ORIGINAL RESEARCH PAPER

Engineering

BIOACCUMULATION OF HEAVY METALS IN SOIL AND CASSAVA *(Manihot esculenta Cranzt)* CULTIVATED IN FARMS NEAR DUMPSITES IN NEKEDE MECHANIC VILLAGE OWERRI NIGERIA.

KEY WORDS: Heavy metals, soil, cassava, bioaccumulation, automobile mechanic, Nigeria.

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ABSTRACT

Farming activities around dumpsites in Nekede mechanic village Owerri, pose a lot of health risks to consumers of agricultural produce in the area. Studies on heavy metal contamination of the soil samples from farms, and their possible bioaccumulation in cassava plants in two locations, with the third location at Ihiagwa - a neighbouring town as control were carried out. Using the atomic absorption spectrophotometer, the mean concentrations of the heavy metals analysed which included Cu, Cd, Zn, Al, Pb, Ni, As, Hg, Ag, Fe, and Cr in soil samples from dumpsite1 ranged from 0.00± 0.00 to 63.27± 0.12 MgKg-$_1$ dry weight in decreasing order Fe Al As Cu Hg Zn Pb Ni Cd, dumpsite 2 ranged from 0.00± 0.00 to 65.17± 0.42 MgKg-$_1$ dry weight in the order Fe Al Cu As Zn Pb Hg Ni Cd whereas in site 3, the range was 0.00 ± 0.00 to 1.20±0.85 MgKg-$_1$ dry weight in the order Hg As Fe Al Cu with Cd, Zn and Pb recording the same mean concentration of 0.09± 0.00MgKg-$_1$. This indicated higher concentration of these heavy metals in soils near dumpsites in the mechanic village compared with control site. The pH values of soil samples from mechanic village ranged from 5.8 to 6.6 showing slight acidity while the control was 4.5 to 5.0 (acidic soils). The conductivity values were higher in impacted soils (45.0- 462.0µs/cm) than control site (10.0-20.0 µs/cm). The mean concentrations of the heavy metals in cassava tubers (CT) ranged from 0.00± 0.00 to 9.36±0.43 MgKg-^{1} dry weight, cassava stems (CS) 0.00± 0.00 to 7.84± 0.34 MgKg-^{1} dry weight and cassava leaves (CL) 0.00± 0.00 to 8.63± 0.33 MgKg-^{1} dry weight. The levels of Pb(0.006), As (0.033) and Hg (0.003) in cassava differed significantly across the sampling locations at P 0.05. However, Cu(0.124), Cd (0.606), Zn (0.482), Al (0.611), Ni (0.315) and Ag (0.121) were not significantly different across the sampling locations. The principal component analysis(PCA) done on the heavy metals in soil showed that Al and Zn were the metals that made much impact in the farms near the dumpsites with cumulative percentage variability of about 87.9%. The presence and levels of heavy metals in soil led to accumulation in cassava due to the proximal location of the tubers to the heavy metal–laden soil. Cassava sampled had some heavy metals in high concentration exceeding the permissible limits recommended by FAO/WHO for food crops since they have the ability to absorb heavy metals in high titer in the area. Proper automobile waste management system is recommended and farmers are advised to cultivate from 50m to 100m upstream of the dumpsites to avoid contamination of agricultural produce.

INTRODUCTION

Heavy metals are among the contaminants in the environment. Besides the natural activities, almost all human activities also have potential contribution to producing heavy metals as side effects. Migration of these contaminants to non-contaminated areas as dust or leachates through the soil and spreading of heavy metals containing sewage sludge are a few examples of events contributing towards contamination of the ecosystem (Gaur & Adholeya, 2004). Heavy metals are important environmental pollutants, particularly in areas with high anthropogenic pressure. Their presence in the atmosphere, soil and water, even in traces, can cause serious problems to all organisms. Heavy metal accumulation in soils is of concern in agricultural production due to the adverse effects on food quality (safety and marketability), crop growth (due to phytotoxicity)(Ma *et al*., 1994; Masky and Calvert, 1990; Fergusson, 1990) and environmental health (soil flora / fauna and terrestrial animals). Mobilization of heavy metals into the biosphere through human activities has become an important process in the geochemical cycling of these metals. This is acutely evident in urban areas where various stationary and mobile sources release large quantities of heavy metals into the atmosphere and soil, exceeding the natural emission rates (Nriagu, 1989; Bilos *et al*., 2001). Increased human activities, such as industrialization, coupled with over- population and increased ambient temperature amongst other factors, have become major environmental issue in recent years. Soil prospecting and other industrial activities result in pollution through gas flares, content oil spills, and industrial effluents. These affect both aquatic and terrestrial ecosystems and can result in destruction of forest and farmlands (Dambo, 2000). Heavy metal bioaccumulation in food chain can be very dangerous to human health. These metals enter the human body mainly through two routes, namely, inhalation and ingestion, with ingestion being the main route of exposure to these elements in human population. Heavy metal intake by human populations through the food chain has been reported in many countries with this problem receiving increasing attention from the public as well as governmental agencies, particularly in developing countries like Nigeria (Adefila *et al.*, 2010).

Poor waste management in most mechanic villages has led to high values of metals in the vicinity resulting in ecological and public health problems in the environment. Plant crops are often grown in polluted and degraded environmental conditions. Cassava is an important component in the diet of more than 800 million people round the world (FAO, 2007). It is the third largest carbohydrate food source within the tropical regions, after rice and corn (Ceballos et al., 2004). Cassava is referred to as a 'food security crop' (Barratt *et al.*, 2006), which can be left in the ground for extended periods of up to two years, until required. It is used mainly as a fresh food item, but is also processed into various food and non-food products, such as starch, flour, beverages, animal feeds, biofuels and textiles. Cassava, as a tropical root crop, requires at least 8 months of warm weather to produce a crop. It is traditionally grown in savannah climate but can be grown at extremes of rainfall (Coursey, 2000).

