Physiochemical Characteristics and Heavy Metal Levels of Soils Associated With Maize Processing Mill Effluent in Nise and its Environs, Anambra State Nigeria

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Abstract

Selected heavy metals and physiochemical characteristics of the soils around some maize processing mills in Nise and its environs were analysed in order to assess the impact of the maize mill effluent on the soil. The results of the physiochemical 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 indicated the presence of dissolved inorganic salts while the phosphorus values confirm the rich source of phosphorus in Maize grains. The result of heavy metal analysis shows elevated levels of heavy metals in the soil receiving maize 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 bio-availability in the soils studied.

Key Words: *Heavy Metals, Maize Mill Effluent, Physiochemical Characteristics, Soil Pollution, Electrical Conductivity*

INTRODUCTION

In Nigeria and in most tropical countries, processed maize grain has been the staple food. 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; Ohochukwu, 2005). In this part of the country, maize is processed and made ready for consumption mainly either as maize flour, starch or as dried or wet maize flour. In each of these, the major processing stage is the milling stage and this leads to the location of maize milling machines all over the environment. The residues obtained during this process include the solid and the liquid wastes.

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 (Shegerian, 2006).

Although several studies have been conducted or carried out on the biochemical change associated with the fermentation of maize marsh and liquid effluent, 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 maize mill effluent on soils with respect to heavy metal levels and physiochemical characteristics.

MATERIALS AND METHODS

Study Area

This study was carried out in Nise, Federal Government College town located in Awka South Local Government Area of Anambra State, Nigeria, which lies approximately on latitude $5^{O}45$‘N and longitude $6^{O}04$‘. Its main relief feature is lowland type of landscape grouped under the lowland of Eastern 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.

Sampling and Sample Preparation

Soil samples containing maize mill effluent were collected from five selected locations in Nise and its environs. Soil sample free of maize 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 0-15cm for top soil, 15-30cm for subsoil and 30-45cm for bottom soil, and horizontally 10m, 20m, 30m and 40m away also at the same depth.

The soil samples were air-dried for a period of one week in a clean well-ventilated laboratory as suggested by Bamgbose (2007), homogenized by grinding, passed through a 2mm (10mesh) 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% perchlorio acid, 15cm^3 of concentrated nitric acid and 1cm^3 of concentrated sulphuric acid (Cossica, 2000). 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 (Eddy, 2004). Total organic carbon (TOC) was determined by the method of Jackson (1960) while particle size analysis to separate sand, silt and clay was achieved according to the method of Ohochukwu (2005). Available phosphorus was determined by the method of Bray and Kurz while total nitrogen was analyzed using micro-kjeldahl method (IFAD 2005). Electrical conductivity was determined by the method Chopra and Nwajei (2007). All reagents used in this study were of pure analytical grade, and were checked for possible trace metal contamination. All glassware were previously soaked in 14% nitric acid for 24 hours to remove entrained metals, washed with detergents and rinsed with deionised water. Quality control was assured by the use of duplicates standard reference materials and procedural blanks.

RESULTS AND DISCUSSIONS

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

Table 1. Physicochemical properties of the soil associated with maize processing mill effluent

