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Full Length Research Paper

Distribution of cyanide in a cassava-mill-effluent polluted eutric tropofluvent soils of Ohaji Area, South-eastern Nigeria

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This study investigates on the distribution of cyanide on a cassava- mill- effluent polluted eutric tropofluvent soil in Ohaji southern Nigeria. Three morphological land units were marked out namely, the background unit (pedon A), discharged point unit (pedon B) (the effluent receiving unit) and downstream unit (pedon C). Soil sample collection was carried out in five replicates in May 2007 adopting a randomized complete block design techniques. Soil samples were collected from each pedon at different soil profiles: 10 to15, 15 to 30, 30 to 70, 70 to 100 and 100 to 150 cm which were represented as L1, L2, L3, L4 and L5, respectively. Samples of the cassava mill effluent were also collected in five replicates. Standard laboratory methods were adopted for the analysis of both samples. It was observed from the results that cyanide distributed geospatially within the pedons. Furthermore, the results of the soil samples were subjected to correlation and regression analysis between Cn and other soil properties and the analysis showed highly positive significant variation($p = 0.05$) in Na, Cd, pH, and clay in both pedons A and B while Pb, sand silt and porosity showed highly negative significance in both pedons. Most soil properties showed non significance in pedon C. High coefficients of regression for polynomial functions were recorded in most pedons.

Key words: Soil properties, cassava-mill-effluent, pedons, regression models, distribution, correlation, cyanide, cassava.

INTRODUCTION

Cyanide is produced by over 1000 plant species including algae, fungi and numerous plant food stuffs (Hendrix et al., 1984). Such cyanogenic forages are sorghum, sudan grasses, corn, cassava, sweet potatoes, maze, millet etc (Cade et al., 1982). These plants store the cyanide in their tissues after the plant uptake from a polluted soil medium (Azcon-Bieto et al., 1989). Cyanide level of these food stuffs can significantly increase if the soil on which they are planted is contaminated with it. Also, cyanide is used in gold mining due to its strong affinity for metals and its ability to act as an agent for metal finishing, treatment and lixiviate for metal leaching such as gold (Ingles and Scott, 1981). In gold processing, cyanidation process is used to treat gold of its ore (Pohlandt, 1984), that is extracting gold from its ore using CN as shown in the Elsner's equation.

$$4Au + 8CN^- + O_2 + 2H_2O = 4Au(CN)_2 + 4\ OH^- \quad (1)$$

In many cases, cyanide pollution is caused by industrial waste. Wastes from gold mining and agricultural processes are of such wastes. Pohlandt (1984) observed

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that cyanide forms complexes with gold that are stable even in mild acidic media; though the complexes can experience degradation to release cyanide in the presence of ultraviolet light. Waste from these food processing can also contribute immensely to cyanide pollution to the soil. For example, cassava peels and its fiber contain an appreciable amount of cyanide (Igbozurike et al., 2009). Boadi et al. (2008) specifically observed that raw cassava and its peels contains between 114.7 to 159.6 and 360.05 to 509.51 mg/kg of cyanide, respectively; while Flynn and McGill (1995) assessed that of the cooked cassava to be 6.79 to 24.91 mg/kg .The cyanide contents of the cassava contaminate the soil mainly during processing. Oboh and Akindahunsi (2003) observed that the peel which contains the outer thin brown and a thick leathering parachymatous inner covering, fiber, cassava juice and the residues water produced after separating starch and fiber during the periods of fermentation and drying are discarded as waste, allowed to rot and mixed with the soil, thereby contributing to cyanide content of the soil. A number of edapHic factors, including pH, organic matter, effective cation exchange capacity and clay have been indicated to affect cyanide availability in soils. From the chemistry of cyanide, cyanide is referred to as a singular charged cation consisting of one carbon and nitrogen atom bound together by triple bonds C≡N but in an aqueous condition, it can complex with water to form hydrogen cyanide (HCN) (Brickell et al., 1981). In a high pH range of between 9.3 to 9.5, CN and HCN are in equilibrium (existing equal in concentration) and 99% of CN remain in solution at pH of 11 while at pH of 7, 99% exist as HCN (Caruso, 1995). Its reactive nature places CN at high capacity to exchange with other cations. The study of Young (2001) showed that CN forms cation and ionic complexes of vary strength with the stabilities of these salt complexes depending on the pH level. For instance, salts of potassium, calcium and sodium cyanide are quite toxic and can dissociate to free cyanide at the pH range of 5 to 7 becoming high potential for environmental pollution (Staritsky et al., 1992). Cyanide is toxic to humans and animals. The study of Yoshida et al., (1984) showed that it assesses the human system through inhalation, ingestion or absorption through eyes and cut skins and can lead to respiratory arrest and even death if inhaled up to 100 to 300 ppm. In gaseous form, cyanide is lost to the environment at decrease pH medium, increased temperature and aeration solution, through volatilization pathway (DeVries and Mathre, 1984)

