Characterization of Cassava-waste Effluents Contaminated Soils in Ile-Ife, Nigeria

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ABSTRACT

Cassava processing into gari, lafun, tapioca and starch by processors is gaining more attention in Ile-Ife, Osun State, southwestern Nigeria. The various food products are rich sources of carbohydrate in the staple diets of many households. Gari is one of the most common staple foods in every home in many parts of the country so this processing procedure will witness more cassava-waste effluent generation whose disposal has not been given any attention in recent times. The release of wastewater from the wet processing operations such as washing, grating and pressing results in the pollution of the soil and the water environment. This study therefore aimed at characterizing cassava-waste effluent contaminated soils in Ile-Ife, Nigeria by sample analysis following standard methods and procedures. Analyses were found to have great variation in terms of pH (5.5-6.2), electrical conductivity EC (0.62-0.86 mmhos/cm) and were quite high for Location IV and V when compared to that of other locations, heavy metal ions with high concentrations values well above acceptable limits (0.74, 5.66, 0.38, and 3.12 ppm for Zn, Fe, Cu and Mn respectively) apart from the environment being odorous and the soil of high coloured pigmentation. The percent organic matter (OM) ranged from 0.33-0.45% while the organic carbon (OC) ranged from 0.24-0.32%. It is therefore recommended that cassava waste effluent, which is a major source of pollution in the cassava processing areas and with deleterious effects on the flora and fauna, be properly treated before being discharged to the adjourning environment.

Key words: cassava-waste effluent, characterization, *gari*, *lafun*, pollution, Ile-Ife.

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INTRODUCTION

Cassava is one of the world's most important food crops. Throughout the tropics, the roots and leaves of the plant serve as an essential source of calories and income. About 600 million people in Africa, Asia and Latin America depend on cassava crop for their food and incomes. In Africa, cassava production showed a fourfold increase over the last fifty years: from around 30 to above120 million tonnes/year (CBN 2011). In cassava producing countries like Nigeria and Ghana, wide adoption of high-yielding varieties and better pest management have resulted in a sharp rise in production (IFAD, 2010). The clusters of small and medium-sized cassava processors in Ile-Ife, southwestern Nigeria generates income and improves the household economy by adding value to the cassava roots harvested. These clustered and seasonal processing activities tend to generate more wastewater effluent than can be utilized, converted or managed. Also, the directives by the Federal Government of Nigeria (FGN) on the use of at least 10% of cassava flour as partial substitution for wheat flour in bread baking boosted output in cassava production and utilization. The introduction of cassava bread into the Nigerian market which is gaining widespread acceptance will continue to generate tremendous cassava processing waste effluent from the industrial processing of cassava into flour (CBN, 2011).

With the rapid industrialization in India, environment pollution by industrial waste has increased tremendously and the discharge of waste water from industries such as tanneries, pulp and paper, textile, petroleum, chemical industries etc. pollute water bodies (Tiwari, 1994; Muthuswamy and Jayabalan, 2001, Noorjahan et al., 2004, and Noorjahan and Jamuna, 2012). The quantities and characteristics of the discharged effluent vary from industry to industry depending on the product, water consumption and average daily production (Joshi and Santani, 2012). It is therefore highly hazardous or harmful if billions of gallons of wastewater produced everyday from cassava processing locations in Nigeria are not treated before being released to the environment.

A large volume of wastewater is released onto the soil and surface waters of Ile-Ife through the drainage systems which majorly seep into the groundwater and adjoining water bodies and later flows through the major water tributaries (Plate 1.). The cyanide content of cassava root varies with the plant variety and soil conditions and may range between 75 and 1000 mg cyanide/kg (Piva, 1987). However, some cassava roots have very high cyanide content, sometimes exceeding 2600 mg/kg (Oke, 1968). They are thus, a potent hazard to the natural sources like soil, water, flora, fauna, livestock and the human population around the processing locations. The high content of organic matter and the high toxicity of cyanide in effluents are drawbacks for the local environment. On the other hand, fragments of cassava and peels are the principal solid residues produced.