								PARTICLE SIZE			
Sample	Depth (cm)	pH	E/C (μS/cm)	TOC % (TOC)	TN %	P. mgk g^{-1}	(CEC) Cmolkg^{-1}	SAND	SILT	CLAY	TEXTURE
Site A	0-5	4.00	180.4	1.17	0.09	71.10	0.49	84	0	16	Sandy loam
	15-30	4.02	340.2	0.45	0.12	75.20	0.94	77	0	21	Sandy clay loam
	30-45	4.51	131.8	0.74	0.08	68.80	0.72	70	1	29	Sandy clay loam
Site B	0-15	4.71	405.0	0.35	0.10	86.20	0.66	90	1	7	Sand
	15-30	4.90	245.5	0.12	0.10	85.52	0.82	76	2	20	Sandy loam
	30-45	5.74	182.4	0.60	0.11	70.64	0.81	72	11	14	Sandy loam
Site C	0-15	4.12	148.3	3.25	0.12	90.72	0.84	83	0	14	Sandy loam
	15-30	4.30	152.8	0.35	0.09	86.57	0.80	80	1	17	Sandy loam
	30-45	4.83	384.0	1.36	0.08	87.50	0.93	71	10	16	Sandy loam
Site D	0-15	3.89	116.2	0.64	0.10	55.50	1.63	76	2	20	Sandy loam
	15-30	4.43	476.0	0.88	0.09	55.70	1.00	67	1	29	Sandy clay loam
	30-45	4.47	407.0	0.95	0.11	53.60	0.98	80	1	18	Sandy loam
Site E	0-15	4.60	938.0	0.02	0.08	46.75	1.23	70	2	24	Sand clay loam
	15-30	4.92	497.0	1.08	0.11	43.82	0.95	74	1	21	Sandy clay loam
	30-45	5.41	181.2	0.84	0.09	45.72	0.91	70	2	24	Sandy clay loam
Control	0-15	6.96	42.2	0.68	0.11	68.30	0.84	76	2	20	Sandy loam
	15-30	7.40	73.70	0.45	0.11	70.20	0.85	63	4	30	Sandy clay loam
	30-45	7.81	35.03	0.77	0.10	69.20	0.83	74	2	21	Sandy clay loam

Sampling	Location
Site A	Ngodo
Site B	Ara
Site C	Isiakpu
Site D	Umuazu
Site E	Umugbulu
Control	Ngodo and Ara 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 maize mill effluent. The acidity decreased with depth in all the sites. The pH values recorded in this study area were in the same range with those reported by Rashad and Shalaby (2007), Onweremadu *et al.* (2007), Oguntimahin and Ipinmoroti (2007) and Oviasogie and Ofomaja (2007). The values were however lower than those reported by Ano *et al.* (2007), Amusan *et al.* (2005) and 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 indicated 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 (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 (Igwegbue, 2007). The total organic carbon ranged from 0.02 to 3.25%. 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 (Oviasogie & 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 humid substances and increased carbon content of the soil. The total organic carbon recorded in this study were similar to the values reported by Oviasogie and Omoruyi (2007), but comparatively lower than the values reported by Tukura *et al.*, (2007).

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. Osakwe, (2010) observes that both anthropogenic and natural processes have resulted in elevated concentrations of organic carbon in sediments; the total nitrogen ranged from 0.08 to 0.12%. 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. This is consistent with the views of Oviasogie and Ofomaja (2007) following the analysis of total nitrogen in urban wastes. Nitrogen is one of the elements needed by plants for healthy growth. The electrical conductivity values ranged from 136 to 958 μS/cm. These values are similar to the values reported by Osemwota (2009) but higher than the values reported by Iwegbue *et al*., (2006), Oviasogie and Omoruyi (2007), and Onweremmadu *et al.*, (2007). 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. The implication of high electrical conductivity in soils is that there is reasonable or significant presence of anions. 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 value of phosphorus in the soils is not surprising since maize 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 Assah *et al.* (2005), Isirimah (1987) and 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. 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.

