



Research Article

Biodegradation of Polyethylene (Macro-plastics to Microplastics)
within the vicinity of Damaturu, Yobe State

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ARTICLE INFO: ABSTRACT

Keywords:

Microbial
degradation,
Polyethylene,
Macro-plastics,
Microplastics,
Plastic waste

In order to address the negative effects of low-density polyethylene (LDPE) pollution on the environment, this study explores the possibility of using microbial degradation as an environmentally benign remedy. Microbial degradation employs microbes and enzymes to break down, detoxify, or transform environmental pollutants. It is a safe and cost-effective procedure. Given its persistence and lack of biodegradability, plastic trash poses serious threats to ecosystems and human health as it accumulates worldwide, especially in soils. An analysis was conducted to identify bacteria with possible biodegradation capabilities and to ascertain the physicochemical characteristics of the soil samples obtained from Damaturu, Yobe State, Nigeria. Important bacterial species, such as *Escherichia coli*, *Klebsiella species*, and *Pseudomonas aeruginosa*, showed encouraging capacities to break down LDPE in particular lab settings, indicating that microbial degradation is a feasible strategy for cutting down plastic waste. According to the results, environmental elements including pH, moisture content, and soil nutrient availability affect how well biodegradation occurs. Although microbial degradation can potentially be a sustainable method of handling plastic waste, the study emphasizes the necessity of more investigation into how to best optimize these processes. Future research might examine the genetic mechanisms of microorganisms to understand how to genetically manipulate microorganisms to produce more useful antimicrobial compounds. Cutting-edge technologies like bioaugmentation can also be used to improve the existing microbial population in a contaminated area to enhance the biodegradation of contaminants. This study offers important new information for creating biologically based, integrated approaches to controlling plastic pollution.

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INTRODUCTION

The plastic bag debate has been long and unending. The worldwide utility of polyethylene is expanding at a rate of 12% per annum. Approximately 140 million tons of synthetic polymers are produced worldwide each year. On one hand, polyethylene bags are a convenient package that is easy to carry around, reusable, and easy to clean. On the other hand, they wreak havoc on the environment because they are not degradable (Schwab *et al.*, 2024). Plastics are of great significance in today's world due to their wide use, which has enabled improvement in the quality of human life through the ease of packaging of foods and other items, thus lengthening their shelf life (Karali *et al.*, 2024). The plastics used include polyethylene, polypropylene, polystyrene, polyvinyl chloride, and polyethylene terephthalate, all of which are high molecular weight polymers whose biodegradability is low (Schwab *et al.*, 2024). Hence, plastics are persistent in the environment and are one of the sources of environmental pollution. Plastics are characteristically inert and resistant to microbial attack and therefore survive for years (Keshu *et al.*, 2024). These disposed plastics are a significant source of environmental pollution, potentially harming delicate life forms. Discarded plastics, what is interesting is that the process of making plastic bags begins with natural gases. While you would expect a more favorable ending to a process that begins naturally, that is not the case. Highly visible is a rapidly increasing percentage of solid waste in landfills, resistant to biodegradation leading to pollution and harmful to the natural environment (Leinonen, 2024). Plastic and polythene contamination of both aquatic and terrestrial environments from waste discharges. Industrial raw materials, manufacturing pellets or fragments of fishing nets, are becoming a future research priority. Since it has been recognized to be an emerging global threat for its multiple (social and environmental) implications (Schwab *et al.*, 2024)

To further improve the environmental compatibility of polymer materials, it is necessary to incorporate as many circular systems as possible in this area. However, at present, only 14% of plastic waste is recycled, while another 14% is incinerated for energy recovery; the remaining 72% is discarded (Cao

et al., 2024). Every year, around 500 billion plastic bags are used worldwide which is a lot of bags. Over one million bags are used every minute and they are damaging our environment. Statistically every man, woman, and child on our planet uses 83 plastic bags every year. That is one bag per person every four and a half days. Out of those 500 billion bags, about 50 billion are used in Nigeria (Hill Malawi *et al.*, 2024; Nayanathara Thathsarani Pilapitiya & Ratnayake, 2024).

