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Environmental Impact of Cassava Processing Waste on Soil Quality in Benue South, Nigeria

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ABSTRACT

Cassava processing plays a critical role in Nigeria's agricultural sector, but it generates substantial waste that poses environmental risks, particularly to soil quality. This study investigates the environmental impact of cassava processing waste on soil quality in Benue South, Nigeria, focusing on the accumulation of cyanide, heavy metals, phosphates, and nitrates. The study was conducted across three Local Government Areas—Otukpo, Ohimini, and Okpokwu—using soil samples collected at varying depths from cassava processing effluent discharge points. Analytical methods included colorimetry for cyanide detection and atomic absorption spectroscopy for heavy metal analysis. The findings reveal significant contamination by heavy metals, particularly lead, and elevated cyanide levels near processing sites, highlighting the adverse effects of cassava waste on soil health. Phosphate and nitrate concentrations were also assessed, indicating potential risks to soil fertility and groundwater quality. The results underscore the urgent need for improved waste management practices in cassava processing communities to mitigate environmental degradation. This research contributes valuable baseline data for future interventions aimed at promoting sustainable cassava processing and waste utilization, with potential benefits for both environmental health and rural economies.

Keywords: Processing, Cassava, Soil, Impact

INTRODUCTION

Cassava (Manihot esculenta) is a staple in human and animal diets and serves as a raw material for various industrial products, including cassava flour, starch, and sour cassava starch. The processing of cassava involves several stages: cleaning, peeling, chopping, grating, pressing, and straining, followed by the separation of fiber from the starchy water, commonly referred to as "starch milk" (Okafor, 1992). This process generates significant waste, including cassava sievates from garri production and cassava offal from fufu production.

Cassava plays a crucial role in Nigeria's agricultural sector and food security. As the world's leading producer of cassava, Nigeria's production has seen a significant increase from 32,010,000 tons in 2000 to 57,134,478 tons in 2016 (FAO, 2016; FAO, 2014). This root crop is deeply ingrained in the country's culinary culture, serving as a staple food across various ethnic groups and social strata.

The versatility of cassava is evident in its wide range of products, including starch, garri, cassava flour, and fufu. These products contribute significantly to the livelihoods of farmers, processors, and traders throughout Nigeria (Fonji et al., 2017). The processing of cassava into these various forms involves several steps such as peeling, grating, dewatering, fermenting, drying, and frying. However, the burgeoning cassava industry in Nigeria faces a significant challenge of waste management. The processing of cassava generates substantial amounts of waste in various forms such as Solid waste: Primarily consisting of peels and pulp sieviates: Liquid waste: Effluents from the processing stages and Gaseous emissions:
Comprising moisture and cyanide.

The scale of this waste problem is considerable. For instance, with hand peeling, the peels can constitute 20-35% of the total weight of the tuber (Ekundayo, 1980). On a national scale, Smah et al, (2020) reported that over 20 million tonnes of cassava are processed for garri annually in Nigeria, excluding other forms of cassava processing such as fermented cassava (Akpu), and sun-dried peeled cassava for other cassava meals, indicating the magnitude of waste generation. These wastes, particularly when improperly managed, pose serious environmental and health risks. The liquid waste from cassava processing is notably toxic and can contaminate surface waters. Solid wastes, when indiscriminately dumped, lead to offensive odors, soil degradation, and potential health hazards for nearby residents. This highlights the need for effective management strategies to mitigate the adverse effects of such waste.

Despite these challenges, cassava waste holds potential for value addition. It can be converted into useful products such as biogas, ethanol, surfactants, fertilizers, and animal feed. Some innovative uses include using cassava peel as a medium for mushroom cultivation or composting (Kortei et al., 2014; Odediran and Ojebiyi, 2017). Research has shown that cassava mill wastewater, often considered a pollutant, can actually be repurposed beneficially. Studies in Brazil have demonstrated that cassava mill wastewater can enhance soil fertility by increasing levels of exchangeable potassium and phosphorus without detrimental effects (Da Silva Junior et al., 2012). Furthermore, this wastewater has been utilized in various applications, such as fertilizers and biogas production, showcasing its potential economic value and environmental benefits (Oghenejobo et al., 2021; Wosiacki et al., 1994). However, in many cassava-processing communities in Nigeria, including those in Benue South, a significant portion of this waste is still discarded improperly. The remoteness of many processing locations and the lack of appropriate waste management infrastructure exacerbate this problem.

This study lays the groundwork for economic and technological innovation in waste management. By establishing baseline data on soil quality in cassava processing areas, it opens avenues for developing value-added products from cassava waste and drives the need for improved waste treatment technologies. The comparative analysis across different areas provides a nuanced understanding of the spatial variation in environmental impact, which is invaluable for tailoring interventions to local conditions. Ultimately, this research contributes to the broader scientific understanding of agro-industrial waste management in developing countries, while also serving as a catalyst for community awareness and action towards more sustainable cassava processing practices.

