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Analysis of the Uptake and Distribution of Heavy Metals in Sweet Corn Grown on Municipal Solid Waste Dumpsite Soil in Delta State, Nigeria

EZE, J. N.[1] OKOH, P. A.[2] and ADEMIJU, T. A.[1]*
[1]Department of Agricultural Education, [2] Department of Home Economics Education,
School of Secondary Education (Vocational),
Federal College of Education (Technical), Asaba, Delta State, Nigeria

Abstract:- The build-up of heavy metals in agricultural soils is a growing source of worry due to issues with food safety, potential health risks, and negative effects on the environment of the soil. This development required investigation into the relationship between the quality of the dumpsite-soil metal and the rate of plant bioaccumulation. Soil samples were collected at a depth of 0 -45cm from four municipal solid waste dumpsites and farmland within Delta State, Nigeria. The municipal solid waste dumpsite selected are the area with heavy domestic and industrial waste which were over-populated. Physico-chemical properties of the soil samples were analyzed using standard procedures. The study examined at the levels of heavy metals (Cd, Cu, Pb, Fe, Mn, and Zn) in the soil and sweet corn that was wildly growing on farmland that also had soil from a dumpsite. The statistical analysis of variance software SPSS 17 for Windows (SPSS Inc., USA) was used to evaluate the data gathered (ANOVA). The results of the soil samples' physicochemical analysis showed that the soils from municipal solid waste dumpsites were moderately acidic, had sizable amounts of organic matter, and contained some ionisable inorganic compounds. The mean concentration of heavy metals found in the dumpsite was higher than the metals in the control site. Sweet corn is an excluder plant, a prospective accumulator plant, and can make an excellent slope remediation plant, according to the results of translocation factors (TF) and bioaccumulation factors (BAF) for heavy metals. According to the findings, different heavy metals may be categorized as mild contaminants (Fe, Cd, and Mn), moderate contaminants (Zn and Pb), and severe contaminants (Cu). Except for the sweet corn grown in the control site, the levels of heavy metals in the sweet corn grown in the plot with amended dumpsite soils above the WHO/FAO permissible limits. The results of the t-test showed values of $p < 0.05$, indicating that there were significant differences in the content of heavy metals in the soil and the sweet corn. The study made several recommendations, including the creation and enforcement of a rule barring any type of farming on the dumpsites, moving the dumpsites outside of the city, and enforcing other environmental protection laws to prevent the continued accumulation of these metals there. The findings of this study will be very helpful to academics and environmental regulators in developing nations.

I. INTRODUCTION

With the high industrial activity on soils, and increase in the world population which has resulted in the development of significant quantities of domestic, municipal and industrial waste, thus the introduction into our ecosystem, the industrial and municipal solid waste has significantly led to a rise in the number of heavy metals in the soil and vegetation cultivated at dumpsites. The degradation of these solid wastes releases substances which affect the quality of soil nutrients, increase the concentration of heavy metals in the soil, alter the natural balance of nutrients available for plant growth and development, affecting the diversity of species and agricultural production. The soil and plants on these dumpsites are at significant danger to the health of individuals who consume such plants (Adefemi & Awokunmi, 2009). In many developing countries, the management of municipal solid waste presents a challenge to the urban environment which is due to rapid population raise, unsatisfactory urbanization and undesirable economic growth. The high concentration of heavy metals in the soil which is accumulated by animal manure, fertilizers, pesticides, industrial discharge of waste is a source of concern because the non-biodegradable metals are a danger to the capacity of the earth to assimilate and carry (Oyedele *et al.*, 2008).

According to Oyeleke *et al.* (2016), the contaminated farmlands used for the cultivation of crops and plants in some way negatively influence physiological activities of the plants (plant growth, dry matter accumulation and yield. Plants, which are also referred to as bio accumulators, are capable of absorbing toxins from the soil and depositing them both in their roots and in their above-ground organs. The accumulation in the soil over a long period of time of heavy metals [lead (Pb), nickel (Ni), chromium (Cr), cadmium (Cd), mercury (Hg), aluminum (Al), zinc (Zn), copper (Cu), tin (Sn)] inadvertently becomes part of the biogeochemical cycle (Afolayan, 2018; Ayeni *et al.*, 2017). Plants' ability to absorb metals and potentially other pollutants varies with the type of the plant species as well as with the nature of the metal contaminant. Cereals such as Zea mays L (maize) are considered to be strong contaminant accumulators.

Sweet corn (*Zea mays saccharata L.)* in Nigeria is becoming a popular horticultural product and is very popular because of its sweeter taste when eaten. Due to its delicious flavour, along with its soft and sugary texture compared to other maize varieties, sweet corn is favorable for fresh consumption. Sweet corn, however, faces challenges such as low soil fertility and types and levels of fertilizers to boost soil health and thus increase agricultural production (Pangaribuan & Hendarto, 2018). Sweet corn is a horticultural crop with the ability to contribute to Nigeria's realization of food security. Sweet corn is type of cereal that is a familiar agricultural crop that is commonly adapted to the study area's environmental condition and can be easily cultivated. It has a higher dry-mass than many bio accumulative heavy metal plants.

The roots and straws may accumulate many types of heavy metals, especially from the soil at municipal solid waste dumpsites. Sweet maize will be one of the maize species to be used in this study in order to check the capacity to accumulate heavy metals from the soil in the municipal solid waste dumpsites. The transfer and accumulation of heavy metals from the soil in the municipal solid waste dumpsite in soil-plant systems has therefore become an important area of study. Therefore, study is to analysis the uptake and distribution of heavy metals in the sweet corn grown on the soil from municipal solid waste dumpsites in Delta State, Nigeria, in order to assess their possible risks to humans and animals in this study.

