Water quality and land-based pollution

Marine litter and microplastics in the Western Indian Ocean: current knowledge and recommendations

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Summary

This review collates available information on marine litter and microplastics in the Western Indian Ocean (WIO) region with a specific focus on the sources, transport and fate of litter, and the resultant ecological and human health impacts. Most litter comes from land-based sources, especially in the case of continental countries, and urgent action is needed to curb the release of local litter into the sea. This can be achieved by promoting reusable items, improving waste management at the municipal level, and educating citizens from the WIO region about the adverse effects of litter on the marine environment. While some litter is also released from land-based sources in WIO island states, a significant proportion originates offshore, either from fisheries or shipping activity or via long-distance drift from foreign nations, mainly in Southeast Asia, which is especially relevant on remote coasts and islands that receive little or no local input of litter. International measures are therefore also needed to address these problems. Given that waste generation in all WIO countries is expected to increase in the future, WIO governments and municipalities should prioritise action plans to curb this socio-environmental problem. At the same time, monitoring programmes should continue to assess the efficacy of the prevention and mitigation measures.

Background

The Western Indian Ocean (WIO) is a region where high biodiversity is increasingly being impacted by anthropogenic marine debris (Ryan and others, 2016a; Abreo and others, 2019; Cartraud and others, 2019), but information about the amounts, types and sources of marine litter are scattered widely in the literature. The last review of the topic across the region was published in 2008 by the United Nations Environment Programme and the Western Indian Ocean Marine Science Association (UNEP and WIOMSA, 2008). The report focused on eight countries within the WIO region (South Africa, Mozambique, Madagascar, Tanzania, Kenya, Mauritius, Comoros and Seychelles). It indicated that most of the litter found in the region likely originates on land. However, a fraction of litter was attributed to at-sea activities such as illegal dumping from ships and fishing activities. The 2008 UNEP/WIOMSA report highlighted large knowledge gaps in all countries in the region except South Africa. Substantially more research on marine litter has been published since this report's publication, and a review of the latest research for the entire WIO region is urgently needed. For instance, while comprehensive national hot-spotting assessments about plastic waste in four WIO continental countries provided up-to-date information on the sources, density, and distribution of plastic waste and recommended interventions

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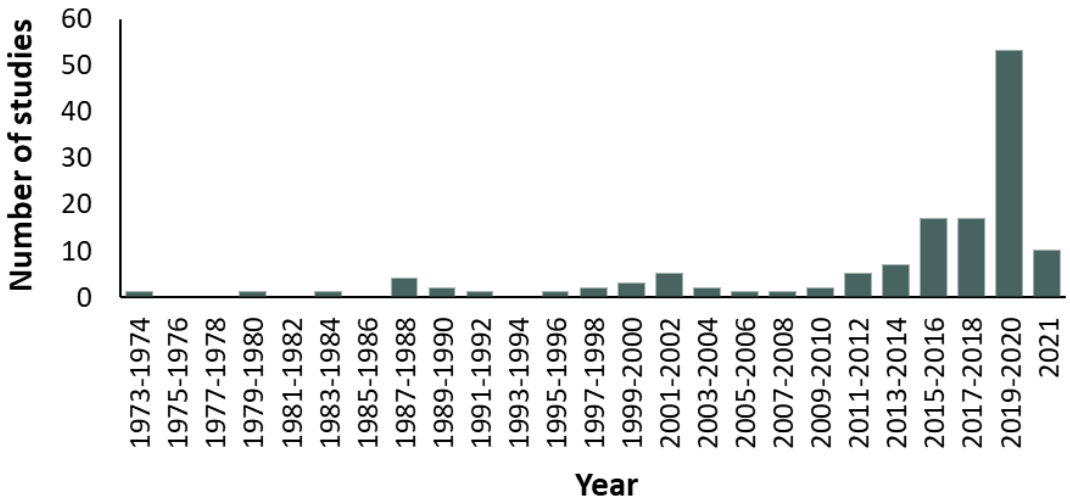

Figure 1. Number of studies reporting data on marine litter or microplastics in the WIO region, grouped by two-year intervals from the first study conducted to the present day.

to curb its generation and release to the environment (IUCN-EA-QUANTIS, 2020a,b,c,d), there has been no recent region-wide review of the densities, distribution, sources, fate and threats of waste plastics. There is also a lack of clarity concerning key knowledge gaps, and there is an urgent need to identify effective mitigation actions to tackle plastic waste at a regional level. Mismanaged plastic waste has been identified as an important issue in WIO continental countries (with mismanagement rates reaching 99 per cent in Mozambique; IUCN-EA-QUANTIS, 2020a,b,c,d), and its amount is predicted to increase significantly (Jambeck and others, 2015; 2018), which could result in even more litter entering the WIO in future. WIOMSA thus commissioned a comprehensive review of the existing literature on the amounts, sources and fate of marine litter and microplastics in the WIO region and their resultant ecological and human health impacts. The main goal of this review is to identify the principal sources of marine litter in the WIO countries, which is essential knowledge for effective prevention and management measures.

Advances – state of the art

To synthesise existing knowledge, we reviewed 136 studies on marine litter and microplastics in the WIO region (79 per cent of articles from peer-reviewed scientific journals, 20 per cent grey literature reports, 1 per cent book chapters). The first study was conducted in 1973, but 71 per cent of studies are from 2015 to 2021 (Figure 1). Studies were mainly from South Africa (57 per cent), followed by Kenya (8 per cent) and Mozambique (5 per cent), while Madagascar, Seychelles, Comoros, Tanzania, Mauritius and La Réunion accounted for smaller proportions; 27 studies (20 per cent) included data from several countries, international waters, or covered seabirds that forage widely across the Indian and Atlantic Oceans. Most studies sampled for macrolitter (>25 mm), but knowledge about the distribution of microplastics on the seashore has also improved since the publication of the 2008 UNEP/WIOMSA review (UNEP and WIOMSA, 2008).

The best-studied coastal habitat was the seashore (mostly sandy beaches), followed by the sea surface. It was often difficult to compare macrolitter and microplastics densities among studies because of differences in sampling methods; for example, most studies reported litter per linear metre of shoreline while some reported densities per unit area. Studies also differed on the lower size limit sampled (for example, using different mesh sizes to sample floating litter), and it was difficult to compare litter densities on shorelines determined for standing stock versus accumulation surveys. Even accumulation studies were sampled at different intervals between repeat surveys. Greater efforts are needed to harmonise survey methods and reporting units (*eg* GESAMP, 2019; Barnardo and Ribbink, 2020).

Amounts and characteristics of marine litter

Macrolitter densities on the seashore were generally greater on urban or popular recreational beaches close to point sources (Swanepoel, 1995; Lamprecht, 2013; Ryan and others, 2014a; Gjerdseth, 2017; Chitaka and von Blottnitz, 2019; Okuku and others, 2020a; Opie, 2020; Ryan, 2020a). In most studies, plastics

dominated, with generally >50 per cent of items being plastics, in terms of number (Pereira and others, 2001; Duhec and others, 2015; Bouwman and others, 2016; Jost, 2019; Dunlop and others, 2020; Okuku and others, 2021a). Of particular concern is plastic packaging, which often dominates litter loads, especially on urban sandy beaches (Ryan and Moloney, 1990; Chitaka and von Blottnitz, 2019; Okuku and others, 2020a; Opie, 2020; Ryan, 2020a), and has been identified as one of the main sources of marine litter in WIO continental countries, at least numerically (IUCN-EA-QUANTIS, 2020a,b,c,d). Litter items on urban and tourist beaches are often smaller and have a faster turnover rate due to increased cleaning efforts targeting large litter, whereas these same large litter items tend to persist for longer periods on rarely cleaned beaches. Therefore, while the number of items on tourist beaches may be higher, the mass of litter is normally concentrated on remote beaches, highlighting the importance of also reporting litter densities by mass (Ryan and others, 2020a).

Data on the density and distribution of meso- (5-25 mm) and microplastics (<5 mm) on the seashore are only available for sandy beaches and estuaries. In both Kenya and South Africa, studies conducted using sieve transects on sandy beaches (that is, to sieve sand along a transect perpendicular to the shoreline to sample meso- and microplastics >2 mm) reported higher densities of plastic litter on beaches closer to populated areas compared to semi-populated and remote regions (Lamprecht, 2013; Ryan and others, 2018; Okuku and others, 2020b; Ryan and others, 2020a). Most research on smaller microplastics on the seashore has been conducted in South Africa, with one study available from Tanzania and one from the Comoros Archipelago. Results of these studies show that microplastics (most of which are microfibres) also tend to be concentrated around large coastal cities (de Villiers, 2018). Still, nearshore surface currents may also influence the distribution of microplastics on the seashore (Nel and Froneman, 2015). One study extrapolated microplastic densities across the entire beach profile and found an average density that completely dwarfed counts of macrolitter or mesolitter but only contributed <0.01 per cent to the total mass of litter (Ryan and others, 2020a), highlighting that a few large items dominate the mass of litter. It is important to remove these large items from beaches before they degrade into microplastics (Ryan and others, 2020a). In South Africa, the average density of mesoplastics and macroplastics increased from 1984 to 1989 (Ryan and Moloney, 1990). In contrast, little change in mesoplastic densities was detected in surveys between the 1990s and the 2010s (Ryan and others, 2018). Trends in the standing stocks of macroplastics on beaches are compromised by changes in beach cleaning efforts (Ryan and others, 2020a). The limited data from accumulation studies suggest increases in some seasons but decreases in others, linked to mitigation efforts to intercept litter in rivers before it reaches the sea (Opie, 2020).

Floating macrolitter has been studied off the coasts of Kenya and South Africa (Ryan, 1988; Ryan, 1990; Ryan and others, 2014b; Okuku and others, 2021b), where densities are much higher than in the Southern Ocean off South Africa (Suaria and others, 2020a), likely due to higher inputs and shorter distances from land-based sources. Twelve studies conducted net tows for floating mesolitter and microlitter (Ryan, 1988; Ryan, 1990; Cózar and others, 2014; Eriksen and others, 2014; Massot Mascaró, 2015; Nel and Froneman, 2015; Jost, 2019; Naidoo and Glassom, 2019; Kerubo and others, 2020; Kosore, 2020; Suaria and others, 2020a; Okuku and others, 2021b), while five collected bulk surface water samples for microplastics (Nel and others, 2017; Kosore and others, 2018; Kerubo and others, 2020; Suaria and others, 2020b; Preston-Whyte and others, 2021). The highest densities of floating mesolitter and microplastics were found in the coastal waters of Kenya (Kosore, 2020; Okuku and others, 2021b). All studies reported that plastics were the most common anthropogenic material caught in the nets. Several studies suggested that ocean currents play a significant role in determining the distribution and accumulation of meso/microplastics (Nel and Froneman, 2015; Naidoo and Glassom, 2019). Microfibres were common in bulk water samples (Nel and others, 2017; Preston-Whyte and others, 2021), although most fibres in surface waters are not synthetic (Suaria and others, 2020b). Nel and others (2017) and Preston-Whyte and others (2021) suggested that harbours may be important sources of microplastics and microfibres because they often receive stormwater and other run-offs from adjacent urban areas, which is in agreement with several studies from other parts of the world (Ballent and others, 2016; Rose and Webber, 2019).

Only one study from the WIO region sampled litter in the water column (along a transect from Cape Town to the Prince Edward Islands; Ryan and others, 2020b), which remains one of the least studied marine habitats. Five studies have surveyed macrolitter on the seafloor (in Mayotte, South Africa, and international waters;

Rundgren, 1992; Woodall and others, 2015; Mulochau and others, 2020; Ryan, 2020a; Ryan and others, 2020c), with highest litter densities found at deep-sea sites along the Southwest Indian Ocean Ridge, >1,300 km south of Madagascar, most of which was fishing gear (Woodall and others, 2015). Macrolitter densities on the continental shelf off the south and west coasts of South Africa were lower (Ryan and others, 2020c). Most of this litter was plastic packaging and disposable plastics, which may have originated from land-based sources or ships (Ryan and others, 2020c). Dive transects on coral reefs in the Comoros Archipelago also found mostly discarded fishing gear, suggesting that most reef litter comes from fishing activity (Mulochau and others, 2020). Three studies reported microplastic densities from bottom sediments in the WIO region (in South Africa and international waters; Woodall and others, 2014; Matsuguma and others, 2017; Preston-Whyte and others, 2021). The highest densities were generally found close to point sources such as sewage overflows, stormwater drains and river mouths (Preston-Whyte and others, 2021).

Sources, transport, and fate of marine litter

Identification of litter types and local concentration around urban source areas indicates that most litter is from local, land-based sources (Gerber, 2017; de Villiers, 2018; Ryan and others, 2018; Mayoma and others, 2020; Okuku and others, 2020a; Ryan, 2020a,b; Ryan and Perold, 2021), reaching the ocean via urban and river run-off or direct deposition by beachgoers. The national hot-spotting assessments implemented in Kenya, Mozambique, South Africa and Tanzania identified low waste collection rates along with high rates of improperly disposed waste as major drivers of mismanaged plastic waste and its leakage into rivers and consequently to the ocean (IUCN-EA-QUANTIS, 2020a,b,c,d). Recent studies show that much litter does not disperse far from the source (Collins and Hermes, 2019; van der Mheen and others, 2020; Ryan and Perold, 2021; Chenillat and others, 2021), suggesting that shorelines in the WIO region are important sinks for litter (although buried plastics in beaches will be exposed as coasts erode due to rising sea levels). The type of habitat and its physical characteristics play a significant role in determining the fate of stranded litter. For example, mangroves and rocky shores are significant sinks for larger or heavier litter items (Weideman and others, 2020a).

Although most macrolitter from land-based sources strands on shorelines close to where it washes into the sea, a small proportion may also be transported offshore (Duhec and others, 2015; Collins and Hermes, 2019; van der Mheen and others, 2020; Chenillat and others, 2021). Land-based sources dominate in areas close to urban centres, especially in continental areas, while offshore inputs dominate away from these sources. As the WIO region is downstream of southeast Asia, ocean models suggest that some of the litter from that region reaches the WIO countries after extended oceanic journeys (van der Mheen and others, 2020). This is supported by reports of Asian-branded packaging covered in epibionts (Duhec and others, 2015; Bouwman and others, 2016; Okuku and others, 2020a; Ryan, 2020b; Ryan and Perold, 2021; Ryan and others, 2021) and the predominance of HDPE bottles and lids from Indonesia (compared to PET bottles from China, Singapore/Malaysia and UAE, many of which are dumped illegally from ships; Ryan, 2020b; Ryan and others, 2021). The problem of sea-based inputs, especially long-distance transport of litter from southeast Asia, is particularly challenging for small island states in the region, where most litter derives from these sources (Duhec and others, 2015; Bouwman and others, 2016; Burt and others, 2020). The lack of data on the characteristics and densities of litter on the seafloor of the WIO region makes it difficult to ascertain to what degree the seafloor acts as the ultimate sink for marine litter, but some studies already confirm accumulations of litter on the seafloor in coastal and offshore regions (Woodall and others, 2015; Mulochau and others, 2020; Ryan and others, 2020c).

Ecological and human health impacts of marine litter

More than one-third of the 136 reviewed studies reported interactions between organisms and marine litter or microplastics (in all countries except mainland Comoros and Somalia), among which ingestion and entanglement were documented most commonly. Plastic ingestion has been recorded in 101 species from the WIO region, including many seabirds (Ryan, 1987; Nel and Nel, 1999; Ryan, 2008; Ryan and others, 2016b; Cartraud and others, 2019), bony fishes (Naidoo and others, 2016; Naidoo and others, 2017; Bakir and others, 2020; McGregor and Strydom, 2020; Naidoo and others, 2020a) and sharks (Cliff and others, 2002). All four species of sea turtles studied have presented plastic debris in stomach contents or faecal samples (Claro and Hubert, 2011; Hoarau and others, 2014; Chebani, 2020), but none of the four species of marine mammals studied had ingested

macrolitter (Ryan and others, 2016b; Chebani, 2020). Invertebrates (mussels, oysters, crabs, sea anemones and some zooplankton) have also been found with microplastics in their guts (Kosore and others, 2018; Awuor and others, 2020; Chebani, 2020; Mayoma and others, 2020; Sparks, 2020; Weideman and others, 2020b). Further studies will likely find microplastic ingestion in virtually all marine species.