Bioaccumulation of heavy metals in the tubers of cassava, fruits of paw-paw as well as their various non-edible parts has become an inevitable challenge these days. A number of serious health problems can emanate as a result of excessive uptake of dietary heavy metals. Furthermore, consumption of food contaminated with heavy metals can seriously deplete some essential nutrients in the body causing a decrease in immunological defenses, intra-uterine growth retardation, impaired psychosocial behaviors, disabilities associated with malnutrition and a high prevalence of upper gastrointestinal cancer (Asia *et al*., 1998).

Against this backdrop therefore, there is need to investigate possible bioaccumulation of these heavy metals in cassava (Manihot esculentum Crantz) cultivated in farmlands near dump sites in Nekede automobile, village, Owerri.

MATERIALS AND METHODS

STUDY AREA

Nekede automobile mechanic village is located in Nekede Community, Owerri West Local Government Area of Imo State, Nigeria. The mechanic village is situated along Aba-Owerri Road of Imo State with geographical coordinates as 5026′ North, 702′ East in Owerri West L.G.A.

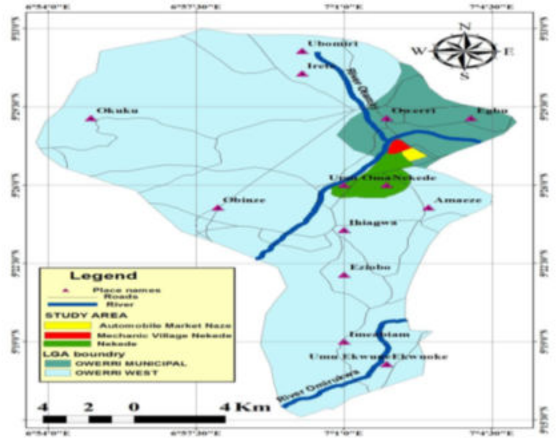

Fig. 1: Map of the study area showing sampling locations
Source: National Space Research and Development Agency (NASRDA), (2013).

It serves as a big settlement and base for many technical and engineering activities especially for services, repairs and maintenance of different types and sizes of automobiles, thus the name "Mechanic Village". There are two major dumpsites in this mechanic village and these serve as recipients of all kinds of wastes generated in the area.

TOPOGRAPHY OF THE AREA.

The topography of Nekede mechanic village is slightly rugged. Several runoffs have carved channels (gully erosion) on the table land and flow into the Otamiri River. These channels and burrow pits now serve as waste dumpsites or pits.

SAMPLE COLLECTION

Samples of edible and non-edible parts (tubers, stems and leaves) of cassava were collected and packaged in well-labeled transparent sterile cellophane bags and transported to the laboratory for analyses.

Soil samples of the farm lands near the dumpsite where the cassava plants were cultivated were also collected using soil auger at the depth of 0-30 cm for top and sub -soils as described by Radojevic & Bashkin (1999). These were also labeled accordingly.

The samples were labeled as follows; CT_1 = Cassava tuber sample from site one (1) CT_2 = Cassava tuber sample from site two (2) CS_1 = Cassava stem sample from site one (1) CS_2 = Cassava stem sample from site two (2) CL_1 = Cassava leaf sample from site one (1) CL_2 = Cassava leaf sample from site two (2) and TS_1 = Top soil sample from site one (1) TS_2 = Top soil sample from site two (2) SS_1 = Sub-soil sample from site one (1) SS_2 = Sub-soil sample from site two (2), TSC = Top soil control SSC = Sub-soil control.

STERILIZATION TECHNIQUES.

The moist heat, dry heat, direct flaming and chemical methods of sterilization as described by Cruickshank *et al.*(1982) and Ogbulie et al.(1998) were adopted for the sterilization of materials. All glass wares such as Petri dishes, conical flasks, beakers, McCartney bottles, test tubes, slides and others were sterilized using hot oven at 1700C for 2 hours. All media, diluents and water were sterilized using an autoclave at 1210C for 15 minutes. Forceps, inoculation needles, wire loops and other small tools were sterilized by direct flaming until red-hot using the burnsen burner. Acid alcohol was used as chemical in rinsing containers and other plastics.

SAMPLES PREPARATIONS.

The cassava tubers harvested from the farms near dumpsites and control farm were separately peeled, washed with fresh running water to remove dirt, dust and other contaminants. Furthermore, the cassava samples were washed with deionised water for more cleaning. The cassava samples were sliced separately using stainless steel knife, and then ground with porcelain mortar and pestle. Cassava leaf and stem samples were also washed and dried using the hot air oven and ground using mortar and pestle to produce fine powder for digestion.

SAMPLE DIGESTION.

A homogenous solution of 650 ml conc. HNO_3, 80 ml perchloric acid ($Hcl0_4$), and 20 ml conc. H_2SO_4 was prepared. One gram of the wet homogenized cassava sample was weighed out into a digestion flask and 20 ml of the prepared acid mixture were added. To increase solubility, the sample solution was heated on hot plate at 1300C until the volume was reduced to 3 ml. Then, the solution was allowed to cool and later was filtered into 25 ml volumetric flask using Whatman 42 filter paper. The filtrate was diluted up to the mark with distilled water (Khan *et al*., 2008).