II. MATERIALS AND METHODS

A. Study Area

The study was carried out at the Demonstration Farm of the Federal College of Education (Technical), Asaba, Delta State, Nigeria. Delta State is one of the Nigeria's oil and agricultural producing state, located in the South-South geo-political area of the Niger Delta region with a population of 4,098,291 (males: 2,674,306; females: 2,024,085) (NPC, 2006). With an approximate area of 762 square kilometers (294 sq. mi), the capital city is Asaba, situated at the northern end of the state, while Ogwashi-Uku has the largest land space for any industry, Warri is the state's economic nerve and also the most populated in the southern end of the state (Umeri *et. al.*, 2017).

The total land area of the state is 16,842 Km^2. It is bounded on the north by Edo state, Anambra state to the east, Rivers state to the southeast, Bayelsa state to the south, the Atlantic Ocean Bay of Benin to the west, and Ondo state to the northwest. Delta State is located in the tropics and thus has a fluctuating climate, ranging from the tropical humid in the south to the sub-humid in the northeast. The northward decrease of humidity is followed by an increasingly pronounced dry season. In the coastal areas, the annual rainfall is around 266.5mm and in the extreme north, 1905mm.

The state is divided in to three (3) senatorial district namely, Delta central senatorial district, Delta south senatorial district and Delta north senatorial district. Delta State currently has twenty-five local government areas. Agriculture is the main stay of the state’s economy; yams, cassava (manioc), oil palm produce rice, and corn (maize) are grown for local consumption. Delta state is a major exporter of petroleum, rubber, timber, and palm oil and palm kernels via the Niger Delta ports of Burutu, Forcados, Koko, Sapele, and Warri. Petroleum is exported by pipeline from the Ughelli fields, and other major oil fields existing near Warri, Koko, and Escravos, as well as offshore.

B. Soil Sample Collection

For this study, soil from four (4) municipal solid waste dump sites spread over the two (2) senatorial district of Delta state were randomly selected. The dumpsite locations are; Umuagu, and cable point quarters in Asaba (Delta North Senatorial District). While the dumpsite locations in Warri (Delta South Senatorial district) are Refinery road and NNPC Complex dumpsite respectively. Considering the amount and nature of waste, the proximity to agricultural settlements, and their age, the dumpsites were chosen. After removing the overlying waste, a total of twenty (20) soil samples were collected from the selected dumpsites, making five (5) from each dumpsite. Another five (5) soil samples were collected from the uncultivated land (where there was no dumpsite or any form of human activities that could generate wastes) at Demonstration Farm of Federal College of Education (Technical) Asaba, Delta State which serve as the control samples. Soil samples were collected from each point at the soil profile (depths) of 0-15, 15-30 and 30-45 cm at a radius of 5cm with the aid of a soil auger. The surface soil samples were air- dried; rocks and pebbles were removed before pulverization using a mortar and pestle. To achieve uniform particle size, the pulverized soil samples were pass through a 2mm filter sieve. To avoid contamination, the sampling bags was kept inside clean plastic containers. The soil samples were scooped into air tight containers labelled according to the name of the area from which the samples were collected as well as the sampling point depth.

C. Laboratory Analysis

A total of twenty - five (25) soil samples were taken to the laboratory for analysis. The samples collected were taken to the laboratory at the Central Research Laboratory, University of Benin, Benin, Edo state for determination of pH, available phosphorus, total nitrogen, exchangeable cations (potassium and calcium), particle size (silt, clay and loam), textural classes and effective cation exchange capacity (ECEC). The soil sample were identified the with locations, towns and notations as shown in table:

Sample	Location	Town	Notation
1-5	Umuagu	Asaba	UAS1 – UAS5
6-10	Cable Point	Asaba	CAS6 – CAS10
11-15	NNPC Complex	Warri	NNW11- NNW15
16-20	Refinery Area	Warri	RAW16- RAW20
21-25	Control	Farm	CLF21- CLF25

Table 1: Necessary precautionary quality assurance methods were observed to prevent sample contamination.

***UAS – Umuagu Area in Asaba, CAS – Cable Point in Asaba, NNW – NNPC Complex Area in Warri, RAW – Refinery Area in Warri, CLF – Control in the Farm**

D. Experimental Design

The field experiment was carried out at the Federal College of Education (Technical) Demonstration Farm, Asaba, Delta State, Nigeria, where a 1296sqm (36m x 72m) land area (Uncultivated) were ploughed with disc plough in April 2022 and then harrowed after a week of ploughing. According to the experimental design, the land was demarcated into plots. The experiment was carried out in a 5 x 2 factorial, randomized complete block design (RCRD) i.e. Five (5) treatments were replicated twice (2), using a plot size of 2.57 m x 5.14 m to arrange growth patterns in an area of 1296sqm for the different treatments. For easy identification, each plot was separated by a distance of 1.0 m from one another. The soil from the municipal solid waste dumpsite was collected at least 15 cm into the experimental field topsoil and thoroughly mixed manually with the soil at uniform rates. The strength of the soil from the waste dumpsite in the soil would be within the range, the soil would be ploughed beyond the average high soil depth so that the entire rooting depth of sweet maize can be covered in the field (Nigussie *et al.*, 2012). This study was carried during the rainy season of the study area which is the month of March – September. The sweet corn seed was planted with 3 seeds per hole at a depth of 3-4 cm. After the sweet corn has grown for 15 days, due to the germination rate of the seed, the maize was thinned to one plant per hole

