SOLID WASTE RECYCLING USING MICROORGANISM FOR ENVIRONMENTAL CONSERVATION

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Abstract

This research focuses on transforming waste materials into valuable substances using microorganisms to promote environmental restoration. Microbes play a significant role in ecosystem recovery, particularly through their complex interactions with sewage. Bacteria, for example, are crucial in various stages of nutrient cycling by facilitating nutrient recycling. Samples were collected from landfill sites, and 25 agar plates were prepared under sterile conditions. Microorganisms also show considerable potential for bioremediation, enabling waste detoxification, extraction, and transformation of contaminants in sewage. These microbes further support rhizoextraction and rhizodegradation, enhancing the purification of polluted environments. The findings reveal that heavy metals constituted the highest proportion (44%) of waste samples, while paper waste accounted for the least (5%). The microbes demonstrated optimal degradation efficiency at temperatures between 20°C and 30°C. This study highlights the feasibility of leveraging microorganisms for sustainable environmental restoration while mitigating unintended consequences.

Keywords: Bioremediation, Microbes, Sewage, Extraction, Sustainable Environment.

Introduction

Solid waste management is one of the most pressing environmental issues faced globally, driven by rapid urbanization, industrialization, and population growth. According to the World Bank, approximately 2.01 billion tonnes of municipal solid waste are generated annually worldwide, with this number expected to grow to 3.4 billion tonnes by 2050 if current practices persist (World Bank, 2022). Improper management of this waste leads to severe consequences, including pollution of land, water, and air, as well as greenhouse gas emissions that exacerbate climate change. The need for sustainable and eco-friendly waste management solutions has become more urgent than ever, and microorganisms have emerged as a vital tool in addressing these challenges. Microorganisms, which include bacteria, fungi, and other microscopic organisms, play an essential role in the natural recycling of organic matter. Their ability to degrade complex materials into simpler compounds can be harnessed for managing various types of solid waste, including organic waste, plastics, and hazardous materials. Unlike conventional waste management practices such as landfilling and incineration, microbial recycling offers a more sustainable approach by reducing environmental pollution, conserving natural resources, and promoting circular economies (Ayilara & Babalola, 2023).

The incorporation of microorganisms into solid waste recycling processes has shown significant promise in recent years. Advances in biotechnology and microbiology have enabled researchers to identify specific microbial strains capable of degrading a wide range of waste materials. For example, the use of effective microorganisms (EM) in composting has revolutionized organic waste management by accelerating the decomposition process and improving the quality of compost produced (Ab Muttalib et al., 2016). Similarly, novel microbial systems have been developed to address the persistent challenge of plastic pollution. Recent discoveries, such as plastic-degrading bacteria and

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fungi, have opened new avenues for mitigating the environmental impact of synthetic polymers (Reuters, 2024). Moreover, microbial recycling extends beyond waste degradation to include the transformation of waste into valuable resources. Through processes such as anaerobic digestion, microorganisms can convert organic waste into biofuels, reducing dependence on fossil fuels and contributing to renewable energy production (Ayilara & Babalola, 2023). Another innovative approach involves the upcycling of waste materials into marketable products. For instance, researchers have used genetically engineered bacteria to transform fatbergs into fragrances, demonstrating the economic potential of microbial recycling technologies (NY Post, 2025).

While the potential of microorganisms in solid waste management is immense, challenges remain. The efficiency of microbial degradation depends on factors such as waste composition, environmental conditions, and the specific strains used. Additionally, the introduction of genetically modified organisms (GMOs) for waste recycling raises ethical and ecological concerns, necessitating rigorous risk assessments and regulatory oversight. Public acceptance of these technologies is another critical factor, highlighting the importance of education and transparent communication to build trust and support for microbial recycling initiatives. Biological waste (biowaste) originates from diverse sources, including animal and plant residues, domestic, commercial, biomedical, industrial, and radioactive waste. Its management involves collection, transportation, processing, disposal, or recycling, along with rigorous monitoring to mitigate hazardous effects, such as those posed by radioactive materials (Ayilara & Babalola, 2023). The escalating human population, lifestyle changes, urbanization, economic development, and industrialization have led to a global increase in waste generation. Approximately one-third of food produced annually is wasted, exacerbating global hunger, economic disparity, and environmental issues (Farayi et al., 2024)).