PHYSICO-CHEMICAL ANALYSIS OF SOIL SAMPLES.

One gram of each pre-weighed soil sample was dissolved in 20 ml of the prepared acid mixture. To increase the solubility, the sample solution was heated on hot plate until the volume was reduced to 3ml. Then, the solution was cooled and filtered into 25 ml volumetric flask using Whatman 42 filter paper. The filtrate was diluted up to the mark of distilled water (Soylak *et al.*, 2004).

pH AND SOIL CONDUCTIVITY DETERMINATION The pH meter was first calibrated using pH buffer 7, pH buffer 4/10 and distilled deionized water. The pH of the samples was determined using a DIST3 by HANNA H198303 digital pH meter in a sample to water ratio 1:10, that is, 20g of each sample was weighed in a beaker, then 200 ml of distilled water were added to it. The pH electrode was dipped into the solution in a beaker. The conductivity electrode was also dipped into the beaker for 10 minutes after the meter was switch on, and the pH and conductivity readings were recorded when the reading became stable.

NITRATE.

Nitrate was determined by cadmium reduction method using HI 83200 multi parameter bench photometer at a wavelength of 525nm. Ten milliliters of the sample were poured into two separate sample cell bottles. One was used as blank to zero the photometer and one sachet of nitrate reagent powder pillow was added to the second sample cell bottle and was swirled into the cell compartment and timed for 4 minutes 30 seconds. At the end of the countdown, the READ button was pressed to display the results in mg/l of nitrate and nitrate-nitrogen.

PHOSPHATE.

Phosphate was determined by Amino acid method using HI 83200 Multiparameter bench photometer at a wavelength of 525 nm. Ten milliliters of the sample was poured into two separate sample cell bottles. One was used as blank to zero the photometer and ten drops of HI 93717A-0 molybdate reagent, then the content of one packet of HI 93717B-0 phosphate HR reagent B were added to the cuvette. It was shaken gently to dissolve and was inserted into the cell compartment and timed for 5 minutes. At the end of the countdown, the READ button was pressed to display the results in mg/l of phosphate, phosphorus and phosphate (P_2O_5).

SULPHATE.

Sulphate was determined by turbid metric method using HI 83200 multiparameter at a wavelength of 466nm. Ten milliliters of the sample were poured into two separate sample cell bottles. One was used as blank to zero the photometer and one sachet of sulphate reagent powder pillow was added to the second sample cell bottle and swirled into mix. It was then inserted into the cell compartment and timed for 5 minutes. At the end of the countdown, the READ button was pressed to display the result in mg/l of sulphate.

DETERMINATION OF HEAVY METALS USING ATOMIC ABSORPTION SPECTROPHOTOMETER (AAS)

Atomic Absorption Spectrophotometer (AAS) model FS240AA was used for analyzing the aforementioned heavy metals. The mode of operation of AAS is based on the sample being aspirated into the flame and atomized when the light beam in the AAS is directed through the flame into the monochromator, and onto the detector that measures the amount of light absorbed by the atomized element in the flame. Since metals have their own characteristic absorption wavelengths, a source lamp composed of that element is normally used, a method relatively free from spectral or radiation interferences. The amount of energy of the characteristic wavelength absorbed in the AAS is proportional to the concentration of the element in the sample.

RESULTS AND DISCUSSION

The results of the physicochemical parameters of the various soil samples determined are shown in Table 1.0. The pH range of the top soil samples was 4.5-6.6 while that of sub-soil samples was 5.0-6.5. The electrical conductivity values of the topsoil samples ranged from 20.0 to 184.0µs/cm while the conductivity of the subsoil ranged from 10.0 to 462.0µs/cm The nutrient contents of the various soil samples are also shown; nitrate (0.9-192.0 mg/g), phosphate (2.6-60.8 mg/g) and sulphate (0.0-160 mg/g).

Table 1.0 Physicochemical analyses of the soil samples in farmlands 4m away from dumpsites in Nekede mechanic village Owerri

S/N	Soil Samples	pH	Conductivity (µs/cm)	Nitrate mg/g	Phosphate mg/g	Sulphate mg/g
1	TS1	5.8	184.0	93.0	60.8	70.0
2	TS2	6.6	45.0	32.8	16.4	10.0
3	TSc	4.5	20.0	43.0	2.6	0.0
4	SS1	6.5	462.0	192.0	29.6	160.0
5	SS2	6.5	45.0	7.1	16.7	0.0
6	SSc	5.0	10.0	0.9	7.7	0.0

TS_1=Topsoil sample site 1, TS_2=Topsoil sample site 2, TS_C=Topsoil sample control, SS_1= Subsoil sample site 1, SS_2= Subsoil sample site 2 and SS_C= Subsoil sample control.

The results of the mean concentration of heavy metals in the various cassava samples are shown in Table 1.1.

The mean concentration of the extractable heavy metals in cassava tuber (CT) samples analyzed for Cu, Cd, Zn, Al, Pb, Ni, As, Hg, Ag, Fe and Cr ranged from 0.00±0.00 to 9.36±0.43 mgkg-$_1$ dry weight, in the order As>Al>Zn>Pb>Cd>Ni>Hg while Cu, Ag, Fe and Cr recorded zero concentrations.

Also, the mean concentration of the heavy metals in cassava stems (CS) sampled ranged from 0.00±0.00 to 7.84±0.34 mgkg-1 dry weight, in the order As>Al>Zn>Hg>Cd>Ni>Pb>Ag with Cu, Fe and Cr recording zero concentration. In the cassava leaf (CL) samples, the mean concentration of the heavy metals analyzed ranged from 0.00±0.00 to 8.63±0.33 mgkg-1 dry weight, in the order As>Al>Hg>Zn>Pb>Cd>Ni>Cu with Ag, Fe and Cr recording zero concentration.