Entanglement has been reported for 57 species of seabirds, marine mammals, sea turtles and sharks (Shaughnessy, 1980; Cliff and others, 2002; Hofmeyr and Bester, 2002; Hofmeyr and others, 2002; Ryan, 2018), but few systematic studies have been conducted, and it was difficult to differentiate entanglement of seabirds in marine debris from bycatch in active fishing gear (Ryan, 2018). Of particular concern are fish aggregating devices (FADs) because they are often reported with entangled, dead sea turtles (Balderson and Martin, 2015). Fisheries litter (nets and lines) is often entangled on coral reefs, macro-algae and horny corals (Rundgren, 1992; Schleyer and Tomalin, 2000). Some invertebrates (echinoderms, sea anemones) which use natural objects for shading or camouflage also attach plastics to their body surface (Rundgren, 1992; Spencer, 2020; Weideman and others, 2020a). Ten studies have reported data about organisms growing on marine litter (that is, epibionts, in Kenya, Mozambique, Tanzania, South Africa, Madagascar, Mauritius, and at deep-sea sites east of Madagascar), with floating substrata colonised by various species, including bryozoans, spirorbid worms and six species of goose barnacles (Rundgren, 1992; Whitehead and others, 2011; Fazey and Ryan, 2016; Ryan, 2020b; Ryan and others, 2020c; Ryan and others, 2021). Long-distance transport of some species on floating plastics has been suggested (Barnes, 2004).

The potential impact of marine litter on human health remains severely understudied. One study from Tanzania confirmed high concentrations of human pathogens and multi-drug resistant bacteria growing on waste plastics (Rasool and others, 2021). Other studies identified microplastics in different edible marine organisms throughout the South African, Kenyan and Tanzanian coastlines, including estuarine fish (Naidoo and others, 2020a), mussels (Gerber, 2017; Sparks, 2020), oysters (Awuor and others, 2020), and cockles (Mayoma and others, 2020). While it is unclear what proportion of these microplastics are ingested by humans, their ingestion is potentially harmful to humans because of the toxicity of plastic additives and the sorption of persistent organic pollutants (POPs), which have been detected on the surfaces of polyethylene pellets beached in Mozambique and South Africa (Ogata and others, 2009; Ryan and others, 2012). The transfer of these compounds to humans remains speculative, and the effects of marine litter and microplastics on human health remain a largely unknown and understudied field (Naidoo and others, 2020b; Vethaak and Legler, 2021).

Regional and global outlook

Identification of knowledge gaps and future research priorities

The reviewed information suggests several important knowledge and research gaps about marine litter and microplastics in the WIO region (broadly summarised and prioritised in Table 1). Most studies have been conducted on sandy beaches, while other habitats, such as mangroves, rocky shores, rivers and estuaries, the water column, coral reefs, and the seafloor, lack important information across the region. There is also a geographic gap in marine litter research, with most studies conducted in South Africa. Studies from South Africa also cover the most diverse array of topics and habitats; for example, rivers and drainage systems have only been researched in South Africa, and given the variable rainfall and run-off dynamics within the WIO region, there is a need for better understanding on the amounts, composition, sources and sinks of litter in these habitats in the other countries. To help focus clean-up efforts, knowledge of the fate of litter needs to be improved, whereas sociological research into why people litter can aid understanding and addressing this behaviour. Quantitative data about the impacts of litter on marine organisms at a physiological level (for example, toxicological effects of chemicals associated with plastics, potential diseases caused by litter, increased drag and breakage) and at the population level are lacking, as well as data about impacts on human health (for example, toxic chemicals, dangerous items on the seashore, spreading of diseases such as cholera and malaria, burning of litter, entanglement of propellers, etc). Despite these knowledge gaps, we already know enough to prioritise actions to reduce the amounts of waste plastics entering the environment. Research should also focus on identifying effective mitigation efforts by, for example, testing the impact of programmes to reduce particular types of litter (such as bans on plastic bags), the retention rate of river booms and stormwater traps, and the effectiveness of beach, river, and street clean-up programmes (Ryan and others, 2020d).

Table 1: Main knowledge gaps on marine litter that need to be addressed in the WIO region and their priorities.

Actions to address knowledge gaps in the WIO region	Priority
Determine amounts and types of litter in habitats other than sandy beaches	High
Quantify the amounts of litter from land-based versus offshore sources	High
Determine breakdown dynamics of macroplastics under different conditions	Medium
Determine whether litter aids the spread of diseases	High
Evaluate the health implications of burning litter	High
Improve understanding of the economic costs of marine litter	Low
Improve understanding of the fate of litter to help focus clean-up efforts	Low
Improve understanding of littering behaviour to address it effectively	High

Recommendations for action

The information gathered and presented above (and synthesised in Figure 2), coupled with the results and recommendations of the hot-spotting assessments implemented in Kenya, Mozambique, South Africa and Tanzania (IUCN-EA-QUANTIS, 2020a,b,c,d), highlight the need to address the marine litter problem through locally driven measures and a life cycle intervention approach, emphasising actions on the source and the end-of-life. We recommend a series of actions mostly focused on monitoring/research, prevention, and management that can be implemented at the regional, national and local level in the WIO region (recommendations summarised in Table 2).

First, the regional monitoring programme that has recently been established (Barnardo and Ribbink, 2020) should continue and be extended within countries, given that ongoing litter monitoring is important to (i) help identify the major sources of litter and (ii) provide information to evaluate whether measures and policies aimed at reducing marine litter are effective or not (Ryan and others, 2020d). Policy-making and litter monitoring need to go hand in hand as integral parts in any life cycle intervention approach implemented to curb the release of litter into the environment. Regional monitoring activities should be coordinated and harmonised in terms of protocols

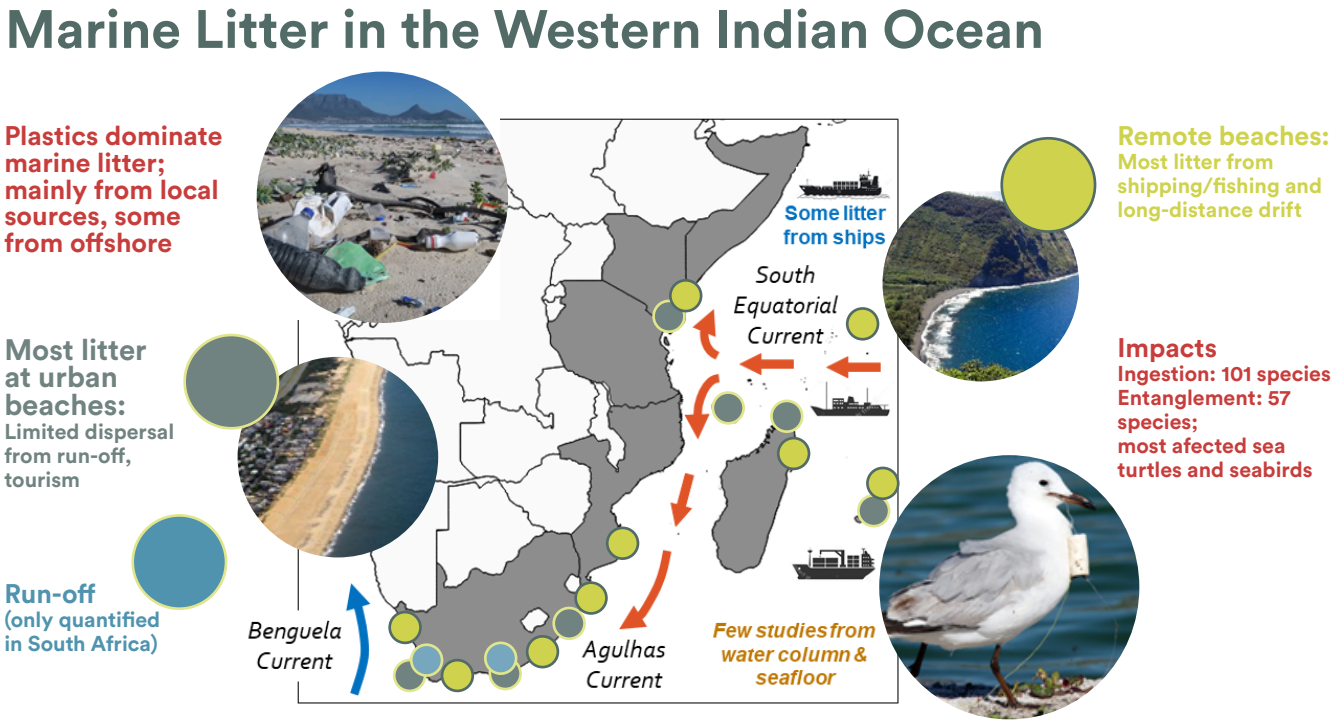

Figure 2. Synthesis of the current knowledge on marine litter, its sources and impacts in the WIO region, and the main oceanic currents that influence its transport. The points show a selection of study sites at urban (black) and remote (dark blue) beaches and sites where urban run-off has been measured (light blue). The countries' outlines on the map were generated using the freeware QGIS.

Table 2: Main recommended actions to address the marine litter and microplastics problem in the WIO region, based on the information gathered in this review and the recommendations provided by the national hot-spotting assessments implemented in Kenya, Mozambique, South Africa and Tanzania (IUCN-EA-QUANTIS, 2020a,b,c,d).

Research and monitoring	Actions for addressing land-based sources			Actions for addressing sea-based sources
	Prevention	Management	Clean-up	
• Extend regional monitoring programme within all WIO countries • Coordinate and harmonise protocols and reporting units within and beyond WIO • Include understudied habitats • Strengthen research of understudied topics • Ensure data availability	• Reduce production and consumption of single-use plastics • Add fiscal incentives to promote re-use or recycling • Promote design, production and consumption of reusable/returnable alternatives • Implement and enforce Extended Producer Responsibility (EPR) • Tax imported plastic products • Promote and carry out educational campaigns	• Ensure appropriate and more frequent waste collection • Increase capacity for proper waste disposal • Increase number of waste bins • Conduct anti-littering campaigns • Increase recycling capacity • Increase waste segregation at households and in public spaces • Ensure plastic waste has enough value to cover collection costs • Reduce open burning of waste	• Promote community-based clean-ups on land • Intercept litter in wastewater and rivers before it enters the sea • Promote and strengthen beach clean-up efforts close to source points (for example, river mouths)	• Implement and enforce stricter international regulations (for example, to ensure adhesion of ships to MARPOL Annex V) • Require that waste audits are conducted on ships upon departure and docking • Adopt a regional and coordinated approach for litter reception facilities in ports, based on a general fee

and reporting units (in coordination with global programmes, such as GESAMP, 2019). All data generated should be readily available, most notably for decision-makers.

Although several major knowledge gaps still need to be addressed (see Section 4.1), we should prioritise efforts to reduce the amounts of waste plastic entering the sea. Given that most marine litter in the WIO region comes from local, land-based sources, especially from the packaging sector (Figure 2), the most effective way to reduce plastic pollution is to prevent the generation of litter at the sources. We recommend modifying and converting the production of single-use plastics to reusable/returnable materials (which could also be reusable/returnable plastics). Promoting designs of alternative materials or processes that favour reuse will be essential (IUCN-EA-QUANTIS, 2020c). Governments should approve, implement, and enforce Extended Producer Responsibility (EPR), including take-back schemes, given that EPR is a fundamental and integral policy tool covering the entire waste life cycle and involving all sectors of society. These types of policies need to be accompanied and supported by educational campaigns directed towards citizens.

At the end-of-life step of the cycle, waste management must be improved at the municipal level, given that the national hot-spotting assessments revealed low rates of collection and proper disposal of waste, which translates to high rates of mismanaged waste (IUCN-EA-QUANTIS, 2020a,b,c,d). This is particularly relevant in Kenya, Mozambique and Tanzania, where 92 to 99 per cent of the generated waste is mismanaged (IUCN-EA-QUANTIS, 2020a,b,d). To improve waste collection and infrastructure, we recommend eliminating unregulated dumpsites and unsanitary landfills, ensuring appropriate waste collection and increasing the capacity for proper disposal. We also recommend additional waste collection, management and clean-up measures (Table 2), which could be helpful mitigation strategies until effective prevention measures are implemented.

In the case of remote beaches and small island states, most litter originates from offshore sources, coming from fishing, shipping, and long-distance drift (mostly from southeast Asia). In addition to local measures, stricter international regulations also need to be put in place and enforced (see Table 2 for examples). Major polluters such as Indonesia and other southeast Asian countries must also pledge their support for small island nations by implementing local measures to curb the release of litter into the sea, which is fundamental to keep litter out of downstream regions such as WIO.

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Economic consequences of unmanaged plastics and economic opportunities in the Western Indian Ocean: steps toward action plans

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Summary

The unprecedented accumulation of plastic litter on land and its leakage into the world's seas is a global crisis that is becoming unmanageable. In addition to costing countries economically, it has human and environmental costs, negatively impacts biodiversity, and contributes Green House Gases to the atmosphere. Reports suggest that this global problem will increase dramatically unless decisive concerted actions to combat plastic waste are implemented. The urgency is greater within the countries of the Western Indian Ocean as predictions are that the growth rate of plastic littering in this region will be considerably higher than the global average. An urgent regional response involving all countries is required. It is recommended that National and Regional Action plans should be developed that take a systemic and plastics life cycle approach. In developing such strategies, consideration needs to be given to each step in the upstream, midstream, and downstream components of the plastics value chain, focusing on developing markets for recycled and repurposed plastic waste. Other recommendations include the need for 1) enabling policies and legislation, 2) drawing upon regional expertise to build capacity and promote education at all levels, 3) increasing collaboration and knowledge-sharing by promoting regional networking systems. It is recommended that a guide to developing the national and regional action plans be compiled in a regionally inclusive manner. Further, the guide should contain a decision-making framework that facilitates the adaptation of prescribed actions to differing circumstances within the region.

Background

Recognizing the burgeoning plastic litter management challenges facing the Western Indian Ocean (WIO) countries, the Nairobi Convention and Western Indian Ocean Science Association (WIOMSA) initiated a regional assessment on the status of marine litter and microplastics and their ecological, human health and economic impacts. The focus of the evaluation was on the economic consequences and opportunities of unmanaged plastics. This paper includes abbreviated parts of a more comprehensive assessment that is in preparation.

It is estimated that between eight and twelve million tonnes of plastic enter the seas of the world annually (Jambeck and others 2015; The Pew Charitable Trusts and SYSTEMIQ 2020). The contributions from the Western Indian Ocean (WIO) countries and the rest of Africa have not been quantified (Jambeck and others 2018). Nevertheless, they could be considerable because the Africa Waste Management Outlook (UNEP 2018) shows that unmanaged plastic waste has accumulated over decades in many countries. Every day, newly discarded litter adds to the load already in the environment. The waste management endeavours of coastal cities cannot keep pace with the growth of litter (UNEP 2018). The situation is worsening. If current global trends are not slowed or reversed, plastic waste generation will double by 2040 (The Pew Charitable Trusts and SYSTEMIQ 2020).

Consequently, the amount of plastic waste accumulating on land worldwide will increase on average by 38 per cent of its current load, with an estimated threefold increase of inflow to the seas from the current 11 million metric tonnes per annum (about 350 kgs per second) to 29 million metric tons per year (about 920 kgs per second), by 2040 (The Pew Charitable Trusts

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and SYSTEMIQ 2020). This would result in a four-fold increase in plastic stocks in the ocean (The Pew Charitable Trusts and SYSTEMIQ 2020). The implication is that globally, on average, the flow of plastics into the oceans will treble. In WIO countries, however, a higher than the average growth rate is expected, given that predictions suggest plastic pollution for the middle to low-income countries will grow from 58 per cent in 2016 to 71 per cent by 2040. Reversing this trend will require well-planned, multidisciplinary steps to combat littering (The Pew Charitable Trusts and SYSTEMIQ 2020). The underlying causes are similar to those in other countries of Africa within the low to middle-income bracket. They include increasing population growth, urbanization, increasing proportion of affluent middle-class citizens and economic development (The Pew Charitable Trusts and SYSTEMIQ 2020; UNEP 2018). These contribute to rising per capita waste generation, including significant increases in plastic pollution (Jambeck and others 2018). As WIO countries cannot handle the current challenges of solid waste management (UNEP 2018), capacity building within municipalities is required to cope with the anticipated regional growth of plastics and other waste.

Waste accumulation carries high costs to every country in terms of human and environmental health (Kimani (2007), management costs, the decline in property value, loss of recreational and tourism facilities (Jambeck and others 2018, UNEP 2018) and decreasing general human well-being and quality of life. It also has negative impacts on agriculture and the fishing industries. A Business As Usual (BAU) approach, which does not keep pace with the growing plastic challenges, is unaffordable.

