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Ecological consequences of microplastic pollution in sub-Saharan Africa aquatic ecosystems: An implication to environmental health

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ABSTRACT

Microplastic pollution (MPs) emerged as a significant environmental concern due to its persistent nature. These MPs particles endure in waters, soils, and even the atmosphere, posing potential threats to the entire ecosystem. Aquatic organisms are at risk of ingesting MPs, leading to accumulation in tissues, ultimately affecting entire food chain. This study aims to provide an overview of sources of MPs, distribution, and potential environmental impacts. MPs have been documented in various substances such as bottled water, salts, seafood, and even the air. However, the full extent of the health consequences on human exposure remains uncertain. Therefore, it is imperative that we draw public attention to the presence of these pollutants in the environment. To mitigate adverse effects of MPs, reducing plastic consumption, implementing improved waste management practices, and advocating sustainable behaviors are essential for well-being of natural ecosystems and the health human populations.

Contents

1. Introduction

Microplastics are condemned for decades, due to their effect on the environment, including their persistence (Geyer et al., 2017; Geyer, 2020; H and Ripanda, 2019; Miraji, 2018; Hossein et al., 2018). However, there is a lack of broad global knowledge, particularly about their

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prognosis despite their continual production and uses (Geyer et al., 2017). The global plastic production is continually increasing reached 390.7 million tonnes in 2021 (Tiseo, 2022) compared to 288 t in 2012 (Tiseo, 2022), 200 t in 2002 (Tiseo, 2022). It is unfortunately most of the plastic material is released into the environment after their use. The 2021 report indicate that only 9% of global plastic wastes were recycled, >20% is mismanaged (OECD, 2022), while >75% of plastic waste globally is being discharged to landfills or open environments (Khan et al., 2020; Abdellatif et al., 2023; Liang et al., 2021). Efforts to fight plastic hazards have been given a global agenda. For instance, the Basel Convention of 1989, classifies plastic trash as hazardous waste (Khan et al., 2020; Abdellatif et al., 2023; Liang et al., 2021; Karungamye, 2022a; Karungamye, 2022b; Karungamye et al., 2022). Amendments of 2019, with the goals of strengthening control over transboundary plastic waste movements and defining the convention's application to such garbage. Global statistics indicate larger quantity of plastic materials are being disposed off to the environment every year. The 2015 capita plastic consumption in Africa was 16 kg/capita/year (Khan et al., 2020; Abdellatif et al., 2023), meanwhile USA was 80 kg/capita/year, and the consumption of 84.3 million tonnes reported 2019 (Tiseo, 2022). Globally, the main producers of plastics are Asia, China, North America, and Europe (Gourmelon, 2015; Wang et al., 2020a). Among the plastics materials, polyethylene Terephthalate (PET) such that used for preparation of bottles and trays, high density polyethylene (HDPE) including that used for production of toys and denser bottles, and polypropylene (PP) used for preparation of tubs are the most preferred and recyclable plastic material (Dai et al., 2022; Çepelioğullar and Pütün, 2013); Whereas Low Density Polyethylene (LDPE) used to make packaging bags, and Polystyrene (PS), used to make pipes such as plastic cutlery which are least recyclable requiring specialized facility are least preferred (Dai et al., 2022; Çepelioğullar and Pütün, 2013). Similarly polyvinyl chloride (PVC), a synthetic plastic polymer that is widely used in various applications due to its versatility and durability (Li et al., 2023). There are two main types: flexible PVC, which is softer and more malleable and is suitable for applications like electrical cables, inflatable structures, and vinyl flooring; and rigid PVC, which is strong and stiff and frequently used for pipes, fittings, window frames, and other construction materials (Li et al., 2023). PVC can be recycled, but because of its special qualities, it needs to go through a different recycling process (Lu et al., 2023). Recycled PVC is frequently utilized in lower-grade applications (Lu et al., 2023). On the other hand, composites, cling film, polycarbonates and blisters are non-recyclable (Dai et al., 2022; Çepelioğullar and Pütün, 2013).

Microplastics (MPs) are tiny particles of plastics measuring <5 mm in size, basically originating from degrading, and disintegrated domestic, industrial, and commercial plastic materials. Fig. 1 shows an insight into microplastic sources and their environmental fate including possible interactions and exposure with aquatic organisms and humans, and circulation in the ecosystems including aquatics.

MPs originate from multiple sources including fragments of substantial plastic items, like bottles, packaging materials, and nets, through natural degradation processes or mechanical forces (Geyer et al., 2017; Geyer, 2020; OECD, 2022; Kumar et al., 2021; Da Costa et al., 2020). The shedding of synthetic fibers from textiles during washing, the breakdown of pellets used in production, and the dispersion of microbeads from cosmetics like exfoliating scrubs and toothpaste (Geyer, 2020; OECD, 2022; Kumar et al., 2021; Da Costa et al., 2020; Nyanza et al., 2014; Ejaredar et al., 2015), are all linked with MPs. MPs are lightweight and some are resistant to degradation, allowing them to dwell in the environment for long periods as hazards (Torres et al., 2021; Ripanda et al., 2023). The distribution of microplastic spans the globe (Lee et al., 2023; Meng et al., 2023), with both terrestrial and aquatic ecosystems affected. Report indicates that oceans are hotspots (Wilson et al., 2023; Campillo et al., 2023; Davtalab et al., 2023), for microplastic accumulation. The currents and tides transport MPs across vast distances, resulting in their deposition on marines ecology (Wilson et al., 2023; Campillo et al., 2023; Davtalab et al., 2023). Similarly, rivers perform a crucial role in transferring MPs from inland sources to coastal environments (Silori et al., 2023), making them conduits for the dispersal of these pollutants. The marine environment faces significant ecological threats.

The effect of microplastic contamination on ecosystems is an emerging concern. Marine organisms can ingest MPs among or with food (Koelmans et al., 2022; Rahman et al., 2023a; Rahman et al., 2023b; Egbeocha et al., 2018), leading potential internal injuries. Filter-feeding organisms, such as mussels and zooplankton (Fossi et al., 2014; Cole et al., 2013), are particularly susceptible to ingest large quantities of MPs. This not only affects their health and reproductive capabilities but also poses risks to higher-level predators, including fish, birds, and marine mammals (Koelmans et al., 2022; Rahman et al., 2023a; Rahman et al., 2023b; Fossi et al., 2014; Cole et al., 2013; Laursen et al., 2023; Shruti et al., 2023; Buyukunal et al., 2023; Nantege et al., 2023; Adikari et al., 2023). Moreover, MPs have the potential to alter habitats, disrupt ecological interactions, and contribute to the transport of other environmental pollutants. The incidence of MPs circulation through the food chain raises concerns about human exposure and health risks (Rahman et al., 2023a; Buyukunal et al., 2023; Mamun et al., 2023; Vitali et al., 2023). Studies have detected MPs in seafoods, drinking water including bottled water, packed ready to use ice cubes and even table salt (Rahman et al., 2023a; Shruti et al., 2023; Buyukunal et al., 2023; Mamun et al., 2023; Vitali et al., 2023). While the full consequences of microplastic ingestion on human health are not yet fully recognized, there are concerns about the probable transfer of toxic chemicals such as bisphenol A and phthalates associated with plastics into the human body (Rahman et al., 2023b; Egbeocha et al., 2018; Shruti et al., 2023; Buyukunal et al., 2023; Adikari et al., 2023). Additionally, the physical effects of MPs on human tissues and organs are still being investigated. However, a study by Ejaredar and Coallegues (2015) (Ejaredar et al., 2015), provided evidence that prenatal exposure to phthalates is linked to negative behavioral and cognitive consequences in children, including hyperactivity, attention issues, and decreased IQ (Ejaredar et al., 2015). Additionally, their study suggested

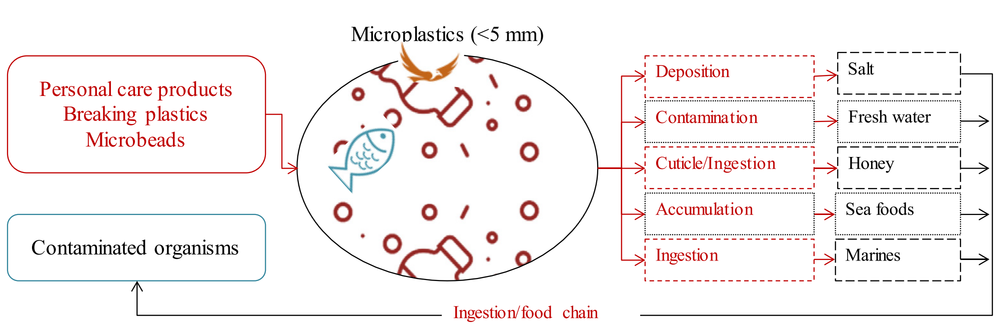

Fig. 1. Sources of microplastic pollution, possible interactions and exposure with aquatic organisms and humans, and circulation in the ecosystems.

the next investigation should concentrate on defining the relationships between phthalate metabolites and children's neurodevelopmental outcomes. This will facilitate the creation of mitigating measures to improve the creation of suitable health policy (Ejaredar et al., 2015). Reports of the presence of MPs in environmental compartments are available including marine, fresh waters, and terrestrial. Approximations on the quantity of plastics generated per day, ban implementation, presence of recycling activities, presence of coastlines for selected Sub-Saharan Africa (SSA) countries are presented by Table 1.

The challenges of MPs (Koelmans et al., 2022; Rahman et al., 2023a; Egbeocha et al., 2018; Laursen et al., 2023; Shruti et al., 2023; Nantege et al., 2023), requires a comprehensive and collaborative approach. The production, and importation of plastics, usages, plastic waste, and plastic waste management needs proper management to ensure ecosystem safety and sustainability (Koelmans et al., 2022; Rahman et al., 2023a; Laursen et al., 2023; Shruti et al., 2023). To better comprehend the causes, fate, and impacts of MPs (Wichai-Utcha and Chavalparit, 2019), strong monitoring systems and research initiatives are required. This will allow for the creation of policies for mitigation that are evidence-based. The global scale and persistence of MPs demand immediate action to reduce plastic waste, improve waste management practices, and promote sustainable consumption of plastic products for environmental health. Collective efforts to address the impacts of microplastic contamination, protect the environment to achieve sustainability, and regional evaluation of microplastic episodes.

2. Transport behavior of microplastics

Tiny plastic particles measuring <5 mm in size (MPs), exhibit unique transport behaviors due to their diminutive size, in the environment., buoyancy, and surface properties (Cole et al., 2013; Crawford and Quinn, 2016; do Sul and Costa, 2014). Understanding the transport behaviors of MPs (Pérez-Guevara et al., 2021), is crucial for comprehending their distribution and potential impacts on ecosystems and environmental health. MPs can be transported by water currents as suspended materials (Peng et al., 2017), indicating its potential transboundary nature requiring collective efforts for their mitigation. Therefore, in aquatic environments (Peng et al., 2017), MPs can be carried over long distances through rivers, streams, and ocean currents. MPs can be transported both advection and laminar flow (Laermanns et al., 2021), depending on the water flow patterns and their characteristics. Vertical transport can occur as MPs are suspended or settle down to the sediments, while longitudinal transport can result from the movement of water currents and wind-driven processes (Laermanns et al., 2021; Owens et al., 2023). Some MPs, particularly those made of low-density polymers like expanded polystyrene, can float and transported by wind and surface currents (Zhang, 2017). On the other hand, heavier MPs may sink and transported by bottom currents or accumulate in sedimentary environments (Ballent et al., 2016), and remain dynamic with the continues moving sediments. Physical processes like irrigation, withdrawing of water and materials such as sand tend to distribute MPs to different locations.

The surface properties influence the transport behaviors of MPs (Rummel et al., 2017), by adsorbing various organic and inorganic compounds onto their surfaces, altering their buoyancy and interactions with water. The adsorption process may lead to aggregation and the formation of microplastic clusters (Rummel et al., 2017), affecting their transport patterns. Similarly, human activities, such as wastewater discharge, irrigation, agricultural runoff, sand excavation and coastal development, can enhance the transport of MPs. These activities can introduce MPs into water bodies and accelerate their movement through altered flow regimes or changes in sediment dynamics (Crawford and Quinn, 2016; Laermanns et al., 2021; Zhang, 2017; Ballent et al., 2016; Rummel et al., 2017). Therefore, understanding the transport behaviors of MPs is vital for predicting their fate and potential ecological impacts. Globally, MPs have been located and measured in a variety of matrices. For instance, reports of MPs from the USA in the year 2023 ranged from 27,000 MPs per km^2 in the Elk Lake to 152,000 MPs per km^2 in the White Iron Lake (Conowall et al., 2023). From 30 MPs per kg dry sediment in the White Iron Lake to 270 MPs per kg dry sediment in the Peltier Lake USA, additional benthic sediments included MPs (Conowall et al., 2023). Most of the polypropylene fragments found in wastewater treatment plants (WWTP) in USA were polypropylene fragments, whereas the reference sites

Table 1
Presents the quantity of plastics generated per day, ban implementation, presence of recycling activities, presence of coastlines for selected countries in Sub Saharan Africa.

