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REVIEW ARTICLE

Microbes Associated with Bioremediation of Microplastic Waste in Nigerian Freshwater Bodies: A Review

Ibrahim Muhammad Magami[1], Aminu Yusuf Fardami[2], Aminu Abdullahi Yarima[3] and Muntasir Sabitu[2]*

[1]Department of Biology, Faculty of Chemical and Life Sciences, Usmanu Danfodiyo University Sokoto, Sokoto State, Nigeria
[2]Department of Microbiology, Faculty of Chemical and Life Sciences, Usmanu Danfodiyo University Sokoto, Sokoto State, Nigeria
[3]School of Science Education, Federal College of Education (Technical) Gombe State, Nigeria

ABSTRACT

Microplastic pollution in freshwater bodies is a serious environmental issue affecting agriculture, human consumption, and ecological well-being. Microbial bioremediation is a promising method for removing microplastic waste. Bacterial and fungal species have shown efficiency in breaking down microplastic either aerobically or anaerobically. The alphaproteobacteria class, particularly the Rhodobacteraceae family, and the gammaproteobacteria family were home to the majority of bacteria that could break down microplastic. Several researchers investigated the *Rhodococcus* genus and the genera *Pseudomonas sp.* with noteworthy outcomes. Fungal phyla of Ascomycota (Dothideomycetes, Eurotiomycetes, Leotiomycetes, Saccharomycetes, and Sordariomycetes), Basidiomycota (Agaricomycetes, Microbotryomycetes, Tremellomycetes, Tritirachiomycetes, and Ustilaginomycetes), and Mucoromycota (Mucoromycetes) were found efficient in the degradation of microplastic in both land and fresh water bodies. It is important to take action to lessen the amount of plastic garbage that enters freshwater bodies, as well as to improve waste management procedures and encourage sustainable plastic usage patterns in Nigeria.

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INTRODUCTION

Freshwater is any naturally occurring liquid or frozen water containing low concentrations of dissolved salts and other total dissolved solids (Anang *et al.,* 2023). Lakes, rivers, and streams are examples of freshwater bodies important for agriculture, human consumption, and ecological well-being. However, these ecosystems are confronted with rising pollution levels from human activities, such as the buildup of microplastic trash (Talukdar *et al.,* 2023). Microplastics, which are tiny plastic particles with a diameter of less than 5 millimeters, are frequently produced when plastic degrades or fragments. These contaminants can build up in freshwater habitats and pose a serious hazard to aquatic life and the larger ecosystem (Eerkes-Medrano *et al.,* 2015).

In freshwater environments, microplastics can have a variety of detrimental effects. They have the ability to change the chemical and physical characteristics of water, causing adjustments to its temperature, pH, and dissolved oxygen content (Scherer *et al.,* 2018). Aquatic species can consume microplastics, potentially altering food webs and causing bodily harm or obstructions in their digestive tracts. In addition, hazardous compounds contained in microplastics may accumulate in species that consume them, thus having an adverse effect on human health (Martins *et al.,* 2023).

Microbial communities are crucial to bioremediation since they are in charge of contaminant degradation and breakdown. Research on the ability of microbial communities to biodegrade microplastic trash in freshwater habitats is expanding. To fully comprehend the potential for bioremediation of the microbial communities found in freshwater habitats, additional study is necessary due to their diversity and complexity (Wani *et al.,* 2023).

The results of Nyika and Dinka (2022) showed that the microorganisms utilized, the qualities of the wastewater being cleaned, and the physicochemical and biological characteristics of the contaminated environment all affect how efficient bioremediation is. It was also found that microbe incompatibility with the pollutant, which results in enzyme inhibition, toxic chemical synthesis, and

Correspondence: Muntasir Sabitu. Department of Microbiology, Faculty of Chemical and Life Sciences, Usmanu Danfodiyo University Sokoto, Sokoto State, Nigeria. sabitumuntasir@gmail.com. Phone Number: +234 907868 0669
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sluggish microbial metabolism capability, can occasionally limit bioremediation in the remediation of refractory contaminants. These elements may cause bioremediation methods to take longer and lessen the effectiveness of the resultant decontamination. Most of the bacteria screened from polluted dumpsites are members of the phyla proteobacteria, firmicutes, and actinobacteria, and they have the potential to break down plastics. The biodegradation of microplastics should be the main emphasis of research, with the most well-known pollutants, like polyethylene, as a particular focus (Nguyen, 2022; Hadian-Ghazvini *et al.,* 2022).

