Research Journal of

Environmental Sciences

ISSN 1819-3412

Academic
Journals Inc.

www.academicjournals.com

Research Journal of Environmental Sciences 5 (4): 342-353, 2011
ISSN 1819-3412 / DOI: 10.3923/rjes.2011.342.353

Quality Assessment of the Cassava-Mill-Effluent Polluted Eutric-Tropofluvent Soil

[1]Atulegwu Patrick Uzoije and [2]Nnamdi Egwuonwu
[1]Department of Environmental Engineering,
[2]Department of Agricultural Engineering, School of Engineering and Engineering Technology, Federal University of Technology Owerri, Nigeria

Corresponding Author: Atulegwu Patrick Uzoije, Department of Environmental Engineering, School of Engineering and Engineering Technology, Federal University of Technology Owerri, Nigeria

ABSTRACT

Industrialization of garri processing has impacted enormous stress on the soil medium of the processing center of Umuagwo and its immediate environment which stretched up 4 km. Therefore, this study assessed the cassava-mill-effluent -polluted eutic tropofluvent soil quality typical of the study area. Three soil morphological units namely; pedond A (Background or control), pedon B (Discharged point DP) and pedon C (Down stream DS) were identified and transect was used to link the three pedons at the inter-pedon distance of 500 m. Soil samples were collected from the pedons at different soil profiles of layers; 10-15, 15-30, 30-7 and 70-100 cm which were represented as L1, L2, L3 and L4, respectively, using the stratified random sampling technique. The samples were analyzed to determine %sand, %silt, clay, organic matter, porosity, bulk density, CEC, Cn, Na, Cd, Zn, Pb and Ph using standard analytical methods. The analysis showed normal soil physiochemical values typical of eutric tropofluent soil at Pedon A (background unit) but glaring deviation from normal at pedons B and C. Pollution load indexes used to assess the level of pollution in the study area showed a significant Pollution Load Index (PLI) as the PLI is greater than 1. The pollution was equally classified with Na constituting excessive pollution, Cn and Cu impacting moderate pollution, Zn severe pollution and Cd and Pb producing slight pollution. The study area is likely to face serious heavy metal pollution if unprecedented measure is not taken to remediate it.

Key words: CME, soil property, heavy metals, pedons, pollution

INTRODUCTION

Cassava is extensively cultivated in the tropical and subtropical regions of the world and it grows to edible starchy tuberous roots with more than 200 calories/day of food value (FAO, 2004). Claude and Denis (1990) classified cassava as the major source of carbohydrate and precisely the third largest in the world. In Nigeria, cassava can be converted to diverse traditional delicacies which include; garri, fufu, lafun flour etc some of which are fermented products (Oti, 2002). Among all the products processed from cassava, garri is the most common in Nigeria. Garri production is done in varying scales; in a small, medium and large scale. Most garri processing plants in Nigeria produce between 7-10 million tones of garri annually (FAO, 2004). In processing of cassava, the outer covering of the cassava root is peeled off. The peel which contains the outer thin brown and a thick leathering parachymatous inner covering are discarded as waste and allowed to rot, also discarded are the fiber, cassava juice and the residues water produced after separating starch and fiber during the periods of fermentation and drying, respectively (Oboh and Akindahunsi, 2003). These wastes contain varying concentration of heavy metals either as simple metals or complexes (Igbozuruike *et al.*, 2009). Oti (2002) revealed that cyanide forms complexes with zinc and also hydrogen to form an acidic complex called hydrogen cyanides acid. Continuous discharge of these wastes has accentuated the adverse effect of cassava waste to the environment and biodiversities (Goodley, 2004). For instance, the garri processing waste discharged to the environment causes foul smell and produces unattractive sights (FAO and IFAD, 2001). Like every other waste, cassava mill effluence upsets the marine ecological equilibrium. Arimoro *et al.* (2008) showed a depletion of dissolved oxygen, depression in Ph values, elevation of BOD and Nitrate values in the tropical stream of southern Nigeria. They also observed an extinction of sensitive benthic macro invertebrate species and a dominance of oligocheats and dipterans. In the same vein, the pH value of the cassava mill-effluent-polluted stream has been known to be as low as 2.6 and also known to spoil streambeds by the settled suspended solid of the effluent, thereby making marine lives such as fish breeding pretty difficult to survive (Zualiya and Muzondo, 1993; Wade *et al.*, 2002; Abiona *et al.*, 2005; Yang *et al.*, 1994).