Country	Approx. plastics generated per day (tonnes)	Ban implemented	Land locked	Coastlines	Recycling activities	References
South Africa	>1000	√	×	√	√	(Wichai-Utcha and Chavalparit, 2019)
Tanzania	100 to 1000	√	×	√	√	
Madagascar	100 to 1000	√	×	√	√	
Botswana	<100	√	√	×	√	
Zambia	<100	×	√	×	√	
Zimbabwe	<100	√	√	×	√	
Malawi	<100	×	√	×	√	
Kenya	100 to 1000	√	×	√	√	
Uganda	<100	√	√	×	√	
Somalia	<100	×	×	√	√	
Ethiopia	<100	√	√	×	√	
Rwanda	<100	√	√	×	√	
Burundi	<100	√	√	×	√	
Angola	<100	×	×	√	√	
DRC	<100	×	×	√	√	
Sudan	>1000	×	×	√	√	
Congo	<100	√	×	√	√	
Garbon	<100	×	×	√	√	
Cameroon	100 to 1000	√	×	√	√	
Nigeria	>1000	√	×	√	√	
Namibia	<100	√	×	√	√	
Burkina Faso	100 to 1000	√	√	×	√	
Mali	100 to 1000	√	√	×	√	
Niger	100 to 1000	√	√	×	√	
Eritrea	>1000	×	×	√	√	

contained polypropylene fragments, polyethylene, and polyester fibers (Conowall et al., 2023). While form and polymer compositions were more closely connected to dissolved oxygen levels and the distance to the next water source input, MPs sizes were substantially correlated with distance from the closest WWTP (Ridall et al., 2023).

According to assessments of urban streams in North Carolina, USA, in 2023, water had median microplastic levels of 0.44 p m3 (Ridall et al., 2023). The highest concentrations were found in urban rivers, and the most densely populated areas showed a substantial link between streamflow and MP concentration (Kurki-Fox et al., 2023). Additional findings displayed that polystyrene, polypropylene, and polyethylene were the three most prevalent polymer kinds for MPs >335 μm (Kurki-Fox et al., 2023; Sathish et al., 2020). When samples were analyzed using a smaller mesh size >64 μm, substantially more MP particles were detected, with concentrations ranging from 20 to 130 p m3, with polyethylene terephthalate being the most abundant polymer type (Kurki-Fox et al., 2023). The 64 μm to 335 μm MP concentration ratio ranged from 35 to 375, showing that the 335 μm mesh significantly underestimates MPs in comparison to the 64 μm mesh. In 14/15 sediment sample sets, MPs were found (Kurki-Fox et al., 2023). Table 2 summarizes more reports regarding global reports on the occurrence of MPs from different environmental matrices.

3. Microplastic pollution in sub-Saharan Africa

Microplastic pollution is a significant environmental issue affecting SSA, with potential impacts on the region's ecosystems. Sub-Saharan Africa faces unique challenges in dealing with microplastic pollution due to a combination of factors including population growth, inadequate infrastructures for waste management, and limited regulatory frameworks (Deme et al., 2022; Ayeleru et al., 2020; Mihai et al., 2022; Honorato-Zimmer et al., 2022). Reported cases of microplastic pollution in various matrices in Africa environmental compartments are presented in Table 3. The primary sources of microplastic contamination in SSA includes poor waste management practices (Mihai et al., 2022). Many countries in the region struggle with limited waste collection systems and inappropriate disposal of plastic waste, leading to its heap in water bodies and terrestrial environments (Mihai et al., 2022). Inadequate recycling facilities further exacerbate the problem, resulting in an elevated fractions of plastic waste being discarded in open dumpsites or burned, contributing to the environment's exposure to MPs and other emerging contaminants (Deme et al., 2022; Ayeleru et al., 2020; Mihai et al., 2022). Fig. 2 represents reports of microplastic pollution (a) MPs in coastal areas, sea waters, effluents, and sludge, (b) MPs in agricultural soils and fresh waters, (c) MPs in fresh waters organisms including *Gastropods*, and (d) MPs in sediments and other marine organisms. The area of SSA is 24.35 million km^2 with proximity coastlines, the size of this coastline affects the reliance on marine resources make its ecosystems vulnerable to microplastic pollution (Kirkman et al., 2020; Landrigan et al., 2020; Preston-Whyte and Maes, 2022). Coastal cities, fishing communities, and tourism hubs are key areas where MPs can accumulate due to improper plastic waste disposal as a result of lacking active monitoring and controlling regulations (Kirkman et al., 2020; Shilla, 2019; Egessa et al., 2020). Plastic bottles and packaging bags are almost dominating all over the region due to their frequent uses. This indicates the possibility of MPs occurrence and spreading in these cities.

Similarly, landlocked SSA countries are not immune to microplastic pollution either (Egessa et al., 2020). Rivers and freshwaters stream act as conduits for microplastic transport from inland sources to coastal areas (Abdellatif et al., 2023; Deme et al., 2022; Ayeleru et al., 2020; Mihai et al., 2022; Preston-Whyte and Maes, 2022;

Table 2
Global occurrence of microplastics.

Country and year	What have been reported	References
India, 2022	According to the findings, plastic accounted for between 45% and 89% of all objects found throughout the ten collecting sites. With debris densities ranging from 0.38 to 3.86 items/m2, the study collects baseline data at eleven sites.	(Owens et al., 2022)
Mumbai coastal waters, India, 2022	It was noted that each fish's gills had 6.2 items, compared to 6.6 in GI tract. The majority of the MPs were made up of beads <100 m. The tissues contained the most microplastic with blue and black shades. The post-monsoon season saw the highest number of MP incidences of all the analyzed months.	(Debbarma et al., 2022)
China, 2022	The study found that MPs were abundant in saltwater and sediments	(Wang et al., 2022)
	In mangrove sediments, microplastic abundances of up to 5738.3 items/kg, coral reef surface waters of up to 45,200 items/m3, and seagrass bed sediments of up to 927.3 items/kg have all been observed	(Zheng et al., 2023)
	Water contained the greatest concentrations of MPs. 4.70 objects/L plus silt (728 items/kg) from a textile-producing area, most likely brought on by human activity	(Hu et al., 2022)
Canada, 2022	Most plastics, 68%, were polyethylene fragments	(Smith et al., 2022)
Brazil, 2021	The microplastic content showed significant geographical and temporal small-scale variability. The findings suggest that microplastic pollution occurs often in Fernando de Noronha.	(Carvalho et al., 2021)
Portugal, 2021	According to the findings, 3.9 million pieces of plastic made up 88% of the beach trash, and there were 330 items per 100 m of beach, which is more microplastic than the EU median of 149 items per 100 m and needs to be reduced to 20 items per 100 m (94%)	(Prata et al., 2022)
Malaysia, 2023	The agricultural soils contained an average of 2.1 to 3.4 microplastic particles/kg. MPs extensive breakdown processes resulted in a range of particle sizes from 16.7 to 1.246 m. The morphologies and colors of the microplastic particles in the soil samples were indicative of the sources.	(Praveena et al., 2023)
	The main sources of MPs were plastic nets, mulching films, and mismanaged plastic debris. Our research confirms soil contamination with MPs in tropical agricultural areas	
Fiji, 2020	Low MPs levels were discovered in waters and deposits. The WWTPs reported as hotspot. MP in sediments and species intake were strongly correlated. There were 15 different polymers, most of which were detected as fibers and fragments.	(Ferreira et al., 2020)
Bengal, coast of Bangladesh, 2021	According to the findings, MPs were retrieved, with abundance of 2.2 items per person. 53.4% of the MPs discovered were fibers. The most prevalent colors and sizes among the MPs that were found were green (about 39%) and 500 m (about 85%). 55% of the polymers were polyethylene, 33% were polypropylene, and 6% were polyester, 2% were polyurethane.	(Ghosh et al., 2021)
Northern west Pacific Ocean, 2019	The findings show that there are variations in MPs abundance, shape, color, and size. Strong environmental implications are provided by the study, including those related to sources, environmental degradation, dwell time, travel patterns, and biological interactions	(Pan et al., 2019)
Caspian Sea, 2020	The research revealed that the bordering countries illegally manage. Their garbage. Estimates show that the nations along the Caspian Sea's shore created 425 kt of plastic trash, with a probability of 58 to 155 Kt reaching the sea.	(Ghayebzadeh et al., 2020)

Table 3
Studies that reported MPs pollution in various matrices in Africa.

Study	Year	Country	Study site	Results	Implication	Remarks	References
Investigation on plastic pollution	2023	Tanzania	Coastal areas	Marine environments are contaminated with plastics	Impairment of marine ecosystems quality, endangering wildlife, and other organisms through food chains.	Strict rules and policies for the proper management of the plastics are needed	(McIlgorm and Xie, 2023b)
Analysis of plastics waste on coastlines	2021		Waters from the coastal region	48.5% of the waste inflow to coastal environments are plastics	Detrimental effects and threat to the ecosystem's sustainability	Formulation of strict rules and policies for the proper management of the plastics	(Lu et al., 2023)
Assessment of MPs in aquatic environment	2022		Beaches and seabed zones	About 640 MPs identified across sites, equivalent to 84% from beaches, while seabed sediments had 16%	This indicates contamination of marine environments, threating marine ecosystems	Strict rules and policies for the proper management of the plastics are needed	(Kumar et al., 2021)
MPs in surface waters investigated	2020		Surface waters of Lake Victoria	Occurrence of MPs in all sites at a ranging from 2834 to 329,167 particles/km2 with the highest abundance ranging from 103,333 to 329,167 particles/km2 and lowest ranging from 2834 to 20,840 particles/km2	The accumulation of MPs which may threaten marine ecosystems and other organisms through food web	Formulation and implementation of strict rules and policies for the proper management of the plastics	(Da Costa et al., 2020)
MPs investigated from surface waters, sediments, and soils	2021		Surface waters, sediments, riverbanks, and soils from irrigated farms	The findings demonstrated that there were four times as many MPs in irrigated farms as there were in riverine sediments, more MPs in sediments than in surface waters	Microplastic pollution threaten marine ecosystem	Strict rules and policies for the proper management of the plastics are needed	(Nyanza et al., 2014)
MPs pollution investigated	2021	Kenya	Creecks sediments, and estuaries	Overall mean concentration was 9.1 (SE 0.8) particles cm − 2 for the large size category of MPs ranged from 500 to 4999 µm.	This shows deadly threats towards the marine ecosystem	Strict rules and policies for the proper management of the plastics are needed	(Kerubo et al., 2021)
MPs pollution investigated	2020		Surface waters within creeks	MPs with variable shapes and colors were identified ranging from 20 to 250 µm	Microplastic pollution threaten marine ecosystem	Strict rules and policies for the proper management of the plastics are needed	(Ejaredar et al., 2015)
MPs investigated Surface Waters	2020		Surface Waters	Surface waters are contaminated with plastics, mean abundancy 0.41 particles/m2.	Plastics pollution, threaten marine ecosystems	Implementation of proper techniques and policies for a major control of the plastics waste pollution	(Migwi et al., 2020)
MPs investigated in zooplankton	2018		Sea, surface waters and zooplankton	150 plastics items reported in water. About 130 were reclaimed ingested by zooplankton groups, of which Chaetognath swallowed 0.5, Copepod 0.3, Amphipoda 0.2, and fish larvae 0.2 particles	Potential exposure to the marine ecosystem, MPs may enter pelagic food webs and cause harm	Formulation and implementation of strict rules and policies for the proper management of the plastics	(Kumar et al., 2021)
MPs investigated in marine ecosystem	2022		Surface watersnearshore	1473 particles in total, with a mean concentration of 0.58 MPs m3, were identified	Marine pollution that causes threats leading to higher potential risks to the organisms either within or around the marine ecosystem	Strict rules and policies for the proper management of the plastics are needed	(Kosore et al., 2022)
Microplastic pollution was investigated	2022	Uganda	Freshwater	Report of contamination of freshwaters with MPs	Plastic pollution may lead to potential health consequences	Intervention is required for ecological safety	(Owens et al., 2023)
Surface waters investigated for plastic pollution	2020		Surface water	MPs identified in all sites ranging from 2834 to 329,167 particles/km^2, with the highest abundance in group A ranging from 103,333 to 329,167 particles/km^2 and in group C ranged from 2834 to 20,840 particles/km^2	Pollution of aquatic systems	Strict rules and policies for the proper management of the plastics are needed	(Egessa et al., 2020)
Abundance, distribution, and composition of plastics investigated	2019	Nigeria	Marine waters	3487 macrodebris items/m2, comprising of 59% of plastics,7% rubber, 3% medical and 3% agricultural trash. Further MPs had the highest concentration occurring downstream. Dominant types were 30% of PET, followed by 20% of PE, 16% of PVC, and 14% of PP.	Marine environment pollution	Formulation and implementation of strict rules and policies for the proper management of the plastics	(Ebere et al., 2019)

(continued on next page)

Table 3 (*continued*)