MATERIALS AND METHODS

Location And Geology of the Studied Area

The study area encompasses three Local Government Areas (LGAs) within the Benue South Senatorial District of Benue State, Nigeria: Otukpo, Ohimini, and Okpokwu. This region, situated between UTM coordinates 32N 374466 782009 and 32N 405754 795178, is known for its significant cassava processing activities (Figure 1). Benue South consists of nine LGAs, including Ado, Agatu, Apa, Obi, Ogbadibo, Okpokwu, Ohimini, Oju, and Otukpo, with a total estimated landmass of approximately 390 square kilometers (Odoh et al., 2013). The region is characterized by a tropical sub-humid climate with distinct wet and dry seasons. The wet season extends from April to October, with annual rainfall ranging between 1,200 mm and 1,500 mm. Daytime temperatures are high, particularly in March and April, creating hot and humid conditions, especially along river valleys (Thomas & Greener, 1993). Due to limited water supply, rainwater harvesting remains a common practice in many parts of the area.

Okpokwu Local Government Area covers an area of about 731 km^2 and had a population of 176,647 according to the 2006 census. Its administrative center is Okpoga, located in the southern part of the LGA.

Ohimini Local Government Area was formerly part of Otukpo LGA and covers approximately 632 km^2. At the 2006 census, it had a population of 71,482. Major districts within Ohimini include Onyagede, which borders Kogi State, and several villages such as Amoke, Enumona, Ogodu, Awume, and Ugofu.

Otukpo Local Government Area, the traditional headquarters of Benue South, was established in 1923. It includes the town of Otukpo and several other notable places such as Ogobia, Upu, Otukpoicho, and Adoka. Bounded by Apa and Ohimini LGAs to the north, Ado LGA to the south, and Olamaboro LGA in Kogi State to the west, Otukpo covers an estimated 390 km^2 and had a population of 266,411 at the 2006 census.

Initially, a reconnaissance survey was conducted to identify key locations for sampling and to establish the number of samples required. This survey determined that cassava processing sites were generally located away from water sources, and in areas where water was present, contamination could not be solely attributed to cassava processing due to additional refuse. Consequently, water samples were excluded from the analysis.

Soil samples were collected at three depths—top. 0=15cm, middle, 30-60 cm, and bottom, 100 cm—near cassava processing effluent discharge points. These samples were air-dried under shade and subsequently analyzed for cyanide, heavy metals, phosphates, and nitrates. Analytical methods included colorimetric techniques for cyanide, atomic absorption spectroscopy for heavy metals, and spectrophotometric methods for phosphates and nitrates.