Advances

Call for action plans

A positive development arising from the fourth session of the United Nations Environment Assembly (UNEA-4) of March 2019 is that countries are expected to develop national and regional action plans to manage plastic waste in a coordinated manner (Resolution UNEP/EA.4/L.10, UNEA). Such action plans are essential, but the development of effective evidence-based plans depends upon nations having knowledge of and expertise in a wide range of plastic associated disciplines and the societies in which plastics are to be managed. The fields in which expertise is required range from the chemistry of plastics (including polymer chemistry) to a detailed understanding of key steps of the plastics industry. Fields of economics, socio-economics, the plastics economy (including the principles and practice of the circular economy), retailing, marketing, and consumer behaviour are fundamental to developing management plans. Experts in these core disciplines must be strategically integrated within the societies and communities to represent them in the planning and positively influence societal behaviour.

Moreover, educators must develop and deliver appropriate educational programmes at many levels. Environmental experts should formulate necessary actions to protect ecosystem processes and the biodiversity in terrestrial, freshwater, estuarine, marine, and aerial environments. Scientists are required to measure the impacts of remedial interventions accurately. Central players are those with expertise in waste management, engineering, recycling, repurposing, and upcycling. Collectively, planners need to guide legal experts who work with policymakers to develop enabling legal environments that will facilitate the implementation of recommended actions.

Any multidisciplinary planning required to develop the national and regional action plans should take a systemic approach (UNEP 2019) that includes life cycle assessments (UNEP 2021). Recommendations will need to be evidence-based, within the limitations of data scarcity in much of Africa, including the WIO (Jambeck and others 2015; Jambeck and others 2018, UNEP 2018). In the WIO, knowledge gaps need to be identified and research undertaken to fill those gaps. Given that research might be time-consuming and the urgency to implement the action plans, it may be necessary to adopt the precautionary principles and an adaptive management process to work with the best available data and adapt strategies as new data become available.

Different roles of the value chain in plastic pollution: points for action

Within the Life Cycle Assessment approach to the management of plastics (UNEP 2021), the plastics value chain represents the steps in the life cycle of plastics, starting from the extraction of fossil fuels from their sources and their transformation into raw materials. Subsequent stages are manufacturing and selling marketable plastic products, which consumers discard to become plastic litter and end the cycle. These different stages can be grouped into upstream, midstream and downstream sectors, with

different characteristics, costs and benefits. Each step needs to be considered when developing national and regional action plans. Here, we discuss the entire value chain. However, not all WIO countries have all the upstream components, especially the initial production of raw materials.

Upstream value chain components are concerned with producing raw plastic materials, primarily plastic pellets (nurdles), flakes and powders, or resins from fossil fuels (oil, coal, gas) and biofuels. They also include converting raw materials into manufactured plastic products and subsequent provision of the plastic products by the brand owners and packagers to the retailers who sell them. Those steps that are most directly involved in producing the plastic end products, which the retailers sell to consumers, are considered the true upstream aspects. Both retailers and consumers use and discard plastic packaging and plastic products, which initiate the downstream components that require waste management. Waste management activities represent the downstream components of the value chain. They are diverse, ranging from municipal waste management (in terms of collection and transport) to the management of landfills. The informal waste sectors are involved in sorting, collection, transportation, and upcycling. The waste is received by recyclers and those who transform plastic waste into other materials (repurpose plastics), which in turn are sold to consumers. We begin by examining the upstream and midstream components.

Characteristics of the three principal stages of the value chain: upstream Characteristics

Upstream components are run along business lines, in a competitive industry, by knowledgeable people who must provide products to the market and remain profitable. Employment opportunities are numerous, and the sector builds capacity. Economic inputs from the industry contribute to national GDPs. Plastic products are developed to meet the market demands by providing retailers. Hence, consumers, finished products that are easy and convenient to use, are lightweight, and relatively low cost (metal or glass containers would be heavier and more expensive). Plastics also contribute positively to the health sector, particularly in clinics and hospitals. Very little plastic is wasted during the manufacturing process because none of the factories can afford to lose plastics as profit margins are narrow. The industries run coordinated campaigns to reduce any loss (for example, Operation Clean Sweep, a global movement to help every plastic resin handler achieve zero loss to the environment; https://www.opceansweep.org/) and are conscious of the need to avoid criticism from governments and environmentalists.

Value is added at every step, from producing raw materials from fossil fuels to reaching a maximum value at the point of sale to the consumer. However, the moment the consumer uses and discards the product, there is an immediate loss of value.

From a purely economic and human convenience perspective, the benefits of plastics during the upstream

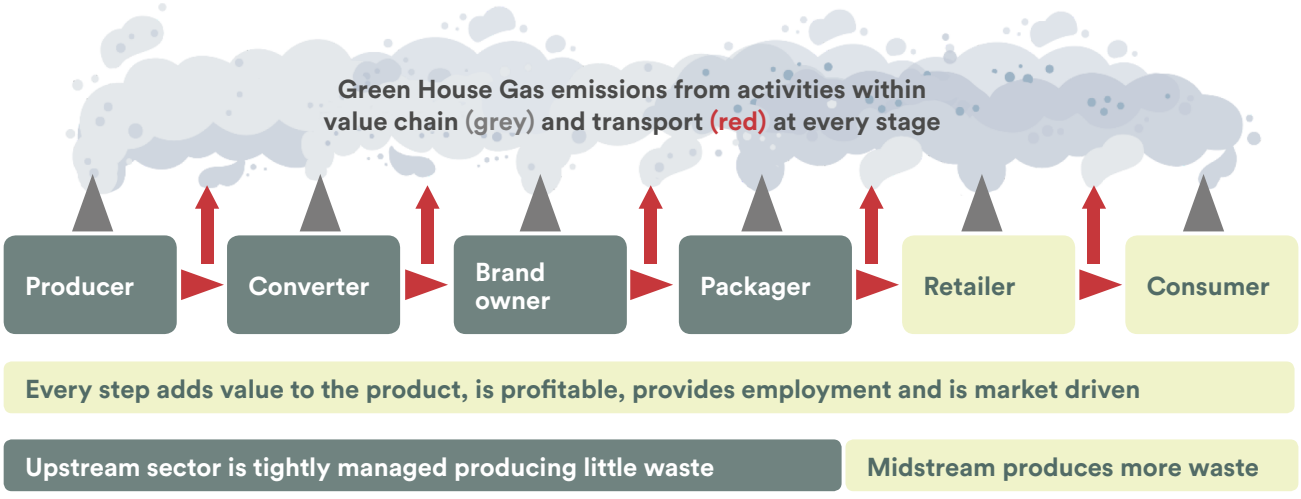

Figure 1. Every step of the value chain impacts the environment due to the operations involved and transport of materials, including contributions of Green House Gases to the atmosphere. The upstream and midstream components are driven by market objectives and are financially well managed. The upstream steps produce little plastic waste, whereas the consumers are the major contributors to the retailers' waste streams. Figure by Sustainable Seas Trust.

steps outweigh the costs. Environmentalists, however, are critical of the upstream components indicating that there are environmental costs at every step of the way, including Green House Gas (GHG) emissions (Figure 1). Some environmentalists argue that the plastics industry is entirely responsible for the downstream waste crisis and should pay for the cleaning of the environment, such as through the Extended Producer Responsibility initiatives (Dimitropoulos and others 2021). Considerable work is being undertaken to find alternatives to plastics that will offer the same benefits with no environmental costs. However, studies on plastic replacements are in their infancy, and successful results are probably decades away. In the meantime, the critical focus is on improvements to the value chains, particularly the downstream chain.

Midstream characteristics

Retailers are the crucial link between the manufacturers of plastic products, the brand owners and packagers on the one hand, and the consumers to whom they sell the final products. The role and interactions of retailers are complex, but they are involved in considerable repackaging and discarding of packaging. They sell high volumes of plastic products and plastic-wrapped materials to the consumers, most of which they discard, often after a single-use. The retailers and, particularly, consumers are primary contributors to discarded packaging and other waste materials, which are the source of downstream challenges.

Downstream characteristics

As indicated in Figure 1, at every step of the upstream and midstream of the value chain, the value increases in a market-driven sequence, from the raw material producers to the consumers. However, as soon as consumers discard the packaging or the plastic product, they drop in value or lose all value. The loss of all value occurs when there is no demand for discarded plastic waste. Consequently, the discarded, unwanted litter accumulates in all environments with many associated costs, including the burden of waste management by municipalities, which collect and transport plastic litter to landfills or dumps. As municipal waste management cannot keep pace with waste accumulation, burning is a commonly used alternative given the ease and low cost (UNEP 2018). Still, it has toxic effects on human health (UNEP 2018) and contributes considerably to GHG emissions (Beaumont and others 2019). However, developing sustainable end-markets for plastic waste can create a demand for litter to reduce waste management and human and environmental costs and accrue economic benefits. This is consistent with the philosophies that underpin the principles promoted by the circular economy publications (for example, World Economic Forum 2016). This New Plastics EEconomicreport draws attention to the potential value of punmanaged plasticsin the environment, including dumps and landfills, or are lost to the seas, for they can be worth millions of dollars if they are retained in the national economy. Building demand for discarded plastics can provide employment and clean the environment. In the WIO countries, taking steps to turn plastic waste into a valuable resource is a priority. We propose a simplified theoretical framework, although the management of plastics is complex, and circumstances may vary within and between countries. When developing Action Plans, details will need to be added to the framework outlined here.

The role of the end market

Without an end market, litter has no real value. There is no financial incentive to collect it, so the waste remains in the environment unless there are effective but costly municipal collections and transport to managed landfills. However, transforming litter into a product with a sustainable market is the first step after a market analysis to develop an enterprise that uses the volumes of available plastic waste to build and sell the products. The most apparent enterprise is to construct a recycling plant. Still, only certain plastics are recyclable and can be used in the enterprise—for example, polyethylene terephthalate, high-density polyethylene, polyvinyl chloride low-density polyethylene. As soon as the factory is operational, there is a demand for the selected recyclable plastics. This: a) gives them a value; b) leads to the collection of those plastics by the company; c) leads to the collection by the informal sectors (sometimes referred to as waste pickers or waste retrievers) who sell what they collect; and d) makes the sorting of plastics at source worthwhile. Immediate outcomes are that recyclable plastics are reduced in the environment, jobs are created in the formal enterprise and for the informal collectors, and local economy support. In addition, developing such an enterprise leads to a practical understanding of the differences between recyclable and non-recyclable plastics, the appreciation of plastics as inherently valuable material, and reduced waste management costs.

Furthermore, plastics that stay in the environment for a long time may become contaminated or weather

damaged, especially if collected from landfills or dumpsites. The enterprise will pay more for clean and fresh plastics devoid of sun damage, wind, or water exposure. This creates incentives for pre-processing at the primary source (such as sorting at home) before selling to collectors. Consequently, litter already in the environment is reduced, and the amount of new plastic litter is reduced.

As processes for recycling plastics differ from one plastic to the next, the next step is to establish which other recyclable plastics can be used to develop marketable products and then establish another enterprise. Building such recycling enterprises is a valuable step toward reducing plastic pollution but is only one relatively small step in meeting the overall challenge (The Pew Charitable Trusts and SYSTEMIQ 2020). Repurposing plastics that are not easily recycled is another valuable step in Africa. The recycling process involves mixing plastic waste with other materials, such as ground glass and crushed rubble, to produce various products. Such products include furniture, building blocks, tiles, paving stones, and fence poles. Some products are used to construct buildings, surface roads, provide paving, agricultural poles, and more. The process is to identify the market and build and expand the enterprise to satisfy and grow the market. Outcomes will be employment opportunities, growth of capacity, reduced load on the formal waste management sector, and the impact that fewer plastics pollute the environment. Additional outcomes are that humans and the environment will be healthier and local economies will grow.

Regional Outlook Promoting the municipal waste collection

As WIO countries cannot handle the current solid waste management challenges (UNEP 2018), the human, infrastructural and financial capacity must be built within municipalities to cope with the anticipated regional growth of plastics and other waste. In this regard, it would be valuable to ensure that positive working relationships between the formal and informal waste collectors are fostered to promote mutual benefits and collectively reduce national solid waste burdens.

Enabling legislation

The urgency to meet the growing waste crisis is such that it is essential that enabling policies and legislation are in place to support the development of the enterprises within municipal jurisdictions, nationally and regionally. Legislation should also govern what plastic products are permitted to enter the country. Equally, sensible guidance on which plastics should be released to the markets is required (for example, banning microbeads, plastic straws, cutlery, earbuds, and other carefully selected single-use plastics). Those in positions to guide policy and formulate legislation need to be knowledgeable and be supported by experts from different disciplines.

Developing recycling and repurposing enterprises that are profitable and large enough to reduce plastic litter significantly requires a) substantial capital investments, b) that the volumes of recyclable materials are large enough to ensure the viability of the initiative, and c) a secure, growing market. Enabling legislation can facilitate the achievement of all of these. For example, legislation, including significant tax benefits, can encourage local and foreign investment in enterprises. Legislation to promote Extended Producer Responsibility (EPR) can ensure that products are redesigned to become recyclable and the availability of funds to pay for aspects of post-consumer waste management (Dimitropoulos and others 2021). Similarly, legislation to promote the Ellen MacArthur Foundation's Plastics PACT network initiatives (Ellen MacArthur Plastic Pact 2021), which aim to stop plastic waste from packagers entering the environment, is potentially beneficial. Further, markets can be stimulated by legislation that promotes demand for recycled material and ensures that municipalities use products made from repurposed plastic waste (for example, paving, building blocks, tiles, signposts, furniture, walkways) rather than other alternative conventional products.

Regional collaboration and networking

The Nairobi Convention and WIOMSA noted that while many national initiatives deal with marine litter-related aspects within the region, there is little coordination, communication, and mutual learning among WIO countries, experts, and partners working in this field. They recognized a need for mechanisms to facilitate communication between practitioners and experts and between different programmes and funding agencies. They argued that this could help reduce duplication of work, establish partnerships, improve coordination, and provide a forum for sharing information and knowledge among experts, managers, and funding agencies, as well as joint regional planning and implementation. They pointed out that such regional efforts are of particular significance, as marine litter is transported widely by ocean currents and impacts distant localities both in the region and globally.

In response to these needs, searchable, interactive maps (to promote coordination, provide information, share knowledge, and encourage partnerships) are being developed by the African Marine Waste Network and have more than 3,000 entries. It is recommended that the African Waste Network mapping programme is further designed to best meet requirements, starting with organizations and institutions of the WIO placing their information on the maps at https://sst.org.za/maps/african-waste-network-maps/

Building of capacity, knowledge sharing, and promoting education

The Nairobi Convention and WIOMSA are concerned that the current level of knowledge about marine litter in the WIO is still insufficient to make region-wide recommendations to solve the problems related to marine litter. Although plastics have impacted people's lives since the 1950s, they have only become management, health, environmental, and economic challenges in the last few decades. Consequently, relatively few people in the WIO countries are trained in the broad spectrum of plastic-related disciplines. Most experts in the field are self-taught. Preliminary results from an ongoing survey by Sustainable Seas Trust (SST) show that only 12 out of 60 WIO universities examined thus far run courses with any plastic-related content or supervise plastic-related post-graduate studies. None of the universities covers the full spectrum of plastics-related disciplines, but rather each tends to follow the interests of the staff members who lead the courses. Despite the preliminary nature of the evaluation, it is clear that, while well-qualified experts are present within the WIO region, they are widely distributed. The need to collaborate in building regional teaching and research capacity in tertiary education institutes is apparent.

Similarly, a preliminary survey of education curricula in the countries of Africa by SST shows that the majority of the school syllabuses do not include plastic-waste issues. A coordinated, collaborative approach to education is recommended, ensuring that all countries access accurate information and valuable courses. Furthermore, capacity building in municipalities and strong promotion of understanding among public members, particularly the consumers, is required.

Nairobi Convention and WIOMSA might consider drawing together experts from within the WIO region to plot a regional strategy for education and capacity building, including the types of resources required for the different groups, how such materials should be delivered and in which languages.

