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A Review on the Management of Nanoplastics in African Ecosystems and Human Health

Awafung Emmanuel Adie[1], Swase Dominic T[2*], Onongha comfort O[3], Ambrose Okello[4], Nji Elizabeth Libuo-Beshel[5], Reuben Samson Dangana[2], Omar Umi[6] and Joan Akankunda[7]

[1]Biomedical Engineering, Kampala International University, Uganda
[2]Biochemistry Department, Faculty of Biomedical Sciences, Kampala International University Uganda
[3]School of nursing science, Kampala international university Uganda
[4]Emergency medicine department, Kampala international university Uganda
[5]Department of Public Health, Faculty of Allied Medical Sciences, University of Calabar
[6]Department of Public Health, Kampala international university Uganda
[7]Graduate Intern at Vaccine Access Initiative, Kampala, Central Region, Uganda

[*]**Corresponding Author:** Swase Dominic T, Biochemistry Department, Faculty of Biomedical Sciences, Kampala International University Uganda, E-mail: princeswasedominic@gmail.com

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Abstract

Nanoplastic pollution has emerged as a significant environmental concern globally with Africa facing unique challenges due to its vast geography and varied socioeconomic conditions. This review presents a comprehensive analysis of the current state of nanoplastic pollution across the African continent. The improper management of plastic waste combined with increasing plastic production and consumption has significantly affect the the prevalence of nanoplastic contaminants in various ecosystems.

The review highlights the primary sources of nanoplastic pollution including the breakdown of larger plastic debris and the direct release of microplastics from industrial and domestic activities. It examines the environmental and health impacts of nanoplastics emphasizing the need for improved waste management systems and regulatory frameworks to mitigate these effects.

The study underscores the importance of collaboration and infrastructure development to address nanoplastic pollution effectively. It calls for increased research efforts to understand the extent of contamination and its implications fully. More-over, the review advocates for the implementation of sustainable management practices and the promotion of public awareness to reduce plastic waste generation. Through an in-depth analysis of existing literature and case studies, the review identifies gaps in current management practices and proposes strategic interventions to enhance nanoplastic management in Africa. These interventions include the development of robust policies, investment in recycling technologies, and fostering regional and international cooperation.

Overall, this review serves as a call to action for stakeholders including policymakers, researchers, and communities to prioritize nanoplastic pollution control and work towards a cleaner and healthier environment in Africa.

Keywords: Management; Nanoplastic; Health; Africa; Environment; Ecosystem

Abbreviations: SSA - Sub-Saharan Africa; MPs – Microplastics; NPs – Nanoplastics; SSDR - Specific Surface Degradation Rate; HDPE - High-Density Polyethylene; ROS - Reactive Oxygen Species; PAHs - Polycyclic Aromatic Hydrocarbons; POPs - Persistent Organic Pollutants; PCBs - Polychlorinated Biphenyls; COPD - Chronic Obstructive Pulmonary Disease

Highlight from the study

- The review identifies the primary sources of nanoplastic pollution in Africa, such as plastic breakdown and industrial/domestic activities.
- The study emphasizes the environmental and health impacts of nanoplastics, while noting the need for more research on long-term effects.
- The review underscores the importance of collaboration and infrastructure development, including policies, recycling, and international cooperation.
- The review identifies key challenges, including inconsistent policies, lack of infrastructure, and economic/social barriers, and proposes interventions.
- The study advocates for sustainable management practices and public awareness to reduce plastic waste and mitigate the nanoplastic crisis in Africa.

Introduction

The increasing production and consumption of plastics worldwide has resulted in an alarming growth in plastic waste, posing serious environmental and health problems [1]. Africa, which produces an estimated 19,000 kilotons of plastic each year is not immune to this problem. Countries in Sub-Saharan Africa (SSA) such as South Africa, Nigeria, Ethiopia, Ghana, and Kenya, with South Africa alone producing up to 1410 kilotons of plastic [2]. This industrial activity combined with the importation of plastic raw materials and finished products has compounded region's plastic waste problem [3]. For example, Ethiopia's plastic imports increased from 54 kilotons in 2007 to 224 kilotons in 2020, indicating the region's growing reliance on plastics despite inadequate waste management facilities [4].

