

## ASSESSMENT OF THE IMPACT OF CASSAVA MILL EFFLUENT (CME) ON THE MICROBIAL DIVERSITY, PHYSICOCHEMICAL PARAMETERS AND HEAVY METAL CONCENTRATIONS IN THE RECEIVING SOIL

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### ABSTRACT

Cassava mill effluent has become a major cause of environmental degradation which affects soil properties. This study revealed the impact of cassava mill effluent on microbial diversity, physicochemical parameters and heavy metal concentrations in the receiving soils collected in triplicate between April and June, 2015 from five sites in Ogwa, Edo State, Nigeria. Standard methods were used for the soil analysis. The mean heterotrophic, coliform and fungal counts ranged from  $1.38 \pm 4.6 \times 10^8$  CFU/g to  $8.90 \pm 5.5 \times 10^8$  CFU/g,  $1.20 \pm 6.1 \times 10^8$  CFU/g to  $9.4 \pm 5.6 \times 10^8$  CFU/g and  $4.17 \pm 2.4 \times 10^8$  CFU/g to  $7.90 \pm 2.8 \times 10^8$  CFU/g respectively ( $p < 0.05$ ). The microbial isolates identified in order of decreasing prevalence were *Staphylococcus aureus* (19.71%), *Escherichia coli* (12.87%), *Proteus* sp. (12.50%), *Bacillus* sp. and *Klebsiella* sp. (12.01%), *Pseudomonas aeruginosa* (11.30%), *Penicillium* sp. (7.21%), *Aspergillus* sp. (6.25%) and *Rhizopus* sp. (3.13%). The pH values ranged from 5.78 – 6.12, electrical conductivity (112 – 211  $\mu$ S/cm), chloride (30.24 – 56.97 mg/kg), sulphate (1.23 – 2.32 mg/kg), nitrate (15.90 – 29.96 mg/kg), phosphate (10.98 – 20.68 mg/kg), total carbon (3.17 – 5.83%), total nitrogen (0.32 – 0.58%) and moisture content (10.65 – 17.63%),  $\text{Na}^+$  (42.56 – 80.18 mg/kg),  $\text{K}^+$  (78.40 – 147.70 mg/kg),  $\text{Ca}^{2+}$  (9.07 – 17.09 mg/kg),  $\text{Mg}^{2+}$  (11.09 – 20.89 mg/kg). The pH at the different sample locations were lower than the control, and other physicochemical parameters were higher ( $p < 0.05$ ). The concentrations of heavy metals in the contaminated soils are in the following ranges:  $\text{Fe}^{2+}$  (7.95 – 14.98 mg/kg),  $\text{Zn}^{2+}$  (0.22 – 2.13 mg/kg),  $\text{Mn}^{2+}$  (0.35 – 1.18 mg/kg),  $\text{Cu}^{2+}$  (1.01 – 1.90 mg/kg),  $\text{Ni}^{2+}$  (0.24 – 0.80 mg/kg),  $\text{Cd}^{2+}$  (0.001 – 0.60 mg/kg),  $\text{V}^{2+}$  (0.19 – 0.72 mg/kg),  $\text{Cr}^{6+}$  (0.26 – 1.03 mg/kg) and  $\text{Pb}^{2+}$  (0.04 – 0.35 mg/kg). These values are still below the permissible limits recommended in Nigeria by the Department of Petroleum Resources except for iron which was higher in all sampled sites and significantly different from the control ( $p < 0.05$ ). The order of accumulation of heavy metals was  $\text{Fe}^{3+} > \text{Cu}^{2+} > \text{Zn}^{2+} > \text{Mn}^{2+} > \text{Cr}^{6+} > \text{Ni}^{2+} > \text{V}^{2+} > \text{Cd}^{2+} > \text{Pb}^{2+}$ . The cassava mill effluent negatively affected the soil microbial diversity, physicochemical parameters and heavy metal concentrations in the impacted soils.