Table 1.1: Concentration of heavy metals in cassava samples from farmlands 4m away from dumpsites in Nekede mechanic village Owerri

i Cassava Sample	Cu	Cd	Zn	Al	Pb	Ni	As	Hg	Ag	Fe	Cr
						mgkg-1					
CT1	0.000	0.177	0.323	3.189	0.144	0.384	9.960	0.000	0.000	0.000	0.000
CT2	0.000	0.266	1.362	3.889	0.303	0.057	8.750	0.035	0.000	0.000	0.000
CT (mean)	0.00±0.00	0.22±0.00	0.84±0.37	3.54±0.05	0.22±0.06	0.22±0.12	9.36±0.43	0.02±0.01	0.00±0.00	0.00±0.00	0.00±0.00
CTc	0.00	0.01	0.01	1.67	0.01	0.00	0.83	0.00	0.00	0.00	0.00
CS1	0.000	0.218	0.817	2.333	0.064	0.049	7.350	0.000	0.027	0.000	0.000
CS2	0.000	0.192	0.576	3.652	0.000	0.100	8.320	0.440	0.000	0.000	0.000
CS(Mean)	0.00±0.00	0.21±0.01	0.70±0.09	2.99±0.47	0.03±0.02	0.08±0.03	7.84±0.34	0.22±0.16	0.01±0.01	0.00±0.00	0.00±0.00
CSC	0.17	0.13	0.34	2.03	0.00	0.00	7.68	0.01	0.00	0.00	0.00
CL1	0.000	0.245	0.723	4.069	0.202	0.007	8.170	0.567	0.000	0.000	0.000
CL2	0.115	0.104	0.261	1.840	0.300	0.208	9.090	0.783	0.000	0.000	0.000
CL(Mean)	0.06±0.04	0.17±0.05	0.49±0.02	2.96±0.74	0.25±0.04	0.11±0.08	8.63±0.33	0.68±0.08	0.00±0.00	0.00±0.00	0.00±0.00
CLC	0.10	0.02	0.07	1.64	0.03	0.03	6.07	0.41	0.00	0.00	0.00
FAO/WHO 2011	NA	0.10	NA	NA	0.10	0.15	0.10	0.10	NA	NA	2.30

= Standard error of mean, mgkg-$_1$ = Milligram per kilogram, CT_1= Cassava tuber site 1, CT_2 = Cassava tuber site 2, CTc =Cassava tuber control, CS_1 = Cassava stem site 1, CS_2 =Cassava stem site 2, CSc= Cassava stem control, CL_1= Cassava leaf site 1, CL_2 = Cassava leaf site 2, CL_c =Cassava leaf control.

NA = Not Available.

The results of the mean concentration of heavy metals in soil samples are shown in Table 1.2. The mean concentrations of the heavy metals in soil samples (top soils and sub-soils) in site 1 ranged from 0.00 ± 0.00 to 63.27 ± 0.12 mgkg-1 dry weight, in the order Fe > Al > As > Cu > Hg > Zn > Pb > Ni > Cd with Ag and Cr recording zero concentration. Also in site 2, the mean concentrations of heavy metals in soil samples ranged from 0.00 ± 0.00 – 65.17 ± 0.42 mgkg-$_1$ dry weight, in the order Fe > Al > Cu > As > Zn > Pb > Hg > Ni > Cd with Ag and Cr recording zero concentration. Nevertheless, the mean concentrations of heavy metals in soil samples from the control site ranged from 0.00 ± 0.00 – 1.20 ± 0.85 mgkg-1 dry weight, in the order Hg > As > Fe > Al > Cu. Cd, Zn and Pb had the same mean concentration of 0.00 ± 0.00 and Ni 0.01 ± 0.00. Ag and Cr recording zero concentrations.

Table 1.2: Concentration of heavy metals in soil sample from farmlands 4m away from dumpsites in Nekede mechanic village Owerri

Soil Sample	Cu	Cd	Zn	Al	Pb	Ni	As	Hg	Ag	Fe	Cr
						mgkg⁻¹					
TS_1	2.600	0.254	0.425	37.297	0.362	0.110	8.960	2.000	0.000	63.438	0.000
SS_1	[illegible]	0.168	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.000	0.000	[illegible]	0.000
Mean Conc. Site 1	3.30±0.49	0.21±0.03	0.87±0.33	35.45±1.33	0.54±0.12	0.22±0.09	9.50±0.35	1.00±0.71	0.00±0.00	63.27±0.12	0.00±0.00
TS_2	6.313	0.202	1.424	26.742	1.139	0.275	8.240	0.000	0.000	64.575	0.000
SS_2	17.972	0.168	4.800	22.413	1.170	0.376	8.230	1.000	0.000	65.761	0.000
Mean Conc. Site 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00±0.00	65.17±0.42	0.00±0.00
TS_C	0.000	0.008	0.006	0.142	0.010	0.001	1.050	0.000	0.000	0.844	0.000
SS_C	0.110	0.010	0.013	0.120	0.008	0.000	0.981	2.400	0.000	0.711	0.000
Mean Conc. Control Site	0.06±0.06	0.01±0.00	0.01±0.00	0.13±0.01	0.01±0.00	0.01±0.00	1.02±0.02	1.20±0.85	0.00±0.00	0.78±0.06	0.00±0.00

± = Standard error of mean, mgkg-$_1$ = Milligram per kilogram, TS_1= Top soil sample site 1, SS_1= Sub soil sample site 1, TS_2= Top soil sample site 2, SS_2= Sub soil sample site 2, TS_C =Top soil sample control and SSC =Sub soil sample control.