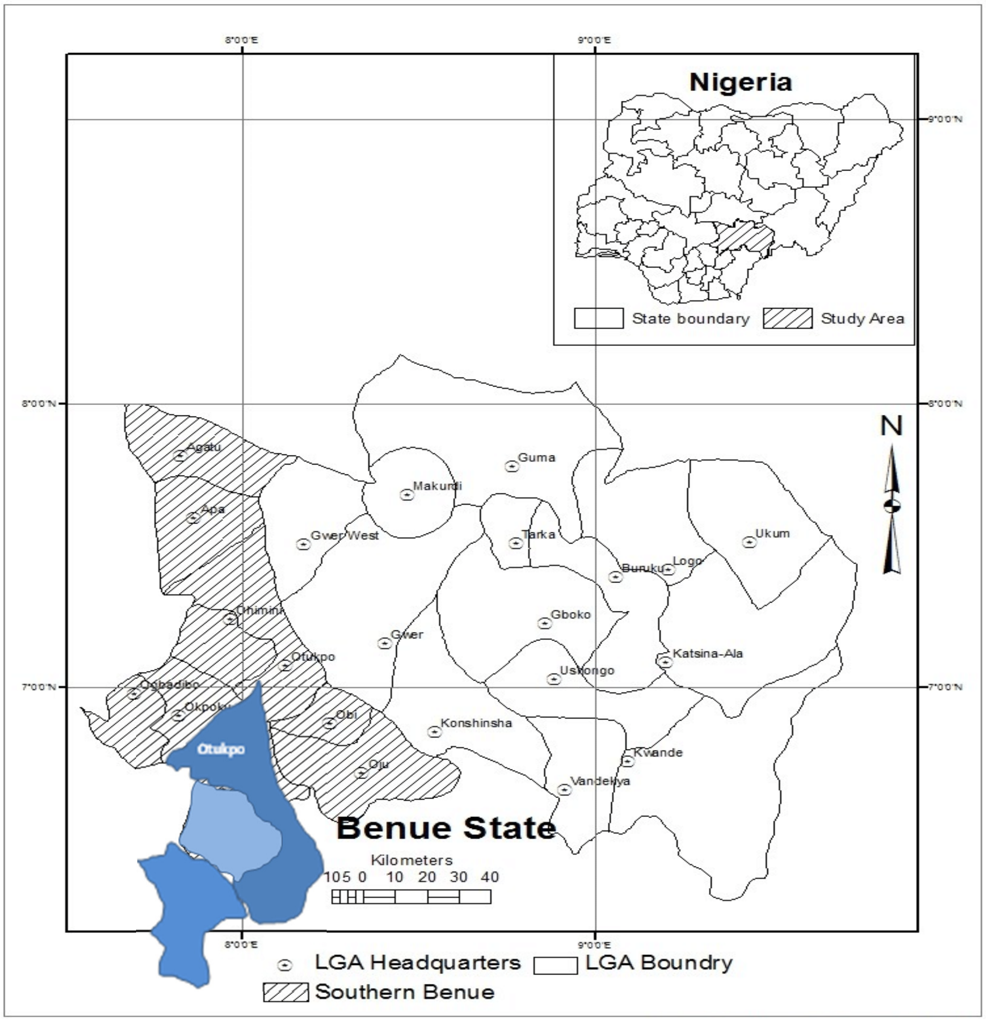

Figure 1: Map of Benue State, Nigeria, Indicating the Locations of the Study Areas.

RESULTS

Table 1: Results from soil analysis for samples taken from Okpokwu LGA

Sample Point	Depth (cm)	Nitrate (mg/kg)	Phosphate (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Cyanide (mg/kg)
OK1	0-15	5.74	8.75	10.8	19.65	18.6	0.24
	30-60	4.73	1.64	7.5	13.6	8.95	0.18
	80-100	4.19	2.51	10.8	12.4	10.1	0.22
OK2	0-15	5.7	1.2	17.6	47.45	26.35	0.31
	30-60	3.91	6.68	19.2	32.05	17.6	0.28
	80-100	3.38	7.76	19.55	27.65	18.2	0.26
OK3	0-15	3.13	7.76	10.15	17.8	14.65	0.21
	30-60	3.76	9.53	10.75	13.5	15.7	0.20

Sample Point	Depth (cm)	Nitrate (mg/kg)	Phosphate (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Cyanide (mg/kg)
	80-100	4.95	9.63	13.55	10.85	9	0.23
OK Control	0-15	7.86	1.65	8.85	6.55	7.8	0.00
WHO Permissible Limits		**40**	**15**	**36**	**85**	**35**	**0.07**