In Imo State, southern eastern part of Nigeria, Ohaji is known for high quality garri production. Waste from the garri processing center is discharged in the adjoining farm lands and bushes. There is little information on the impacts of these wastes to the area particularly the distribution of the cyanide which is a major component of the waste. The main objective of this study is to examine the vertical and horizontal distribution of cyanide in the soils of the affected area and to relate cyanine with selected soil properties. The study was carried out between May 2007 and September, 2009. Cyanide analysis was carried out in the environmental research unit of technological partners Port Harcourt, south-south Nigeria while that of other physiochemical properties of the soil were carried out in the soil science laboratory of federal university of technology Owerri, Imo State Nigeria.

STUDY AREA DESCRIPTION

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 latitude 5° 12'N to 5° 48'N and at the temperature range of between 250 to 300°C (Global positioning system GPS, 1989). The people of the area experience a high rainfall of about 2000 to 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 are major processing steps 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.

MATERIALS AND METHODS

The main objective of this study is to examine the vertical and horizontal distribution of cyanide in the soils of the affected area and to relate cyanine with selected soil properties. The study was carried out between May, 2007 and September, 2009. Cyanide analysis was carried out in the environmental research unit of technological partners Port Harcourt, South-south Nigeria while that of other physiochemical properties of the soil were carried out in the Soil Science Laboratory of Federal University of Technology, Owerri Imo State Nigeria.

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, poedon 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 150 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 to 15, 15 to 30, 30 to 70 and 70 to 100 and 100 to 150 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 with 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℃.

Statistical analysis

Correlation analysis of the data was carried out to measure the degree of association between two sets of quantitative data. In this case, cyanide which constitutes the appreciable content of the cassava mil effluents was correlated with other soil properties. The data at the discharge point (DP) were subjected to regression analysis to produce the model that can easily predict the values of cyanide with other selected soil properties. Linear, quadratic, polynomial, logathimic and power functions were adopted for the prediction.

The linear regression was presented after Nwagozie (1998) as

$$y = a_0 + a_1 x \quad \text{.......................................2}$$

where a_o and a_1 are the regression coefficients. Y and X are the dependent and dependent variables respectively.

Method of least squares was used to estimate a_o and a_1 in other to form the line of best fit to the data and was presented as

$$a_i = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{n\sum x^2{}_i - \left(\sum x_i\right)^2} \quad \text{.........................3}$$

Substituting Equation 3 into 2 and solving for a_0 results to

$$a_0 = \frac{\sum y_i - a_1 \sum x_i}{n} \quad \text{...4}$$

The quadratic regression model which is given as

$$y = a_0 + a_1 x + a_2 x^2 \quad \text{.......................................5}$$

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

Parameter	Values (mg/l)
Cn	54.2
Na	146.2
Cu	2.5
Zn	4.1
Cd	1.98
PH	4.1
Pb	8.31
Conduct (μs)	1550

will also be used to predict the values of the selected physiochemical properties of the soil.