pH is known to effect a number of edaphic factors including clay, organic matter, cation exchange capacity and some other soil physiochemical properties such as heavy metals (Alloway, 1995; Nabulo *et al.*, 2008; Okafor and Opuene, 2007). With high level of pH value of cassava mill effluent, germination of seed seems to be inhibited. The percentage germination of pennisetum americanum with increase dosage of cassava effluent is low while *Zea mays* show a higher degree of tolerant. Olorunfemi *et al.* (2007) attributed this to high acidity of the effluent which in turn determines the behavior of many heavy metals in the soil. In view of these effects of acidity on some soil properties including the heavy metals, a study on the availability of heavy metals and behavior of some soil properties in a cassava-effluent-polluted-soil will offer immense help in reclaiming such soil. Therefore this study focuses on the vertical and lateral distribution of heavy metals and the extent to which the cassava-processing-wastes influence some selected soil properties.

MATERIALS AND METHODS

Description of study area: The study was carried out at central garri processing center at Umuagwo, in Ohaji Egbema Local Government of Imo state; South- Eastern Nigeria between the months of may 2007 to September 2009. The area lies within the latitude 50 12'N to 50 48'N and at the temperature range of between 25-30°C (Global Positioning System, 1989). The people of the area experience a high rainfall of about 2000-2500 mm. Umuagwo is located in the sandy benin formation and therefore the geology of the region is characterized by quarternary, alluvium, meander belt, wooded back swamps as well as fresh water swamps (Orajaka, 1975). The soil of the area is classified as Eutric Tropofluvent (FDALR, 1985). Vegetation of the study area is that of a rain forest and the soil supports arable crop production. That explained why the major socio-economic activity of the area is cassava cultivation and processing. The garri processing centre which has been in operation for over ten years, takes up in commercial quantity, processes ranging from cassava grinding, fermentation to frying and the liquid and some solid waste such as fibers are channeled to the nearby farmland and ordinary land that has been left fallow for years.

Soil sampling techniques and analytical methods: The entire study area was divided into three morphological units or pedons; namely the background (BA) or control, the waste receiving area or point of discharge (PD) and down stream (DS) of the discharged waste or the waste drainage channel. The three morphological units represent pedon A, pedon B and pedon C, respectively. A transect was drawn to link the three units. Given the high mobility of most substances constituting the cassava mill effluent in the soil, soil sampling was extended up to 100 cm in depth. Along the transect, three pedons were dug at the inter-pedon distance of 500 m. At each pedon, soil samples were collected form different soil layers corresponding to 0-15, 15-30, 30-70 and 70-100 cm in depth with a sterilized soil auger which was rinsed with a lot of distilled water and dry cleaned after every sampling to avoid contamination. The method adopted for the sample collection was stratified random sampling technique. The layers were designated as L1, L2, L3 and L4, respectively. The samples collected from each unit and layer were done in three replicates at the interval of 20 m, making a total sample of 36 soil samples for this study. The soil samples were subjected to various laboratory analysis using the following analytical methods after processes of air-drying, crushing and sieving using 2 mm sieve; Hydrometer method as conducted by Gee and Or (2002) was used to analyzed for the particle size distribution, the SOLAAR UNICAM 969 Atomic Absorption Spectrometer (AAS) was used to analyze all the metals (Barabara *et al.*, 2002; Pardo, 2000), Core method of Grossman and Reinsch (2002), was used for the analysis of bulk density. Moisture content was determined using the gravimetric method as carried out by Obi (1990). Organic carbon was determined directly by furnace combustion at 379°C.

RESULTS AND DISCUSSION

Physiochemical properties of mill effluent: Table 1 represents the physiochemical properties of the cassava processing wastewater effluent. The physiochemical values of the effluent shows that it is highly acidic (4.1) with varieties of dissolved cations and high conductivity. CEC has the highest value of 1550 µsec with Cd having the least value. The values are arranged in ascending order as CEC>Na>Cn>Pb>Zn, pH>Cu>Cd. The results have close resemblance with that of Oviasogie and Ndiokwere (2008) especially in lead and cadmium values. Most of the values were at variance with the results of Olorunfemi *et al.* (2007) the variance is glaring in the cyanide and pH values. This can be attributed to specie of cassava and difference in soil properties as observed by Cooke and Maduagwu (1978).

