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Assessment of the Effects of Cassava Leachates on Soil Media in Selected Areas in Omu-Aran, Nigeria

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Abstract - Cassava production wastewater pose harm to soil quality. Given the limited research on soil contamination from cassava effluents in Omu-Aran, this study examined the impact of a local cassava processing unit on nearby soil. Physicochemical parameters were analyzed and heavy metals in soil samples collected at various points near and around the processing unit in Omu-Aran, Kwara State, Nigeria, using principal component analysis. Thirty-six soil samples were collected from varying distances and elevations around individual-owned cassava mills, including a control site. Standard methods were used to analyze the soil samples' physicochemical parameters. Data analysis was carried out using descriptive statistics and ANOVA, with significance determined at p < 0.05. The mean values of Physico-chemical parameters of the soilsamples ranged from 6.39±0.65 to 9.20±0.54, 90.00±34.31 and 1062.57±868.70mg/L, 17.17±2.38 to 47.17±10.38mg/L and 0.00±0.00 to 19.80±2.37mg/L to for pH, Total Suspended solids, Sulphate, and Cyanide respectively which exceeded the WHO permissible limit. However, the average values of the heavy metals (Pb, Fe, Cd, Cr, Co, Ni, and As) though lower than that of the control, were above permissible limits. PCA shows that three principal components (PC) account for up to 87.027% of the original mean dataset variability. PC1 explaining 49.831% of the total variance, showed strong loadings for BOD, COD, PO4, NO3, and Ph, indicating anthropogenic origin. These elements are associated with microbial action in cassava mill operations. PC2 accounts for 21.559% of the variance, with pH, Pb, and EC as key contributors. Given the negative impact of cassava production on

surrounding arable soils in Omu-Aran, implementing sustainable pollution control measures in local cassava mills is essential..

Keywords— Cassava Waste Effluents, Soil Samples, Heavy Metals, Physicochemical Parameters, Omu-Aran

I. INTRODUCTION

Cassava is one of the most consumed carbohydrate foods in the world due to the various food products gotten from it, thereby making it capable of providing food security [1]. According to IITA, Africa produced over 60% of the world's cassava in 2017, with global production exceeding 291 million tons [2], [3]. In 2017, Nigeria led the world in cassava

producers in the world. Its contribution to food security and local economy, especially in rural economies, has led to huge processing into products such as gari, fufu, and starch [4]. In Nigeria, most of the daily diet of the people consists of cassava in the form of garri, and chips. According to FAO (2021), the country is one of the largest producers of cassava contributing to about 20.3% of the global production [5]. Also, cassava farming and processing is a major source of livelihood for several families, especially in rural areas [6], [7]. The processing of cassava is done through the milling process which has led to the vast use of cassava milling machines. The framework of the cassava processing plant that generates wastewater as by product is shown in Figure 1. The increasing demand and consumption of cassava food products have led to the increase of processing its tubers, especially in Omu-Aran Township. As the population grows, more cassava is produced, resulting in more waste. The direct disposal of these cassava effluents into soil media and later into the groundwater, streams, and rivers has led to the coagulation of the particles and because of the inability of the water to treat itself due to the various activities of man, this results in environmental pollution.

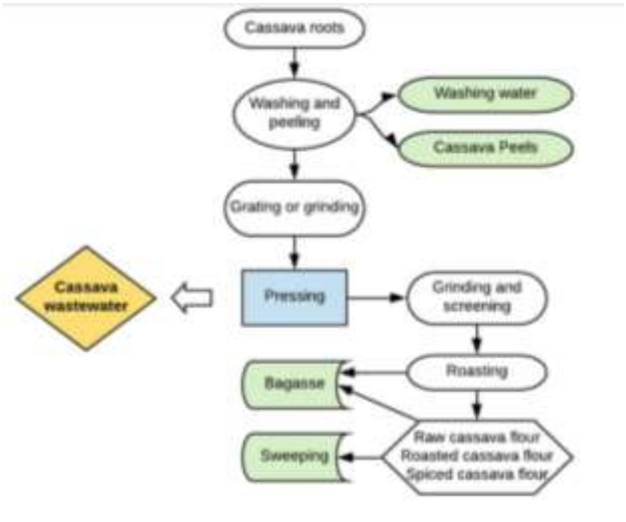

Figure 1. The generation of Cassava wastewater

Source: [8]

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production, producing 59 million tons. This represents a 37% increase over the last decade. Nigeria exports around 3.2 million tons annually, generating significant revenue, including a record $136 million in 2013 [2].