**Key words:** Cassava mill effluent, Microbial diversity, Physicochemical parameters, Heavy metals, Receiving soil.

### INTRODUCTION

Presently, the methods involved in cassava processing are referred to as crude and un-standardized, lacking scientific principles and waiting for possible upgrade (Omomowo *et. al.*, 2015). Nigeria being the world leading producer of cassava accounts for 52,403 million tons annually (FAO, 2012). In Africa, cassava is being used as a substitute for flour, thus providing income to poor farmers, saving foreign exchange for national governments and providing a cheap and rich source of protein and vitamins A and B when the leaves of the cassava are eaten by some people as green vegetables (Omomowo *et. al.*, 2015). The cassava mill effluent (CME) from traditional grating during processing is a major cause of environmental degradation,

contaminating agricultural farmlands, streams and affecting biodiversities (Olorunfemi *et. al.*, 2008; Chinyere *et. al.*, 2013; Izonfuo *et. al.*, 2013). The discharged CME contains large amount of water, hydrocyanic acid and organic matter in the form of peels and sieves from the pulp as waste products.

The toxicity of cassava mill effluent is basically associated with its acidic pH and cyanide content. In acidic soils, plants are likely to take up toxic metals, which may prevent seed germination or eventual death (Olorunfemi *et. al.*, 2008). When these cassava mill effluents are improperly disposed, they generate offensive odour and unsightly scene (Okafor, 2008). They are thus, a potential hazard to soil, water, flora, fauna,

livestock and human population living around the processing locations (Omonoma and Akipelu, 2010).

The increasing level of heavy metals in the environment from various anthropogenic sources like cassava mill effluent should be a source of concern for environmentalists (Iwegbue 2007; Opeolu *et. al.*, 2008; Osakwe and Egharevba, 2008). These heavy metals that are released into the environment tend to persist indefinitely, accumulating in living tissues through food chain causing severe diseases to man (Akpoveta *et. al.*, 2010; Enerijiofi and Ajuzie, 2012).

With attention paid to industrial sites in urban centres, relatively few studies have been reported on the impact of cottage industries such as cassava processing mills in sub-urban and rural soils. In view of the above, this study was undertaken to provide an assessment of the impact of cassava mill effluent on the microbial diversity, physicochemical properties and heavy metal concentrations in soils from Ogwa, Edo State.

## **MATERIALS AND METHODS**

**The Study Area:** Ogwa is a University town located in Esan West local Government Area of Edo State, Nigeria. It lies approximately on latitude 6° 30' 0N and longitude 6° 12' 0E. It is among the constituent communities of Esan land. The soil type is precisely reddish-brown in colour and fertile. The main occupation of the people is farming with cassava being the highest among their farm produce.

**Sample Collection:** Soil samples contaminated with cassava mill effluent for over five years were aseptically collected from five selected locations namely Dumorue, Eguare, Eha, Idumuhijie and Lower Izogen in Ogwa in triplicate on a monthly basis from April to June, 2015. Soil samples free of cassava mill effluent were also collected from Samuel Adegboyega University garden located within the same community which served as control. The sites were cleared of debris and soil samples collected within depth of 0 - 15cm from each sampling site with the aid of a sterilized Auger. All the soil samples were transported to Samuel Adegboyega University Laboratory, Ogwa for Microbiological analysis and Splendid Stain

Research Laboratory, Benin for physicochemical and heavy metal analysis.

**Inoculation and Enumeration of Bacterial and Fungal Isolates:** Aliquots (1 ml) of appropriate ten-fold serial dilution of the soil samples were inoculated into Nutrient, MacConkey and Potato Dextrose agars in triplicate using pour plate method. The inoculated plates were incubated at 37 °C for 24 hrs for the enumeration of the total heterotrophic bacteria and coliform counts while Potato dextrose agar plates were incubated at 25 °C for 72 hrs for the enumeration of total heterotrophic fungal count. Visible discrete colonies on inoculated plates were enumerated, purified and expressed in CFU/g (Cheesbrough, 2005).

## **Characterisation of Bacterial and Fungal Isolates**

The purified bacterial isolates were characterized culturally, morphologically and biochemically while the fungal isolates were also characterized microscopically and macroscopically using the method of (Cheesbrough, 2005) to confirm their identity.

## **Physicochemical and Heavy Metal Analysis of Soil Samples**

**Sample Preparation:** The soil samples were air-dried to constant weight, crushed with mortar and pestle to fine particles. The fine particles were sieved using 2 mm sieve to remove stones and other particles. They were stored in fresh clean polyethylene bags in a refrigerator at 2 °C for about 7 days to maintain the stability of the samples without significant alteration in their properties.