Soil physiochemical properties l along the transect: The physiochemical values of the soil samples from the three pedons; the background (BA) unit or control, the discharge point (DP) and down stream (DS) were shown on Fig. 2.

Virtually all the values in BA unit (pedon A) are within the range of natural soil properties. This is evident on the results of Kabata-Pendias (1995) where analysis of unpolluted soil of similar

Table 1: Physiochemical properties of cassava mill wastewater (CMW) effluent

Parameters	Values (mg L^{-1})
Cn	54.20
Na	146.20
Cu	2.50
Zn	4.10
Cd	1.98
Ph	4.10
Pb	8.31
Conduct (µsec)	1550.00

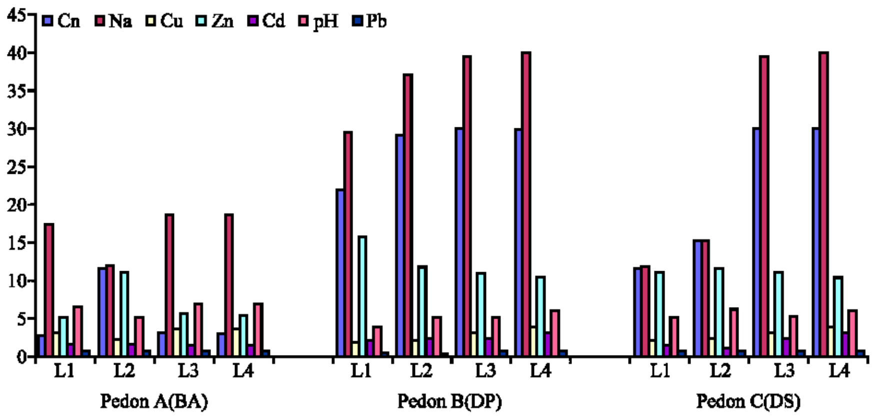

Fig. 1: Distribution of heavy metals along the transect

origin was conducted with the values of the sandy, clay and pH values being similar to the present study. Similar porosity, moisture content and bulk density values were equally observed in the study of Chukwuma *et al.* (2010). Figure 1 shows the distribution of the heavy metal characteristics in the pedons of background (BA), Discharged Point (DP) and Down Stream (DS) or direction of drainage respectively . The distribution varied spatially among the three pedons.

Heavy metal values in the DP were virtually the highest in all the three pedons, followed by the DS with the background (BA) values having the least values. The trend indicated that the metals values of DP and DS, i.e., pedons B and C respectively, were well above the BA (Pedond A) values with values in DP unit appearing the highest. This can led to severe pollution which is a potential source of hazards to human and the entire ecosystem. It also implies that the pollution level of the DP and DS units was not of natural ecology but anthropogenic visa-vis the discharge of the cassava mill effluent. In case of plant growth and germination, the situation inhibits plant development. In particular, germination of *Zea mays* seeds treated with 25-100% of cassava mill effluent was delayed (Olorunfemi *et al.*, 2007). The figure equally shows decreased trend in the heavy metal values at the DS land unit . This is attributable to the natural attenuation capacity of the soil ecosystem which is a function of the age of the pollution, degrading ability of the micro-organisms and distance from the pollution point as observed by Gerzabek (1998). Pb values increased at the Background Unit (BA) but decreased drastically at DP unit and increased again down the direction of drainage (DS). The observed decreased value of Pb within the discharged point (DP unit) implies that the cassava mill effluent seems to have Pb mitigating ability. The abundant complexing of cassava mill effluent with Pb ion as observed by Oviasogie and Ndiokwere (2008) may be responsible for this behavior. Although, Folson *et al.* (1981) observed a low exchange capacity and amount of clay in the soil as the reasons for low Pb detection in a cassava mil effluent polluted soil, but these are contrary to the findings of this study where an appreciable increase in the clay values were observed. On the contrary, the highest values of Cd was recorded at the Discharge Point (DP) where appreciable amount of CME was received. The reason is not necessarily the Cd content of the CME but mainly due to the release of Cd from the soil occasioned by the low acidic medium of the effluent. Another reason could be high adsorption capacity of Cd to soils predominant with clay (Sanchez *et al.*, 1999). The pH values in the Discharged Point (DP) appeared to be lower than the value in the effluent. This was explained by the study carried out by Ogboghodo *et al.* (2001), where the activities of micro-organisms responsible for increase in soil

