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Review

Plastic and Micro/Nanoplastic Pollution in Sub-Saharan Africa: Challenges, Impacts, and Solutions

Edith Dube * and Grace Emily Okuthe

Department of Biological & Environmental Sciences, Walter Sisulu University, Mthatha 5117, South Africa; gokuthe@wsu.ac.za

* Correspondence: edube@wsu.ac.za; Tel.: +27-47-502-1952; Fax: +27-47-5022725

Abstract: Sub-Saharan Africa faces increasing levels of plastic production and importation, unregulated usage, and inadequate waste management systems. This region's harsh conditions often lead to plastic breaking down into microplastics and nanoplastics. This review explores the abundance of micro/nanoplastics across different environmental mediums, such as surface waters, sediments, and aquatic organisms, in sub-Saharan African countries. It also highlights knowledge gaps concerning the region's abundance of micro/nanoplastics. The effects of plastics and micro/nanoplastics on food production, water quality, health, and the environment are discussed. Strategies to address the challenges of plastic pollution are proposed. Finally, the review concludes with future perspectives for addressing the ongoing challenges of plastic waste management in sub-Saharan Africa. The materials for this study were sourced from published articles on Scopus, Google Scholar, ResearchGate, and additional platforms, including reports and various press releases, using keywords such as plastic waste, micro/nano-plastic, sub-Saharan Africa, toxicity, and circular economy. Articles were initially screened by reviewing abstracts, followed by a thorough reading of full papers to identify relevant studies. Key information was extracted from these selected articles and incorporated into this review.

Keywords: plastic waste; micro/nano-plastic; sub-Saharan Africa; toxicity; circular economy

Citation: Dube, E.; Okuthe, G.E. Plastic and Micro/Nanoplastic Pollution in Sub-Saharan Africa: Challenges, Impacts, and Solutions. *World* **2024**, *5*, 325–345. https://doi.org/10.3390/world5020018

Academic Editors: Wang-Kin Chiu and Hon-Ming Lam

Received: 27 March 2024
Revised: 11 May 2024
Accepted: 12 May 2024
Published: 15 May 2024

1. Introduction

Global plastic production continues to escalate, leading to an increase in plastic waste generation [1]. Africa is estimated to produce 19,000 kilotons (kt) of plastic annually [2]. Within Sub-Saharan Africa (SSA), South Africa, Nigeria, Ethiopia, Ghana, and Kenya are notable for their substantial contributions to plastic production, with figures for 2018 and beyond indicating annual production levels of up to 1410 kt, 513 kt, 386 kt, 205 kt, and 130 kt, respectively [3]. These statistics demonstrate significant industrial activity despite these countries producing considerably less than more industrialized regions.

However, a concerning trend accompanies this production: the steady increase in the importation of plastic raw materials and finished products into several SSA countries. This rise is particularly alarming in light of the inadequate waste management infrastructure [2–4]. For instance, Ethiopia's imports of plastic raw materials have escalated dramatically, from 54 kt in 2007 to 224 kt in 2020 [3]. Such increases in plastic imports, combined with local production, aggravate the waste management crisis.

The management of plastic waste is becoming increasingly challenging, with projections indicating that mismanaged plastic waste in Africa could more than double by 2025, from 4.8 million tons to an estimated 11.5 million tons [2]. This highlights the critical need for effective waste management solutions to address the severe environmental issues posed by widespread and unregulated plastic use.

The persistence of plastic pollution in SSA is intensified by inadequate waste management infrastructure and limited regulatory frameworks, further complicated by socioeconomic constraints [2,5,6]. Plastic waste degrades our urban environments and infiltrates various ecosystems, from rivers and lakes to coastlines, endangering water quality, soil health, wildlife, and human communities. Dahms et al. reported the presence of microplastics in water, sediment and fish (*Clarias gariepinus*) from the Vaal River, South Africa [7]. This poses significant threats to food safety and public health. Additionally, the durability of plastics, which contributes to their widespread use, unfortunately also poses serious environmental challenges, as these materials are resistant to natural degradation, breaking down into microplastics (MPs) and nanoplastics (NPs) that spread throughout the environment. Chamas et al. showed that, in marine environments, the specific surface degradation rate (SSDR) values for high-density polyethylene (HDPE) ranges from almost zero to approximately 11 µm per year. By applying the average SSDR to HDPE in these marine conditions, linear extrapolation suggested that the estimated half-lives of HDPE products can vary widely, from 58 years for plastic bottles to 1200 years for plastic pipes [8], showing the durability of plastic material in the environment. This durability highlights the severe challenges posed by plastic waste in aquatic ecosystems, as plastics not only linger for centuries but also continue to impact marine life and ecosystems over prolonged periods [9,10]. Hence, strategies that reduce plastic use and enhance biodegradability are critical to mitigating the long-term environmental impact of plastic waste.

This review aims to explore the prevalence, impact, and potential solutions to plastic and micro/nanoplastic pollution (referred in this review as MNPs) in SSA. It will examine recent studies on micro/nanoplastic contamination, evaluate their impacts on food production, water quality, health, and the environment, and review various existing and proposed waste management and recycling strategies. The review seeks to provide a complete understanding of the plastic pollution crisis in SSA and generate insights that could guide policy decisions, encourage community initiatives, and stimulate further research in this vital area of environmental concern.

2. Materials and Methods

The aim of this review was to compile and analyze existing research on the prevalence, impacts, and management of plastic and MNP pollution in SSA, with a particular focus on their impact on food production, water quality, health, and the environment and possible measures to reduce plastic waste in the region. Research materials were collected from a variety of academic databases, including Scopus, Google Scholar, and ResearchGate. Additional relevant information used in the introduction and discussion was also obtained from grey literature, including reports and various news articles (Table 1). The search was conducted using specific keywords and phrases such as plastic waste, micro/nanoplastic, micro/nanoplastic abundance, sub-Saharan Africa, plastic toxicity, and plastic circular economy. These terms were employed both individually and in combination to ensure a thorough search.

The selection criteria for articles were based on their relevance to plastic pollution in the SSA context, their discussions on the abundance of microplastics, investigations into the impact of MNPs, or their exploration of circular economy strategies applicable to plastic waste management in the region. Duplicate articles were removed, and exclusions were made for articles that either did not focus on SSA, did not align with the theme of the review, or were not published between 2020 and 2024. The screening process began with an initial review of article titles and abstracts to ascertain their relevance to the specified timeframe. Subsequently, a thorough analysis of the full texts was conducted to extract detailed information pertinent to the review's themes. The steps of this screening process are depicted in Figure 1. Finally, the information collected was organized into a structured review document, ensuring a clear and cohesive presentation of the findings, predominantly citing journal articles, as shown in Table 1.