**Physicochemical Analyses:** Physicochemical properties of the soil samples: soil pH was determined ex-situ as described by Bates (1954). The moisture content, texture, chloride and electrical conductivity were determined using the method of APHA, (1998). Total organic carbon was determined by the method of Akubugwo *et al.* (2007), soil nitrates, phosphates and sulphates were carried out as described by Dewis and Freitas (1970) while soil nitrogen was determined using method of Udoh and Ogunwale (1986).

### Analyses of Cations and Heavy Metals in Soil Samples

The method of Etori and Etori, (2012) was used. Two grams (2 g) of the fine soil samples were digested with 1: 10 of HNO<sub>3</sub>: HCl. Twenty five millilitres (25 ml) of distilled water was added to the mixture and then heated for 20 minutes in a water bath to obtain a milky colour. The samples were removed from heat, allowed to cool and transferred into 50 ml sample bottles and made up to the 25 ml mark with distilled water. The concentrations of cations like Na<sup>+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup> and K<sup>+</sup> were determined with a digital Jenway flame photometer model PFP-7 by aspiration while the concentrations of the heavy metals were determined using Shimadzu atomic absorption spectrophotometer, model PG 550.

### Assessment of the Impact of Cassava Mill Effluent on Cations and Heavy Metals in the Receiving Soil

Three indices were employed to assess the impact of cassava mill effluent in receiving soils according to the method of Pam *et. al.* (2013).

- (i)  $C_f = C_{0-1}^i / C_n^i$ . Where  $C_{0-1}^i$  is the mean content of metals from at least 5

contaminated samples and  $C_n^i$  is the pre-industrial (control) concentration of individual metals.

- (ii)  $I\text{-geo} = \log_2 (C_n / 1.5B_n)$ . Where  $C_n$  is the concentration of the heavy metal in the contaminated soil sample and  $B_n$  is the concentration of the metal in the unpolluted (control) sample. The factor 1.5 is introduced to minimize the effect of the possible variations in the control values which may be attributed to lithogenic variations in the soil.

- (iii) Quantification of anthropogenic metal.

$$\frac{\bar{x} - \bar{x}_c}{\bar{x}} \times 100\%$$

Where  $\bar{x}$  = average concentration of the metal in the contaminated soil sample and  $\bar{x}_c$  = average concentration of the metal in the control samples.

### Statistical analysis

Conventional statistical methods were used to calculate means and standard errors. Data were statistically tested for one-way analysis of variance (ANOVA) and Duncan's multiple range test was applied for comparing means according to the method of Ogbeibu, (2005).

## RESULTS AND DISCUSSION

Table 1: Total heterotrophic counts of microorganisms  $\times 10^8$  in CFU /g

Source of Sample	Heterotrophic counts	Coliform counts	Fungal counts
Dumorue	8.90 $\pm$ 5.51 <sup>c</sup>	1.20 $\pm$ 6.12 <sup>a</sup>	4.90 $\pm$ 2.31 <sup>a</sup>
Eguare	5.50 $\pm$ 2.92 <sup>b</sup>	7.20 $\pm$ 5.30 <sup>c</sup>	5.70 $\pm$ 9.40 <sup>b</sup>
Eha	6.48 $\pm$ 4.60 <sup>b</sup>	5.70 $\pm$ 3.64 <sup>b</sup>	6.20 $\pm$ 1.53 <sup>b</sup>
Idumuhijie	1.41 $\pm$ 4.70 <sup>a</sup>	9.40 $\pm$ 5.60 <sup>c</sup>	4.17 $\pm$ 2.44 <sup>a</sup>
Lower Izogen	1.38 $\pm$ 4.13 <sup>a</sup>	8.80 $\pm$ 4.91 <sup>c</sup>	7.90 $\pm$ 2.80 <sup>c</sup>
Control	1.29 $\pm$ 3.62 <sup>a</sup>	1.10 $\pm$ 2.93 <sup>a</sup>	2.13 $\pm$ 1.52 <sup>a</sup>

Values are in mean  $\pm$  standard error (n=9) of soil samples

NB: Mean with different superscript on the same column are significantly different (P<0.05).