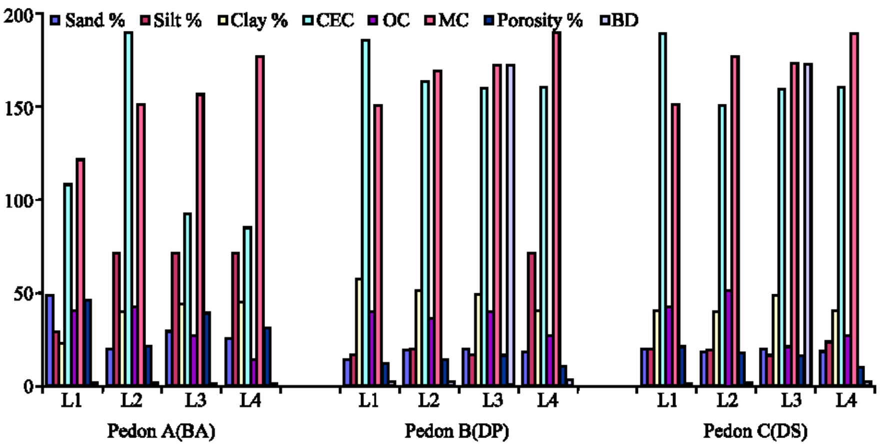

Fig. 2: Soil characteristic in various pedons

ecosystem pH, organic matter and nitrogen were observed to have been given a boast by cassava mill effluent. Low pH values observed at the DP was no doubt the consequent of the cassava mill effluent pollution. The fact that the low value of Cd observed from CME analysis as displayed in Table 1 with a high pH value, compared with the Cd values at DP unit of low pH value substantiated the fact that more Cd substance was produced. The observation is in line with the studies of Balon and Duraisamy (2003) and Wang *et al.* (2003).

Also along the transect, some other selective soil properties showed some variations among the pedons. %Sand, %Silt, porosity and organic matter decreased in value at the discharged point unit (pedon B), where the effect of the CME was high and increased again down the direction of drainage (Pedon C) as shown in Fig. 2.

The decrease in values of the aforementioned soil properties was due to the binding characteristics of CME. The starchy constituent of the effluent formed a bridge between the soil aggregates, reducing its pore sizes with its attendant reduction in porosity values and making the soil assumed a behavior of a clay soil. Consequent upon this, the bulk density of the soil soared . Similar observation was made by Ros and Nudelman (2005) in a study on the effect of crude oil contamination on the geotechnical properties of clay and sandy soils . This situation reduces the quality of the soil as it makes it impermeable and also make the land susceptible to flooding. Organic carbon depression observed was due to inertness of the micro- organisms responsible for organic matter generation resulting from low acidic range occasioned by the CME (Bolan and Durasiamy 2003). A reverse trend was observed for %Clay, CEC and MC. The increase in %Clay observed at the discharged point was as a result of the binding constituents of the cassava waste which increased the clay content of the soil. This is evident on the high Cd values observed in the DP unit (pedon B) due to its high clay content. This was already substanciated by the study (Sanchez *et al.,* 1999). The CEC value of the soil increased due to increase in the concentration of the waste (CME) as observed by Igbozuruike *et al.* (2009).

Vertical distribution of the physiochemical values of the soil: Spatial distribution of metals in the four layers; (0-15), (15-30), (30-70) and (70-100) of the 100 cm soil profile of three pedons was also observed. Figure 3 shows that most heavy metal values were observed to increase down the layers of all the pedons except Cd. Values of Cn, Na, Cu, Zn and Pb were maximum at