Microplastic (MP) contamination of Nigerian freshwater bodies is increasing as a result of the country's severe plastic pollution caused by a lack of recycling practices and the fact that freshwater ecosystems serve as a conduit for the transfer of inland plastics to the ocean (Akindele *et al.,* 2019). This review offers one of the few empirical descriptions of the MP contamination in Nigerian fresh water bodies as well as information on the bacteria and fungi involved in the degradation and bioremediation of microplastic waste pollution in the country's freshwater bodies. Microplastics (MPs) have been documented in Nigeria's freshwaters very infrequently (Akindele *et al.,* 2019).

MICROPLASTIC WASTE IN NIGERIAN FRESHWATER BODIES

Microplastic waste is a serious environmental issue that Nigeria and other countries with freshwater bodies are dealing with (Aderonke *et al.,* 2019). Little plastic particles known as microplastics, which are less than 5 mm in size, can arise from a variety of products, including cosmetics, clothing, and industrial activities (Akhmad and Fauziah, 2020). These tiny plastic particles can build up in water bodies and endanger aquatic life as well as human health. Microplastic pollution is an increasing issue in Nigeria's freshwater bodies, according to several researches (Dada and Bello, 2023).

In the water and sediments of Lagos Lagoon, the largest urban estuary in Nigeria, substantial amounts of microplastic contamination were discovered during a study. The investigation revealed that microplastics were present at every site that was analyzed, with fibers and fragments being the most frequently discovered kinds (Adeyemo *et al.,* 2021). Microplastic pollution was discovered in the water and sediments of the River Niger, the largest river in Nigeria, according to another study. According to the study, fibers were the most prevalent type of microplastic discovered, and water had the maximum amount of microplastics (Aderonke *et al.,* 2019). Although the effects of microplastic pollution on human health are not entirely understood, it is known that they can accumulate in aquatic animals' tissues and perhaps enter the food chain (Emenike and Fauziah, 2019). In addition to harming the ecology, the presence of microplastics in freshwater bodies can also change the behavior and reproductive patterns of aquatic creatures and reduce the amount of oxygen available for aquatic life (Ogunola and Owojori, 2021).

SOME NEGATIVE IMPACTS OF MICROPLASTIC POLLUTION ON FRESHWATER BODIES

Microplastic pollution, consisting of tiny plastic particles less than 5mm in size, has become a pervasive environmental issue that threatens the health of our freshwater bodies (Ferdous *et al.,* 2023; Kurniawan, *et al.,* 2023). The extensive uses of plastics and improper waste management practices have resulted in the accumulation of microplastics in lakes, rivers, and other freshwater ecosystems (Dad *et al.,* 2023). Below are some of the negative impacts of microplastic pollution on freshwater bodies.

i. Impaired Water Quality

Microplastics, derived from various sources such as synthetic fibers, microbeads in personal care products, and fragmented larger plastics, contaminate freshwater bodies (Kutralam-Muniasamy *et al.,* 2023). These particles have a high surface area-to-volume ratio, allowing them to adsorb and concentrate harmful pollutants such as polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) (Zoppas *et al.,* 2023). As a result, microplastics act as carriers and vectors for these toxic substances, which can then enter the food chain, posing a threat to aquatic organisms and human health (Da-Costa *et al.,* 2023).

ii. Disruption of Aquatic Ecosystems

Microplastic pollution can disrupt the delicate balance of freshwater ecosystems (Avazzadeh-Samani and Meunier, 2023). These particles are ingested by a wide range of aquatic organisms, including fish, invertebrates, and even plankton (Avazzadeh-Samani and Meunier, 2023). When ingested, microplastics can cause physical damage to internal organs, hinder digestion, and block the intestinal tract, leading to malnutrition, reduced growth rates, and even death (Narayanan, 2023). This disruption of the food web can have far-reaching consequences on the overall biodiversity and ecological functioning of freshwater ecosystems (Jägerbrand and Spoelstra, 2023).

iii. Threat to Fish and Wildlife

Freshwater fish species are particularly vulnerable to the negative impacts of microplastic pollution (Liang *et al.,* 2023). A study by Çıtar-Dazıroğlu and Bilici (2023) have shown that fish exposed to microplastics experience altered behavior, reduced reproductive success, and impaired immune responses. Additionally, microplastics can accumulate in fish tissues over time, potentially leading to bioaccumulation and biomagnification up the food chain (Çıtar-Dazıroğlu and Bilici 2023). This means that humans consuming contaminated fish may be exposed to elevated levels of microplastics and associated toxic compounds as reported by Osman et al. (2023).