National and regional action plans

The multifaceted nature of the plastics issues throughout every step in the lifecycle suggests that it is unlikely that any single institute will have the full range of expertise to develop national and regional action plans alone. Instead, a collaboration of a diversity of experts is key to ensuring that national and regional action plans are crafted to achieve desired outcomes and impacts. As the circumstances of each of the continental and island states of the Nairobi Convention are so different from the others, no single action plan can apply to every country. It is recommended, therefore, that a priority is to develop an overarching guide to what should be included within a national action plan and, in addition, have a decision-making framework that enables each country to adopt the actions to its own needs. Ideally, the overarching guide on developing national and regional action plans should be inclusively created by representatives drawn from every step in the plastics life cycle. It should have academic contributions (education, capacity building, skills development, research), government (including those directly responsible for waste management), economists and lawyers from every country. Such collaboration will ensure that the guide has a systemic approach and can be adapted to the circumstances that prevail in each country.

The purpose of the national action plans will be to provide a time-based roadmap for combating plastic waste, and in doing so, assist with the achievement of several Sustainable Development Goals. Regional action plans will promote international collaboration in achieving regional targets. They will define regional policy and open doors to transferring knowledge and harmonizing data collection methods.

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The Role of the Private Sector in the Management of Plastics as an Environmental Challenge

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Summary

Since their earliest days, plastics have been used to protect nature and help humans. Today, plastic is among the world's most widely-used materials. Scientifically advanced, lightweight and inexpensive, plastics suit a broad spectrum of uses. Unfortunately, this mass production and widespread use have brought the challenge of dealing with plastic products that have reached their end of life. In South Africa and around the world, far too much plastic still end up in landfills, or worse still – in the environment and, in particular, the oceans. The plastics industry is tirelessly working to raise awareness about plastics' versatility and use around the world. Moreover, it is even more important that the plastics industry and its entire value chain demonstrates its commitment to ending the contamination of the environment by plastics. As a result, manufacturers use fewer natural resources and energy, reduce CO2 emissions, create jobs, and support a variety of different industries and people. The reality is that there has been an increase in the awareness of the importance of recycling in society, the collaboration between industry, government, and NGOs, and the political will to create the infrastructure to make recycling possible and address plastic pollution. Businesses and big brand owners, retailers, and large corporates encourage recycled plastics in their packaging and products. Plastics contribute to circularity, health and safety and mitigate climate change. Businesses and big brand owners, retailers, and large companies encourage recycled plastic in their packaging and products. Plastic contributes to circularity, health and safety, and climate mitigation. In this respect, the private sector believes that plastics will play a vital role in our daily lives and our future.

Background

Plastics in the Environment

The problem caused by plastics litter in the environment has compelled governments, manufacturers and brand owners to rethink the way we produce, use and ultimately dispose of plastic. Many are now looking for innovative products that are inexpensive, non-disruptive to supply chains, and can be re-used and recycled at the end of their useful life without increasing CO_2 emissions. Lightweight plastic materials are used in many industries, helping to ensure food and water safety and reducing waste, health challenges and energy costs.

Plastic can either be synthetic or bio-based.

In South Africa, synthetic plastics are derived from coal, crude oil or natural gas, whilst bio-based plastics come from renewable products such as carbohydrates, starch, vegetable fats and oils, bacteria and other biological substances. The vast majority of plastic in use today is synthetic because of the ease of manufacturing methods involved in processing crude oil. Internationally, only a small proportion, four per cent, of the oil and gas reserves go towards the production of plastics, with the rest used for transport, electricity, heating and other applications (Plastics SA 2019).

Plastics Waste Management

On average, only 4 per cent of Africa's plastic waste is recycled (UNEP 2018). Across WIO countries, recycling rates range from nearly 45.7% in South Africa to virtually none in Comoros. Urbanisation and changing consumer behaviour are driving an increase in plastics consumption which, combined with weak municipal solid waste (MSW) collection systems, places WIO countries at risk of growing amounts of unmanaged plastics entering the Environment (UNEP 2018). Overfilled landfills are common in WIO countries and

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Figure 1. Roadside litter – Tembisa, Gauteng (credit: Douw Steyn, Plastics SA)

burden waste management services, with unmanaged plastics eventually contaminating coastal environments (Ferronato and Torretta 2019).

Current advances of plastics waste management and future directions

South African Plastics Industry

Plastics SA is a not-for-profit company that serves as an umbrella organisation for the South African plastics industry. The association is supported by membership fees derived from sales of locally manufactured plastics raw material, importers, and contributions and sponsorships from industry associations. Training activities generate the majority of the association's income. Plastics SA is a Federation of Associations. With the help of our industry associations, Plastics SA actively participates in the growth and development of the plastics industry in South Africa. The Plastics Industry Association of South Africa represents all industry sectors, including polymer manufacturers and importers, converters, fabricators, machine suppliers, and recyclers. Among Plastics SA's core

Figure 2. Learners on training at Plastics SA, Midrand, Gauteng (credit: Douw Steyn, Plastics SA)

functions are membership services, training, advocacy, research, communication, and sustainability (Plastics SA 2019).

As the largest plastics manufacturing industry in Sub-Saharan Africa, South Africa produced and imported 1 841 745 tonnes of virgin and recycled polymers in 2019. Virgin plastics in South Africa account for a very small percentage of the global market - less than half a per cent. Domestic virgin consumption is 88 per cent made up of commodity materials (polyolefins, PVC, PET and PS). Locally, recycled materials (recyclate) are converted into plastic products. Over time, many recyclates have developed unique markets that match the quality of available virgin polymers, while others complement virgin polymers well. Recyclate will replace (complement) many more virgin applications with a circular economy
(Plastics SA 2019).

Plastics Recycling in South Africa

In 2019, South Africa recycled 3 52 600 tonnes of plastics into raw materials. Of this 14 755 tons were exported to converters elsewhere, and 337 745 tonnes were converted in South Africa. The largest quantity of recyclables (approximately 70.4 per cent) came from landfills and other post-consumer sources in 2019. Post-industrial sources contributed 18 per cent. Incoming materials that have reached their end of life make up 82 per cent of the incoming recyclables. Post-industrial materials are sourced from distribution centres, shopping centres, farming communities and other waste generators. Recyclers are increasingly going directly to the waste generators to improve the quality of the incoming recyclables and reduce the costs. As a result, recyclers get cleaner materials and maintain their margins, even when fewer quantities. This is an important difference between South Africa and other developed countries. For instance, in the European Union, recyclables are retrieved as early from the waste stream as possible; in South Africa, on the other hand, recyclables are primarily obtained from landfills at a high cost (Plastics SA 2019).

Recyclable Materials

The majority of incoming materials - 57 per cent - came from the formal sector, collectors, and waste management companies - mainly baled materials and some loose materials.

Yet only three per cent of recyclables are collected directly by waste pickers and walk-ins, despite their importance to the value chain. Approximately six per cent was collected from drop-off facilities and buyback centers. Recycling companies are not geared toward buying small quantities of unsorted, unbalanced materials. Waste management companies buy recyclables from buyback centres, waste pickers and small informal collectors, compact the material before selling it to the recyclers. Only a handful of recyclers

Figure 3. An informal collector taking collected plastics to a buyer – Johannesburg (credit: Douw Steyn, Plastics SA)

have collectors and depots established over the years to complement their incoming stream of recyclables. Identifying potential sources of recyclable materials is one of the major barriers to entry for new start-ups (Plastics SA 2019).

Recycling Operations

There were 288 recycling operations recorded in South Africa at the end of 2019. Of the recyclers surveyed, 36 per cent processed post-consumer materials and granulated, wash and pelletised. Only a portion of these recyclers can successfully process landfill-sourced material. Good wash plants' high capital investment cost is feasible only for more extensive operations. Cleaner post-industrial and pre-consumer materials don't have to be washed, and the processors will only granulate and pelletise (Plastics SA 2019).

End Markets for Recyclate

Suitable end markets are critical for the sustainability of the plastics recycling industry. Markets for recyclate exist in most local market sectors. Only 4.1 per cent of the recyclate was exported as raw material to plastics converters in the SADC region and Asia. Brand owners and retailers have committed to the recycled content in packaging – 97 260 tons of recyclate were used for packaging again. Currently, only rPET is suitable for food contact. Recycled PP, PE-LD and PE-HD are used in non-food applications for personal care and domestic applications. Recycled flexible packaging was the largest market for recyclate in 2019, with 24 per cent of all recycled materials finding a local market in shopping bags, refuse bags and general, flexible packaging (Plastics SA 2019).

Industry initiatives and collaborations to deal with plastics waste

To address plastics in the environment, it is crucial to collaborate with the full plastics value chain, which includes raw material suppliers, converters, brand owners, retailers, recyclers, civil society and NGO's such as African Marine Waste Network WWF, IUCN, UNEP. Here, we focus more on the key partners of the plastics industry, such as the World Plastics Council (WPC), Global Plastics Alliance (GPA), Alliance To end Plastics Waste (AEPW) and South African initiatives. The global plastics industry supports various projects, actions, initiatives and finding best solutions to address plastics pollution:

- Plastics Waste Management Solutions
- Advocacy and Outreach
- Marine Litter Solutions
- Research
- Communication
- Education and Awareness
- Clean-up campaigns

South African initiative to end plastics waste

This initiative was started in 2019 and enjoys the support and active participation of the entire packaging value chain – including the chemicals sector, polymer and/or raw material producers, importers, packaging converters, retailers, brand owners, fast food franchises, producer responsibility organisations and

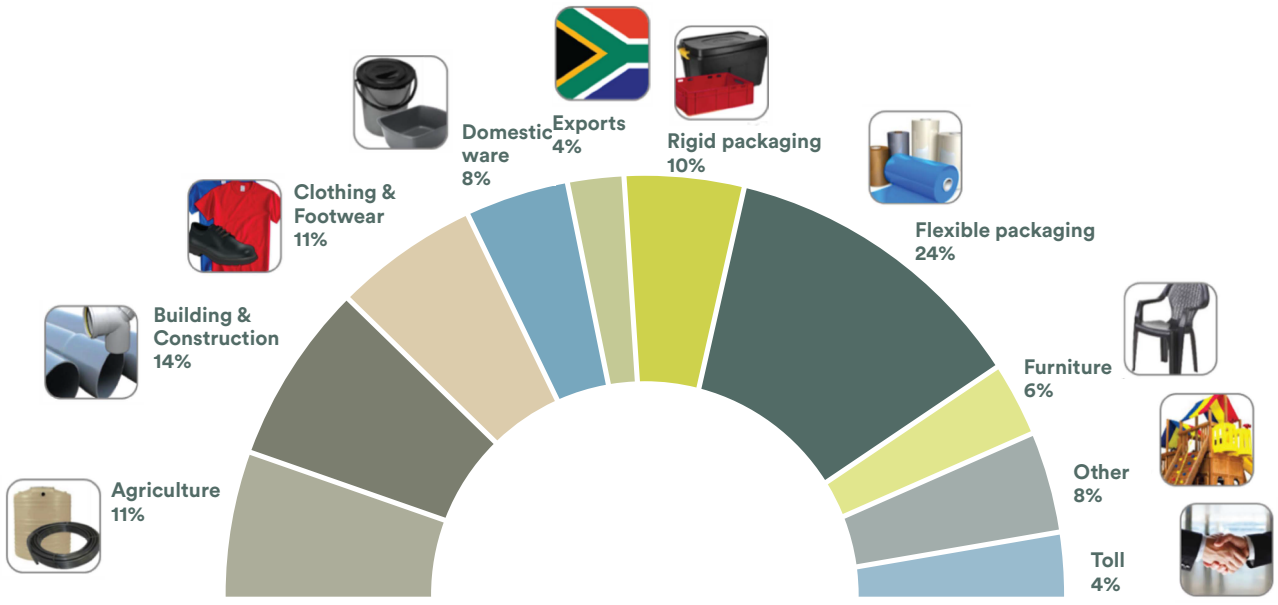

Figure 4. Domestic market applications for recycled plastics materials Plastics SA (2019)

many other stakeholders. Coordinated by the Consumer Goods Council of South Africa (CGCSA) as secretariat, six working groups were formed to look at, among other things, the role of technology, innovation and design; infrastructure; bioplastics and alternatives; and education and awareness in combatting litter, integration of the informal economy and product standards and certification. These working groups comprise industry leaders representing the entire value chain and government representatives of the forestry, fisheries and environment, trade industry and competition departments, and the UNEP.

The technology, innovation and design working group are focusing on improving the South African plastics industry's success with design for sustainability, increasing recycled content in products; securing demand for recyclate; generating energy from waste; increasing commercial and home composting facilities, developing end-markets for recycled plastic and developing refuse-derived fuels.

Improving plastics waste management, recycling infrastructure and developing reverse logistics are only some of the focus areas of the infrastructure working group. They are looking at the best ways of diverting plastic waste from landfills and the environment by considering existing infrastructure, river catchment projects and linking existing local and global networks. Their ultimate objective is to support infrastructure, create blueprint model(s) for implementation, and roll out relevant waste management projects. The bioplastics and alternatives working group developed a position paper on biodegradable and compostable packaging materials. Before introducing such packaging products, retailers and brand owners must consider various factors. One such factor is the importance of using appropriate labels and logos to ensure that they can be easily differentiated from their conventional counterparts.

The education and awareness working group's goals focus on awareness campaigns using information booklets, pamphlets, websites, mobile apps and clean-up events. They are developing a plan of action that utilises existing and new networks in the industry and government to improve awareness in schools, communities, consumers, industry and retailers, government, waste management companies, entrepreneurs and waste pickers.
The informal waste economy's integration focuses on the lack of collaboration between stakeholders – if the municipality can work with waste pickers, it will improve efficiency. Robust self-regulation and demand from retailers, manufacturers and consumers for decent quality products will go a long way in addressing product standards and certification. Participation of all key stakeholders (at all levels) is required to develop and manage plastics standards (Plastics SA, 2019).

South African Plastics Pact – The South African Plastics Pact is a collaborative initiative that brings together key stakeholders from the local plastics value chain, including businesses, the South African government, NGOs and other organisations, to tackle plastics waste and pollution at its source. The development of the SA Plastics Pact has been led by the World Wide Fund for Nature (WWF) and the South African Plastics Recyclers Organisation (SAPRO). It is supported by WRAP – the UK based global environmental NGO. Green Cape manages it with the support of WWF and WRAP. The Pact works towards the Ellen MacArthur Foundation's New Plastics Economy vision and an ambitious set of joint 2025 targets to create a circular economy for plastics in South Africa. The Pact encourages revised thought on the design, use, and re-use of plastics to achieve the targets. The SA Plastics Pact will build on the positive work started by other initiatives and help scale up and disseminate good practice. By 2025, The SA Plastics Pact will transform the country's plastic packaging sector by meeting four ambitious targets:

- Taking action on problematic or unnecessary plastic packaging through redesign, innovation or alternative (re-use) delivery models,
- 100 per cent of plastic packaging to be reusable, recyclable or compostable,
- 70 per cent of plastic packaging is effectively recycled, and
- Thirty per cent average recycled content across all plastic packaging.

By meeting these targets, the SA Plastics Pact will also stimulate job creation in the South African plastics collection and recycling sector and help create new product design opportunities and re-use business models (SA Plastics Pact 2021)

Producer Responsibility Organisations (PRO's) – A non-profit company established by producers operating in an industrial sector to support the implementation of their extended producer responsibility scheme. The PRO's plastics industry operations include PETCO, Polyco, PSA and SAVA.

PET Recycling Company (PETCO) – PETCO fulfils the PET industry's Extended Producer Responsibility (EPR) role, a voluntary industry-driven and financed environmental solution for post-consumer PET plastic. By imposing accountability over the entire life cycle of PET products and packaging, companies that manufacture, import and/or sell PET products are financially and physically responsible for such products after their useful life. PETCO raises the EPR fee directly from its members. This amount is applied to the raw material and pre-form purchases, both locally produced and imported. Those companies who purchase PET resin (both virgin and recycled) or pre-forms/sheeting pay the EPR fee to PETCO on a rand/tonne basis. A Board of Directors comprising the entire value chain of the obliged industry governs PETCO (Plastics SA 2019).

Polyolefin Recycling Company – Polyco aims to grow the collection and recycling of polyolefin plastic packaging in South Africa and promote the responsible use and re-use of polyolefins. Their mission is to reduce plastic going to landfills and end plastic waste in the environment. Polyco collaborates with various stakeholders, invests in innovation and recycling infrastructure in South Africa, and educates the industry and the consumer about recycling. Polyco was established in 2011 as a non-profit organisation by South Africa's polyolefin plastic packaging converters. Polyco members pay a voluntary levy for every ton of virgin polyolefin polymer purchased from either local or overseas raw material suppliers to ensure that Polyco will perform its extended producer responsibilities (Plastics SA 2019).

Polystyrene Association of SA – The Polystyrene Association of South Africa (POLY SA) represents their manufacturing and convertor industry members who primarily supply the food and protective packaging industries. The health and safety of products produced in South Africa is a core focus of POLY SA.