Studies have shown that most of the heavy metals essential for growth of organisms are only required in low concentrations (Akpoveta *et al*, 2010). The increasing concentration of heavy metals due to cassava processing has led to bioaccumulation of metals in flora and fauna. Heavy metals are not biodegradable so they accumulate in primary organs in the body and over time begin to fester, leading to various symptoms of diseases (Siyanbola *et al.*, 2011). Several studies have been conducted on adverse effects of waste effluents on soil and water environment (Sponza, 2002 and Chaturvedi *et al.* 1999). Untreated or incompletely treated waste effluent can be harmful to both aquatic and terrestrial life by adversely affecting on the natural ecosystem and also long term health effects (Joshi and Santani, 2012). Bioremediation is emerging as most ideal technology for removing pollutants from the environment by the action of microbes.

This paper reports the collection and laboratory analysis of cassava-wastewater contaminated soil in order to find out the physico-chemical load put in by the waste effluent generated from these industries to the processing environment. The study also helps in finding the impact of the cassava-waste effluents on corresponding soil and water ecosystem.

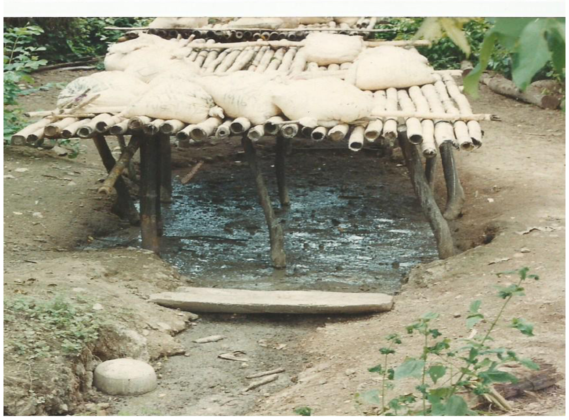
MATERIALS AND METHODS

This study was carried out in Ile-Ife, Osun State, in southwest Nigeria (Lat 07° 26' N - 07 ° 33' N of the Equator and Long 004 ° 30' E - 004 ° 35' E of the Prime Meridian). It is an ancient town comprising the Obafemi Awolowo University campus and about 40 km south of Osogbo, the State Capital. The sampling of soil was carried out from five clustered cassava processing locations (Plate 2). Samples 1 were collected during the off-season period while Samples 2 were collected during the peak of the processing season which is from April to October before the dry season of the year begins, all samples were replicated. The peak of the cassava processing period represents the best time of least resistance by soil to uprooting during harvesting. Samples were collected directly from the locations in sterilized dry plastic bags and subsequently used for physico-chemical examination. The samples collected were analyzed for parameters such as: pH, Electrical Conductivity (EC), percent organic carbon (OC), percent organic matter (OM), available N, phosphate and potash; all by standard methods (APHA, 1992).

Plate 1: Cassava wastewater from the press (A) and draining rack (B) flowing into the cemented drain collection pits (C). (The cassava wastewater later flows through the drainage systems into streams and nearby water bodies).

