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Effect of Cassava Processing Mill Effluent on Physical and Chemical Properties of Soils in Abraka and Environs, Delta State, Nigeria

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Abstract

Selected heavy metals and physicochemical characteristics of the soils around some cassava processing mills in Abraka and environs were analyzed in order to assess the impact of the cassava mill effluent on the soils. The results of the physicochemical analysis showed overall decrease in pH values and corresponding increase in the other parameters. The pH values indicated that the soils were acidic which suggests that the effluents imparted acidic property on the soils. The elevated levels of Total Organic Carbon and Total Nitrogen are suggestive of increased organic matter and microbial activities in the effluent residues. Electrical conductivity values indicate presence of dissolved inorganic salts while the phosphorus values confirm the rich source of phosphorus in cassava tuber. The result of heavy metal analysis shows elevated levels of heavy metals in the soil receiving cassava mill effluent. The relative potential index and enrichment coefficient values of the metals in the soils coupled with the observed physiochemical characteristics revealed that there are some levels of heavy metal enrichment, contamination and bioavailability in the soils studied.

Key words: cassava mill effluent, heavy metals, physicochemical characteristics soil pollution, Abraka

INTRODUCTION

Increasing level of heavy metals in the environment from various anthropogenic sources has become a source of concern for environmentalists (Opeolu *et al.*, 2008). As a result there is a need for increasing awareness of the emergency created by environmental pollution caused by human activities. Unlike the toxic organics that in many cases, can be degraded, the metals that are released into the environment, tend to persist indefinitely, accumulating in living tissues through food chain (Cossic *et al.*, 2002). Evidence of the potential and observed human hazard due to environmentally acquired heavy metals and their ecological impact have been extensively studied (Ademoroti, 1996, Shegerian, 2006, Killburn and Washaw, 1993, Willis and Saviry, 1985, Davis and Weiss, 1990).

In Nigeria and in most tropical countries, processed cassava tuber has been the staple food and with the present increase in production, it is gradually transforming from a famine reserve commodity and rural staple food to cash crop for urban consumption and to an export commodity for international market (IFAD, 2005, Ohochuku, 2005). In this part of the country, cassava tuber is processed and made ready for consumption mainly either as garri, starch, or as dried or wet cassava flour. In each of these, the major processing stage is the milling stage and this leads to the location of cassava milling machines allover the environment. The residues obtained during this process include the solid and the liquid wastes.

Although several studies have been conducted or carried out on the biochemical change associated with the fermentation of cassava marsh and liquid effluent (Okafor and Uzueqbu, 1987, Okafor and Ejiofor, 1990), there are a few and scanty reports on the effect of the disposal or discharge of these mill effluent or processing waste on land especially in soil physical and chemical properties. This study aims at investigating the effect of cassava mill effluent on soils with respect to heavy metal levels and physicochemical characteristics.

MATERIALS AND METHODS

Study Area:

Abraka, a University town, located in Ethiope East Local Government Area of Delta State, Nigeria, lies approximately on latitude $5^{'0}$ 48$^{'}$N and longitude 6^{0}O6$^{'}$ E. Its main relief feature is lowland type of landscape grouped under the coastal lowland of Western Nigeria within the tropical rainforest region. The parent topography consists, of rolling lowland plain generally above 45m sea level. The soil type is made up of ferrosal precisely the red and brown soil with abundant free iron oxide. The topography and location factors and prevalence of the tropical rainy climate that is warm, humid and moist in most part of the year, encourages their major occupation which is farming.

Samples Collection

Soil samples containing cassava mill effluent were collected from five selected locations in Abraka and environs. Soil samples free of cassava mill effluent were also collected from two different locations to serve as control samples.

In each of the sampling sites, soil samples were taken using soil auger. These auger borings were bulked and representative samples were taken. Composite soil samples collected at each site included 0-15 cm for top soil, 15-30 cm for subsoil and 30-45 cm for bottom soil, and horizontally 10m, 20m, 30m and 40m away also at the same depth.

