Bioresources Development Conference (BDC26)
NABDA
Journal of Biotechnology Research
ISSN: 1119-0531
Special Issue Vol. 5(2): (2026)

Harnessing Microbial Bio-resources and Biotechnologies for Wealth Creation and Bio-economic Growth in the Niger Delta Region of Nigeria

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Article ID: NJBR-BDC26-A003 | Received: 5 June, 2026 | Accepted: 13 June, 2026

ABSTRACT

The Niger Delta Region of Nigeria is endowed with one of the richest assemblages of biological diversity in West and Central Africa, yet its economy remains tethered almost exclusively to the extraction of crude oil. Decades of petroleum dependence have delivered ecological devastation, soil and water contamination, mangrove loss and depressed agricultural productivity without commensurate and broad-based wealth for the host communities. This review advances the argument that the microorganisms of the region, hitherto regarded largely as agents of disease and spoilage, constitute an undervalued bio-resource capable of underpinning a diversified, sustainable bio-economy. Drawing on the global literature on microbial biotechnology and on regional evidence from the Niger Delta and the wider Nigerian context, the paper examines five complementary value streams: (i) bioremediation of hydrocarbon- and heavy-metal-polluted environments using indigenous hydrocarbonoclastic consortia; (ii) value addition to indigenous fermented foods and agricultural wastes; (iii) microbial inputs for sustainable agriculture, comprising biofertilizers, biopesticides and biostimulants; (iv) production of high-value microbial metabolites such as biosurfactants, enzymes and pharmaceuticals; and (v) the bioenergy potential resident in the region's abundant agro-residues. It is argued that the same molecular tools that have transformed diagnostic and environmental microbiology globally—the polymerase chain reaction, high-throughput sequencing and metagenomics—can be deployed to characterise, conserve and exploit Niger Delta microbial germplasm for wealth creation. The principal constraints, namely weak biorepository infrastructure, fragmented funding, limited human capital and an unfavourable regulatory climate, are discussed, and a roadmap anchored on culture-collection development, public–private partnership and the cultivation of skilled manpower is proposed. Microbial bio-resources offer the Niger Delta a credible pathway out of the resource curse and towards inclusive bioeconomic growth.

Keywords: Bio-economy, Microbial biotechnology, bioremediation, sustainable agriculture, Molecular techniques

INTRODUCTION

Man and the microbial world have co-existed as long as time could tell; whilst some microorganisms strike a symbiotic balance with their hosts, others invade, spoil and destroy (Etebu & Arikekpar, 2016). For the majority of people, the microbial world is largely defined by the adversarial role some play, and the microorganisms of tropical regions have therefore been studied principally as agents of diseases of humans, animals and plants. This emphasis, though understandable, has masked a more important truth of microorganisms as being members of the most versatile and renewable bio-resources available to any economy. Their metabolic versatility underwrites the production of food, fuels, pharmaceuticals, industrial enzymes and agricultural inputs, and their ability to degrade pollutants offers a route to environmental restoration. All over the world, microbial biotechnologies are increasingly recognized as drivers of economic growth and employment creation, contributing directly to the United Nations Sustainable Development Goal 8 on inclusive and sustainable economic growth and decent work for all (Timmis *et al.*, 2017). Bio-economy, in which renewable biological resources are converted into food, feed, bio-based products and bioenergy, is now a conscious and deliberate object of national strategy in countries as diverse as Costa Rica, Malaysia and South Africa (World Economic Forum, 2024).

The Niger Delta Region occupies the southern coastal lowlands of Nigeria and comprises a medley of freshwater swamp forest, mangrove, lowland rainforest and coastal barrier islands. It is a biodiversity hotspot whose warm, humid climate, abundant rainfall and year-round sunshine sustain prolific microbial activity in its soils, sediments and waters. Paradoxically, the region that hosts Nigeria's petroleum wealth remains among its most economically deprived. The extraction of crude oil has, over five decades, generated more than twelve thousand recorded oil spills, leaving wells contaminated with benzene at concentrations far exceeding World Health Organization limits and irreparably damaging native mangrove ecosystems (Hellingwerf and co-workers, as reviewed by McDonald *et al.*, 2020). Agricultural soils have been degraded, fisheries depleted, and public health jeopardised, while the almost exclusive dependence on petroleum has rendered the regional economy fragile.