Open dumping, landfilling, composting, and incineration remain the primary disposal methods, with open dumping being the most prevalent due to its low cost. However, the need for large landfill areas and their production of toxic pollutants, such as leachates and greenhouse gases, necessitates alternative solutions. Biological technologies, including municipal solid waste pretreatment, can improve waste treatment efficiency (Mansi et al., 2020). Among various methods, composting is the most eco-friendly and cost-effective waste treatment technology when managed properly. This approach not only reduces greenhouse gas emissions from landfills but also enhances soil properties, such as texture, porosity, and nutrient content. Redirecting organic raw materials from landfills to composting offers numerous environmental benefits, making it a vital component of sustainable waste management practices (Mansi et al.,2020). The application of microorganisms in solid waste recycling represents a transformative approach to sustainable waste management and environmental conservation. By leveraging their natural abilities to break down waste and create valuable byproducts, microorganisms offer a promising solution to the growing problem of solid waste. Continued research, technological innovation, and policy support are essential to fully realize the potential of microbial recycling and ensure its successful integration into global waste management systems.

Literature Review

The increasing generation of solid waste poses significant environmental and public health challenges worldwide. Effective waste management strategies, particularly recycling, are essential for environmental conservation. Among these, microbial-based recycling has garnered attention due to its sustainable and eco-friendly nature (Chandra et al., 2021). Microorganisms play a pivotal role in breaking down organic and inorganic waste, thereby minimizing waste accumulation and promoting resource recovery. Microorganisms, including bacteria, fungi, and Achaea are widely utilized for recycling organic waste through processes such as composting, anaerobic digestion, and bioremediation. Composting employs aerobic microorganisms to decompose organic matter into nutrient-rich compost, which can be used as a soil amendment. For example, Bacillus spp. and Pseudomonas spp. are efficient degraders of organic waste, significantly reducing waste volume and enhancing soil fertility (Singh et al., 2020).

Anaerobic digestion, another microbial process, converts organic waste into biogas and digestate. Methanogens such as Methanobacterium play a crucial role in methane production during this process. Biogas serves as a renewable energy source, while the digestate can be applied as a fertilizer, contributing to circular economy goals (Angelidaki et al., 2018). Microorganisms have also shown potential in recycling non-organic waste, such as plastics and electronic waste. Certain bacterial strains, such as Ideonella sakaiensis, can degrade polyethylene terephthalate (PET) plastics into reusable monomers (Yoshida et al., 2016). Similarly, fungal species like Aspergillus niger and Penicillium chrysogenum have demonstrated effectiveness in bioleaching metals from electronic waste, recovering valuable elements like gold and copper (Ilyas et al., 2017).

The use of microorganisms in waste recycling offers numerous environmental benefits. First, it reduces the reliance on landfills, minimizing greenhouse gas emissions and leachate production. Second, microbial recycling processes generate by-products, such as biogas and compost, which can substitute non-renewable resources. Additionally, the biodegradation of plastics and recovery of metals help mitigate pollution and conserve natural resources (Chandra et al., 2021). Despite its potential, microbial recycling faces challenges, including the need for optimized conditions to enhance microbial efficiency and scalability. Furthermore, some microorganisms may produce toxic intermediates during waste degradation, necessitating careful monitoring (Singh et al., 2020). Future research should focus on genetic engineering and biotechnological advancements to develop robust microbial strains capable of recycling diverse waste streams efficiently. Microbial-based recycling represents a promising approach to solid waste management and environmental conservation. By leveraging the natural capabilities of microorganisms, it is possible to reduce waste, recover resources, and mitigate environmental impacts. However, addressing the current limitations is essential to maximize the potential of this technology in achieving sustainable waste management.