A. The cassava-mash pressing mechanism

C. The cemented drain collection pit



B. The draining rack

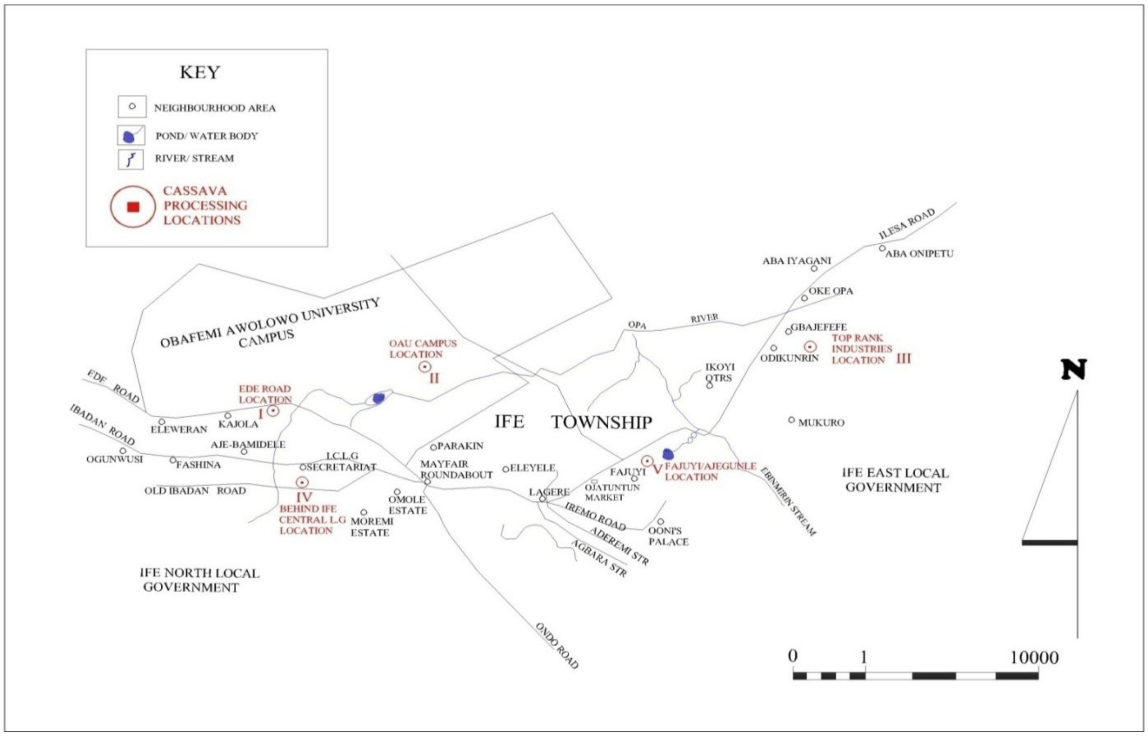


Plate 2: The study area

RESULTS AND DISCUSSION

Soil infiltration rates and permeability

Changes in hydraulic properties in response to the impact of cassava-waste effluent were observed. There is a wide variation in the infiltration characteristics of the five soil types collected from each of the processing centers under the study compared with a non-impacted soil condition from the same location Table 1. For Locations II and IV, the initial infiltration rate was high with a sharp decrease over time until almost a constant infiltration rate was obtained compared with Locations I and V that has low initial infiltration rate which attained a constant rate over time. The infiltration rates of the impacted soil condition differ significantly from that of the non-impacted from within the same location, so also there are considerable difference between locations. This could be attributed to the nature, type, the extent and effect of cassava waste-effluent disposal on the soil and the contributing effect of microorganisms and the organic matter content. The nature of the pores and voids that exist in the impacted soils, which in some cases might have been clogged as a result of the cassava waste effluent, may be responsible for the low water infiltration rates.

There is no significant effect of waste on soil classification. The soil class varied from sandy clay and silty clay loam to sandy loam and clay loam with a high percentage of sand in most locations. In the poorly graded soil, the hydraulic conductivity increases with a decrease in moisture content. This shows that the water-retaining ability of the poorly graded soil is low. In the well-graded gravel-sand mixture, the hydraulic conductivity varies linearly with moisture content with a corresponding small change in water content. The nature of pores that exist in the soils is responsible for variations in soil behavior at different rates. These variations may not be the effect of texture alone but also the structure, which affects the water retention capacity and the hydraulic conductivity. This will also affect the pore spaces or void in the soil which conductivity is a function. The hydraulic conductivity in the impacted and the non-impacted soil conditions differ significantly (Table 1).