Sample Preparation and Analysis

The soil samples were air-dried for a period of one week in a clean well-ventilated laboratory (Boulding, 1994) homogenized by grinding, passed through a 2mm (10 mesh) stainless sieve, and stored in labeled plastic cans until analysis. The samples for metal analysis were digested using a mixture of 2cm^3 of 60% perchloric acid, 15cm^3 of concentrated metric acid and 1cm^3 of concentrated sulphuric acid (Burrell, 1974). The digested samples were analysed for the metals using Atomic Absorption Spectrophotometer (PerkinElmer Model A Analyst 2002) fitted with deuterium lamp for background correction. Soil pH was measured in a soil-water ratio of 1:2 (Davey and Conyers, 1988). Total Organic Carbon (TOC) was determined by the method described by Nelson and Sommers, 1982. Cation Exchange Capacity was estimated by the method of Jackson, 1960. While particle size analysis to sperate sand, silt and clay was achieved according to the method of Bououcos, 1962. Available phosphorus was determined by the method of Bray and Kurtz while total nitrogen was analysed using micro-Kjeldakl method (Bremner, 1965). Electrical conductivity was determined by the method of Chopra and Kanzar, (1988). All reagents used in this study were of pure analytical grade, and were checked for possible trace metal contamination. All glasswares were previously soaked in 14% nitric acid for 24 hours to remove entrained metals, washed with detergents and rinsed with deionized water. Quality control was assured by the use of duplicates, standard reference materials and procedural blanks.

RESULTS AND DISCUSSION

Soil Physicochemical Properties

The results of the physicochemical properties of the soil receiving effluent are shown on table 1.

Table 1:

Physicochemical Properties of the Soil Associated with Cassava Processing Mill Effluent

								PARTICLE SIZE			
Sample	**Depth (cm)**	**pH**	**E/C (μS/cm)**	**TOC% (TOC)**	**TN %**	**P mgkg^{-1}**	**(CEC) Cmolkg^{-1}**	**SAND**	**SILT**	**CLAY**	**TEXTURE**
Site A	0-5	4.00	200.4	1.17	0.09	71.10	0.49	85	0	15	Sandy loam
	15-30	4.02	360.2	0.55	0.12	76.20	0.94	79	0	21	Sandy clay loam
	30-45	4.51	151.8	0.94	0.08	69.80	0.72	71	1	28	Sandy clay loam
Site B	0-15	4.71	425.0	0.35	0.10	88.20	0.66	92	1	7	Sandy
	15-30	4.90	265.5	0.12	0.10	86.52	0.82	78	2	20	Sandy loam

	30-45	5.74	202.4	0.70	0.11	71.64	0.81	72	13	15	Sandy loam
Site C	0-15	4.12	168.3	3.35	0.12	90.75	0.84	85	0	15	Sandy loam
	15-30	4.30	172.8	0.55	0.09	86.60	0.80	81	1	18	Sandy loam
	30-45	4.83	404.0	1.56	0.08	87.50	0.93	73	10	17	Sandy loam
Site D	0-15	3.89	136.2	0.66	0.10	55.50	1.63	78	2	20	Sandy loam
	15-30	4.43	496.0	0.90	0.09	55.70	1.00	69	1	30	Sandy clay loam
	30-45	4.47	427.0	0.98	0.11	53.60	0.98	81	1	18	Sandy loam
Site E	0-15	4.60	958.0	0.02	0.08	46.75	1.23	72	2	26	sandy clay loam
	15-30	4.92	517.0	1.09	0.11	43.82	0.95	76	1	23	sandy clay loam
	30-45	5.41	201.2	0.86	0.09	45.72	0.91	72	2	26	sandy clay loam
Control	0-15	6.96	44.2	0.70	0.11	68.30	0.84	78	2	20	Sandy loam
	15-30	7.40	75.70	0.47	0.11	70.20	0.85	65	4	31	Sandy clay loam
	30-45	7.81	37.03	0.78	0.10	69.20	0.83	76	2	22	Sandy clay loam