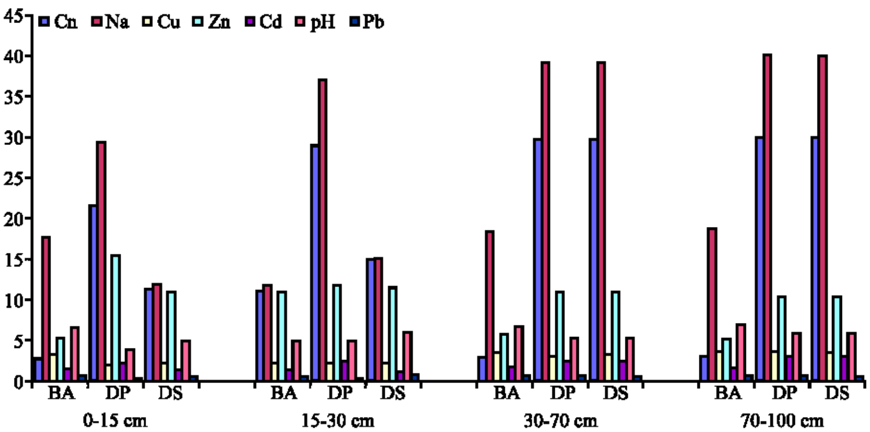

Fig. 3: Heavy metal distribution in layers of various pedons

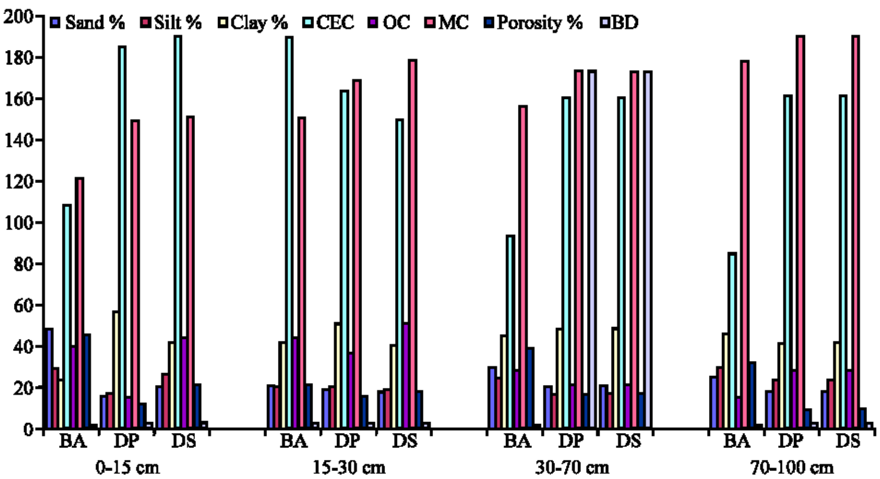

Fig. 4: Soil quality through the layers of various pedons

100 cm. Cd value is expected to be low due to pH elevation at the maximum depth. Abundance of the respective metals in the layers of various pedons is in this order L1<L2<L3<L4. This trend is due to the high mobility index of the heavy metals (Sanchez-Martin *et al.*, 2007). The pH values seemed to increase with the increase in the soil layers. The trend could be attributed to concentration attenuation of some of the constituents of the CME, as the effluent constituents were migrated down the subsoil. This is further buttressed by the seemingly low values of most metals highly sensitive to high pH such as Cd.

There were also variations in the soil properties of all the layers of the pedons, but the variations at the discharge point were glaring. Figure 4 showed that at the point of discharge, DP (pedon B), %sand, %silt, CEC and OC increased down the layer. This implies that a reasonable amount of waste constituents especially the starchy constituent which constitute the binding characteristic of CME must have been trapped at the top layer of the units. Decrease in the organic matter of the soil observed at the discharged point was due to influence of CME on the pH of the soil. As observed by Oviasogie and Ndiokwere (2008) the low acidic range occasioned by the cassava effluent, created a medium un-conducive for the propagation of organic matter production microorganism. This was buttressed by the increased values of the organic matter observed in the layers where influence of the CME was lowly felt. For instance, the values of organic matter was quite high at the highest depth of 70-100 cm (L4) of pedon-C and highest in the layers of pedon-A (background unit) where there were low CME pollution impacts. Also, presence of clay in a soil not influenced by low pH which can act as a substrate for organic matter flocculation due to its high surface area of the clay and can as well encourage adsorption of organic matter and heavy metals (Keil *et al*., 1994). This has given strength to the observation of this study where accumulation of heavy metals down the profile was stated to be responsible by appreciable amount of organic matter due to relatively high pH values.