E. Heavy Metal Assessment

The heavy metals analyzed for the soil and plants are Cd, Cu, Fe, Pb and Zn. In order to extract adhering soils, plant samples obtained from the field were washed under running tap water and then divided into components like roots, stem, leaf, fruits and shoots. The samples were dried at 80°C for 48 hours (hr) in an oven. Using agate mortar and pestle, the dried samples were crushed, sieved to < 2 mm and transferred to polyethylene bags for storage until later review. The soil samples were air-dried for two weeks at room temperature, mechanically grind and sieved to a size of < 2 mm in diameter Both the soil and plants sample were analyzed using atomic absorption spectrophotometers (AAs VGB 210 System) according to the method of Ayten (2004).

F. Determination of Bioaccumulation Factor and Translocation factor of Heavy Metals

The Bioaccumulation factor (BAF) is the ratio of heavy metal concentrations in plants and soils. It's a measure of a plant's ability to absorb heavy metals (Borga, 2008). The BAF was calculated (Wang *et al.*, 2017):

$$BAF_I = \frac{P_I}{S_I}$$

where, Pi is the concentration of a heavy metal in plants (mg/kg−1);

Si is the concentration of the same heavy metal in the soil where the plant grows (mg/kg−1).

The Translocation factor (TF) is the ratio of heavy metal concentrations in shoots of the plant and that of the plant roots. It's a measure of a plant's ability to absorb heavy metals. (Onyedika, 2015). The Translocation factor (TF) were calculated to determine the degree of heavy metals accumulation in the plants cultivated with dumpsite soil and the control site.

$$Transcolation\ factor\ (TF) = \frac{Concentration\ of\ metal\ in\ plant\ shoot\ (\frac{mg}{kg})}{Concentration\ of\ metal\ in\ plant\ rot\ (\frac{mg}{kg})}$$

G. Statistical analysis

To evaluate the significant difference on the effects of municipal solid waste dumpsite on soil physicochemical (pH, N, P, K, OC, Ca, and EC) properties and heavy metal concentrations (Cd, Cu, Fe, Pb and Zn) at the various sampling location, data recorded were subjected to one-way analysis of variance (ANOVA) using SPSS 17 for Windows (SPSS Inc., USA). Correlation/regression analyses were carried using SPSS to determine the relationship between soil chemical properties, sweet corn yield and heavy metal contents in sweet corn grain. The level of significance was set at P > 0.05 (two-tailed). Correlation analysis (Pearson's correlation coefficient) was also done to establish correlations between the measured soil chemical indicators (pH, N, P, K, Ca, and ECEC) and heavy metal concentrations (Cd, Cu, Fe, Pb and Zn) in the dumpsite soils at the various locations and correlation chart drawn by the "corrplot" package of the SPSS software. All heavy metal concentrations were compared to the critical limits of FAO/WHO (2001) standards.

III. RESULTS AND DISCUSSION

A. Characteristics of the Soil Samples

The mobility and bioavailability of heavy metals, as well as their uptake by plants, have been shown to be influenced by their physicochemical properties (Tukura *et al.*, 2007; Adaikpoh & Kaiser, 2012). The properties of the soils collected from the municipal solid waste dumpsites and demonstration farm were determined, including pH, available phosphorus, total nitrogen, exchangeable cations (potassium and calcium), particle size (silt, clay, and silt) textural classes and effective cation exchange capacity (ECEC). The purpose of examining the physical and chemical properties of soil at the dumpsites and demonstration farm is to evaluate whether the soil is suitable for sweet corn growth.

Parameters	Depth(cm)	Dumpsite Soil (UAS)	Dumpsite Soil (CAS)	Dumpsite Soil (NNW)	Dumpsite Soil (RAW)	Dumpsite Soil (CLF)
pH	0 – 15	6.4	6.70	6.40	6.8	6.4
	15 – 30	6.2	6.50	5.70	6.4	5.8
	30 -45	5.9	6.30	5.50	6.5	6.3
Sand (%)	0 – 15	67.40	68.40	62.70	64.70	62.00
	15 – 30	72.50	64.40	71.70	63.30	68.00
	30 -45	78.80	70.40	68.70	61.70	61.30
Silt (%)	0 – 15	32.04	31.1	32.6	33.9	29.00
	15 – 30	28.10	30.1	29.6	32.8	28.90
	30 -45	20.06	29.6	27.0	29.5	28.10
Clay (%)	0 – 15	11.70	11.60	13.40	13.30	11.78
	15 – 30	10.60	10.12	13.41	12.41	11.21
	30 -45	10.70	10.90	13.60	12.60	10.89

Table 2: Physical Properties and Particle Distribution of the Soil at Different Depth