Study	Year	Country	Study site	Results	Implication	Remarks	References
MPs investigated	2021		Surface waters, sediments, and marine organisms	Existence of MPs	Potential exposure to ecosystems	Strict rules and policies for the proper management of the plastics are needed	(Enyoh et al., 2023; Yalwaji et al., 2022)
MPs investigated from surface waters	2022	Ethiopia	Surface sediments	Near the lake's eastern catchment area, MP ranged from 11 to 74 items/m3. Comprising of 90% of fibers, 5% pieces, and 5% of pellets (5%), with variety of colors, including white, black, blue, and red. Polyester predominant, followed by polyethylene, and polystyrene	Potential plastic pollution	Formulation and implementation of strict rules and policies for the proper management of the plastics	(Jeevanandam et al., 2022)
Plastics in surface waters was investigated	2022		Marine environment	MPs identified, mostly originating from PPEs such as surgical face masks	Potential exposure to the ecosystem	Strict rules and policies for the proper management of the plastics are needed	(Aragaw et al., 2022)
MPs investigated	2022		Water bodies	61% of the 240 MP particles were smaller than 0.5 mm, majority of these transparent particles were fragmented in shape.	Pollution to the marine environment, hence leading to potential exposure to the ecosystem	Formulation and implementation of strict rules and policies for the proper management of the plastics	(Mhiret Gela and Aragaw, 2022)
MPs investigated in waters, sediment, and species of fish	2022	Ghana	Water sediments, Fish species	MPs was prevalent in all examined compartments, with average counts of 2 and 3. Bagrid Catfish had, and Black-chinned Tilapia had similar amounts of MPs	MPs pollution	Formulation and implementation of strict rules and policies for the proper management of the plastics	(Blankson et al., 2022)
MPs in Freshwater was investigated	2021	Ghana	Fresh water	The presence of quantified MPs in Waterbodies	Pollution of acquatic environment	Strict rules and policies for the proper management of the plastics are needed	(Acquah et al., 2021)
MPs in gastrointestinal tract of fish investigated	2022		Fish	Highly contaminated with MPs, with 133 different plastic items being found in the fish and 68% of the fish being infected. Three polymers, polyvinyl acetate, polyamide, and polyethylene, were discovered.	Pollution of acquatic environment	Strict rules and policies for the proper management of the plastics are needed	(Pappoe et al., 2022)
Microplastic pollution along the coastline investigated	2015	South Africa	Sediments and surface waters	Sediments had 688.9 to 3308 particles$\cdot$m^{-2}, while surface waters had 257.9 to 1215 particles$\cdot$m^{-3}. microplastic	Potential microplastic pollution	Potential ecosystem exposure and injury	(Nel and Froneman, 2015)
MPs in Sediment Cores investigated	2017	South africa,	South africa, Tokyo Bay sediments surface waters	The silt had MPs made of polyethylene, polypropylene, polystyrene, polyacrylates, polyethyleneterphthalates, and polyethylene-polypropylene, ranged from 315 nm to 5 mm	Potential MPs pollution	Potential ecosystem exposure and injury	(Matsuguma et al., 2017)
Investigation of MPs pollution	2017	South africa	Sediment and surface waters	MPs identified in sediment and surface waters ranging from 413.3 to 1200 particles per cubic meter	Potential plastic pollution	Potential ecosystem exposure and injury	(Nel et al., 2017)
Micro and meso plastics assessment along the coastlines	2021	South africa	Water and sediments	All the investigational samples contained MPs. Results indicate that input areas for mitigation should concentrate on wastewater treatment overflow, stormwaters, and surface waters	This can potentially lead ecological exposure	Monitoring and management in a harbour environment.	(Preston-Whyte et al., 2021)
MPs endorheic along river basins investigated	2023	Botswana	Sediments from the river	Sediment had 56.7 to 399.5 particles kg − 1, and highest ranged from 1075.7 to 1756.3 particles kg − 1	Microplastic polllution	Potential ecosystem exposure and injury	(Kelleher et al., 2023)
MPs investigated surface waters and fish	2022		Surface waters, and fish (*Tilapia sparrmanii*)	MPs in surface waters samples from 10.18 to 22.67 items L-1 and 138.18 to 381.67 g m-3. Higher microplastic abundance in intestines, followed by stomach and gills, with prevailing size of 1–2 mm in fish and 2–3 mm in waters, while fragments were dominant shape followed by fibers	Potential pollution	For the appropriate management of plastics, strict regulations and guidelines are required.	(Ditlhakanyane et al., 2022)

Table 3 (*continued*)

Study	Year	Country	Study site	Results	Implication	Remarks	References
MPs investigated in aquatics	2021	Mauritius	Meso-litter	Plastics was dominant litter vegetation line zone had higher microplastic fragments. Mostly blue colored, while polyethylene was prevalent polymer type	Microplastic polllution	Strict rules and policies for the proper management of the plastics are needed	(Mattan-Moorgawa et al., 2021)
MPs investigated in agricultural soils, wastewaters, and sludge	2021		Agricultural soils wastewaters effluents and sludge	Shallow soils had 320 particles.kg-1 and deep soils had 420 particles.kg-1. Sludge had 14,750 items.kg-1 and wastewaters had 276.3 particles. L-1 Polypropylene, fibers, fragments, and flakes being abundant in agricultural soils while polyamide fibers predominated WWTP	Microplastic polllution	Potential ecosystem injury	(Ragoobur et al., 2021)
Assessment of MPs in public beaches	2022		Soils	Sands had 6 items per kg	Microplastic polllution	Potential ecosystem injury	(Boodhoo et al., 2022; Foolmaun et al., 2022)
MP pollution in river investigated	2019	West africa	Gastropods (*Lanistes varicus* and *Melanoides tuberculata*)	*L. varicus had f*ibre and film, whereas *M. tuberculata had only fibre*. Contamination of African gastropods with polyethylene which resembled strongly black polyethylene bags that covered surface waters	Microplastic polllution	Potential ecosystem injury	(Akindele et al., 2019)
MPs in MENA ecosystems	2023	Northern Africa	Marine waters, air, and terrestrial, sediments, and biota	Marine waters had 400 items/m3 and sediments had 7960 items/kg of sediments. Biota had MP ranging from 0 to 7525 per individual across aquatics. Further, air had 56,000 items/g of dust	Contamination of aquatic ecosystem	Potential ecosystem injury	(Malli et al., 2023)
MPs investigated from surface sediment and litter	2020	North Africa	Surface sediments	MPs ranged from 182.66 to 649.33 kg − 1 in sediments Fibers were dominant MP Polyethylene dominated	Potential pollution		(Tata et al., 2020; Simon-Sánchez et al., 2022)
Assessment of MPs pollution	2022	Morocco	Central Atlantic coastline of Morocco	With fibers, fragments, films, and pellets predominating, microplastic abundances above other world beaches varied from 7500 items/kg to 34,000 items/kg. Polyethylene dominating followed by polypropylene, polystyrene and polyvinyl chloride, and ethylene-vinyl acetate	Microplastic pollution	Potential harm to aquatic ecosystems	(Abelouah et al., 2022a)
MPs in Namibian river sediments investigated	2022	Namibia	Sediments from namibian river	Sediments had 13.2 particles/kg, mainly polyethylene and polypropylene	Microplastic pollution	Potential ecosystem injury	(Faulstich et al., 2022)
MPs investigated east African coastal waters	2023	Mozambique	Coastal waters	Meso- and micro-litters had 8570 items·km − 2, 43 g·km − 2, while microfibres had 2.4 fibers·L − 1	Microplastic pollution	Strict rules and policies for the proper management of the plastics are needed	(Weideman et al., 2023)
Investigation of the presence of MPs	2015		Maputo Bay in southern Mozambique	Relatively even distribution of MPs, the only significant differences regarded macrodebris where the 'polluted' site was substantially higher in abundance	Potential harm to ecosystems	Intervention is required	(Karlsson, 2015)
MPs investigated	2021	Somalia	Urban areas	Urban areas generate more waste plastic from varying sources	Potential harm to ecosystems	Formulation and implementation of strict rules and policies for the proper management of the plastics	(Hussein et al., 2020)
MPs investigated from agricultural soils	2023	Sudan	Agricultural products from fields or farm	MPs pollution, with polybutyleneadipate-*co*-terephthalate and polypropylene	Microplastic pollution	Strict rules and policies for the proper management of the plastics are needed	(Ni et al., 2023)
Marine MPs investigated	2019	Egypt	Seawater and shoreline sediments.	Plastic litter and its deposition in waterways	Aquatic environments potential polluted with MPs	Potential ecosystem injury	(Shabaka et al., 2019)
MPs investigated in fish	2020	Egypt	Surface waters, fish species	MPs were identified in >75% of the fish samples, with incidence of in their gastrointestinal tracts75.9% for Nile tilapia and 78.6% for catfish. Fibers was frequent by 65%, followed by films 26.5%, and fragments, which are mostly polyethylene, polyethylene terephthalate, and polypropylene	Aquatic environments potential polluted with MPs	Potential ecosystem injury	(Khan et al., 2020)

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Table 3 (*continued*)

Study	Year	Country	Study site	Results	Implication	Remarks	References
Contamination of the marine environment with PPEs investigated	2022	Egypt	Protective equipment	Daily collections from Hurghada, Alexandria, and Jeddah totaled 3673, 255, and 848 items, respectively. In each of the three cities, gloves and face masks made up 40–60% of the total plastic items recovered, whereas plastic bags made up 7–20% of the total plastic litter.	Severe potential exposure to the ecosystem	Potential ecosystem injury	(Hassan et al., 2022)
MPs investigated in sediments, waters, and fishes	2021	Egypt	Sediment and water samples	Highest microplastic abundance recorded, the two most frequently discovered polymers in fish are rayon and polyethylene terephthalate.	Potential injury to marine ecosystems	Strict rules and policies for the proper management of the plastics are needed	(Sayed et al., 2021)
MPs investigated in fish	2020		Fish digestive tracts	There have been reports of seven thermoplastic polymers, or MPs, in fish. *Sphyraena viridensis* and *Atherina boyeri* had the lowest average MP numbers at 46 and 28, respectively, whereas *Siganus rivulatus* had the highest average MP number at 7527, *Diplodus sargus* had the highest average MP number at 3593, and *Sardinella aurita* had the highest average MP number at 1450.	Potential icroplastics pollution	Potential ecosystem injury	(Shabaka et al., 2020)
Microplastic in aquatic insects investigated	2023		Aquatic fauna from water and sediment	Predators (*Aeshnidae*) had the lowest MP load per gram, whereas *Chironomidae* and *Hydrophilidae* had the greatest values. The most frequent was polyester fibre, polyethylene, and polypropylene splits The various insect taxa contained polyester fibers, and blue hues predominated in the water, sediment, and insect flora	Increasing plastic contamination within aquatic ecosystems	Potential ecosystem injury	(Khedre, 2023)
Microplastic contamination in gills and GT of fish investigated	2022	Eastern Libya	Marine organism ie fish	All analyzed samples were contaminated by MPs (100.0%)	Microplastic contamination of marine ecosystems	Potential ecological injury	(Hamid et al., 2023)
Microplastic pollution investigated	2023	Libya	*Mytilus galloprovincialis*	In all samples, MP occurrence was >75%. Mussels and digestive glands both had colored MP, with densities of 1.88 MPs/g, and 0.92 MPs/g, respectively	Potential risk of MPs contamination and injury in mussels	Strict rules and policies for the proper management of the plastics are needed	(Abelouah et al., 2023)
Microplastic in water and biota investigated	2022		surface water samples	MPs were abundant in surface water samples at high levels, only a small number of the examined species consumed MPs on average, with a maximum of 20% of individuals	Microplastic pollution	Potential ecosystem injury	(Ben Ismail et al., 2022)
MPs in freshwater investigated	2019	Tunisia	Surface sediments	Occurances of colored MPs, with mean value of 2340 objects per kg, while MP abundance was 6920 items per kg.	Potential MP contamination in freshwaters ecosystems	Strict rules and policies for the proper management of the plastics are needed	(Toumi et al., 2019)
MPs investigated in biotics	2019		Aquatic organisms	Colored MPs were extracted with concentrations ranging from 704 to 1483 pieces kg1.	Potential MP in seafood and other marine organisms.	Potential ecosystem injury	(Abidli et al., 2019; Saad et al., 2022)
Plastic pollution in beach sediments investigated	2022	Algeria	Sediments	Mesoplastics had an average mass that was twice as large as MPs, indicating a significant reservoir of plastics. The most common forms were white/transparent pieces and pellets. Average total plastic concentrations were 107 items/kg, 1067 items/m2, and 51 g/m2.	Potential MPs pollution	Potential ecosystem injury	(Grini et al., 2022)
Marine litter investigated	2021		Seafloor litter	The highest MPs was 58,998 items/ha, with plastics accounting for 88% of the total.	Microplastic pollution	Potential ecosystem injury	(Mankou-Haddadi et al., 2021)
Plastic in intertidal surface sediments investigated	2013		Surface Sediments	MPs debris were uncovered in deposits up to 13.9%, and most of the material was between 0.5 cm and 0.1 cm in size.	Microplastic pollution	Potential ecosystem injury	(Salim and Driss, 2013)

Table 3 (*continued*)