Pollution criteria: The following pollution criteria were used to assess the pollution level of various metals; Pollution Load Index (PLI), pollution factor, pollution index and Pollution Classification (PC),

Pollution Load Index (PLI): Equation employed by Tomlinson *et al*. (1980) was used for the calculation of the Pollution Load Index(PLI) and the equation is presented thus:

$$CF = C_{metal} / C_{background} \tag{1}$$

$$PLI = n\sqrt{CF_1 X CF_2 X CF_3 X CF_4 .... CF_n} \tag{2}$$

where, CF represents the contamination factor, C_{metal} is the concentration of the metals at the Point of discharge and Down the drainage, i.e., in pedons B and C respectively. $C_{background}$ is the concentration of the metals at the Background or control unit (pedonA); n is the number of the sampled metals. With PLI >1 pollution is considered significant while there is no pollution if PLI<1.

Figure 3 showed that discharged point and down stream units were polluted with virtually all the metals. By virtue of its PLI values, Cn posed the highest pollution potential in all the pedons along the transect, followed by Zn. This implies that Cn and Zn are more abundant in all the pedons than other metals. However, the order of their abundance is as follows; Cn>Zn>Na>Cd>Pb>Cu. With respect to depth, the pollution load index analysis showed spatial variation. The load increased with depth in all the pedons . PLI is represented in all the pedons, in this order for Cn, Na, Cu, Cd and Pb, L1<L2<L3<L4 this trend of pollution load implies danger to the ground water.

Pollution Factor (pf) and Pollution Classification (PC) of the metals were derived using the Lacatusu (1998) and Poh *et al*. (2006) models.

$$Pf = \frac{C_I(m) - C_I(b)}{C_I(m)} \tag{3}$$

While pf is the pollution factor, $C_I(m)$ and $C_i(b)$ are concentration of metals at the background, i.e., pedon A and the polluted units (pedon B and C), respectively.

Pollution classification values were computed as follows:

$$PC = \frac{C_I(m) - C_I(b)}{P_I} \quad (4)$$

PC, C_I(m) and C_I(b) are as previously defined. Pi is pollution index and is expressed as:

$$P_i = \frac{C_I(m)}{C_I(b)} \quad (5)$$

Distinction between contamination and pollution was made using the ratio between contamination and pollution index and this was expressed as C_I/P_I. With this index, it will be determined at what level certain metal constitutes contamination and pollution. C_I/P_I values greater than 1 defines pollution range while that lower than 1 defines contamination range. Lacatusu (1998) went a step further to categorize pollution ranges as follows; 1.1-2, 2.1-4.0, 4.1-8.0, 8.1-16.0, >16.0 as slight, moderate, severe, very severe and excessive pollution respectively. This index was used to assess the heavy metal pollution classification in this study. It was observed from assessment that the heavy metals did not constitute contamination but pollution as all the C_I/P_I values computed were all less than 1. Results of the pollution classification in Fig. 5 show that Cn and Cu have pollution range of between 2.1-4.0 in pedons B and C.

This implies that the pedons are under moderate pollution with Cn and Cu. But Zn with the pollution classification range values of between 5.1-5.6 is said to impact severe pollution on all the pedons while Na which has PC values greater than 17.0 in pedons B and C means excessive pollution for all the pedons. Cd having the pollution classification range of between 1.2 and 1.9 implied slight Cd pollution for all the pedons despite the mobility and availability of Cd metal in the pedons under the influence of CME.

Pollution classification was carried out with respect to depth or sampling layers. Figure 6 showed that pollution potential of virtually all the metals increase with depth in all the pedons. At each layer, various metal impact one form of pollution or another to the soil but got it crescendo at the highest depth. The order of pollution potential of the metals in the layers of all the pedons is