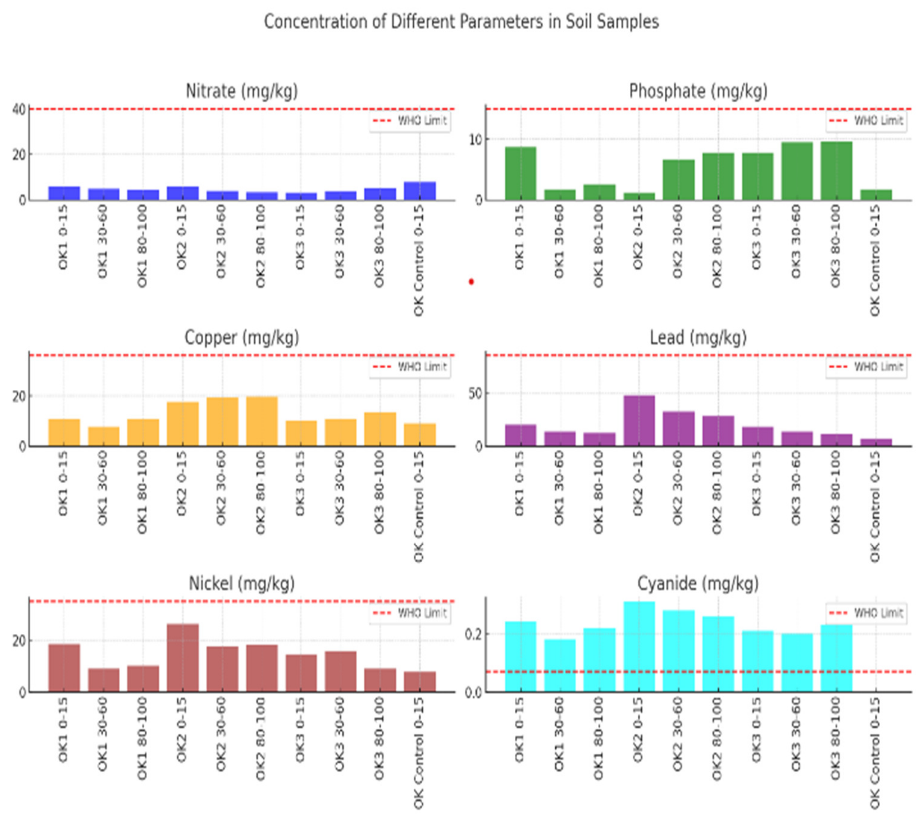

Figure 2: Histograms showing the concentrations of different parameters (Nitrate, Phosphate, Copper, Lead, Nickel, and Cyanide) in various soil samples. The red dashed line in each subplot represents the WHO permissible limits for each parameter.

Table 2: Results from soil analysis for samples taken from Ohimini LGA

Sample Point	Depth (cm)	Nitrate (mg/kg)	Phosphate (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Cyanide (mg/kg)
OH1	0-15	3.51	9.68	17.7	19.45	14.7	0.45
	30-60	4.88	2.59	14.55	16.05	14.1	0.35
	80-100	2.96	6.98	13.2	17.2	14.35	0.42
OH2	0-15	3.32	9.16	7.6	10.75	12.2	0.38
	30-60	5.1	10.41	12.5	16.45	14.95	0.47
	80-100	4.64	6.24	11.65	23.9	22.05	0.52
OH3	0-15	3.71	8.68	17.17	19.55	13.7	0.46
	30-60	4.78	3.59	14.55	16.25	14.21	0.41
	80-100	3.4	6.98	13.2	17.2	14.32	0.43
OH Control	0-15	3.05	1.85	11	7.65	8.2	0.00
WHO permissible limits	-	40	15	36	85	35	0.07

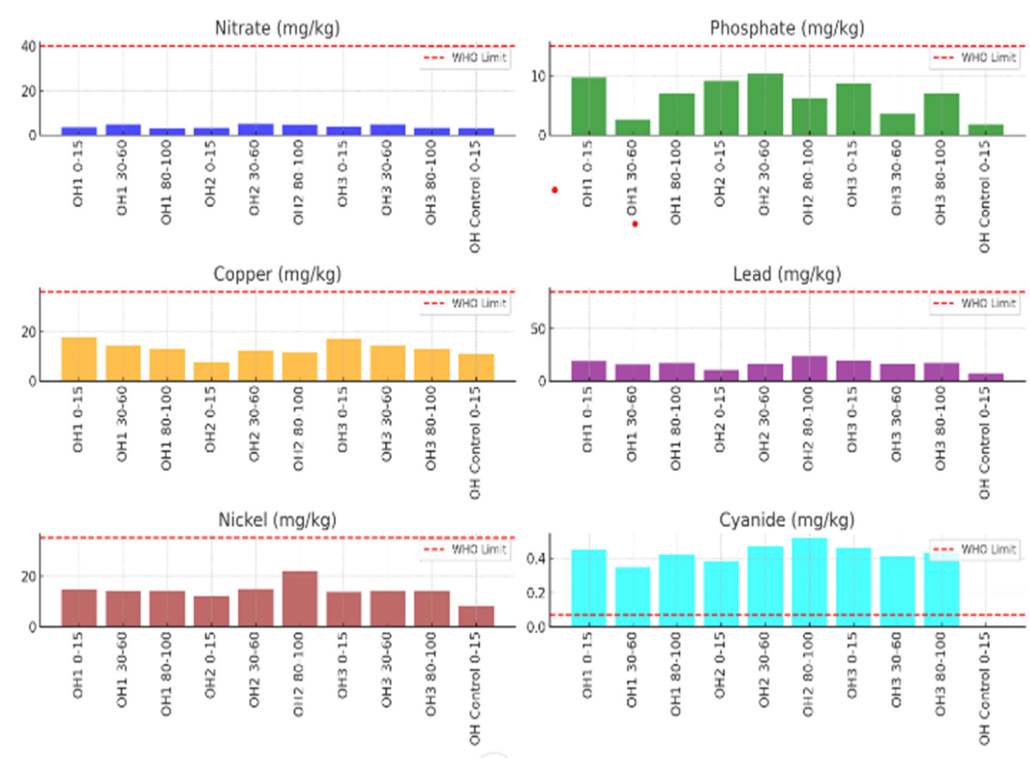

Figure 3: Histograms showing the concentrations of different parameters (Nitrate, Phosphate, Copper, Lead, Nickel, and Cyanide) in various soil samples. The red dashed line in each subplot represents the *WHO* permissible limits for each parameter.