Sapling Locations

Site A = Urhuovie
Site B = Urhuoka
Site C = Erho
Site D = Oria
Site E = Abraka Main town
Control = Urhuoka and Urhuovie Bush

The pH of the soils ranged from 3.89 to 5.74 indicating that the soils were acidic. This suggests that the effluent imparted acidic properties to the soil. The acidity could be attributed to the presence of hydrogen cyanide in the cassava mill effluent. The acidity decreased with depth in all the sites. The pH values recorded in this study are in the same range with those reported by Rashad and Shalaby, (2007), Onweremadu *et al.*, (2007) Oguntimehin and Ipinmoroti, (2007) and Oviasogie and Ofomaja, (2007). The values are however lower than those reported by Ano *et al.*, (2007). Amusan *et al.*,(2005), Bamgbose *et al.*,(2007). The soil pH determines the availability of nutrients and the potency of toxic substances as well as the physical properties of the soil. The pH values of these study sites indicate a generally high tendency for high availability of the metals, hence, this increases the risk of heavy metals plant uptake. Previous studies have shown decreased metal availability with increasing pH (Itana, 1998, Bhattacharya *et al.*, 2002) and that a reduction in pH may allow the release of toxic metals that would otherwise be adsorbed in the soil or sediment (Mouvet and Borg, 1983). The total organic carbon ranged from 0.02 to 3.35%. The values may be due to the discharge of the waste with some contents of organic matter and also suggests presence of degradable and compostable substances in the effluent (Mumoz *et al.*,1994, Oviasogie and Omoruyi, 2007). It is also suggestive of increased microbial activity on the residues contained in the effluent. Such decomposition processes would lead to the deposition of humic substances and increased carbon content of the soil (Haider *et al.*, 1975). The total organic carbon recorded in this study is similar to the values reported by Oviasogie and Omoruyi, (2007) and Isirimah, (1987), but comparatively lower than the values reported by Tukura *et al.*,(2007) and Gupta and Pant, (1983). Total Organic Carbon is a measure of organic content in soils, sediments and water (Yun, 2003) and contributes significantly; to acidity through contributions from organic acids and biological activities. Lopez-Sanchez *et al.*,(1996) observed that both anthropogenic and natural processes have resulted in elevated concentrations of organic carbon in sediments: The total nitrogen ranged from 0.08 to 0.10%. These values are in the same range with the values reported by Osemwota (2009), but relatively higher than the values reported by Oviasogie and Omoruyi, (2007) in soils around foam manufacturing industry. The total nitrogen recorded was probably due to nitrogen mineralization as a result of organic matter (Jadhav and Savant, 1975). This is consistent with the views of Goi and Kurchara, 1987) following the analysis of total nitrogen in urban wastes. Nitrogen is one of the elements needed by plant for healthy growth. The electrical conductivity values ranged from 136 to 958 µS/cm. These values are similar to the values reported by Isirimah, (1987) but higher than the values reported by Iwegbue *et al.*,(2006), Oviasogie and Omoruyi, (2007), and Odu *et al.*,(1985). Electrical conductivity is used as a means of appraising soil salinity. The values recorded in the soils may be due to increase in the concentration of soluble salts (Rajannan and Oblisami, 1979). The implication of high electrical conductivity in soils is that there are reasonable or significant presence of anions (Fullen *et al.*, 1995). For soil particle size, the distribution of sand fraction was highest followed by clay and then silt. Similar observation of sand size fraction dominance had been reported (Ano *et al.*, 2007, Onweremadu *et al.*, 2007). The high values of phosphorus in the soils is not surprising since cassava tuber is a rich source of phosphorus (Jung *et al.*, 2002). The soil cation exchange values range from 0.49 to 1.63 Cmolkg^{-1} These values are in the same range with the values reported by Odu *et al.*, (1985); Isirimah 1987), Oviasogie and Ofomaja, 2007). Cation exchange capacity is directly related to soil capacity of adsorbing heavy metals. It is important to emphasize that organic matter (Carbon) content and clay composition are solely responsible for cation exchange capacity of soils (Thompson *et al.*, 1989). In the present study the organic matter composition as indicated by the levels of organic carbon and the clay fractions can be regarded as having additive contribution to the overall cation exchange capacity of the soil.