The safest planting distances upstream of the dumpsites ranged from 50m to 100m to avoid heavy metal contamination of the soil due to the topography of the area (Table 1.3).

Table 1.3: Mean values in concentration (mg/kg) of the various heavy metals in the soil samples from different distances from dumpsites showing the safest planting area

Distances from Dumpsites (m)	Cu	Cd	Zn	Al	Pb	Ni	As	Hg	Ag	Fe	Cr
						Mg/kg					
4m	7.67	0.20	1.99	30.02	0.85	0.27	9.40	0.75	0.00	64.22	0.00
10m	7.02	0.17	2.01	20.50	1.11	0.22	7.03	0.19	0.00	40.00	0.00
20m	6.01	0.11	2.00	15.50	0.24	0.12	5.11	0.07	0.00	32.05	0.00
50m	1.02	0.04	0.10	1.27	0.02	0.10	1.01	0.05	0.00	9.28	0.00
100m	0.06	0.01	0.01	0.13	0.01	0.01	1.02	1.20	0.00	0.78	0.00
Control(300m)	0.02	0.03	0.01	0.11	0.02	0.10	1.00	0.02	0.00	4.03	0.00

Variation plots

The mean concentrations of Cu, Cd, Zn, Al, Pb, Ni, As, Hg, Ag, Fe, and Cr in cassava and their values on corresponding soil samples analysed are presented in Fig2.

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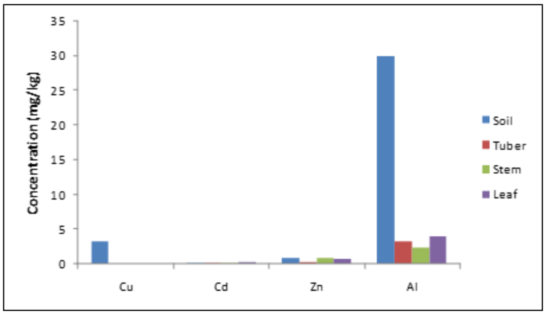

Fig. 2. Mean Concentrations of Cu, Cd , Zn, and Al in Soil and Cassava Parts Sampled in Site 1.

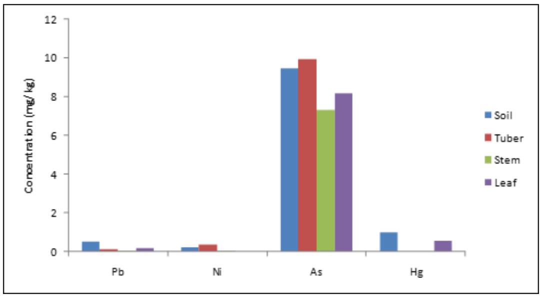

Fig. 3. Mean Concentrations of Pb, Ni, As, and Hg in Soil and Cassava Parts Sampled in Site 1.

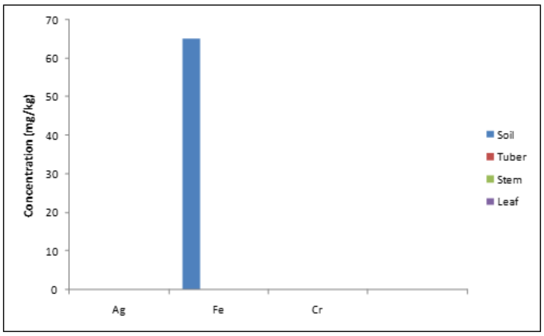

Fig. 4. Mean Concentrations of Ag, Fe, and Cr in Soil and Cassava parts Sampled in Site 1.

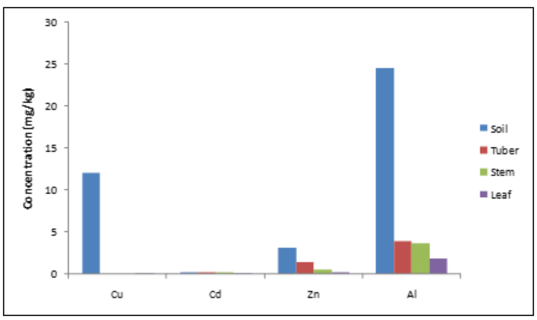

Fig. 5. Mean Concentrations of Cu, Cd, Zn, and Al in Soil and Cassava Parts Sampled in Site 2.

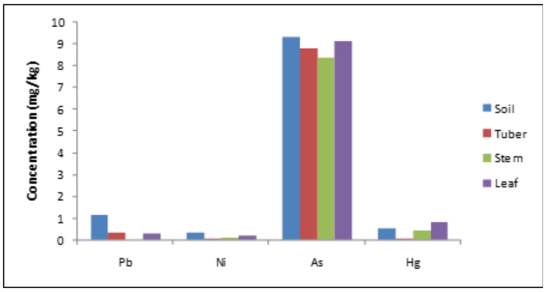

Fig. 6. Mean Concentrations of Pb, Ni, As and Hg in Soil and Cassava Parts Sampled in Site 2.