The mean heterotrophic, coliform and fungal counts ranged from 1.38  $\pm$  4.6 $\times 10^8$  CFU/g to 8.90  $\pm$  5.5 $\times 10^8$  CFU/g, 1.20  $\pm$  6.1 $\times 10^8$  CFU/g to 9.40  $\pm$  5.6 $\times 10^8$  CFU/g and 4.17  $\pm$  2.4 $\times 10^8$  CFU/g to 7.90  $\pm$  2.8 $\times 10^8$  CFU/g (Table 1). Soil is a natural store for microbes, little wonder, the control had some counts but the contaminated soils had higher counts which may be due to the presence of

organic components of the cassava mill effluent that enhanced more microbial growth and proliferation. This trend agreed with the submission of Ezeigbo, *et al.* (2014) and Nwaugo *et al.* (2008) where they reported that cassava mill effluent contaminated soils had higher bacteria and fungi counts than the control soils.

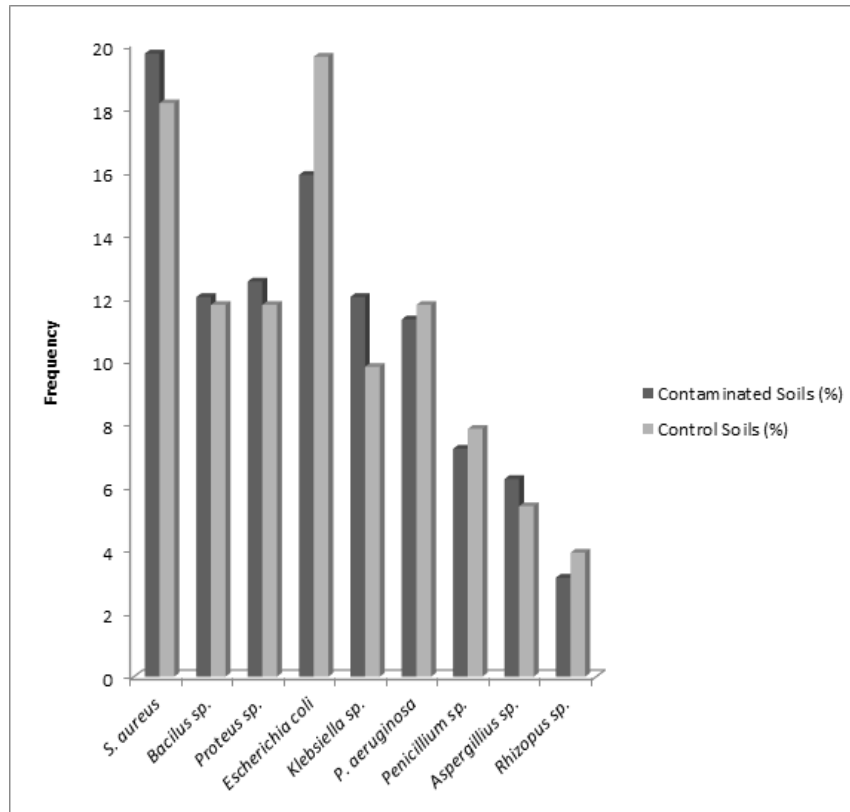


Figure 1: Frequency of Occurrence of Microbial Species

The microbial isolates included *Staphylococcus aureus* (19.71%), *Escherichia coli* (12.87%), *Proteus sp.* (12.50%), *Bacillus sp.* and *Klebsiella sp.* (12.01%), *Pseudomonas aeruginosa* (11.30%), *Penicillium sp.* (7.21%), *Aspergillus sp.* (6.25%) and *Rhizopus sp.* (3.13%) (Figure 1). The result agreed with the findings of Ahanotu *et. al.* (2013), Ezeigbo *et. al.* (2014) and Omomowo *et. al.* (2015) who reported similar organisms. *Bacillus* has been implicated in the spoilage of starchy foods and in food poisoning (Omomowo *et. al.*, 2015). The presence of *Proteus* species was an indication that the contaminated soils were enriched with protein

substances (Achudume and Olawale, 2007). The fungi isolated are known to be responsible for causing a lot of diseases especially *Aspergillus sp.* which is known for aflatoxin production that destroys the liver by inducing fatty acid metamorphosis in cells (Uraih, 2004). However, the cassava mill effluent contaminated soils had higher bacteria and fungi diversities than the control. This was an indication that the cassava mill effluent soils contained more organic matter from the cassava mill effluent than the control which corroborated the report of Nwaugo *et. al.* (2008).

Table 2: Physicochemical Parameters of Contaminated and Control Soils.