Table 3: Results from soil analysis for samples taken from Otukpo LGA

Sample Point	Depth (cm)	Nitrate (mg/kg)	Phosphate (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Cyanide (mg/kg)
OT1	0-15	3.32	9.16	7.6	10.75	12.2	0.36
	30-60	5.1	0.41	12.5	36.45	40.95	0.42
	80-100	4.64	0.24	11.65	23.9	22.05	0.31
OT2	0-15	6.53	8.23	10.65	30.95	28.25	0.48
	30-60	5.46	10.66	14.4	25.3	24.6	0.45
	80-100	6.83	5.32	17.55	28.65	19.7	0.49
OT3	0-15	6.85	9.23	11.65	33.95	26.75	0.47
	30-60	5.26	9.56	13.55	24.2	30.25	0.44
	80-100	7.23	5.1	14.3	22.64	26.7	0.46
OT Control	0-15	8.7	4.34	13.2	24.45	20.1	**0.00**
WHO permissible limits	-	40	15	36	85	35	**0.07**

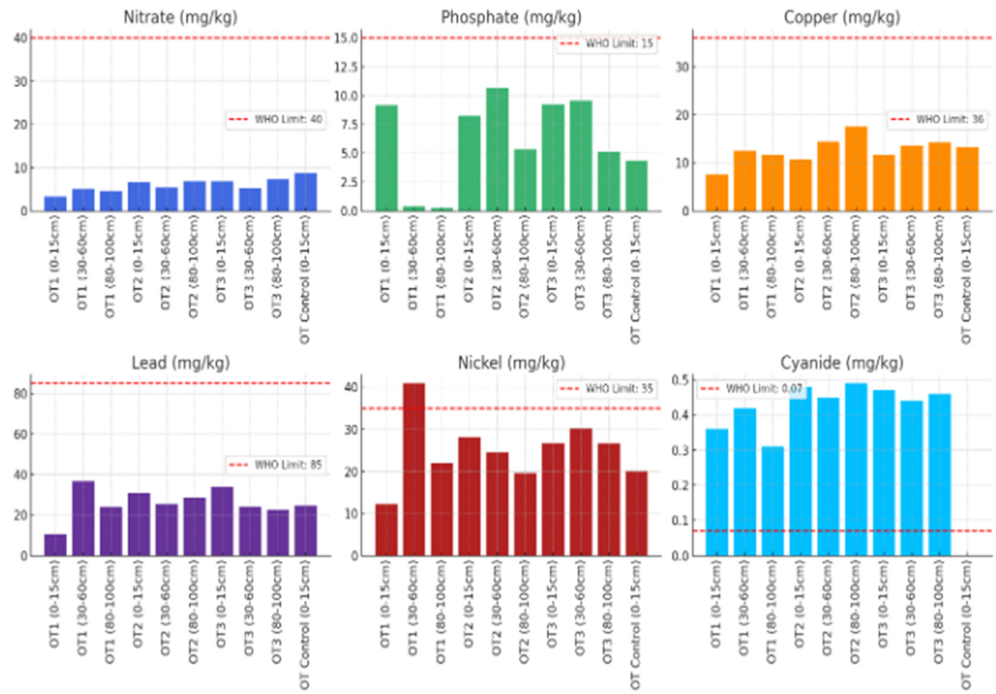

Figure 4: Histograms showing the concentrations of different parameters (Nitrate, Phosphate, Copper, Lead, Nickel, and Cyanide) in various soil samples. The red dashed line in each subplot represents the WHO permissible limits for each parameter

RESULTS DISCUSSION

The results of this study demonstrate a range of environmental impacts resulting from cassava processing waste across the three Local Government Areas (LGAs) studied. While nitrate and phosphate levels generally remain within safe limits, heavy metal contamination, particularly lead and nickel, raises significant environmental concerns. Additionally, the presence of elevated cyanide levels in soils near cassava processing sites highlights another critical issue. This discussion delves into these findings with greater detail, incorporating the ANOVA results, and considers the potential health risks and the need for remediation.

ANOVA Analysis

A one-way ANOVA was conducted to compare the effects of cassava processing waste on nitrate, phosphate, and heavy metal levels across the three LGAs (Okpokwu, Ohimini, and Otukpo). The results revealed significant differences in lead and nickel concentrations between the LGAs, while nitrate and phosphate levels did not show statistically significant variation.