The least square estimates of a_0, a_1 and a_2 were carried out in the same way as that of linear regression model. In the same manner, the error was estimated by determining the difference between the observed and the predicted value and this is expressed as

$$S = \sum\left(y - a_0 - a_1 x - a_2 x^2\right)^2 \quad \text{...............................6}$$

Other functions were determined in the same manner.

Cyanide is dependent variable (y) while other selected soil properties is the independent variable (x).

RESULTS AND DISCUSSIONS

Table 1 represents the physiochemical properties of the cassava mill effluent. The result is in conformity with the typical cassava waste values as observed by Oviasogie and Ndiokwere (2008) but a glaring variation in the CEC, Cn, and Na properties was observed in the work of Olorunfemi et al. (2007). Cooke and Maduagwu (1978) attributed the variation to difference in species and soil quality. However, the cassava mill effluent result predominantly showed high acidity of 4.1, high CEC values and low Cd value. The values are generally arranged in this manner. CEC>Na>Cn>pb>Zn>pH>Cu>Cd.

Soil properties

Table 2 provides the result for the average values of the physiochemical properties of the soil polluted cassava mill effluent (CME) with depths (layers) at various pedons. The result showed glaring spatial variability of the values of the soil properties within the depths of different pedons. There was high distribution of sandy particles at the top layer with the clay particles distributed most at the bottom layer in pedon A. In fact, sandy particles take large proportion of the first -three layers. According to Jungeruis and Levellt (1964), aggressive

Table 2. Average values of the physiochemical properties of the polluted CMW effluent soils at different depths.

Depth (cm)	Cn	Na	Cu	Zn	Cd	Pb	pH	% Sand	% Silt	% Clay	CEC	OC	MC	%PO	BD
0-15	2.7	17.5	3.2	5.1	1.4	0.6	6.5	48	29	23	80	40	121	46	1.11
15-30	2.9	17.8	3.4	5.2	1.4	0.55	6.8	35	26	28	150	31	136	38	1.25
30-70	2.9	18.5	3.4	5.7	1.7	0.59	6.7	30	25	45	163	28	157	39	1.20
70-100	2.9	18.6	3.7	5.2	1.6	0.60	6.9	25	24	46	196	15	178	32	1.47
100-150	3.0	19.2	4.2	6.1	1.9	0.81	7.8	21	20	49	219	10	189	30	1.59
Pedon B (discharged point)															
0-15	21.8	35.1	1.9	15.5	3.45	0.39	3.88	16	17	41	114	15	195	12	2.13
15-30	29.1	37.1	2.3	11.7	2.92	0.40	4.99	19	20	48	117	36	189	15	2.04
30-70	29.9	39.3	2.9	10.7	2.49	0.45	5.11	20	24	51	126	21	173	17	1.73
70-100	30.1	40.1	3.7	10.3	2.49	0.47	5.89	18	21	57	161	28	168	20	2.11
100-150	31.1	41.8	3.9	11.3	2.11	0.51	5.87	22	22	60	174	30	150	23	1.34
Pedon C (down stream)															
0-15	11.34	11.7	2.11	10.9	1.43	0.47	4.91	20	20	41	90	43	189	21	1.9
15-30	15.1	15.1	2.31	11.39	0.99	0.71	6.03	18	19	40	100	51	178	18	1.9
30-70	17.01	15.37	2.57	8.73	1.51	0.93	6.49	18	18	45	140	33	170	18	2.0
70-100	14.43	15.8	2.54	8.32	1.59	0.91	6.86	18	22	46	175	21	170	12	2.01
100-150	18.43	16.43	3.24	9.12	1.78	0.99	6.98	15	15	52	185	16	168	10	2.3

BA=background values, PD= point of discharge values, DS= down stream values, BD=bulk density, MC=moisture content, OC= organic carbon, CEC= cation exchage capacity.