Cassava remains one of the most produced and processed subsistence food staples in Nigeria and is one of the top

Due to the use of these machines or traditional methods of processing cassava, residues of both solid and liquid are obtained during the process. The environmental pollution which is caused by these residues has a long history of negatively impacting the environment, sequentially, causing foul odour and leading to the contamination of surface water, groundwater and soil due to the percolation of this cassava wastewater. Several ways of properly disposing of these residues have been investigated and implemented accordingly. However, in a developing country like Nigeria, proper disposal of these wastes is not implemented, which gives room for environmental problems. In some of these places, which have been greatly affected by improper disposal of cassava wastes, it has been investigated that it causes acidification, as shown in Figure 2. The hydrolysis of cyanogenic glucosides (linamarin and lotaustralin) in cassava releases hydrogen cyanide, posing a risk to household animals, fisheries, and other organisms [9], [10].

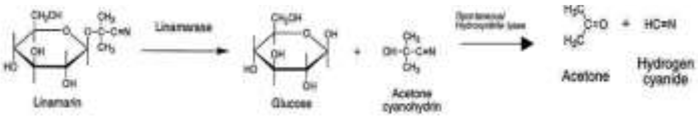

Figure 2. The Chemical reaction for the formation of hydrogen cyanide

Source: [11]

Starch and 'gari' production usually involve simple technology, consuming an average of $23m^3$ of water per tonne of cassava. Wastewater from cassava processing is subject to relatively rapid breakdown, it is odorous and its microbial content is often high [12].

Several methods have been used to assess and monitor the concentration of chemicals in soil media [13], [14], [15]. One of the most effective techniques to assess chemical concentration is principal component analysis. Principal component analysis (PCA) is a statistical technique that reduces parameters from interrelated datasets into principal components [16], [17]. It uses total variance in the real data, but the number of variables is reduced while the maximum variance is retained [18]. PCA is used by several studies to assess the levels of heavy metal contamination in soil analysis, which involves data reduction and interpretation [19].

Cassava wastewater usually contains the presence of lethal substances such as cyanide which is available in a simple or complex form and often has different toxicity.

The presence of varying amounts of cyanogenic glucoside and their breakdown products – cyanohydrin and hydrogen cyanide in cassava and cassava-food products has been a cause of concern because of their possible effects on health and the environment [12]. It affects biodiversity including marine lives, benthic macro-invertebrates, fisheries, microbes, plants, human, domestic animals (goat and sheep), fauna and flora, and affect water and soil physicochemical parameters [20], [21].

Despite extensive research on soil contamination, the impact of cassava processing on soil quality in Omu-Aran remains poorly documented. Hence, there is a need to conduct a risk assessment and quality evaluation of the soils surrounding the cassava processing site in Omu-Aran Township.

II. MATERIALS AND METHODS

A. *Study Area*

Omu-Aran is the study area, situated in southern Kwara State, Nigeria. This town is located at 8°8′00″N latitude, 5°6′00″E longitude, and 564 meters above sea level [22]. Omu-Aran is characterized by significant rainfall during the wet season and minimal rainfall during the dry season. The average annual temperature is 24.9°C, with an annual precipitation of approximately 1273 mm [23]. The region's soil is predominantly clayey, sandy or gravely.

B. *Sample Collection*

Cassava-processing sites, namely Latinwo Street, Oro Ago Road, Bovas Area, Aperan Area and Odo Areyin. Six other samples were obtained from the Landmark University field, which has been identified that no activity is occurring there. Figure 3 shows the latitude and longitude of the various study areas.

Figure 3. Map showing the location of the study area and the control.

At a depth of 0-500 cm at different locations twice a week for a period of three weeks using a steel soil auger. It was stored in labeled, clean polythene bags at room temperature for laboratory analysis. The digested soil samples were analyzed for physicochemical parameters at Landmark University's Environmental Engineering Laboratory and for heavy metals at Afe Babalola University's Environmental Engineering Laboratory.