Whilst not downplaying this reality, this paper sought to depart from the prevailing disease-causing narrative about microorganisms and to present microorganisms of the Niger Delta as a strategic bio-resource. The central proposition is that the deliberate harnessing of microbial bio-resources and biotechnologies can create wealth, generate employment, restore degraded environments and catalyze a diversified bio-economy in the region. The paper first situates the Niger Delta within the global bio-economy debate; it then examines, in turn, the principal value streams through which microbial bio-resources may be exploited—bioremediation, food and waste valorization, sustainable agriculture, high-value metabolites and bioenergy. The enabling molecular toolkit is discussed, followed by an honest evaluation of the constraints and a roadmap for realization.

MICROBIAL BIO-RESOURCES AND THE BIO-ECONOMY: A CONCEPTUAL FRAMEWORK

A bio-resource is any biological material of actual or potential value. Microbial bio-resources comprise the bacteria, archaea, fungi, microalgae, protozoa and viruses, together with their genes, enzymes and metabolic products that can be utilized for economic, environmental or social benefit. Unlike fossil reserves, which are finite and non-renewable, microbial bio-resources are self-renewing, rapidly propagated and astonishingly diverse in their biochemistry. A single gram of tropical soil may harbour billions of microbial cells representing thousands of species, the overwhelming majority of which have never been cultured or characterized. This uncharacterized majority—often described as microbial dark matter—represents a reservoir of novel genes, enzymes and pathways of immense potential value.

The bio-economy, on the other hand, is the aggregate of economic activity derived from the sustainable use of such biological resources. Microbial biotechnology occupies a privileged place within it because microorganisms can be cultivated at scale, engineered for defined functions and harnessed to convert low-value or waste biomass into high-value products. Timmis and colleagues (2017) posited that microbial biotechnologies provide significant potential for improving labour supply, education and investment, and thereby for substantially increasing the demographic dividend of developing economies. Crucially, the bio-economy is not the exclusive preserve of industrialized nations; oil-importing and resource-rich countries alike are leveraging biological resources and emerging technologies to create high-value products from natural and residual biomass (World Economic Forum, 2024).

Yet a sobering asymmetry persists. Low- and middle-income countries are frequently rich in biodiversity but poor in the infrastructure required to conserve and exploit their own microbial resources. Of the several hundred microbial culture collections registered with the World Data Centre for Microorganisms, the largest public-service collections are concentrated in Europe, North America and East Asia, while provision in low- and middle-income countries remains sparse (Ryan *et al.*, 2019). The Niger Delta exemplifies this asymmetry: a region of exceptional microbial wealth with negligible capacity to bank, characterize and commercialize it. Redressing this imbalance is the precondition for any microbial bio-economy, and it is a recurring theme of this review.

BIOREMEDIATION OF POLLUTED ENVIRONMENTS: TURNING LIABILITY INTO ASSET

Nowhere is the case for microbial bio-resources in the Niger Delta more urgent or more compelling than in the remediation of petroleum pollution. The region's soils, sediments and waters have been chronically contaminated by crude oil from pipeline ruptures, operational discharges and,

increasingly, artisanal refining. Conventional physico-chemical clean-up methods are costly, energy-intensive and frequently transfer the contaminant from one medium to another. Bioremediation—the use of living organisms, principally microorganisms, to transform or mineralise pollutants into innocuous end-products—offers a cost-effective, ecologically benign alternative that is particularly well suited to the region.

Indigenous hydrocarbonoclastic microorganisms as a regional asset

A consistent finding across the regional literature is that the favourable tropical conditions of the Niger Delta—abundant hydrocarbon-degrading microbes, adequate rainfall and intense sunshine—make bioremediation a reliable and economical option for oil-spill clean-up (Obieze *et al.*, 2020). Indigenous, or autochthonous, microorganisms are especially valuable because long-term exposure to petroleum has selected for populations that are pre-adapted to the contaminant. Comparative studies confirm that oil contamination selectively enhances the diversity and enzymatic adaptation of native bacteria, equipping them for effective hydrocarbon degradation and underscoring their potential as viable bioremediation agents (Eli *et al.*, 2025).