Parameters	Unit	Dumorue	Eguare	Eha	Idumuhijie	Lower Izogen	Control
pH		5.78± 0.51 <sup>b</sup>	6.12± 0.72 <sup>c</sup>	5.91± 0.14 <sup>c</sup>	5.87± 0.28 <sup>c</sup>	5.95± 0.46 <sup>b</sup>	7.93± 0.93 <sup>c</sup>
Electrical conductivity	µS/cm	112.00±2.51 <sup>g</sup>	211.00± 4.12 <sup>i</sup>	187.00± 1.14 <sup>i</sup>	194.00± 2.12 <sup>j</sup>	154.00± 1.15 <sup>g</sup>	52.00± 2.31 <sup>e</sup>
Cl <sup>-</sup>	mg/kg	30.24± 0.12 <sup>e</sup>	56.97± 1.11 <sup>g</sup>	50.49± 1.14 <sup>g</sup>	52.38± 0.76 <sup>g</sup>	41.58± 1.11 <sup>e</sup>	14.04± 0.63 <sup>d</sup>
SO <sub>4</sub> <sup>2-</sup>	mg/kg	1.23± 0.04 <sup>a</sup>	2.32± 0.12 <sup>b</sup>	2.06± 1.20 <sup>b</sup>	2.13± 1.33 <sup>b</sup>	1.69± 1.32 <sup>a</sup>	0.57± 0.01 <sup>a</sup>
NO <sub>3</sub> <sup>-</sup>	mg/kg	15.90±1.29 <sup>d</sup>	29.96± 2.16 <sup>f</sup>	26.55± 1.14 <sup>f</sup>	27.55± 2.12 <sup>f</sup>	21.87± 1.97 <sup>d</sup>	0.62 ± 0.33 <sup>a</sup>
PO <sub>4</sub> <sup>3-</sup>	mg/kg	10.98±1.41 <sup>c</sup>	20.68± 1.11 <sup>c</sup>	18.33± 0.93 <sup>c</sup>	19.01± 1.17 <sup>c</sup>	15.09± 1.18 <sup>c</sup>	0.16± 0.56 <sup>a</sup>
Sand	%	87.00± 1.16 <sup>f</sup>	92.00± 1.61 <sup>h</sup>	86.00± 1.98 <sup>h</sup>	90.00± 2.56 <sup>h</sup>	94.00± 2.19 <sup>f</sup>	91.00± 1.97 <sup>f</sup>
Silt	%	8.00± 2.45 <sup>c</sup>	6.00± 1.11 <sup>c</sup>	11.00± 0.94 <sup>d</sup>	8.00± 1.21 <sup>c</sup>	5.00± 0.18 <sup>b</sup>	6.00± 1.01 <sup>c</sup>
Clay	%	5.00± 1.63 <sup>b</sup>	2.00± 0.18 <sup>b</sup>	3.00± 1.14 <sup>b</sup>	2.00± 1.36 <sup>b</sup>	1.00± 0.14 <sup>a</sup>	3.00± 1.04 <sup>b</sup>
Total carbon	%	5.83± 1.41 <sup>b</sup>	4.66± 1.12 <sup>c</sup>	3.84± 0.16 <sup>b</sup>	3.17± 1.08 <sup>b</sup>	4.72± 1.01 <sup>b</sup>	0.64± 0.04 <sup>a</sup>
Total nitrogen	%	0.58± 1.24 <sup>a</sup>	0.47± 0.02 <sup>a</sup>	0.38± 0.24 <sup>a</sup>	0.32± 0.01 <sup>a</sup>	0.47± 1.04 <sup>a</sup>	0.06± 0.06 <sup>a</sup>
Moisture	%	13.25± 1.73 <sup>c</sup>	10.65± 1.02 <sup>d</sup>	17.63± 1.64 <sup>e</sup>	14.67± 0.04 <sup>d</sup>	12.98± 1.14 <sup>c</sup>	6.75± 1.96 <sup>c</sup>

Values are in mean ± standard error (n=9) of soil samples

NB: Mean with different superscript on the same column are significantly different (P<0.05).