Biodegradation is a natural process that occurs in various environments, including soil, water, and air. It involves the breakdown of organic substances by microorganisms such as bacteria, fungi, and other decomposers (Dinakarkumar *et al.*, 2024). These microorganisms utilize the organic material as a source of energy and nutrients, leading to the conversion of complex organic compounds into simpler compounds (Ethiraj *et al.*, 2024). The process of biodegradation is threefold: first, an object undergoes biodeterioration, which is the mechanical weakening of its structure. Then, follows bio-fragmentation, which is the breakdown of materials by microorganisms. Finally, assimilation, which is the incorporation of the old material into new cells (Kanzo *et al.*, 2023). Biodegradation plays a crucial role in the recycling of nutrients in ecosystems and the breakdown of pollutants in the environment (Kumar *et al.*, 2024). Microbial degradation provides a more sustainable alternative to physical and chemical pollutant removal methods. While it may take longer to completely degrade, its environmental benefits and capacity to mineralize complex molecules make it the preferred option in many situations. Physical and chemical procedures, on the other hand, can yield quick results at the expense of environmental safety and increased costs (Jaiswal & Shukla, 2020; Ru *et al.*, 2020).

Biodegradable pollutants are organic substances that can be broken down and metabolized by microorganisms into simpler compounds, such as carbon dioxide, water, and biomass. Unlike persistent pollutants, which remain in the environment for long periods without significant degradation, biodegradable pollutants have the potential to be naturally processed and removed from the environment over time through microbial action (Pinaeva & Noskov, 2024).

Non-biodegradable pollutants are substances that resist degradation by natural processes over extended periods, persisting in the environment and accumulating in ecosystems (Kothawade et al., 2024). These pollutants can have detrimental effects on environmental quality, human health, and ecological balance. Non-biodegradable pollutants pose significant environmental, health, and socioeconomic challenges due to their adverse effects. These pollutants can accumulate in soil, sediment, water bodies, and living organisms through bioaccumulation and biomagnification processes. Effective management strategies, regulatory measures, and scientific innovations are essential for mitigating the impact of non-biodegradable pollutants and promoting sustainable development (Fayshal, 2024). Plastic pollution is a significant environmental concern worldwide. Most conventional plastics, such as polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyethylene terephthalate (PET), are non-biodegradable and can persist in the environment for hundreds to thousands of years (Chukwuemeka Udekwu et al., 2024). As such finding an efficient method of eradicating such pollutants from our environment is imperative and required urgently. Hence, this study explores the potential of using the microbial degradation method as an efficient method of degradation of polyethylene in our environment (Abraham et al., 2017; Usha et al., 2011). To the best of our knowledge, in this part of the world, a study of this kind has not been reported before. As such, this work provides valuable additional information for developing integrated, biologically based strategies to reduce plastic pollution.

EXPERIMENTAL

Soil samples for isolating microorganisms to assess their ability to degrade plastics were collected within the vicinity of Damaturu, Yobe State North Eastern Nigeria. The area is located between latitude 11.7470°N, and longitude 11.9662°E. It is bordered in the east by Borno States, in the west by Bauchi and Jigawa States, and in the North by Diffa and the Zinder Region in Niger Republic. Soil samples from three different locations about a few meters apart (Sabon Fegi, Nayi-Nawa, Yobe State University and low-cost) including those that have harbored waste plastic and polyethylene for different lengths of time, as

well as those that visibly had not encountered any plastic waste, were used for this study.

The soils with physical contact with polyethylene were sampled at 5-10 cm depth. Surface soils exposed to sunlight were avoided because any observation of degradation of waste plastics might be mainly due to UV radiation, rather than micro-organisms. The soil samples were collected in June 2024 and taken to the laboratory for physicochemical analysis. In the laboratory, a portion of soil samples were dried, ground, and sieved through a 2 mm sieve for physicochemical characterizations. Soil temperature, pH, and Electrical conductivity were measured at the collection site. The dissolved soil sample was subjected to further analysis of some essential parameters including % Nitrate, % Phosphates, % organic carbon, % organic matter, and % moisture content.

