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INVESTIGATING THE ROLE OF INDIGENOUS SOIL MICROBIAL CONSORTIA IN BIODEGRADATION OF PLASTIC WASTE IN ANAMBRA STATE, NIGERIA

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Abstract

This paper will discuss how plastic-contaminated native soil microbial consortia contained in the state of Anambra, Nigeria can be used to biodegrade plastic (PE) and polyethylene terephthalate (PET) waste materials. The main aim is to identify and describe these consortia, determine its degradation performance at both laboratory and field setup and establish an initial bioremediation procedure. Three locations, namely a landfill site in Onitsha, a dumpsite in Awka and an industrial area in Nnewi were used as the locations of soil sampling which consisted of 30 samples at 0-20 cm depth of the soil in each site. Isolation of microbes entailed enrichment cultures under PE and PET as the only carbon sources and thereafter, 16S rRNA and ITS sequencing was done. Degradation was measured through an 60 days incubation by weight loss and by products GC-MS study. Mesh bags were used in in-situ assessment. Findings determined six consortia, the majority of which included Bacillus spp., Pseudomonas spp., and Aspergillus spp., which produced PE and PET with 12-18% and 10-15% weight loss, respectively, which the ANOVA verified as site-specific. Field degradation achieved 8-12 hence applicability. Intermediates that were identified by GC-MS included aldehydes and carboxylic acids, which were indicators of oxidative pathways. The research paper is relevant to microbiology because it emphasizes the microbial diversity of an area to manage waste sustainably, and it suggests a scalable approach to Nigeria. Limitations are that the incubation period is not very long and that the environmental variables may be hazardous, in future research genetic engineering ought to be researched on so as to make better use of it. On the whole, the indigenous consortia are a promising and environmentally-friendly way of solving plastic pollution in developing areas.

Keywords: Plastic Biodegradation, Microbial Consortia, Polyethylene, Polyethylene Terephthalate, Soil Microbiology, Bioremediation

Introduction

Plastic waste pollution has become one of the most acute current environmental issues of the contemporary world, which is already increased multiple times to more than 400 million tons per year, and it is expected to increase twice as much by 2050. Plastic deposition in soils, rivers, and landfills has very dire environmental impacts in developing nations such as Nigeria because waste management systems are usually poor. A case in point is represented by the Anambra state, in southeastern Nigeria, where industrial, commercial, and domestic sources of plastic waste will lead to a significant amount of plastic waste in urban centers like Onitsha, Awka, and Nnewi. Polyethylene (PE) and polyethylene terephthalate (PET which occupy more than half of plastic wastes are especially recalcitrant as they are so highly molecular weight, hydrophobic and crystalline in nature and thus persist in the environment over centuries. This research examines the use of indigenous soil microbial consortia in biodegrading

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these polymers in order to be able to offer empirical data related to the implementation of microbial-based remediation approaches that can be specific to the local state.

Research into the biodegradation of plastics dates back to the 1970s and 1980s, when the first instances of microbial assault of the synthetic polymers were recorded. An initial investigation by Fields et al (1974) has shown fungal degradation behavior with polyurethane especially the presence of enzymes such as esterases which can break down the bonds in the polymer. On the same note, experiments undertaken by Albertsson (1980) over extended durations regarding low-density polyethylene (LDPE), showed that abiotic-biotic synergies took ages to manifest during the course of the degradation graphs; it was found that the accelerated microbial colonization occurred only after the degradation process had been photo-oxidized. The basis studies made it clear that under certain conditions, microorganisms could use plastics as a source of carbon, but the rates were too low in the absence of pretreatment. Tokiwa et al. (1986) added this by isolating amylolytic bacteria degrading polycaprolactone and the role of specificity of enzyme on the biodegradation process was highlighted. In the 1990s, there was more interest in the variation of one consortia, since in isolation individual strains could be ineffective; yet Potts and Culver (1993) have reviewed small-scale experiments with bacterium-fungal interactions in soil, and observed a notable synergistic depolymerization in mixed cultures.

In contemporary literature, both indigenous microbes associated with polluted locations and transitioning to indigenous microbes have been the recent developments, employing the advantages of metagenomics and omics technologies to gain a deeper insight. As an example, Ojo et al. (2022) extracted fungi in Nigeria, obtaining the polyethylene degradation process in the form of biofilm formation and extracellular activity. The 2020-2025 literature focuses more on consortia than on isolates in the study of microbial diversity; Li et al. (2024), having conducted a review of the literature on microbial diversity of plastic biological films, determined that the prevalent organisms in the marine and terrestrial environments were Proteobacteria and Ascomycota. Sangale et al. (2022) reported increased degradation of the PET microplastics by the bacteria in soil under conditions of natural ecosystems, where consortia outperformed monocultures by 30-40. The results are timely with the findings of Wilkes and Aristide (2017), whose protocols on enrichment cultures were used to guide this research and show that metabolic pathways consisted of cutinases and lipases to degrade PET hydrolysis.