Materials and Methods

Study Area

The research was conducted in a peri-urban area within Ilorin Township, specifically in Ilorin East, one of the 16 local government areas in Kwara State, Nigeria. This region is characterized by an agro-pastoral environment with shrubs and grasslands. The local government headquarters is situated in Oke Oyi, covering an area of 486 square kilometers with a population of 204,310, as reported in the 2006 census. (NPC,2006)

Experimental Procedure

Reagents

Solid sewage samples were collected from dump sites at the Oyun/Elekoyangan area in Ilorin East Local Government Area. The reagents used in this study, including Gram’s iodine solution, crystal violet (primary stain), acetone/ethanol (50:50), 0.1% basic fuschin solution (counterstain), peptone water, MacConkey agar, Simon citrate agar, nitrate broth, and distilled water, were procured from Labtrade Ltd, Kwara State, Nigeria. Additional reagents, such as malachite green solution and materials for nitrate reduction tests, were sourced from the same supplier.

Sample Dilution

Ten grams of sewage sample were measured and mixed with 90 milliliters of distilled water. One milliliter of this mixture was then transferred into 9 milliliters of distilled water, and this step was repeated sequentially until the fifth dilution. Subsequently, 0.1 milliliters from each diluted sample was streaked onto agar plates. A hockey stick was employed to spread the dilution evenly on the medium. The plates were sealed with foil, labeled, and incubated at 37°C for 24 hours. (Sneath, 1986)

Isolation of Microbes

Sewage samples were taken from dumping sites, and microorganisms were isolated using serial dilution and streaking methods. Twenty-five agar plates were aseptically prepared, and the rapidly growing bacterial colonies were selected. Different bacterial shapes were isolated and streaked onto divided agar plates using aseptic techniques. These plates were incubated at 30°C for 24 hours. The bacteria were further purified through subsequent spread plate techniques and incubation. Additionally, gram staining was conducted, and the samples were observed microscopically to characterize the microorganisms (Prashant, 2022)

Biochemical Identification of Microorganisms

Biochemical tests were conducted following standard procedures described in Bergey's Manual (10) to identify microorganisms from the waste samples. These tests included the catalase test, starch hydrolysis, coagulase test, gram staining, and the methyl red/Voges-Proskauer test. The tests were designed to identify various biochemical characteristics of sewage sludge microorganisms.

Results and Discussion

Table 1. Biochemical Analysis of treated Solid waste

Tests	N 1	N 2	N 3	N 4	N 5	N 6	N 7	N 8
Catalase	-	-	-	+	-	+	-	-
Nitrate Broth	-	-	+	-	-	+	-	-
Starch Hydrolysis	-	+	-	-	-	+	-	-
Oxidase	+	+	+	+	+	+	+	+
Urease	-	-	+	-	+	-	-	-
Glucose	+	+	-	+	-	-	-	-
Coagulase	+	+	_+	-	+	+	+	-
Methyl Red/Voges proskauer	-	-	+	-	-	-	-	-

Eight bacterial strains were isolated from solid waste under aerobic conditions at temperatures between 20°C and 30°C. Based on physiological and biochemical characteristics, the identified strains included Protobacteria, Bacillus schlegelii, Cellulomonas spp., Bacillus badius, Penicillium, Bacillus licheniformis, Aspergillus spp., and Phosphobacteria. Mesophilic bacteria demonstrated growth within a temperature range of 20°C to 40°C, while thermophilic bacteria exhibited optimal growth between 40°C and 60°C. Enzyme activity was evaluated using biochemical tests such as nitrate reduction, triple sugar iron agar (TSIA), Voges-Proskauer (VP), and spot indole tests. The most significant results were observed in oxidase and coagulase activity, with positive enzymatic reactions exceeding 75%. This spontaneous enzymatic activity led to a rise in temperature, aiding pathogen elimination and enhancing compost safety.