The polyethylene bag samples used for this study are low-density polyethylene with physical contact with soils and those 5 to 10 cm depth in soil were sampled. Three (3) samples each were collected from four (4) different areas in Damaturu, making 12 samples altogether. The areas were Sabon Fegi, Nayi-nawa, Low-cost, and Yobe State University. The polyethylene bag samples were also collected in June 2024 and taken to the laboratory to test their degradation rate. Bacteria were subsequently tested for their ability to degrade the sample. The Polyethylene bags were cut into 15 small strips with varying weights.

Reagents

Sodium salicylate (99.5%) and potassium dichromate (99.5%) were all obtained from BDH Chemicals. While sulfuric acid (99.5%) and phosphoric acid (85%) were obtained from Guandong Guanghua Sci-tech Co. Ltd. However, ferrous sulfate (99.5%) and diphenylamine (99.5%) were obtained from Sigma-Aldrich respectively.

Determination of Physicochemical parameters of the soil sample

Determination of Total Nitrogen

Total nitrogen was determined by the modified Kjeldahl digestion-distillation method. 1 g of soil was mixed with 25 ml (65%) concentrated sulfuric acid in a digestion vessel. 1.5 g of sodium sulfate and 1.0 g of copper sulfate were added. The mixture was digested using a KDN-04C digestive furnace at 350°C until the

mixture turned greenish (about 3 hours). The digest was diluted to 50 mL with distilled water. 25 mL of the diluted digest was mounted to the Kjeldahl distillation unit (ZDDN-11) and to it 40 mL of 40% sodium

hydroxide was added. The mixture was distilled for 15 mins. About 150 mL of the distilled was collected into a solution of 2% boric acid. The mixture was titrated with 0.5 molar HCl.

$$\% \text{Nitrogen} = \frac{(V_1 - V_2) \times N \times 0.014 \times 100}{M}$$

V_1 = Volume of the dilute HCl

V_2 = Volume of Reagent blank consumed

N = Concentration of the Acid (HCl)

0.014 = 1 N HCl standard liquid 1 mL is equal to the quantity of the N g

M = Mass of sample used

Determination of Total Phosphate

2 g of soil samples were scooped and weighed into a 50 mL Erlenmeyer flask, tapping the scoop on the funnel to remove all of the soil from the scoop. 20 mL of extracting solution to each flask was added and shaken at 200 rpm for 5 minutes at 27°C. ~200 mg of charcoal was added to each flask to obtain a colorless filtrate. Whatman No. 42 filter paper was used to extract the filtrate. The Filtrates were analyzed for phosphate in digital colorimeter model S1073 using a blank and standards prepared in the Bray P-1 extracting solution.

Determination of moisture content

Crucibles were weighed. An Aliquot of approximately 50 g of moist soil was transferred into each Crucible and was reweighed. Hence, the moist weight of the soil sample was known. The soil samples were dried in an oven at 105 °C for 24 hours. Crucibles were removed from the oven, allowed to cool, and reweighed. The dry weight of the soil was known. Walkley-Black (1947). The moisture content was obtained using the following formula:

$$\% \text{ Moisture Content (MC)} = \frac{\text{Weight of moist soil (M)} - \text{Weight of dry solid (D)}}{\text{Weight of dry solid}}$$

Determination of Organic Matter

To determine the organic matter contents, 1 g of soil samples were transferred to 250 ml Erlenmeyer. Then 10 ml of 1N $K_2Cr_2O_7$ and 10 ml of concentrated H_2SO_4 were added respectively. After 30 minutes, 50 ml of deionized water, 3 ml of concentrated H_3PO_4 , and 0.5 ml of 1% diphenylamine indicator were added. Then, titrated slowly with 1N $FeSO_4$ solution up to a green color endpoint.