B. Soil Ph

At the municipal solid waste dumpsites, the soil Hydrogen ion concentration (pH) ranged from 5.5 to 6.8 for both surface and subsurface soil, while control soil had pH values of 5.8 and 6.4 for surface and subsurface soil, respectively, as shown in table 1. This indicates that the soils were slightly acidic. The slightly acidic pH of the soils indicates that they are good for vegetable planting. Most vegetables prefer a slightly acidic soil (Osunbitan, 2013). Plant growth can occur anywhere in the pH range of 3.5 to 10.0. A soil pH of 6.0 to 7.0 is excellent for good plant growth, with certain exceptions (Haby *et al.*, 2011). The highest pH values, however, were recorded at the CAS and RAW dumpsites. Most plants and soil microorganisms grow best in soil with a pH of 6.5-7.5 (Isrimah *et al.*, 2003). The pH of the soil sampled from the CLF ranged between 5.8 and 6.4, indicating that it was slightly acidic. This may be due to the usage of inorganic fertilizer and other chemicals in the farms. This was also expected, given that most tropical soils have a pH range of acidic to slightly neutral (Abdallah *et al.*, 2011). The higher pH levels at the dumpsites than in the controls have been attributed to liming materials as well as microbial activity on the solid wastes (Ideriah *et al.*, 2006). Obasi *et al.* (2011) found that acidic pH values result in enhanced micronutrient solubility and mobility, as well as higher heavy metal concentrations in the soil. The pH measurements at the dumpsites reveal a reduction in values with depth, indicating that the soil acidity increased with depth. The pH values obtained in this study are in the same range with the values reported by Osakwe and Okolie (2015). Because metals are more soluble and bioavailable in the soil solution at low pH (acidic), the pH values observed in this study will favor heavy metal uptake, and hence toxicity problems are conceivable.

C. Textural Classes

From table 4.1, it was observed that soil samples from CAS has higher percentage of sand (67.40%), followed by soil samples from UAS (72.50%) followed by RAW (67.40%). The soils from the CLF have the lowest percentage of sand. In soil samples collected from the RAW and NNW dumpsites, greater percentage values of silt and clay were also found. Soil samples taken from the farm land site (Control site) included less sand, silt, and clay particles than soil samples collected from the dumpsites. Although the sand fraction was generally high in all of the dumpsite soils, this may be attributed to the poorly sorted and nature of the varied particle sizes of the soils, which were generated from dumped wastes rather than the natural process of weathering of the underlying parent materials. This result, however, is consistent with Amos-Tautua *et al.* (2014), who discovered that soils with high sand and low clay content have high pollutant leaching potentials. The particle size distributions of the dumpsites and control site soils do not differ significantly. The soils from the municipal solid waste dumpsites and the control site ranged from sand to loamy sand. Low clay and silt contented in UAS, CAS, and CLF account for this textural class. This shows that these soils have a moderate rate of water infiltration and a high water retention capacity. The parent soil was classified as loamy sand due to the predominance of sand fraction, followed by clay, and then silt. Both water and metals are known to be poorly retained in sandy soils (Wuana *et al.*, 2010). Ideriah et al. (2006) corroborated this by analyzing the soil quality near a solid waste dumpsite in south-south Nigeria, which is located in the same humid tropical wetland area.

D. Effective Cation Exchange Capacity (ECEC)

As indicated in table 2, the effective cation exchange capacity (ECEC) at dumpsites ranged from 10.5cmol/kg to 25.16cmol/kg for surface and subsurface, respectively, whereas the ECEC for control sites ranged from 4.67cmol/kg to 6.83cmol/kg for surface and subsurface, respectively. The ECEC in the dumpsite soil was higher than in the control, indicating that the trash dumpsite had a larger nutrient storage capacity. As a result, trash dumpsite soils are more fertile. The highest concentration of exchangeable cations (CEC) was observed in RAW dumpsite soil, at 25.16cmol/kg, which is substantially greater than the CLF's 6.83cmol/kg. The concentrations of exchangeable cations were, however, higher than the control, implying that the usage of dumpsite soil had a favourable impact on the farm. This could be owing to the distinct heterogeneous nature of trash, which is likely to have a different impact on soil parameters (Abdallah *et al.*, 2011). The excessive sandy character of the soil samples from dumpsites and the control site was blamed for the low ECEC values. The findings of the study were consistent with those published by Isirimah *et al.* (2003) for productive agricultural soil, indicating that solid waste may have boosted the soil's natural ability to retain nutrients and absorb water.

Parameters	Depth(cm)	Dumpsite Soil (UAS)	Dumpsite Soil (CAS)	Dumpsite Soil (NNW)	Dumpsite Soil (RAW)	Dumpsite Soil (CLF)
	0 – 15	0.08	0.17	0.25	0.18	0.16
Av.P(ppm)	15 – 30	0.36	0.19	0.12	0.11	0.17
	30 -45	0.31	0.11	0.11	0.19	0.18
TN(%)	0 – 15	0.63	0.60	0.96	0.21	0.11
	15 – 30	0.35	0.23	0.17	0.13	0.50
	30 -45	0.35	0.30	0.38	0.14	0.21
K(cmol/kg)	0 – 15	0.27	0.21	0.42	0.30	0.10
	15 – 30	0.21	0.27	0.36	0.47	0.11
	30 -45	0.24	0.21	0.27	0.35	0.14
Ca(cmol/kg)	0 – 15	14.93	14.9	13.88	13.30	11.24
	15 – 30	16.16	14.5	13.25	13.00	10.92
	30 -45	12.88	14.3	12.59	12.30	10.92
ECEC(cmol/kg)	0 – 15	16.28	13.60	18.47	25.16	5.89
	15 – 30	17.44	11.22	13.30	20.19	4.67
	30 -45	15.44	10.50	11.67	19.21	6.83

Table 3: Variation of Chemical Properties of Soil at Different Depth

*** Available Phosphorus (Av. P), Total Nitrogen (TN), Potassium(K), Calcium (Ca), , Effective Cation Exchange capacity (ECEC).**

E. Phosphorous

The dumpsite soils showed greater Phosphorous (P) contents, ranging from 0.08 to 0.36cmol/kg, compared to the control soils, which had 0.16 to 0.18cmol/kg. The presence of a large amount of organic debris and plant breakdown could explain the results (Ideriah *et al.*, 2006). As was discovered, the increased phosphorus concentration contributes to plant growth. P levels greater than 0.1cmol/kg in all soil samples were declared appropriate for crop development (FAO, 2001). Phosphorus is required for the growth of fibrous root systems in plants, according to Isirimah *et al. (*2003). The high concentration of these nutrients at the UAS dumpsite, as indicated in table 4.2, can be related to the waste composition, as the majority of the wastes come from households with high organic matter content. High phosphate levels have also been shown to limit the availability of cation metals to plants (Obianefo, *et al.*, 2017).