C. *Determination of Physico-chemical Parameters*

- pH

First, buffer solutions of 7, 4, and 10 were used to calibrate the pH meter. The sample was probed, and the outcome was then shown on the screen.

- Electric Conductivity and Total Dissolved Solid

Conductivity measures a water sample's ability to conduct electricity, while TDS quantify the concentration of inorganic salts and small amounts of organic matter dissolved in the water. By immersing an EC probe into distilled water, the conductivity was first calibrated. The probe was then immersed in the sample, results were displayed on the screen.

- Total suspended solids (TSS)

These are the solids obtained by filtering 100ml of sample on filter paper. The gravimetric method was used to determine the TSS using a digital weighing balance, conical flask, beaker, Desiccator and measuring cylinder. Measure 1g of the soil sample and mix thoroughly into 100 ml of water with a measuring cylinder. The sample was poured into the filter, folded in the funnel, and placed on the conical flask. Allow the water to well drain from the filter. The residual was placed in the Desiccator to allow moisture to be completely removed from the residue. The residue was weighed, and the reading was noted down.

- Cyanide

Reflux distillation is a method for detecting cyanide, involving a procedure that extracts both soluble cyanide salts and insoluble cyanide complexes from waste and leachatesThe hydrogen cyanide (HCN) released from the sample is captured in an alkaline solution, and the cyanide concentration in this solution is then measured.

- Other Chemical Parameters

Chemical parameters were carried out. Palintest Photometer 7100 was used to analyze the samples for chemical concentration. A test tube was filled to the 10ml mark with distilled water to serve as a blank for photometer calibration. The photometer was calibrated using the blank, and then the sample was inserted to obtain readings in mg/L, which were recorded accordingly. The concentrations of cations in the solution or extract were determined using (AAS) of the appropriate model.

D. Determination of Microbial Parameters

- Biological Oxygen Demand (BOD)

BOD is an important indication of the amount of organic matter in the sample, showing the richness of waste in organic matter. BOD testing is an empirical method that uses standardized laboratory procedures to measure the amount of oxygen required to break down organic matter in polluted water.

Seeding was not necessary since microorganisms were already present in domestic waste. The dilution water was aerated for approximately 20 minutes to saturate it with air. Several solutions of the samples were prepared with dilution (i.e., dilution covered a wide range of BOD).

Elevated BOD levels signify significant organic pollution. The standard BOD test involves incubating a sample at 20°C for 5 days,

measuring the decrease in dissolved oxygen levels, which indicates the BOD value. This value is used to determine treatment plant

efficiency and design parameters. It is also used in sewer rental charges calculations.

The rate of oxidation of carbonaceous organic matter in the BOD test is mathematically written as:

$X=L_o\ (1-10^{-kt})$

where L_o=ultimate BOD

X=Amount of Do at any time

t=Time in days

k=first order rate of reaction rate constant

Apparatus:

a. Incubation bottle (300ml capacity)

b. Air incubator or water bath

- Total Organic Carbon

To obtain TOC, sample was ground to fine powder (fine enough to be able to pass through sieve of diameter 0.5mm). 1g of soil sample is weighed into a 250ml conical flask then 10ml of 0.167M $K_2CR_2O_7$ (Potassium Dichromate) is added along with 20ml concentrated H_2SO_4 rapidly. The mix is then stirred in the flask gently to mix reagents properly. 100ml is then added along with 3-4 drops of Ferroin indicator to the standing mixture after the 30 minutes, which was then followed by titrating with 0.5M Iron (II) Ammonium Sulphate or Iron (IV) Sulphate. Following all of these, the solution turned from green to a brownish red color after which readings were then finally taken for blank samples. The following formula was employed for Organic Carbon.

$$Percentage\ Organic\ Carbon = \frac{[B-T] \times M \times 0.003 \times 1.33 \times 100}{WT}$$

Where,

B = Blank

T = Titre of sample

M = Molarity

Wt = Weight of Sample

E. Determination of Heavy metals Parameters

An AA320N Atomic Absorption Spectrophotometer was employed to quantify trace and major metal elements in samples using AAS. The analysis focused on heavy metals, following standard laboratory protocols (APHA, 1992).