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	0-13	135.628	0.001	0.663	2.595	0.001	1.525
	13-28	133.678	0.015	0.655	2.126	0.001	1.452
	28-43	136.541	0.003	0.512	2.417	0.003	1.477
Mean ± S.D		137.282	0.006	0.543	2412	0.002	1.484
		±1.462	±0.007	±0.027	±0.346	±0.001	±0.037
Site B	0-13	139.221	0.006	0.598	1.535	0.023	1.998
	13-28	125.542	0.011	0.112	1.178	0.011	0.553
	28-43	126.939	0.058	0.117	2.074	0.009	0.345
Mean ± S.D		129.900	0.025	0.275	1.529	0.014	0.731
		±0.377	±0.028	±0.179	±0.148	±0.007	±0.463
Site C	0-13	129.112	0.013	0.212	1.303	0.008	0.377
	13-28	128.223	0.015	0.231	4.357	0.010	0.357
	28-43	80.926	0.021	0.111	0.219	0.012	0.522
Mean ± S.D		112.087	0.016	0.151	2.093	0.010	0.418
		±26.991	±0.004	±0.021	±2.228	±0.002	±0.090
Site D	0-13	83.221	0.036	0.032	6.298	0.022	0.198
	13-28	83.636	0.055	0.056	3.375	0.026	0.425
	28-43	81.779	0.031	0.052	0.197	0.012	0.510
Mean ± S.D		82.878	0.040	0.046	3.220	0.020	0.477
		±1.378	±0.040	±0.056	±3.149	±0.007	±0.046
Site E	0-13	130.612	0.093	0.122	0.205	0.024	1.131
	13-28	130.317	0.001	0.106	0.291	0.028	1.098
	28-43	131.487	0.001	0.135	0.323	0.016	1.178
Mean ± S.D		130.805	0.031	0.121	0.273	0.022	1.102
		±0.608	±0.075	±0.014	±0.061	±0.006	0.026
Control Mean	0-13	83.20	0.001	0.106	0.250	0.037	1.098
	13-28	83.62	0.001	0.011	0.367	0.010	0.055
	28-43	82.10	0.005	0.010	0.326	0.001	0.066
Mean ± S.D		82.88	0.002	0.135	0.314	0.016	0.306
		±2.218	±0.002	±0.120	±0.059	±0.008	±0.399

The results of vertical distribution of the heavy metals show that the heavy metal concentrations were generally higher at the top soil than the sub and bottom soils. This higher level 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 (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 maize 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 (Aluko & Oluwande, 2003). Eddy *et al.,* (2004) suggest 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 maize 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 indicate that the maize 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, the abundance of manganese in the maize 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. 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 large amount of copper was used in motors and generators. Studies of heavy metals in various Nigerian crude oils have shown them to contain relatively high concentrations of Fe, Cu, Zn, Pb and Hg. Therefore the presence of Fe, Cu, and Zn in the soils studied could also be attributed to the wearing of or abrasion of the maize wiling machine parts and mission of these metals through the exhaust of the machine.

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	119.28	112.8	104.10	104.5	83.88
	B	111.90	105.6	108.5	102.6	95.8
	C	114.09	106.8	80.5	89.6	64.5
	D	64.88	50.5	42.5	56.7	69.9
	E	112.81	106.0	105.6	93.6	
Cd	A	0.004	0.002	0.002	0.002	ND
	B	0.023	0.020	0.020	0.017	0.010
	C	0.014	0.014	0.012	0.010	0.010
	D	0.040	0.036	0.036	0.035	0.030
	E	0.030	0.026	0.024	0.021	0.020
Cu	A	0.643	0.611	0.500	0.380	0.250
	B	0.375	0.310	0.296	0.246	0.201
	C	0.251	0.236	0.215	0.211	0.182
	D	0.146	0.140	0.132	0.116	0.007
	E	0.221	0.208	0.192	0.180	0.133
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	2.420	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 maize milling points, the lower the concentrations of these metals. This is consistent with some other reports (Osakwe, 2010).

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	0.20	0.65	0.30	0.24	0.73	0.44
B	0.12	0.26	0.28	0.24	0.64	0.41
C	0.23	0.17	0.41	0.24	0.63	0.31
D	0.30	0.11	0.51	0.89	0.41	0.31
E	0.23	0.17	0.17	0.15	0.08	0.34

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. The Enrichment Coefficient (Ec) of the metals in the soil were calculated based on the equation given by 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	1.62	3.48	27.61	3.48	0.10	3.31
B	1.53	12.68	1.58	12.25	0.85	1.82
C	1.32	7.83	1.05	6.65	0.60	1.20
D	1.00	19.62	0.60	10.87	1.23	1.32
E	1.54	15.20	0.92	0.85	1.35	2.36

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 maize 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 maize 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 maize grains to be ready for consumption. As a result, use of maize 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 maize 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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