Numerous genera have been recovered from Niger Delta soils and shown to degrade petroleum hydrocarbons, including *Pseudomonas*, *Bacillus*, *Acinetobacter*, *Rhodococcus*, *Klebsiella*, *Enterobacter* and *Micrococcus*. A bacterial consortium recovered from a heavily inundated, artisanally refined site in the Bie-Ama community of Rivers State—where total petroleum hydrocarbon concentrations exceeded twenty-two thousand milligrams per kilogram, far above the regulatory intervention limit—achieved more than a quarter reduction in hydrocarbons, with several isolates additionally producing biosurfactants and degrading aromatic compounds (Nwankwegu and co-workers, as reported by Obi *et al.*, 2020). In preliminary studies of polluted soil from Okarki, crude-oil degradation rates of individual isolates reached almost ninety-nine per cent, with *Bacillus subtilis* the most efficient degrader (Ekpenyong and co-workers, 2021).

Biostimulation, bioaugmentation and field-scale application

Two broad strategies dominate field practice. Biostimulation supplies nutrients, oxygen or other amendments to stimulate the resident microbial community, whereas bioaugmentation introduces selected exogenous strains. Studies on modelled petroleum-contaminated Niger Delta soils have demonstrated that a mixed culture of *Acinetobacter*, *Rhodococcus* and *Pseudomonas* can achieve very high biodegradation levels, with bioavailability rather than intrinsic recalcitrance frequently being the limiting factor; augmentation with zeolite further improved performance (Agarry and co-workers, 2014). At field scale, landfarming—the addition of fresh unpolluted topsoil followed by periodic ploughing—has been shown to drive enhanced hydrocarbon degradation in the Niger Delta even without inorganic fertiliser addition, with Firmicutes and Gammaproteobacteria dominating the active oleophilic community (Obieze *et al.*, 2020).

Emerging molecular approaches promise still greater efficiency. A horizontal gene-drive strategy, in which a mobile vector carrying a cytochrome P450 monooxygenase gene is transferred into indigenous bacteria, reduced the total petroleum hydrocarbon content of polluted soil by nearly half within sixty days while minimising ecosystem disturbance, the engineered trait persisting only under the selection pressure of the pollutant (McDonald *et al.*, 2020). Such techniques illustrate how molecular biotechnology can amplify the native bioremediation potential of the region's microflora.

From clean-up to wealth creation

Bioremediation transforms an environmental liability into an economic asset along several dimensions. First, it restores degraded land and water to agricultural and fishery productivity, recovering livelihoods. Second, it creates a service industry—soil characterisation, consortium formulation, field monitoring and verification—with attendant skilled and semi-skilled employment. Third, the indigenous strains themselves, once isolated, characterised and banked, become intellectual property and biotechnological products that can be licensed, formulated and sold. The recovery of biosurfactant-producing and enzyme-rich strains during remediation projects (discussed further in Section 6) means that clean-up and product discovery can proceed in tandem. A regional bioremediation industry, grounded in local microbial germplasm and supported by appropriate biorepositories, is among the most immediately realisable elements of a Niger Delta bio-economy.

NABDA
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ISSN: 1119-0531
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INDIGENOUS FERMENTED FOODS AND AGRO-WASTE VALORISATION

The hidden economy of indigenous fermentation

Long before microbiology emerged as a formal science, the peoples of the Niger Delta and the wider Nigerian society were practising sophisticated microbial biotechnology in their kitchens. Indigenous fermented foods are produced almost entirely by the activities of microorganisms and remain, to this day, a household art (Achi, 2005). The Nigerian repertoire is extensive and includes *ogi* (fermented cereal porridge), *garri* and *fufu* (fermented cassava products), *ugba* (fermented oil-bean seed), *iru* and *dawadawa* (fermented locust-bean condiments), *ogiri*, *burukutu* and *pito* (fermented beverages), and *nono* (fermented milk). These products are driven by a diverse microbial community—lactic acid bacteria, yeasts and moulds—that transforms raw substrates into nutrient-rich, digestible and culturally treasured foods (Adebayo and co-workers, as reviewed by Nkhata and others).

The socio-economic significance of this sector is profound but under-recognised. Indigenous fermented food products enhance sustainable development through the provision of employment, poverty alleviation, market improvement and enhanced food security, generating regular income for predominantly female producers using simple, low-cost techniques (Achi, 2005). They are inexpensive, affordable and of deep socio-cultural value, and they are marketed extensively for income generation (Olukunle and co-workers, 2020). The fermentation process itself enriches foods with B-vitamins and bioactive compounds that promote gut health, and the resident microbiomes are increasingly recognised as a source of probiotic strains (Sanusi and co-workers, 2025).