The principal law of Brown-Bill which is given below:

$$A = \log\left(\frac{I_o}{I}\right) = KCL$$

Where Io= In-coming light intensity,

I = Intensity

K=Coefficient,

C=concentration

L= Distance

Sample concentrations were calculated using the calibration curve equation derived from the analysis. Specifically, for heavy metal analysis using an AA320N Atomic Absorption Spectrophotometer, concentrations were determined based on this established relationship.

F. Data Analysis

Data analysis was conducted using SPSS version 25.0. ANOVA was used to compare soil sample parameters across sampling points.

III. RESULTS AND DISCUSSION

A. physio-chemical analyses of Samples.

pH levels were found within the range of 6.39±0.65 mg/L (Aperan) to 9.10±0.54 mg/L (Bovas). The World Health Organization (WHO) has recommended a pH range of 6.5-8.5 for drinking water. While Aperan being considered acidic was below the accepted pH range, Bovas, as well as others (except for Control, which recorded 6.80), exceeded the pH range slightly and presented alkaline conditions possibly due to chemical changes instigated by leachates. At high pH or alkalinity, metals become less soluble and less bioavailable [24]. According to Nwankwoala (2011), leachates usually change pH to alkalinity as a result of organic decomposition and ammonia formation.

TDS was below the WHO threshold of 500 mg/L, ranging from 5.83±1.55 (Control) to 182.47±67.74 mg/L (Latinwo). These higher TDS values at Latinwo and Aperan are due to salts liberated from cassava waste. EPA and WHO have noted that higher TDS affects taste and may be indicative of other pollutants. If the TDS values were high, it would cause toxicity through changes in ionic composition of the water and individual ions [25].

The TSS has an average value of 90.00±34.31, which is the lowest value because it corresponds to the control. The highest value is 1062.57±868.70 mg/L, recorded at Latinwo, with all values exceeding the WHO limit of 35 mg/L, indicating serious contamination. Cassava effluents as a major source of TSS. There were significant differences in the values of the TSS.

TS ranged from 95.83 mg/L (Control) to 1245.82 mg/L (Latinwo), far above permissible limits, showing the presence of dissolved and suspended material in high proportion. The implication of this parameter again is pollution of the soil and water by cassava leachates. EC ranged from 8.19±2.14 µS/cm (Control) to 260.60±91.18 µS/cm (Latinwo), with the highest value being less than the WHO limit of 1000 µS/cm. Notably, Latinwo and Aperan showed enhancements, reflecting the ionic concentration present in the leachates [24]. Electrical conductivity was used as a means of assessing soil salinity. The values obtained for the electrical conductivity in the soil samples may be as a result of the increase in the concentration of soluble salts [7].

Calcium concentrations all registered 0.00±0.00 mg/L, which is far below the 75 mg/L permitted limit set by the WHO. A possible reason is cassava leachate depleted the soil of calcium or a naturally low calcium content of the soil. Normally, Ca is essential for soil structure and plant growth. This is not the usual finding, as cassava peels tend to raise the Ca levels; Akinbile and Yusoff (2012) reported 4.5-12.8 mg/L Ca in waters affected by cassava effluent.

The values of potassium ranged from 3.08±0.47 mg/L (Oro-Ago) to 0.20±0.09 mg/L, with the control being the lowest. The values of potassium between the study area were significant different from the control, however they were within the WHO permissible limit of 50mg/L.

The values of magnesium ranged between 3.67±2.22 and 23.67±12.29mg/L (Oro-Ago). The value of magnesium is significantly different in between the study areas and the control, they were still within the WHO permissible level of 50mg/L.