In Nigeria, plastic waste contributes to poor soil conditions, and local reports on environmental conditions in Anambra State shows the piles of plastic waste in the dumpsites adding up to over 100,000 tons every year. Local edaphic factors such as pH, moisture and organic content create an opportunity of using cost-effective solutions in the form of indigenous consortia. Recent studies including that of Adeyemi and Obayomi (2025) on PET-degrading soil bacteria reported a 10-20% weight loss during lab tests and placed is emphasis on the taxonomic diversity through the use of the 16S rRNA sequencing.

In like manner, Muhammad et al. (2025) examined LDPE macro-to-microplastic transformation in soils of the northern part of Nigeria and the isolating bacilli were resilient. The work in these studies is a continuation of the work by Sanni and Ojo (2003) who studied the degradation of polythene of mangrove soils using a microorganism community with modest degradation rates relying on fungal-bacterial synergy. The diversity of the landscapes of sampling sites used in the current study is the following one: In Onitsha landfill, (urban, high-organic load, pH 6.5-7.5), Awka dumpsite, (semi-urban, moderate contamination, pH 5.8-6.8), and Nnewi industrial area (heavy metal co-pollution, pH 6.0-7.0). The microbial communities in soils in this area are affected by anthropogenic pressures, resulting in plastic-adapted communities. Prior knowledge about microbial assimilation was predetermined in

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historical literature about the 1980s, including Darby and Kaplan (1968) study on plasticizer degradation, which explained the superiority of consortia in converting wastes to biofuels. Recent meta-analysts by Mohanan et al. (2020) also prove the advantage of consortia.

Biodegradation mechanisms include biodeterioration and bio fragmentation, assimilation and mineralizations. Earlier reports such as the ones by Guillet (1973) on photodegradable plastics stressed the occurrence of the early abiotic processes, enhanced by the microbial enzymes. Recent studies, such as Yuan et al. (2020), describe PETase and MHETase of Ideonella sakaiensis, of which equivalent enzymes in soil consortia should be sought. Operations are fast in tropical soils such as the Anambra, where the high humidity and temperature have been observed to cause the same processes (Pathak and Navneet, 2017).

The research helps to fill the gaps in localized data, with most of the Nigerian studies being done on isolation with lack of field validation. It allows applying laboratory and field experiments to the scholarship of microbiology, suggesting bioremediation at scale. Different aims are isolating consortia, measuring degradation, the characterization of the pathways, and protocol development, and these results are in line with the sustainable development objectives to mitigate plastic pollution.

Adding to the effects of plastics across the world, the additives such as phthalates found in the plastics leach into soil microbiomes. Newton et al. (2023) associated microplastics with a change in bacterial diversity, decreasing beneficial ones. This has been reflected in destruction of agricultural produce in Nigeria; as the farm lands in Anambra are being affected by pollution. Initial work on polyurethane degradation by microorganisms by Haines (1977) was used to guide enzyme kinetics and recent synthetic consortia engineering by Zhang et al. (2025) demonstrated 50% growth subtlety. However, the indigenous approaches focus on the natural interpretation with respect to soil plastispheres per Deng et al. (2025). The socioeconomic demography of Anambra people including mainly Igbo with urban population density of greater than 1,000/km 2 in Onitsha is a worsening factor to waste production. Microbial demography varies on-site: Local surveys of Onitsha soils reveal oil co-pollution of Onitsha soils by hydrocarbonoclastic bacteria. This research has the use of primary data; that is; collection of data through soil sampling, and it will be representative along gradients.

The literature on consortia synergies is rather strong; Kumar et al. (2025) managed to show bacterial-fungal interactions and their promotion of PP degradation. In Nigeria, isolation on soils of Lagos by Adeleye et al. (recent) resulted in plastic-degraders as previously experienced in Anambra. The advances in the scientific domain influenced the development of historical standards such as Cornell et al. (1987) of starch-blended plastics, turning into pure synthetic degradation.

By integrating GC-MS on byproduct analysis such as in the case of Skariyachan et al. (2017), the pathways such as beta-oxidation are determined. The field aspect of the study deals with laboratory-to-real world discrepancies which have been observed in the critique of initial literature (Swift, 1993).

In general, the study strikes a balance between historical backgrounds and current-day solutions, with a focus on indigenous remedies to the problem of plastic crisis in Anambra.

Theoretical Framework

This paper is based on the theoretical basis of microbial ecology and enzymatic biodegradation using the conceptualizations of syntrophy in consortia and a polymer degradation cascade model. According to

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Atlas and Bartha (1993), microbial ecology acknowledges that soil communities are dynamic networks in which species interact to decompose complex materials in their metabolism. Syntrophic interactions in plastic degradation, where one microbe population forms an externality on another, promotes efficiency as older research on anaerobic digestion demonstrates (Schink, 1997). Gu (2003) has suggested a cascade of degradation in which the stages of beginning colonization to mineralization depend on environmental conditions.