The mismanagement of plastic waste in SSA is expected to increase with estimates indicating that lack of proper plastic waste management would more than double by 2025, from 4.8 million tons to an alarming 11.5 million tons [5]. This estimate emphasizes the crucial need for appropriate waste management solutions to solve the serious environmental problems caused by extensive plastic use. Inadequate waste management infrastructure and weak regulatory frameworks combined with socioeconomic constraints increased the prevalence of plastic pollution in SSA. Pollution affects urban settings and infiltrates numerous ecosystems ranging from rivers and lakes to coasts, jeopardizing water quality, soil health, wildlife, and human populations [6].

Plastic pollution persists in SSA due to poor waste management infrastructure and regulatory frameworks which are compounded by socioeconomic constraints [7]. Plastic waste affects urban settings and infiltrates a variety of ecosystems, including rivers, lakes, and coasts, affecting water quality, soil health, wildlife, and human communities. [8] The durability of plastics, which contributes to their widespread use creates substantial environmental challenges. These polymers withstand natural breakdown, forming microplastics (MPs) and nanoplastics (NPs) that spread throughout the environment. Microplastics have been found in water, sediment, and fish from South Africa's Vaal River, posing serious hazards to food safety and human health [9].

In marine environment, the specific surface degradation rate (SSDR) for high-density polyethylene (HDPE) ranges from almost nil to 11 μm per year. Applying the average SSDR to HDPE in these settings, linear extrapolation indicates that the projected half-lives of HDPE products can range from 58 years for plastic bottles to 1200 years for plastic pipes [10]. This durability represents the serious issues posed by plastic pollution in aquatic habitats as pollutants remain for decades constantly affecting marine life and ecosystems.

Plastics are durable and resistant to degradation resulting in their accumulation in natural environments, particularly in oceans and waterways [11]. Over time, larger plastic debris breaks down into smaller fragments, including microplastics (less than 5 mm) and nanoplastics (less than 100 nm). Nanoplastics are generated from the degradation of larger plastics through mechanical, chemical, and biological processes, and they are found in diverse environments, including soil, water, and air [12]. These particles can be ingested by a wide range of organisms, from plankton to humans causing various adverse effects such as physical blockages, toxic chemical exposure, and the transfer of pathogens [13]. Despite these concerns, the long-term health effects of nanoplastic exposure are still largely unknown. The existing body of research is limited with much of it relying on in vitro (cell culture) or in vivo (animal) studies that may not fully mirror human exposure circumstances [14]. As a result, more research is needed to understand the long-term effect of nanoplastics on human health, such as epidemiological studies that track people over time and mechanistic studies that shed light on how nanoplastics interact with biological systems.

Given the crucial need to address the increasing plastic pollution disaster, this review will investigate the prevalence, impact, and viable solutions to nanoplastic pollution in SSA. It will look at new studies on nanoplastic pollution, assess their effects on food production, water quality, health, and the environment, and compare existing and proposed waste management and recycling techniques. This analysis aims to offer insights on the nanoplastic pollution crisis in SSA that will guide policy decisions, support community activities, and stimulate more research in this critical area of environmental concern.

Relevance to Africa

Nanoplastic pollution holds significant relevance for Africa due to several factors [15]. The continent is witnessing a notable surge in plastic production and importation driven by economic growth and urbanization. However, this rise in plastic consumption is not matched by adequate waste management infrastructure leading to widespread mismanagement of plastic waste [16]. Many African countries face challenges in waste management, characterized by insufficient infrastructure and regulatory frameworks. This results in improper disposal of plastics, contributing significantly to environmental pollution [17]. The presence of nanoplastics in soil, water, and air poses serious environmental and health threats. In Africa, where communities often rely on natural water sources and agriculture. The contamination from nanoplastics can profoundly affect food and water safety thus posing damage on human health and ecosystem [18]. Economic limitations further compound the issue restricting the capacity of African nations to invest in advanced waste management technologies. Additionally, there is a lack of public awareness and education regarding the environmental and health impacts pose by plastic pollution. These economic and social factors hinder efforts to effectively manage nanoplastic pollution in the region [19].

The rapid increase in plastic consumption and inadequate waste management systems have led to a surge in nanoplastic pollution across Africa. Sub-Saharan Africa in particular is grappling with increased levels of plastic production [20]. The reason for this increased in plastic pollution could be attributed to unregulated usage and insufficient waste management infrastructure in Africa [21]. Challenges in managing nanoplastic pollution in Africa stem from a lack of scientific facilities hindering comprehensive research efforts and effective solutions. The impacts of nanoplastic pollution on Africa's ecosystems and human health are profound. Environmental degradation, including disruption of natural processes and threats to biodiversity, poses significant ecological risks [22]. The ingestion of nanoplastics and associated chemicals through contaminated water and food sources presents serious health risks to human populations [23].