TABLE 1. PHYSICO-CHEMICAL ANALYSIS OF CASSAVA LEACHATE SOIL SAMPLE FROM SAMPLING LOCATION

Parameters	**Sampling points**						**WHO**
	Oro-Ago	***Aperan***	***Latinwo***	***Odo-Areyin***	***Bovas***	***Control***	
pH	9.20±0.54^{b}	6.39±0.65^{a}	8.86±0.51^{b}	8.58±0.56^{b}	9.10±1.07	6.80±0.10^{a}	6.5-8.5
Ca	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	75
K	3.08±0.47^{c}	2.25±0.27^{a}	2.80±0.51^{b}	2.98±0.34^{c}	2.30±0.11^{ab}	0.20±0.09^{a}	50
Mg	23.67±12.29^{b}	4.00±3.79^{a}	15.67±10.65^{a}	18.33±8.78^{b}	5.17±4.07^{a}	3.67±2.22^{a}	50
SO_4	45.17±14.72^{b}	25.33±5.01^{a}	40.33±13.84^{b}	40.83±10.44^{b}	25.33±3.39^{a}	17.17±2.38^{a}	100
NO_3	1.16±0.51^{b}	0.45±0.13^{a}	0.82±0.31^{ab}	0.89±0.33^{ab}	0.50±0.18^{a}	0.40±0.11^{a}	50
PO_3	0.77±0.37^{b}	0.34±0.10^{a}	0.61±0.38^{ab}	0.72±0.23^{b}	0.35±0.13^{a}	0.23±0.10^{a}	1
Cl	76.50±25.71^{b}	36.50±11.66^{a}	61.33±28.42^{ab}	70.50±18.31^{b}	38.00±9.03^{a}	21.00±9.30^{a}	250
TDS	64.35±18.61^{ab}	132.13±64.18^{bc}	182.47±67.74^{c}	70.78±32.48^{ab}	128.40±65.43^{bc}	5.83±1.55^{a}	500
TSS	920.00±306.20^{ab}	710.00±142.21^{ab}	1062.57±868.70^{ab}	613.33±350.01^{ab}	500.00±241.99^{a}	90.00±34.31^{a}	35
TS	984.35±320.15^{ab}	842.13±132.04^{ab}	1245±821.95^{ab}	684.12±340.52^{ab}	628.40±198.41^{a}	95.83±34.39^{a}	
EC	103.80±23.17^{ab}	189.98±91.18^{bc}	260.60±97.17^{c}	98.55±49.14^{ab}	183.27±93.96^{bc}	8.19±2.14^{a}	1000
TOC	3.37±0.34	4.16±0.20	3.72±0.08	4.00±0.18	1.54±0.16	0.35±0.09^{a}	1
BOD	114.00±4.20	120.67±5.89	124.67±4.68	131.33±4.68	144.00±8.00	52.00±7.16^{a}	0
Cyanide	11.97±0.82	12.55±1.03	9.72±1.56	16.27±1.02	19.80±2.37	0.00±0.00^{a}	0.07

For each parameter, means with the different letters (superscripts) are significantly different ($p<0.05$), using Duncan's multiple range test

The value of sulphate ranged between 17.17±2.38 and 45.17±14.72mg/L with the control having the lowest value and Oro-Ago having the highest value. There were significant differences in the values of sulphate between the study area and the control, although it has been reported that there is no guideline value based on human health; however, WHO recommends that any concentration higher than the permissible limits of 100mg/L is termed unhygienic [26].

The range of the values of nitrate was between 0.40±0.11 and 1.16±0.51mg/L with Oro-Ago having the highest value and the control with the lowest. The values of nitrate fell within the WHO permissible level of 50mg/L.

The values of phosphate ranged between 0.34±0.10 and 0.83±0.27mg/L with Aperan having the lowest value and the control with the highest value. There were significant differences between the values of phosphate, although they fell within the WHO permissible limit of 1mg/L.

B. *Total Organic Carbon*

The maximum 4.16±0.20mg/L of TOC was at Aperan, whereas the control registered 0.35±0.09 mg/L. Although the WHO has not fixed any limit, TOC > 1 mg/L can be regarded as an indication of organic pollution, which all the leachate sites clearly do have. Cassava peels import high TOC levels to soil and water.

C. *Biochemical Oxygen Demand*

BOD values ranged from 52.00±7.16 mg/L (Control) to 144.00±8.00 mg/L (Bovas), all beyond the WHO limit of 0 mg/L (BOD should ideally be zero for potable water). BOD shows higher likelihood of oxygen depletion due to organic pollution, especially from the fermentation of cassava. Akinbile and Yusoff (2012) observed BOD higher than 100 mg/L in cassava mill effluents [27].