The recent extensions include omics, and Bugg et al. (2011) predict PET hydrolysis by using cutin-like enzymes. In the case of Anambra soils, this framework postulates that native consortia, which are adapted to tropical environments, have more syntrophic diversity, and thus better in degradation than the isolates. Ruiz-Duenas et al. (2021) provided empirical data that makes fungal ligninases associated with plastic oxidation. This combined method can direct the organic composition of the study to predict site-specific differences by edaphic ecology.

Methodology

The study design was an experiment where isolation was carried out in the laboratory and its effectiveness measured in the field using a mixed quantitative-qualitative approach. The selection of the sites was carried out based on high plastic accumulation: the Onitsha landfill (approximately 6.15 -6.78 E), the Awka dumpsite (6.21 -7.07 E), and the Nnewi industrial area (6.02 -6.91 E). At depths of 0- 20 cm, sterile augers were used to collect 90 soil samples (30 each site) and store them at a temperature of 4 o C and processed in less than 48 hours.

Enrichment was used to collect primary data: 10 g of soil inoculated in low salt medium with 1 cm 2 pieces of PE or PET films (carbon source) incubated at 30 C after 4 weeks under shaking (150 rpm). Subcultures singled out consortia, which was determined through 16S rRNA (bacteria) and ITS (fungi) sequencing, using the Illumina MiSeq at a qualified laboratory. The degradation assays were done on 0.5 g plastic in which consortia (108CFU/mL) were added and the weight lost was measured gravimetrically over 60 days. Extracts were analyzed by GC-MS (Agilent 7890A) and standards were aldehydes and acids.

Field experiments were used to put mesh bags (50 µm pore) with 1 g plastic at 10 cm depth that was retrieved after 60 days and in which the bags were washed with 2 ml of ethyl acetate. Descriptive statistics with SPSS, comparative statistics with ANOVA (= 0.05), and thematic analysis of the GC-MS spectra were implemented.

Anambra State Ministry of Environment was contacted and granted ethical permits; wastes were disposed as per the instructions.

Site geo-demography: Onitsha clay-loam, 45 percent organic matter, microbial load 107 CFU/g laboratory clay-loam Onitsha Onitsha Awka Onitsha Onitsha, clay-loam 30 percent organic matter, 107 CFU/g microbial load Onitsha Onitsha, clay-loam 35 percent organic matter, 107 CFU/g with heavy metals Nnewi Onitsha, clay-loam Nnewi, clay-loam Onit

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Results

Three bacterial-dominant (Bacillus subtilis, Pseudomonas aeruginosa) and two fungal (Aspergillus niger) and one mixed consortia were isolated. PE weight loss (15.2 SD 2.1) PET (12.4 SD 1.8) lab highest (18) Onitsha consortia.

Table 1

Characteristics of Sampling Sites and Microbial Loads

Site	Soil Type	pH	Organic Matter (%)	Microbial Load (CFU/g)	Dominant Phyla
Onitsha	Clay-loam	7.2	45	1.2 × 10^7	Proteobacteria, Ascomycota
Awka	Sandy-loam	6.3	30	8.5 × 10^6	Firmicutes, Basidiomycota
Nnewi	Loamy	6.8	35	1.0 × 10^7	Actinobacteria, Ascomycota

Note. Data from initial soil analysis; n=30 per site.

ANOVA showed significant differences ($F(2,87) = 12.45$, $p < 0.01$). Field degradation: 10.5% PE, 8.7% PET. GC-MS identified hexanal and adipic acid.

Table 2

Degradation Efficiency by Consortium

Consortium	Site	PE Weight Loss (%)	PET Weight Loss (%)	Byproducts Detected
C1 (Bacterial)	Onitsha	18.1	14.2	Aldehydes, carboxylic acids
C2 (Mixed)	Awka	13.5	11.0	Esters, alcohols
C3 (Fungal)	Nnewi	14.0	10.5	Ketones, acids

Note. Mean of triplicates; incubation 60 days.

Discussion

Results corroborate literature, with consortia efficiencies exceeding historical single-strain reports (Albertsson, 1980). Synergies align with Kumar et al. (2025). Site variations reflect ecological adaptations, per Deng et al. (2025). Pathways suggest laccase-mediated oxidation, echoing Tokiwa et al. (1986).

Conclusion and Recommendations

Indigenous consortia demonstrate promising biodegradation potential, achieving targeted efficiencies. Recommendations include scaling protocols for state-wide implementation, genetic enhancement, and policy integration for sustainable waste management.

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