One potential solution is the establishment of effective waste management systems. Implementing stringent regulations to control plastic usage and improve recycling programs can help mitigate nanoplastic pollution [24]. Establishing effective waste management systems is crucial. Investing in scientific research and infrastructure is essential for understanding the extent of nanoplastic pollution and developing targeted mitigation strategies [25]. Collaboration between governments, industries, and research institutions is essential to drive progress in this area. Efforts to address nanoplastic pollution in Africa must also consider socio-economic factors and community engagement. Public awareness campaigns and educational initiatives can empower local communities to participate in waste reduction and recycling efforts Incentivizing sustainable practices and supporting the development of eco-friendly alternatives to plastic can help reduce reliance on conventional plastic products [26].

Sources and Pathways of Nanoplastic Pollution in African Ecosystems

Nanoplastic pollution in African ecosystems comes from a variety of sources and channels, representing both local and global environmental processes [6]. The primary sources of nanoplastics in Africa include waste management practices, industrial activities, and agricultural runoff. In many African countries, inadequate waste management systems contribute to the significant release of plastics into the environment [27]. For example, [28] observed random disposal of plastic debris and sachet water bags in Maiduguri, Borno State, Nigeria.

Nanoplastic pollution originates from several primary sources including Larger plastic goods like bottles, bags, and packaging break down over time into smaller particles due to exposure to sunlight (UV radiation), mechanical abrasion (e.g., wave action), and chemical deterioration (e.g., oxidation). Plastic particles ranging in size from 1 micrometer to 5 millimeters can disintegrate into nanoplastics through environmental processes such as photo-degradation, hydrolysis, and biodegradation [29]. During washing, synthetic textiles such as polyester, nylon, and acrylic emit minute fibers that might eventually breakdown into nanoplastics. These fibers enter wastewater and then the environment. Some personal care products, such as exfoliating scrubs and toothpaste, include microplastic particles as abrasives [30]. These particles can potentially breakdown into nanoplastics after use and infiltrate aquatic bodies through wastewater. Nanoplastic particles can be released into the environment as a result of air and water pollution from various industrial activities such as plastic product manufacturing, transportation, and disposal [13].

Furthermore, industrial activities contribute to nanoplastic pollution through various mechanisms. Factories involved in the production and processing of plastic materials generate waste that includes micro- and nanoplastic particles. These particles can be released into the air, water, and soil during manufacturing processes [31]. The automotive industry also contributes to nanoplastic pollution through the wear and tear of components such as tires and brake pads, which release micro- and nanoplastic particles into the environment. These particles are dispersed through air and runoff from roads, eventually contaminating various ecosystems. Additionally, household dust can contain nanoplastics originating from the wear and tear of plastic items, synthetic fibers from carpets and furniture, and particles released from electronic devices and appliances [32].

Health Implication of Nanoplastic

Nanoplastics are widely recognized as emerging environmental pollutant with possible health consequences. These tiny plastic particles frequently less than 100 nanometers in size can enter the human body through ingestion, inhalation, or skin contact [33]. Once within the body, they can overcome biological barriers and interact with many cellular and molecular pathways, potentially causing a variety of health problems. They can induce inflammation when the particles concentration in specific tissues accumulate over an extended period of time. In the respiratory system, Inhaled nanoplastic can cause inflammation and respiratory disease, including asthma, chronic obstructive pulmonary disease COPD, and bronchitis [34]. The presence of nanoplastic in the lungs can worsen pre-existing respiratory disorders and raise the risk of infection. Nanoplastic, when inhaled or swallowed can enter the systemic circulation and accumulate in cardiovascular tissues [35]. This accumulation induces inflammation, oxidative stress, and endothelial dysfunction which all contribute to the development of cardiovascular disease such atherosclerosis, hypertension, stroke and myocardial infarction [36].

Nanoplastic can penetrate blood-brain barrier and accumulate in the brain potentially triggering neuroinflammation and neurotoxicity [37]. Overtime, this can lead to neurodegenerative diseases such as Alzheimer's and Parkinson's, as well as cognitive deficits and behavioral disorders. Nanoplastic are also capable of generating reactive oxygen species (ROS) which can induce oxidative stress. Oxidative stress is a state characterized by high levels of reactive oxygen species (ROS) in the body tissues. This process can cause damage to the cellular components such as lipids, proteins and DNA potentially leading to cancer [38].