Determination of organic carbon

Organic carbon was determined by the wet digestion (oxidation) method. 0.5 g soil sample, 10 ml of 1 M $K_2Cr_2O_7$, and 25 ml of concentrated H_2SO_4 were added and allowed to stand for 30 minutes to oxidize organic carbon. 200ml of water was added to cool the mixture followed by the addition of 10 ml of phosphoric acid. The reaction was carried out at room temperature. The amount of $K_2Cr_2O_7$ reduced was used to estimate the organic carbon content of the soil by the titration of

excess dichromate against a 0.5 N ferrous sulfate solution indicator using diphenylamine.

Determination of Soil pH and Temperature

Soil pH was measured using Hanna Direct soil portable meter model HI99121. While soil temperature was measured using Hanna Digital thermometer model HI98501.

Medium for isolation of bacteria

The medium used for bacteria isolation was nutrient agar prepared by mixing the following; 7g of nutrient agar was dissolved in 250ml distilled water. The mixture was boiled before sterilization by autoclaving at 1.05 kg/cm² (15 lb./sq.in) and 121°C for 15 minutes. The sterile medium was left to cool up to about 50°C and then poured into sterile Petri dishes and left to solidify. Cooled Petri dishes containing the medium were aseptically stored at 4°C until used (Erkmen, 2021c; Harrigan & McCance, 1966; Sandle, 2019).

Gram-staining of bacteria

The bacteria smears were prepared on microscopic slides. The slides were cleaned

with alcohol, followed by drying using paper towels. The prepared slides were labeled by drawing a circle on the underside of the slide using a marker pen to clearly designate the area in which the smear will be prepared. The loop to be used was sterilized by heating it on a burner and cooled. With a sterile cooled loop, a drop of sterile normal saline solution was placed on the slide. The loop was sterilized and left to cool, and a very small sample of a bacterial colony was picked up and gently stirred into the drop of normal saline on the slide to create an emulsion that was subsequently air-dried. After the smear was air-dried, the slides were passed through the flame of a Bunsen burner two to three times with the smear-side up ready to be stained. The fixed smear was flooded with crystal violet solution and allowed to stand for one minute. The crystal violet was rinsed off with distilled water, and the slides were then flooded with an iodine solution and allowed to remain for one minute. The iodine solution was rinsed off with distilled water, and the slides were flooded with acetic acid (decolorizer) for five seconds. The decolorizer was rinsed off with distilled water and the slides were flooded with safranin and allowed to stand for 30 seconds, after which safranin was rinsed off with distilled water. The slides were air-dried by placing them in an upright position and smears were viewed using a light-

microscope under oil immersion at 1000x magnification.

Microbial degradation of plastics under Laboratory conditions

To assess this, the pre-weighed discs of 1 cm diameter prepared from low-density polythene bags were aseptically transferred to the conical flask containing 50 ml of culture broth medium, and inoculated with different bacterial species separately. Nutrient broth medium was used for bacteria. Control was maintained with plastic discs in the microbe-free medium. Five flasks were maintained for each treatment and left in an incubator for weeks. After measuring and weighing at several-day intervals. The low-density polyethylene discs were collected, washed thoroughly using distilled water, shade-dried, and then weighed for final weight. From the data collected, weight loss of the low-density polythene bags was calculated.

RESULT AND DISCUSSION

Physicochemical Parameters of the Soil samples

The soil samples used for this analysis were sandy soil taken from three different locations. They were subjected to physicochemical analysis to find the characteristics of each soil sample. Table 1 presents the result of the physicochemical analysis of the soil samples used in this study.