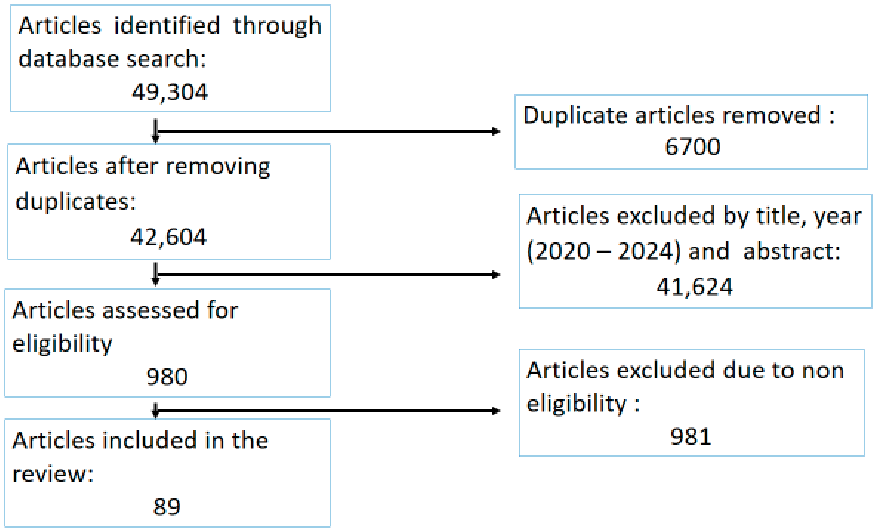

Figure 1. The flow diagram for the article selection process.

Table 1. Article types utilized in this review.

Article Type	Number
Journal articles	124
Book sections	3
Reports	8
News articles	4
Total used	139

3. The Sources and Abundance of MNPs in Sub-Saharan Africa

Plastic pollution in SSA originates from various sources, including urban waste, industrial facilities (packaging, textiles, and manufacturing), agricultural practices, maritime activities and imported plastic products, among others. Common plastic items, such as packaging materials, single-use plastics, and various discarded products, contribute to environmental pollution [11]. These items are ubiquitous in daily life, encompassing everything from plastic bags, straws, and food packaging to water bottles and take-away containers. Due to their convenience and low cost, the production and consumption of these plastics have surged, worsening waste management challenges. Donuma et al. reported a random disposal of plastic waste and sachet water bags in Maiduguri, Borno State, Nigeria [12]. Unfortunately, some SSA countries face challenges with waste collection, resulting in piles of plastic waste accumulating on dumpsites, roadsides, and open areas. Some of this waste is swept away, obstructing drains and water systems [13].

Exposure of these plastics to environmental conditions, such as ultraviolet radiation, moisture, oxygen, wind or wave abrasion, and high temperatures, which are increasingly prevalent in SSA due to climate change, coupled with the action of certain microorganisms (such as *Streptococcus*, *Klebsiella*, *Micrococcus*, *Staphylococcus*, and *Pseudomonas*), accelerate the weathering and fragmentation of plastic materials to microplastics (MPs, 100 nm–5 mm) and/or nanoplastics (NPs, <100 nm) [14]. This fragmentation process is particularly significant in SSA, where climatic conditions intensify the breakdown and spread of plastic fragments. These plastic fragments end up in the soil, air, and water systems, as illustrated in Figure 2.

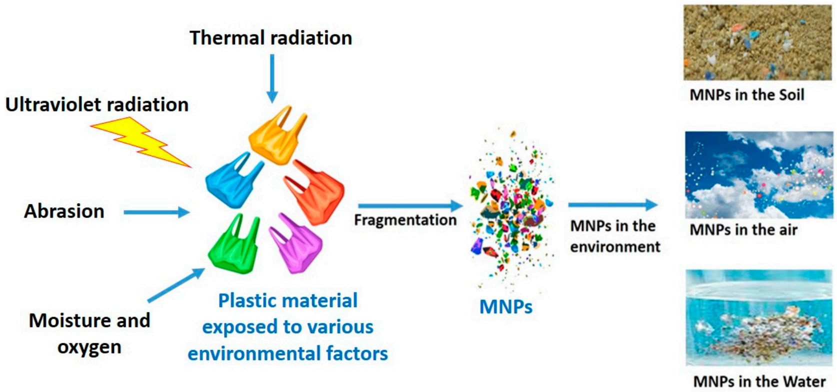

Figure 2. An illustration of plastic fragmentation to MNPs and release to the environment.

MNPs migrate from various sources, including landfill disposals, street runoff, atmospheric deposition, and agricultural activities. They are also released into the atmosphere through urban dust, agricultural dust, fiber shedding from synthetic clothing or plastic material, particles blown from inadequately managed landfills, abrasion from synthetic rubber tires, waste incineration, and emissions from synthetic polymer industries [15,16]. Eventually, both soil-bound and airborne MNPs are transported into aquatic systems through runoff [17].

Given the significant volume of plastic waste in SSA and the region's harsh weather conditions that accelerates the fragmentation of plastics into MNPs [18], it is imperative to continuously monitor and assess the levels of these MNPs. Understanding the abundance of MNPs is crucial for protecting environmental and human health, as well as for developing effective management strategies and policy responses to tackle the ongoing issue of plastic pollution.

Research focusing on the abundance of these minute plastic fragments across different environmental mediums, such as surface waters, sediments, and within aquatic organisms, has been conducted in several SSA countries [19–28], as illustrated in Figure 3.

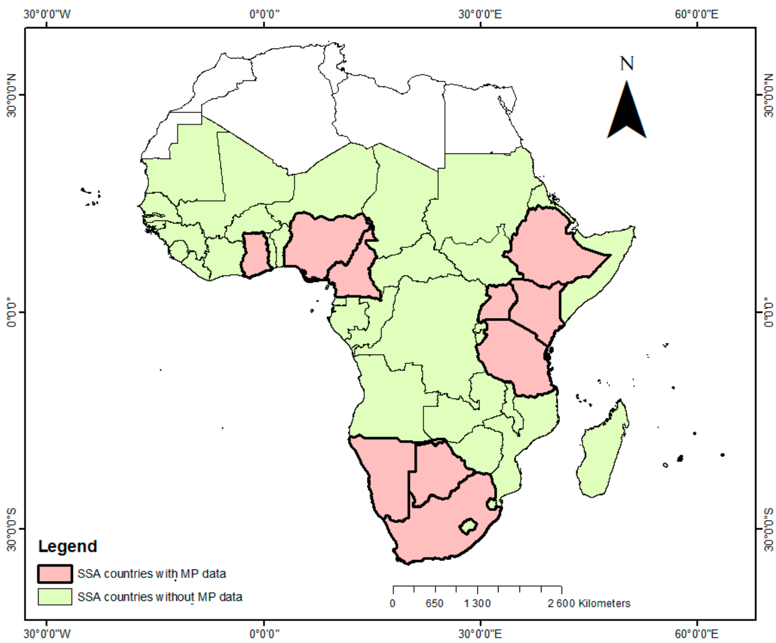

Figure 3. Map of Africa, illustrating sub-Saharan African countries and identifying those that have measured the abundance of MPs in surface waters, sediments, and aquatic organisms as indicators of pollution.