iv. Harmful Effects on Human Health

Microplastics can also pose a threat to human health when present in freshwater bodies (Ghosh *et al.,* 2023). As microplastics enter the water supply through various routes, including surface runoff and wastewater discharge, they can contaminate drinking water sources (Menon *et al.,* 2023; Sharma *et al.,* 2023). The ingestion of microplastics through drinking water or consumption of contaminated food, such as fish and shellfish, has raised concerns about potential health impacts (Unuofin and Igwaran, 2023). While the long-term effects on human health are still being studied, there is evidence linking microplastics to inflammation, oxidative stress, and the potential for the transfer of toxic chemicals to human tissues (Osman *et al.,* 2023).

v. Economic Consequences

The negative impact of microplastic pollution on freshwater bodies extends beyond ecological and health concerns, encompassing economic consequences as well (Khanjani *et al.,* 2023). Contaminated water sources can pose challenges for water treatment facilities, leading to increased costs for water purification processes (Parde and Behera, 2023). Additionally, the decline in fish populations due to microplastic pollution can have detrimental effects on fishing industries and the livelihoods of communities dependent on freshwater resources (Babuji *et al.,* 2023).

SOURCES AND EFFECTS OF MICROPLASTIC WASTE IN NIGERIAN FRESHWATER BODIES

Nigerian freshwater bodies contain microplastic trash in a variety of sizes and shapes, including fibers, films, fragments, pellets, and beads (Okeke *et al.,* 2022; Kumar *et al.,* 2021; Aragaw, 2021). These microplastics are mostly made of polyethylene (PE) and polypropylene (PP) polymers, which are frequently utilized in consumer goods like bags, packaging, and textiles (Aragaw, 2021). Moreover, polystyrene (PS), polyvinyl chloride (PVC), and polyethylene terephthalate (PET), which are used in consumer goods like electronics, toys, and bottles, have been discovered in freshwater bodies of water in Nigeria (Kumar *et al.,* 2021). Microplastics in freshwater bodies in Nigeria range in size from 1 mm to several millimeters, with smaller particles being more prevalent (Khdre *et al.,* 2023). These tiny particles can easily get into aquatic organisms' food chains and build up there, endangering both human and animal health (Mishra *et al.,* 2019).

Moreover, microplastic trash can spread other toxins and dangerous compounds to various areas of the freshwater ecosystem, where they will bioaccumulate and grow in strength (Bencheikh *et al.,* 2023). Overall, the types and quantities of microplastic waste discovered in freshwater bodies in Nigeria point to a variety of sources that may be causing the ecosystems there to become polluted (Kwon *et al.,* 2023). For the purpose of creating effective mitigation strategies that can help safeguard freshwater ecosystems and the livelihoods of the people who depend on them, identifying the sources of microplastic waste is essential. In Nigerian freshwater bodies, there are numerous sources of microplastic waste (Akindele *et al.,* 2019). Lack of recycling and poor waste management practices are frequently to blame for MP contamination in Nigeria as it was shown (Plate I) in Lagos lagoon of Nigeria, and many places of West African nations (Akindele *et al.,* 2019).

Plate I: Source of plastic pollution from a Lagoon in Lagos, Lagos State Nigeria (Ekpei, 2023).

There are very few studies on the amount and distribution of microplastic trash in Nigeria's freshwater bodies (Alimi *et al.,* 2021; Okeke *et al.,* 2022). But the scant research indicates that microplastic trash is pervasive in Nigerian freshwater ecosystems (Okeke *et al.,* 2022).

For instance, a recent investigation into four freshwater systems in Nigeria discovered microplastics in every sample taken (Khdre *et al.,* 2023). In a different study, Sarkar *et al.* (2023) found that the average number of microplastic particles per liter of water was 12.5, with a maximum number of 54 particles per liter. Another study on the Lagos Lagoon, one of Nigeria's largest estuaries, found that the mean concentration of microplastic particles in a liter of water was 14.5 and that the maximum concentration was 86 (Akindele *et al.,* 2020).

Numerous elements, including water currents, wind patterns, and human activities, have an impact on the distribution of microplastic waste in Nigeria's freshwater bodies. For instance, a significant cause of microplastic pollution in Nigeria is the discharge of untreated sewage and solid waste into freshwater bodies. During times of intense rainfall, when runoff transports trash and debris from land-based sources into the rivers, this pollution is frequently made worse (Sakellari *et al.,* 2021).