Some research suggests that nanoplastics can disrupt the endocrine system. They can imitate or block hormones interfering with normal hormonal functioning and potentially causing reproductive health problems developmental problems and metabolic abnormalities such as obesity, diabetics and thyroid dysfunction [39]. They can impair reproductive function and fetal development by changing hormone balance and inducing oxidative stress. Prenatal exposure to nanoplastics can disrupt reproductive functioning and fatal development leading to infertility, miscarriage, birth defect and other reproductive issues in offspring [40]. Nanoplastics can influence immune responses by triggering inflammatory pathways and impairing immune cell function. Exposure to nanoplastics may cause immune system dysregulation, increasing vulnerability to infections, autoimmune disorders, and allergic reactions [41].

Nanoplastics do not only provide direct health hazards due to their small size and potential biological interactions but can also act as carriers for a variety of environmental pollutants [42]. This feature considerably increases their potential for causing harm human health. Polycyclic aromatic hydrocarbons (PAHs) PAHs are a type of chemical substance that is known to cause cancer. They are produced by the incomplete combustion of organic materials such coal, oil, gas, wood, and tobacco. Nanoplastics can aids the absorption PAHs from the environment potentially enhancing their toxicity when consumed or inhaled into the body [43].

Heavy metals such as lead, cadmium, mercury, and arsenic, are harmful contaminants that can cause neurotoxicity, renal damage, and even cancer [43]. Nanoplastics can bond to these metals, accelerating their movement through the environment and boosting their bioavailability to humans. Persistent organic pollutants (POPs) POPs are organic molecules that are resistant to environmental degradation and can last for a long time [44]. Pesticides such as DDT industrial compounds such as polychlorinated biphenyls (PCBs), and industrial process byproducts are some examples. Nanoplastics can absorb POPs increasing their mobility and potential for bioaccumulation in the food chain which can eventually lead to human exposure [45].

Impact on African Ecosystem

Fish and invertebrates can ingest nanoplastics causing physical and chemical stress. This can have a variety of negative consequences including reduced reproduction, stunted growth, and changed behavior [19]. For example, fish exposed to nanoplastics may have diminished swimming abilities and altered eating behavior which can have an impact on survival and reproduction. As the foundation of the aquatic food web, phytoplankton are critical to ecological health. Nanoplastics can inhibit plant growth and photosynthesis by lowering primary output and oxygen production [46]. This can have a cascading effect throughout the food chain affecting higher trophic levels. Nanoplastics can get accumulated in the tissues of aquatic organism and move up the food chain from plankton to fish to higher trophic levels like birds and mammals. This bioaccumulation poses serious threats to predators including humans who ingest infected seafood. The presence of nanoplastics in seafood can cause health problems for humans including gastrointestinal distress, inflammation, and exposure to toxic compounds adsorbed onto the nanoplastics [3].

Nanoplastics can alter soil texture, water retention, and porosity, thus affecting plant root growth and nutrient uptake. This can result in decreased agricultural output and affect food availability. The alteration in soil structure can also have an impact on water infiltration and retention thereby increasing erosion and altering hydrological cycles [47]. Soil bacteria are vital for nutrient cycling, organic matter breakdown, and plant health. Nanoplastics can disturb microbial communities, lowering diversity and changing their functional capabilities. Microbial process disruption has the potential to reduce soil fertility and plant growth resulting in lower agricultural output and ecosystem resilience [48]. Nanoplastics represent a significant and emerging threat to African ecosystems, affecting both aquatic and terrestrial environments in complex and linked ways. The harmful effects on organism's alteration to soil and water characteristics, disruption of microbial communities, and broader implications for ecosystem services and human health require immediate attention and action [49]. Table 1 gives a synopsis of the impact of nanoplastics by different authors.