Table 1: Physicochemical parameters of the soil samples

Soil sample	pH	Nitrate (%)	phosphorus (%)	Organic carbon (%)	TDS (%)	Organic matter (%)	Moisture content (%)
Sample A	5.67±0.8	0.6±0.02	2.00±0.1	2.95±0.4	0.25±0.01	4.50±0.25	11.25±0.65
Sample B	5.89±0.6	0.84±0.02	2.51±0.3	2.46±0.7	0.28±0.3	2.90±0.5	15±1.07
Sample C	7.2±0.3	8.5±0.9	11.85±0.53	1.98±0.5	0.14±0.1	3.40±0.15	15±0.98

pH

Soil pH is a critical factor influencing nutrient availability and microbial activity. A pH of 5.67 and 5.89 indicates that samples A and B are slightly acidic soils while a pH of 7.2 indicates sample C is neutral to slightly alkaline soil. An acidic or slightly acidic soil affects nutrient availability depending on the soil's acidity level. In slightly acidic soils, macronutrients like nitrogen and phosphorus can still be reasonably available, though certain micronutrients such as iron and manganese become more soluble, which can

be beneficial for some plants (Warke & Wakgari, 2024). However, phosphorus may start becoming less available because it can form insoluble compounds under acidic conditions (Espinosa et al., 2024).

Usually, slightly acidic or alkaline soil pH enhances and improves the biodegradation ability of soil. However, acidic soil pH leads to less biodegradation ability of the soil (Omenna et al., 2024). So it can be deduced that sample C may be more appropriate for the biodegradation of the polyethylene bags.

It was reported that many bacteria species, including *Pseudomonas fluorescens* and *P. aeruginosa*, can degrade polyethylene in aqueous environments at pH 7 and 30-37 °C. The acidic pH has a significant negative impact on their activities when compared to the alkaline situation (Hussain & Khudair, 2015). Likewise, under slightly alkaline conditions (pH 7.5) at 26 °C, a bacterial consortium (*Pseudomonas putida*, *Pseudomonas fluorescens*, *Vibrio alginolyticus*, *Pseudomonas aeruginosa*, *Pseudomonas stutzeri*, *Flavobacterium species*, and *Anabena species*) were reported to degrade LDPE (Veethahavya *et al.*, 2016).

Nitrogen content

Nitrate (NO₃⁻) is a crucial form of nitrogen that is readily absorbed by plants. The nitrate content of 0.6% suggests that sample A has moderate nitrogen availability and the nitrogen level of 0.84% indicates that sample B has a good nitrogen supply, supporting vegetative growth, especially leaf development. A nitrate concentration of 8.5% indicates that sample C has an exceptionally high nitrogen (Grzebisz & Biber, 2024).

Nitrogen can increase the DNA synthesis and activity of fungi that break down pollutants, as well as the membrane integrity of bacteria that do so. Additionally, nitrogen can improve the structure of the soil's bacterial community, which can influence the soil nitrogen cycle and increase enzyme activity (Thirumalaivasan *et al.*, 2024). When it comes to speeding up the breakdown of organic contaminants, organic nitrogen may be more efficient than inorganic nitrogen. Meanwhile, it was reported that Nitrogen metabolism supports bacterial strains in degrading and metabolizing Polyethylene (Peixoto *et al.*, 2022).

Phosphorus content

Phosphorus is essential for energy transfer in plants (ATP) and is vital for root development and flowering. A phosphorus content of 2.00% in sample A represents a high concentration, which is beneficial for early root formation and overall plant vigor. The phosphorus level of 2.51% in sample B is considered high, meaning that the soil can support strong root and fruit development. The phosphorus content of sample C was 11.85% which is extremely high, much higher than typical agricultural needs which may cause nutrient imbalances (Bhat *et al.*, 2024).

The slightly acidic pH of samples A and B could reduce phosphorus availability by forming less soluble compounds like aluminum phosphates. Excessive phosphorus can interfere with the uptake of other nutrients such as zinc and iron, potentially leading to deficiencies in these elements (Bhat *et al.*, 2024). Moderate to low content of phosphorus is required for enhanced biodegradation in soil (Ou *et al.*, 2024). As such sample A will be more desirable in terms of the phosphorus content of soil for biodegradation.