Heavy Metals

Vertical Distribution

The vertical distribution of the heavy metals is presented on table 2.

Table 2: Vertical Distribution of heavy metals (mgkg^{-1}) in the soil profile.

Sample	Depth (cm)	Fe	Cd	Cu	Mn	Cr	Zn
Site A	0-15	137.628	0.001	0.663	2.795	0.001	1.725
	15-30	135.678	0.015	0.655	2.126	0.001	1.652
	30-45	138.541	0.003	0.612	2.617	0.003	1.677
Mean ± S.D		139.282	0.006	0.643	2.512	0.002	1.684
		±1.462	±0.007	±0.027	±0.346	±0.001	±0.037
Site B	0-15	139.221	0.006	0.698	1.735	0.023	1.698
	15-30	127.542	0.011	0.212	1.378	0.011	0.552
	30-45	128.939	0.058	0.217	2.074	0.009	0.545
Mean ± S.D		131.900	0.025	0.375	1.729	0.014	0.931
		±0.377	±0.028	±0.279	±0.348	±0.007	±0.663
Site C	0-15	129.112	0.013	0.312	1.503	0.008	0.577
	15-30	130.223	0.015	0.331	4.557	0.010	0.557
	30-45	82.926	0.021	0.111	0.219	0.012	0.722
Mean ± S.D		114.087	0.016	0.251	2.093	0.010	0.618
		±26.991	±0.004	±0.121	±2.228	±0.002	±0.090
Site D	0-15	85.221	0.036	0.132	6.498	0.022	0.698
	15-30	85.636	0.055	0.156	3.575	0.026	0.625
	30-45	83.779	0.031	0.152	0.197	0.012	0.710
Mean ± S.D		84.878	0.040	0.146	3.420	0.020	0.677
		±1.378	±0.040	±0.056	±3.149	±0.007	±0.046
Site E	0-15	132.612	0.093	0.222	0.205	0.024	1.231
	15-30	132.317	0.001	0.206	0.291	0.028	1.198
	30-45	133.487	0.001	0.235	0.323	0.016	1.178
Mean ± S.D		132.805	0.031	0.221	0.273	0.022	1.202
		±0.608	±0.075	±0.014	±0.061	±0.006	0.026
Control	0-15	85.20	0.001	0.206	0.250	0.037	1.198
Mean	15-30	85.62	0.001	0.011	0.367	0.010	0.155
	30-45	84.10	0.005	0.010	0.326	0.001	0.166
Mean ± S.D		84.88	0.002	0.235	0.314	0.016	0.506
		±2.218	±0.002	±0.220	±0.059	±0.008	±0.599

The results of vertical distribution of the heavy metals showed that the heavy metal concentrations were generally higher at the top soil than the sub and bottom soils. This higher levels of metals on the top or surface soil is expected since the top soil is the point of contact. Previous studies have shown that surface soils are better indicators of metallic burden (*Nyangababo and Hamuya,* 1986; *Amusan et al.,* 2005). The heavy metal levels for all the sites were significantly higher than the levels observed in the control sites. This implies that the soils receiving cassava mill effluent have some levels of heavy metal enrichments. Iron had the highest concentration in all the sites. It has been confirmed that natural soils contain significant concentration of iron (Ademoroti, 1996; Aluko and Oluwande, 2003; Dara, 1993). Eddy *et al.,* (2004) suggested that the pollution of the environment by iron can not be conclusively linked to waste materials alone but to other natural sources as well. However one can infer that since the levels of iron at the impacted point is higher than the levels in control sites and also at points away from the impacted point, the cassava mill effluent might have contributed to the increased levels of iron in the soils studied.