The recycling of polystyrene is a high priority. By developing end markets for the recycled material and acting as the facilitator between the recyclers/buyers and suppliers of recycled polystyrene, this Producer Responsibility Organisation (PRO) has proven the sustainable recycling of polystyrene. This recyclate is for use in the building and construction industries (lightweight concrete bricks and screeds), decor market (picture frames, cornices, curtain rods etc), arts and crafts (beads) and various charity projects (eg Bread tags for Wheelchairs, Tutu Desk and Wonderbag projects) (Plastics SA 2019).

SAVA – South African Vinyl's Association - SAVA is the representative body for the PVC industry and fulfils an active role in the sector's sustainability. With the support of its members, SAVA addresses PVC related issues. It constructively engages with stakeholders and role-players to create a positive environment for a vibrant and sustainable vinyl industry.

SAVA is dedicated to enhancing the growth and protecting the stature of the Southern African vinyl industry by expanding key markets, protecting the industry's reputation, identifying barriers to growth, and stimulating innovation. SAVA researches strategic interest and provides the industry with leadership and direction to ensure health, environmental issues and product stewardship. Through its Product Stewardship Commitment, SAVA focuses on sustainable manufacturing processes, the sustainable use of additives, closed-loop management and sustainability awareness across the entire value chain (Plastics SA 2019).

Global and Regional recommendations to address plastics in the environment

Plastic waste and plastics in the environment are unacceptable in any habitat, and this is the plastics industry's top priority at all times. Strong partnerships between an interconnected plastics value chain and all stakeholders, be they local, national or global, are needed to solve this problem and develop innovative, sustainable solutions.

Recycling is one of the most important actions currently available to reduce the impact and represents one of the most dynamic areas in the plastics industry today. Recycling provides an opportunity to minimise petrochemical usage, carbon dioxide emissions, and the amount of waste.

The industry needs to take action towards a circular economy for plastics, eliminate plastic litter in the environment, grow recycling rates and find solutions for plastics products that are not currently recyclable in the mechanical recycling value chain (Plastics SA 2019).

The vision plastics industry for a global framework includes:

- Governments commit to eliminating leakage by adopting the G20's 2050 Osaka Blue Ocean Vision.

- Establish national action plans to allow countries the flexibility to develop regionally appropriate plans to eliminate plastic waste leakage based on local circumstances and supported by enabling policies.
- Co-develop, with industry input, globally harmonised definitions and reporting metrics on plastics and plastic waste, using validated and harmonised methodologies.
- Develop global guidance, with industry input, on product design, recycled content, and resources efficiency optimisation.
- Waste management capacity building to ensure access and improved capacity for managing waste.
- Deploy technology through supporting chemical recycling technology, complementing mechanical recycling, to increase the circularity of plastics.
- Achieve climate goals by supporting life cycle analysis to evaluate impacts of plastics and alternatives

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Informing strategies to reduce marine plastic pollution in the Western Indian Ocean Region

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Summary

The plastics crisis is widely recognized, and many regional and national measures have been taken to address it. Moreover, there has been progress in developing methodological approaches that aim to fill a knowledge gap and support countries in better assessing plastic leakage and flow at the national level. Applications of these methodologies have been carried out in the Western Indian Ocean region (WIO), with promising results for guiding the consideration of relevant actions. The paper discusses some of the key challenges facing countries in the WIO region, including continental and island countries. It offers a series of recommendations for consideration at the regional and national levels for reducing plastic pollution in the marine environment. Compared to the level of investment required to upscale infrastructure for effective plastic waste management or advanced technologies for waste management and disposal, the proposed recommendations represent low-hanging fruit that is easier to implement.

Background

In recent years, the pace and scale of plastics production and use, and thus the amount of plastic entering the ocean from land-based sources, has multiplied considerably (Borrelle and others, 2020; Plastics Europe 2019; Jambeck and others, 2018). Despite its usefulness in many applications, countries across the globe struggle with its safe management and disposal at the end of its life (Jambeck and others, 2018). There has been increasing awareness of the challenges posed by plastics in the environment, particularly in the marine environment, where their presence poses dynamic problems for fisheries and wildlife. Plastics are linked to altered fisheries productivity, false satisfaction of shellfish and other wildlife, the entanglement of biota, transportation of toxic persistent organic pollutants, and human health risks from consumption of contaminated seafood. More than 99 per cent of plastics constitute hydrocarbons sourced from fossil fuels; hence their increased production results in more Greenhouse Gas Emissions (GHGs) emissions (Azoulay and others, 2019). As a result, plastic pollution in the marine environment negatively impacts coastal livelihoods and economies in the long run.

In the African continent, plastic pollution has primarily been linked to the mismanagement of solid waste (Alimi and others, 2021; Babayemi and others, 2019; Godfrey and others, 2018; Jambeck, 2017). Many factors contribute to this problem, such as under-investment in waste management infrastructure, increased use of plastics with increasing societal affluence, a lack of policies to address the plastic component of solid waste effectively, and overall low incentives for plastics recovery treatment and recycling. In many countries, municipalities or their local government equivalents are responsible for collecting and disposing of solid waste. Rather than population density, income levels are the most influential factor in accessing waste service infrastructure on the continent (Godfrey and others, 2018). High waste service provision is generally seen in high-income, affluent neighbourhoods compared to high-density, low-income areas. Solid waste management across the continent has primarily been handled through disposal in unsanitary landfills and illegal and unregulated dumpsites. The recovery of plastic waste material for recycling has been low but is slowly picking up in many countries.

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Figure 1. Accumulated plastic litter in an open space in a low-income urban community in Cape Town, South Africa. (Photo credit: Drakenstein Municipality)

In recent years, many African countries have adopted policy and regulatory measures to address plastic pollution in the environment, whether directed at solid waste management or outright bans on products and applications. In addition, the private sector and civil society organisations are also engaged. The private sector has mobilised to address plastic waste management, mainly by developing circular economy action plans for their operations (Borrelle and others, 2020), while civil society and non-governmental organisations continue to play an important role in empowering communities to engage in sound waste

Figure 2. Local women earn a livelihood from sorting and trading plastic waste in Durban, South Africa. (Photo credit: WildOceans/IUCN)

management practices (Godfrey and others, 2018). A few countries are deploying additional mechanisms such as Extended Producer Responsibility (EPR), which shifts the burden to address the end-of-life of different products to their respective producers and brand owners. These policy and regulatory measures have resulted in increased consideration, engagement, and action planning by different sectors and actors on redesign, management and disposal of plastics. There is incineration and waste-to-energy as plastic waste treatment options. However, these have not been applied widely across the continent due to their associated high costs, mechanical and institutional challenges, and risks to human health from hazardous byproducts (Borrelle and others, 2020).

Advances in understanding the dynamics of marine plastic pollution

Parties to the Nairobi Convention, also known as the Convention for the Development, Protection, Management and Development of the Marine and Coastal Environment of the Western Indian Ocean, have taken measures to combat marine plastic pollution in the Western Indian Ocean. In their ninth Conference of Parties (COP) – the decision-making forum in which policies and strategies are agreed upon – the Parties approved Decision CP.9/3, targeted at managing marine litter and municipal wastewaters in the Western Indian Ocean. This critical decision prioritised developing a regional strategy for managing marine litter and microplastics and forming a regional technical working group on the topic. Among the other priorities was the need to implement action programs for outreach and public awareness for municipal waste and marine litter, the phase-out of microbeads in the region and the exchange of expertise and best practices.

In addition, United Nations Member States, major groups and stakeholders have recognised the challenges countries face in addressing marine plastic pollution and microplastics and have passed resolutions at past meetings of the United Nations Environmental Assembly (UNEA). The group urged governments to implement measures and action plans to reduce marine litter, improve knowledge about marine plastics and microplastics, and examine the effectiveness of appropriate governance strategies and approaches.

Accordingly, the International Union for Conservation of Nature (IUCN), in partnership with the United Nations Environment Programme (UNEP), has piloted the development and application of methodological guidance that provides countries with tools and methods to account for plastic flows and leakage at a country level, and determine appropriate interventions. The methodological guidance '*UNEP/IUCN National Guidance for Plastic Pollution Hotspotting and Shaping Action*' has been applied in a select group of countries within the WIO region, including Kenya, Tanzania, Mozambique and South Africa. These four countries have a combined coastline stretching more than 8 000 kilometres, representing nearly half of the total coastline length of all Nairobi Convention countries.

The guidance outlines a scientific approach to mapping plastic leakage and its impacts by collecting and analysing relevant plastic production, consumption, waste management, and disposal data. It enables the tracking of plastic consumption in various sectors such as healthcare, agriculture and food, logistics and transport, and households to develop corresponding solutions to reduce the adverse impacts of plastics. The modelling of these inputs results in the generation of actional hotspots that governments, in collaboration with key stakeholders, can use to identify and implement corresponding interventions and instruments to address plastic pollution. The metrics generated avail decision-makers the opportunity to set targets, agree and implement actions, and monitor progress towards success.

Such a harmonised quantification of plastic leakage and impact could benefit all countries of the Convention as it allows establishing a baseline for benchmarking and tracking the progress of interventions. From the select countries where the assessment has been implemented, there is evidence of the need for comprehensive, consistent, and credible metrics on marine plastic pollution in the WIO region. A methodology that harmonises existing data, tools and resources could support countries to achieve this objective. The assessment considers a holistic approach, covering major plastic polymers and products and their leakage and impacts along the plastics life cycle. The overall output of the plastic pollution hotspotting exercise is action-oriented and supports users with a set of options for planning and implementation.

The results from the assessment have supported and informed the development and review of relevant national action plans and strategies aimed at addressing marine plastic pollution. The results are a timely provision of metrics to influence the thinking and refinement of the implementation of objectives of

Decision CP.9/3 (2018), and the more recent Decision CP.10/10 on Water Quality and Marine litter adopted at the 10th Conference of Parties to the Convention in the year 2021.

The national assessments provide a partial basis to support a regional understanding of key plastic flows and leakage into the Western Indian Ocean as it covers the continental countries of the Convention, except for Somalia. The result provides reliable and credible baseline metrics that benefit from a quantitative and qualitative technical assessment to quantify the potential fate of plastics in the marine environment and presents a preliminary overview of strategic priority interventions and policy options for consideration by countries. The assessment outlines robust metrics of regional significance, with enough granularity for action that enables governments and regional bodies in the WIO to promote, enact and enforce legislation and other practical measures to contain and reduce marine plastic pollution.

The Indian Ocean Island nations have attempted to quantify plastic leakage to the ocean, estimated based on World Bank data on mismanaged plastic solid waste and Country Working Papers. The estimated leakage from Comoros, Madagascar, Mauritius, Seychelles has thus been provided (Kelleher 2021). Still, it will not be discussed in detail in this paper as they are not based on a comprehensive application of the '*Guidance for plastic pollution hotspotting and shaping action*'.

Measuring and forecasting plastic leakage and impacts is complex due to the multifaceted nature of leakage pathways and the general lack of data to inform leakage models. Addressing the pollution problem is even more challenging. Therefore, it requires that stakeholders from all levels and facets of society join forces to understand and benchmark the issue towards action.

Outlook for the Western Indian Ocean region

In terms of plastic leakage, the application of the hotspotting assessment across the four continental countries shows that approximately 190 000 tonnes of plastics leak into the ocean, representing 8 per cent of a total estimated 2.3 million tonnes of mismanaged plastic waste using 2018 baseline figures. Suppose estimates of the island nations in Kelleher (2021) are added to the above estimates based on country working papers. In that case, the total regional leakage to the Western Indian Ocean is about 195,528 tonnes each year, from a total of 2.41 million tonnes of mismanaged plastic waste. It is evident from this that the estimated leakage figure from the island nations does not alter the basis for discussion on plastic leakage in the region, as it represents about 3 per cent of the regional leakage component. It may be worth noting that the total regional leakage and mismanaged plastic waste could be higher if modelled on 2021 figures, during which plastic use in packaging and personal protective equipment has risen significantly due to the COVID-19 pandemic.

There are variations in per capita waste leakage across the continental countries, ranging from a low of 0.5 kg/capita/year in Tanzania to 1.4 kg/capita/year in South Africa according to IUCN-EA-QUANTIS (2020 a,b,c,d). These variations differ even more within countries when a comparison is made between rural and urban per capita leakage, with a general high figure in urban areas. The per capita waste leakage across the island nations ranges from a low of 0.12 kg/capita/year in Mauritius to a high of 2.13 kg/capita/year in Comoros. These estimates show that only Comoros and South Africa have a higher per capita waste leakage than the regional average of 1.3 kg/capita/year estimated in Jambeck and others (2015).

To better understand how the WIO countries within the assessment perform relative to one another, the per capita plastic leakage results are illustrated relative to their Human Development Index (HDI)[1] in Figure 3 below. The blue line represents the HDI score, while the orange represents their plastic leakage per capita.

The observed general trend among the continental countries Kenya, Mozambique, Tanzania, and South Africa is that plastic leakage per capita increases with HDI. South Africa, which is categorised as a 'High Human Development' country under the Human development groups of the HDI, also has a high plastic leakage per capita (1.9 kg/person/year) compared to its continental peers. Kenya, which is categorised as a 'Medium Human Development', follows in second position (0.8 kg/person/year), while Tanzania and Mozambique, categorised as 'Low Human Development', show much lower per capita leakage rates of 0.5 and 0.6 kg/person/year respectively. Different modelling methodologies also result in different outputs,

[1] Human Development Index (HDI) is a composite index that measures average achievement in three basic dimensions of human development—a long and healthy life, knowledge and a decent standard of living. See http://hdr.undp.org/sites/default/files/hdr2020_technical_notes.pdf for details on how the HDI is calculated.

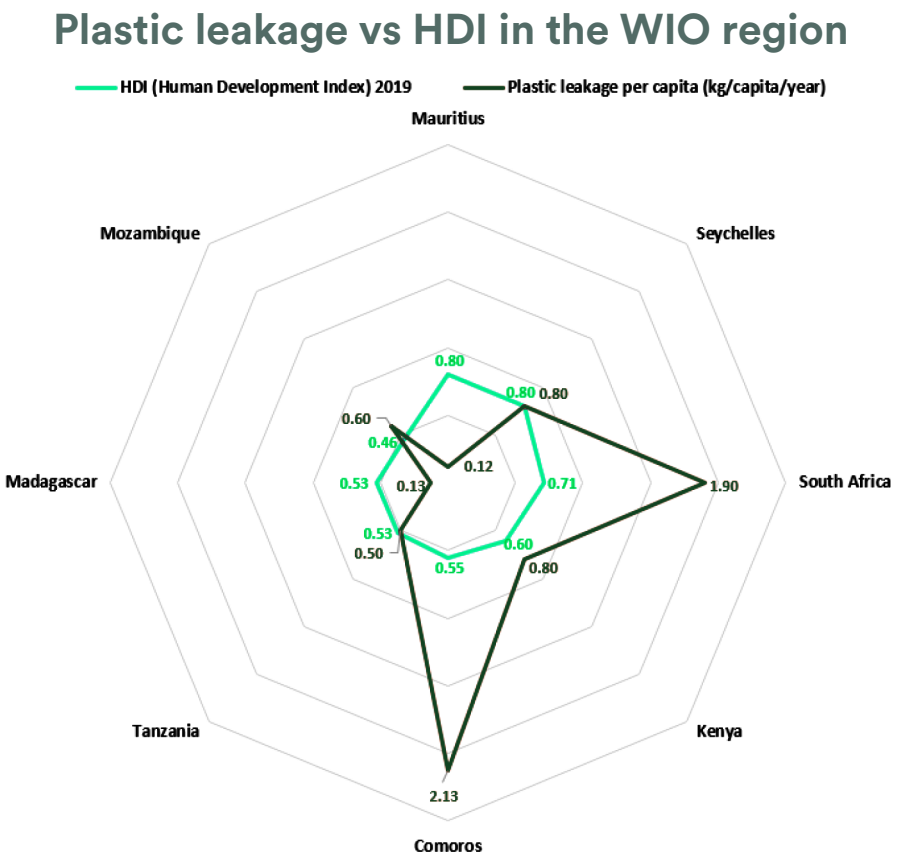

Figure 3. Relationship between plastic leakage with Human Development Index among eight countries in the WIO region (Data from IUCN-EA-QUANTIS, 2020 a,b,c,d; Kelleher 2021; UNDP 2020).

even for the same country. For example, while the leakage rate is estimated at 107 thousand tonnes per year, it is lower than that of 157 thousand tonnes estimated by Jambeck and others (2015), while for Kenya, the figure of 37 thousand tonnes is six times greater than Jambeck's estimate.