Furthermore, the location and activities of human settlements can have an impact on how microplastic trash is distributed in Nigerian freshwater bodies. For instance, freshwater systems close to heavily inhabited cities or industrial areas typically have larger concentrations of microplastic garbage than freshwater systems in less populous or rural areas (Akindele *et al.,* 2020).

MICROBIAL BIOREMEDIATION A TOOL IN ADDRESSING MICROPLASTIC WASTE IN FRESH WATER BODIES

The removal of microplastic debris from freshwater habitats via microbial bioremediation is a promising strategy. A variety of contaminants, including plastics, can be broken down and degraded by microbes (Anand *et al.,* 2023). Over other approaches to managing plastic waste, such as physical removal and cremation, microbial bioremediation of microplastic waste in freshwater ecosystems provides a number of benefits. In general, bioremediation is less expensive and uses less energy than other techniques. Also, it has a lower environmental impact and may yield beneficial byproducts (Jeyavani *et al.* 2021). In aquatic environments, especially freshwater bodies, microplastics are extremely problematic and pose a serious risk to food chains. They take a long time to biodegrade, therefore they stay in the ecosystems for a long time (Sharma *et al.,* 2023). This causes microplastics to be ingested by species, where they are transferred and retained down the food chain, posing a serious threat to both aquatic life and people (Azfaralariff *et al.,* 2023; Sharma *et al.,* 2023).

Microplastic waste pollution of water bodies is currently being effectively addressed by bioremediation employing bacteria. The bioremediation of industrial wastewaters is recognized as a very effective approach due to its environmental safety and low cost. The role of microbes in this process is played by bacteria, fungus, and microalgae, just like in industrial wastewater bioremediation (Ghaffar *et al.,* 2023). A quick, easy, environmentally friendly, and socially acceptable bioremediation technique is enzymatic bioremediation. Many bioremediating microbial enzymes, such as oxidases, reductases, transferases, as well as hydrolytic and degrading enzymes, have been discovered and reported in natural sources (Brahmachari, 2023). Microbial enzymes perform a variety of activities, such as mineralization, oxidation, reduction, transformation, and degradation, to reduce or completely eliminate environmental contamination (Yagnik *et al.,* 2023). However, their continued usage is being limited by the poor synthesis of such enzymes. Enhancing enzyme efficiency, activity, stability, substrate selectivity, and shelf life can all help remove pollutants from the environment. These techniques include genetic engineering, immobilization, nanoenzymes, biosensors, and bioleaching (Brahmachari, 2023; Yagnik *et al.,* 2023).

BACTERIA ASSOCIATED WITH THE BIOREMEDIATION OF MICROPLASTIC WASTES

Several bacterial species have the ability to consume microplastic wastes either aerobically or anaerobically. The main factor affecting how quickly and how an ecosystem's polymers degrade is weathering of microplastics (Boots *et al.,* 2019). Rhodobacteraceae, an alphaproteobacteria class member, and the gammaproteobacteria class were the major bacteria in the plastisphere, respectively (Xu *et al.,* 2019). The plastisphere of the microplastics can show evidence of bacterial deterioration through scanning electron microscopy investigation (Xu *et al.,* 2019). One evidence that bacteria and other microorganisms can colonize and breakdown or attack xenobiotics through several distinct metabolic pathways is the adaptation of bacterial communities on the plastisphere in conjunction with a more diverse microbial community (Wright *et al.,* 2021). Chigwada and Tekere (2023) outlined the bacterial and enzymatic biodegradation of plastic in a wide range of synthetic plastics such as polyethylene terephthalate (PET), polyethylene (PE), polypropylene (PP), polystyrene (PS), polyurethane (PUR), polytetrafluoroethylene (PTFE) and polyvinyl chloride (PVC). Plastic biodegradation can be achieved and perform by the genus of *Acinetobacter, Bacillus, Brevibacillus, Escherichia,* Pseudomonas, *Micrococcus, Streptomyces,* and *Rhodococcus* bacteria where enzymes such as proteases, esterases, lipases, and glycosidases are higly involved.