Organic carbon content

Organic carbon is a key component of organic matter and is important for maintaining soil health. A soil organic carbon content of 2.95%, 2.46%, and 1.98% for samples A, B, and C respectively can be considered good, as it suggests a healthy balance of carbon inputs and outputs. Organic carbon acts as a reservoir for plant nutrients and helps in improving soil structure and microbial activity. Soils with higher organic carbon are generally more resilient to erosion and degradation. A low value of soil is healthy for soil microbial processes, enhancing the breakdown of organic materials and improving nutrient availability (Paul, 2016). It was demonstrated that plastics release dissolved organic carbon (DOC) into the surrounding seawater, increasing the activity of heterotrophic bacteria. According to the estimations, marine plastics leach up to 23,600 metric tonnes of DOC per year around the world. Approximately 60% is available for microbial utilization in less than 5 days (Romera-Castillo *et al.*, 2018). Likewise, it was reported that microplastics dissolve at the sea surface due to sunlight-driven photochemistry, dissolved organic carbon is therefore produced as microplastics photo-dissolve in sunlight. This photo-produced dissolved organic carbon impacts marine bacteria (Zhu *et al.*, 2020).

Organic matter

Organic matter improves soil structure, water retention, and nutrient availability, and serves as a food source for soil organisms. Soils rich in organic matter tend to have better moisture retention and cation exchange capacity (CEC), improving their ability to supply nutrients to plants (Murphy, 2015). Organic matter content of 4.50% and organic matter content of 3.40% (samples A and C) is a strong indicator of fertility and biological activity. The 2.90% organic matter content moderately contributes

to soil fertility and nutrient cycling. Organic matter supports microbial communities that play a key role in breaking down organic residues and releasing nutrients like nitrogen and phosphorus. Soils rich in organic matter can store carbon more effectively, reducing atmospheric carbon dioxide levels (Khatoon et al., 2017).

Moisture content

Moisture content affects the physical, chemical, and biological properties of soil. A moisture content of 11.25% suggests moderate water availability, which supports microbial activity and root function. Sample B and C have a moisture content of 15% which is relatively high, indicating that the soil retains a significant amount of water. It is beneficial for crops that require consistent moisture, but it can also increase the risk of waterlogging or leaching, especially for nitrate (Kaur et al., 2020)

Proper moisture is critical for nutrient uptake and overall plant health. Moisture levels must be monitored, particularly in regions prone to drought or excessive rainfall. Soil moisture directly affects plant growth by influencing nutrient uptake and microbial activity (Khatoon et al., 2017)

3.1.7 Total dissolved solids

Total dissolved solid (TDS) measures the combined content of all inorganic and organic

substances dissolved in the soil's water. A TDS value of 0.25% and 0.28% are low, indicating that the soil does not have high levels of soluble salts, which is generally positive for plant health. High TDS levels can result in saline conditions that reduce plant growth due to osmotic stress (Saiyood et al., 2012). The TDS of 0.14% indicates a low concentration of dissolved salts in the soil, which is favorable for most crops. High salinity in soil can hinder water absorption by plants, leading to osmotic stress and reduced plant growth. The low TDS level suggests the soil is not saline and will support healthy plant development. Low salinity levels are critical for crops sensitive to salt, such as beans and strawberries. However, for crops that are more tolerant to salinity, such as barley, this level of TDS poses no risk (Hailu & Mehari, 2021).

Characterizations of the bacteria

Characterization aims to obtain a complete collection of data describing the properties of a given microorganism for easy description and identification. Table 2 presents the types and characters of the bacteria used in this study. It can be seen from the table that 3 gram-negative bacteria (*Pseudomonas aeruginosa*, *Klebsiella spp*, *Escherichia coli*) and 2 gram-positive bacteria (*Staphylococcus epidermis*, *Staphylococcus aureus*) were use