Table 2: Waste Type Analysis

Waste Type	Bacteria Isolates	Temperature ºC	Compost %
	Mesophilic stage		
Micro-pollutant	Protobacteria	20-30	11
Urine	Bacillus Schlegeli	25-35	7
Paper	Cellulomonas spp	35-40	5
Animal Dung	Bacillus Badius	30- 35	12

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	Thermophilic Stage		
Raw Waste	Penicillium	40-45	15
Heavy metal	Bacillus Licheniformus	45-55	44
Food Waste	Aspergillus spp	55-60	6

Proto-bacteria exhibited a preference for micro-pollutants at 20°C–30°C.Bacillus schigeli primarily interacted with urine at 25°C–35°C.Cellulomonas spp. demonstrated the lowest activity with paper waste (5%) at 35°C 40°C.Bacillus badius showed high activity with animal dung (12%) at 30°C–35°C.Bacillus licheniformis dominated heavy metal waste (44%) at 45°C–55°C.

Table 3: Carbon Nitrogen ratio of Various Waste

Waste Type	Carbon/Nitrogen Ratio	Temperature ºC
Micro-pollutants	10:20	20-30
Urine	25:30	25-35
Paper	10:20	20-30
Animal Dung	30:40	25-35
Raw Waste	20:30	25-35
Heavy Metal	35:40	35-45
Food Waste	25:35	20-30
Plastics	20:30	30-40
Raw Dust	25:35	25-35

Table 3 indicates the carbon-to-nitrogen (C/N) ratios of various waste types, with an optimal balance achieved between 20:30 and 35:40. The nitrogen release rate varied depending on waste type, ranging from gradual release in raw waste to rapid release in micro pollutants and paper.

Discussion

The study confirms that aerobic microbial metabolism is optimized at a C/N ratio between 20:30 and 35:40. Composting progresses efficiently within this range, ensuring a balance between carbon and nitrogen. This aligns with previous findings by Mansi et al. (Mansi et al., 2020), which emphasize the importance of C/N ratios for efficient composting. Ratios below the ideal range result in nitrogen loss through ammonia volatilization, while higher ratios slow down microbial activity and composting. Temperature played a critical role in waste decomposition and pathogen elimination. The optimal range of 35°C–45°C facilitated putrefaction and ensured sanitization. However, excessive temperatures above 60°C hindered microbial activity, as observed in Penicillium, Bacillus licheniformis, and Aspergillus spp.. (Ayilara & Babalola, 2023)These findings align with previous studies, which highlight the importance of temperature regulation during composting to maximize efficiency and ensure environmental safety. The incorporation of microorganisms into sewage treatment was shown to deactivate toxic materials while enriching the environment with nitrogen and carbon dioxide. This aligns with findings by Shamshudeen & Muritala (Shamshudeen& Muritala, 2003), emphasizing the critical role of microbes in nutrient recycling and sustainable ecosystem management. Additionally, the average temperature range of 20°C–30°C achieved during microbial treatment demonstrates its potential to mitigate global warming by reducing greenhouse gas emissions. The study underscores the value of using microorganisms to address global environmental challenges, such as waste management, nutrient cycling, and climate change mitigation (Sharma et al., 2013).

However, achieving a sustainable balance between human activities and natural ecosystems requires further exploration of microbial applications and their long-term impacts.

Conclusion

This study highlights the pivotal role of microorganisms in solid waste recycling, demonstrating their capacity to degrade organic matter, detoxify pollutants, and produce valuable bye-products. By integrating microbial technologies into waste management practices, communities can achieve significant environmental and economic benefits. Public education on composting and sustainable practices is essential to maximize these benefits and foster environmental sustainability.

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