The findings from these studies are summarized in Tables 2–4. These tables provide valuable insights into the prevalence of MNPs, which, despite their often-invisible size, are widespread in sediments, air, and aquatic systems. Living organisms frequently ingest these particles through food, drinking water, and even the air they breathe, posing significant health risks and ecological impacts [29].

The data on these tables serve as a resource for understanding the current state of MNPs pollution in SSA. Table 2 displays data from SSA countries concerning the abundance, size, shape, and polymer types of MPs in surface water.

Table 2. MPs in sub-Saharan African countries' surface water.

Sub-Saharan Country	Study Area	MPs Concentration	MP Size	MP Shape	Polymer Type	Ref.
			East Africa			
Ethiopia	Ditch in Bahir Dar city (sewage water)	3 ± 1 items/50 mL	>0.5 mm (38 items) and <0.5 mm (66 items)	fragments	PE, PP, PS, and PA	[19]
Kenya	Malindi surface waters	3.22 ± 2.04 MPs/m^3	2–5 mm (66%), 1–2 mm (27%), 0.5–1 mm (6%), and 0.3–0.5 mm (1%)	Fragments, films and fibers	PP, PE	[20]
	Lake Naivasha	0.407 ± 0.135 particles/m^2	1–5 mm	fragments, fibers and films	PP, PE, and PES	[30]
	Creeks along the Kenyan coast	2897.7 ± 232 MPs/m^3	20 μm–250 μm	Fibers, fragments and films.	Not reported	[31]
	Kenya coast	110 particles/m^3	0.25–2.4 mm	Fragments	PE, PP	[32]
Tanzania	River Themi and its tributaries	0.2–0.6 items/L	0.05–1 mm	Fibers, fragments, films and microbeads	PE and PET	[22]
	East African coastal waters (Dares Salaam and Zanzibar)	0.01–0.76 items/m^3	2–5 mm	Fragments and fibers	PP and PE	[21]
Uganda	Northern Lake Victoria	0.69–2.19 particles/m^3	<1 mm	Fragments	PE, PP, PS, PES	[23]
			Southern Africa			
Botswana	Okavango delta	10.18 to 22.67 items/L	2–3 mm	fragments and fibers	Not reported	[33]
	Gaborone Dam	36.0 to 76.0 particles/L	0.032–4 mm	Fibers, fragment, micro-bead and film	Not reported	[34]
South Africa	Cape Town Harbour and the Two Oceans Aquarium	10.3 ± 1.1 MPs/L	1000–2000 μm	Filaments and fragments	PET, PP, and PMMA	[24]
	Durban Bay	80.72 MP/m^3	Not reported	Fragments, fiber	PP, PE, PES	[35]
	Western Cape coastline	1.33 ± 0.15 particles/L	1000–2000 μm	Filaments and film	PET and PE	[36]
	Vaal River	0.68 ± 0.64 particles/m^3	0.055 mm	Fragments, fibers, and pellets.	PE and PP	[37]
	Plankenburg river	5.13 ± 6.62 MP/L	500–1000 μm	Fiber	Cotton, PE and PET	[38]
	Braamfontein Spruit	705 particles/m^3	>53 μm	Not reported	Not reported	[39]
	Crocodile River	250–2600 particles/m^3	Not reported	Fibers and fragments	Not reported	[40]
	Zandvlei Catchment and estuary, Cape Town	2.62 ± 0.41 MP/L	<0.5 mm	Fibers	PE and PP	[41]
	Simon's Town Marina (rocky shore)	0.37 ± 0.06 MP/L	100–500 μm	Not reported	Cotton, nylon, PET	[42]
			West Africa			
Ghana	Densu River	1 ± 0.72 particles/10 mL	1 mm	Not reported	Not reported	[25]
	Ghana Gulf of Guinea	1.14–2.79 particles/m^3	Not reported	Fragments, pellets, film, fiber, and foam	PP, PS, PE,	[43]

Table 2. *Cont.*

Sub-Saharan Country	Study Area	MPs Concentration	MP Size	MP Shape	Polymer Type	Ref.
Nigeria	Osun River	22,079 ± 134 particles/L	Not reported	Fragment, fiber, pellet, foam and bead	Not reported	[26]
	Lagos Lagoon	65.2 particles/L	0.45 to 1000 µm	Fiber	Nylon	[44]
	Ikpoba Rivers (Edo State)	2.67 ± 0.58–8.00 ± 1.00 particles/m^3	Not reported	Fragments, film, fiber and foam	PE, PS, PP, PET, PVC	[45]
	Rivers in southwestern Nigeria (Ibese, Ogbese, Ona, Asejire, Ogun)	6.71–22.73 particle/L	< 1 mm	Fiber and foam	PP and PE	[46]
	Lagoonal system, Lagos (Agbowa, Makoko, Ojo, and Liverpool)	139–303 particles/L	100 µm.	Fiber, fragments and film	PP and PE	[47]
	Nwangele area rivers, Imo state	440 to 1556 particles/L	11 µm	Fragments, fiber and film	PET, PE, PVC, PP	[48]
			Central Africa			
Cameroon	Beaches, coastline of Cameroon	78 items/m^2	2.1 mm	Fragments, pellet, film, fiber and foam	Not reported	[27]

Polypropylene (PP), polyester (PES), polyethylene (PE), polystyrene (PS), polyethylene terephthalate (PET), polyamide (PA), and polyvinylchloride (PVC), polymethyl methacrylate (PMMA).

Table 2 reveals significant variations in MP abundance in surface waters, with concentrations reaching up to 3791 particles per liter. The MPs are predominantly composed of fibers, fragments, and films. Fibers, often derived from synthetic textiles and clothing [15,16], highlight the consequences of inadequate waste management and disposal practices allowing these materials to enter and contaminate water sources. Meanwhile, fragments and films generally originate from the breakdown of larger plastic items such as plastic bags, bottles, containers, and packaging materials. These items are typically made from polymers like polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), and polystyrene (PS) [13], which are also shown to be present in SSA surface waters (Table 2).

The dynamics of MPs presence in surface waters are influenced by a variety of factors including seasonal changes, water flow, and human activities, which contribute to the fluctuations in MPs levels. For example, natural forces such as currents, tides, and wind can transport MPs over considerable distances across water bodies, leading to variable concentrations in different areas over time [49].

It is important to note that while Table 2 provides valuable data on MPs, it exclusively reports on MPs (and not NPs). These data may not fully capture the complete spectrum of plastic pollution, as the potential presence of nanoplastics is likely overlooked due to the limitations of current sampling methods [50]. Commonly used sieves and nets are designed to retain only particles the size of microplastics or larger. As Boyle et al. have reported, a substantial amount of plastic, particularly smaller microplastics and nanoplastics, escapes detection and quantification due to these methodological constraints [51]. The actual particle sizes recorded could also be influenced by the specific characteristics of the methods employed.