F. Potassium

Table 4.2 shows that exchangeable potassium (K) in dumpsite soils ranged from 0.21 to 0.42cmol/kg, while K in control site soils ranged from 0.1 to 0.14cmol/kg for surface and subsurface soils, respectively. The higher the levels in dumpsite soils and above 0.2 cmol/kg, which is considered the crucial limit of exchangeable K in soils, the richer the soils in the dumpsites are in nutrients and thus an indication of good yield potential without fertilizer input (Umeri *et al.*, 2017). In plants, potassium acts as a catalyst. It aids in the production and transport of plant sugars/carbohydrates, increases chlorophyll in leaves, controls the opening and closing of leaf stomata, disease resistance, water uptake, and fruit ripening.

G. Nitrogen

Table 4.2 shows that total nitrogen (N) levels in dumpsite soil ranged from 0.13 % to 0.96 %, while levels in control sites ranged from 0.5 to 0.21 % for surface and subsurface, respectively. A similar range of values has been reported for this study (Osakwe, 2014). Natural processes such as lightning and plant tissue breakdown can transfer nitrogen into soils (Eddy *et al.*, 2006). Total N at the dumpsites were marginal based on the recommendation by FDALR (2004). The total nitrogen in dump site soils was higher than in control areas, which could be attributable to the waste mix, which was primarily from agricultural and farmyard sources. Organic matter, which is the source of most of the nitrogen and phosphorus that improve soil fertility and stimulate plant development, has been found in solid waste dumpsites (Ideriah *et al.*, 2010). The rich nutrient content of the soil could also be attributed to the actions of soil organisms in the degradation of these wastes (Amos-Tautua *et al.*, 2014).

H. Calcium

The calcium (Ca) content of soils from the dumpsite ranged from 12.3cmol/kg to 14.93 cmol/kg, which was greater than the 10.92 cmol/kg to 11.24 cmol/kg for surface and subsurface, respectively. Calcium levels are adequate in all of the locations where soil samples were taken, which is similar to the findings of Umeri *et al.* (2017). The dumpsites had the greatest magnesium (Mg) levels, ranging from 2.69 cmol/kg to 3.93 cmol/kg, compared to control soil, which had values ranging from 1.70 cmol/kg to 1.99 cmol/kg for surface and subsurface, respectively. In plants, magnesium also serves as a phosphorus transporter.

I. Accumulation of Heavy Metals in the Soil

This study has attempted to identify the concentrations of heavy metals in the various soil samples since it is crucial for healthy crop development to assess the concentration levels of harmful components in dumpsite soils. The study takes into account both essential/non-essential heavy metals that are hazardous to plants when present in soil at concentrations beyond the tolerance limit, such cadmium and lead, as well as micronutrient metals like copper, manganese, iron, and zinc. In table 3, the concentration of copper, manganese, iron, zinc, cadmium, and lead respectively from four (4) municipal solid waste dump sites distributed over two (2) senatorial districts of Delta State and control site (farm land) are shown, respectively, at different depths.

Sample site	Depth (cm)	Cu(mg/kg)	Pb(mg/kg)	Fe(mg/kg)	Zn(mg/kg)	Cd(mg/kg)	Mn(mg/kg)
UAS	0 – 15	2.89	12.75	9.92	3.02	4.8	5.39
	15 –30	2.31	11.75	8.93	2.58	3.3	4.28
	30 -45	1.87	11.35	8.19	2.34	2.9	3.19
CAS	0 – 15	4.98	10.67	8.68	4.80	5.00	3.34
	15 –30	4.18	10.20	8.46	3.30	4.50	3.20
	30 -45	2.78	7.60	7.32	2.05	4.40	2.77
NNW	0 – 15	5.87	12.70	8.79	3.93	5.67	7.44
	15 –30	4.54	12.1	8.79	2.72	4.71	5.47
	30 -45	3.44	11.96	6.56	1.50	4.08	3.43
RAW	0 – 15	3.16	13.12	10.47	4.73	6.12	6.63
	15 –30	2.79	12.85	6.78	3.64	5.43	5.34
	30 -45	1.15	12.21	6.78	2.22	4.64	4.11
CLF	0 – 15	1.11	3.60	6.00	2.14	3.15	2.44
	15 –30	0.98	2.31	4.31	0.92	2.10	1.50
	30 -45	0.91	0.81	3.21	0.69	1.08	1.00

Table 4: Mean Concentration of Heavy Metals in the Soil Samples at Different Depth