Study	Year	Country	Study site	Results	Implication	Remarks	References
MPs in surface waters investigated.	2021		Surface water	MPs, with significantly varying quantities 0.3 to 1.3 items/m3 Fibers have a 32% share of the total, with fragments coming in second at 27%, films at 16%, foams at 13%, and granules at 12%.	Microplastic pollution	Potential ecosystem injury	(Setiti et al., 2021)
MPs pollution in ocean was investigated	2022	Morocco	seawater	MPs abundances ranged from 0.048 to 3.305 items/m3. Surface seawater from metropolitan areas had a larger concentration of MPs than villages and rural locations. Thet most popular materials after PET-53.8%, were PP 24%, PA 7.6%, PS 6.9%, PVC 2.6%, EVA 2.6%, PUR 1.4%, and AC-0.8%. Fibers accounted for >50% of the most common shapes. Most MPs (71%) featured colorful characteristics and were under 2 mm in size.	Microplastic pollution	Potential ecosystem injury	(Abelouah et al., 2022b)
Assessment of MPs pollution in sediments	2022		Sediments from Moroccan urban beaches	The average MPs density increased from 915 MPs/kg in 2018 to 1448 MPs/kg, indicating rising pollution	Microplastic pollution	Strict rules and policies for the proper management of the plastics are needed	(Ben-Haddad et al., 2022)
Investigation of ingestion of MPs by Ichthyofauna	2023	Cameroon	Southern Coastline	For *E. fimbriata*, *P. senegalensis* and *P. typus* numerous MPs particles were identified. The majority of MPs came in a variety of colors, symbolizing its origin.	Microplastic pollution	Potential harm to aquatic ecosystems	(Mboglen et al., 2019)

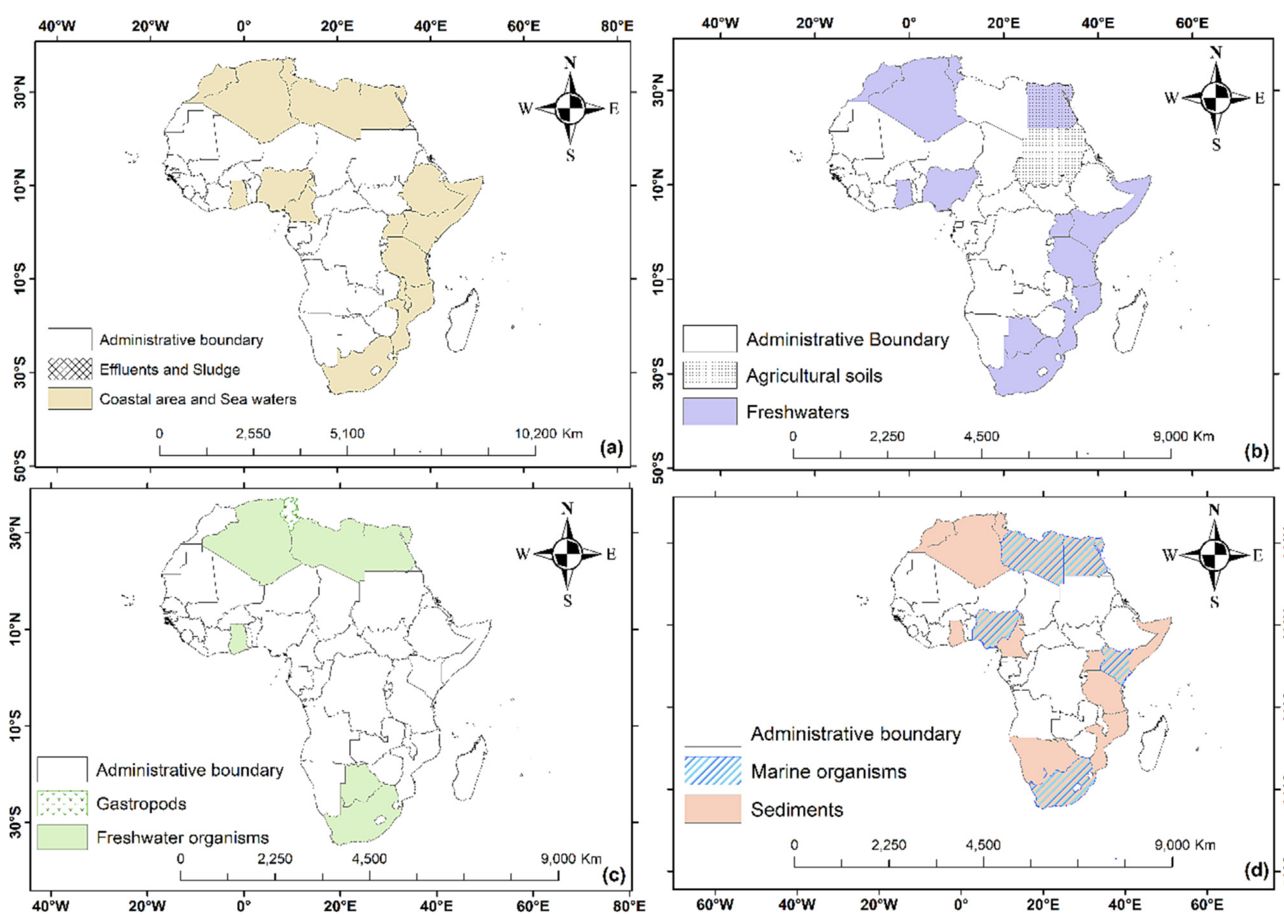

Fig. 2. Represents reports of MPs contamination (a) MPs in coastal areas, sea waters, effluents, and sludge, (b) MPs in agricultural soils and fresh waters, (c) MPs in fresh waters organisms including *Gastropods*, and (d) MPs in sediments and marine organisms. Base map data source: OCHA, https://data.humdata.org/dataset/cod-ab-tza. Map created by authors.

Egessa et al., 2020), where they eventually accumulate, and may create harm to fresh waters organism. For example, trans-boundary rivers including the Nile River connecting ten additional African countries including Burundi, Tanzania, Rwanda, Democratic Republic of the Congo, Kenya, Uganda, Sudan, Ethiopia, South Sudan, and Egypt. Clean water is necessary for hygiene (Vuai et al., 2022; Ripanda et al., 2022a) and wellbeing of the entire ecology. The incidence of MPs pollution in our water sources raises concerns not only about water hygiene but also for the long-term availability of safe drinking water. Therefore, addressing MPs contamination is crucial to ensure clean and sustainable water resources for present and future generations.

MPs can enter soils because of agronomic practices, like use of artificial plastic mulch that is not biodegradable and irrigation systems (Abdellatif et al., 2023; Deme et al., 2022; Ayeleru et al., 2020; Mihai et al., 2022; Preston-Whyte and Maes, 2022; Shilla, 2019; Egessa et al., 2020), potentially impacting agricultural productivity and the quality of water resources. The impacts of microplastic pollution in SSA extend beyond environmental concerns. Apart from MPs, they may further chemically disintegrate to release chemicals such as styrene monomer, styrene dimer, and styrene trimer (Bernstein, 2010), which extends to secondary effects such as development of cancer. Further styrene is a suspected human carcinogen (Bernstein, 2010). Since BPA and PS oligomer are not present in nature, they must be byproducts of the breakdown of plastic (Bernstein, 2010). Sub-Saharan Africa, alone, more than two billion individuals, or fish is the principal source of animal protein and micronutrients for around 30% of the African population (De Graaf and Garibaldi, 2015). The inland fishery sector employs approximately 40.4% of the 12.3 million people working in the fisheries and aquaculture sector, which also significantly contributes to food and nutrition security (De Graaf and Garibaldi, 2015; Beintema and Stads, 2017). Between 3 and 10% of the GDP of numerous SSA countries, including Chad, Mali, Tanzania, and Uganda, comes from freshwaters fisheries (Muringai et al., 2022). If fish populations are impacted by microplastic contamination in this situation, there would be significant economic consequences (Yusoff et al., 2021), requiring intervention.

Additionally, if coastal regions are visibly contaminated with MPs, it may have an adverse effect on tourism, an important economic sector in the area (Rahman et al., 2023a; McIlgorm and Xie, 2023a; Lubchenco and Haugan, 2023). According to the most recent conservative UNEP estimates, plastic accumulation in the marine environment has a variety of negative effects (Avio et al., 2017), ranging from the aesthetic impact of litter and the financial costs of beach cleaning to adverse biological and ecological effects that would cause $13 billion in annual economic harm to marine ecosystems (Avio et al., 2017). While the world has been aware of MPs for many years, a growing trend in study has led to reports (Ryan, 2015), that the world produced 279 million tonnes of plastic in 2011. In 2021, there were 353.3 million tonnes of plastic generated and 390.7 million tonnes of plastic produced globally, with 15% of plastics reportedly recycled. Many of the 17 million tonnes of plastic waste produced annually in SSA are reportedly thrown in open landfills (Musah et al., 2021; Idowu et al., 2019). As a result, plastic debris makes its way into the ocean, lakes, and rivers (van Emmerik and Schwarz, 2020; Valdenegro-Toro, 2016; Kaye and Cousteau, 2010). During this time SSA awareness on MPs was minimal despite the possibilities of their existence due to common sources. From the first global awareness on MPs, Fig. 3 indicates the number of published articles reporting aquatic microplastic pollution globally. Again, the quantity of imported plastics is an indication of physical trans-boundary movements of microplastic sources across the world. A predictive geological time scale indicates that, future formation of oceanic petroleum products and sedimentary rocks will have microplatics contaminants as one of their compositions due to gradient deposition of MPs in aquatics.

4. Implications of microplastic pollution

The effects of environmental microplastic contamination, its impacts on human health, and well-being are significant. As tiny plastic particles infiltrate various ecosystems and food chains, humans are increasingly exposed to these pollutants through multiple pathways, leading to potential adverse effects (Lehel and Murphy, 2021). Ingestion of MPs (Liang et al., 2021; Mihai et al., 2022; Preston-Whyte and Maes, 2022; Lehel and Murphy, 2021; Wu, 2022), through contaminated food and water is among the concerns regarding microplastic pollution. Reports (Abdellatif et al., 2023; Liang et al., 2021; Mihai et al., 2022; Preston-Whyte and Maes, 2022; Egessa et al., 2020; Lehel and Murphy, 2021; Wu, 2022), indicates that a wide range of food products, including seafood, drinking water, and even air-borne particles contained MPs, which

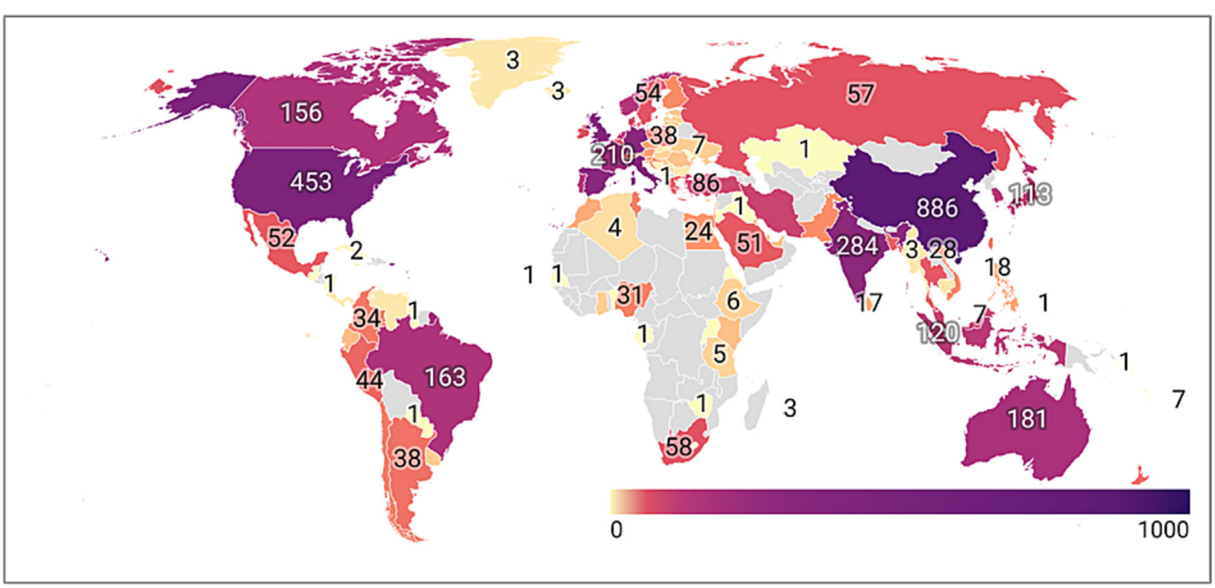

Fig. 3. Published articles globally on aquatic microplastic contamination, including report of aquatic organism exposure. Global map shape file source: https://app.datawrapper.de/, publication data from SCOPUS database.

may potentially harm environmental health. Consumption of contaminated items by human, and other organisms (Laermanns et al., 2021; Zhang, 2017; Ballent et al., 2016; Lehel and Murphy, 2021), MPs can enter the gastrointestinal tract, raising concerns about their potential impacts on digestive health and nutrient absorption. Futher, MPs can adsorb and accumulate toxic chemical elements including cadmium, lead, and nickel (Turna Demir et al., 2022; Khalid et al., 2021), from the surrounding environment or may chemically disintegrate to release waste chemicals that may potentially harm the entire ecology. Such pollutants may include polychlorinated biphenyls (PCBs), a persistent organic pollutant (POPs) (Ripanda et al., 2023; Miraji et al., 2021; Ripanda et al., 2022b; Ripanda et al., 2023a; Hossein et al., 2023a; Ripanda et al., 2023b; Hossein et al., 2023b), pesticides (Hossein et al., 2023a; Hossein et al., 2023b; Ripanda et al., 2021; Makaye et al., 2022; Sk et al., 2019), and heavy metals (Nyanza et al., 2014; Rwiza et al., 2022; Rwiza and Kim, 2016; Nkinda et al., 2021; Nyanza et al., 2020; Charles et al., 2013; Bosse Jønsson et al., 2013). When MPs are ingested, there is a risk of these harmful substances being released and absorbed into the body, potentially leading to long-term health issues (Kirkman et al., 2020; Landrigan et al., 2020), including endocrine disruption, developmental disorders (Ejaredar et al., 2015), and increased risk of certain cancers.