Despite these limitations, the information presented in Table 2 offers crucial insights into the prevalence of these minute particles in water bodies. Understanding the abundance and distribution of MPs provides a foundational step towards addressing the broader implications of plastic pollution and developing strategies for effective management and mitigation. Table 3 presents data on MPs from SSA countries detailing the abundance, size, shape, and polymer types found in sediments.

Table 3. MPs in sub-Saharan African countries' sediments.

Sub-Saharan Country	Study Area	MPs Concentration	MP Size	MP Shape	Polymer Type	Ref.
			East Africa			
Ethiopia	Lake Ziway shoreline	400–124,000 particles/m^3 (median 30,000 particles/m^3)	0.15–40 mm	Pellets and fibers	PP, PE, and alkyd-varnish	[52]
	Lake Hawassa shoreline	11–74 items/m^3	<1 mm	Fiber (90%), fragments (5%) and pellets (5%)	PS (82%), PE (15%) and PES (3%)	[53]
	Ditch in Bahir Dar city	5 ± 1 items/50 g	0.5–5 mm (55 items) <0.5 mm (80 items)	fragments	PET, PE, PP, PS, PVC, and PA	[19]
Kenya	Creeks along the Kenyan coast (Mida Creek, Port Reitz, Tudor Creek)	1.61 ± 0.14 particles/g	Not reported	Fibers, fragment, and film	PE, PP	[54]
Tanzania	Coasts of Dar es Salaam and Zanzibar	79–864.15 MPs/kg	Not reported	Fibers, Fragments	PE and PS	[55]
	Tanzanian coast	15–2972 particles/kg	Not reported	Fragments and fibers	PP and PE	[56]
	Farms around River Themi and its tributaries	0.21 to 1.5 items/g	0.05 to 5 mm	Fibers, fragments, films and microbeads	PE	[22]
			Southern Africa			
Botswana	Okavango Delta	56.7 to 1756.3 particles/kg	20 µm–5 mm	Fragment, film, sphere and fiber	PET, PVC and PE	[57]
Namibia	Perennial rivers (Kunene, Kavango, Oranje)	2–7 MP/kg	0.3–1 mm	fragments and films	PP, PE	[58]
	Lishana system	0–53 MP/kg	0.3–5 mm	Fragments, fiber and films	PP, PE	
	ephemeral rivers	0–66 MP/kg	0.3–1 mm	Fragments, fiber and films	PE.PS	
Mauritius	Agricultural soils	420.0 ± 244.0 particles/kg	<1 mm	Fiber, fragments	PP, PE and PA	[28]
South Africa	Durban Bay	1.76 MP/g	Not reported	Fragments, fiber	PP, PE, PES	[35]
	Western Cape coastline	185.07 ± 15.25 particles/kg	2000–5000 µm	Filaments and film	PET and PS	[36]
	Vaal River	4600 ± 2800 particles/kg	<2 mm	Fragments and fibers	PE, PP, PES, PU, PEH and PEVA	[59]
	Plankenburg river	1587.50 ± 599.32 MP/kg	500–1000 µm	Fiber	Cotton, PE, PET and PP	[38]
	Braamfontein Spruit	166.8 particles/kg	>53 µm	Not reported	Not reported	[39]
	Crocodile River	340–900 particles/kg	Not reported	Fragments and fibers	Not reported	[40]
	Zandvlei Catchment and estuary, Cape Town	70.23 ± 7.36 MPs/Kg	<0.5 mm	Fibers	PE and PP	[41]
	Limpopo province (recreational reservoirs)	25.3–140.6 particles/kg	2–5 mm	Not reported	PP and PS	[60]
	Simon's Town Marina (rocky shore)	38 ± 2 MP/kg	100–500 µm	Not reported	Cotton, nylon, PET	[42]
			West Africa			
Ghana	Densu River	3.88 ± 1.25 particles/10 g	0.7 mm	Not reported	Not reported	[25]
	Ghana's Gulf of Guinea	0.144 ± 0.061 items/g	Not reported	Pellets and fibers	Not reported	[61]
	Sakumo II Lagoon	1.85 particles/g	0.1–5 mm	Not reported	Not reported	[62]
Nigeria	Osun River	392–1590 MPs/kg	Not reported	Fragment, fiber, pellet, foam and bead	PET, PE, PVC, PU, EVA and nylon	[26]
	Lagos Lagoon	3906 particles/kg	0.45–1000 µm	Fiber	Nylon	[44]
	Ikpoba Rivers (Edo State)	40 ± 13.4–55 ± 16.8 particles/kg	Not reported	Films, fragments, fibers, and foams	PE, PS, PP, PET, PVC, PC, and PU	[45]
	Rivers in southwestern Nigeria (Ibese, Ogbese, Ona, Asejire, Ogun)	5.69–22.90 particle/kg	< 1 mm	Fiber and foam	PP and PE	[46]

Table 3. *Cont.*

Sub-Saharan Country	Study Area	MPs Concentration	MP Size	MP Shape	Polymer Type	Ref.
	Lagoonal system, Lagos (Agbowa, Makoko, Ojo, and Liverpool)	310–2319 particles/kg	100 µm.	Fiber, fragments, and film	PP and PE	[47]
	Badagry, Oniru Elegushi, Atican and Eleko beach	3424 particles/m^2	1–5 mm	foam, fragments, fiber and pellets	PE, PP and PS	[63]

Polypropylene (PP), polyester (PES), polyethylene (PE), polystyrene (PS), polyethylene terephthalate (PET), polyamide (PA), polyvinylchloride (PVC), polyamide (PA), polyurethane (PU), Polyethylene vinyl acetate (PEVA), polyethylene/hexene-1-copolymer (PEH) and ethylene vinyl acetate (EVA).

The data presented in the table highlights MPs concentrations in sediments, with levels reaching up to 4600 $\pm$ 2800 particles per kilogram. This highlights the extensive plastic pollution problem within the SSA environment. The range of MP types in these samples is diverse, and includes fragments, fibers, films, pellets, foam, spheres, and beads, suggesting widespread plastic waste degradation and distribution throughout the region. However, while the table details MPs in sediments, these findings likely represent only a portion of the total MNP pollution. Due to methodological constraints, finer particles, such as nanoplastics, may not have been captured in these studies [51], suggesting that the true extent of plastic pollution could be even greater. These findings emphasize the need for more comprehensive studies to overcome current methodological limitations and better quantify and understand the full spectrum of MNPs pollution. The detected particles were composed of a variety of polymers, including polypropylene, polyester, polyethylene, polystyrene, polyethylene terephthalate, polyamide, polyvinyl chloride, polyurethane, polyethylene vinyl acetate, polyethylene/hexene-1 copolymer, and ethylene vinyl acetate. This variety illustrates the complexity of synthetic materials and their widespread presence in SSA environments. The presence of such a wide array of polymer types in sediments reflects the varied uses of these materials in consumer products and the challenges posed by their long-term environmental impact. Each type of polymer has different physical and chemical properties that affect its durability, degradation rate, and potential toxicity [64]. This diversity complicates efforts to manage and mitigate the effects of MNP pollution, as each polymer type may require specific strategies for removal or breakdown in the environment. Greater investment in research and enhanced monitoring techniques will be crucial for developing effective environmental policies and waste management practices to reduce plastic pollution's impact in SSA and beyond.