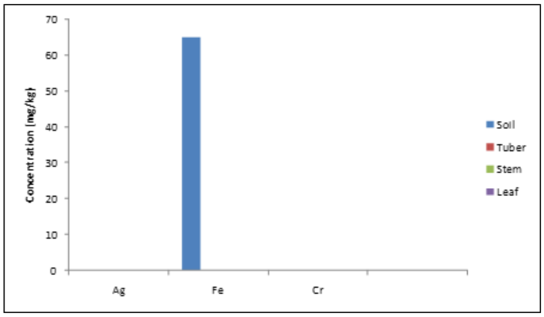

Fig. 7. Mean Concentrations of Ag, Fe, and Cr in Soil and Cassava Parts Sampled in Site 2.

STATISTICAL ANALYSES OF RESULTS

SOIL SAMPLES

The One-way Analysis of Variance (ANOVA) test revealed that the significant values of F; Cu (0.013), Cd (0.000), Zn (0.023), Al (0.000), Pb (0.000), Ni (0.003), As (0.000) and Fe (0.000) differed significantly across the sampling locations (SL) at P<0.05.

However, the levels of Hg (0.666) were not significantly different across the sampling locations.

The post-hoc Duncan multiple Range Test revealed that the levels of Cu and Zn differed between SL2 and other locations, the levels of Cd, Ni and As differed between SL3 and the other locations, and the levels of Al, Pb and Fe differed in all the locations (Table 1.4).

Table 1.4: Mean separation in concentration of heavy metals in soils across the sampling locations using Duncan Multiple Range Test (P<0.05)

Heavy metal	Sampling Location (SL)		
	SL_1	SL_2	SL_3(Control)
Cu	3.297b	12.043a	0.055b
Cd	0.211a	0.185a	0.009b
Zn	0.872b	3.112a	0.009b
Al	35.449a	24.577b	0.131c
Pb	0.535b	1.155a	0.009c
Ni	0.218a	0.324a	0.002b
As	9.495a	9.285a	1.007b
Hg	1.000a	0.500a	1.200a
Fe	63.271b	65.169a	0.778c

Values with same superscripts along same row are not significantly different at P<0.05

SL1=Sample location 1, SL_2= Sample location 2 and SL_3=Sample location 3 (control).

CASSAVA SAMPLES

The One-way Analysis of Variance (ANOVA) test revealed that the significance values of F; Pb (0.006), As (0.033), and Hg (0.003) differed significantly across the sampling locations (SL) at P<0.05. However, the levels of Cu (0.124), Cd (0.606), Zn (0.482), Al (0.611), Ni (0.315) and Ag (0.121) were not significantly different across the sampling locations.

The post-hoc Duncan Multiple Range Test as presented in Table 1.5 above carried out on cassava samples across the sampling locations revealed that the levels of Cu, Cd, Zn, Al, Ni and Fe were not significantly defferent in all locations, Pb differed only in SL_2, Hg also differed only in SL^3 but the levels of As differed between sampling locations 1 and 2.

Table 1.5: Mean separation in concentration of heavy metals in Cassava samples across the sampling locations using Duncan Multiple Range Test (P<0.05)

Heavy metal	Sampling Location (Sl)		
	SL_1	SL_2	SL_3(Control)
Cu	0.000^a	0.000^a	0.0577^a
Cd	0.214^a	0.205^a	0.174^a
Zn	0.843^a	0.697^a	0.492^a
Al	3.539^a	2.993^a	2.955^a
Pb	0.224^a	0.032^b	0.251^a
Ni	0.221^a	0.075^a	0.108^a
As	9.355^a	7.835^b	8.630^{ab}
Hg	0.012^b	0.220^b	0.675^a
Fe	0.000^a	0.014^a	0.000^a

Values with same superscripts along same row are not significantly different at P<0.05

PRINCIPAL COMPONENTS ANALYSIS (PCA)

The heavy metals detected in soil which were subjected to PCA procedure produced initial and extraction communalities which were all high.

The first two principal components (PCS) formed the extraction solution, with a cumulative % variability of about 87.97% in the original nine variables (Table 1.6)

Table 1.6: Extraction sums of squared loadings of the heavy metals in soil 4m away from dumpsites in Nekede mechanic village Owerri, Imo State

Component	Total	% of Variance	Cumulative %
1	6.483	72.036	72.036
2	1.434	15.928	87.965

The rotation maintained the cumulative % of variation explained by the extraction components (Table 1.7)

Table 1.7: Rotation sums of squared loadings of the heavy metals in soil 4m away from dumpsites in Nekede mechanic village Owerri, Imo State

Component	Total	% of Variance	Cumulative %
1	4.338	48.196	48.196
2	3.579	39.769	87.965

The first PC alone contributed about 48.20% variability, while the second PC contributed about 39.77%.

The scree plot represents the Eigen value of each component in the initial solution (fig 8). The extracted components are on the steep slope, while the components on the shallow slope contributed little (12.03%) to the solution. The last big drop occurred between the 2nd and 3rd components.

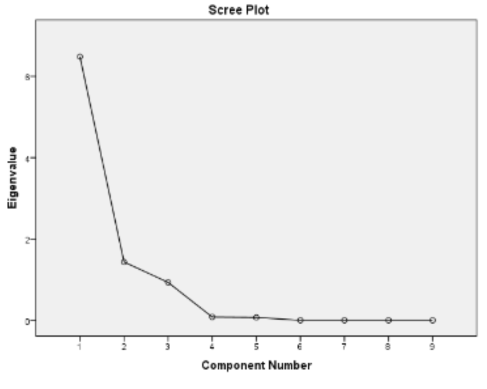

Fig 8: Scree plot of Eigenvalues by components numbers of the heavy metals in soil

Table 1.8: Rotated component matrix of the heavy metals in soil 4m away from dumpsites in Nekede mechanic village Owerri, Imo State

Heavy Metal	Components	
	1	2
Al	0.986	
Zn		0.928

The first PC was most highly correlated with Al ions (0.986) and also had high positive loadings for Cd ions (0.966), As ions (0.907), Fe ions (0.899), Ni ions (0.611) and Pb ions (0.543).