The inhalation of airborne MPs is another growing concern. Recent studies have found MPs in atmospheric samples, indicating that humans may be exposed to these particles through inhalation (Ageel et al., 2022). The potential impacts on respiratory health and the respiratory system are not yet fully understood, but the incidence of MPs in the air raises worries about their ability to reach delicate lung tissues and cause inflammation or other respiratory complications (Prata et al., 2020; Campanale et al., 2020; Lu et al., 2021). Microplastic pollution also poses social and environmental justice concerns. Vulnerable communities, particularly those living in areas with limited waste management infrastructure or near plastic production and disposal sites (Abdellatif et al., 2023; Crawford and Quinn, 2016; do Sul and Costa, 2014; Pérez-Guevara et al., 2021; Laermanns et al., 2021; Zhang, 2017; Ballent et al., 2016), may face higher exposure to MPs and associated health risks (Prata et al., 2020; Campanale et al., 2020; Lu et al., 2021). This includes coastal communities heavily reliant on seafood as a food source and livelihood, and marginalized communities living near plastic waste dumps or in areas with high levels of plastic pollution (Mihai et al., 2022; Bennett et al., 2021).

In Sub-Saharan Africa, rivers, lakes, and coastal regions offer vital homes for a variety of aquatic creatures (Campanale et al., 2020; Lu et al., 2021; Sahni et al., 2023). Therefore, occurrence of MPs can cause physical damage to their digestive systems, impair their feeding capabilities, and lead to malnutrition or starvation (Prata et al., 2023). According to Prata and Coallegues, 99.7% of the fourth-instar *C. riparius* gut is filled with microscopic MPs in high quantities (Prata et al., 2023). There are reports of marine creatures being polluted with MPs, including identification of microplastic flagments in *Mytilus Galloprovincialis*, fibers in *Aulacomya atra*, and fragments in *Crassostrea gigas* (Bajt, 2021). The average size of further consumed MPs was 38–61 μm, and they were eliminated at a slower rate than undigested organic or mineral particles (Prata et al., 2023). Microplastic ingestion rates are primarily determined by encounter rates, and hence by accessible concentrations, until they approach a plateau corresponding to the maximal stomach volume (Prata et al., 2023). According to reports, damage to the gut epithelium causes inflammation, the production of reactive oxygen species, as well as a negative energy balance exacerbated by MPs (Bajt, 2021). Rather than a loss in nutritional absorption, long-term toxicity is characterized by a decrease in larval body length and an increase in emergence time (Prata et al., 2023). In a similar vein, environmental levels in hotspots may already be higher than no impact levels, and wild *Chironomids* had MPs in their stomachs. Environmental exposure to MPs may have negative impacts on wild *C. riparius* in freshwater benthic habitats, jeopardizing their ecological function as foundational species and deposit-feeders in aquatic food webs across the globe.

According to reports, exposure to MPs might cause histological and molecular changes in fish gonads, which could have a negative effect on the fish reproductive system (Qiang and Cheng, 2021). After three weeks of constant aquatic exposure, Chiang and Cheng reported that no appreciable variation was seen at a dose of 10 g/L (Qiang and Cheng, 2021). Reactive oxygen species (ROS) levels higher than 100 g/L were discovered in both male and female gonads and liver (Qiang and Cheng, 2021). Further, at 1000 g/L, male testes showed significantly higher levels of apoptosis, which enhanced the expression of p53-mediated apoptotic pathways was altered, resulting in a significant reduction in testis basement membrane thickness (Qiang and Cheng, 2021). Further, pesticides and other harmful contaminants, like heavy metals, could potentially be transported via MPs. These contaminants may stick to the surfaces of MPs when they enter the environment, increasing environmental pollution by possibly transferring hazardous compounds to organisms (Qiang and Cheng, 2021; Gkoutselis et al., 2021; Sridharan et al., 2021; Galloway et al., 2017). Several fungal species, including significant causative of diseases in animal and plant that made up the plastisphere core mycobiome, have been shown to thrive in the terrestrial plastisphere, according to Gkoutselis and Coallegues' observations (Gkoutselis et al., 2021). Additionally, MPs work as well-chosen artificial microhabitats that draw fungi communities as well as a variety of opportunistic human infections like cryptococcal and Phoma-like species (Gkoutselis et al., 2021). In this instance, MP was thought to be a long-lasting reservoir and potential vector for fungi infections in soil conditions.

5. Future of microplastics in sub-Saharan Africa

The need for SSA to address microplastic pollution is evident. To ensure microplastic free environment SSA needs to improve waste collection, segregation, and recycling infrastructure (Hira et al., 2022; Sarkar et al., 2022). In most developing countries, design for removal of emerging contaminants (Hossein et al., 2018; Ripanda et al., 2023; Miraji et al., 2021; Ripanda et al., 2023a; Hossein et al., 2023a; Ripanda et al., 2023b; Hossein et al., 2023b; Makaye et al., 2022; Sk et al., 2019; Miraji et al., 2023; Miraji et al., 2014; Hossein, 2019; Miraji et al., 2020; Miraji et al., 2016; Ripanda and Miraji, 2022; Hossein et al., 2022), such as MPs is lacking. A study by Chaerul and Coallegues reported that in Bandung, Indonesia, with the generation rate of 25.1 g per day, the overall amount of plastic packaging waste (PPW), produced by 2.3 million, is 58.4 t per day equivalent to 4% of municipal solid waste produced (Chaerul et al., 2014). Whether these findings can be utilized to explain the situation in other emerging nations, such as SSA countries, remains unclear. Furthermore, the municipality's poor management of PPW is related to the absence of integrated municipal solid waste (MSW) management (Chaerul et al., 2014). The informal sector dominates the assortment of valuable wastes, including plastics, with little regard for health and safety of workers (Chaerul et al., 2014). According to the predictions, the entire amount of plastics recycled by different informal waste recycling actors, such as scavengers, junkmen, intermediaries, and dealers, is 27.5 t per day, or 64.6% of the total amount of PPW created (Chaerul et al., 2014). Designing and implementing management plans that call for the ethical disposal and recycling of plastic items is essential (Sarkar et al., 2022; Oberoi et al., 2021). Recycling plastics was recommended by Joseph and Coallegues as a response to the problem of plastic pollution (Joseph et al., 2021). Coordination between the healthcare industry and recycling companies is also required to address issues with medical plastic recycling (Joseph et al., 2021). Sustainability requires the deployment of cutting-edge recycling technologies (Miraji et al., 2023). Similarly, the recycling potential of plastics used in medical applications should be considered (Oberoi et al., 2021; Joseph et al., 2021). Including public education programs to inform people of the dangers of microplastic pollution and the value of using plastics responsibly (Hammami et al., 2017; Sandu et al., 2020). According to a study by Charitou and Coallegues, participants were not informed about the EU single-use plastics legislation, things that will be banned, or marine plastic pollution (Charitou et al., 2021). Participants did, however, exhibit a willingness to pay and take action to limit their plastic trash, among other positive attitudes (Charitou et al., 2021). This indicates that educating the public on ecological consequences of plastic pollution will help to archive plastic free environment globally. Therefore, emphasis for behavior change, such as reducing plastic consumption, reusing plastic items, and proper disposal of plastic waste is needed. Investing in research initiatives to know the sources, distribution, and MPs ecological impacts in SSA context is inevitable. It is necessary to support monitoring programs to assess the extent of microplastic contamination and its consequences on ecosystems health in SSA and the world at large (Makando, 2020; Kandziora et al., 2019; Knoblauch and Mederake, 2021; Adam et al., 2020; Nwafor and Walker, 2020). There is a need to develop and enforce policies and regulations that aim to reduce plastic pollution (Makando, 2020; Kandziora et al., 2019; Knoblauch and Mederake, 2021; Adam et al., 2020; Nwafor and Walker, 2020). This may include banning or restricting plastics including single use plastics, promoting sustainable alternatives, and imposing penalties for non-compliance. To engage in international cooperation and share best practices, knowledge, and experiences in addressing microplastic pollution (Alpizar et al., 2020). For example, the bill, to prohibit plastic bags use intended to ban all plastic bags for retail packaging, the production and importation of those bags, and residential consumption, was approved by the Nigerian government in May 2019. The Nigerian government's proposed bill is modelled after harsh laws already in place throughout Africa (Makando, 2020; Kandziora et al., 2019; Knoblauch and Mederake, 2021; Adam et al., 2020; Nwafor and Walker, 2020). To collaborate with international organizations (Miraji et al., 2021; Obura, 2005; Le Corre et al., 2012; Kerubo et al., 2021), neighboring countries, and research institutions to develop joint initiatives and share resources. To encourage industries to adopt sustainable production practices (Machiwa, 2010; Duhec et al., 2015; van der Elst et al., 2009), decrease the use of MPs in their products, and promote eco-friendly alternatives.

The need to support initiatives that promote the circular economy (Makando, 2020; Kandziora et al., 2019; Knoblauch and Mederake, 2021; Alpizar et al., 2020), where the rate of plastic recycling and reusing is higher than discarding. The involvement of local communities, including coastal residents and fishing communities (Ferreira et al., 2021; Kaviarasan et al., 2022), in microplastic pollution management efforts is key. This provide training and resources for community-led clean-up activities and sustainable waste management practices (Faseyi et al., 2023), to ensure environmental health. The need to invest in research and development of innovative technologies for microplastic detection, filtration, and remediation, is essential for creating microplastic fee future (Pico et al., 2019; Mishra and Ahmaruzzaman, 2022; Wang et al., 2020b). This will support the development of cost-effective and sustainable solutions in SSA (Obura, 2005; Le Corre et al., 2012; Machiwa, 2010; van der Elst et al., 2009; Kaviarasan et al., 2022; Faseyi et al., 2023), to tackle microplastic pollution in the region.

6. Recommendations

Sub-Saharan Africa requires a multi-faceted approach to address microplastic pollution (Do and Armstrong, 2023). It involves improving waste management infrastructure, promoting ecological practices, and raising awareness on the impacts of plastic contamination on the ecosystems and human health (Rahman et al., 2023a; McIlgorm and Xie, 2023a; Lubchenco and Haugan, 2023; Do and Armstrong, 2023). Collaborative efforts among governments, non-government organizations (NGOs), and local communities are crucial for employing operative waste management strategies, encouraging reprocessing initiatives, use of recyclable plastics, and developing policies to adjust the use and disposal of plastic products (Wu, 2022; Moh, 2017). Assessment and monitoring programs focusing on quantifying the extent of microplastic contamination and evaluating its ecological and health impacts will aid to archive a sustainable and plastic-free future in SSA is possible. This can be achieved by building local capacity, fostering international collaborations, and implementation of evidence-based interventions, to mitigate the risks posed by microplastic and promote environmental health in SSA. Strategies to prevent release of plastic to the environments, promoting recycling and sustainable alternatives to single use plastics, and raising awareness about the impacts of microplastic on ecosystems (Qiang and Cheng, 2021; Gkoutselis et al., 2021; Sridharan et al., 2021; Galloway et al., 2017). Research to understand pathways and impacts of MPs and its role in deterioration of the total environment and ecological health, enabling evidence-based policies and mitigation measures and their implementation. This will safeguard the ecosystems from the impacts of microplastic and promote sustainable environmental health, protect biodiversity, maintain ecosystem services, and promote a sustainable future for SSA. The governments, organizations, and individuals perform a role in reducing plastic consumption, improving waste management practices, and supporting the development of sustainable alternatives (Sahni et al., 2023; Ncube et al., 2023; Debnath et al., 2023), for heathier environment. Robust monitoring and research efforts on microplastic pollution and the extent of human and other organisms exposure, to understand the health risks associated with MPs (Sahni et al., 2023; Ncube et al., 2023; Debnath et al., 2023), and inform evidence-based policies and interventions are required. Furthermore, public awareness and education campaigns are crucial in promoting behavioral changes and responsible plastic use (Debnath et al., 2023). Societies may lessen the potential negative effects of microplastic pollution on human health and work towards a cleaner, healthier environment worldwide, especially in SSA, by eliminating plastic waste at its source and implementing efficient waste management systems.

7. Conclusions

An urgent global problem, microplastic contamination has negative effects on the environment, human health, and the economy. The presence of MPs in SSA ecosystems poses significant health risks to marine and terrestrial life, disrupting food chains, impairing reproductive processes, and threatening biodiversity globally. The consumption of MPs by humans and other organisms through contaminated food and water raises concerns about potential long-term health effects, and the sustainability of ecosystems. Transboundary water bodies present a significant challenge in the transportation of MPs. In addition, SSA economy may be significantly affected as a secondary effect after reduced production of aquatic organisms and coastal pollution that may reduce coastal tourism. Collaborative efforts at local, national, and international levels are required in addressing microplastic pollution. Governments, industries, scientific communities, and individuals must work together to implement effective waste management practices, promote sustainable alternatives to plastics, and raise awareness about the impacts of microplastic pollution. Additionally, it is important to conduct study and monitor developments to properly comprehend the sources, distribution, and ecological effects of MPs. Even though microplastic pollution presents serious problems, there is cause for hope. Therefore, increased awareness and public engagement, combined with concerted collaborative actions, can drive positive change towards microplastic pollution free environment. The inclusion of proactive measures, supporting innovative solutions, and embracing sustainable practices, the ecological and human health risks linked with microplastic contamination can be mitigated. This will lead to a cleaner, healthier, and more sustainable future globally.

