org/10.1126/sciadv.1700782.

[2] United Nations Environment Program, Marine Plastic Debris and Microplastics – Global Lessons and Research to Inspire Action and Guide Policy Change, United Nations Environment Programme, Nairobi, 2016.

[3] J. Jambeck, R. Geyer, C. Wilcox, T.R. Siegler, M. Perryman, A. Andrady, R. Narayan, K. Lavender Law, Plastic waste inputs from land into the ocean, Science 347 (6223) (2015) 768–771, http://dx.doi.org/10.1126/science.1260352.

[4] E. van Sebille, C. Wilcox, L. Lebreton, N. Maximenko, B.D. Hardesty, J.A. van Franeker, M. Eriksen, D. Siegel, F. Galgani, K. Lavender Law, A global inventory of small floating plastic debris, Env. Rsch Letters 10 (2015) 12.

[5] C.M. Rochman, M.A. Browne, A.J. Underwood, J.A. van Franeker, R.C. Thompson, L.A. Amaral-Zettler, The ecological impacts of marine debris: unravelling the demonstrated evidence from what is perceived, Ecology (2016), http://dx.doi.org/10.1890/14-2070.1.

[6] S.C. Gall, R.C. Thompson, The impact of debris on marine life, Mar. Pollut. Bull. 92 (1) (2015) 170–179, http://dx.doi.org/10.1016/j.marpolbul.2014.12.041.

[7] C. Wilcox, E. Van Sebille, B.D. Hardesty, Threat of plastic pollution to seabirds is global, pervasive, and increasing, Proceedings of the National Academy of Sciences 112 (38) (2015) 11899–11904, http://dx.doi.org/10.1073/pnas.1502108112.

[8] C. Wilcox, N. Mallos, G.H. Leonard, A. Rodriguez, B.D. Hardesty, Using expert elicitation to estimate the impacts of plastic pollution on marine wildlife, Mar. Pol 65 (2016) 107–114.

[9] M.R. Gregory, Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions, Philos. Trans. R. Soc. B 364 (1526) (2009) 2013–2025, http://dx.doi.org/10.1098/rstb.2008.0265.

[10] J.G.B. Derraik, The pollution of the marine environment by plastic debris: a review, Mar.Pollut.Bull. 44 (9) (2002) 842–852, http://dx.doi.org/10.1016/S0025-326X(02)00220-5.

[11] C. Leggett, N. Scherer, M. Curry, R. Bailey, Assessing the economic benefits of reductions in marine debris: A pilot study of beach recreation in Orange County, California (Final report, pp. 45). Cambridge, MA, 2014.

[12] Y.C. Jang, S. Hong, J. Lee, M.J. Lee, W.J. Shim, Estimation of lost tourism revenue in Geoje Island from the 2011 marine debris pollution event in South Korea, Mar.Pollut.Bull 81 (1) (2014) 49–54.

[13] United National Environment Programme, Global Waste Management Outlook, ⟨http://web.unep.org/ourplanet/september-2015/unep-publications/global-waste-management-outlook⟩, 2015 (accessed 8 November 2017).

[14] B. Neumann, A.T. Vafeidis, J. Zimmermann, R.J. Nicholls, Future coastal population growth and exposure to sea-level rise and coastal flooding - a global assessment, PLoS ONE 10 (2015) 6, http://dx.doi.org/10.1371/journal.pone.0131375.

[15] Deloitte, The Deloitte Consumer Review. Africa: A 21st century View, ⟨https://www2.deloitte.com/content/dam/Deloitte/ng/Documents/consumer-business/the-deloitte-consumer-review-africa-a-21st-century-view.pdf⟩, 2003.

[16] L. Creel, Ripple Effects: population and Coastal Regions, Population Reference Bureau, Washington, DC, 2003.

[17] L.C.M. Lebreton, J. van der Zwet, J.W. Damsteeg, B. Slat, A. Andrady, J. Reisser, River plastic emissions to the world's oceans, Nat. Commun 8 (2017), http://dx.doi.org/10.1038/ncomms15611.

[18] G. Macfadyen, T. Huntington, R. Cappell, Abandoned, lost or otherwise discarded fishing gear, FAO Fisheries and Aquaculture Technical Paper, 523, UNEP regional seas reports and studies, 185.FAO Fisheries and Aquaculture Technical Paper, 523, UNEP regional seas reports and studies, 185 (2009).

[19] N.W. Heo, S.H. Hong, G.M. Han, S. Hong, J. Lee, Y.K. Song, M. Jang, W.J. Shim, Distribution of small plastic debris in cross-section and high strandline on Heungnam beach, South Korea, Ocean Sci. J 48 (2) (2013) 225–233.

[20] I.A. Hinojosa, M. Thiel, Floating marine debris in fjords, gulfs and channels of southern Chile, Mar. Pollut. Bull. 58 (3) (2009) 341–350, http://dx.doi.org/10.1016/j.marpolbul.2008.10.020.