Mauritius, categorised as a 'Very High Human Development' country, has the lowest plastic per capita leakage rate (1.2 kg/person/year) among the island nations. This could be directly attributable to its high gross national income (GNI) per capita (UNDP 2020) and low poverty rate (0.2 per cent) according to a 2017 survey of poverty rate at the US$1.90-a-Day Poverty Line World Bank (2020). Seychelles, categorised as 'High Human Development', seem an outlier. It shows a higher leakage rate of 0.8 kg/person/year compared to Mauritius, despite having comparable HDI (0.8) and poverty rate (1.2 per cent, based on a 2013 survey). As the data from the island nations did emanate from applying the '*Guidance for plastic pollution hotspotting and shaping action*', it is difficult to deduce the underlying factors that could explain this disparity. Comoros, categorised as a 'Medium Human Development' country, has the highest plastic leakage rate of all the countries (2.13 kg/person/year), despite having an HDI comparable to Tanzania and Madagascar (0.55) and poverty rates of 19.1 per cent. This seems to be an outlier as there are stack disparities in yearly plastic leakage estimates between different sources, as Kelleher (2021) captured.

The WIO region has observed high quantities of plastic waste generation and leakage due to several factors, including the low levels of plastic waste collection and recovery, which range from 27 to 60 per cent and the low recycling rates, which range from 1 to 14 per cent in the four continental countries (IUCN-EA-QUANTIS, 2020 a,b,c,d). With such low collection and recycling rates, the bulk of plastics used in these countries is bound to be mismanaged and leak into the environment.

Other factors that contribute to the high levels of mismanaged waste include the dilapidation of waste management infrastructure, including the widespread use of unsanitary landfills. A landfill is considered unsanitary when waste management quality standards are not met, thus entailing a potential for leakage. Such

landfills have no regular, daily waste compaction, and neither are their bottoms designed in a way to avoid spills. There is overall low investment towards maintenance and upgrade of infrastructure, low value of most plastics after their first use, institutional and human resource deficiencies, high rates of urbanisation surpassing the capacity of existing systems. A common problem across all countries is the overuse of plastics—especially on-the-go type of plastics used in food and beverage packaging, lack of adequate waste separation at source or separate collection, leading to high contamination of most recyclables and hence their low value for recycling. Lastly, policy reform and related uncertainties, and a plastics economy stuck on the linear model of make-use-dispose hinders progress towards a circular economy.

On the positive, many countries in the region are enacting policy and regulatory measures that promote a shift towards a circular economy. Since the COVID-19 pandemic began in early 2020, the recycling sector has been quite fragile, affected by the decline in fossil fuel prices, which created a context where virgin plastics are cheaper than recycled plastic. If these factors persist, the projected increase in coastal populations across the continent could result in higher rates of plastic pollution to the ocean in the long term.

Conclusion

Based on the analysis above, it is evident that marine plastic pollution threatens the viability of coastal livelihoods and marine biodiversity and wildlife in the Western Indian Ocean. Further, it emphasises the urgent need for improving waste collection and management – the first step towards more circularity – to reduce and contain plastic inputs in the ocean. The following paragraphs provide insight and entry points for policy engagement and management intervention for countries in the WIO region and Africa to reduce overall plastic waste mismanagement and plastic leakage into the ocean.

In the WIO, a key concern is that recycling capacity remains low and is therefore not adequate to handle the increasing volume of plastic waste generated. As a result of the COVID-19 pandemic, the challenges society faces in managing waste have been brought to light. There is a growing amount of plastic waste generated in many cities due to the high production and use of single-use plastics and personal protective equipment. The pandemic has disrupted regional waste trade and logistics, especially countries with lower capacity for handling waste that must export parts of their high-value waste to countries with capacities. Thus, there is a strong case for improving local capacities and waste infrastructure to handle domestic waste in-country.

Waste collection services and management are implemented more in urban areas and cities than rural and low-income areas. As can be deduced from IUCN-EA-QUANTIS (2020 a,b,c,d), a few major cities, districts or provinces are responsible for the bulk of plastic leakage into the marine environment. In Tanzania, for example, Dar es Salaam accounts for 71 per cent of the country's leakage contribution to the Indian Ocean. Acknowledging the intricate relationship between the Human Development Index and plastic waste generation (Figure 3), the density of leakage per kilometre squared tends to be higher in urban areas and cities than in rural areas.

IUCN's partnership and collaboration with seven local, small-scale initiatives to promote circular principles towards diverting and preventing plastic waste flow into marine environments saw approximately more than 150 000 kg of plastics prevented from ending up in landfills, dumpsites and the marine environment during the period 2019 to 2021. As no single actor can independently drive full life-cycle and circular improvements, the efforts of local-level initiatives need to be acknowledged both for waste management and in enhancing livelihood options and opportunities for waste pickers, reclaimers and communities. The key lesson derived from these initiatives is the potential to build capital from waste through rethinking and redesigning sector components, minimising loss of resources, and extending the product's life. Unfortunately, despite the positive intentions in promoting a circular economy across the region, it remains weak on the social-equity dimension despite the increasing number of community and citizen-driven initiatives in the region.

Some recommendations for regional consideration

Urge governments to undertake measures to strengthen plastic recycling capacity, lessen the burden of entry and scaling for informal and formal actors, and adhere to established norms, standards, and licensing requirements as applicable.

- Encourage governments to implement measures that discourage producing and importing plastic objects that do not benefit from a recycling solution within national jurisdiction.

- Facilitate strengthening tools, capacities, and knowledge for municipalities and local government to address plastic pollution in major cities, towns, and peri-urban areas.
- Urge municipalities and local governments to scale measures to address widespread littering and open burning of plastics through increased waste collection efforts.
- In the WIO region, encourage governments and the private sector to develop and support policies to increase the value of after-use plastics, as well as redesign products and materials for End-of-Life value and circularity.
- Increase funding to local initiatives to address the socio-equity gap in the circular economy, scale-up plastic waste collection and recovery, and improve the integration of the informal sector in the waste economy.

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A Strategic Framework for Coastal and Marine Water Quality Management in the Western Indian Ocean

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Summary

Governments in the Western Indian Ocean (WIO) region, through a consultative process, have agreed on the need for a suite of national and regional actions to address major stresses on the marine environment. This is demonstrated in several initiatives, including:

- The Protocol for the Protection of the Marine and Coastal Environment of the Western Indian Ocean from Land-Based Sources and Activities (LBSA Protocol) to the Nairobi Convention
- Implementation of the Strategic Action Programme for the protection of the Western Indian Ocean from land-based sources and activities (WIOSAP)
- The Western Indian Ocean Large Marine Ecosystems Strategic Action Programme Policy Harmonisation and Institutional Reforms (WIO LME SAPPHIRE)
- Enforcing Environmental Treaties in African, Caribbean and Pacific (ACP) Countries (ACP-MEA Phase III) - funded by the European Union.

For coastal and marine water quality management (C&MWQM), improved capacity and the implementation of strategic frameworks can improve ecosystem integrity with consequent socio-economic and environmental benefits, locally, regionally and globally. Countries in the WIO region vary in their current planning and implementation in C&MWQM, and the development of a regional strategic framework will provide a basis for adoption and integration into national frameworks. This paper presents a strategic framework for C&MWQM to be considered for implementation in the region. Ultimately, achieving the strategic objective for coastal and marine water quality in the WIO region, which states '*Water quality in the WIO region meets international standards by the year 2035,*' depends on the success of the framework and on adopting the proposed implementation thereof into national policy and best practice. It also requires political commitment to assist in securing dedicated financial resources and the skilled personnel required to execute C&MWQM programmes.

Background

Protection of valuable natural resources is at the core of coastal and marine water quality management (C&MWQM), not only for conservation of biodiversity but also to safeguard and enhance socio-economic ecosystem benefits to society. Ironically, root causes in the social system are significant contributors to the deterioration of coastal and marine resources in the Western Indian Ocean (WIO). These include population growth, poverty, inequality, inadequate knowledge and awareness, inappropriate governance and lack of financial resources (UNEP and others, 2009). While these root causes typically manifest in indirect societal dynamics that contribute to the deterioration of marine ecosystems, sectors that pollute marine areas include urban development and tourism, agriculture and forestry, fisheries and aquaculture, industry, mining, marine transportation and energy production. Different types of pollution arising from these sectors have an array of environmental impacts and socio-economic consequences, including microbiological contamination, nutrient enrichment

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(eutrophication), marine litter, suspended sediment loading, and toxic pollution (UNEP and others, 2009). Not surprisingly, hotspots of marine pollution primarily coincide with the larger coastal cities and towns, where key sources of pollution are concentrated.

Reflecting on marine water quality policy and management status in the WIO region, most countries are signatories to major international conventions and agreements on combating marine pollution. At the national level, most countries have some form of legislation in place to enable the control and management of marine water quality, some more advanced than others. However, dedicated management initiatives focusing on marine water quality management are limited. Where policies and plans have been put in place, implementation remains a major challenge (eg UNEP and others, 2009; UNEP and others, 2015).

The Nairobi Convention is an important regional platform for addressing challenges facing coastal and marine ecosystems in the WIO region through catalytic interventions, dialogue and partnerships. The governments of the Contracting Parties to the Nairobi Convention have agreed, through a highly consultative process, on a suite of national and regional collective actions that are required to address major stresses on the coastal and marine environment of the region, including:

- Implementation of the Strategic Action Programme for the Protection of the Western Indian Ocean from Land-based Sources and Activities (WIOSAP) - funded by the Global Environment Facility (GEF);
- The Western Indian Ocean Large Marine Ecosystems Strategic Action Programme Policy Harmonisation and Institutional Reforms (WIO LME SAPPHIRE) - funded by the Global Environment Facility (GEF) and implemented by the United Nations Development Programme (UNDP); and
- Enforcing Environmental Treaties in African, Caribbean and Pacific Countries (ACP-MEA Phase III) - funded by The European Union.

These initiatives, amongst others, are important for the implementation of The Protocol for the Protection of the Marine and Coastal Environment of the Western Indian Ocean from Land-Based Sources and Activities (LBSA Protocol) to the Nairobi Convention.

In terms of C&MWQM, it is expected that through improved capacity and the implementation of appropriate strategic frameworks, ecosystem integrity can be improved, leading to local socio-economic and environmental benefits, in addition to global environmental benefits. Developing a regional strategic framework for C&MWQM would, therefore, provide a basis for adopting and integrating this into national coastal and marine water quality frameworks, acknowledging that countries are at different stages of development. Within this context, the Contracting Parties urged the Secretariat of the Nairobi Convention to establish such a regional framework to fast-track implementation, building on previous initiatives linked to C&MWQM in the region (eg UNEP and others, 2009; UNEP and Nairobi Convention 2009; UNEP 2010; ACSLME and others, 2014; UNEP and others, 2015). The request from the Contracting Parties is backed by various CoP Decisions, for example Decision CP.9/2.2 that encourages the Contracting Parties to harmonise legislation and strenghten institutional capacity, Decision CP.9/3 on the management of marine litter and municipal wastewater in the Western Indian Ocean, and Decision CP.9/8.4 on the reactivation of the subregional centre on combating marine pollution from oil spills and hydrocarbons, based in Madagascar, as was recommended by the Ministerial Conference on Maritime Security in the Western Indian Ocean, held in Balaclava, Mauritius in April 2018.

Advances: Proposed Strategic Framework for C&MWQM

In essence, the need for C&MWQM stems from a tension between the need to protect biodiversity, and associated socio-economic benefits, and the need for economic development in sectors which may contribute to sources of marine pollution. A Strategic Framework, as conceptualised in Figure 1, will provide direction in achieving effective C&MWQM.

C&MWQM starts with the establishment of strategic objectives and targets. The Strategic Action Programme for the Protection of the Coastal and Marine Environment of the Western Indian Ocean from Land-based Sources and Activities (UNEP and Nairobi Convention 2009) set the following Strategic Objective for water quality in the region, supported by an array of specific targets: *'Water quality in the WIO region meets international standards by the year 2035.'*

Basic principles provide broad direction within which to position implementation of C&MWQM. Five basic principles recommended for the WIO region are:

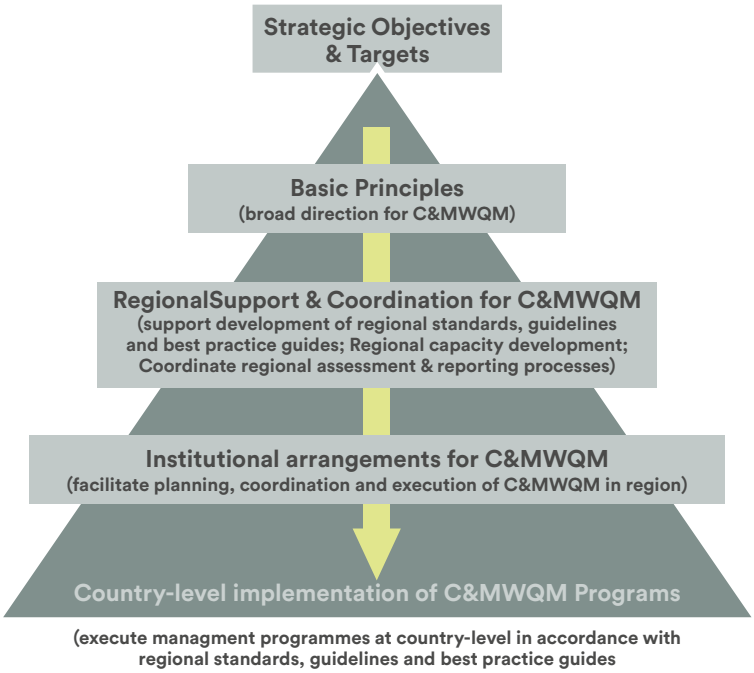

Figure 1. Conceptualisation of the strategic framework for C&MWQM in the WIO region

- Principle 1: Pollution prevention, waste minimisation and precautionary approach
- Principle 2: Receiving water quality objectives approach
- Principle 3: Integrated, adaptive assessment approach
- Principle 4: Polluter pays principle
- Principle 5: Participatory approach.

Harmonisation of C&MWQM in the WIO region requires regional support and coordination (eg through the Nairobi Convention Secretariat and partners), for example coordinating the development of regional standards, guidelines and best practice guides for developing regional capacity and regional reporting processes. Aligned with the Objectives and Targets of the Strategic Action Programmes (UNEP and Nairobi Convention 2009; ASCLME and others, 2014), many regional standards, guidelines and best practice guides relevant to C&MWQM have already been developed. These include:

- The Protocol for the Protection of the Marine and Coastal Environment of the Western Indian Ocean from Land-Based Sources and Activities (LBSA Protocol) to the Nairobi Convention;
- WIO Action Plan on Marine Litter (UN Environment 2018);
- African Marine Litter Monitoring Manual (African Marine Waste Network, Sustainable Seas Trust - Barnardo and Ribbink 2020);
- WIO Marine Highway development and Coastal and Marine Contamination Prevention Project (2020); and
- Regional oil spill preparedness in eastern Africa and WIO (UNEP and others, 2020a, 2020b).

In the case of Regional State of the Coast Reporting - derived from the requirements of the Nairobi Convention - the Western Indian Ocean Marine Sciences Association (WIOMSA) has in the past guided the technical process at the regional level together with experienced scientists, in consultation with the Contracting Parties and their National Focal Points in terms of the political agendas (UNEP and others, 2015). Ideally, in the case of future regional status reports, regional coordinators will be able to draw on national-level status reports produced as part of their C&MWQM implementation programmes.

Also key in a strategic framework, is the establishment of appropriate institutional arrangements to facilitate ongoing implementation, and alignment and coordination of effective C&MWQM in the WIO region (UNEP and GPA 2006; Taljaard and others, 2013; DEA RSA 2014) (Figure 2).

