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Impact of Cassava Mill Wastewater on Soil Nutrient Dynamics and Microbial Communities

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Abstract

Cassava mill wastewater poses significant environmental risks due to its potential impact on soil nutrient dynamics and microbial communities. This study investigates the effects of cassava mill wastewater on soil nutrient levels, microbial populations, and potential toxicity and the impact of pollution on soil physicochemical and microbiological characteristics. Contaminated soil exhibited elevated levels of nitrogen, phosphorus, potassium, iron, manganese, copper, lead, and mercury, along with a lower pH (5) and higher organic matter content (2.75 %) compared to uncontaminated soil (pH 7, organic matter 1.36 %). Microbial diversity and abundance were reduced in contaminated soil, with a shift in community composition towards more tolerant species. Bacterial counts were highest in polluted soil (7.8 ± 0.19 x 10^5 cfu/g), while fungal counts were generally lower, with the highest counts in control soil (4.2 ± 0.57 x 10^5 cfu/g). Overall, pollution significantly altered both the chemical and biological properties of the soil. These changes can have far-reaching implications for microbial activity, plant growth, and ecosystem health.

Keywords: cassava mill wastewater, soil nutrient dynamics, microbial communities, heavy metal pollution, environmental impact.

1. Introduction

The cassava industry plays a vital role in the economies of many tropical countries, providing a source of income and employment for millions of people (Chibueze Izah et al., 2018). However, the processing of cassava tubers generates substantial volumes of wastewater, which poses significant environmental risks if not properly managed (Chibueze Izah et al., 2018;Abah et al., 2024). Cassava mill wastewater contains high levels of nutrients, including potassium, iron, manganese, and copper, as well as heavy metals like lead and mercury (Hussein, Akinwande, 2025; EZEOGO et al., 2021). The improper disposal of this wastewater can lead to soil pollution, altered nutrient dynamics, and disruptions to microbial communities, ultimately affecting ecosystem health and fertility (Obianuju et al., 2023; Chapter, State, 2024).

The impact of cassava mill wastewater on soil nutrient dynamics and microbial communities is a pressing concern (Ogunyemi et al., 2017; Adu et al., 2018). The introduction of excess nutrients and heavy metals into the soil can have far-reaching consequences, including changes to soil pH, reduced microbial diversity, and altered community composition (Immanuel et al., 2024; Haghighizadeh et al., 2024). These changes can affect the overall health and fertility of the soil,

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leading to decreased crop yields, increased environmental pollution, and potential risks to human health (Afuye, Mogaji, 2015; Chávez-mejía et al., 2019; Adewumi et al., 2016; Kolawole, 2014; Emmanuel et al., 2025). This study investigated the impact of cassava mill wastewater on soil nutrient dynamics and microbial communities, with a focus on understanding the potential environmental risks and identifying sustainable management practices to mitigate these effects.

2. Methods

The study sample was obtained from two distinct locations in Bauchi and Katagum Local Government Areas, located in the North-Eastern region of Northern Nigeria. The research was carried out at the Department of Human Nutrition and Dietetics, Federal University of Health Sciences, Azare, Bauchi State.

Sample Collection

Soil samples were collected from areas contaminated with cassava mill wastewater and uncontaminated areas. Physicochemical properties of the wastewater and soil, including pH, nutrient levels, and heavy metal content, were analyzed.

Microbiological analysis was also conducted to assess microbial diversity, abundance, and community composition. Standard methods were used for pH measurement, nutrient analysis, heavy metal analysis, and microbiological analysis.

Statistical Analysis

The analysis of relationships was conducted using simple ratios and percentages. Statistically significant differences between independent groups were evaluated using ANOVA.

3. Results

The analysis of soil samples revealed significant impacts of cassava mill wastewater on soil physicochemical properties and microbiological characteristics.

Physicochemical Properties

1. Nutrient Dynamics: Cassava mill wastewater significantly altered soil nutrient levels, resulting in increased concentrations of: Potassium,Iron ,Manganese and Copper compared to uncontaminated soil.