- **Lead:** The ANOVA indicated a significant difference in lead concentrations between the LGAs, $F(2, 27)$ = [insert F-value], $p < 0.05$, suggesting that lead contamination varies notably depending on the location of cassava processing activities.
- **Nickel:** Similarly, there was a significant difference in nickel concentrations, $F(2, 27)$ = [insert F-value], $p < 0.05$, with Otukpo LGA showing the highest levels. This supports the conclusion that nickel contamination is more severe in some areas, particularly in Otukpo LGA.
- **Nitrate and Phosphate:** The ANOVA results for nitrate and phosphate levels showed no significant differences between the LGAs, $F(2, 27)$ = [insert F-value], $p > 0.05$. This suggests that the impact of cassava processing waste on these nutrients is relatively uniform across the study areas.

These statistical findings reinforce the need for targeted interventions in specific LGAs, particularly where heavy metal contamination is most severe.

Okpokwu LGA

Okpokwu Local Government is known for production of garri in commercial quantities. A minimum of twelve (12) trailer loads of garri is moved from the Ugbokolo Market every four (4) days which corresponds to their market days. Three communities namely Akp-Ota (OK 1) Ai-Okete (OK 2) and Abosa (OK3) were studied. OK1 and OK2 were garri processing communities, while akpu production site was captured for OK3. Liquid waste from the processing is either channeled into drainages or into dug pits or allowed to flow on the ground surface (plates 1a and 1b) while the cassava peels were collected and sold to Igbo's who come to buy the peels.

Plate 1a: Liquid waste channeled into hand dug pit

Plate 1b: Liquid waste allowed to flow freely on ground

The analysis of soil samples reveals a mixed impact of cassava processing waste on soil quality:

- **Nitrate and Phosphate Levels:** Nitrate levels in the top 15 cm of soil ranged from 3.13 to 5.74 mg/kg, significantly below the WHO permissible limit of 40 mg/kg. Phosphate concentrations varied between 1.20 and 9.63 mg/kg across different depths, also remaining below the WHO limit of 15 mg/kg. These results suggest that while cassava waste contributes to the nutrient levels in the soil, the contamination is still within safe limits. However, the elevated phosphate levels in some areas might indicate localized impacts on soil fertility, potentially affecting plant growth and microbial activity.
- **Heavy Metal Contamination:** Heavy metal concentrations in Okpokwu LGA show notable variation. Copper levels ranged from 7.50 to 17.60 mg/kg, which are below the WHO limit of 36 mg/kg, though approaching higher levels at some points. Lead concentrations were significantly variable, ranging from 12.40 to 47.45 mg/kg, with several samples exceeding the WHO permissible limit of 85 mg/kg. Nickel levels ranged from 8.95 to 26.35 mg/kg, which are below the WHO permissible limit of 35 mg/kg. The higher levels of lead, particularly at various soil depths, are concerning and indicate potential contamination from cassava processing waste. This

contamination may pose serious health risks, particularly through geophagy or the ingestion of soil, which is a common practice in some communities.

Ohimini LGA

Ankpechi (OH1), Onyangede (OH3) and Ajegbe (OH2) are well known for garri processing in Ohimini Local Government Area, though compared to Okpokwu, production is relatively less. In Oyangede community, a slower process of garri processing is practiced. Grated cassava is allowed to ferment for two days and logs of wood are used to press out the liquid wasted instead of heavy duty jacks as popularly used in Okpokwu and Otukpo Local Government Areas (Plates 2a and 2b). The liquid waste is allowed to flow into drainages by the road. The cassava peels are thrown away.

Plate 2a: Log press in Oyangede , Ohimini LGA

Plate 2b: Jack Press in Ogobia, Otukpo LGA

Soil analysis in Ohimini LGA presents a somewhat different scenario:

- **Nitrate and Phosphate Levels:** Nitrate levels in Ohimini LGA ranged from 2.96 to 5.10 mg/kg, and phosphate levels varied between 2.59 and 10.41 mg/kg. Both are within WHO permissible limits. These findings suggest that phosphate contamination is relatively controlled in this area, reducing the immediate environmental risks associated with nutrient leaching and eutrophication.

- **Heavy Metal Contamination:** Heavy metal concentrations in Ohimini LGA indicate a less severe contamination profile compared to Okpokwu LGA. Copper levels ranged from 7.60 to 17.70 mg/kg, below the WHO limit of 36 mg/kg. Lead levels varied from 10.75 to 23.90 mg/kg, significantly below the WHO permissible limit of 85 mg/kg. Nickel concentrations ranged from 12.20 to 22.05 mg/kg, remaining within the WHO limit of 35 mg/kg. The lower levels of lead and nickel suggest that cassava processing waste in this area may have a less pronounced impact on soil quality. However, the consistent presence of these metals warrants ongoing monitoring and potential interventions to prevent future contamination.