A Regional Task Force (RTF) for Water, Sediment and Biota Quality has already been established under the WIOSAP project. This provides an ideal platform for regional coordination in the future. To ensure it

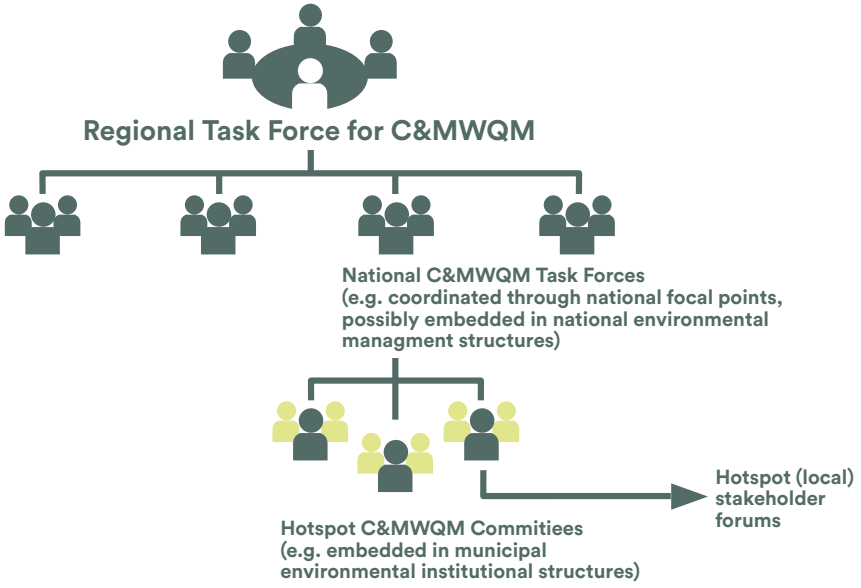

Figure 2. Proposed institutional arrangements for coordination and implementation of C&MWQM in the WIO region

has requisite political support and sustainability, it is proposed that this Task Force be formalised through a relevant CoP Decision so that it operates at the Convention level beyond the lifespan of a project. The oversight and coordination of C&MWQM within countries requires national institutional structures (eg National C&MWQM Task Forces), preferably coordinated through the National Focal Points, to facilitate coordination and alignment with the RTF. National Task Forces need to be cross-sectoral, comprising not only of environmental authorities but also those involved in activities potentially impacting on the coastal and marine environment. These may include urban development and tourism, agriculture, aquaculture and forestry, industry and mining, marine transportation, and energy production amongst others, depending on country context.

Experience in integrated coastal management (eg DEA RSA 2014) has shown that it is usually not viable for national management structures to effectively implement environmental management at the local or site-specific level, or, in this case, within identified pollution hotspots. Therefore, effective environmental planning and implementation at the local (or pollution hotspot) level necessitates local management committees. Similar to the National Task Forces, these forums can also be mainstreamed through broader local (or municipal) environmental management structures to ensure cross-sectoral representation. A dedicated local management institution actively involved in C&MWQM is also ideally positioned to test the effectiveness and applicability of legislation and policies normally developed at regional or national levels. It is, therefore, also important that higher tiers of government utilise these local institutions as a mechanism for improving legislative frameworks related to coastal management, supporting the principle of adaptive management. In the spirit of *Principle 5: Participatory approach*, stakeholder collaboration and regular consultation are essential (CSIR 2006). Towards achieving this, local stakeholder forums have proven to be effective platforms to facilitate a participatory approach to decision-making and implementation.

The implementation of C&MWQM programmes primarily happens at the country level, per adopted regional standards, guidelines, and best practice guidance. These programmes should be coordinated through the National Task Forces and Pollution Hotspot C&MWQM committees in consultation with local stakeholders. Drawing on an existing model for Integrated Coastal Management (the broader domain within which C&MEQM is nested) (Taljaard and others, 2013; DEA RSA 2014), an ecosystem-based Implementation Framework for C&MWQM has been developed for the WIO region (Figure 3) as part of the overarching Strategic Framework for C&MWQM.

To wisely allocate human and financial resources, tackling C&MWQM in a phased approach may be necessary. In this regard, identifying marine pollution *hotspots* or emerging hotspots provides a transparent mechanism to prioritise intevention in areas where coastal and marine environmental quality is most at risk of being impacted by human activities (eg Shaban

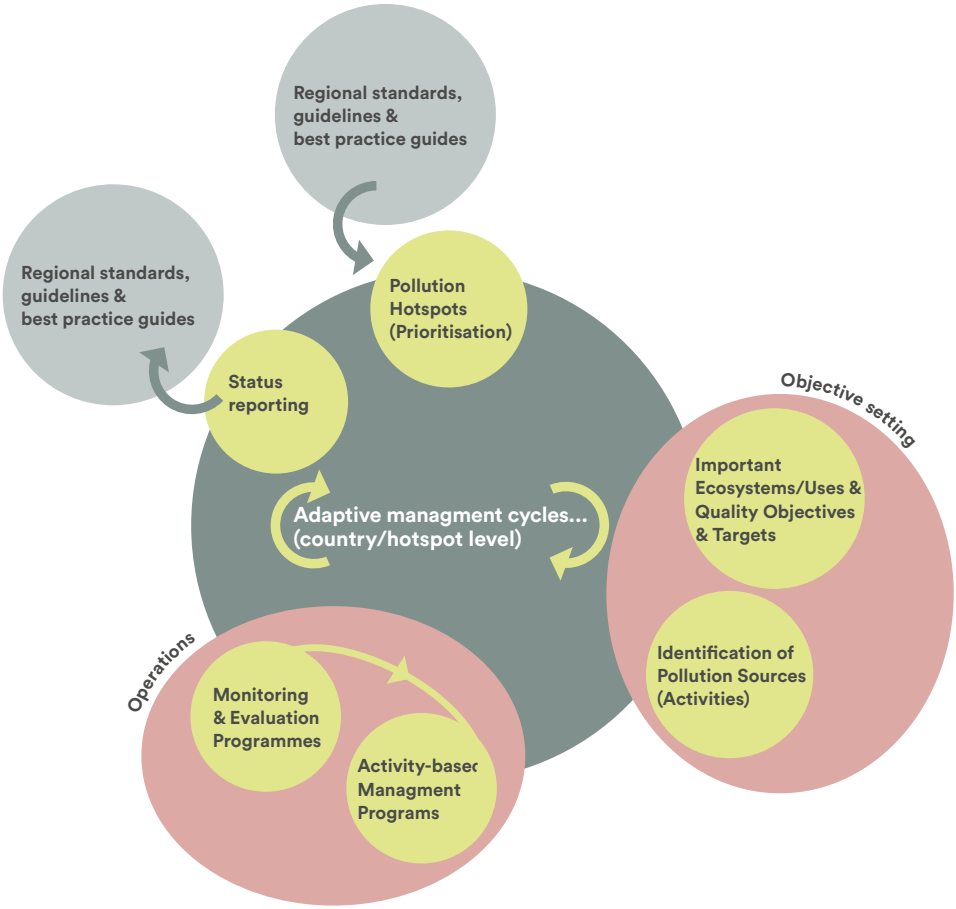

Figure 3. Ecosystem-based Implementation Framework for C&MWQM in the WIO region

2008; Lankford and Hepworth 2010). Marine pollution hotspots usually coincide with coastal urban centres (or cities) and industrial nodes in coastal and marine areas (UNEP and others, 2009). The identification and mapping of *important ecosystems, and key socio-economic beneficial uses* in a specific area, and their environmental quality objectives and associated targets are key components in a C&MWQM programme. Internationally, water and sediment quality guidelines for coastal and marine ecosystems are typically divided into four broad categories. They include the protection of aquatic ecosystems, recreational use and tourism, marine aquaculture, and industrial uses (eg Australian Government 2018; DEA RSA 2012; Health Canada 2012; US-EPA 2012).

The regional *Guidelines for Setting Water and Sediment Quality Targets for Coastal and Marine areas in the WIO*

Table 1. Summary of constituent types for which QTs are addressed in the guidelines, as well as relevance to broad categories of beneficial uses.

Type of constituent		Protection of aquatic ecosystem	Recreation	Marine aqua-culture	Industrial use
Water	Objectionable matter	•	•	Similar to Protection of Aquatic Ecosystems	Based on site-specific requirements of industries
	Physico-chemical properties	•	Refer to Drinking water guidelines		
	Nutrients	•			
	Toxicants	•			
	Microbiological indicators		•	•	
	Tainting substances			•	
Sediment	Toxicants	•		Similar to Protection of Aquatic Ecosystems	

region (UNEP and others, 2021) can be used to derive such site-specific quality targets (QTs) (Figure 3). Guided by international best-practice, selected water and sediment quality constituents and their relevance to protecting aquatic ecosystems and other beneficial uses are indicated in Table 1 (UNEP and others, 2021). Regional guidelines for setting water and sediment QTs are usually broad-based and fairly conservative to accommodate natural variability but still minimise impact risk. Therefore, such recommended QTs should be considered as a first phase in setting site-specific QTs, and depending on site-specific conditions (ecological, social and/or economic), these may need to be refined at specific national or local seascapes. As a result, the recommended QTs proposed in the regional guidelines cannot automatically become legally binding.

A participatory process (*Principle 5: Participatory approach*) is important in negotiating these objectives as they may affect local economies and the livelihoods of local communities. The aim is to negotiate and achieve a balanced, environmentally and socio-economically sustainable outcome through an integrated, consultative process (*Principle 3: Integrated assessment process*). Another key component of the objective setting phase is the identification and characterisation of potential marine pollution sources - both land-based and sea-based - that may alter water and sediment quality in a specific study area, as well as setting limits for such pollution sources. In setting limits for pollution sources, a hierarchy of decision-making should be applied as advocated by *Principle 1: Pollution prevention, waste minimisation, and the precautionary approach*. Activity-based management programmes involve the operational management of specific activities potentially contributing to marine pollution. These programmes often show a strong sectoral focus (ie activities are managed by different governing authorities through activity-specific statutory systems). However,

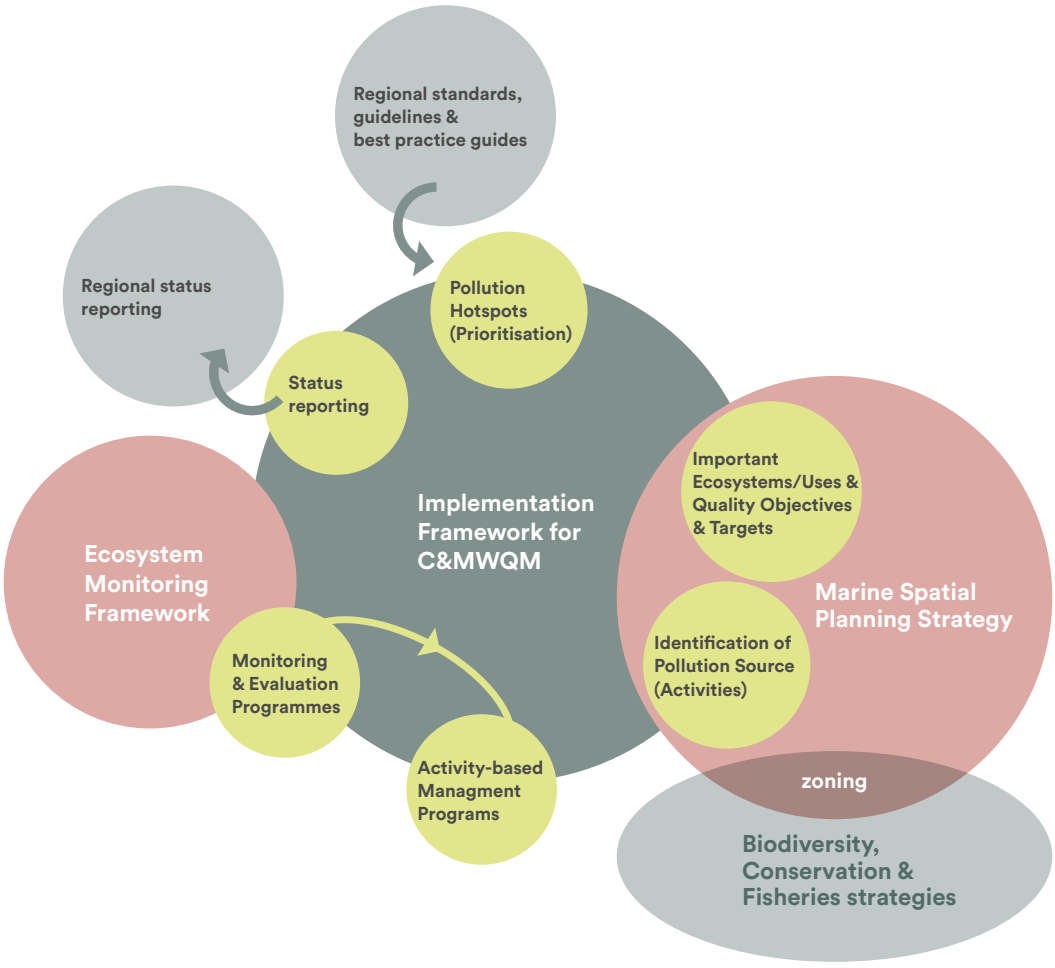

Figure 4. Alignment of elements in Implementation Framework for C&MWQM with related strategies and frameworks within the WIO region

the implementation framework places such sector- or activity-based management programmes between the overarching objective setting phase, and the monitoring and evaluation component. This implies that management programmes, even though sector-based, remain nested in an ecosystem-based approach subservient to the agreed environmental quality objectives and targets for the study area. The cost of mitigating and controlling pollution sources or activities should follow *Principle 4: Polluter pays principle*. The design and implementation of environmental quality monitoring and evaluation programmes form an integral and critical component of the operational phase in the Implementation Framework, together with activity-based mmanagement programmes. Importantly in C&MWQM, monitoring and evaluation is a means to an end, providing the data and information to inform activity-based management intervention (*Principle 3: Integrated, adaptive assessment process*), as is illustrated with the feedback loop in Figure 3. The data and information from these programmes also continuously renew understanding of the complexities of marine ecosystems and their uses and so inform management responses.

In support of a transparent, participatory process (*Principle 5: Participatory approach*), findings from monitoring and evaluation programmes also need to be communicated and shared at regular intervals with the broader society. Status reporting provides a high-level reflection on progress and ensures transparency on issues of concern that need to be addressed through a cycle of adaptive management (ie improving-by-learning, *Principle 3: Integrated, adaptive assessment process*). In turn, national-level status reports feed into the overarching regional status assessment processes, such as the WIO State-of-Coast reporting. Their production should be the responsibility of the RTF for C&MWQM. Although the Implementation Framework for C&MWQM is largely executed at the country level (eg at selected marine pollution hotspots), it reflects the overarching support and guidance provided to countries from the regional level, thus acknowledging the importance of regional coordination.

It is important to understand possible links between the implementation of C&MWQM and other initiatives within the WIO region (Figure 4). While the Implementation Framework has unique elements specifically aimed at effective implementation of C&MWQM, elements within the framework are aligned with other complementary strategies and frameworks implemented in the WIO region.

For example, the demarcation of important ecosystems, uses and location of activities contributing to marine pollution needs to be coordinated with outcomes of the marine spatial planning strategy, which should align with biodiversity, conservation and fisheries strategies in terms of zoning. In addition outputs from monitoring and evaluation programmes can contribute to the ecosystem monitoring framework initiative and vice versa. Implementation of C&MWQM should acknowledge these linkages and coordinate operations wisely to prevent unnecessary duplication of effort.

Outlook for Region and Global

Operationalisation of the proposed Strategic Framework for C&MWQM will be a major milestone in the WIO region for implementing the LBSA Protocol. Towards initiating the effective operationalisation of this framework, the following policy recommendations are proposed for consideration by the Contracting Parties:

- Contracting Parties adopt the Strategic Framework for C&MWQM for the WIO region, including the *Guidelines for Setting Water and Sediment Quality Targets for Coastal and Marine areas*.
- Where applicable, Contracting Parties develop national level C&MWQM frameworks using lessons and experiences provided in the regional Strategic Framework for C&MWQM.
- Contracting Parties formally establish a Regional Task Force (RTF) for C&MWQM (currently a project-level task force under the WIOSAP – RTF for Water, Sediment and Biota Quality).
- Contracting Parties establish national C&MWQM Task Forces to facilitate and coordinate C&MWQM, feeding into the RTF through national focal points.
- Contracting Parties adopt, as appropriate, the Strategic Framework for C&MWQM at the country-level, including *the Guidelines for Setting Water and Sediment Quality Targets for Coastal and Marine areas.*
- Established national C&MWQM Task Forces coordinate the identification of country-level pollution hotspots and establish local C&MWQM committees to oversee the execution of pollution hotspot implementation programme.
- Established national C&MWQM Task Forces coordinate the compilation of country-level status

reports that feed into overarching regional status reports - coordinated by the RTF - to inform various regional processes (eg WIO State-of-Coast reporting, Ecosystem Monitoring Strategies).