The soils' physicochemical parameters are shown in table 2. There was significant difference in the concentrations of the physicochemical parameters between the contaminated soils and the control ( $p < 0.05$ ) except for nitrogen. The pH reported in the contaminated soil was found to be acidic (5.78 - 6.12) as against 7.93 in the control soils. The acidity of the cassava mill effluent-impacted soils could be attributed to the presence of hydrogen cyanide and organic acids produced during the decomposition of cassava mill effluent by microorganisms. The acidic pH reported in this study determines the availability of nutrients and promotes movement of heavy metals (Akpoveta *et. al.*, 2010). The electrical conductivity values of the effluent-impacted soils ranged from 112 – 211  $\mu\text{s}/\text{cm}$  while control had the least (52  $\mu\text{s}/\text{cm}$ ). The implication of these values indicated that there was a reasonable presence of anions in soils (Olorunfemi *et. al.*, 2007). The sulphate concentration attested to the enhanced microbial activities in soil which are responsible for sulphate ester hydrolysis (Chinyere *et. al.*, 2013). This study reported nitrate values of between 15.90 - 29.96 mg/kg. Nitrate is one of the most frequently utilizable forms of nitrogen in soil which can be converted to proteins (Stanton, 2010; Nestic *et al.*, 2008). Phosphate recorded ranged from 10.98 - 20.68 mg/kg. This value in the impacted soil could

be because cassava tubers are rich in phosphate (Omomowo *et. al.*, 2015). The result of this study revealed that the soils were more of sand, followed by silt and least in clay as earlier reported by Onweremadu and Duruigbo (2007). Hence, the high sand content encouraged leaching of heavy metals deep down into the soil depth due to the larger pore size (Akpoveta *et. al.*, 2010).

The total organic carbon ranged from 3.17 - 5.83%. The impacted soils were higher in carbon content which may be due to the presence of biodegradable components which were readily available in the effluent. Total nitrogen ranged from 0.32 - 0.58%. The low nitrogen levels were indicative of low nitrification which could be due to the acidic pH reported in this study. This may have influenced the activities of microorganisms in the soils (Ezeigbo *et. al.*, 2014). The moisture content was relatively higher in the contaminated soils than the control. This could be because the cassava mill effluent contains water which could have accounted for the increased moisture content in the contaminated soils. The chlorine values reported ranged from 41.58 - 56.97 mg/kg. The concentrations in the cassava mill effluent-contaminated soils were higher than the control which may have been from the water used in the processing of the peeled cassava tubers.

Table 3: Cation Concentrations in Contaminated and Control Soils (mg/kg)