Table 4 provides an overview of MP concentrations in various aquatic organisms across SSA. Living organisms are used as bioindicators to track the potentially harmful effects of MNPs in the environment [65]. The prevalence of MNPs within organisms underscores the pervasive reach of plastic pollution and its transformation into potentially harmful micro-sized particles. Whether absorbed directly from water or indirectly through the food chain, these MNPs accumulate in tissues, posing a threat to the health of various species and ultimately endangering humans, especially those reliant on fish consumption as a source of protein [66,67].

Table 4. MPs in sub-Saharan African countries' aquatic organisms.

Sub-Saharan Country	Study Area	Organism	MPs Concentration	MP Size	MP Shape	Polymer Type	Ref.
			East Africa				
Ethiopia	Lake Ziway	Fish (*Clarias gariepinus*, *Cyprinus carpio*, *Carassius carassius*, *Oreochromis niloticus*)	0.0002–385.2 mg/kg	0.15–40 mm	Pellets and fibers	PP, PE, and alkyd-varnish	[52]

Table 4. *Cont.*

Sub-Saharan Country	Study Area	Organism	MPs Concentration	MP Size	MP Shape	Polymer Type	Ref.
Kenya	Kenyan Coast (Mida Creek and Mombasa)	Jellyfish (*Crambionella orsini*)	0.03–0.05 MP/g of tissue	0.1–3 mm	Fibers	Not reported	[68]
	Kenya coast	Chaetognatha, Copepods, Amphipoda and fish larvae	0.16–0.46 particles individual	0.01–1.6 mm	Fragments	PE, PP	[32]
	Kenyan coast.	brachyuran crabs oyster	0.65 MPs/g 3.36 MPs/g tissue	0.1–4.2 mm	Fibers	Not reported	[69]
Tanzania	Tanzania Coast	Cockles (*Anadara antiquata*)	0–5 particles /individual	Not reported	Fibers and fragments	PP and PE	[56]
			Southern Africa				
Botswana	Okavango delta	Fish (*Tilapia sparrmanii*)	Not reported	1–3 mm	Fragments, micro-beads, fibers and films	Nor reported	[33]
	Gaborone Dam	Clams (*Corbicula fluminea*)	2.2 to 8.0 count/site	1–4 mm	Fibers and film	Not reported	[34]
		Fish (*Oreochromis niloticus* and *Coregonus kiyi*)	1.5 to 4.2 count/fish	0.032–5 mm	Fragments, micro-beads, fibers and film	Not reported	[34]
South Africa	Cape Town	mussels	3.83 MPs/mussel 0.04 MPs/g tissue	Not reported	Filaments and fragments	PET	[70]
	Cape Town Harbour and the Two Oceans Aquarium	Mussels	6.27 ± 0.59 MPs /individual	1000–2000 µm	Filaments and fragments	PET, PMMA and PE	[24]
	South African coastline (Orange River mouth to Mossel Bay	Fish (*Engraulis encrasicolus* *Etrumeus whiteheadi* *Sardinops sagax*)	1.13 items /individual 1.38 items /individual 1.58 items /individual	Not reported	Microfibers and fragments	PE, PP, PA, PES	[71]
	Agulhas Bank	Fish	2.8 to 4.6 items/fish	500–1000 µm	Fibers	Not reported	[72]
	KwaZulu-Natal (east coast mangroves)	Fish (*Oreochromis mossambicus*, *Terapon jarbua*, *Ambassis dussumieri*)	0.79 ± 1.00 particles per fish.	0.1–4.8 mm	Fibers and fragments	Rayon, PES, nylon and PVC	[73]
	Braamfontein Spruit	*Chironomus* sp. larvae	53.4 particles/g	>53 µm	Not reported	Not reported	[39]
	South-east coastline (Kenton-on-Sea, Kayser's Beach, Kidd's Beach)	Mussel (*Mytilus galloprovincialis and Perna perna)*	0.10–0.97 MPs/g	Not reported	Microbeads, fiber	PE	[74]
	Simon's Town Marina (rocky shore)	Mussel, Redbait, Cushion star, Limpet, Winkle, Starfish, Whelk	0.28 ± 0.04 MP/g	100–500 µm	Not reported	Cotton, nylon, PET	[42]
			West Africa				
Ghana	Eastern Central Atlantic Ocean	*Sardinella maderensis*, *S. a aurita*, *Dentex angolensis*	25.7–40 MPs/g	Not reported	Micro-beads, film, fragments, fibers and foams	Not reported	[75]
	Jamestown fish landing beach	Fish (*Pseudupeneus prayensis*, *Pagellus bellottii*, *Sardinella maderensis*, *Decapterus rhonchus*)	133 items/fish	0.5–1.0 mm	fibers	PE, PVA, PA	[76]
	Volta Lake	prawn (*Macrobrachium vollenhovenii)* Volta clam (*Galatea paradoxa*), Nile tilapia (*Oreochromis niloticus*)	4.7 ± 2.1 items /individual 3.0 ± 1.3 items /individual 2.8 ± 0.6 items /individual	654 µm	fibers	PE, PP, PS, PES	[77]

Table 4. *Cont.*

Sub-Saharan Country	Study Area	Organism	MPs Concentration	MP Size	MP Shape	Polymer Type	Ref.
	Pra estuary, Shama District	Fish (*Sarotherodon melanotheron)* gastrointestinal tract	9.83 ± 4.63 items /individual.	0.5–5 mm	Fragments, pellets, and fiber	PE	[78]
	Densu River	*Chrysichthys nigrodigitalus* gills	4.83 ± 2.08 items /individual				
		Fish *Chrysichthys nigrodigitatus*,	2.88 ± 2.11 MP /individual	0.10–2.22 mm	Not reported	Not reported	[25]
		Sarotherodon melanotheron	2.38 ± 1.66 MP /individual	0.15–3.2 mm			
	Gulf of Guinea	oysters (*Crassostrea tulipa)*	1.4–3.4 items /individual (and 0.34 to 1.7 items/g tissue	33–4870 µm,	Fragments, film, and fiber	PE, PP and PS	[79]
Nigeria	Osun River	Fish (*Chrysichthys nigrodigitatus*)	1691.7 ± 443 particle/fish	Not reported	Fragments, microbeads, fiber, film, pellets, foam	Not reported	[26]
	Ikpoba Rivers (Edo State)	*Clarias gariepinus*	3.00 ± 1.00 particles–7.33 ± 2.08 particles/fish	Not reported	Films, fragments, fibers, and foams	PE, PS, PP, PET, PVC, PC, and PU	[45]
		Oreochromis niloticus	2.33 ± 0.58–6.67 ± 0.58 particles/fish				
	Eleyele lake	Commercial fish species	1–34 MP/fish	1 µm–1.53 mm	Not reported	Not reported	[80]

Polyethylene (PE), polyvinyl acetate (PVA), and polyamide (PA), polyurethane (PU), Polypropylene (PP), polyester (PES), polystyrene (PS), polycarbonates (PC), polyethylene terephthalate (PET), polyvi-nylchloride (PVC) and polymethyl methacrylate (PMMA).