Table 2: Properties of the various bacteria used in this study

Bacterium	Gram Reaction and Morphology	Habitat	Pathogenicity	Antibiotic resistance
<i>Pseudomonas aeruginosa</i>	Gram-negative, rod-shaped	Soil, plants, and human skin	Opportunistic pathogen. Cause pneumonia and sepsis	Multidrug-resistant
<i>Klebsiella spp</i>	Gram-negative, rod-shaped	Soil, Human guts, and water	Causes pneumonia, UTIs, liver abscesses, and bloodstream infections.	Rising incidence of carbapenem
<i>Staphylococcus epidermis</i>	Gram-positive, cocci-shaped	Human skin and mucous membrane	Associated with infections on medical devices and implants	Methicillin resistance strains
<i>Staphylococcus aureus</i>	Gram-positive, cocci-shaped	Skin, Nasal passages, and mucous membrane	Causes skin infections, sepsis, endocarditis and pneumonia	Methicillin resistance
<i>Escherichia coli</i>	Gram-negative, rod-shaped	Human guts, soil and water	Causes UTIs, Food born illness and gastrointestinal infections	Rising rates of extended spectrum

Degradation ability of the bacteria***Pseudomonas aeruginosa***

Table 3 presents the results of the degradation of LDPE by *Pseudomonas aeruginosa*. The first three LDPE samples placed in the first medium had a total weight of 0.7829g and a total weight loss of 0.2272g. The bacteria

reduced the weight of the first three samples by 0.5557g, with an average weight loss of 0.1852g. This indicates that the first medium containing *Pseudomonas aeruginosa* was capable of degrading LDPE under controlled lab conditions. A whopping 74.81% weight loss was observed for the sample

Table 3: Degradation of polyethylene by *Pseudomonas aeruginosa*

Number of samples	Days/Temperature				
	0day/28°C	3/28°C	7/32°C	10/36°C	14/40°C
Sample 1	0.5429g	0.4018g	0.3540g	0.2534g	0.0908g
Sample 2	0.1130g	0.1030g	0.1002g	0.0952g	0.0608g
Sample 3	0.1270g	0.1101g	0.0985g	0.0822g	0.0756g

Klebsiella spp

The LDPE samples in the second medium containing *Klebsiella spp.*, had a total weight of 0.6961g and a total weight loss of 0.2272g, as presented in Table 4. The bacteria reduced the weight of the LDPE samples by 0.4689g,

with an average weight loss of 0.1563g. This indicates that the second medium containing *Klebsiella spp.* was also capable of degrading low-density polyethylene under controlled lab conditions. A percentage weight loss of 67.37% was observed for *Klebsiella spp*

Table 4: Degradation of polyethylene by *Klebsiella spp*

Number of samples	Days/Temperature				
	0day/28°C	3/28°C	7/32°C	10/36°C	14/40°C
Sample 1	0.3837g	0.3654g	0.3095g	0.2775g	0.0998g
Sample 2	0.1012g	0.0906g	0.0837g	0.0807g	0.0773g
Sample 3	0.2117g	0.1985g	0.1188g	0.1082g	0.0501g

Staphylococcus epidermis

Table 5 presents the result of the third media containing *Staphylococcus epidermidis*. It can be seen that there are no significant degradation abilities, as the weight of the samples remained constant throughout the testing period. This is an indicator that *Staphylococcus epidermidis* is not suitable for degradation of LDPE. Degradation of LDPE by *Staphylococcus epidermidis* is difficult and rarely reported. However, *Staphylococci* have been known to survive on plastic materials like polyester and polypropylene for almost two to three months (Beard-Pegler et al., 1988). *Staphylococcus epidermidis* is known for its capacity to build biofilms on plastic surfaces, such as polyethylene. This biofilm is predominantly made of poly-N-acetylglucosamine (PNAG), which acts as a

protective barrier, making it difficult for external agents to enter and break down the polyethylene underneath. The biofilm not only aids in adhesion but also provides a microenvironment that can protect the bacteria from harsh environments, further complicating disintegration efforts (Gökçen et al., 2013). Meanwhile, commercially available extruded LDPE packaging material was reported to be degraded by the P(3-HB) accumulating organism BP/SU1 of the *Staphylococcal epidermis*. The degradation was shown by the growth of the bacterial strain in a nutrient medium separated from the inoculums through LDPE film. This was the first evidence, according to the authors, of enzyme-mediated biodegradation of commercial-grade petrochemical-based polyethylene after heat treatment alone (Chatterjee et al., 2010).