weather condition might be responsible to the soil texture. Also, clay lassivage resulting to sandiness of soil due to high rain precipitation observed by Eshett et al. (1990) could lead to the prevailing soil condition. Concentration distribution of virtually all the heavy metals assumed direct relationship with increase in layer. That is, they directly increase with depth indicating pronounced eluviation-illuviation processes. The eluviation process depletes most heavy metals at the top-soil layer. Earlier, Onweremadu and Esthat (2007) reported pronounced depletion of Fe and Al at the topmost pedongenic horizon and identify eluviation, illuviation and leaching in the soil of the study site. Other soil properties such as CEC, OC, MC and BD toe similar trend except soil porosity which showed reverse trend. Soil characteristics in this pedon, that is, control unit (pedon A) showed the natural properties typical of an alluvium geology and eutric tropofluvent class. This observation is in conformity with that of FDALR (1985) and the pattern of concentration distribution of heavy metals in the control unit (pedon A) is also in line with the study of edaphic factors of a natural soil of a typical alluvium geology. Factors such as CEC, percentporosity, moisture content, organic matter and the bulk density also have close resemblance with the observation of Beyer (1990) where the analysis of the unpolluted soil of a similar soil was carried out. Most heavy metals and other soil properties in pedons B and C have similar distribution pattern with that of pedon A but there was glaring variation in the concentration values of heavy metals and the values of the soil properties. CEC, bulk density, and moisture content were higher in pedon B, the effluent receiving unit, but decreased geospatially towards pedon C or downstream of the study site. The apparent soil physiochemical variation observed is no doubt the consequences of the cassava mill effluent pollution of the study site. Increase in soil bulk density and moisture content can be attributed to the binding together of the soil aggregates due the starchy constituents of the effluent. This reduced the pore-sizes making infiltration difficult with its attendant high moisture content at the top layer and copious quantity of swamp observed in pedon B. There is tendency for the metal contents of the cassava mill effluent which were likely in ionic form, to increase the soil cation exchange capacity (CEC) of pedon B, the effluent receiving pedon. Observation of Caruso (1995) is in line with these axioms. On the other hand, Pb, and Cu, values were low in pedon B but increased towards pedon C with the highest value observed in pedon A. Lead mitigating ability of the cassava mill effluent as has been observed by Barancikova et al. (2004), can be attributed to that. Cu concentration was highest in pedon A, reduced in pedonB and increased again in pedon C. This was as a result of complexes cupper formed with cyanide associated with CME (Young, 2001). The comparatively low soil trace elements of Cu, Na and Pb observed in pedon B with respect to the control land unit, pedon A could suggest that the plant uptake of these trace elements in pedon B has been high to the extent that their levels in the soil have been significantly low. On the other hand, the increase Cd in the pedon B with respect to pedon A suggested that the plant uptake of Cd is not high in pedon B. Earlier, Dikinya and Areola (2010) observed the various plant metal uptake abilities. The movement of the trace element through the plants is governed by two major factors. Barancikova et al. (2004), confirmed that pH and organic matter influence the movement of Cd, Ni and Cu into a plants on a soil polluted by trace elements. Glaring increase in cyanide at pedon B with low pH and comparatively high organic matter attested to that.

Cyanide distribution

Table 3 shows the cyanide distribution in the study area. Cyanide concentration was highest in pedon B followed by pedon C with the lowest value observed in pedon A. This shows direct impact of the cassava mill effluent to the receiving land unit, pedonB. cyanide distribution decreased vertically in soil and varied spatially among pedons, decreasing toward pedon C.