In a study by Habib *et al.* (2020), the growth and biodegradation potential of the Antarctic soil bacteria Rhodococcus sp. ADL36 and Pseudomonas sp. ADL15 on waste polypropylene (PP) microplastics was examined. In addition to the bacterial species, samples of microplastic waste were included in Bushnell Haas (BH) medium for 40 days. The degradation was tracked using the weight loss of the waste PP microplastics, removal rate constant per day (K), and their half-life, and he later recorded a significant degradation activity (Habib *et al.,* 2020). Several researches in Nigeria and other part of the world have reported different group of bactceria associated with the bioremediation of microplastic such as Anwar *et al.,* (2023), Haghighatjoo *et al.,* (2023), Hooda and Mondal, (2023), Nantege *et al.,* (2023), Sun *et al.,*(2023) and Viel *et al.,* (2023).

FUNGI ASSOCIATED WITH THE BIOREMEDIATION OF MICROPLASTIC

Fungi have been used in bioremediation as an environmentally friendly way to break down plastics. Early research reports have shown encouraging results that call for more investigation of these strategies. Of all the microbes that have been researched for bioremediation, fungi have received the least attention (Kumar *et al.,* 2022). Fungi's extracellular and intracellular enzymes break down plastic polymers into monomers and release carbon dioxide and water in aerobic environments, while methane is produced in anaerobic environments (Solanki *et al.,* 2022). Moreover, fungi release hydrophobins, surface proteins that facilitate substrate mobility and bioavailability throughout the bioremediation process (Solanki *et al.,* 2022).

According to the research of Ekanayak *et al.,* (2022), there are eleven groups of plastic-degrading fungus in the fungal kingdoms Ascomycota (Dothideomycetes, Eurotiomycetes, Leotiomycetes, Saccharomycetes, and Sordariomycetes), Basidiomycota (Agaricomycetes, Microbotryomycetes, Tremellomycetes (Mucoromycetes). A brief discussion of the taxonomic location of fungi that break down plastic is presented. The majority of plastic degraders in the kingdom of fungus are found in the Eurotiomycetes, which continues to be the largest among all taxa classified as plastic-degrading fungi (Ekanayak *et al.,* 2022).

In recent years, fungal bioremediation has emerged as a promising eco-friendly solution to address the microplastic pollution problem (Mahesh *et al.,* 2023). Fungi possess unique enzymatic capabilities and interactions with microplastics, enabling them to effectively degrade and assimilate these persistent pollutants (Wang *et al.,* 2023). Fungi have evolved the ability to attach and adhere to microplastic surfaces (Mishra *et al.,* 2023). This initial step is crucial for their colonization and subsequent enzymatic action. Fungal hyphae secrete extracellular polymeric substances (EPS), forming a biofilm-like matrix that facilitates the adherence of fungal cells to microplastics (Andreu and del Olmo, 2023). Attachment not only provides stability but also increases the contact area between the fungal biomass and microplastics, enhancing the degradation efficiency (Debroy *et al.,* 2022; Cai *et al.,* 2023). Fungi are prolific producers of extracellular enzymes, including lipases, esterases, and peroxidases, that play a key role in microplastic biodegradation (Dwivedi *et al.,* 2023). These enzymes act as catalysts, breaking down the polymer chains of microplastics into smaller fragments. Lipases, for example, hydrolyze plastic polymers into fatty acids and monomers, making them more accessible for fungal assimilation or further microbial degradation (Jenkins *et al.,* 2023).

FACTORS INFLUENCING MICROBIAL COMMUNITIES IN FRESHWATER ECOSYSTEMS

Many environmental conditions affect the make-up and variety of microbial communities in freshwater habitats. For the creation of successful bioremediation techniques for microplastic waste in freshwater ecosystems, it is essential to comprehend these factors (Sharma *et al.* 2022).

Nutrient availability is one of the major factors affecting microbial populations in freshwater habitats (Yang *et al.,* 2020). Because they are necessary for microbial development and metabolism, nutrients like nitrogen and phosphorus also have a significant impact on the diversity and composition of microbial communities (Yi *et al.,* 2022). The composition and function of microbial communities can alter as a result of nutrient pollution, such as an excess of nitrogen and phosphorus from agricultural or urban runoff, including a shift towards more damaging or opportunistic species.

Another significant aspect affecting microbial populations in freshwater habitats is temperature. (Wang *et al.,* 2023). For optimal growth and metabolism, certain microbial taxa require distinct temperature ranges, and variations in temperature can cause changes in the makeup of the microbial community. For instance, increasing temperatures in freshwater habitats may boost some microbial species while decreasing the abundance of others (Litchman, 2023).