A broad range of MP concentrations in organisms is reported in some cases. For instance, in Ethiopian waters, fish species like *Clarias gariepinus* and *Oreochromis niloticus* have shown MP concentrations ranging from 0.0002 to 385.2 mg/kg [52], which indicates a significant variation that could be attributed to habitat, feeding strategies, and local pollution levels. In Kenya, different species, including jellyfish and smaller marine organisms, like chaetognatha and copepods, show lower MP concentrations but are still notably affected by MPs, predominantly fibers and fragments.

In Botswana and South Africa, studies have focused on various aquatic organisms, including fish, clams, and mussels. The reported concentrations vary, with mussels in South African waters found to have up to 6.27 MPs per individual [24], highlighting the substantial presence of MPs in coastal areas. The polymers identified include PET, PMMA, and PE, which are common in consumer products and packaging, suggesting local pollution sources such as urban runoff and waste disposal practices.

The data reveal high levels of MPs in fish and other marine life in Ghana and Nigeria. Notably, fish from the Jamestown fish landing beach in Ghana contained up to 133 items per fish [76]. This suggests intense pollution, likely worsened by inadequate waste management and high local plastic use. The MPs identified include fibers, fragments, films, and foams made from polymers like PE, PP, PS, PES, and others.

Tables 2–4 and Figure 3 vividly depict the scarcity of data regarding microplastic abundance in surface waters, sediments, and aquatic organisms across just 11 out of more than 40 SSA countries. This glaring data deficit underscores substantial gaps in understanding the extent of microplastic pollution in this expansive and varied region. The absence of comprehensive data reflects a broader problem of inadequate representation in environmental research within SSA, posing a formidable obstacle to crafting effective regional strategies to combat plastic pollution. The limited data available on MNPs contamination in SSA reveal various underlying challenges, which might include constraints in resources and capacity and a substantial lack of awareness about MNPs [81] and their potential environmental and health impacts among policymakers and the general public. This makes mobilizing resources and support for research in this area particularly difficult.

Expanding both research and data collection is imperative to empower SSA to craft comprehensive strategies to combat the escalating plastic and MNP pollution crisis.

4. Impact of Plastic Waste

Plastic pollution threatens ecosystems by modifying habitats and natural processes and by reducing the ecosystem's adaptation to climate change. This affects food production [62] and the livelihood of plants, animals, and humans. This adds to the existing challenges of food insecurity, and water scarcity and quality in SSA. Figure 4 illustrates the general impact of plastic waste.

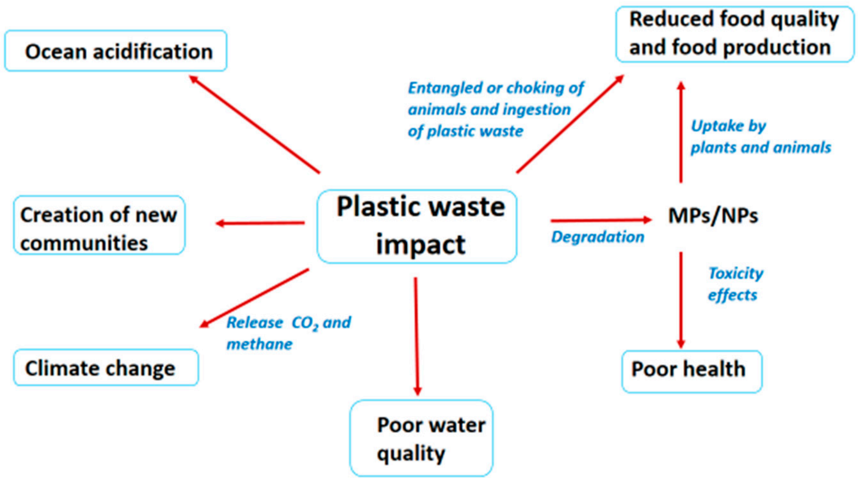

Figure 4. An illustration of the impact of plastic waste.

4.1. The Effect of Plastics on Food Production

Plastics exist in different forms and play important beneficial roles within food and production systems. Unfortunately, with the massive use of plastics, plastic waste accumulates, which negatively affects the food system [82]. The pervasive presence of plastic waste in aquatic and agricultural environments poses a dire threat to global food security. As plastic infiltrates these ecosystems, marine life, crucial for sustenance, faces the peril of ingestion or entanglement, while livestock suffer from consuming non-degradable plastic, resulting in a cascade of detrimental health consequences, including diminished productivity, stunted growth, and increased mortality rates [83]. For instance, Wegi et al. reported on the presence of indigestible foreign bodies, including plastic, in Ethiopian cattle [84].

In farmlands, plastics can hinder the flow of air and water in the soils, thus decreasing the output of these farmlands [83]. MNPs have also been reported in the soil system, and these could be emanating from degrading plastics in the soil, the use of sewage compost or wastewater rich in MNPs, or deposits from the atmosphere. Beriot et al. observed MNPs in the sheep feces and soil from an intensive vegetable farm that utilizes plastic mulch [85], suggesting that the plastic mulch degrades into MNPs. Plastic or MNPs alter the pH value and nutritional composition of the soil system [86], ultimately affecting crop production and food security. Brtnicky et al. showed that poly-3-hydroxybutyrate, a bacterial intracellular carbon and energy-storage polymer, being a carbon source, reduces plant-available nitrogen in the soil, thus strongly hindering plant growth [87]. MNPs have been shown to infiltrate plant cells via cracks in wheat and lettuce crops and have been observed in the roots, stems and leaves of wheat [88]. Jia et al. showed that MNPs can adsorb other contaminants and facilitate their entry into vegetables (rape), resulting in plant damage [89], which negatively affects their growth and development.

The uptake of MNPs by plants shows that these materials enter the food chain. Plastics entering the food chain threaten both animal and human health. In aquatic systems, phyto/zooplanktonic organisms take in or ingest MNPs and pass them to higher trophic levels [46]. Plastic particles have been reported in livestock feed, blood, milk, and meat [90]. MNPs have been observed in the gastrointestinal tracts and flesh of fish [48], and since fish, meat and milk are vital sources of proteins, these can be passed on to humans through diet. For instance, Idowu et al. observed plastic fragments in fish from the Osun river, Nigeria [26].