Table 1: Infiltration rates and hydraulic conductivity in the waste-impacted and no waste-impacted soil condition

Locations	Soil condition					
	Infiltration rates (cm/hr)		Hydraulic conductivity (cm/sec)		Average water content (%)	
	Impacted	Non-impacted	Impacted	Non-impacted	Impacted	Non-Impacted
I	249.65	345.83	2.47×10^{-1}	3.38×10^{-1}	18.4	16.2
II	158.19	266.30	7.58×10^{-2}	1.52×10^{-1}	11.9	12.1
III	55.65	83.50	1.44×10^{-1}	2.33×10^{-1}	8.3	7.9
IV	166.05	275.69	7.79×10^{-2}	2.33×10^{-1}	20.5	18.3
V	258.05	371.65	1.47×10^{-1}	2.99×10^{-1}	5.7	5.2

Soil aggregate stability and Wet Stability Index

The cassava-waste impacted soil shows a significant increase in light fraction organic matter but had no effect on the heavy fraction polysaccharides when changes in soil structure in response to impact or non-impact with waste effluents were examined. The light fraction organic matter extracted from the soils responded significantly to the effect of waste effluent at all sampled points (Table 2). The impacted soil increased the dispersible clay fraction; this might be interpreted as a direct effect of the light fraction organic matter on the clay which might not be a good and clear indicator of macro-aggregate stability interpretation. The Wet Stability Index (WSI) responded significantly to the cassava-waste-impacted soils and the level of organic matter fractions in each of the locations considered. The comparison of the mean value of WSI for the samples further shows as much as 83.04, 81.77, and 81.20% for Locations I, II and V respectively. However, WSI for all the impacted soils were significantly higher than the non-impacted conditions which indicates the improvement in the aggregate stability of the impacted soil over the non-impacted.

The rapid improvement in the stability of the aggregates due to starch content of the effluent suggests the formation of extra-cellular polysaccharides, which are important bonding agents for soil aggregation. It also acts as energy source for soil microbes. This phenomenon becomes very pronounced in cassava waste-laden soils. The lower WSI values of non-impacted soils suggest that the contribution of cassava-waste effluent to aggregate stabilization in impacted soil condition is significant. This may be due to the low microbial activity, because microorganisms require inorganic nitrogen for the formation of their body protoplasm. Pores greater than 10µm and WSA differs significantly even at 5% between the impacted and the non-impacted soil condition of the same environment.

Table 2: Effect of cassava waste effluent on some soil parameters

Soil Parameters	Locations									
	I		II		III		IV		V	
	A	B	A	B	A	B	A	B	A	B
Light fraction organic matter (g/kg)	5.63	5.46	6.70	7.30	8.10	8.90	6.75	7.08	6.88	7.02
Heavy fraction polysaccharides (g/Mg)	5.44	5.43	5.50	5.22	5.38	5.45	5.49	5.58	5.49	5.43
Dispersible clay (g/g)	0.53	0.67	0.33	0.42	0.42	0.49	0.48	0.51	0.39	0.40
Water stable aggregates (g/g)	0.43	0.52	0.46	0.56	0.46	0.46	0.44	0.43	0.48	0.46
Pores [a] < 10µm (m^3/m^3)	0.19	0.13	0.18	0.20	0.20	0.19	0.17	0.12	0.19	0.19
Porosity [b] (m^3/m^3)	0.50	0.58	0.54	0.62	0.33	0.40	0.45	0.40	0.57	0.55
Pores [c] >10µm (m^3/m^3)	0.31	0.36	0.33	0.38	0.36	0.30	0.32	0.31	0.34	0.35
Saturated hydraulic Conductivity [d] (m/s x 10^{-5})	8.70	8.50	10.60	11.00	10.80	11070	12.80	11.20	11.00	11.00

A and B - Impacted and non-impacted soil conditions respectively

[a] Water retained at -300hPa matrix potential

[b] Water retained at saturation

[c] Difference between water retained at saturation and at -300hPa matrix potential

[d] Geometric mean

Other physico-chemical characteristics of the impacted soil

The soil samples from locations with the impact of cassava-waste effluent in the study area showed great variations in some physico-chemical properties. The soil samples were analysed for pH, organic carbon, organic matter, percentage nitrogen, phosphate and potash. Samples collected were observed to be reddish-brown and brown to dark-brown in colour with a pungent-choky, fishy smell. The pH of the cassava-waste impacted soil samples were acidic in nature (5.5-6.2) and majorly higher than standard values expected on agricultural soils with the exception of Location III that was alkaline (pH 8.1) in nature.