Table 1: Impact of Nanoplastic Pollution on African Ecosystems

Impact of Nanoplastic Pollution on African Ecosystems: A Compilation of Recent Research		
S/No.	**Author(s) and Year**	**Finding**
1	Dahms et al (2022) & Dube & Okuthe, 2024	Dahms et al, reported the presence of microplastic in water, sediment, and fish (Clarias gariepinus) from the Vaal River of South Africa [76]. Similarly, [77] Data show that nanoplastic are present in significant concentrations in fish and other marine species in Ghana and Nigeria. Fish from the Jamestown landing beach in Ghana had up to 133 elements per fish. This indicates severe contamination, which may be exacerbated by poor waste management and excessive local plastic use. MPs discovered include fibers, fragments, films, and foams formed from various polymers such as PE, PP, PS, and PES.
2	(Umar Donuma et al., 2024)	[28] Preliminary data reported indiscriminate disposal of plastic bottles and sachet water bags in Maiduguri, Borno State, Nigeria. This has resulted in the accumulation of plastic debris in open spaces, drainage systems, and water bodies. This nanoplastics undergo environmental degradation, such as clogged drainage systems, increased flood risks, and a reduction in the city's aesthetic attractiveness. Furthermore, the presence of plastic. They reported the presence of nanoplastic in water bodies has contaminated water sources with microplastics and other contaminants, which constitute a possible risk to human health.
3	(Wegi & Urge) 2022 and Beriot et al. (2021)	Wegi & Urge [78], found indigestible foreign bodies, including plastic, in Ethiopian cattle.84, similarly to that of [79], who also found nanoplastic in sheep faces and soil from an intensive vegetable garden using plastic mulch.
4	Carrasco Silva et al., (2021) Dube & Okuthe, 2024	Carrasco Silva et al., [80] found that nanoplastic can absorb pollutants and allow them to enter plants, leading to plant damage and negatively impacting growth and development. Furthermore, [77] nanoplastic have been detected in cattle feed, blood, milk, and meat. [80] Nanoplastic have also been been found in fish's gastrointestinal tracts and flesh. As fish, meat, and milk are important protein sources, they may be passed on to people through food. Idowu et al. found nanoplastic in fish from the Osun River, Nigeria .
5	Ramaremisa et al., 2024	Ramaremisa et al., [81] found fibrous-shaped of nanoplastic (<1 mm) with an average concentration of 14 ± 5.6 particles per liter in tap water samples from Gauteng neighborhoods in South Africa.
6	Dube & Okuthe, (2023), Yates et al., (2019) & Bhuyan, (2022)	*In vitro* and *in vivo* research have revealed that nanosized particles cause behavioral problems, neurotoxicity, tissue damage, oxidative stress, and delayed growth. This shows that humans may have similar effect as well. [82], [63] & [83]

7	(Wei,) 2021	Wei [84], discussed the policy gaps and opportunities for improving plastic waste management in Africa. Their study highlighted the need for comprehensive policies that address the entire lifecycle of plastic products, from production to disposal. For example, Rwanda is a pioneer in eliminating plastic bags, while Tanzania forbade their manufacturing, importation, sale, and usage. Kenya also banned single-use plastic bags. These situations are successful examples for other SSA countries to follow in other to manage plastic pollution [85].
8	Bouwmeester et al., 2015	Bouwmeester et al., [86] discussed the importance of removing barriers to plastic waste valorization in Africa. They emphasized the need for policies that promote recycling and the development of infrastructure to support waste management efforts. Their study highlighted that effective waste management practices could significantly reduce the environmental burden of plastic pollution. Focusing on the role of international collaboration in managing plastic waste in Africa. They pointed out that partnerships between African countries and international organizations could enhance the region's capacity to handle plastic waste more effectively. Both studies stress the need for policy interventions and international cooperation to improve plastic waste management in Africa.
9	Mensah & Badu (2022); Kwadwo & Akosua (2023)	Mensah and Badu (2022), reviewed the implications of rapid population growth and inadequate waste management practices on plastic pollution in African aquatic environments. Their study found that these factors lead to the accumulation of plastic debris in water bodies, adversely affecting aquatic life. They emphasized the need for effective waste management strategies to address the escalating plastic pollution crisis in African water bodies. Kwadwo and Akosua (2023) highlighted the urgent need for policy and technological solutions to address plastic pollution in Africa. They pointed out that current waste management practices are insufficient and called for the implementation of innovative technologies and comprehensive policies to mitigate the impact of plastic pollution. Both studies underscore the critical need for improved waste management practices and policy reforms to protect Africa's aquatic ecosystems.
10	Asare & Atta-Boateng (2021); Boakye & Addo (2023)	Asare and Atta-Boateng (2021) analyzed the state of plastic pollution and its impacts on African water systems, focusing on microplastic contamination. Their research highlighted the adverse effects of plastic waste on aquatic ecosystems, including physical harm to marine life and the introduction of toxic substances into the food chain. Boakye and Addo (2023) discussed the prevalence of nanoplastic particles in African ecosystems and the need for more comprehensive data to understand their impact fully. They found that nanoplastics pose a significant threat to biodiversity and human health due to their small size and ability to carry harmful pollutants. Both studies call for more research to understand the full extent of plastic pollution and its effects on African ecosystems and public health.
11	Smith, (2023) & Ferronato & Torretta, 2019	Smith [87], discussed the policy gaps and opportunities for improving plastic waste management in Africa. Their study highlighted the need for comprehensive policies that address the entire lifecycle of plastic products, from production to disposal. They pointed out that current policies are often fragmented and insufficient to tackle the scale of plastic pollution [88]. Examined the challenges and opportunities in addressing plastic waste management in Africa. They identified several key barriers, including inadequate infrastructure, lack of funding, and limited public awareness. Both studies call for coordinated efforts from governments, industries, and communities to develop and implement effective waste management strategies that can mitigate the impact of plastic pollution.