4.2. The Effect of Plastic on Water Quality

Plastic can be transported to freshwater through multiple pathways, including storm runoff from dumps, farmlands, landfills, and airborne deposits. Additionally, industrial and municipal waste is discharged into these water bodies, leading to the introduction of plastic particles. As a result, plastic particles have been reported in freshwater sources [21,53,60] such as tap water and bottled water [91]. Ramaremisa et al. reported on the presence of mostly fibrous-shaped MPs (<1 mm) with an average concentration of 14 $\pm$ 5.6 particles per liter in tap water sampled from certain suburbs in Gauteng, South Africa [92].

Additionally, MNPs can leach chemicals (especially plastic additives and adsorbed co-pollutants) into water bodies, further altering water quality. Both urban and rural communities in SSA, along with local wildlife, depend on these freshwater resources for drinking, making the impact of such pollution particularly concerning. Eamrat et al. showed that the presence of MNPs in water alters crucial water-quality parameters, including their conductivity, turbidity, biological oxygen demand, and total solids [93].These findings highlight a pressing environmental issue: degraded water quality not only poses health risks to humans and animals but also compromises the ecological integrity of freshwater ecosystems.

4.3. The Effect of Plastics on Health

Humans and animals are exposed to MNPs, which threaten their health. Exposure can be through inhalation, dietary uptake, drinking water, and using products containing or contaminated with these materials [29]. Due to their size, MNPs can easily be absorbed and distributed within the body after entry, leading to toxicity effects such as cytotoxicity, genotoxicity, neurotoxicity, oxidative stress, and inflammation, among others [66,67,94]. Wang et al. demonstrated the toxic effects of polystyrene (PS) MNPs on goat mammary epithelial cells. These effects included changes in cellular morphology, damage to organelle structure, mitochondrial dysfunction, oxidative stress, endoplasmic reticulum stress, and apoptosis [95].

Reports have shown that MNPs can be carriers of other toxic pollutants, thus facilitating their uptake, internalization, and translocation. MNPs have a much greater surface area-to-volume ratio than larger particles, increasing their reactivity and pollutant-loading capacity [96]. Numerous pollutants, such as heavy metals, organic pollutants (persistent organic pollutants and/or polycyclic aromatic hydrocarbons), pesticides, pharmaceuticals, nanoparticles, and microorganisms, in different environments, can be loaded onto MNPs through surface adsorption and void filling [97]. The interaction between MNPs and pollutants (responsible for adsorption) is primarily through complexation, hydrogen bonding, ion exchange, hydrophobic, π-π and electrostatic interactions. MNPs behave like a reservoir, accruing chemical pollutants. The MNP-bound pollutants can be transported over long distances and, when ingested by organisms, can lead to high bioavailability and toxicity [98]. The ingestion of MNP-bound pollutants not only causes toxicity due to MNPs but also enhances toxicity due to the presence of other toxic pollutants. Cao et al. demonstrated that PSNPs and Cd^{2+} co-exposure enhanced microalgae *Euglena gracilis* toxicity due to their synergistic effects, which induced substantial growth inhibition, probably through disruptions of purine and carbohydrate-related metabolisms [99]. In vitro and in vivo studies have shown that nanosized particles cause behavioral abnormalities, neurotoxicity, tissue damage, oxidative stress, and slow growth [100–102]. This suggests that humans may experience the same effects.

4.4. The Effect of Plastics on the Environment

4.4.1. The Effect of Plastics on Greenhouse Gas (GHG) Emissions

Oceans play a huge role in reducing the amount of CO_2 in the atmosphere. Oceans are thus effective carbon sinks, absorbing huge amounts of carbon dioxide. However, MNPs interfere with the flow of carbon in the ocean, reducing its absorption. Plastics also damage phytoplankton, which are critical in absorbing carbon dioxide and releasing oxygen (photosynthesis) [103]. Plastic monomers are derived from fossil fuels, hence, plastic production, decomposition, degradation and incineration release CO_2 and methane, contributing to greenhouse gas emissions and exacerbating climate change [15,103,104]. Climate change in SSA is characterized by reduced water supplies, extreme weather conditions (heat waves, severe storms and floods) and more incidences of pests and diseases which negatively affect agricultural production and human health (due to malnutrition, heat stress and outbreaks of diseases such as malaria and diarrhea) [105].

4.4.2. The Effect of Plastic on the Creation of New Communities

Recent studies have highlighted the presence of plastic in the ocean's surface waters. Plastics floating on the surface have been reported to consist of a massive mix of garbage called "garbage patches" [106], inhabited by a mix of coastal and marine species on surface waters. This occurrence increases the possibility of biological invasions, which may be detrimental to native species through competition for space and food, including predation. It is well-documented that several invertebrates, such as crustaceans and molluscs, inhabit plastic debris [107–109]. The fact that these coastal communities can thrive and breed successfully miles away from the shore, creating new communities (neopelagic) in the open ocean [107] is a grave concern, as continued successful breeding may lead to invasion and eventual extinction (of species used as seafood by humans). This warrants the urgent need to take drastic steps to reduce the amounts of plastic debris deposited into the ocean.

Additionally, MNPs create ideal conditions for microbial life due to their high surface area-to-volume ratios, making them perfect substrates for microbial colonization. Once microbial cells attach to these particles, they multiply and produce extracellular polymeric substances, forming a biofilm. This biofilm can trap more microbial cells and abiotic particles like nutrients and organic matter, further enhancing its growth and stability [110,111]. This process is particularly concerning because it can alter the physical and chemical properties of the plastics. For instance, the formation of biofilms can increase the density of the plastics, causing them to sink and potentially disrupt benthic ecosystems [111]. Moreover, as these plastic fragments travel, they can transport these microorganisms to new locales, disturbing local ecosystems and posing risks to biodiversity [112]. The colonization of plastics by microbes, and the resultant formation of biofilms, necessitate a re-evaluation of the impact of plastic pollution on marine ecosystems and highlight the need for urgent action to address this global issue.

4.4.3. The Effect of Plastic on Ocean Acidification

Plastics in the ocean have been shown to be responsible for ocean acidification. The work by Romera-Castillo et al. demonstrated that leachates from plastic fragments in seawater are responsible for decreases in pH. Aged and plastic exposed to weathering agents, such as UV radiation release dissolved organic carbon, CO_2 and other chemicals such as organic acids from additives, lowering seawater pH [113]. Ocean acidification is negatively affecting marine biodiversity and ecosystems. Rowlands et al. have reported poor Antarctic krill embryo development due to ocean acidification and the presence of nanoplastics [114]. Huang et al. showed that ocean acidification and MPs decrease the energy budget and increase the oxidative stress of a mussel species (*Mytilus coruscus*) by lowering its immune capacity [115]. The effects of ocean acidification are concerning, as they could affect marine ecosystems while altering marine food chains, which could affect the seafood supply to humans.