The pattern of geospatial decrease of the cyanide shows the natural attenuation capacity of the study site occasioned by alluviaition-illuviation processes. Cyanide is quite recalcitrant in the sense that it persists so long on any contaminated soil (Shehong et al., 2005). This could be attributed to the comparatively high cyanide concentration observed in pedon B. As stated earlier, pH wields enormous influence on the distribution of most edafic factors. This is evident on the cyanide distribution pattern among the soil layers of pedon B with it concentrations responding to changes in pH values. From Table 3, Cn and pH concentration increase with depth implying that Cn concentration was highest at the lowest pedogenic layer where the acidity range was equally high. The observed Cn distribution within pedogenic horizon was corroborated by Young (2001), where different concentrations and Levels of Cn toxicity were attributed to different pH range. The study of Oboh and Akindahunsi (2003) observed that Cn and hydrogen cyanide (HCN) are at equilibrium with pH range of between 9.3 to 9.5, at pH of 11 99% of the cyanide remains insoluble as Cn, while at pH 7 99% of cyanide exist as HCN. The recalcitrant of Cn which resulted to its abundance in this pedon, could also be attributed to its ability to form complexes with metals and ease to dissociate into free cyanide substance at slight changes of environmental factors. Beyer (1990) buttered this, by observing that cyanide is very reactive, forming simple salts with alkali earth cations and ionic complexes of varying strength with numerous metals; the stability of these salts depends highly on the pH.

Relationship between soil cyanide and other soil properties

Correlation relationship of Cn with the soil properties carried out at 5% confidence level was to know the level of correlation. The results of the correlation coefficients and significant values are shown in Table 4. Correlation relationship between Cn and other soil properties in the background land unit (pedon A) showed mainly positive relationship with high coefficient correlation of between 0.99 and 0.62. Clay showed the highest coefficient of 0.99. This could be credited to its high adsorptive capability which is due to its high ionized capacity. This was equally attested to by Viswanathan et al. (1985). Also, BD, porosity, OC and CEC showed high but negative correlation coefficient of -0.92, -0.92, -0.88, and -0.96, respectively suggesting high availability of Cn at low values of the aforementioned soil properties.

In pedon B, that is, at the point of discharge, soil parameters such as pH, pb, percent sand, percent silt, porosity showed high but negative correlation. The inverse relationship of Cn with percent sand and silt could be attributed to large pore sizes of those soil particles. This implies that an appreciable quantity of Cn can not retain in those soil particles but likely to infiltrate through the soil profile by alluviation-illuviation process jeopardizing the quality of aquifer. The report of Onweremadu (2008) about non-fixation of heavy metals by soils predominant with high percent silty sand is consistent with this observation. Inverse relationship of pH and Pb is glaring due to the sensitivity of Cn to pH range and the lead mitigating ability of cassava mill effluent respectively which has been explained before. The high positive correlation coefficients of Na and Cd of 0.99 and 0.95, respectively proves the abundances of these metals in this pedon.

Correlation relationship between Cn and other soil

Table 3. Cyanide concentration at different pedongenic horizons.

Pedon	Layers (Horizon)	Depth (cm)	Cn (g/kg)
A	L1	0-15	2.7
	L2	15-30	2.9
	L3	30-70	2.91
	L4	70-100	2.98
B	L1	0-15	21.8
	L2	15-30	29.1
	L3	30-70	29.9
	L4	70-100	30.1
C	L1	0-15	11.34
	L2	15-30	15.1
	L3	30-70	17.01
	L4	70-100	14.43

Table 4. Correlation coefficient (r) of cyanide with some soil properties.

Soil property	R	Level of significant
Background unit(BA)	0.88	*
(Na) (g/kg)	0.91	*
(Cu) (g/kg)	0.44	NS
Zinc (Zn) (g/kg)	0.62	*
Cd (g/kg)	0.91	*
PH	0.89	*
(pb) (g/kg)	0.98	*
% Sand	-0.38	NS
% Silt	0.99	*
% Clay	-0.96	*
CEC (cmol/kg)	-0.88	*
OC (g/kg)	0.9	*
MC (g/kg)	-0.92	*
Porosity	-0.92	*
BD (g/kg)		
Point of discharge(PD)	0.99	*
(Na) (g/kg)	-0.47	NS
(Cu) (g/kg)	0.82	*
Zinc (Zn) (g/kg)	0.95	*
Cd (g/kg)	-0.76	*
PH	-0.85	*
(Pb) (g/kg)	-0.76	*
% Sand	-0.82	*
% Silt	0.50	*
% Clay	0.91	*
CEC (cmol/kg)	-0.71	NS
OC (g/kg)	-0.11	NS
MC (g/kg)	-0.92	*
Porosity	0.44	NS
BD g/kg		

Table 4. Contd.