Heavy metal concentrations in soil are impacted by anthropogenic activities such agricultural practices, industrial operations, and waste disposal techniques. These activities are linked to biological and geochemical cycles and affect heavy metal concentrations in soil (Zauyah *et al.*, 2004). The amounts of heavy metals in the soils taken from the dumpsite compared to the control site in this study varied significantly ($P < 0.05$). This is consistent with Adelekan and Alawode (2011) findings that the levels of metals in dumpsites were higher than the levels at the control site (farm land), which showed that the solid waste deposited at the site contained a high number of substances containing heavy metals. This is also in line with the findings of related research conducted by Amusan *et al.* (2005), and it may be explained by the presence of metal-containing wastes at dump sites that eventually leach into the soil beneath. The disposal of municipal solid waste, according to Adefemi and Awokunmi (2013), has also increased the amount of heavy metals in soil. The levels of increase were in the following order: Pb < Fe < Mn < Cd < Cu < Zn, and all metal concentrations were deemed to be high. For both the dumpsite soil and the control site, the mean values of all heavy metals fall as one descends the soil profile. In general, the top soils had the highest metal concentrations. Given that the top soil serves as the point of contact, this is expected.

J. Uptake of Heavy Metals by Sweet Corn

The results of the heavy metal content in sweet corn grown under different conditions are shown in Fig. 1. It was found that the plant bio-accumulated the metals in the following order: Pb > Fe > Mn > Cd > Cu > Zn, which may be an indication of the metal concentrations in the soil. The FAO/WHO (2001) recommended limit and measured quantities of heavy metals in sweet corn were compared to determine the extent of food contamination. The sweet corn grown on a plot with NNW dumpsite soil had the highest concentration of copper (3.76 mg/kg), followed by the CAS treatment (2.88) and the CLF treatment (with the lowest concentration of copper) (0.67). Mining, pesticides, production, the chemical industry, and metal pipes in the dumpsite soil that was utilized to grow the sweet corn could be the main causes of Cu contamination in the sweet corn. Mining, pesticides, production, the chemical industry, and metal pipes in the dumpsite soil that was utilized to grow the sweet corn could be the main causes of Cu contamination in the sweet corn. Comparing the lead accumulation of sweet corn in this study to similar research by Malomo *et al.* (2012) and it was high. The sweet corn grown on the plot treated with RAW dumpsite soils had the greatest Pb concentration. The sweet corn from the plot treated with UAS dumpsite soil had the highest measured Fe concentration (7.09 mg/kg). Fe is a common element found in both human and plants, and it is present in food at relatively high levels. In healthy individuals, adverse effects from daily doses between 2.5 and 7.5 mg/kg are unlikely (Ozkutlu *et al.*, 2011). In general, Fe concentrations was high in all the treatment plots, which may be related to its capacity to transport oxygen for the synthesis of protein and the creation of chlorophyll (Kashif *et al.*, 2009).

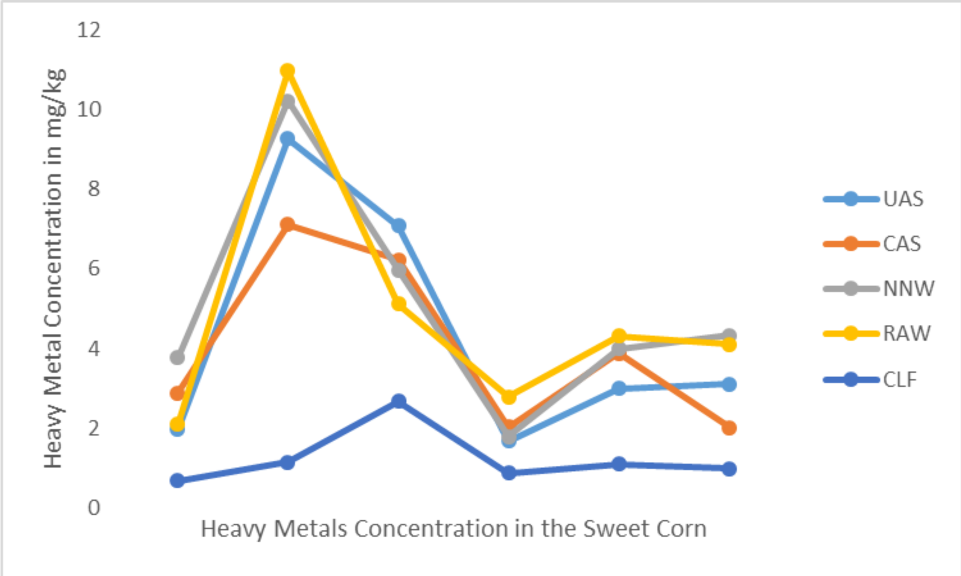

Fig. 1: Variation in Levels of Heavy Metals in Sweet Corn Cultivated with Different Treatment