However, the second PC was most highly correlated with Zn ions (0.928) and also had high positive loadings for Cu ions (0.913), Pb ions (0.806) and Ni ions (0.764).

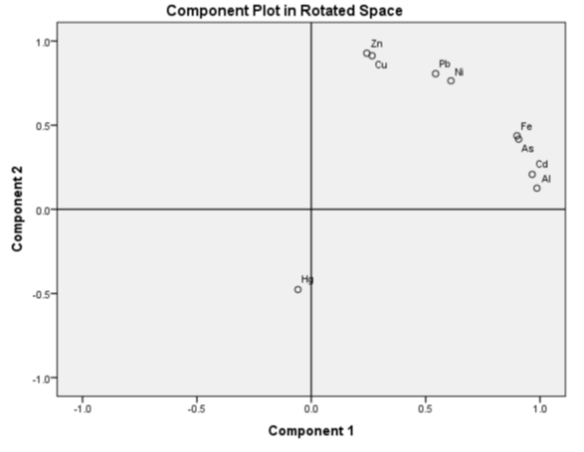

Fig 9: Component plots in Rotated space of heavy metals

The component plot in rotated space (Fig 9.) of the heavy metals revealed that the extracted components had skewed distributions with Zn, Cu, Pb, Ni, Fe, As, Cd and Al ions more closely related with each other than with Hg.

The Pearson correlations (r) between levels of the heavy metals in soil and cassava parts sampled are shown in Table 1.9. At P<0.05, Pb in soil correlated negatively with Pb in the plant parts (r = -0.775). However, at P<0.01, Fe in soil correlated positively with Fe in the plant parts (r = 0.886).

Table 1.9: Correlation (r) matrix between the concentration of heavy metals In soil and cassava samples from farmlands 4m away from dumpsites in Nekede mechanic village, Owerri.

	Cu_s	Cd_s	Zn_s	Al_s	Pb_s	Ni_s	As_s	Hg_s	Ag_s	Fe_s
Cu_c	-0.436									
Cd_c		0.283								
Zn_c			0.155							
Al_c				0.255						
Pb_c					-0.775*					
Ni_c						-0.239				
As_c							-0.003			
Hg_c								0.354		
Ag_c									0.365	
Fe_c										0.886**

** = Significant at P<0.05** = Significant at P<0.01*

Subscript "s" refers to concentrations of heavy metal in soil samples

Subscript "c" refers to concentration of heavy metals in cassava samples

The physico-chemical properties of the various soil samples revealed that the pH of the top soil samples in sites 1, 2 and 3 (control site) ranged from 4.5 to 6.6.

Top soil control (TS_C) had pH 4.5 which is acidic while top soil site 1(TS_1) and Top soil site 2 (TS_2) had pH values of 5.8 and 6.6 respectively indicating less acidity. In the sub-soil samples, the pH ranged from 5.0 to 6.5 where as the control site (SS_C) recorded the lowest pH of 5.0 (acidic) and pH of 6.5 for subsoil site 1 (SS_1) and subsoil site 2 (SS_2) showing that they were still less acidic.

This suggests that the soil samples from the farmlands near the dumpsite were less acidic; this agrees with the findings of Uba *et.al*, (2008) Elaigwu *et.al*, (2007) and Gupta & Sinha, (2006). The degree of acidity and /or alkalinity is considered a master variable that affects nearly all soil properties. While some organisms are unaffected by rather broad range of pH values, others may exhibit considerable intolerance to even minor variations in pH.

For example, the amount of acid or alkaline in soils determines availability of many nutrients for plant growth and maintenance (Arias *et.al,* 2005). Thus, as a key player in soil microbial reactions, pH values may as well have implication on availability and uptake of metals by plant and micro organism.

The electrical conductivity of the top soil samples ranged from 20.0 to 184.0 µs/cm with TS_1 (184.0 µs/cm), TS_2 (45.0µs/cm) and TS_C (20.0 µs/cm). The electrical conductivity of the sub-soil samples ranged from 10.0- 462.0 µs/cm with SS_1 recording the highest (462.0 µs/cm), SS_2 (45.0 µs/cm) and the least SS_C(10.0 µs/cm).

This implies that the soil samples near the dumpsite recorded higher conductivity values than the control sample. Similar results were reported for some dumpsites at Zaria (Uba *et.al*, 2008). The high conductivity values of soil samples at dumpsites may be linked to the presence of metal(s) which is one of the constituents of the refuse dumpsites and it implies that there are more soluble salts in the soil (Arias *et.al*, 2005; Karaca, 2004; Singer & Munns, 1999).

The high levels of nutrients (nitrate, phosphate and sulphate) in the soil near the waste dumpsites may have contributed to the good growth of plants around these sites as in line with the findings of Obasi *et.al,* (2012).

The decreasing order of accumulation of the heavy metals in cassava tubers in contaminated sites was As>Al>Zn>Pb>Cd> Ni>Hg with Cu, Ag, Fe and Cr recording zero concentration while the order in control site was Al>As>Cd>Zn> Pb>Ni>Hg.

In the stem samples, the decreasing order of accumulation of the heavy metals in contaminated sites was As>Al>Zn>Hg> Cd>Ni>Pb>Ag while in the control site was As>Al>Zn>Cu> Cd>Hg>Pb.