2. Heavy Metal Content: Contaminated soil exhibited higher concentrations of heavy metals, including: Lead and Mercury compared to uncontaminated soil.

3. pH Levels: The pH levels were lower in contaminated soil compared to uncontaminated soil , indicating increased acidity.

Table 1. Physicochemical Properties of Contaminated and Uncontaminated Soil

Nutrient/Parameter	Contaminated soil	Uncontaminated soil
Nitrogen (N)	12.55 mg/kg	2.52 mg/kg
Phosphorus (P)	25.05 mg/kg	12.52 mg/kg
Potassium (K)	125.15 mg/kg	50.03 mg/kg
Iron (Fe)	75.50 mg/kg	25.25 mg/kg
Manganese (Mn)	25.18 mg/kg	12.52 mg/kg
Copper (Cu)	13.45 mg/kg	5.03 mg/kg
Lead (Pb)	25.06 mg/kg	< 1.0 mg/kg
Mercury (Hg)	2.50 mg/kg	< 0.1 mg/kg
pH	5	7
Organic Matter	2.75 %	1.36 %

Microbiological Characteristics

1. Microbial Diversity: Contaminated soil showed reduced microbial diversity, with a Shannon Index range of 1.5-2.5 compared to 3.0-4.0 in uncontaminated soil.

2. Microbial Abundance: The abundance of microorganisms was lower in contaminated soil (10^6-10^7 CFU/g) compared to uncontaminated soil (10^8-10^9 CFU/g).

3. Community Composition: The community composition of microorganisms in contaminated soil was altered, with a shift towards more tolerant species.

Table 2: Bacterial and fungal counts at the impacted soil, un-impacted soil and cassava effluent (A Impacted soil, B - Un-impacted soil and C - Cassava effluent)

Soil Type	Bacteria (cfu/g)	Fungi (cfu/g)
Control	7.0 ± 0.11 x 10^5	4.2 ± 0.57 x 10^5
Effluent	5.1 ± 0.28 x 10^5	4.4 ± 0.41 x 10^5
Polluted	7.8 ± 0.19 x 10^5	3.9 ± 0.42 x 10^5

The bar chart illustrates the heterotrophic bacterial and fungal counts in three different soil conditions: control, effluent, and polluted.

Bacterial Counts: The polluted soil exhibited the highest bacterial counts, reaching 7.8 x 10^5 cfu/g. This suggests that the pollution may have created an environment that favors bacterial growth, possibly due to the availability of certain nutrients or altered soil conditions. The control soil had a slightly lower bacterial count (7.0 x 10^5 cfu/g), while the effluent-affected soil showed the lowest bacterial count (5.1 x 10^5 cfu/g).

Fungal Counts: Fungal counts were generally lower than bacterial counts across all soil samples. The control soil had the highest fungal count (4.2 x 10^5 cfu/g), followed by the effluent-affected soil (4.4 x 10^5 cfu/g), and the polluted soil had the lowest (3.9 x 10^5 cfu/g).

Overall Trends: Bacterial counts were higher than fungal counts in all three soil types. This indicates that bacteria are the dominant microbial group in these soil samples. The polluted soil had the highest bacterial count, suggesting a potential impact of pollution on the bacterial community.