[21] G. de Graaf, L.Garibaldi, The value of African fisheries, FAO Fisheries and Aquaculture Circular No. 1093 (2014), Food and Agriculture Organization of the United Nations, Rome, 2014.

[22] Climate Smart Oceans, Towards Sustainable Growth of Ocean Economies un Africa Under a Changing Climate, ⟨http://climatesmartoceans.org/wp-content/uploads/2016/08/Policy-brief-basse-def-en.pdf⟩, 2016 (accessed 1 August 2017).

[23] J. Stoler, J. R. Weeks, G. Fink, Sachet drinking water in Ghana's Accra-Tema metropolitan area: past, present, and future, *J. Water Sanit. Hyg. Dev.* 2:4 (2012) https://dx.doi.org/10.2166/washdev.2012.104.

[24] D. Hinshaw, Ghana's growth spurs uncontrollable trash, ⟨www.wsj.com/articles/ghanas-growth-spurs-uncontrollable-trash-1434928945⟩, 2017 (accessed 8

November 2017).
[25] Global Press Journal, Big bans are widespread in Africa, but it's uncertain how much good they're doing for oceans, ⟨https://globalpressjournal.com/africa/bag-bans-are-widespread-in-africa-but-it-s-uncertain-how-much-good-they-re-doing-for-oceans⟩, 2015 (accessed 8 November 2017).
[26] E. Moss, A. Eidson, J. Jambeck, Sea of Opportunity: Supply Chain Investment Opportunities to Address Marine Plastic Pollution, Encourage Capital on behalf of Vulcan, Inc., New York, New York, 2017.
[27] Y. Matsuguma, H. Takada, H. Kumata, H. Kanke, S. Sakurai, T. Suzuki, M. Itoh, Y. Okazaki, R. Boonyatumanond, M.P. Zakaria, S. Weerts, B. Newman, Microplastics in Sediment Cores from Asia and Africa as Indicators of Temporal Trends in Plastic Pollution, Arch Env Contam Toxicol 73 (2) (2017) 230–239.
[28] B.D. Hardesty, Q. Schuyler, T.J. Lawson, K. Opie, C. Wilcox, Understanding debris sources and transport from the coastal margin to the ocean, CSIRO, 2016.
[29] J. Vince, B.D. Hardesty, Plastic pollution challenges in marine and coastal environments: from local to global governance, Restor. Ecol. 25 (1) (2017) 123–128, http://dx.doi.org/10.1111/rec.12388.
[30] J. Larsen, S. Venkova, Earth Policy Institute, The downfall of the plastic bag: a global picture, ⟨https://earthpolicyinstitute.wordpress.com/page/2/⟩, 2017 (accessed 2 August 2017).
[31] A. Mavropoulos, D. Newman, Wasted Health—The Tragic Case of Dumpsites, International Solid Waste Association, Vienna, 2015.
[32] J. Jambeck, Marine Debris and Wildlife: Impacts, Sources and Solutions, Written testimony before the US Senate Committee on environment and public works (2016).
[33] Ellen MacArthur Foundation, Towards a Circular Economy: Business rationale for an accelerated transition, The Ellen MacArthur Foundation, 2015.
[34] B. Worm, H.K. Lotze, I. Jubinville, C. Wilcox, J. Jambeck, Plastic as a Persistent Marine Pollutant, Annual Review of Environment and Resources 42 (2017) 1–26.
[35] Wecyclers, ⟨http://wecyclers.com/⟩, 2017 (accessed 30 July 2017).
[36] TakaTaka Solutions, ⟨http://takatakasolutions.com/⟩, 2017, (accessed 30 July 2017).
[37] USE-IT, ⟨http://www.use-it.co.za/⟩, 2017 (accessed 30 July 2017).
[38] I. Sane, Collection and recycling of plastic waste in Senegal, ⟨http://impactjournalismday.com/story/proplast/⟩, 2017 (accessed 30 July 2017).
[39] PolyCo, ⟨http://www.polyco.co.za/⟩, 2017 (accessed 30 July 2017).
[40] Pack-a-ching, ⟨http://packaching.pl-dev.co.za/⟩, 2017 (accessed 30 July, 2017).
[41] Sole Rebels, ⟨https://www.solerebels.com/⟩, 2017, (accessed 30 July 2017).
[42] Ocean Sole, ⟨http://oceansole.co.ke/⟩, 2017 (accessed 30July 2017).
[43] All Women Recycling, ⟨http://www.allwomenrecycling.com/⟩, 2017 (accessed 30 July 2017).
[44] Repurpose Schoolbags, ⟨http://www.repurposeschoolbags.com⟩, 2017 (accessed 30 July 2017).
[45] Ecopost, ⟨www.ecopost.co.ke⟩, 2017 (accessed 30 July 2017).
[46] African Marine Waste Network, ⟨https://africanwastenetwork.org.za/⟩, 2017 (accessed 1 August 2017).