Ethics approval and consent to participate

Not applicable.

Concert for publication

Not applicable

Data availability

Not applicable.

Declaration of Competing Interest

None.

References

Abdellatif, G., et al., 2023. Waste Plastics and Microplastics in Africa: Negative Impacts and Opportunities. AIChE New York, NY, USA.
Abelouah, M.R., et al., 2022a. Microplastics pollution along the Central Atlantic coastline of Morocco. Mar. Pollut. Bull. 174, 113190.
Abelouah, M.R., et al., 2022b. Floating microplastics pollution in the Central Atlantic Ocean of Morocco: insights into the occurrence, characterization, and fate. Mar. Pollut. Bull. 182, 113969.
Abelouah, M.R., et al., 2023. Binational survey using Mytilus galloprovincialis as a bioindicator of microplastic pollution: insights into chemical analysis and potential risk on humans. Sci. Total Environ. 870, 161894.
Abidli, S., Lahbib, Y., El Menif, N.T., 2019. Microplastics in commercial molluscs from the lagoon of Bizerte (northern Tunisia). Mar. Pollut. Bull. 142, 243–252.
Acquah, J., et al., 2021. Microplastics in freshwater environments and implications for aquatic ecosystems: a mini review and future directions in Ghana. J. Geosci. Environ. Protect. 9 (3), 58–74.
Adam, I., et al., 2020. Policies to reduce single-use plastic marine pollution in West Africa. Mar. Policy 116, 103928.
Adikari, M.U., Prasadi, N., Jayasinghe, C.V., Microplastics in Salt and Drinking Water., 2023. Microplastics in the Ecosphere: Air, Water, Soil, and Food. pp. 357–367.
Ageel, H.K., Harrad, S., Abdallah, M.A.-E., 2022. Occurrence, human exposure, and risk of microplastics in the indoor environment. Environ Sci Process Impacts 24 (1), 17–31.
Akindele, E.O., Ehlers, S.M., Koop, J.H., 2019. First empirical study of freshwater microplastics in West Africa using gastropods from Nigeria as bioindicators. Limnologica 78, 125708.
Alpizar, F., et al., 2020. A framework for selecting and designing policies to reduce marine plastic pollution in developing countries. Environ. Sci. Pol. 109, 25–35.
Aragaw, T.A., De-la-Torre, G.E., Teshager, A.A., 2022. Personal protective equipment (PPE) pollution driven by the COVID-19 pandemic along the shoreline of Lake Tana, Bahir Dar, Ethiopia. Sci. Total Environ. 820, 153261.
Avio, C.G., Gorbi, S., Regoli, F., 2017. Plastics and microplastics in the oceans: from emerging pollutants to emerged threat. Mar. Environ. Res. 128, 2–11.
Ayeleru, O.O., et al., 2020. Challenges of plastic waste generation and management in sub-Saharan Africa: a review. Waste Manag. 110, 24–42.
Bajt, O., 2021. From plastics to microplastics and organisms. FEBS Open Bio 11 (4), 954–966.
Ballent, A., et al., 2016. Sources and sinks of microplastics in Canadian Lake Ontario nearshore, tributary and beach sediments. Mar. Pollut. Bull. 110 (1), 383–395.
Beintema, N., Stads, G.-J., 2017. A Comprehensive Overview of Investments and Human Resource Capacity in African Agricultural Research. Agricultural Science and Technology Indicators (ASTI) Synthesis Report,International Food Policy Research Institute (IFPRI), Washington, DC.
Ben Ismail, S., et al., 2022. Evolution of the distribution and dynamic of microplastic in Water and biota: a study case from the Gulf of Gabes (southern Mediterranean Sea). Front. Mar. Sci. 9, 385.
Ben-Haddad, M., et al., 2022. Microplastics pollution in sediments of Moroccan urban beaches: the Taghazout coast as a case study. Mar. Pollut. Bull. 180, 113765.
Bennett, N.J., et al., 2021. Blue growth and blue justice: ten risks and solutions for the ocean economy. Mar. Policy 125, 104387.
Bernstein, M., 2010. Plastics in oceans decompose, release hazardous chemicals, surprising new study says. August 19, 2009Hard Plastics Decompose in Oceans, Releasing Endocrine Disruptor BPA.
Blankson, E.R., et al., 2022. Microplastics prevalence in water, sediment and two economically important species of fish in an urban riverine system in Ghana. PLoS One 17 (2), e0263196.
Boodhoo, K., et al., 2022. A quantitative and qualitative assessment of microplastics collected at two public beaches along the east and south-east coast of Mauritius. Environ. Monit. Assess. 194 (9), 640.
Bosse Jønsson, J., Charles, E., Kalvig, P., 2013. Toxic mercury versus appropriate technology: artisanal gold miners' retort aversion. Res. Policy 38 (1), 60–67.
Buyukunal, S.K., Zipak, S.R., Muratoglu, K., 2023. Microplastics in a traditional Turkish dairy product: Ayran. Polish J. Food Nutr. Sci. 73 (2), 139–150.
Campanale, C., et al., 2020. A detailed review study on potential effects of microplastics and additives of concern on human health. Int. J. Environ. Res. Public Health 17 (4), 1212.
Campillo, A., et al., 2023. Searching for hotspots of neustonic microplastics in the Canary Islands. Mar. Pollut. Bull. 192, 115057.
Carvalho, J.P., Silva, T.S., Costa, M.F., 2021. Distribution, characteristics and short-term variability of microplastics in beach sediment of Fernando de Noronha archipelago, Brazil. Mar. Pollut. Bull. 166, 112212.
Çepelioğullar, Ö., Pütün, A.E., 2013. Utilization of two different types of plastic wastes from daily and industrial life. J. Selcuk Univ. Nat. Appl. Sci. 2 (2), 694–706.
Chaerul, M., Fahruroji, A.R., Fujiwara, T., 2014. Recycling of plastic packaging waste in Bandung City, Indonesia. J. Mater. Cycles Waste Manage. 16 (3), 509–518.
Charitou, A., et al., 2021. Investigating the knowledge and attitude of the Greek public towards marine plastic pollution and the EU single-use plastics directive. Mar. Pollut. Bull. 166, 112182.
Charles, E., et al., 2013. A cross-sectional survey on knowledge and perceptions of health risks associated with arsenic and mercury contamination from artisanal gold mining in Tanzania. BMC Public Health 13 (1), 74.
Cole, M., et al., 2013. Microplastic ingestion by zooplankton. Environ. Sci. Technol. 47 (12), 6646–6655.
Conowall, P., et al., 2023. Variability of microplastic loading and retention in four inland lakes in Minnesota, USA. Environ. Pollut. 328, 121573.
Crawford, C.B., Quinn, B., 2016. Microplastic Pollutants. Elsevier Limited.
Da Costa, J.P., Rocha-Santos, T., Duarte, A.C., 2020. The Environmental Impacts of Plastics and micro-Plastics Use, Waste and Pollution: EU and National Measures.
Dai, L., et al., 2022. Paths to sustainable plastic waste recycling. Science 377 (6609), 934.
Davtalab, M., Byčenkienė, S., Uogintė, I., 2023. Global research hotspots and trends on microplastics: a bibliometric analysis. Environ. Sci. Pollut. Res. 1–16.
De Graaf, G., Garibaldi, L., 2015. The value of African fisheries. FAO Fish. Aquac. Circular (C1093), I.
Debbarma, N., et al., 2022. Abundance and characteristics of microplastics in gastrointestinal tracts and gills of croaker fish (Johnius dussumieri) from off Mumbai coastal waters of India. Mar. Pollut. Bull. 176, 113473.
Debnath, B., et al., 2023. Modelling the barriers to sustainable waste management in the plastic-manufacturing industry: an emerging economy perspective. Sustain. Anal. Model. 3, 100017.
Deme, G.G., et al., 2022. Macro problems from microplastics: toward a sustainable policy framework for managing microplastic waste in Africa. Sci. Total Environ. 804, 150170.
Ditlhakanyane, B.C., Ultra Jr., V.U., Mokgosi, M.S., 2022. Microplastic load in the surface water and Tilapia sparrmanii (Smith, 1840) of the river systems of Okavango Delta, Botswana. Environ. Monit. Assess. 194 (8), 572.
Do, H.-L., Armstrong, C.W., 2023. Ghost fishing gear and their effect on ecosystem services–identification and knowledge gaps. Mar. Policy 150, 105528.
Duhec, A.V., et al., 2015. Composition and potential origin of marine debris stranded in the Western Indian Ocean on remote Alphonse Island, Seychelles. Mar. Pollut. Bull. 96 (1–2), 76–86.
Ebere, E.C., et al., 2019. Macrodebris and microplastics pollution in Nigeria: first report on abundance, distribution and composition. Environ. Anal. Health Toxicol. 34 (4).
Egbeocha, C.O., et al., 2018. Feasting on microplastics: ingestion by and effects on marine organisms. Aquat. Biol. 27, 93–106.
Egessa, R., et al., 2020. Microplastic pollution in surface water of Lake Victoria. Sci. Total Environ. 741, 140201.
Ejaredar, M., et al., 2015. Phthalate exposure and childrens neurodevelopment: a systematic review. Environ. Res. 142, 51–60.
van der Elst, R.P., et al., 2009. Nine nations, one ocean: a benchmark appraisal of the South Western Indian Ocean fisheries project (2008–2012). Ocean Coast. Manag. 52 (5), 258–267.
van Emmerik, T., Schwarz, A., 2020. Plastic debris in rivers. Wiley Interdiscip. Rev. Water 7 (1), e1398.
Enyoh, C.E., et al., 2023. Progress and future perspectives of microplastic research in Nigeria. Int. J. Environ. Anal. Chem. 103 (9), 1971–1981.
Faseyi, C.A., Miyittah, M.K., Yafetto, L., 2023. Assessment of environmental degradation in two coastal communities of Ghana using driver pressure state impact response (DPSIR) framework. J. Environ. Manag. 342, 118224.
Faulstich, L., et al., 2022. Microplastics in Namibian river sediments–a first evaluation. Microplast. Nanoplast. 2 (1), 1–17.
Ferreira, M., et al., 2020. Presence of microplastics in water, sediments and fish species in an urban coastal environment of Fiji, a Pacific small island developing state. Mar. Pollut. Bull. 153, 110991.
Ferreira, J.C., et al., 2021. Perception of citizens regarding marine litter impacts: collaborative methodologies in island fishing communities of Cape Verde. J. Marine Sci. Eng. 9 (3), 306.
Foolmaun, R.K., et al., 2022. Is a Plastic-free Mauritius Island achievable by 2030? Opportunities and challenges. Mater. Circ. Econ. 4 (1), 23.
Fossi, M.C., et al., 2014. Large filter feeding marine organisms as indicators of microplastic in the pelagic environment: the case studies of the Mediterranean basking shark (Cetorhinus maximus) and fin whale (Balaenoptera physalus). Mar. Environ. Res. 100, 17–24.
Galloway, T.S., Cole, M., Lewis, C., 2017. Interactions of microplastic debris throughout the marine ecosystem. Nat. Ecol. Evol. 1 (5), 0116.
Geyer, R., 2020. A brief history of plastics. Mare Plasticum-The Plastic Sea: Combatting Plastic Pollution Through Science and Art, pp. 31–47.
Geyer, R., Jambeck, J.R., Law, K.L., 2017. Production, use, and fate of all plastics ever made. Sci. Adv. 3 (7), e1700782.
Ghayebzadeh, M., et al., 2020. Estimation of plastic waste inputs from land into the Caspian Sea: a significant unseen marine pollution. Mar. Pollut. Bull. 151, 110871.