Heavy Metals	Idumuhijie	Eguare	Dumorue	Eha	Lower Izogen	Control	DPR target values
Na <sup>+</sup>	73.72± 0.87 <sup>d</sup>	80.18± 1.41 <sup>d</sup>	42.56± 0.82 <sup>d</sup>	71.06± 1.63 <sup>d</sup>	58.52± 0.82 <sup>d</sup>	1.98±1.67 <sup>a</sup>	NI
K <sup>+</sup>	135.80±2.16 <sup>c</sup>	147.70± 2.45 <sup>c</sup>	78.40± 1.24 <sup>c</sup>	130.90± 1.41 <sup>c</sup>	107.80±1.73 <sup>c</sup>	3.64±0.82 <sup>b</sup>	NI
Ca <sup>2+</sup>	15.71± 1.63 <sup>b</sup>	17.09± 1.41 <sup>b</sup>	9.07± 1.29 <sup>b</sup>	15.15± 1.41 <sup>b</sup>	12.47±2.83 <sup>b</sup>	1.61±1.29 <sup>a</sup>	NI
Mg <sup>2+</sup>	19.21± 1.89 <sup>c</sup>	20.89± 2.16 <sup>c</sup>	11.09± 1.84 <sup>c</sup>	18.51±1.12 <sup>c</sup>	15.25±1.97 <sup>c</sup>	4.21±0.17 <sup>b</sup>	NI
Fe <sup>3+</sup>	13.77± 1.64 <sup>b</sup>	14.98± 1.63 <sup>b</sup>	7.95± 0.28 <sup>b</sup>	13.28±1.76 <sup>b</sup>	10.93±0.33 <sup>b</sup>	2.65±1.64 <sup>a</sup>	4.7
Zn <sup>2+</sup>	2.13± 2.16 <sup>a</sup>	0.42± 0.02 <sup>a</sup>	0.22± 0.21 <sup>a</sup>	2.06±1.21 <sup>a</sup>	0.31±0.02 <sup>a</sup>	0.57±1.33 <sup>a</sup>	140
Mn <sup>2+</sup>	1.18± 0.57 <sup>a</sup>	0.65± 0.28 <sup>a</sup>	0.35± 0.22 <sup>a</sup>	1.14±0.63 <sup>a</sup>	0.48±0.12 <sup>a</sup>	0.32±1.36 <sup>a</sup>	850
Cu <sup>2+</sup>	1.75± 0.01 <sup>a</sup>	1.90± 1.29 <sup>a</sup>	1.01± 1.18 <sup>a</sup>	1.68±0.31 <sup>a</sup>	1.39±1.61 <sup>a</sup>	0.10±1.21 <sup>a</sup>	36
Ni <sup>2+</sup>	0.80± 0.03 <sup>a</sup>	0.44± 1.00 <sup>a</sup>	0.24± 1.24 <sup>a</sup>	0.77±1.14 <sup>a</sup>	0.32±0.51 <sup>a</sup>	0.21±0.49 <sup>a</sup>	35
Cd <sup>2+</sup>	0.60± 1.21 <sup>a</sup>	<0.001± 1.0 <sup>a</sup>	<0.001± 0.04 <sup>a</sup>	0.58±0.02 <sup>a</sup>	<0.001±0.01 <sup>a</sup>	0.16±0.14 <sup>a</sup>	0.8
V <sup>2+</sup>	0.72± 1.10 <sup>a</sup>	0.36± 0.16 <sup>a</sup>	0.19± 0.01 <sup>a</sup>	0.69±0.18 <sup>a</sup>	0.26±1.01 <sup>a</sup>	0.19±1.04 <sup>a</sup>	NI
Cr <sup>6+</sup>	1.03± 0.06 <sup>a</sup>	0.49± 0.29 <sup>a</sup>	0.26± 0.52 <sup>a</sup>	0.99±1.24 <sup>a</sup>	0.35±1.04 <sup>a</sup>	0.28±1.20 <sup>a</sup>	100
Pb <sup>2+</sup>	0.35± 1.14 <sup>a</sup>	0.08± 0.12 <sup>a</sup>	0.04± 0.72 <sup>a</sup>	0.34±0.28 <sup>a</sup>	0.06±0.08 <sup>a</sup>	0.04±1.01 <sup>a</sup>	85

Values are in mean ± standard error (n=9) of soil samples, resources

NI = not indicated, DPR= Department of petroleum

NB: Mean with different superscript on the same column are significantly different (P<0.05).

The results of the cations, some of which are heavy metals are shown in table 3. The values of  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  in all sites of the contaminated soils were higher than the control. The increase in these cations may be because they are components of cassava tubers. However, there was significant difference in the cation concentrations between the contaminated soils and the control ( $P < 0.05$ ). The heavy metals abundance was in the order:  $\text{Fe} > \text{Cu} > \text{Zn} > \text{Mn} > \text{Cr} > \text{Ni} > \text{V} > \text{Cd} > \text{Pb}$ . There was significant difference in iron concentration between the contaminated soils and the control ( $P < 0.05$ ), but for other heavy metals, there was no significant difference. The concentration of iron (7.95 - 14.98 mg/kg) reported was higher in all the contaminated soils sampled than the control and DPR (2002) standard. The concentration in the impacted soils may have been from corrosion of the metal parts of the processing machine. However, Aluko and Oluwande (2003) reported that natural soils contained significant concentration of iron. The presence of zinc could be attributed to corrosion of metal parts of the milling machine and it's also a component of crude oil used in lubricating metal parts of the processing machine (Adriano, 2001). The concentration of manganese in the cassava mill effluent ranged from 11.09 - 20.89 mg/kg which was lower than the DPR (2002) standard. However, the concentration could be attributed to wears and tears of the machinery parts. Copper, cadmium and chromium concentrations reported were far below the DPR (2002) standard but their presence could be due to their use in the prevention of corrosion of metal parts (Tucker *et al.*, 2003). The presence of Fe, Cu, and Zn in the

soils studied could also be attributed to the wearing or abrasion of the cassava milling machine parts and the emission of these metals through exhaust of the machine.