D. *Cyanide*

The values of cyanide ranged between 0.00±0.00 and 19.80±2.37mg/L with the control having the lowest value and Bovas with the highest value. As there were no activities of cassava production at the control area, the concentration of cyanide was almost non-existent, but in the affected locations, the concentration of cyanide was very high, especially in Bovas. The high concentration of cyanide can probably be due to the improper waste disposal of the cassava peels and wastewater. Hence, the values of the cyanide of the study areas exceeded the WHO permissible limit of 0.07mg/L. When hydrogen cyanide enters the soil via effluent, it dissolves and remains in solution [24].

E. *Heavy metals analysis of cassava leachate sample.*

- Lead

The range of the values of lead was between 0.71±0.09 mg/L (Control) and 4.88 mg/L (Bovas). Every sampling location exceeds the WHO set limit for Pb (0.05 mg/L), indicating very high contamination, especially at Bovas, where the concentration is almost 100 times above the accepted limit. It affects the nervous system and can cause developmental problems, particularly in children. The elevated levels of Pb in soils around some cassava processing zones can be attributed to burning and improper disposal [28], [29].

- Cadmium

The values for Cadmium ranged between 0.40±0.07 (Oro-Ago) and 4.54±0.13mg/L with Bovas having the highest value and the control having the lowest value. All the sites have values far beyond the WHO threshold (0.005 mg/L). Bovas is the highest, indicating that leachate there is very heavily contaminated. Cd causes carcinogenic effects, kidney damage and demineralization of bones [25]. [15] discovered cassava mill wastes could increase the level of Cd in the soil through percolation of wastewater.

- Arsenic

The values for Arsenic ranged between 0.82±0.09 (Control) and 4.08±0.09mg/L (Oro-Ago) with Oro-Ago having the highest value and the control area with the lowest values. The values of Arsenic have significant differences although it exceeded the permissible limit of 0.01mg/L. Long-term exposure to As is associated with causing cancer, skin lesions, and cardiovascular diseases [24]. Although less often reported in cassava context, soil geochemistry and effluent accumulation could be contributing to this grave level of contamination (FAO, 2015).