Upgrading tradition through biotechnology

The wealth-creation opportunity lies in converting an informal, artisanal practice into a standardised, value-added industry. Three interventions are pivotal. First, the isolation and characterisation of the functional microorganisms responsible for desirable fermentations permits the development of defined starter cultures, which improve consistency, safety and shelf-life and shorten fermentation times. Second, the deliberate enrichment of traditional products with characterised probiotic strains can reposition them as high-value functional foods: ogi enriched with Lactobacillus or Bifidobacterium, or wara marketed as a protein-rich probiotic cheese, could command premium domestic and export markets (Sanusi and co-workers, 2025). Third, controlled fermentation under regulated conditions, supported by microbiological quality testing, addresses the food-safety concerns—mycotoxin contamination and pathogen carry-over—that currently limit the formal marketability of these products. Realising this potential requires investment in fermentation facilities with temperature and humidity control and in microbiological laboratories—resources presently scarce in the rural Niger Delta (Sanusi and co-workers, 2025). The prize, however, is substantial: a regional functional-foods industry built on indigenous microbial germplasm and indigenous knowledge.

Valorisation of agro-industrial and fruit wastes

The Niger Delta generates large volumes of organic waste that are presently allowed to rot away, representing both an environmental nuisance and a squandered bio-resource. The author's own work on the postharvest microbiology of *Irvingia* species (African mango, bush mango) is instructive. Metagenomic analysis of the fungal community associated with *Irvingia* fruit wastes revealed a predominance of yeasts of the order Saccharomycetales—including *Issatchenkia hanoiensis*, *Pichia manshurica*, *Candida asparagi* and *Saccharomycopsis vini*—organisms well known as efficient fermenters of sugar (Etebu *et al.*, 2018). Such waste-associated microbial communities are candidate bio-resources for the production of ethanol, single-cell protein, organic acids and flavour compounds. More broadly, the principle of valorisation—converting low-value residues such as cassava peel, plantain waste, oil-palm residue and sawdust into fermentable feedstock—offers a route to bioethanol, biogas, mushroom cultivation, animal feed and enzymes. A circular bio-economy, in which waste streams become inputs to microbial conversion processes, aligns environmental management with wealth creation and is especially apposite for an agriculturally productive region burdened by waste.

MICROBIAL INPUTS FOR SUSTAINABLE AGRICULTURE

Agriculture is the principal alternative livelihood to petroleum in the Niger Delta, yet it is constrained by declining soil fertility, pest and disease pressure, and the high cost of imported agrochemicals. Microbial bio-resources can address all three constraints simultaneously, through biofertilizers, biopesticides and biostimulants.

ISSN: 1119-0531
Special Issue Vol. 5(2): (2026)

Biofertilizers and plant-growth-promoting microorganisms

Biofertilizers are preparations containing viable microbial cells—nitrogen-fixing bacteria such as *Rhizobium* and *Azospirillum*, phosphate-solubilising bacteria and fungi, and mycorrhizal fungi—that enhance plant nutrient acquisition and growth (Seenivasagan and Babalola, 2021). They offer a sustainable alternative to chemical fertilizers, enhancing agricultural productivity, soil health and socio-economic development while contributing to carbon sequestration and the mitigation of greenhouse-gas emissions (Daniel and co-workers, 2024). By reducing dependence on imported chemical fertilizers, biofertilizers strengthen national food security and economic resilience, and their production creates opportunities for innovation, research and employment in biotechnology, microbiology and the agricultural sciences (Daniel and co-workers, 2024).

For Nigeria specifically, the potential is considerable: indigenous biofertilizer production has been valued as a substantial substitute for the heavy expenditure on imported fertilizer subsidy, and microbial inoculants are recognised as an economic input capable of increasing crop productivity within an integrated nutrient-management framework (Chukwuneme and co-workers, as reviewed in the Nigerian context). The Niger Delta, with its rich rhizosphere microbiota, is well placed to isolate locally adapted plant-growth-promoting strains tailored to regional crops and soils.

Biopesticides and biological control

Biopesticides exploit microbial antagonists and their metabolites to suppress crop pests and pathogens. Microbial biocontrol agents act through diverse mechanisms—antibiotic production, secretion of cell-wall-degrading enzymes, elaboration of biosurfactants, competition for nutrients and induction of systemic resistance in the host plant (Mishra and co-workers, 2025). *Bacillus subtilis*, for example, synthesises surfactin and iturin lipopeptides that effectively inhibit fungal pathogens by disrupting their cell membranes (Mishra and co-workers, 2025). The author's long-standing research on the biological control of black Sigatoka disease of plantain and banana—a major constraint in Niger Delta plantain markets—demonstrated that plant and microbial extracts can inhibit germ-tube formation in *Mycosphaerella fijiensis*, pointing to indigenous biocontrol options (Etebu, 2012; Etebu and co-workers, 2005).