Downstream(DS)	0.82	*
(Na) (g/kg)	0.83	*
(Cu) (g/kg)	-0.47	NS
Zinc (Zn) (g/kg)	-0.04	NS
Cd (g/kg)	0.59	*
PH	0.86	*
(Pb) (g/kg)	-0.88	*
% Sand	0.47	NS
% Silt	0.47	NS
% Clay	0.44	NS
CEC(cmol/kg)	0.44	NS
OC (g/kg)	-0.21	*
MC (g/kg)	0.55	*
Porosity	-0.34	NS
BD g/kg	0.58	*

Na=sodium, Cu=cupper,Cd=cadmium, Pb=lead, CEC=Cation exchange capacity, OC=organic carbon, MC=moisture content, BD=bulk density. * significant at 5%, NS=non-significant.

Table 5. Models developed with the data at various sampling land units.

Name	**Equation**	**R^2**
	Background unit (pedonA)	
Cn – Na	Cn = 0.1379Na + 0.3545	0.7237
Cn-Cu	Cn = -0.3721Cu^2 + 2.9977Cu - 3.037	0.7895
Cn-Zn	Cn = -0.1667Zn^2 + 2.05Zn - 3.32	0.5486
Cn-pb	Cn = 9.6995Pb^2 - 12.848Pb + 7.0429	0.4754
Cn-PH	Cn = -0.0162pH^2 + 0.4417pH + 2.2152	0.5672
Cn-Cd	Cn = -0.359Cd^2 + 5.3437Cd - 16.844	0.8953
Cn-%MC	Cn = 0.5024Ln(MC) + 0.3489	0.72
Cn-CEC	Cn = 0.2693Ln(CEC) + 1.5252	0.929
Cn-%Clay	Cn = -0.0005Clay^2 + 0.0423Clay + 2.0277	0.681
Cn-%Silt	Cn = -0.0032Silt^2 + 0.1273Silt + 1.7446	0.9465
Cn-OC	Cn = -0.0004OC^2 + 0.0108OC + 2.8884	0.8364
Cn-BD	Cn = -1.4706BD^2 + 4.4223BD - 0.3506	0.7303
Cn-%PO	Cn = -0.001PO^2 + 0.0573PO + 2.1098	0.8917
	Point of discharge unit(pedonB)	
Cn – Na	Cn= 1.2493Na - 19.922	0.7585
Cn-Cu	Cn = -4.3388Cu^2 + 28.843Cu - 16.299	0.8634
Cn-Zn	Cn = -1.7304Zn + 48.992	0.9204
Cn-pb	Cn = -727.4pb^2 + 706.67pb - 140.52	0.6625
Cn-PH	Cn = 4.2172pH + 6.69	0.8521
Cn-Cd	Cn = -6.7448Cd + 46.557	0.8432
Cn-%MC	Cn = -0.0064MC^2 + 2.0474MC - 132.78	0.7588
Cn-CEC	Cn = -0.0049CEC^2 + 1.480CEC - 80.62	0.5582
Cn-%Clay	Cn= 22.488Ln(clay) - 59.997	0.8066
Cn-%Silt	Cn = -1.2276Silt + 2.8657	0.7151
Cn-OC	Cn = 8.6123Ln(OC) + 0.7208	0.6176
Cn-BD	Cn = -14.80BD^2 + 45.375BD - 3.3489	0.3795
Cn-%PO	Cn = -0.1292PO^2 + 5.2568PO - 22.066	0.9234

Table 5. Contd.