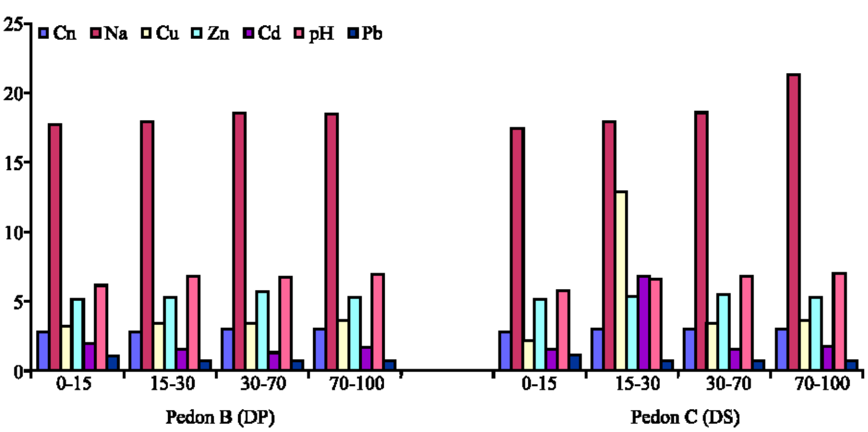

Fig. 5: Pollution potential classification in different layers of various pedons

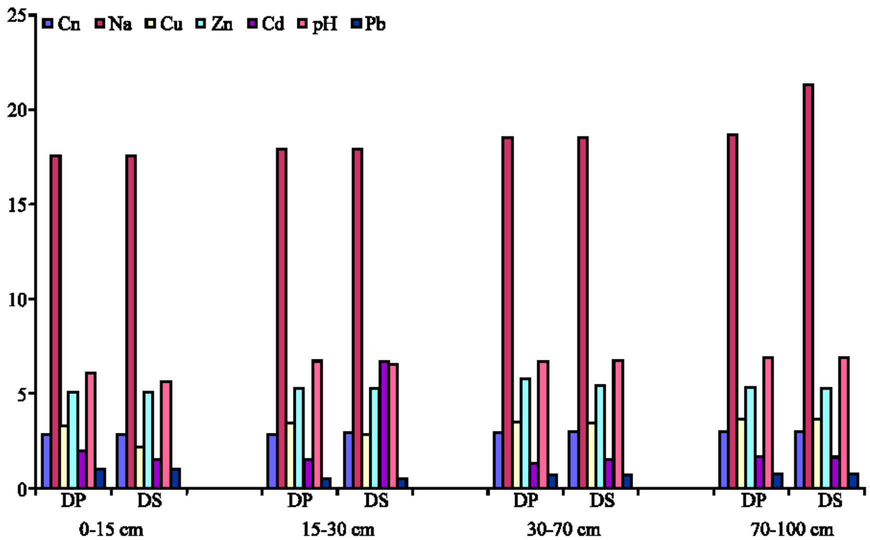

Fig. 6: The PC of the metals down the depths

as follows ; L1<L2<L3<L4. This does not make for safe farming especially cultivation of tubers and vegetable as there is usually plant uptake of these metals. This axiom was substantiated by the studies of Wang *et al.* (2003) and Folson *et al.* (1981) where tubers and vegetables planted in a mechanic village tested positive for high concentration of heavy metal due to speciation the metals in soil solution. Again, the integrity of the aquifer will highly be compromised as infiltration of these metals down the soil profile continues with time.

CONCLUSION

Assessment of the selected soil property of a cassava –mill- effluent polluted Eutric tropofluvent has been studied. There were variations in the soil quality when compared with the results of the soil samples from sampling units (pedond A, B and C) and their various layers. The soils at the receiving units, that is, the discharge point (pedon B) and the down stream (pedon C) lost their natural sandy loam nature of the Eutric tropofluvent which characterizes the alluvium geology of the region due to the trap of some starchy constituents of the effluent within the soil matrix. This manifested on the decrease in the soil pore sizes with its attendant reduction of porosity and increase in the soil bulk density. With this, the soil becomes impermeable with its concomitant flooding at the surface. In terms of heavy metal values of the soil, the effluent increased the values to various pollution potential levels. For instance, in the effluent receiving units, the soils were under moderate pollution with Cu and Cn, severe pollution with Zn, excessive pollution with Na while Cu impacted slight pollution. Given the prevailing pollution potentials of the heavy metals the risk of metal plant uptake of the crops within the units is high. Soils at the effluent receiving units regained their textures down the soil profile or layers. Values of the % sand, silt, pore sizes, prorsity and organic matter increased appreciably at the highest depth of 70-100 cm. heavy metal distribution down the soil layers also took place in the same fashion and may jeopardize the ground water quality.

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