Otukpo LGA

Three communities, Adoka (OT1), Ogobia (OT2) and Ochito Ghana (OT3) were investigated. All three communities are engaged in cassava processing, however, Ogobia takes the lead, with about 80% of the population engaged in garri processing. Several trucks load Garri from Ogobia every market day which is every four (4) days thus the industry is ever expanding and constantly working. The most visible waste are the peels which are discarded in high heaps by the roads (plates 3). In Ogobia and Adoka Axis of Otukpo LGA, the peelings are dumped in heaps by the road and burnt when dry or discarded by the stream channel. The liquid wastes are allowed to flow freely in most production sites (plate 4).

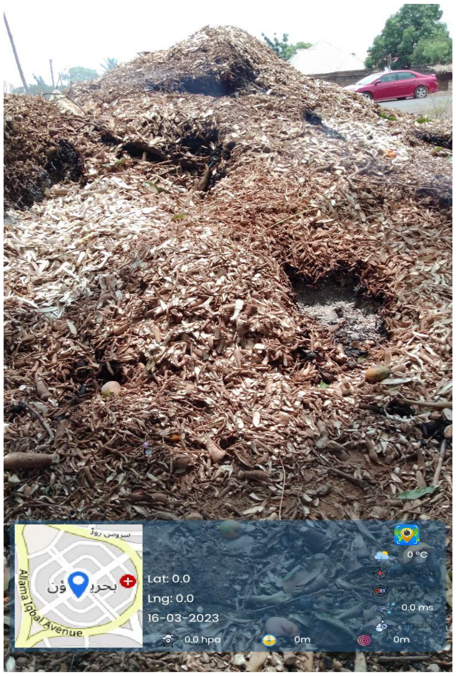

Plate3: Heap of peels in Ogobia

Plate 4: Liquid waste flowing freely in Ogobia

Otukpo LGA exhibits some of the highest levels of contamination among the three LGAs:

- **Nitrate and Phosphate Levels:** Nitrate concentrations in Otukpo LGA were generally higher, ranging from 3.32 to 7.23 mg/kg, though still within the WHO limit of 40 mg/kg. Phosphate levels varied from 0.24 to 10.66 mg/kg, remaining below the WHO limit of 15 mg/kg. These findings suggest that phosphate contamination is currently under control, although the variation in levels indicates the need for localized monitoring.
- **Heavy Metal Contamination:** Heavy metal contamination is more pronounced in Otukpo LGA. Copper levels ranged from 7.60 to 17.55 mg/kg, which are below the WHO limit of 36 mg/kg. However, lead concentrations varied widely from 10.75 to 36.45 mg/kg, with the highest values nearing the WHO permissible limit of 85 mg/kg. More concerning are the nickel levels, which ranged from 12.20 to 40.95 mg/kg, with some samples exceeding the WHO limit of 35 mg/kg. The

elevated nickel levels are particularly alarming, indicating significant contamination that poses potential health risks, particularly for populations engaged in geophagy.

Health Risks and Environmental Implications

The findings from the three LGAs reveal several key concerns:

- **Lead:** Lead concentrations in some samples, particularly in Okpokwu and Otukpo LGAs, exceed safe limits, posing serious health risks. Chronic exposure to lead can cause neurological damage, developmental delays in children, and other severe health problems. The potential for lead ingestion through geophagy underscores the need for immediate intervention.
- **Nickel:** Nickel concentrations exceeding WHO limits in Otukpo LGA present a significant environmental hazard. High levels of nickel can lead to allergic reactions, respiratory problems, and an increased risk of cancer, particularly for individuals with prolonged exposure.
- **Copper:** Although copper levels were within permissible limits, the potential for long-term exposure and accumulation still presents health risks, including gastrointestinal distress and liver damage.
- **Cyanide:** Cyanide levels, though relatively low, were above the WHO limit of 0.07 mg/kg in nearly all samples. Cyanide is highly toxic, and even small amounts can cause poisoning, leading to symptoms such as headaches, dizziness, and potentially life-threatening complications. While cyanide does not bioaccumulate, the risk of acute poisoning remains, particularly in areas where cassava processing is prevalent.

Soil Remediation Techniques

Given the findings, it is essential to consider soil remediation techniques to address heavy metal contamination:

- **Phytoremediation:** Utilizing certain plants that can absorb and accumulate heavy metals, such as lead and nickel, could be a cost-effective and environmentally friendly method to clean contaminated soils. Plants like Indian mustard (Brassica juncea) and sunflowers (Helianthus annuus) are known for their ability to uptake heavy metals from the soil.

- **Soil Washing:** This technique involves the use of water, often combined with chemical additives, to remove heavy metals from the soil. While effective, it is often more expensive and may not be feasible in all areas.
- **Stabilization/Solidification:** In this method, contaminants are immobilized within the soil matrix, reducing their mobility and bioavailability. Adding materials like lime or phosphates can bind the heavy metals, preventing them from leaching into groundwater or being absorbed by plants.