The UAS dumpsite amended plot had the lowest Zn uptake by sweet corn (1.67 mg/kg), whereas the RAW dumpsite amended plot had the highest uptake (4.32 mg/kg). Zn accumulated the least since it is known to be a mobile metal that is rapidly leached by soil water infiltration (Ayari *et al.*, 2008). Zn is a crucial micronutrient component of several enzymes, which are unique proteins that belong to the dry mass and have a significant impact on biochemical reactions. Cd was discovered to be the most harmful element for the maize crop at all tested concentrations and produced the greatest reduction in the dry weight of shoot, root, and seed yield. The level of Cd was substantially greater (3.21 mg/kg) than the maximum values permitted for vegetables (0.20 mg/kg) (Myung, 2008). In sweet corn, the Cd concentration was substantially higher than the advised limit levels. In addition to foliar absorption of Cd via air deposition on plant leaves, Amusan *et al.* (2005) found that Cd is rather easily taken up by food crops, especially by sweet corn. Due to the plant's use as a source of food and oil for human consumption as well as pasture for livestock, the Cd concentration in sweet corn is a serious problem for food safety. Low mobility of heavy metals in the control site may be the cause of the low levels of heavy metals in the sweet corn grown on CLF treatment, which were 0.67, 1.14, 2.67, 0.87, 1.09, and 0.98mg/kg for Cu, Pb, Fe, Zn, Cd, and Mn plants, respectively. Except for the sweet corn produced on CLF treatment, the heavy metal accumulation by the plot treated with dumpsite soil in this study is significantly higher than the advised limit. According to Amusan *et al.* (2005), sweet corn cultivated in heavy metals-contaminated soils had higher amounts of heavy metals than sweet corn grown in soils without contamination. Plant species, particular metal concentrations, chemical forms, soil chemistry, and pH all show how hazardous metals are to plants (Malamo *et al.*, 2013). The findings of this study were consistent with those of Singh and Bhati (2005) and Aghabarati *et al.* (2004), who found that plants at the plot treated with dumpsite soils had much higher concentrations of these heavy metals than plants at the control site. Furthermore, in this study, a variety of soil variables, including pH and organic matter, combined to affect how well plants absorbed heavy metals. Heavy metals are known to be more easily mobilized in soil that is more acidic, which increases their absorption.

K. Bioaccumulation Factor of Heavy Metals into Sweet Corn

The ratio of the overall metal concentration in the soil environment to the level of metal in the plant parts is known as the bioaccumulation factor (BAF). Pb> Cu> Cd> Mn> Fe> Zn were the reported trends for BAF in sweet corn as illustrated in fig. 2. This soil-to-plant factor is one of the most important elements of how humans are exposed to metals through the food chain. The values show the amounts of metals in the edible sections of the sweet corn as a percentage of the total metal concentration in the soil. These findings suggest that sweet corn has a higher potential for Pb accumulation than Zn accumulation. Despite the possibility that environmental parameters including pH, ECEC and binding capabilities contributed to the slow transfer rates between the soil and the sweet corn (Udosen *et al.*, 2006).

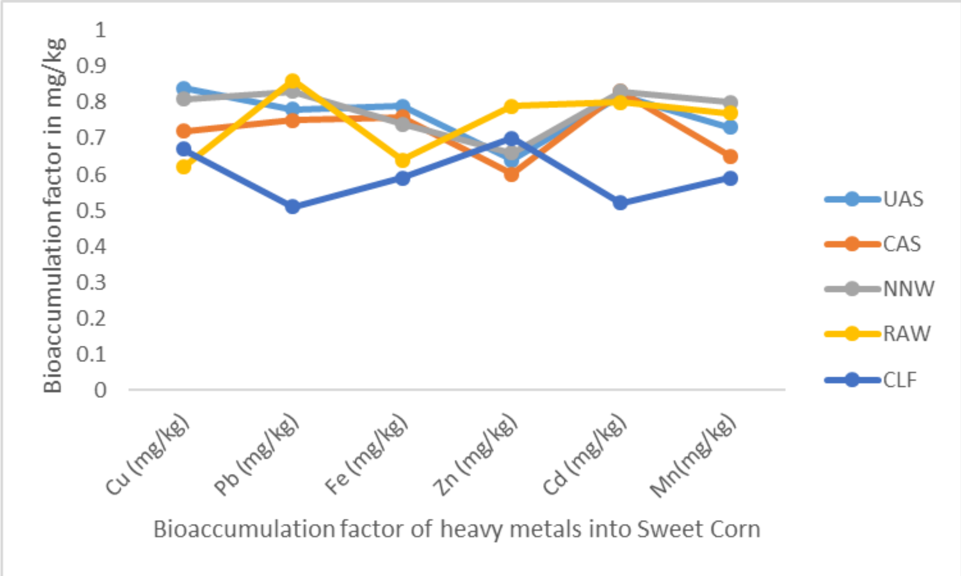

Fig. 2: Variation in Levels of Bioaccumulation factor (BAF) in Sweet Corn Cultivated with Different Treatment

High BAF values have been described as indicators or symptoms of soil heavy metal levels that are relatively high in reactivity, liability, and biological availability. In accordance with the findings of Oluyemi *et al.* (2008), the difference in the variation in values obtained for these heavy metals in the soil and crop plant samples at the plot treated with dumpsite compost as compared to the values obtained in the control site is an indication of their mobility from the dumpsites to the farmlands. The control site (CLF) had the lowest BAF values, ranging from 0.67 mg/kg for copper, 0.51 mg/kg for lead, 0.59 mg/kg for iron, and 0.70 mg/kg for zinc, 0.52 mg/kg for cadmium, and 0.59 mg/kg for manganese. It was initiated that the bioaccumulation factors for the heavy metal in the plot treated with dumpsites were considerably different from those for control sites. The BAF found in this study gives an indicator of the likelihood that heavy metal present in the dumpsite soil may enter the food chain if an animal or a human consumes an edible plant of the sweet corn. Varied heavy metal concentrations in the soil and different plant absorption of different elements may be the cause of variation in the bio concentration factor among different roots and leaves of plants (Zheng *et al.*, 2007). The discovery of trace metals in plant tissues and samples were not unexpected as plants are known to absorb and store trace metals from contaminated soil. Consuming plants with high levels of heavy metals on a regular basis could result in accumulation and have negative health effects, especially for Pb and Cd (Opabunmi, & Umar, 2003).