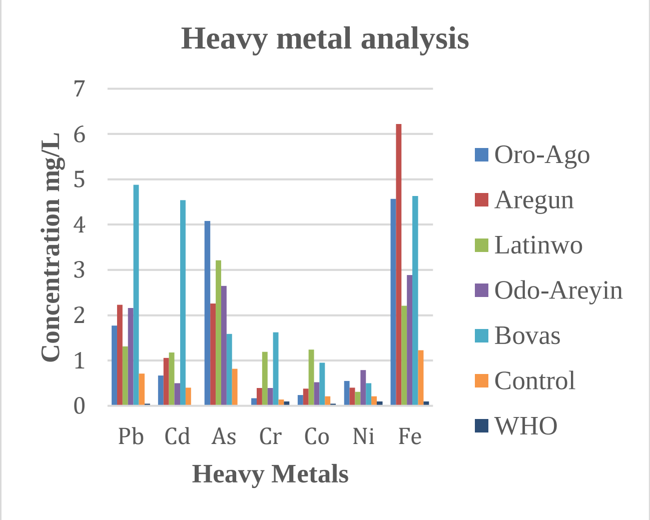

Figure 4. Heavy metal analysis of soil samples collected from sampling points

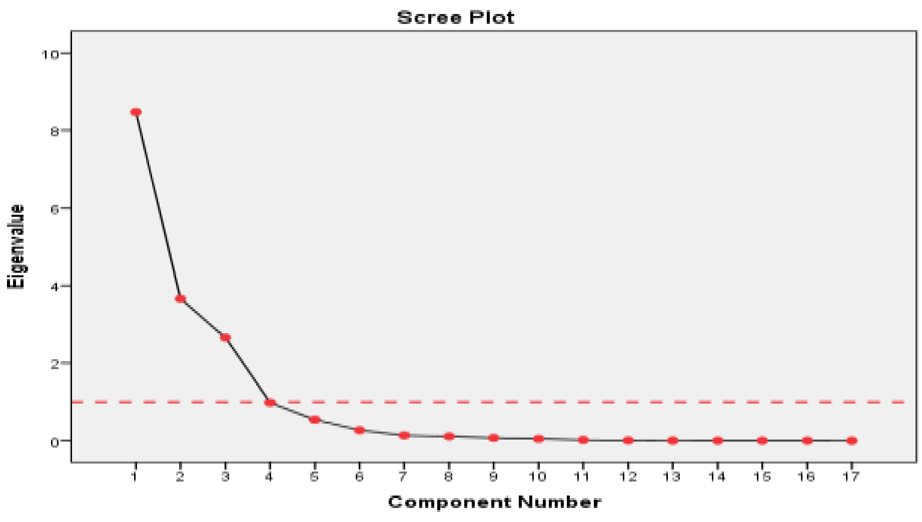

Figure 5. Scree plots used to identify the number of principal components from eigenvalues (>1)

TABLE 2. EXTRACTION METHOD: PRINCIPAL COMPONENT ANALYSIS

	Component		
	PC1	***PC2***	***PC3***
BOD	.977	.097	.125
COD	.951	.199	.024
PO_4	.948	.174	.184
Cl	.941	.205	.221
NO_3	.822	.011	.552
SO_4	.693	.095	.140
Cr	.691	.330	-.468
Mg	.687	.617	-.174
Fe	.687	.617	-.174
pH	-.427	.796	-.152
Pb	.380	.770	.459
EC	-.364	-.769	-.038
TDS	-.396	-.717	-.039
As	.249	-.107	.940
Cd	.303	.331	.888
Ni	-.054	.509	-.794
Co	.480	-.391	-.683
Eigenvalue (>1.0)	8.471	3.665	2.658
Proportion	49.831	21.559	15.638
Cumulative	49.831	71.389	87.027

TABLE 3. RESULT OF KMO AND BARTLETT'S TEST

KMO and Bartlett's test		
Kaiser–Meyer–Olkin measure of sampling adequacy		.651
Bartlett's test of sphericity	Approx. chi-square	82.19
	df	10
	Sig.	.000

- Chromium

The range of the values of lead was between 0.14 mg/L (Control) and 1.90 mg/L (Latinwo). Each sample is above WHO limit (0.1 mg/L) with Latinwo and Bovas being the most polluted. Cr toxicity can target kidney, liver, and DNA, particularly in its hexavalent form (Cr^{6+}). Iwegbue et al., (2013) found enriched Cr in soils contaminated by wastewater, which corroborates the impact of cassava processing.

- Cobalt

The range of values for cobalt was between 0.21±0.06 and 1.24±0.09mg/L with Latinwo having the highest value and the control area with the lowest value. All sites exceed the WHO limits (0.05 mg/L) with Latinwo and Bovas showing high levels. Excess cobalt can affect cardiovascular and thyroid functions. Co is less frequently monitored but might be released by corrosion of cassava processing equipment from metallic wastes [24].

- Nickel

The values of Nickel ranged between 0.21±0.06 (Control) and 0.79±0.07mg/L (Odo-Areyin). The Ni levels exceed the WHO standard set (0.1 mg/L) at all locations but particularly in Odo-Areyin. Ni exposure can cause dermatitis, lung fibrosis, and carcinogenesis. Ni elevation within proximity to food processing plants was found by Olayinka et al., (2009) and was consistent with this result [24].

- Iron

The values for Iron ranged between 1.23±0.10 (Control) and 4.63±0.15mg/L (Aregun). All sampling locations exceeds the WHO limit (0.1 mg/L), with the highest contamination levels found at Aregun. Fe is ordinarily an essential element, but at this level, it stains water and surfaces and encourages microbial growth. Elevated Fe-level is, however, normal in organic waste-affected soils and cassava leachate further contributes to iron complexation.