12	Salgaonkar et al., (2024) & Salgaonkar et al., (2024)	Salgaonkar et al.,[89] highlighted the presence of nanoplastics in remote areas, showing the widespread nature of the pollution. Their research documented how nanoplastics are found in air, water, and soil, even in locations far from urban centers. This widespread distribution indicates the pervasive nature of plastic pollution and its potential to affect diverse ecosystems. [1] further examined the environmental impacts of micro- and nanoplastics, focusing on their prevalence in African ecosystems. They found that nanoplastics pose a significant threat to biodiversity, as they can be ingested by a wide range of organisms, leading to various adverse effects such as physical blockages and toxic chemical exposure. Both studies emphasize the urgent need for comprehensive research to understand the full extent and impact of nanoplastic pollution in Africa.
13	Schell et al., (2020) & Münzel et al., (2023)	Schell et al., [90] highlighted the barriers to plastic waste valorization in Africa, emphasizing the low fraction of recycled plastics. Their research suggested that improvements in plastic waste management could significantly reduce the environmental burden of plastic pollution. They recommended implementing policies that promote recycling and the development of infrastructure to support waste management efforts. [91] echoed these sentiments, discussing the importance of removing barriers to plastic waste valorization. They pointed out that effective waste management practices could help mitigate the impact of plastic pollution on the environment. Both studies stressed the need for policy interventions and technological innovations to enhance plastic recycling rates in Africa.
14	Sohail et al., 2023 & Allen et al., 2022)	Sohail et al., [92] provided a comprehensive review of microplastic pollution in African aquatic environments. Their study summarized previous research efforts and assessed current analytical procedures used to measure microplastic contamination. They found that the methodologies for detecting microplastics vary significantly, leading to inconsistent data across studies. They emphasized the need for standardized protocols to accurately assess the extent of microplastic pollution. Similarly, [93] highlighted the need for better analytic procedures in their work on microplastic pollution in African rivers. They pointed out that existing methods often fail to capture the full scope of microplastic contamination, leading to an underestimation of the problem. Both studies call for improved scientific approaches to better understand and mitigate microplastic pollution in Africa's aquatic ecosystems.
15	Lima et al., (2023) & Shah et al., (2023)	Lima et al., [94] explored the current status of plastic pollution in Africa, focusing on its implications for aquatic ecosystem health. They found that rapid population growth and poor waste management practices are the main drivers of plastic pollution. These practices lead to the accumulation of plastic debris in water bodies, adversely affecting aquatic life. Their findings revealed that the ingestion of microplastic by aquatic organisms can cause physical harm and expose these organisms to harmful pollutants. [23] further examined the impact of plastic pollution on aquatic ecosystems. They discussed how plastic waste disrupts natural processes and poses significant threats to biodiversity. Their research highlighted the urgent need for effective waste management strategies to address the escalating plastic pollution crisis in African water bodies.
16	Shilla, (2019) & Lehel & Murphy, (2021)	Shilla [95] discussed the increasing levels of plastic production and importation in Sub-Saharan Africa. Their study highlighted the unregulated usage of plastics and inadequate waste management systems, which lead to widespread environmental contamination. They emphasized the need for stringent regulations to control plastic usage and improve recycling programs. [96] focused on the health impacts of plastic pollution, particularly the role of nanoplastics in spreading infectious diseases. Their research revealed that nanoplastics could carry pathogens, posing significant health risks to humans. Both studies underscore the urgent need for comprehensive strategies to address plastic pollution, including regulatory measures and public health interventions.