The substitution of imported synthetic pesticides with locally produced biopesticides would reduce the chemical burden on the region's already stressed soils and waters, protect non-target organisms and create a domestic manufacturing opportunity. Adoption barriers—inconsistent field performance, short shelf-life and the need for specialised storage—are real but surmountable through formulation science and quality assurance (Ortiz-Castro and co-workers, as reviewed by da Silva and others, 2024).

HIGH-VALUE MICROBIAL METABOLITES AND PHARMACEUTICALS

Beyond bulk applications, microorganisms are prolific producers of high-value molecules. Biosurfactants—surface-active compounds produced principally by bacteria—possess the functional properties of chemical surfactants while being biodegradable, low in toxicity and biocompatible, with applications spanning the petroleum, cosmetic, textile, food and agricultural industries (Santos and co-workers, 2023). Biosurfactant-producing strains are routinely recovered from Niger Delta oil-impacted soils during bioremediation studies, so that pollution clean-up and the discovery of commercially valuable surfactant producers can be pursued simultaneously (Obi *et al.*, 2020).

Microbial enzymes—amylases, proteases, cellulases, lipases and laccases—are central to the detergent, food, textile, leather and biofuel industries, and the thermotolerant, halotolerant microbiota of tropical and brackish Niger Delta habitats are a promising source of robust industrial biocatalysts. The region's microflora is similarly a potential reservoir of antimicrobial and other pharmacologically active compounds. The discovery of antibiotics in the 1940s arose directly from the antagonistic interactions of soil microorganisms, and the search for novel antimicrobials—driven by the global crisis of antibiotic resistance—continues to depend on the bioprospecting of untapped microbial diversity (Etebu and Arikekpar, 2016). Tropical soils and sediments of the kind that abound in the Niger Delta remain among the richest and least-explored hunting grounds for such molecules.

The commercial logic of high-value metabolites is favourable to a developing region: production volumes are modest, but unit values are high, and the principal input—microbial diversity—is locally

abundant. The binding constraint is again infrastructural, namely the capacity to screen, identify, optimise and scale up production, which returns the argument to the centrality of biorepositories and skilled manpower.

BIOENERGY FROM MICROBIAL CONVERSION

The Niger Delta's abundant biomass—agricultural residues, food-processing waste, water hyacinth that chokes its waterways, and municipal organic refuse—constitutes a large, renewable and presently wasted energy resource. Microbial conversion technologies can transform this biomass into clean energy. Anaerobic digestion by consortia of hydrolytic, acidogenic, acetogenic and methanogenic microorganisms yields biogas (methane) for cooking, heating and electricity generation, while the digestate serves as a biofertilizer, closing the nutrient loop. Yeast and bacterial fermentation of sugars liberated from cellulosic and starchy residues yields bioethanol, and microbial fuel cells offer a route to direct electricity generation coupled with wastewater treatment.

For a region where energy poverty coexists with environmental degradation, decentralised microbial bioenergy is doubly attractive: it provides off-grid power to remote riverine communities while consuming waste streams that would otherwise pollute. Although the regional research base on bioenergy is still nascent relative to that on bioremediation, the feedstock abundance and the favourable climate make this a strategically important, if longer-horizon, component of the microbial bio-economy.

THE ENABLING MOLECULAR TOOLKIT

The realisation of every value stream described above depends on the capacity to detect, identify, quantify and characterise microorganisms with precision. The polymerase chain reaction has transformed the entire world of scientific research, especially the biological sciences, by enabling the rapid, specific amplification and detection of microbial nucleic acids (Etebu and Pondei, 2013). Quantitative PCR permits the enumeration of target organisms in environmental samples—a technique the author has applied to the quantification of soil-borne pathogens (Etebu and Osborn, 2010)—and is indispensable for monitoring bioremediation progress and verifying the persistence of inoculated strains.