Ghosh, G.C., et al., 2021. Microplastics contamination in commercial marine fish from the bay of Bengal. Reg. Stud. Mar. Sci. 44, 101728.
Gkoutselis, G., et al., 2021. Microplastics accumulate fungal pathogens in terrestrial ecosystems. Sci. Rep. 11 (1), 13214.
Gourmelon, G., 2015. Global plastic production rises, recycling lags. Vital Signs 22, 91–95.
Grini, H., et al., 2022. First evidence of plastic pollution in beach sediments of the Skikda coast (northeast of Algeria). Mar. Pollut. Bull. 181, 113831.
H, M., Ripanda, A.S., 2019. Rational integration of principal component analysis in soliciting spatial 'landmark-contaminants' of Tanzania groundwater. Int. J. Curr. Res. 11 (1), 110–116.
Hamid, I., et al., 2023. Microplastic Contamination in Gills and Gastrointestinal Tract of Fish Collected from the Tobruk Coast, Eastern Libya.
Hammami, M.B.A., et al., 2017. Survey on awareness and attitudes of secondary school students regarding plastic pollution: implications for environmental education and public health in Sharjah city, UAE. Environ. Sci. Pollut. Res. 24, 20626–20633.
Hassan, I.A., et al., 2022. Contamination of the marine environment in Egypt and Saudi Arabia with personal protective equipment during COVID-19 pandemic: a short focus. Sci. Total Environ. 810, 152046.
Hira, A., et al., 2022. Plastic waste mitigation strategies: a review of lessons from developing countries. J. Dev. Soc. 38 (3), 336–359.
Honorato-Zimmer, D., et al., 2022. Amounts, sources, fates and ecological impacts of marine litter and Microplastics in the Western Indian Ocean region: a review and recommendations for actions. Oceanogr. Mar. Biol. Annu. Rev. 60, 533–589.
Hossein, M., 2019. Toxicological aspects of emerging contaminants. Emerg. Eco-Friend. Approach. Waste Manag. 33–58.
Hossein, M., et al., 2018. Spatial occurrence and fate assessment of potential emerging contaminants in the flowing surface waters. Chem. Sci. Int. J. 24, 1–11.
Hossein, M., et al., 2022. Exposure to 1, 4-dioxane and disinfection by-products due to the reuse of wastewater. Emerging Contaminants in the Environment. Elsevier, pp. 87–109.
Hossein, M., et al., 2023a. Monitoring of contaminants in aquatic ecosystems using big data. Artificial Intelligence and Modeling for Water Sustainability. CRC Press, pp. 129–157.
Hossein, M., et al., 2023b. Exploring eco-friendly approaches for mitigating pharmaceutical and personal care products in aquatic ecosystems: a sustainability assessment. Chemosphere, 137715.
Hu, L., et al., 2022. Accumulation of microplastics in tadpoles from different functional zones in Hangzhou Great Bay Area, China: relation to growth stage and feeding habits. J. Hazard. Mater. 424, 127665.
Hussein, B.A., Tsegaye, A.A., Abdulahi, A., 2020. Assessment of the Environmental and Health Impacts of Disposal Plastics in Gode Town, Somali Regional State, Eastern Ethiopia (Master's thesis.).
Idowu, I.A., et al., 2019. An analyses of the status of landfill classification systems in developing countries: sub Saharan Africa landfill experiences. Waste Manag. 87, 761–771.
Jeevanandam, M., et al., 2022. Evidences of microplastics in Hawassa Lake, Ethiopia: a first-hand report. Chemosphere 296, 133979.
Joseph, B., et al., 2021. Recycling of medical plastics. Adv. Indust. Eng. Polym. Res. 4 (3), 199–208.
Kandziora, J., et al., 2019. The important role of marine debris networks to prevent and reduce ocean plastic pollution. Mar. Pollut. Bull. 141, 657–662.
Karlsson, M., 2015. Identifying the Presence of Microplastics in Maputo Bay. Eduardo Mondlane University.
Karungamye, P., 2022a. Counterfeit and substandard drugs in Tanzania: a review. Foren. Sci. Int. Rep. 100302.
Karungamye, P.N., 2022b. Potential of Canna indica in constructed wetlands for wastewater treatment: a review. Conservation 2 (3), 499–513.
Karungamye, P., et al., 2022. The Pharmaceutical Disposal Practices and Environmental Contamination: A Review in East African Countries. HydroResearch.
Kaviarasan, T., et al., 2022. Impact of multiple beach activities on litter and microplastic composition, distribution, and characterization along the southeast coast of India. Ocean Coast. Manag. 223, 106177.
Kaye, C.B., Cousteau, P., 2010. Going Blue: A Teen Guide to Saving our Oceans, Lakes, Rivers, & Wetlands. Free Spirit Publishing.
Kelleher, L., et al., 2023. Microplastic accumulation in endorheic river basins–the example of the Okavango panhandle (Botswana). Sci. Total Environ. 874, 162452.
Kerubo, J., et al., 2021. Microplastics pollution in the sediments of creeks and estuaries of Kenya, western Indian Ocean. Afr. J. Mar. Sci. 43 (3), 337–352.
Khalid, N., et al., 2021. Interactions and effects of microplastics with heavy metals in aquatic and terrestrial environments. Environ. Pollut. 290, 118104.
Khan, F.R., et al., 2020. 'The plastic nile': first evidence of microplastic contamination in fish from the nile river (Cairo, Egypt). Toxics 8 (2), 22.
Khedre, A.M., et al., 2023. Assessment of microplastic accumulation in aquatic insects of different feeding guilds collected from wastewater in Sohag governorate, Egypt. Mar. Freshw. *74* (8), 733–745.
Kirkman, S.P., et al., 2020. Ecosystem health and human wealth–a comparison of sub-Saharan African large marine ecosystems. Environ. Dev. 36, 100551.
Knoblauch, D., Mederake, L., 2021. Government policies combatting plastic pollution. Curr. Opin. Toxicol. 28, 87–96.
Koelmans, A.A., et al., 2022. Risk assessment of microplastic particles. Nat. Rev. Mater. 7 (2), 138–152.
Kosore, C.M., et al., 2022. Microplastics in Kenya's marine nearshore surface waters: current status. Mar. Pollut. Bull. 179, 113710.
Kumar, R., et al., 2021. Impacts of plastic pollution on ecosystem services, sustainable development goals, and need to focus on circular economy and policy interventions. Sustainability 13 (17), 9963.
Kurki-Fox, J.J., et al., 2023. Microplastic distribution and characteristics across a large river basin: insights from the Neuse River in North Carolina, USA. Sci. Total Environ. 878, 162940.
Laermanns, H., et al., 2021. Tracing the horizontal transport of microplastics on rough surfaces. Microplast. Nanoplast. 1 (1), 1–12.
Landrigan, P.J., et al., 2020. Human health and ocean pollution. Ann. Glob. Health 86 (1).
Laursen, S.N., et al., 2023. Settling of buoyant microplastic in estuaries: the importance of flocculation. Sci. Total Environ.
Le Corre, M., et al., 2012. Tracking seabirds to identify potential marine protected areas in the tropical western Indian Ocean. Biol. Conserv. 156, 83–93.
Lee, J.-H., Kang, J.-C., Kim, J.-H., 2023. Toxic effects of microplastic (polyethylene) on fish: accumulation, hematological parameters and antioxidant responses in Korean bullhead, Pseudobagrus fulvidraco. Sci. Total Environ. 877, 162874.
Lehel, J., Murphy, S., 2021. Microplastics in the food chain: Food safety and environmental aspects. In: de Voogt, P. (Ed.), Reviews of Environmental Contamination and Toxicology. Vol. 259. Springer International Publishing, Cham, pp. 1–49.
Li, W., et al., 2023. Comparative study on pyrolysis behaviors and chlorine release of pure PVC polymer and commercial PVC plastics. Fuel 340, 127555.
Liang, Y., et al., 2021. An analysis of the plastic waste trade and management in Asia. Waste Manag. 119, 242–253.
Lu, K., et al., 2021. Detrimental effects of microplastic exposure on normal and asthmatic pulmonary physiology. J. Hazard. Mater. 416, 126069.
Lu, L., et al., 2023. Chemical recycling technologies for PVC waste and PVC-containing plastic waste: a review. Waste Manag. 166, 245–258.
Lubchenco, J., Haugan, P.M., 2023. Leveraging multi-target strategies to address Plastic pollution in the context of an already Stressed Ocean. The Blue Compendium: From Knowledge to Action for a Sustainable Ocean Economy. Springer, pp. 141–184.
Machiwa, J.F., 2010. Coastal marine pollution in Dar Es Salaam (Tanzania) relative to recommended environmental quality targets for the Western Indian Ocean. West. Indian Ocean J. Marine Sci. 9 (1), 17–30.
Makando, D.D., 2020. The Plastic Waste and its Management in Tanzania.
Makaye, A., Ripanda, A., Miraji, H., 2022. Transport behavior and risk evaluation of pharmaceutical contaminants from Swaswa wastewater stabilization ponds. J. Biodivers. Environ. Sci. 20 (2), 30–41.
Malli, A., Shehayeb, A., Yehya, A., 2023. Occurrence and risks of microplastics in the ecosystems of the Middle East and North Africa (MENA). Environ. Sci. Pollut. Res. 1–27.
Mamun, A.A., et al., 2023. Microplastics in human food chains: food becoming a threat to health safety. Sci. Total Environ. 858, 159834.
Mankou-Haddadi, N., et al., 2021. Benthic marine litter in the coastal zone of Bejaia (Algeria) as indicators of anthropogenic pollution. Mar. Pollut. Bull. 170, 112634.
Matsuguma, Y., et al., 2017. Microplastics in sediment cores from Asia and Africa as indicators of temporal trends in plastic pollution. Arch. Environ. Contam. Toxicol. 73, 230–239.
Mattan-Moorgawa, S., Chockalingum, J., Appadoo, C., 2021. A first assessment of marine meso-litter and microplastics on beaches: where does Mauritius stand? Mar. Pollut. Bull. 173, 112941.
Mboglen, D., Oben, L., Ondo, S.N., 2019. Ingestion of Microplastics by Ichthyofauna in the southern coastline of Cameroon. Curr. J. Appl. Sci. Technol. 35 (1), 1–8.
McIlgorm, A., Xie, J., 2023a. In: Xie, A.M.A.J. (Ed.), The Costs of Environmental Degradation from Plastic Pollution in Selected Coastal Areas in the United Republic of Tanzania World bank: 16 March 223.
McIlgorm, A., Xie, J., 2023b. The Costs of Environmental Degradation from Plastic Pollution in Selected Coastal Areas in the United Republic of Tanzania.
Meng, F., et al., 2023. Effects of microplastics on common bean rhizosphere bacterial communities. Appl. Soil Ecol. 181, 104649.
Mhiret Gela, S., Aragaw, T.A., 2022. Abundance and characterization of microplastics in main urban ditches across the Bahir Dar City, Ethiopia. Front. Environ. Sci. 35.
Migwi, F.K., Ogunah, J.A., Kiratu, J.M., 2020. Occurrence and spatial distribution of microplastics in the surface waters of Lake Naivasha, Kenya. Environ. Toxicol. Chem. 39 (4), 765–774.
Mihai, F.-C., et al., 2022. Plastic pollution, waste management issues, and circular economy opportunities in rural communities. Sustainability 14 (1), 20.
Miraji, H., 2018. Brination of coastal aquifers: prospective impacts and future fit-for-use remedial strategies in Tanzania. World Wide J. Multidiscipl. Ina. Res. Dev. 4, 202–206.
Miraji, H., Mgina, C., Ngassap, F., 2014. A Physico-Chemical and Bacteriological Investigation of Groundwater Quality for Domestic Supply, a Case Study of Temeke Municipal. University of Dar es Salaam, Dar es Salaam.
Miraji, H., et al., 2016. Research trends in emerging contaminants on the aquatic environments of Tanzania. Scientifica 2016.
Miraji, H., et al., 2020. Analytical perspectives on emerging organic contaminants in the aquatic ecosystem. Effects of Emerging Chemical Contaminants on Water Resources and Environmental Health. IGI Global, pp. 68–80.
Miraji, H., Ripanda, A., Moto, E., 2021. A review on the occurrences of persistent organic pollutants in corals, sediments, fish and waters of the Western Indian Ocean. Egypt. J. Aquat. Res. 47 (4), 373–379.
Miraji, H., et al., 2023. Naturally occurring emerging contaminants: where to hide? HydroResearch 6, 203–215.
Mishra, S.R., Ahmaruzzaman, M., 2022. Microplastics: identification, toxicity and their remediation from aqueous streams. Sep. Purif. Rev. 1–22.
Moh, Y., 2017. Solid waste management transformation and future challenges of source separation and recycling practice in Malaysia. Resour. Conserv. Recycl. 116, 1–14.
Muringai, R.T., Mafongoya, P., Lottering, R.T., 2022. Sub-Saharan Africa freshwater fisheries under climate change: a review of impacts, adaptation, and mitigation measures. Fishes 7 (3), 131.