The values of the EC ranged from 0.62-0.86 mmhos/cm and were quite high for Location IV and V when compared to that of other locations (Table 3). These high values of EC might be due to the presence of high concentration of ions and wastewater contributed by the numerous and clustered processing centers in that particular location. Gupta *et al.* (1995) and Joshi and Kumar (2011) also reported higher pH and EC values of soil samples affected by industrial effluent from industrial processes and their waste disposal. The percent organic matter and organic carbon ranged from 0.33-0.45% and 0.24-0.32% respectively. Values of nitrogen (N), phosphate (P) and potash (K) concentration in the soil samples also shows significant variability. The amount of nitrogen ranged from 0.019-0.036%. The concentration of phosphate ranged from 31-38 kg/ha and was highest in Location IV (38) with Locations I, III, V and II concentrations in decreasing order. The values of potash concentration ranged from 264-328 kg/ha and the soil sample from Location IV contained a higher amount of potash as compared to samples from all other locations. The analysis of heavy metallic ions (Zn, Fe, Cu and Mn) of the soil samples showed higher values than permissible limits prescribed by ISI for industrial effluents. Presence of heavy metallic ions (Zn, Cu and Ni) may be attributed to the cassava processing centers (Ademoroti et al., 1992; Correia *et al.*, 1994; Yusuff and Sonibare, 2004; Ogunlaja and Ogunlaja, 2009; and Akan et al., 2010.). Long-term irrigation with these wastewater effluents can increase EC, organic carbon content and heavy metals accumulation in groundwater and soils (Gupta et al.,1995; Brar and Arora, 1997; Olaniya and Saxena 1997, and Siyanbola *et al*., 2011).

Table 3: Physico-chemical analysis of cassava-waste effluent contaminated soil

Parameters	Permissible Limit.*	Location I	Location II	Location III	Location IV	Location V
Colour		Dark Brown	Reddish Brown	Reddish Brown	Brown	Dark Brown
Smell		Pungent	Choky	Choky	Pungent	Choky
Ph	7-8.5	5.5	6.2	8.1	6.2	5.7
Organic matter, %	0.8-1.30	0.39	0.45	0.42	0.38	0.33
Organic carbon, %	0.5-0.75	0.28	0.21	0.28	0.32	0.24
Electrical conductivity, *mmhos/cm*	0-1.5	0.62	0.58	0.64	0.86	0.78
Nitrogen, %	0.043-0.065	0.021	0.019	0.028	0.036	0.029
Phosphate, *kg/ha*	23-56	36	31	35	38	34
Potash, *kg/ha*	142-337	288	274	264	328	282
Heavy metals, *ppm*						
Zn	0.6	0.74	0.84	1.04	1.18	0.88
Fe	4.5	5.66	5.24	4.24	6.02	5.92
Cu	0.2	0.38	0.31	0.29	0.32	0.26
Mn	2.0	3.12	2.46	3.28	4.31	2.62

*Standard values of parameters of soil (Neetika and Ashwani, 2013)

CONCLUSIONS

This study has shown that cassava processing waste effluent contaminated soil samples in Ile-Ife, Nigeria were odorous, foul smelling and of a highly coloured pigmentation. The pH was mainly acidic in the impacted soil condition and contained trace metallic ions at concentrations values well above the recommended permissible limits. This study showed that soil in a cassava-processing environment where waste effluents are indiscriminately discharged may be highly polluted. There is urgent need to develop and follow adequate effluent treatment methods to reduce the potential environmental hazards of these wastes before their discharge onto agricultural lands and surface water bodies.

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