Table 5: Degradation of polyethylene by *Staphylococcus epidermis*

Number of samples	Days/Temperature				
	0day/28°C	3/28°C	7/32°C	10/36°C	14/40°C
Sample 1	0.2424g	0.2424g	0.2424g	0.2424g	0.2424g
Sample 2	0.1258g	0.1258g	0.1258g	0.1258g	0.1258g
Sample 3	0.1606g	0.1606g	0.1606g	0.1606g	0.1606g

Staphylococcus aureus

Likewise, In the result of the fourth media (shown in Table 6), containing *Staphylococcus aureus*, there is no change in the weight of the samples signifying no degradation has

occurred on the sample. This signifies that *Staphylococcus aureus* like *Staphylococcus epidermidis* is not suitable for degrading LDPE.

Table 6: Degradation of polyethylene by *Staphylococcus aureus*

Number of samples	Days/Temperature				
	0day/28°C	3/28°C	7/32°C	10/36°C	14/40°C
Sample 1	0.1375g	0.1375g	0.1375g	0.1375g	0.1375g
Sample 2	0.7038g	0.7038g	0.7038g	0.7038g	0.7038g
Sample 3	0.2685g	0.2685g	0.2685g	0.2685g	0.2685g

Escherichia coli

Table 7 shows the result of the last medium, containing *Escherichia coli*. A total weight of 0.6311g and a total weight loss of 0.2385g was observed. With an average weight loss of

0.1308g. This indicates some level of degradation by *Escherichia coli* under controlled lab conditions. A percentage weight loss of 62.19% was recorded for *Escherichia coli*

Table 7: Degradation of polyethylene by *Escherichia coli*

Number of samples	Days/Temperature				
	0day/28°C	3/28°C	7/32°C	10/36°C	14/40°C
Sample 1	0.1200g	0.1139g	0.0884g	0.0793g	0.0657g
Sample 2	0.3424g	0.3378g	0.3158g	0.2730g	0.1130g
Sample 3	0.1687g	0.1400g	0.0939g	0.0868g	0.0568g

CONCLUSIONS

The research underscores the urgent need for sustainable solutions to the growing plastic waste problem, with a focus on the environmental impact of LDPE) through an exploration of pollution types, the study highlights the persistent nature of non-biodegradable plastics in ecosystems and the detrimental effects on biodiversity and human health. The investigation into microbial

degradation of LDPE in soil samples from Damaturu, Yobe State, Nigeria, revealed promising results, particularly the ability of certain bacterial species like *Pseudomonas aeruginosa*, *Klebsiella spp*, and *Escherichia coli* to break down LDPE under specific conditions. The percentage weight loss of the sample when *Pseudomonas aeruginosa* was used is 74.81%, while for *Klebsiella spp* is 67.37%, and for *Escherichia coli* is 62.19%.

However, there is 0% weight loss in the presence of *staphylococcus aureus* and *staphylococcus epidermis*.

The findings suggest that microbial degradation could play a significant role in managing plastic waste, offering a potential path toward reducing the environmental footprint of plastics. However, the study also emphasizes the complexity of this process, influenced by environmental factors such as soil composition, moisture, and temperature. Overall, this research contributes valuable insights into microbial biodegradation as a viable component of plastic waste management strategies. It also highlights the need for continued research and development to enhance the efficiency of these biological processes and integrate them into broader environmental management frameworks. UV irradiation or chemical oxidation can change the structure of polyethylene, making it more susceptible to microbial attack by producing lower molecular weight compounds that

bacteria can metabolize. Likewise, advances in molecular biology enable the generation of genetically engineered microbes that can boost biodegradation rates by expressing specialized enzymes optimized for plastic breakdown. Finally, using consortia of different microbes may boost degradation efficiency by complementing each other's metabolic capacities and enhancing the breakdown process through synergistic interactions.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

ACKNOWLEDGMENT

This work was supported by Yobe State University (YSU), Damaturu Yobe State Nigeria. The authors are grateful to Mal. Idris Garba and Mal. Alkali of Chemistry Research Laboratory I for their support in conducting this research.

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