High-throughput sequencing and metagenomics extend this capability to entire microbial communities, allowing the cultivation-independent inventory of the vast uncultured majority. The author's metagenomic surveys of fruit-waste-associated communities illustrate the power of these approaches to reveal functional bio-resources hidden within environmental samples (Etebu *et al.*, 2018). Together with bioinformatic analysis, these tools allow the Niger Delta's microbial diversity to be mapped, its functional potential predicted, and its most promising members targeted for isolation and exploitation. Building local competence in this molecular toolkit—rather than perpetual reliance on foreign laboratories—is therefore foundational to a sovereign regional bio-economy.

CONSTRAINTS TO REALIZATION

The opportunities outlined are substantial, but so are the obstacles. They must be named honestly if they are to be overcome.

- Weak biorepository infrastructure. The region lacks well-resourced microbial culture collections to bank, authenticate and supply its germplasm; without conservation there can be neither reproducible research nor commercial exploitation, and provision in low- and middle-income countries remains chronically deficient (Ryan and co-workers, 2019).
- Fragmented and inadequate funding. Research and development in microbial biotechnology is capital-intensive and long-gestation, yet regional funding is sporadic, project-bound and rarely sustained to the point of commercialization.
- Limited human capital. There is a shortage of personnel trained in modern molecular microbiology, bioinformatics, bioprocess engineering and bioentrepreneurship, and a corresponding brain drain of the few who are trained.
- Inadequate enabling environment. Erratic power supply, poor laboratory infrastructure and weak intellectual-property and biosafety frameworks deter investment, while the access-and-benefit-sharing obligations of the Nagoya Protocol, if unaddressed, can impede the lawful exploitation of indigenous bio-resources (Ryan and co-workers, 2019).

- Weak research-industry linkages. Promising laboratory findings—such as the in-vitro biocontrol leads against black Sigatoka—too often fail to be translated into deployable products for want of a pathway from bench to market (Etebu, 2012).

A ROADMAP FOR A NIGER DELTA MICROBIAL BIO-ECONOMY

Converting potential into prosperity requires deliberate, coordinated action. The following priorities are proposed.

- Establish a regional microbial biorepository. A well-equipped culture collection, networked with international biological resource centers, should be created to isolate, authenticate, conserve and distribute Niger Delta microbial germplasm and to anchor research, training and commercialization.
- Invest in molecular and bioprocess capacity. Equip regional laboratories for PCR, sequencing, metagenomics and pilot-scale fermentation, and embed these capabilities within the universities and research institutes of the region.
- Cultivate human capital. Develop curricula and fellowships in molecular microbiology, bioinformatics, bioprocess engineering and bioentrepreneurship, and create incentives that retain skilled personnel within the region.
- Forge public-private and community partnerships. Engage petroleum operators, who bear remediation obligations, and agribusinesses, who require sustainable inputs, as co-investors, while ensuring that host communities share equitably in the benefits of their bio-resources.
- Prioritize quick wins. Bioremediation of oil-impacted sites and the upgrading of indigenous fermented foods are technically mature, socially embedded and rapidly deployable; early successes here can build confidence, generate revenue and seed the more research-intensive ventures in high-value metabolites and bioenergy.
- Strengthen the policy and regulatory framework. Enact clear biosafety, intellectual-property and access-and-benefit-sharing regulations that protect indigenous bio-resources while encouraging responsible investment.

CONCLUSION

The Niger Delta stands at a crossroads. The petroleum on which its economy has depended has brought wealth to few and devastation to many, and the model is neither sustainable nor inclusive. This review has argued that the region's microorganisms—long dismissed as agents of disease and decay—are in fact a renewable, diverse and largely untapped bio-resource capable of underpinning a very different economic future. Indigenous hydrocarbonoclastic consortia can restore polluted land and water while seeding a remediation industry; the microbial communities of indigenous fermentation can be upgraded into a value-added functional-foods sector; rhizosphere microorganisms can furnish sustainable agricultural inputs; and the wider microbial diversity of the region's soils, sediments and waters is a reservoir of high-value metabolites, enzymes, pharmaceuticals and bioenergy. The molecular toolkit required to characterize and harness these resources is mature and increasingly accessible. What remains is the will to invest in biorepositories, infrastructure, human capital and an enabling policy environment. Should that will be summoned, the microorganisms of the Niger Delta may yet prove a more durable foundation for wealth creation and bioeconomic growth than the oil beneath its soil.

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How to Cite This Article

Etebu, E. and Wood, T.T. (2026). Harnessing Microbial Bio-resources and Biotechnologies for Wealth Creation and Bio-economic Growth in the Niger Delta Region of Nigeria. *NABDA Journal of Biotechnology Research*, 5(2), 28-35.