The generally elevated levels of the heavy metals at the point of impact which decreased gradually away from the impacted point indicates that the cassava mill effluent is a source of some of the heavy metals. The heavy metals are in the abundance ratio of Fe>Mn>Zn>Cu>Cd>Cr. Fe is the most naturally occurring metal in the soil, so its abundance in the soils studied could be mainly of lithological or crustal origin. Although manganese in the form of oxide is a component of subsoil material (Levy *et al.*, 1992), the abundance of manganese in the cassava mill effluent could also be attributed to wears and tears of the machinery part. Presence of zinc could be attributed to corrosion of metal parts of the milling machine. Zinc is also a component of crude oil and machine exhaust (Adriano, 2001). Copper is a component of bronze and brass and is used as a corrosive resistant and decorating painting in machine. Cadmium is a “modern metal” having been used increasingly in corrosion prevention (Alloway, 1990). It is often used instead of zinc for galvanizing iron and steel (Tucker *et al.,* 2003). Chromium is a component in the manufacture of steel stainless alloys, metal plating for prevention of corrosion (Schwarts and Mertz, 1959) large amount of copper was used in motors and generators (Lagerwerf and Spetch, 1970). Studies of heavy metals in various Nigerian crude oils have shown them to contain relatively high concentrations of Fe, Cu, Zn, Pb and Hg (Kakuku, 1985; Omgbu and Kogho, 1993) Therefore the presence of Fe, Cu, and Zn in the soils studied could also be attributed to the wearing of or abrasion of the cassava willing machine parts and mission of these metals through the exhaust of the machine.

Lateral Distribution

The lateral distribution of the metals in the soil is presented on table 3.

Table 3: Lateral Distribution of the Heavy metals in the soils along a gradient from the impacted point.

Metal	Site	Point of Impact	10m away	20m away	30m away	40m away
Fe	A	139.28	132.8	114.10	104.5	84.88
	B	131.90	125.6	118.5	112.6	96.8
	C	114.09	106.8	90.5	79.6	65.5
	D	84.88	70.5	62.5	56.7	42.8
	E	132.81	126.0	105.6	93.6	70.9
Cd	A	0.006	0.004	0.002	0.002	ND
	B	0.025	0.021	0.020	0.019	0.012
	C	0.016	0.016	0.014	0.012	0.010
	D	0.040	0.038	0.038	0.035	0.030
	E	0.031	0.028	0.026	0.023	0.022
Cu	A	0.643	0.611	0.500	0.380	0.250
	B	0.375	0.310	0.296	0.248	0.201
	C	0.251	0.236	0.215	0.213	0.182
	D	0.146	0.140	0.132	0.118	0.009
	E	0.221	0.208	0.192	0.182	0.135
Mn	A	2.512	2.30	1.85	1.75	1.46
	B	1.729	1.58	1.32	1.25	1.00
	C	2.093	1.90	1.63	1.56	1.10
	D	3.420	0.27	0.25	0.25	0.20
	E	0.273	0.27	0.25	0.23	0.16
Cr	A	0.002	0.002	ND	ND	ND
	B	0.014	0.008	0.007	0.003	0.001
	C	0.010	0.010	0.060	0.002	0.002
	D	0.020	0.016	0.014	0.014	0.002
	E	0.022	0.009	0.009	0.006	0.002
Zn	A	1.684	1.35	1.26	1.00	0.004
	B	0.931	0.78	0.66	0.37	0.202
	C	0.618	0.58	0.50	0.36	0.21
	D	0.677	0.59	0.56	0.41	0.25
	E	1.202	0.98	0.91	0.63	0.57

The soils at the impacted point showed the highest average concentrations of the metals. The further the sampling sites away from the cassava milling points, the lower the concentrations of these metals. This is consistent with some other reports (Pizl and Josens, 1995, Lavado *et al.*, 1998, Osakwe, 2010).