In freshwater habitats, pH has a significant impact on the microbial communities that exist there. Different pH preferences can be seen in microbial communities, and pH alterations can have an impact on the availability of nutrients and other elements crucial for microbial development and metabolism. The stability and solubility of microplastics can also be impacted by pH changes, which may have an impact on how quickly microbial populations break down the materials (Carini *et al.,* 2020).

Another element affecting microbial populations in freshwater habitats is the presence of organic materials. The availability of organic matter can have a significant impact on the makeup and functionality of microbial communities as a source of energy and nutrients. Changes in the amount of organic matter present can also influence how microbial populations break down and degrade microplastic debris (Azeem *et al.,* 2023).

Generally speaking, a variety of environmental parameters, like as nutrient availability, temperature, pH, and organic matter content, have an impact on the composition and diversity of microbial communities in freshwater environments. Effective bioremediation solutions for microplastic waste in freshwater habitats must take into account the effects of these factors on microbial populations (Ren *et al.,* 2023).

RECOMMENDATIONS FOR FUTURE STUDIES

Therefore it can be understood that microplastic pollution presents a multifaceted threat to freshwater bodies, with wide-ranging ecological, health, and economic impacts (Junaid *et al.,* 2023). Urgent action is required to address this issue, focusing on reducing plastic waste generation, improving waste management practices, and developing effective filtration systems to minimize the release of microplastics into freshwater ecosystems (Liu and Liu, 2023). By mitigating microplastic pollution, environment can be protected as well as the health and integrity of freshwater bodies can be ensured and our environment can be sustainable for future generations (Rockström *et al.,* 2023). The following recommendations can be employed in addressing the microplastic pollution in fresh water bodies:

i. Governments should implement and enforce stricter regulations on the production, use, and disposal of plastic products. This includes bans or restrictions on single-use plastics, microbeads in personal care products, and other sources of microplastics. By reducing the input of microplastics into the environment, this can mitigate their negative impact on freshwater bodies.

ii. Efforts should be made to enhance waste management practices, with a focus on proper collection, recycling, and disposal of plastic waste. Public awareness campaigns can educate individuals about the importance of recycling and the potential consequences of improper waste disposal on freshwater ecosystems.

iii. Investing in research and development of advanced filtration systems can help prevent microplastics from entering freshwater bodies. These systems could be integrated into wastewater treatment plants to capture microplastics before they are released into rivers and lakes.

iv. Encouragement of the use of eco-friendly and biodegradable alternatives to conventional plastics. Support businesses that adopt sustainable packaging practices, reducing the likelihood of microplastic pollution entering the environment.

v. Developing and implementing comprehensive monitoring programs to assess the levels of microplastics in freshwater bodies. And this data can help track trends, identify pollution hotspots, and inform targeted mitigation efforts.

vi. Funding research on the ecological and health impacts of microplastic pollution is essential for understanding the full extent of the issue. Additionally, promoting educational initiatives at schools and in communities can raise awareness about the negative consequences of microplastics on freshwater ecosystems, encouraging individuals to take action.

vii. Collaboration between governments, industries, non-governmental organizations (NGOs), and academic institutions is vital in tackling the issue of microplastic pollution. Public-private partnerships can facilitate the development and implementation of effective strategies to reduce microplastic contamination.

viii. Work with fishing industries to adopt sustainable practices and reduce their contribution to microplastic pollution. This may include promoting responsible fishing methods and encouraging the use of eco-friendly fishing gear.

ix. Organizing community-led cleanup efforts to remove plastic debris from rivers, lakes, and other freshwater bodies. Engaging citizens in such initiatives can foster a sense of environmental stewardship and contribute to a cleaner environment.

x. Microplastic pollution is a global issue that requires international cooperation. Encourage governments and international organizations to work together to develop a coordinated approach to address the challenges posed by microplastics in freshwater bodies.

By implementing these recommendations, the problem caused by microplastic pollution to fresh water bodies can be addressed to mitigate the negative impacts of microplastic pollution on freshwater bodies and safeguards these crucial ecosystems for the well-being of both wildlife and human communities.

CONCLUSION

In conclusion, microplastic pollution in Nigeria's freshwater bodies is an increasing issue, and additional study is required to comprehend the mechanisms underlying microbial behaviors that result in the decomposition of microplastic waste in freshwater bodies. Also, steps should be taken to lessen the amount of plastic waste that enters freshwater bodies, as well as the need for creative approaches to be employed in Nigeria to promote sustainable plastic usage patterns and improve waste management practices.

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