5. Measures to Reduce Plastic Waste in SSA

Reducing plastic waste in SSA requires a comprehensive approach that deals with different aspects of plastic use, production, disposal, and recycling. Here are some measures to address plastic waste in SSA:

5.1. Promotion of Environmental Awareness and Education

Communities need to be educated and trained to stop the culture of littering and promote participation in plastic reduction in the environment [16]. For sustainability, this education should be integrated into school curricula to instill awareness about plastic pollution and its environmental impact from a young age [116,117]. Rwanda is a leading example of effectively promoting environmental awareness and tackling plastic pollution through strict policies and public education. The government, together with various non-governmental organizations and community groups, has launched many campaigns to educate the public about the dangers of plastic pollution and the advantages of adopting sustainable practices. Additionally, regular cleanup events known as Umuganda reinforce a community-wide commitment to cleanliness and sustainability [118].

5.2. Implementation of Bans on the Use of non-Biodegradable Single-Use Plastics

The total elimination of non-biodegradable, single-use plastics can significantly reduce the levels of plastic waste in the environment, together with their toxicity effects [11]. However, many SSA countries face challenges in implementing such bans [119]. While taxes imposed on plastic bags aim to discourage their use and promote reuse [120], they often fail to deter consumers from purchasing and discarding plastic bags after use. Therefore, governments must enact and rigorously enforce policies and legislation at both national and regional levels to address plastic waste effectively. Examples include Rwanda, a pioneer in banning plastic bags; Tanzania, which prohibited the production, importation, sale, and use of plastic bags; and Kenya, which banned single-use plastic bags. These cases serve as successful models for other SSA countries to follow [119,121].

5.3. Management of Waste and Waste Management Infrastructure

Plastic waste is in dumpsites, water systems, roads, and free spaces in most SSA countries. The first step towards plastic management is waste sorting and collection [16]. This will reduce the presence of plastic litter everywhere. Other plastic management measures are presented below.

5.3.1. Wastewater Treatment

The discharge of untreated industrial and municipal waste into freshwater bodies is widespread in SSA [122]. For example, in South Africa, dysfunctional wastewater treatment plants were found to be releasing raw sewage into the Vaal River [123]. Saad et al. detected fibrous, small-sized, and colored microplastics in the surface water of the Vaal River [124], which was attributed to the untreated industrial and municipal waste entering the river.

The treatment of wastewater is crucial in order to avoid the release of plastic waste into the environment. Although wastewater treatment might not be able to remove the plastic in nanosized form, it will significantly reduce the levels of plastics, especially larger particles and some MPs, discharged into the environment. Sewage sludge traps most of the plastic waste [125]. Hence, they need to be tested for the presence of MNPs before being applied as soil amendments in agriculture.

5.3.2. Repairs and Maintenance of Waste Facilities

Burst sewage pipes are standard in most SSA countries. This is a health concern and releases MNPs (released when laundering from personal care products and products used in textile and plastic processing industries) into the environment. MNPs leaking from dilapidated wastewater facilities are washed into freshwater bodies through urban runoff [126,127]. Waste and treatment facilities must be continuously repaired and regularly serviced to reduce these environmental leakages.

5.4. Use of Circular Plastic Economy Measures

The circular plastic economy (unlike the linear plastic economy: take–make–dispose) is currently the most encouraging route to a more sustainable use of plastic. It is designed to repair, recycle, and reuse plastic. This not only reduces resource depletion but also significantly reduces plastic waste generation (and its effects), as materials continuously flow around a 'closed loop' system [128]. South Africa has implemented the Extended Producer Responsibility (EPR) regulation, mandating that producers be held accountable for their products throughout their entire lifecycle, particularly in terms of product take-back, recycling, and final disposal [129]. As a result, plastic recycling in South Africa has seen significant growth, demonstrating a strong and proactive strategy for addressing the challenges of plastic waste [130].

Material and energy can also be reclaimed from plastic waste in landfills and dump-sites using the concept of 'Reduce, Recapture, Reuse, and/Recycle' (3R), which is effective in the control and management of plastic waste, in line with the circular economy concept. EcoPost in Kenya collects plastic waste and converts it into high-quality, durable construction materials [131]. Unfortunately, most lower-income economies in SSA lack the resources and capacity to implement the circular plastic economy [132]. However, this can start with a reduction in the use of plastic.

5.5. Biodegradation of Plastic Polymers Using Plastic-Eating Insects and Microorganisms

Alternative ways of managing and degrading plastic-based waste material have recently been reported. Plastic-eating insects and microorganisms are used to degrade polymers into dimers or monomers, altering the physico-chemical properties of plastic waste [133]. Once assimilated and mineralized, non-toxic end-products, such as methane, CO_2 and water, are produced [134]. The resultant metabolites are thereafter re-captured and re-integrated into different chemical cycles. Several plastic-eating insects have been reported [135], including plastic-eating bacteria [136,137].

5.6. Development of New Technologies and Solutions for Plastic Waste Management

Investing in research and innovation, particularly in developing biodegradable plastics and enhanced recycling processes, holds great potential for SSA. Natural materials can substitute for certain plastic polymers, and plastic production could incorporate natural, recyclable, non-toxic, and biodegradable materials, along with non-chemical or non-toxic additives, to facilitate recyclability [138]. In Kenya, local natural resources such as sisal and banana fibers are utilized as substitutes for plastic packaging and bags [139].

6. Conclusions and Future Perspectives

This review highlights the escalating challenges associated with rising plastic production, importation, and use in SSA, coupled with inadequate waste management systems. It specifically points to the breakdown of plastics into MNPs under the region's tough environmental conditions. This breakdown is evident across environments like surface waters, sediments, and within aquatic life in SSA. A major issue is the significant lack of data on how widespread and abundant these MNPs are in most SSA countries, which hinders effective environmental monitoring and the development of sound policies.

The review emphasizes the critical need for research and strong environmental monitoring programs to continuously track the presence and impact of microplastics in water, air, soil, and living organisms. Regular evaluations are essential to inform policy decisions and to support the shift towards a circular economy for plastics that promotes recycling and reuse.

Despite some regulatory efforts, the enforcement of plastic-related policies in SSA remains sluggish and ineffective. The review advocates for advancing a circular plastic economy, urging stringent regulations to curtail harmful practices and phase out single-use plastics. Immediate and collaborative action among SSA nations is essential, necessitating political commitment for the successful adoption and implementation of anti-pollution measures.

Proper waste management in SSA should begin with sorting at the source and consistent waste collection, leading to the recycling or repurposing of plastics through innovative circular economy approaches. Increasing public awareness of the dangers of plastic pollution is also vital. Public education should focus on minimizing plastic waste, encouraging recycling and reuse, and promoting incentives for consumers and manufacturers to choose sustainable and biodegradable options.

In summary, tackling plastic pollution in SSA requires a comprehensive approach encompassing legal measures, community engagement, educational campaigns, and international cooperation. By effectively addressing these facets, SSA can mitigate the environmental impact of plastic waste and transition towards a more sustainable future.

Author Contributions: G.E.O. generated ideas and reviewed the manuscript; E.D. conducted a literature search and wrote the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflicts of interest.

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