Relative Pollution Potentials Of The Heavy Metals

The relative pollution potential of a pollutant with respect to the level of chemical interaction between the pollutant and the recipient was computed using Egharevba and Odjada, (2002) scheme as follows.

$$Y = \frac{[A] - [B]}{[A]}$$

Where Y = Relative pollution potential index

[A] = Metal concentration at impacted point.

[B] = Average metal concentrations at points away from impacted point.

The relative potential values of the metals are presented on table 4.

Table 4: Relative Pollution Potential Index of the Metals in the Soil

Sites	Fe	Cd	Cu	Mn	Cr	Zn
A	0.22	0.67	0.32	0.26	0.75	0.46
B	0.14	0.28	0.30	0.26	0.66	0.43
C	0.25	0.19	0.43	0.26	0.65	0.33
D	0.32	0.13	0.53	0.91	0.43	0.33
E	0.25	0.19	0.19	0.17	0.70	0.36

Negative value of pollution potential indicates that at the level of infusion of waste material in the soil, the soil is not polluted, while positive interaction parameter on the other hand, gives a positive pollution potential suggesting that the soil is polluted at the level of infusion of the waste. The results gave positive values for all the metals in all the sites suggesting that the soils were contaminated at the points of infusion of the wastes.

Enrichment Coefficients (Ec) Of The Heavy Metals

The Enrichment Coefficient (Ec) of the metals in the soil were calculated based on the equation given by Chenhall *et al.*,(1994), Assah *et al.*, (2005) as follows.

$$Ec = \frac{C_1M_e/C_{1n}}{C_2M_e/C_{2n}}$$

Where C_1M_e = The examined metal concentration in the examined environment.

C_2M_e = The examined metal concentration in the reference environment.

C_{1n} = The reference element concentration in the examined environment.

C_{2n} = The reference element concentration in the examined environment.

Fe was applied as the reference element because it is the most naturally abundant element in the soil. Enrichment Coefficient is a convenient measure of anthropogenic environmental status of the area being studied. Five contamination categories are recognized on the basis of Enrichment Coefficient, (Sutherland, 2000) The Enrichment Coefficients of the metals in the studied soils samples are presented on Table 5:

Table 5: Enrichment Coefficients of the Heavy Metals in the Soils from all Sites

SITES	**Fe**	**Cd**	**Cu**	**Mn**	**Cr**	**Zn**
A	1.64	3.50	27.63	3.50	0.12	3.33
B	1.55	12.70	1.60	12.27	0.87	1.84
C	1.34	7.85	1.07	6.67	0.62	1.22
D	1.00	19.64	0.62	10.89	1.25	1.34
E	1.56	15.22	0.94	0.87	1.37	2.38

The values observed in this study are within the range reported by Iwegbue *et al.*, (2006), but higher than the values reported by Nwajei and Iwegbue, (2007). The values recorded for iron, copper, chromium and zinc were within the category of deficiency to minimal enrichment (<2) except in sites A and E for zinc which fell within the moderate enrichment values (2-5). Cadmium and manganese were in the range of significant enrichment (5-20).

CONCLUSION:

The present study has shown that for physicochemical properties, the cassava mill effluent decreases soil pH, while it leads to higher levels of available phosphorus, total organic carbon, total nitrogen, electrical conductivity and cation exchange capacity of the soils. The results of heavy metal analysis showed elevated levels of heavy metals in the soils. The pollution potential index, and enrichment coefficient values coupled with the observed physicochemical properties revealed that cassava mill effluent had detectable changes on the availability of the metals and selected physicochemical properties in the soils.

RECOMMENDATION:

The milling stage is a major stage in processing cassava tuber to be ready for consumption. As a result, use of cassava milling machine can not be avoided. Therefore it is hereby recommended that the government should set aside, an expanse of land away from residential areas where cassava processing milling machines should be located just as we have mechanic villages where mechanic workshops are located in some of our cities today.

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