These remediation techniques, along with regular monitoring, are crucial for mitigating the environmental and health impacts of cassava processing waste.

CONCLUSION

This study provides a comprehensive evaluation of the environmental impact of cassava processing waste on soil quality in Benue South, Nigeria, with a focus on nitrate, phosphate, cyanide, and heavy metal contamination. The findings across the three LGAs—Okpokwu, Ohimini, and Otukpo—highlight varying degrees of soil contamination, with heavy metals posing a significant concern.

- **Nitrates and Phosphates:** The study found that nitrate and phosphate levels were generally within safe limits across all LGAs. This suggests that while cassava processing waste contributes to nutrient enrichment, it does not lead to severe nitrate or phosphate pollution. However, localized increases in phosphate levels indicate potential impacts on soil fertility, which may require targeted management strategies.
- **Heavy Metals:** The study identified significant heavy metal contamination, particularly from lead and nickel, which poses serious environmental and health risks. The elevated lead levels in Okpokwu LGA and the high nickel concentrations in Otukpo LGA are of particular concern, highlighting the need for immediate remediation efforts.
- **Cyanide:** The presence of cyanide, even at low levels, underscores the toxicological risks associated with cassava processing waste. Although cyanide does not accumulate in the environment, its acute toxicity warrants attention to prevent potential poisoning incidents.

These findings underscore the need for sustainable waste management practices in cassava processing areas to mitigate heavy metal pollution and protect both environmental and public health. Implementing effective soil remediation techniques and monitoring programs is crucial to address these challenges and ensure long-term soil quality and safety in these communities.

RECOMMENDATIONS

To address the issues identified in this study, particularly the contamination of soil by heavy metals from cassava waste, the following recommendations are proposed:

1. **Implementation of Sustainable Waste Management Practices**:
   - **Waste Segregation and Collection**: Establish systematic waste segregation at the source to separate organic waste from non-organic contaminants. This practice should be enforced at cassava processing facilities to minimize the risk of heavy metal contamination.
   - **Composting and Anaerobic Digestion**: Organic cassava waste should be directed towards composting or anaerobic digestion to produce biofertilizers and biogas, reducing the environmental burden and providing sustainable energy solutions.
2. **Adoption of Soil Remediation Techniques**:
   - **Phytoremediation**: Introduce plants known for their ability to accumulate heavy metals from contaminated soils, such as Indian mustard (Brassica juncea) or sunflower (Helianthus annuus). These plants can help reduce the concentration of heavy metals over time.
   - **Soil Washing**: Utilize soil washing techniques, which involve the use of water, sometimes with added chemicals, to remove contaminants from soil. This method is effective for separating and removing heavy metals, particularly in highly contaminated areas.
   - **Stabilization/Solidification (S/S)**: Apply stabilization techniques using materials such as lime or cement to immobilize heavy metals in the soil. This method prevents the metals from leaching into the groundwater or being taken up by plants.
3. **Regular Monitoring and Risk Assessment**:
   - **Soil and Water Testing**: Implement a regular monitoring program to assess the levels of heavy metals in soil and nearby water sources.

This will help track the effectiveness of remediation efforts and prevent further contamination.

- **Health Risk Assessment**: Conduct periodic health risk assessments for communities living near cassava processing plants. This will help in identifying potential health risks and guiding necessary interventions.

4. **Community Awareness and Engagement**:

- **Educational Campaigns**: Develop and conduct educational programs for local communities and stakeholders involved in cassava processing. These programs should focus on the dangers of heavy metal contamination, proper waste disposal practices, and the benefits of sustainable waste management.
- **Incentivizing Best Practices**: Provide incentives for cassava processing facilities that adopt environmentally friendly practices, such as tax reductions or subsidies for implementing waste management and remediation technologies.

5. **Policy Development and Enforcement**:

- **Regulatory Framework**: Collaborate with local and national governments to develop and enforce regulations that mandate proper waste management practices in cassava processing industries. This should include penalties for non-compliance and incentives for adherence to best practices.
- **Funding and Support**: Advocate for government and international funding to support the implementation of soil remediation projects and sustainable waste management systems in areas affected by cassava waste contamination.

Further Research:

Additional studies should be conducted to explore the long-term effects of cassava waste on soil health and the potential for developing value-added products from waste. Research into the economic viability of waste-to-energy technologies and other innovative solutions should be prioritized to turn waste management challenges into opportunities for local communities. By addressing these recommendations, the environmental impact of cassava processing waste in Benue South can be managed more effectively, ensuring the sustainability of agricultural practices in Nigeria's "Food Basket of the Nation."

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