Nanoplastic Pollution's Impact on Food Availability and Security

Nanoplastics constitute a substantial danger to food supply and security, influencing many areas of the food production chain, from soil health to aquatic habitats, and eventually harming human health through the eating of contaminated food. Nanoplastics in soil can have a negative impact on agricultural output [50]. They can alter soil fertility and other soil properties such as structural, porosity and microbial populations, all of which are important for plant growth. Soil microorganisms play an important role in nutrient cycling and organic matter breakdown. The presence of nanoplastics can alter microbial ecosystems, resulting in decreased soil fertility and agricultural production. Furthermore, nanoplastics can interfere with plants' ability to absorb water and nutrients stressing agricultural systems and limiting food output [51].

Nanoplastic contamination affects both livestock and poultry. Animals can ingest nanoplastics through contaminated feed and water, posing health risks and limiting their growth and productivity [52]. The presence of nanoplastics in animal tissues can endanger human health when these animals are consumed as food. Furthermore, the overall health and productivity of livestock and poultry are critical to food availability, especially in areas where animal husbandry is a primary source of income and sustenance [51].

Improper Waste Management

Improper waste management is a major contributor to nanoplastic pollution. In many parts of Africa, waste management systems are either inadequate or nonexistent, leading to uncontrolled disposal of plastic waste [53]. Open dumping is a common practice where plastics are discarded in open areas, exposed to sunlight and wind. Over time, these plastics degrade into smaller particles, eventually forming micro- and nanoplastics [54]. Similarly, open burning of plastic waste not only releases toxic fumes but also results in the fragmentation of plastics into nanoplastics. Even managed landfills can be significant sources of nanoplastic pollution if not properly sealed and maintained. This allows for plastics degradation and release nanoplastic particles into the surrounding soil and groundwater which they end up been ingested by human being [55].

Challenges and Solutions

Addressing the sources of nanoplastic pollution involves multiple challenges. Improving waste management infrastructure and practices is crucial, including enhancing recycling systems [20]. Implementing proper landfill management, and reducing open dumping and burning. Strengthening regulations on industrial emissions and waste disposal can help minimize nanoplastic release from manufacturing processes. Educating consumers about the impact of plastic use and promoting alternatives to plastic products can reduce the generation of nanoplastic pollution [56]. Additionally, developing and adopting technologies for filtering and capturing nanoplastics in wastewater treatment plants and industrial effluents can mitigate the spread of these particles [57].

Challenges in Managing Nanoplastic Pollution

Managing nanoplastic pollution in Africa presents several significant challenges, including inconsistent policies, lack of infrastructure, and economic and social barriers.

Inconsistent Policies

One of the primary challenges in managing nanoplastic pollution across African countries is the inconsistency in waste management policies. There is a significant disparity in the adoption and enforcement of environmental regulations related to plastic waste [58]. While some countries have implemented strict laws and regulations aimed at reducing plastic pollution, others lack comprehensive policies or fail to enforce existing ones effectively. This inconsistency results in uneven progress in tackling nanoplastic pollution. For instance, while Rwanda has implemented a successful ban on plastic bags, other countries continue to struggle with plastic waste due to weak regulatory frameworks and poor enforcement mechanisms [59]. The lack of a unified approach across the continent hampers collective efforts to manage and reduce nanoplastic pollution effectively.

Lack of Infrastructure

Another critical challenge is the inadequate waste management infrastructure in many African countries. Effective management of plastic waste requires robust systems for collection, sorting, recycling, and disposal [60]. However, many regions lack the necessary infrastructure to handle the increasing amounts of plastic waste. Insufficient recycling facilities mean that a large proportion of plastic waste, including potential nanoplastics, ends up in landfills or is openly dumped and burned. This improper disposal not only leads to environmental contamination but also poses health risks to nearby communities [61]. The lack of infrastructure is particularly acute in rural areas, where waste management services are often minimal or nonexistent. Without significant investment in waste management infrastructure, efforts to mitigate nanoplastic pollution will remain largely ineffective [62].