The following technical recommendation is proposed for consideration by the Contracting Parties in support of effective operationalisation of the Strategic Framework:

- The Nairobi Secretariat works with partners to support capacity building programmes supporting the effective implementation of the Strategic Framework for C&MWQM, including the *Guidelines for the setting of Water and Sediment Quality Targets.*

Ultimately, achieving the strategic goal for coastal and marine water quality in the WIO region, that '*Water quality in the WIO region meets international standards by the year 2035'* depends on countries embracing this Strategic Framework for C&MWQM and adopting the proposed implementation into national policy and best practice. A successful outcome also requires political commitment to secure dedicated financial resources and the skilled personnel required to execute C&MWQM programmes.

Acknowledgements

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Sans frontières – Ocean and Coastal Sustainability of the Western Indian Ocean

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Executive Summary

The Western Indian Ocean exemplifies the complex interconnection between a land-ocean continuum and a large social-ecological system with many smaller and equally complex nested systems. It is well understood that oceans and coastal resources in the Western Indian Ocean (WIO) are vital to the blue economy and the livelihoods of many millions of people in the region. Due to climate and environmental change and mismanagement, these resources and the human reliance on them are adversely affected. To restore and maintain a positive and nurturing relationship between the ocean, coast, and land and the uses of its resources, a societal transformation toward sustainability is necessary. Ocean, coast, and landform a complex social-ecological system. The complex system is often managed and governed in disconnected and fragmented ways. Land, coasts, and oceans urgently require management systems, governance frameworks, and scientific data, information, and tools that bridge the artificial boundaries imposed by integrated coastal management, marine spatial planning, and protected areas. Geographical and temporal scales and levels of governance are key parameters for understanding and addressing complexity. As a locus for human interest and habitation, the coast poses complex management challenges, often called "wicked problems". Furthermore, planning coastal and ocean space and resources through marine spatial planning, the maritime industry, and the blue economy remain a management challenge. Therefore, it is necessary to integrate the region's contemporary management and governance processes and align them with the global objectives of the UN Sustainable Development Goals, the Paris Agreement, and the UN Decade of Ocean Science activities. This policy discussion highlights the need for awareness, understanding, and institutional mechanisms for integrating coastal sustainability in four dimensions. These dimensions are: 1) **ocean to land,** often referred to as a catchment to coast to the ocean; 2) s**hore-to-shore** is the integration of coastal management of local places along the shoreline, but also across sub-national and national boundaries; 3) a**dministrative integration** of management interventions, planning initiatives between different levels of national to sub-national government, and "downscaling" global policy initiatives such as the SDGs to a local level; and, finally, 4) integration of different **timescales** for management, from political time frames to climate time scales. This policy discussion paper proposes a strategic approach to integrated coastal and marine resource management across the four key dimensions of sustainability, taking a pragmatic approach to the overlap and potential benefits of integrating elements of the existing coastal and marine policy instruments (as recognised in Nairobi Convention COP decision CP9/6). As a result, such commonalities are recognised and used to integrate and plan management and governance activities from ocean to land. It proposes exploring management (strategies, plans, etc.) and institutional (regional and national fora) mechanisms to explore the benefits and management of resources across the land-sea interface.

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Background

Global change impacts all regions of the Earth, impacting livelihoods, economic development, and food security. Governments and communities must adopt adaptive strategies to build resilience in light of global climate change and local impacts, which are already noticeable today. Some are dependent less on the environmental change itself and more on the governance performance of the countries at risk. Global coastal systems and low-lying areas are particularly susceptible to these governance imbalances (including corruption (Walter and Luebke, 2013; Fredriksson and Neumayer, 2016), economic growth agenda (Davidson and others, 2003), slow energy transitioning (Hess and Renner, 2019), social inequality (Islam and Winkel, 2018) and ocean-climate drivers (Nicholls *and others*, 2007; Purvis, Bates and Hayes, 2008; Church *and others*, 2013; Liao *and others*, 2015) (including sea-level rise (Devlin *and others*, 2017; Wahl *and others*, 2017), severe storms (Haigh *and others*, 2016), winds and waves, flooding (Prahl *and others*, 2018) increased sea surface temperatures (Frölicher and Laufkötter, 2018) and ocean acidification (Kildow and McIlgorm, 2010; Ferrari *and others*, 2015), and freshwater inputs (Wong *and others*, 2014).).

The Western Indian Ocean exemplifies the complex interconnection between a land-ocean continuum and a large social-ecological system with many smaller and equally complex nested systems (UNEP-Nairobi Convention and WIOMSA, 2015). These systems are often not well-aligned with governance levels and national boundaries. Therefore, this policy proposal primarily focuses on the need to integrate contemporary management and governance processes of the region and align them with the global objectives of the UN Sustainable Development Goals, the Paris Agreement, and the UN Decade of Ocean Science activities. Important will be the downscaling and customisation of those international frameworks at the local level, taking into consideration existing local regulations and regulatory frameworks such as integrated coastal (zone) management (ICM, ICZM) or marine protected areas (MPAs).

From the situation described above, the following statements are relevant to this policy proposal:

- The resources of the ocean and coastal environment of the Western Indian Ocean (WIO) is the basis for the blue economy and the livelihoods of many millions of citizens in the region.
- These resources, and our dependence thereon, is being negatively affected by the impact of climate and environmental change and mismanagement.
- The ocean, coast and land are a complex social-ecological system.
- We deal with system complexity by using an often disconnected and fragmented management and governance approach. Geographical and temporal scales and levels of governance are key parameters for understanding and addressing complexity.
- The land, coast and ocean urgently require management systems, governance frameworks and scientific data, information and tools that span the artificial boundaries imposed by integrated coastal management, marine spatial planning and marine protected areas.
- An across-the-board transformation toward sustainability is needed to restore and maintain the positive and nurturing relationship between the ocean, coast and land, and our use of resources.
- This policy proposal presents two recommendations to establish institutional arrangements to support the sustainable development of the ocean, coast and land across the land-sea interface, along the shoreline, between levels of administration and over time.

Relationship with Nairobi Convention Decisions

ICM offers a pathway to support climate change adaptation and could act as a proxy for the management approaches needed for climate change adaptation (Ojwang *and others*, 2017; Williams *and others*, 2020). This is recognised by the Nairobi Convention COP decisions CP.9/4 & CP.9/9 (see Figure 1).

In addition to ICM, as a cornerstone for managing coastal resources and MPAs for protecting the ocean and coastal environment, marine spatial planning (MSP) (UNEP-Nairobi Convention Secretariat, WIOMSA and CSIR, 2017) has become a priority mechanism for the implementation of the Blue Economy in the WIO (Obura, 2017) (see COP decision CP.9/10).

Part of the problem, as described above and below, is that the environment of the WIO is an integrated system. As soon as we invent different 'sectoral' approaches to focus on problem areas, the sectoral approach by its nature tends not to be truly holistic. A paradigm shift to a holistic system perspective is key due to the tight interaction of the system's components, which determines the overall performance of the social-ecological system (COP decision on Ocean Governance CP.9/6).

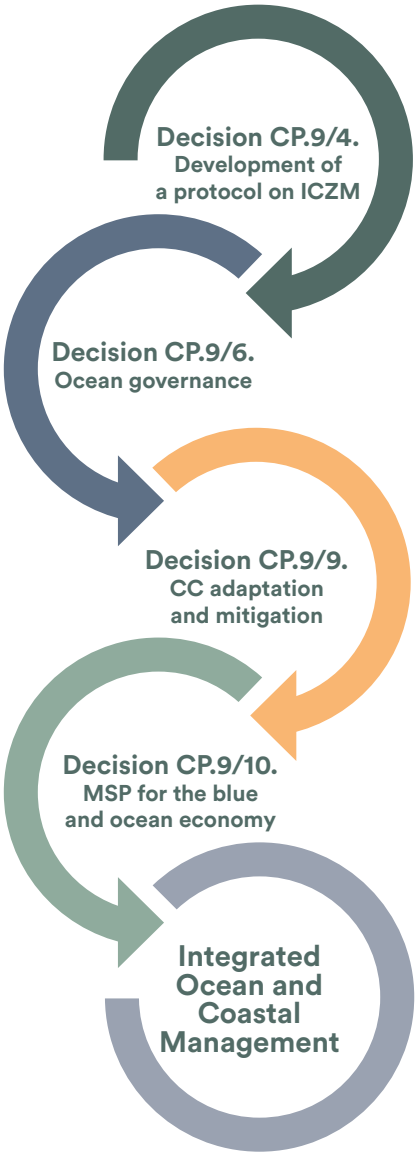

Figure 1. Decisions of the Nairobi Convention of Parties directly and indirectly supporting the development of integrated ocean and coastal management in the Western Indian Ocean.

Advances

Nowhere is this need for change more evident than on the coasts, which also attracts humans and their economic activities to live better and healthier lives. Over the next decades, coastal communities will grapple with the understanding of social-ecological resilience (Hattam *and others*, 2020), the need to adapt to climate impacts (Baills, Garcin and Bulteau, 2020), and the pressure to transform as a society (Scoones *and others*, 2020; Wilson *and others*, 2020), to sustain their activities, and the natural resource-base (Halpern, 2020) which is the cornerstone of all economy (Jouffray *and others*, 2020) and human well-being.

The complexity of the coast as a locus for human interest and habitation is well understood (coastal management challenges often referred to as "wicked problems"). However, the integration of coastal and ocean space and resources (through marine spatial planning and the maritime industry and blue economy) within the future state of the social-environment continuum in a changing climate exponentially drives a level of complexity we are ill-equipped to manage.

Within science, it is increasingly recognised that planning for sustainability requires rapid, large-scale socio-political change as a window of opportunity for transformative change of natural resources governance (Herrfahrdt-pähle *and others*, 2020). There are at least four archetypes of sustainability transformation research, with thematic structures clustered around environmental change and ecosystem services; resilience and vulnerability; knowledge production for sustainability; and governance for sustainability (Horcea-Milcu *and others*, 2020). Governing land-sea interactions requires multi-level and polycentric governance and new forms of policy integration (Schlüter *and others*, 2020).

This policy proposal promotes the creation of awareness, understanding and institutional mechanisms for integration along four dimensions of coastal sustainability (Figure 2):

- **Ocean to land** often referred to as a catchment to coast to the ocean. The actions in the three domains (ocean, land, coast) are scaled differently, and novel and integrated science and policy and governance tools are needed to connect the ocean to land;
- **Shore-to-shore** is the integration of coastal management of local places along the shoreline, but also across sub-national and national boundaries; and,
- **Administrative integration** of management interventions, planning initiatives between different levels of national to sub-national government, and "downscaling" global policy initiatives such as the SDGs to a local level.
- Integration of different **timescales** for management, from political time frames to climate time scales.

Outlook and Policy Recommendations

Main Recommendation: Integrated Coastal Zone Management is already seen as a mechanism for creating enabling conditions for planning sustainable coastal

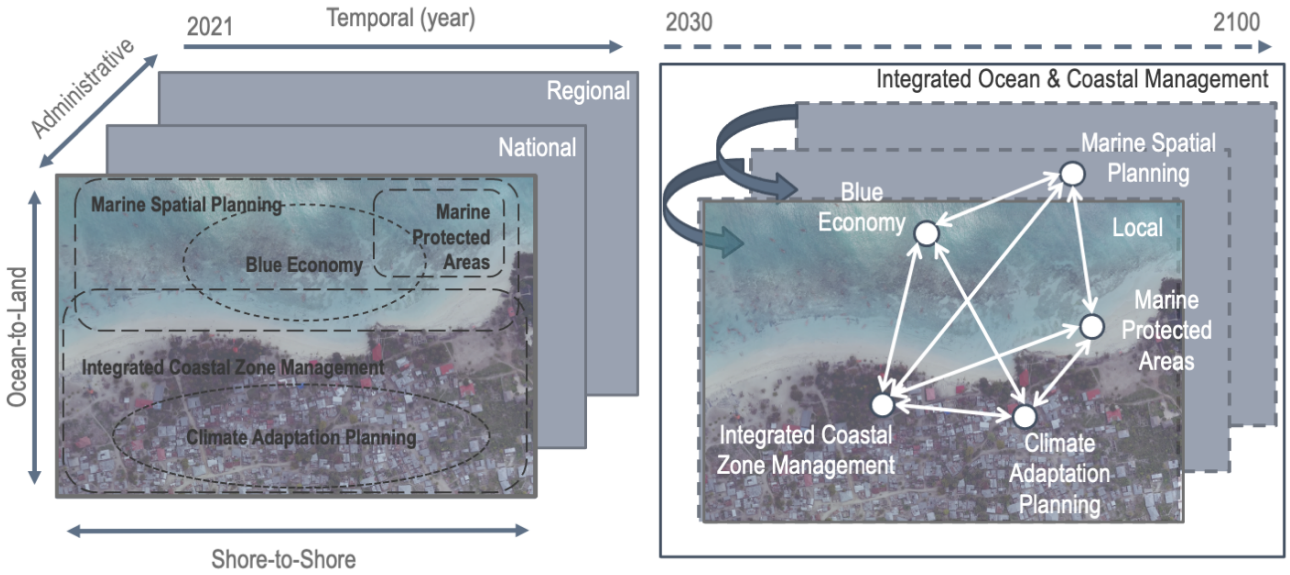

Figure 2. Four dimensions (ocean to land; shore to shore, administrative scale and temporal scale) of coastal sustainability.

resource use and management and climate change adaptation in the WIO (CP9/4 and 9/9). Furthermore, marine spatial planning is an emerging management and planning mechanism to implement the Blue Economy of the region (CP9/10). There are commonalities in the policy implementation cycles of ICM, MSP, the Blue and Green Economies and climate change adaptation. The overlap and integration between these (currently) separated domains in the WIO is the only path to achieving the SDGs and sustainability.

This policy paper proposes a purposeful integration of management across the four dimensions of sustainability and a pragmatic view on the extensive overlap and combined benefit of integrating elements of the existing policy instruments for coastal and marine resource management (in support of CP9/6). Such commonalities are recognised and actioned as a unifying and integrating mechanism to plan a range of management and governance activities from ocean to land. Pragmatically, it proposes exploring management (strategies, plans etc.) and institutional (regional and national fora) mechanisms to explore the benefit flows and management of resources across the land-sea interface. This means that all four dimensions of coastal and ocean sustainability are included in discussions on goal and objective setting, principles for decision-making, policy agreement across agencies, authority and accountability, performance indicators, lead agencies (for example, Brooks *and others*, 2020)particularly in multi-sectoral and jurisdictional systems, with coastal management of New South Wales (NSW as it relates to coastal and marine resource management.

Practical actions and deliverables arising from this policy recommendation may include:

- Developing a white paper for Integrated Ocean and Coastal Management in the WIO.
- Developing a high-level integrated ocean and coastal management strategy for the WIO, incorporating the principles of both ICM and MSP and the targets of the SDGs.
- Including a chapter on the four dimensions of sustainable coastal and ocean management in the WIO Regional State of the Coast.
- Developing a set of indicators to monitor the state of the coastal-ocean systems across contemporary concepts of boundaries
- Convening a workgroup to consider a more comprehensive understanding of the flow of benefits from the Blue Economy, especially between ocean resources (planned at the national level) and local communities and coastal urban administration. Such a working group needs to pay more attention to economic development synergies between coastal and inland areas in the context of the Blue Economy.

Supporting Recommendation: The role of transdisciplinary research to integrate disciplines, sectors and activities such as economic planning, local governance, national climate adaptation, natural sciences, and studies in humanities is recognised and encouraged. The four dimensions of sustainable coastal and ocean management require a different response from the scientific community and greater openness in supporting transdisciplinary approaches and interdisciplinary

research in the WIO. The scaling differences along the four dimensions require the involvement of a vastly increased number of stakeholders. At the same time, the quality of scientific evidence must be improved, but so must the representation of stakeholder engagement within a co-design framework of solutions to resource management issues.

For the supporting recommendation, the practical actions and deliverables may include:

- Developing a protocol for engagement of stakeholders across the four dimensions of coastal and ocean sustainability. This should address the involvement of local stakeholders (citizens, communities, urban settlements, cities) in the planning process and sustainable utilisation of marine resources.

Conclusion

The Nairobi Convention is ideally placed to advance the above recommendations, considering the need for concerted regional action and national specificities and progress in implementing coastal and marine management. This is best achieved by establishing a dedicated working group tasked with supporting planning across the land-sea interface, monitoring progress in implementation, identifying and contributing to addressing capacity development needs, and promoting the exchange of knowledge and experiences with nations in the region.

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