The values reported for nickel (0.24 - 0.80 mg/kg) from all contaminated samples exceeded the control but lower than the DPR (2002) standard. The low concentrations reported could be due to the absence of the major anthropogenic sources of nickel such as metal plating industries, nickel mining and electroplating in the studied area. Nickel, though essential in small doses, but can be dangerous leading to various kinds of cancer when the maximum tolerable amounts are exceeded (Scragg, 2006). The vanadium reported in this work ranged from 0.19 - 0.72 mg/kg and may have come from the cement used in construction of ground support for the grinding and milling machines. Vanadium affect seed germination, growth, photosynthesis, respiration and ATPase activity of plants, as such plants were almost absent in the contaminated sites of this study as earlier reported by Olorunfemi *et al.* (2007). Lead ranged from 0.04 - 0.35 mg/kg in the impacted soils. This concentration may have arisen from incomplete combustion of hydrocarbon compounds from the processing and milling machines. Lead accumulates in the body organs like gastrointestinal tract, kidneys and central nervous system leading to impaired development, lower intelligent quotient, shortened attention span, hyperactivity and mental deterioration in children while adults usually experience decreased reaction time, loss of memory, nausea, insomnia and weakness of the joints (Enerijiofi and Ajuzie, 2012).

**Table 4:** Average contamination factors (CF), geo-accumulation index (L-geo), and quantification of concentration (QoC) and background values (BC) of metals in soils.

Soil parameters	CF	L-geo	QoC (%)	BC
$\text{Na}^+$	31.42	20.94	96.82	1.98
$\text{K}^+$	33.24	21.97	96.97	3.64
$\text{Ca}^{2+}$	8.63	5.74	88.42	1.61
$\text{Mg}^{2+}$	4.04	2.69	75.22	4.24
$\text{Fe}^{3+}$	4.59	3.06	78.24	2.65
$\text{Zn}^{2+}$	1.80	1.15	45.00	0.57
$\text{Mn}^{2+}$	2.38	1.58	44.00	0.32
$\text{Cu}^{2+}$	15.5	10.33	93.55	0.10
$\text{Ni}^{2+}$	2.43	1.59	58.82	0.21
$\text{Cd}^{2+}$	1.50	1.00	30.43	0.16
$\text{V}^{2+}$	2.32	1.52	56.82	0.19
$\text{Cr}^{6+}$	2.21	1.48	54.84	0.28
$\text{Pb}^{2+}$	4.25	2.83	76.47	0.04

The results of the average contamination factor ( $C_F$ ), geo-accumulation index (L-geo), and quantification of concentrations (QoC) of cations and heavy metals are shown in table 4. The  $C_F$  showed highest contamination factor for potassium, sodium, copper and calcium which revealed high contamination, while magnesium, iron and lead showed considerable contamination. Zinc, manganese, nickel, cadmium, vanadium and chromium showed moderate contamination. These values particularly potassium, sodium, copper and calcium were clear indications that the contamination in the vicinity of the soils originated from anthropogenic inputs of cassava mill effluent. The pollution status in the soil expressed in terms L-geo index showed very high pollution with potassium, sodium, copper and calcium and to a lesser degree with magnesium, iron and lead. Zinc, manganese, nickel, cadmium, vanadium and chromium showed moderate pollution status. The QoC trend followed the  $C_F$  and L-geo index. However, despite the different impact assessment indices, the results were consistent with each other in the pattern of metals contamination which indicated that the anthropogenic sources of metals in the contaminated soils were of similar origin. However, the anthropogenic inputs of metals in the soils were in the order:  $K^+ > Na^+ > Cu^{2+} > Ca^{2+} > Mg^{2+} > Fe^{2+} > Pb^{2+} > Zn^{2+} > Mn^{2+} > Ni^{2+} > Cd^{2+} > V^{2+} > Cr^{6+}$ .

## CONCLUSION

This study revealed that cassava mill effluent adversely affected some physicochemical and microbiological parameters of the receiving soils. The substantial accumulation of some salts and heavy metals should be of concern due to their negative impact on soil and human health.

## RECOMMENDATION

Cassava mills must be owned and managed by individuals who have basic knowledge of environmental protection. The rural cassava producers and millers should endeavour to provide ditches where they can dispose cassava mill effluent to avoid contaminating farm lands, surface and underground water bodies. Government should set aside, an expanse of land away from residential areas where cassava processing machines should be located and wastes

treated to an acceptable level before eventual discharge.

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