The decreasing order of accumulation of the heavy metals in leaf samples of cassava for contaminated sites was As>Al>Hg>Zn>Pb> Cd>Ni>Cu while the control The order of abundance or concentration of the heavy metals in the soil samples from mechanic village site 1 was Fe>Al>As>Cu>Hg>Zn>Pb>Ni>Cd. In contaminated site 2, the order was Fe>Al>Cu>As>>Zn> Pb>Hg>Ni>Cd while in the control site the order of abundance of the heavy metals was Hg>As>Fe>Al>Cu>Cd/Zn/Pb>Ni. Cd, Zn and Pb had the sa me mean concentration and were equal in abundance in the soil of control site.

The availability of some of these heavy metals in the soil, especially in the contaminated sites, was due to the activities that are embarked on in the automobile mechanic village. Iron and iron alloy (Steel) are by far the most common metals, and ferromagnetic materials in everyday use and sources include metal processing and plating, paints (car paints) and steel (Sautra, 2008). The higher levels of Cu in the auto mechanic locations may also be traceable to high use of copper conductors and wires, tubes, solders and myriads of other maintenance items made of Cu.

According to Alloway (1990) and Lenntech (2009), when Cu ends up in soils, it strongly attaches to organic matter and minerals. As a result, it does not travel far after release.

Pb can find its way to the soil through use of leaded fuels, old lead plumbing pipes or old orchard sites where lead arsenate was used (Traunfeld & Clement, 2001).

Mercury (Hg), due to several industrial activities such as car-painting, petrochemical usage and agricultural sources like fertilizers and fungicides sprays (Resaee *et.al,* 2005), can find its way into the soil. Chromium (cr) exists as metal alloy and pigment for paints, cement, paper, rubber and other materials (Sautra, 2008).

The values of cadmium (Cd) in the soils in the mechanic village may be because Cd is a "modern metal" used increasingly in corrosion prevention (Alloway, 1990). Mostly, it is often used instead of zinc (Zn) for galvanizing iron and steel (Turker *et.al,* 2005). Cd is also produced inevitably as bye product of zinc refining, since the metal occurs naturally within the raw ore (Idodo-Umeh & Ogbeibu, 2010).

From the variation plots, the concentration of Cu in the soil was higher than those accumulated by the plant parts.

Cd concentration in the soil was of the same with Cd concentration in cassava samples. The values of Zn in soil were higher than Zn in cassava parts. This suggests that the plants are not good accumulators of the Cu, Cd and Zn, or the metals were not within their roots for absorption.

Al, As, and most especially Fe in the soil were sparingly absorbed by cassava plants in the farm. This may be due to poor transport mechanism between roots and the soil environment.

The principal component analysis (PCA) done on the heavy metals in soil samples showed that Al and Zn were the metals that made much impact in the farms near the dumpsites with cumulative % variability of about 87.97% leaving the rest with other heavy metals. This could be attributed to wide use of these metals in the auto mechanic village in galvanizing other materials, scrapping, roofing of workshops etc.

From the correlation (r) analyses, presence and levels of Pb in soil of the farms near the waste dumpsites in the mechanic village did not lead to corresponding accumulation effect of Pb on cassava parts, the leaves, roots and stems of the crop. Presence and levels of Fe in soil near the waste dumpsites caused a corresponding accumulation effect of the heavy metal in the cassava parts. This indicates that the presence of Fe in soil favored the development of the crop parts.

The proximal location of cassava tubers to heavy metal-laden soil of the waste dumpsites may have aided higher accumulation of metals in cassava tubers.

CONCLUSION

The high levels of the heavy metals in the soil, four (4) meters away from the dumpsites in Nekede automobile mechanic village recorded in this study pose health risks to the inhabitants of such area, and people who farm around the dumpsites. It also raises significant environmental concern on the levels of soil contamination which may out of run-off find its way into the nearby river, "Otamiri River" that serves as source of domestic water at study area.

The plants in this study absorbed these heavy metals in their various parts and these plants are often consumed by man as part of his food; if consumed in high concentration they can lead to bioaccumulation of these heavy metals in the tissues, and can also elicit diseases, especially in the immuno-suppressed or immuno-compromised individuals. There were also some local trees and weeds in such environment that could be acting as phytoaccumulators to some of these heavy metals which made them not to be highly concentrated in the plants sampled.

The safest place to cultivate is from 50m to 100m upstream of the dumpsites. This is because downstream of the dumpsite flows into the Otamiri River and naturally all flows whether surface or underground are in the direction of river channels. In this case, the Otamiri River channel serves as the main recipient of all flows. Concentration of heavy metals in the initial stage will be localized around the dumpsites but with time, it will increase downward towards the river.

RECOMMENDATIONS.

It is pertinent to recommend as follows:

i. Efforts should be made to ensure that local trees with phytoaccumulation potentials are cultivated around the dumpsites in mechanic villages to serve as traps for heavy metals so as to decontaminate the soil and avoid further seepage into the groundwater aquifer.
ii. Strict adherence to proper disposal of auto-mechanic wastes should be followed.
iii. Farmers in such areas should refrain from planting around the mechanic villages as the soils there are highly contaminated by heavy metals which tantamount to possible uptake by plants in such area but should cultivate from 50m and above upstream of the dumpsites.
iv. Strict compliance to regulatory limits in sludge to be released from mechanic villages into the environment as stipulated by regulatory bodies is recommended.
v. Seminars, workshops and symposia should be organized periodically by concerned agencies on proper wastes disposal and management.
vi. Finally, these cassava plants can also be modified genetically and used in phytoremediation of such environment since they have the capacity/ potentials of accumulating these heavy metals in them.

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