Musah, B.I., Peng, L., Plastic, Y.Xu., 2021. Waste menace in Ghana, a serious threat to marine ecological diversity. IOP Conference Series: Earth and Environmental Science. IOP Publishing.
Nantege, D., et al., 2023. Microplastic pollution in riverine ecosystems: threats posed on macroinvertebrates. Environ. Sci. Pollut. Res. 1–43.
Ncube, A., et al., 2023. Circular economy and green chemistry: the need for radical innovative approaches in the design for new products. Energies 16 (4), 1752.
Nel, H.A., Froneman, P.W., 2015. A quantitative analysis of microplastic pollution along the south-eastern coastline of South Africa. Mar. Pollut. Bull. 101 (1), 274–279.
Nel, H.A., et al., 2017. Do microplastic loads reflect the population demographics along the southern African coastline? Mar. Pollut. Bull. 115 (1–2), 115–119.
Ni, N., et al., 2023. Comparative analysis of the sorption behaviors and mechanisms of amide herbicides on biodegradable and nondegradable microplastics derived from agricultural plastic products. Environ. Pollut. 318, 120865.
Nkinda, M.S., et al., 2021. Heavy metals risk assessment of water and sediments collected from selected river tributaries of the Mara River in Tanzania. Discov. Water 1 (1), 3.
Nwafor, N., Walker, T.R., 2020. Plastic bags prohibition bill: a developing story of crass legalism aiming to reduce plastic marine pollution in Nigeria. Mar. Policy 120, 104160.
Nyanza, E.C., et al., 2014. Spatial distribution of mercury and arsenic levels in Water, soil and cassava plants in a community with long history of gold Mining in Tanzania. Bull. Environ. Contam. Toxicol. 93 (6), 716–721.
Nyanza, E.C., et al., 2020. Maternal exposure to arsenic and mercury and associated risk of adverse birth outcomes in small-scale gold mining communities in northern Tanzania. Environ. Int. 137, 105450.
Oberoi, I.S., Rajkumar, P., Das, S., 2021. Disposal and recycling of plastics. Mater. Today Proc. 46, 7875–7880.
Obura, D.O., 2005. Resilience and climate change: lessons from coral reefs and bleaching in the Western Indian Ocean. Estuar. Coast. Shelf Sci. 63 (3), 353–372.
OECD, 2022. Plastic Pollution is Growing Relentlessly as Waste Management and Recycling Fall Short, Says OECD. OECD.
Owens, K.A., et al., 2022. Empowering local practitioners to collect and report on anthropogenic riverine and marine debris using inexpensive methods in India. Sustainability 14 (3), 1928.
Owens, K.A., Kamil, P.I., Ochieng, H., 2023. River Engage: Insights on Plastic Debris Polluting the Aturukuku River in Uganda, the Ayung River in Indonesia, and the Connecticut River in the United States.
Pan, Z., et al., 2019. Environmental implications of microplastic pollution in the northwestern Pacific Ocean. Mar. Pollut. Bull. 146, 215–224.
Pappoe, C., et al., 2022. Occurrence of microplastics in gastrointestinal tract of fish from the Gulf of Guinea, Ghana. Mar. Pollut. Bull. 182, 113955.
Peng, J., Wang, J., Cai, L., 2017. Current understanding of microplastics in the environment: occurrence, fate, risks, and what we should do. Integr. Environ. Assess. Manag. 13 (3), 476–482.
Pérez-Guevara, F., et al., 2021. A central role for fecal matter in the transport of microplastics: an updated analysis of new findings and persisting questions. J. Hazard. Mater. Adv. 4, 100021.
Pico, Y., Alfarhan, A., Barcelo, D., 2019. Nano-and microplastic analysis: focus on their occurrence in freshwater ecosystems and remediation technologies. TrAC Trends Anal. Chem. 113, 409–425.
Prata, J.C., et al., 2020. Environmental exposure to microplastics: an overview on possible human health effects. Sci. Total Environ. 702, 134455.
Prata, J.C., et al., 2022. The road to sustainable use and waste management of plastics in Portugal. Front. Environ. Sci. Eng. 16, 1–16.
Prata, J.C., et al., 2023. Mechanisms influencing the impact of microplastics on freshwater benthic invertebrates: uptake dynamics and adverse effects on Chironomus riparius. Sci. Total Environ. 859, 160426.
Praveena, S.M., Hisham, M.A.F.I., Nafisyah, A.L., 2023. Microplastics pollution in agricultural farms soils: preliminary findings from tropical environment (Klang Valley, Malaysia). Environ. Monit. Assess. 195 (6), 1–11.
Preston-Whyte, F., Maes, T., 2022. Introduction to marine litter in Africa. The African Marine Litter Outlook. Springer International Publishing Cham, pp. 1–34.
Preston-Whyte, F., et al., 2021. Meso-and microplastics monitoring in harbour environments: a case study for the port of Durban, South Africa. Mar. Pollut. Bull. 163, 111948.
Qiang, L., Cheng, J., 2021. Exposure to polystyrene microplastics impairs gonads of zebrafish (Danio rerio). Chemosphere 263, 128161.
Ragoobur, D., Huerta-Lwanga, E., Somaroo, G.D., 2021. Microplastics in agricultural soils, wastewater effluents and sewage sludge in Mauritius. Sci. Total Environ. 798, 149326.
Rahman, N., et al., 2023a. Microplastic as an invisible threat to the coral reefs: sources, toxicity mechanisms, policy intervention, and the way forward. J. Hazard. Mater., 131522
Rahman, M.A., et al., 2023b. Plastic pollutions in the ocean: their sources, causes, effects and control measures. J. Biol. Stud. 6 (1), 37–52.
Ridall, A., et al., 2023. Influence of wastewater treatment plants and water input sources on size, shape, and polymer distributions of microplastics in St. Andrew Bay, Florida, USA. Mar. Pollut. Bull. 187, 114552.
Ripanda, A., Miraji, H., 2022. A Review on the Occurrence and Impacts of Nutrient Pollution in the Aquatic Ecosystem of Sub-Saharan Countries.
Ripanda, A.S., et al., 2021. A review on contaminants of emerging concern in the environment: a focus on active chemicals in sub-Saharan Africa. Appl. Sci. 12 (1), 56.
Ripanda, A., et al., 2022a. Evaluation of potentiality of traditional hygienic practices for the mitigation of the 2019–2020 Corona pandemic. Public Health Nurs. 39 (4), 867–875.
Ripanda, A.S., et al., 2022b. Contribution of illicit drug use to pharmaceutical load in the environment: a focus on sub-Saharan Africa. J. Environ. Public Health 2022.
Asha Ripanda, M.J.R., Nyanza, Elias Charles, Bakari, Ramadhani, Miraji, Hossein, Njau, Karoli N., Vuai, Said Ali Hamad, Machunda, Revocatus L., 2023. Removal of lamivudine from synthetic solution using jamun seed (Syzygium cumini) biochar adsorbent. Emerg. Contam. *9*(3), 100232
Ripanda, A., et al., 2023a. Data from the batch adsorption of ciprofloxacin and lamivudine from synthetic solution using jamun seed (Syzygium cumini) biochar: response surface methodology (RSM) optimization. Data Brief 47, 108975.
Ripanda, A.S., et al., 2023b. Antibiotic-resistant microbial populations in urban receiving waters and wastewaters from Tanzania. Environ. Chem. Ecotoxicol. 5, 1–8.
Rummel, C.D., et al., 2017. Impacts of biofilm formation on the fate and potential effects of microplastic in the aquatic environment. Environ. Sci. Technol. Lett. 4 (7), 258–267.
Rwiza, M.J., Kim, K.W., Kim, S.D., 2016. Geochemical distribution of trace elements in groundwater from the North Mara large-scale gold mining area of Tanzania. Groundw. Monit. Remediat. 36 (2), 83–93.
Rwiza, M., Mohammed, N., Banzi, F., 2022. The influence of gold mining on radioactivity of mining sites soil in Tanzania. MEWES. NMAIST.
Ryan, P.G., 2015. A brief history of marine litter research. Marine Anthrop. Litter 1–25.
Saad, D., et al., 2022. Microplastics in freshwater environment: the first evaluation in sediment of the Vaal River, South Africa. Heliyon 8 (10), e11118.
Sahni, H., Chopra, N., Gadhavi, P., 2023. The social rendition of Plastic waste management initiatives in India. Socially Responsible Plastic: Is this Possible?Emerald Publishing Limited, pp. 31–58.
Salim, B., Driss, A.T., 2013. Abundance of plastic debris in intertidal surface sediments from Arzew gulf (Western Algeria). Am. J. Sci. 1 (1), 28–32.
Sandu, C., et al., 2020. Society role in the reduction of plastic pollution. Plastics in the Aquatic Environment-Part II: Stakeholders' Role against Pollution. Springer, pp. 39–65.
Sarkar, B., et al., 2022. Challenges and opportunities in sustainable management of microplastics and nanoplastics in the environment. Environ. Res. 207, 112179.
Sathish, M.N., Jeyasanta, I., Patterson, J., 2020. Occurrence of microplastics in epipelagic and mesopelagic fishes from Tuticorin, southeast coast of India. Sci. Total Environ. 720, 137614.
Sayed, A.E.-D.H., et al., 2021. Microplastic distribution, abundance, and composition in the sediments, water, and fishes of the red and Mediterranean seas, Egypt. Mar. Pollut. Bull. 173, 112966.
Setiti, S., et al., 2021. Seasonal variation of microplastics density in Algerian surface waters (South-Western Mediterranean Sea). Mediterr. Mar. Sci. 22 (2), 317–326.
Shabaka, S.H., Ghobashy, M., Marey, R.S., 2019. Identification of marine microplastics in Eastern Harbor, Mediterranean coast of Egypt, using differential scanning calorimetry. Mar. Pollut. Bull. 142, 494–503.
Shabaka, S.H., et al., 2020. Thermal analysis and enhanced visual technique for assessment of microplastics in fish from an Urban Harbor, Mediterranean coast of Egypt. Mar. Pollut. Bull. 159, 111465.
Shilla, D., 2019. Status updates on plastics pollution in aquatic environment of Tanzania: data availability, current challenges and future research needs. Tanzania J. Sci. 45 (1), 101–113.
Shruti, V.C., et al., 2023. First evidence of microplastic contamination in ready-to-use packaged food ice cubes. Environ. Pollut. 318, 120905.
Silori, R., et al., 2023. Understanding the underestimated: occurrence, distribution, and interactions of microplastics in the sediment and soil of China, India, and Japan. Environ. Pollut. 320, 120978.
Simon-Sánchez, L., et al., 2022. Are research methods shaping our understanding of microplastic pollution? A literature review on the seawater and sediment bodies of the Mediterranean Sea. Environ. Pollut. 292, 118275.
Sk, M., Ripanda, A., Miraji, H., 2019. Quantitative investigation of potential contaminants of emerging concern in Dodoma City: a focus at Swaswa wastewater stabilization ponds. Egypt. J. Chem. 427–436 62(Special Issue (Part 2) Innovation in Chemistry):.
Smith, A., et al., 2022. Quantification and characterization of plastics in near-shore surface waters of Atlantic Canada. Mar. Pollut. Bull. 181, 113869.
Sridharan, S., et al., 2021. Are microplastics destabilizing the global network of terrestrial and aquatic ecosystem services? Environ. Res. 198, 111243.
do Sul, J.A.I., Costa, M.F., 2014. The present and future of microplastic pollution in the marine environment. Environ. Pollut. 185, 352–364.
Tata, T., et al., 2020. Occurrence and characterization of surface sediment microplastics and litter from north African coasts of Mediterranean Sea: preliminary research and first evidence. Sci. Total Environ. 713, 136664.
Tiseo, I., 2022. Global Plastic Production 1950–2021. can be found under https://www.statista.com/statistics/282732/global-production-of-plastics-since-1950/ (accessed 28.12. 2022).
Torres, F.G., et al., 2021. Sorption of chemical contaminants on degradable and nondegradable microplastics: recent progress and research trends. Sci. Total Environ. 757, 143875.
Toumi, H., Abidli, S., Bejaoui, M., 2019. Microplastics in freshwater environment: the first evaluation in sediments from seven water streams surrounding the lagoon of Bizerte (northern Tunisia). Environ. Sci. Pollut. Res. 26, 14673–14682.
Turna Demir, F., Akkoyunlu, G., Demir, E., 2022. Interactions of ingested polystyrene microplastics with heavy metals (cadmium or silver) as environmental pollutants: a comprehensive in vivo study using Drosophila melanogaster. Biology 11 (10), 1470.
Valdenegro-Toro, M., 2016. Submerged marine debris detection with autonomous underwater vehicles. 2016 International Conference on Robotics and Automation for Humanitarian Applications (RAHA). IEEE.
Vitali, C., et al., 2023. Microplastics and nanoplastics in food, water, and beverages; part I. Occurrence. TrAC Trends Anal. Chem. 159, 116670.
Vuai, S.A.H., et al., 2022. A comparative in-vitro study on antimicrobial efficacy of on-market alcohol-based hand washing sanitizers towards combating microbes and its application in combating Covid-19 global outbreak. Heliyon 8 (11).
Wang, C., et al., 2020a. Structure of the global plastic waste trade network and the impact of China's import ban. Resour. Conserv. Recycl. 153, 104591.

Wang, Z., Lin, T., Chen, W., 2020b. Occurrence and removal of microplastics in an advanced drinking water treatment plant (ADWTP). Sci. Total Environ. 700, 134520.
Wang, Q., et al., 2022. Microplastics in China Sea: analysis, status, source, and fate. Sci. Total Environ. 803, 149887.
Weideman, E.A., et al., 2023. Proximity to coast and major rivers influence the density of floating microplastics and other litter in east African coastal waters. Mar. Pollut. Bull. 188, 114644.
Wichai-Utcha, N., Chavalparit, O., 2019. 3Rs policy and plastic waste management in Thailand. J. Mater. Cycles Waste Manag. 21, 10–22.
Wilson, D.R., et al., 2023. Modelling the Transport of Microplastic Pollution across the Antarctic Circumpolar Current. Copernicus Meetings.
Wu, H.-H., 2022. A study on transnational regulatory governance for marine plastic debris: trends, challenges, and prospect. Mar. Policy 136, 103988.
Yalwaji, B., John-Nwagwu, H., Sogbanmu, T.O., 2022. Plastic pollution in the environment in Nigeria: a rapid systematic review of the sources, distribution, research gaps and policy needs. Sci. Af. *16*, e01220.
Yusoff, F.M., et al., 2021. Impacts of COVID-19 on the aquatic environment and implications on aquatic food production. Sustainability 13 (20), 11281.
Zhang, H., 2017. Transport of microplastics in coastal seas. Estuar. Coast. Shelf Sci. 199, 74–86.
Zheng, X., et al., 2023. Distribution and risk assessment of microplastics in typical ecosystems in the South China Sea. Sci. Total Environ., 163678