F. Principal Component Analysis (P.C.A)

The KMO and Bartlett's test yielded values of 0.651 and 82.19 (df = 10; see Table 3). Analysis of anthropogenic metal data revealed that a significant proportion of BOD, COD, PO_4, NO_3, and pH in the samples were of anthropogenic origin, supporting the hypothesis that toxic element accumulation in the cassava mill is primarily driven by human activities [30]. A scree plot (Fig. 5) revealed that the top three principal components account for 87.027% of the dataset's variability. The first two principal components, with eigenvalues greater than one (Fig. 3), captured 49.831% and 71.389% of the variance, respectively, with the top three components cumulatively explaining 87.027% of the variance in heavy metal data across sample locations (Table 4). According to Gradilla- Hernández [17], principal components explaining 70-90% of the overall variance are considered acceptable. Our analysis met this criterion, with the top three PCs accounting for 87.027% of the variance (Table 2). The Kaiser-Meyer-Olkin (KMO) measure of 0.651 (> 0.5) and Bartlett's test ($p < 0.05$) confirmed the suitability of the data for PCA (Table 5), indicating adequate sampling and variable independence. Two main components were identified with eigenvalues greater than one. PC1, accounting for 49.831% of the variance, had strong loadings for BOD, COD, PO_4, NO_3, and pH, suggesting an anthropogenic origin linked to microbial activity in cassava mill operations [3, 21]. PC2, explaining 21.559% of the variance, was dominated by pH, Pb, and EC.

Table 4.Correlation matrix of heavy metal parameters

Variable		pH	Mg	SO4	NO3	PO4	Cl	TDS	EC	Pb	Cd	As	Cr	Co	Ni	Fe	BOD	COD
	pH	1.000	.176	-.121	-.414	-.320	-.288	-.439	-.417	.338	.004	-.299	.064	-.335	.500	.176	-.339	-.251
	Mg		1.000	.446	.452	.749	.742	-.534	-.588	.730	.258	-.104	.717	.094	.452	1.000	.727	.796
	SO_4			1.000	.615	.654	.686	-.447	-.308	.347	.349	.293	.364	.252	-.098	.446	.668	.622
	NO_3				1.000	.892	.902	-.394	-.346	.557	.743	.737	.318	.042	-.473	.452	.872	.789
	PO_4					1.000	.988	-.478	-.454	.594	.502	.375	.580	.230	-.066	.749	.963	.945
	Cl						1.000	-.523	-.507	.622	.544	.407	.581	.212	-.103	.742	.962	.933
	TDS							1.000	.891	-.603	-.378	-.109	-.523	-.060	-.239	-.534	-.424	-.465
	EC								1.000	-.668	-.393	-.083	-.520	.008	-.272	-.588	-.414	-.462
	Pb									1.000	.781	.415	.285	-.513	.038	.730	.512	.546

	Cd										1.000	.888	-.066	-.589	-.551	.258	.442	.376
	As											1.000	-.243	-.428	-.825	-.104	.351	.224
	Cr												1.000	.560	.436	.717	.650	.706
	Co													1.000	.249	.094	.344	.327
	Ni														1.000	.452	-.113	.031
	Fe															1.000	.727	.796
	BOD																1.000	.967
	COD																	1.000

**Correlation is significant at the 0.01 level (2-tailed)

IV. CONCLUSION

This study investigated the impact of cassava leachates on soil quality near Omu-Aran. The results showed that physicochemical parameters in the soil near the cassava production area were generally higher than those in the control sample, except for pH. Significant differences were observed in all heavy metal parameters, with levels exceeding WHO permissible limits in both the study area and control. The findings suggest that cassava mill activities in Omu-Aran negatively impact surrounding arable soils, although the impact may be less severe compared to other areas with similar operations.

PCA confirms that the significant component PC1 includes BOD, COD, PO_4, NO_3, and pH. Therefore, the Cassava mill is experiencing accumulation of toxic elements, and the pollution is more anthropogenic. A strong positive correlation exists between BOD and NO_3. Soil's ability to accumulate elements largely determines chemical concentrations. Residents in the control area appear to be at lower risk.

V. RECOMMENDATION

The detected pollution highlights the need for regular monitoring of anthropogenic activities in these areas to prevent further chemical buildup and potential harm to the environment and human health. Implementing machine learning to analyze and predict future accumulation trends could enhance proactive management.

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