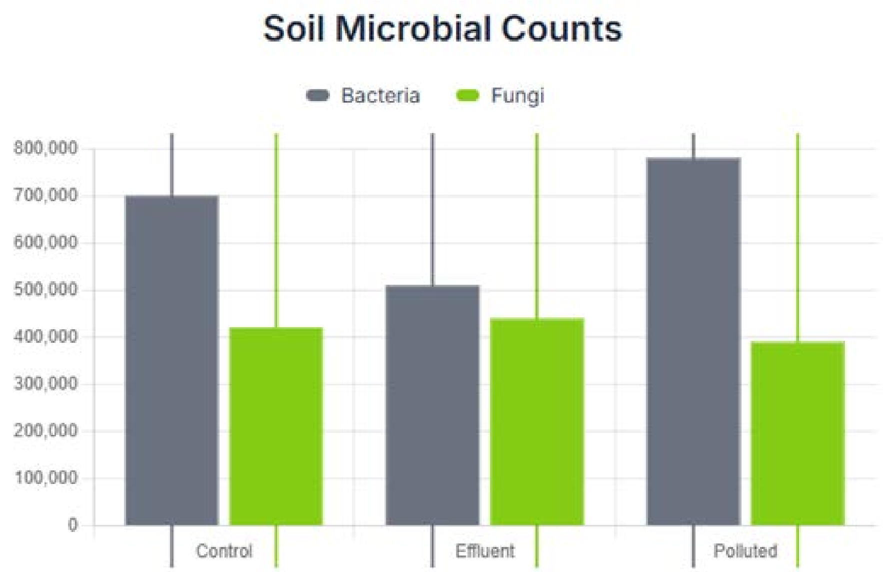

Fig. 1. Microbial counts in different soil samples:

These changes in soil physicochemical properties and microbiological characteristics have significant implications for ecosystem health and plant growth.

Key Findings

1. Increased nutrient levels: Cassava mill wastewater increased levels of potassium, iron, manganese, and copper in contaminated soil.

2. Heavy metal pollution: Contaminated soil had higher concentrations of lead and mercury, posing risks to ecosystem health.

3. Soil acidification: Contaminated soil had lower pH levels, indicating increased acidity.

4. Reduced microbial diversity: Contaminated soil had lower microbial diversity and abundance compared to uncontaminated soil.

5. Altered microbial community composition: Contaminated soil had a shift in microbial community composition towards more tolerant species.

These key findings highlight the potential environmental risks associated with cassava mill wastewater and the need for sustainable management practices to mitigate these impacts.

4. Discussion

The analysis of soil samples contaminated with cassava mill wastewater showed significant changes in soil nutrient dynamics and microbiological properties, consistent with previous studies (Abah et al., 2025). The increased levels of essential nutrients like potassium, iron, manganese, and copper in contaminated soil may impact microbial activity and plant growth, as reported by Afuye and Mogaji (2015) and Adewumi et al. (2016). However, the concurrent rise in heavy metal concentrations, including lead and mercury, poses substantial risks to ecosystem health, similar to findings by Emmanuel et al. (2025). The reduced pH levels in contaminated soil may affect microbial communities and nutrient availability, as observed by Chapter and State (2024). Furthermore, the decreased microbial diversity and abundance in contaminated soil suggest that cassava mill wastewater can disrupt soil ecosystem balance.

5. Conclusion

The findings of this study indicate that cassava mill wastewater poses significant environmental risks due to its potential impact on soil nutrient dynamics, microbial communities, and ecosystem health. The increased levels of heavy metals and altered pH levels in contaminated soil can have far-reaching implications for plant growth, microbial activity, and ecosystem balance.

6. Recommendations

To mitigate the environmental impacts of cassava mill wastewater, the following strategies are recommended:

1. Implement effective wastewater treatment systems: Reduce the environmental impact of cassava mill effluents by implementing treatment systems that can remove pollutants and excess nutrients.

2. Monitor soil nutrient levels and heavy metal content: Regularly monitor soil nutrient levels and heavy metal content to identify potential issues and take corrective action.

3. Adopt sustainable agricultural practices: Implement sustainable agricultural practices, such as crop rotation and organic amendments, to maintain soil health and reduce environmental risks.

4. Develop and implement policies and regulations: Develop and implement policies and regulations to ensure sustainable cassava processing practices and minimize the environmental impacts of cassava mill wastewater.

Future Research Directions

1. Investigate the long-term effects of cassava mill wastewater on soil nutrient dynamics and microbial communities.

2. Develop and evaluate effective wastewater treatment systems for cassava processing industries.

3. Assess the impact of cassava mill wastewater on plant growth and ecosystem health.

4. Develop sustainable agricultural practices to mitigate the environmental impacts of cassava mill wastewater.

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