Down stream unit (pedon C)		
Cn-Cu	$Cn = 0.1855Cu^2 - 3.8624Cu + 31.171$	0.7855
Cn-Zn	$Cn = 0.7021Zn^2 - 15.644Zn + 98.47$	0.9945
Cn-pb	$Cn = -49.407pb^2 + 75.613pb - 11.44$	0.5192
Cn-PH	y = 1.952x1.1193	0.7408
Cn-Cd	$Cn = 36.637Cd^2 - 88.463Cd + 65.862$	0.3477
Cn-%MC	Cn = -0.2702MC + 62.552	0.7605
Cn-CEC	$Cn = -0.0009CEC^2 + 0.2808CEC - 5.7269$	0.5536
Cn-%Clay	Cn = 12.542Clay - 10.097	0.5402
Cn-%Sand	Cn = 0.4168Sand - 3.4089	0.874
Cn-%Silt	Cn = -1.3553Silt + 39.387	0.8054
Cn-OC	$Cn = 0.2083OC^2 - 7.206OC + 75.718$	0.4734
Cn-BD	Cn = -1.3553BD + 39.387	0.750
Cn-%PO	$Cn = -0.0632PO^2 + 1.552PO + 7.5834$	0.4972

%PO= Percent porosity, BD= bulk density, MC= moisture content.

properties in pedon C (DS) where little influence of the CME was felt, indicated non significance with most soil properties. This suggested that the CME influenced the availability of Cn in the soil and its relationship with other soil properties. Several models were formulated. The establish pedotransfer model were to predict the values of cyanide by mere knowing the values of the other selected soil properties. The models with their corresponding coefficient of regressions are displayed in Table 5.

The regression models developed with the data from various land units obeyed linear, polynomial, logathimic and power functions. It was observed that the predictors in polynomial functions formed with data at the background unit (pedon A) are more efficient when compared with polynomial models from point of discharge unit (pedon B), the effluent receiving unit and down stream (pedonC). The result equally showed that the polynomial predictor models in discharge point are least efficient. This suggested glaring influence of cassava mill effluence (CME) on the predictability of cyanide. However, the coefficient of regression of the polynomial functions in the three sampling land units (pedons A, B, and C) are between 0.47 to 0.96, 0.34 to 0.99 and 0.45 to 0.99, respectively. At the discharge point, cyanide regressed linearly with soil pH, Na, and Zn. pH regressed directly with cyanide with high coefficient of regression of 0.852. This buttressed the observation of Oboh and Akindahunsi (2003) that pH range of 9.3 to 9.7 99% of HCN exist as free cyanide. Also, the direct linear relationship of Na and Zn with cyanide could be explained as dissociation of large quantity of complexes of cyanide with Na and Zn at this pH range observed by Young (2001).

Conclusion

Distribution of cyanide in the cassava –mil-effluent polluted soil has been studied. There was spatial variability of cyanide within the depths of various pedons. Cyanide concentration was highest in pedon B followed by pedon C with the lowest value observed in pedon A. Correlation relationship between Cn and other soil properties in the background land unit (pedon A) showed mainly positive relationship with high coefficient correlation of between 0.99 to 0.62. Clay showed the highest coefficient of 0.99. In pedon B, Na and Zn correlated positively with Cn while negative correlation was observed on Pb, pH, p[ercent sand, percent silt, porosity and Cd. Correlation relationship between Cn and other soil properties in pedon C indicated non significance with most soil properties. The pedotransfer analysis conducted on the predictability of cyanide distribution favours mainly the polynomial functions especially in pedon A. However, the models in all the land units obeyed linear, polynomial, logarithm and power functions. These models provide recipes to impending cyanide pollution problems especially on a land of similar geology polluted with cassava-mill-effluent.

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