L. Translocation Factors of Heavy Metals in Sweet Corn Cultivated on Different Treatment

Translocation factors (TF) indicate whether heavy metal bio-magnification take place and TF greater than 1 indicates bioaccumulation. The translocation factor in the study area from root to the shoot of the plant shows mobility in the order: Zn>Cu>Pb>Fe>Cd>Mn for sweet corn cultivated in the plot treated UAS dumpsite soil, Pb>Mn>Fe>Zn>Cu>Cd for sweet corn cultivated in the plot treated with CAS dumpsite soil , Zn>Pb>Fe>Cu>Mn>Cd for sweet corn cultivated in the plot treated with NNW dumpsite soil , Pb>Cu and Zn>Mn> Cd>Fe for sweet corn cultivated in the plot treated with RAW dumpsite soil and Pb>Fe>Mn>Zn>Cu>Cd for sweet corn cultivated in the CLF plot. The results demonstrate that Zn, Pb, and Cu have the maximum mobility, as seen by their highest values. These heavy metals are easily absorbed by plants, which contributes to their great mobility. The maize plant's TF is more than 1, which demonstrates its unique capacity to absorb zinc from soils, transport it, and store it in its above-ground portion (zinc has the highest TF).

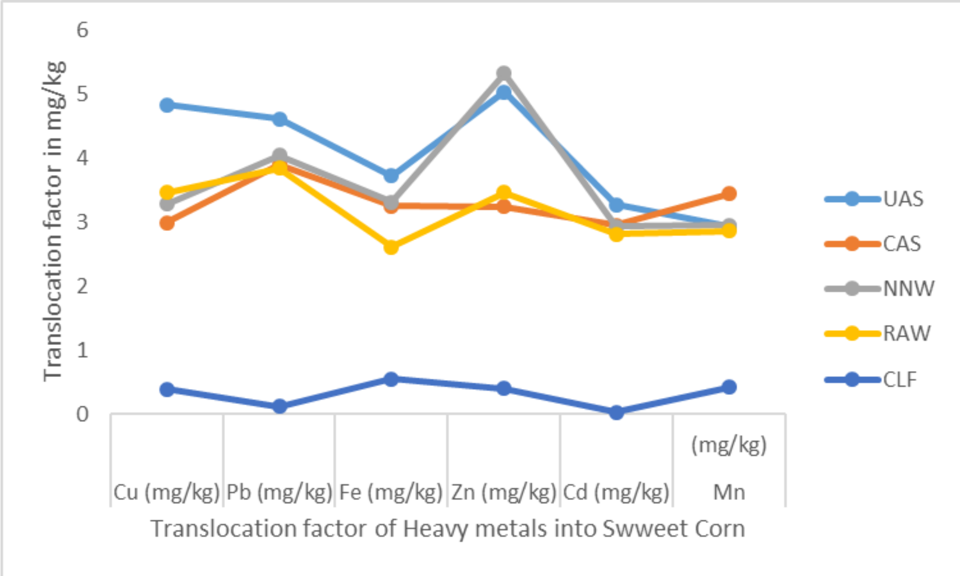

Fig. 3: Variation in Levels of Translocation factor (TF) in Sweet Corn Cultivated with Different Treatment

Oladejo *et al.* (2017) found that TF > 1 indicates that the plant successfully moves heavy metals from the roots to the shoots. Therefore, the tendency for a plant to collect heavy metals in its tissues increases with larger translocation factor values, especially in the case of the fruit, which is an edible component. Since the TF of the sweet corn in relation to the heavy metals investigated in this study is larger than 1, it can be concluded from fig. 3 that the sweet corn plant effectively translocates heavy metals from roots to shoots, with the exception of the control site. Low translocation in shoots and high accumulation of heavy metals in roots may suggest that a plant species is suitable for phytostabilization (Malik *et al.*, 2010). The process of phyto-stabilization depends on roots' capacity to restrict the mobility and bioavailability of heavy metals in the soils, which happens through sorption, precipitation, complexation, or metal valence reduction. According to Malik *et al.* (2010), research, plants that have a high root to shoot translocation of metals have essential traits that can be employed in phytoextraction of the metals.

IV. CONCLUSIONS

The study utilized sweet corn (*Zea mays L. saccharum*) cultivated on soil from a municipal solid waste dumpsite and a control site in Delta State, Nigeria. Soil properties (pH, available phosphorus, total nitrogen, exchangeable cations (potassium and calcium), particle size (silt, clay, and silt) and effective cation exchange capacity (ECEC) were more concentrated and gradually decreased as depth increased. Compared to the soils at the control site, the mobility of these soil characteristics was more significant at the municipal waste dumpsite soil. The study also found that the soils from the dumpsites and control site contained heavy metals (Cu, Pb, Zn, Cd, Mn, and Fe). Additionally, it was also found that some dumpsites had larger concentrations of these metals than others; this may be influenced by the geological formation of the locations and the presence of waste containing more of these heavy metals. The sequence of the heavy metal concentrations in the study's soil was Pb > Fe > Mn > Cd > Cu > Zn. It was also discovered that the plant bio-accumulated the metals in the following order: Pb > Fe > Mn > Cd > Cu > Zn, which may be an indication of the metal concentrations in the soil. The translocation factor found in the study of sweet corn grown in soil taken from a dumpsite is greater than 1, which suggests that the heavy metals are being bio accumulated by the sweet corn. Results of this study showed that plants cultivated on dumpsite soils acquire more toxic metals than plants grown on typical agricultural soils. As a result of this measures to discourage cultivating on dumpsite soils should be intensified.

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