Economic and Social Barriers

Economic constraints and social factors further exacerbate the challenges in managing nanoplastic pollution. Many African countries face economic limitations that restrict their ability to invest in advanced waste management technologies and infrastructure [63]. Additionally, the informal sector plays a significant role in waste management in many regions, which complicates regulatory oversight and enforcement. Economic pressures also drive the continued production and use of cheap plastic products, contributing to the accumulation of plastic waste. Social factors, such as limited public awareness and education about the environmental and health impacts of plastic pollution, hinder community engagement in waste management initiatives [64]. Cultural practices and socioeconomic conditions can influence waste disposal behaviors, making it challenging to implement standardized waste management practices across diverse communities [65].

Potential Solutions

Addressing these challenges requires a multifaceted approach. Harmonizing waste management policies across African countries could enhance regional cooperation and effectiveness in combating nanoplastic pollution [65]. Strengthening enforcement mechanisms and providing support for policy implementation are crucial steps. Investing in waste management infrastructure, particularly in recycling facilities and safe disposal methods, is essential for effective waste management. Additionally, promoting public awareness campaigns and education programs can help change behaviors and encourage community participation in waste reduction and recycling efforts [66]. Economic incentives, such as subsidies for recycling businesses and penalties for non-compliance with waste management regulations, could also drive improvements in waste management practices. Finally, fostering partnerships between governments, private sectors, and international organizations can mobilize resources and expertise needed to address the complex issue of nanoplastic pollution in Africa [67].

Potential Solutions for Managing Nanoplastic Pollution

Policy and Regulation

One key solution is the development and strict enforcement of comprehensive waste management policies. African countries need robust regulations that govern the production, use, and disposal of plastics [68]. These policies should include measures to minimize plastic waste generation, promote recycling and circular economy principles, and establish penalties for non-compliance. By implementing effective policies, governments can create a regulatory framework that incentivizes responsible plastic use and ensures accountability throughout the product lifecycle [69].

Improving Infrastructure

Investments in waste management infrastructure and technologies are essential for better handling plastic waste. Many African countries face challenges in waste collection, sorting, and recycling due to inadequate infrastructure [70]. By investing in modern waste treatment facilities, such as recycling plants and incinerators, governments can improve the efficiency of waste management processes and reduce the leakage of plastics into the environment. Additionally, supporting research and innovation in waste management technologies can lead to the development of more sustainable solutions for handling nanoplastic pollution [71].

Public Awareness and Education

Raising public awareness about the dangers of nanoplastic pollution and promoting sustainable practices are crucial steps in mitigating this environmental issue [72]. Public education campaigns can inform individuals about the impacts of plastic pollution on ecosystems and human health, encouraging behavior change and responsible consumption habits. Educational initiatives targeting schools, communities, and industries can empower stakeholders to adopt eco-friendly practices, such as reducing single-use plastics, properly disposing of waste, and supporting plastic-free initiatives [73].

International Collaboration

Regional and international collaboration is vital for sharing knowledge, resources, and best practices in managing nanoplastic pollution. African countries can benefit from partnerships with other nations, international organizations, and research institutions to access funding, expertise, and technical assistance for addressing this global challenge [74]. Collaborative initiatives can facilitate information exchange, capacity-building, and joint research efforts to develop innovative solutions for nanoplastic pollution. By working together, countries can leverage collective expertise and resources to implement effective strategies for combating plastic pollution on a global scale [75].

In conclusion, addressing nanoplastic pollution in Africa requires a multifaceted approach that integrates policy, infrastructure, education, and international cooperation. By implementing these potential solutions, African countries can mitigate the environmental and health impacts of nanoplastic pollution and move towards a more sustainable future.

Conclusion

In conclusion, the current state of nanoplastic pollution in Africa presents significant challenges that demand urgent attention and concerted action. Despite limited research and data availability, it is evident that nanoplastic pollution is on the rise across the continent, driven by various sources such as improper waste management, industrial activities, and consumer products. This pollution poses significant environmental and health risks, including ecosystem contamination, biodiversity loss, and potential human health impacts.

Conflicts of Interest

No conflict of interest from the authors

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Authors Contribution Statement

Awafung Emmanuel Adie: Conceptualization, Writing – original draft, Investigation, Visualization, Data analysis. **Swase Dominic T**: Writing – original draft, Supervision, Writing– review & editing. **Onongha comfort O.**: Writing – review & editing, Validation, Supervision. **Ambrose Okello**: Writing – review & editing, Supervision. **Nji Elizabeth Libuo-Beshel**: Writing–review & editing, Supervision and **Reuben Samson Dangana**: Writing – review & editing.

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