Bio-Accumulation of some Heavy Metals in Soil, Edible and Non-Edible Parts of Paw-Paw Grown around Dumpsites in Nekede Mechanic Village Owerri, Imo State

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Abstract
Microbial, Physicochemical and heavy metal analysis formed the basis for assessment of the level of accumulation of some heavy metals on the edible and non-edible parts of paw-paw grown around dumpsites in Nekede Mechanic Village Owerri, Imo State. Studies were carried out in two locations, with the third location at Ihiagwa (as control). The total bacterial counts ranged from $2.8x10^7$ to $7.0x10^8$ cfu/g, total heterotrophic fungi, $1.3x10^4$ to $7.0x10^4$ cfu/g, total colform count, $1.1x10^5$ to $6.0x10^5$ cfu/g and total faecal coliform $8.0x10^4$ to $3.0x10^5$ cfu/g in the soil samples. Bacterial species isolated include, Enterobacter, Escherichia, Staphylococcus, Pseudomonas, Bacillus, Vibro, Citrobacter, Serretia, Klebsiella and Erwinia in soil samples while the fungal species include Aspergilus fumigatus, Epicoccum, Aspergilus flavus, Candida, Fusarium and Penicillium. Using the Atomic Absorption Spectrophotometer, the mean concentrations of the heavy metals in soil samples from dumpsite 1 ranged from $0.00\pm$ 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 0.000 ± 0.00 to 65.17 ± 0.42 $mgkg^{-1}$ dry weight in the order Fe >Al >Cu> As> Zn> pb>Hg>Ni> Cd> where as 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 O.09 $\pm$ 0.00. This indicated higher concentration of these heavy metals in soils near dumpsites in the mechanic village compared with control site. The soils in mechanic village had higher microbial contents than the control soil. The pH values of the soil samples in mechanic village ranged from 5.8 to 6.6 indicating slight acidity while the control was 4.5 to 5.0 (acidic soils). The conductivity values were higher in impacted soils (45.0- 462.0 µs/cm) than control site (10.0-20.0 µs/cm).The myriad of microorganisms and their high counts

recorded in impacted soil were due to availability of nutrients and their ability to utilize some of the trace metals as source of nutrient. The levels of Cd(0.521), Zn(0.264), Al(0.574) Pb(0.796), Ni(0.319) , As(0.540) , and Hg(0.658) in pawpaw were not significantly different across the sampling locations, with Cu(0.002) differing significantly across the sampling locations. The presence and levels of heavy metals in soil did not lead to appreciable accumulation in pawpaw plant probably due to dilutions by its water content sampled pawpaw plants had some of the heavy metals in high concentration exceeding the permissible limits recommended by FAO/WHO for food crops. It is not advisable to consume these crops since they have the ability to absorb the heavy metals in high titre in the area. Proper automobile wastes management system is recommended and farmers are adviced to cultivate from 50m to 100m upstream of the dumpsites to avoid contamination of agricultural produce.

Keywords: *Heavy metal, soil, microorganisms, crops, bioaccumulation, automobile mechanic, Nigeria.*

INTRODUCTION

Heavy metals constitute a very heterogeneous group of elements widely varied in their chemical properties and biological functions. The term heavy metals refer to those metals which have specific weights more than 5g/cm^3 (Barron, 1990).

Heavy metals are kept under environmental pollutant category due to their toxic effects on plants, man and animals. These heavy metals are not metabolized to other intermediate compounds and do not easily decompose in the environment.

These metals accumulate in food chain through uptake at primary producer level and then through consumer level. They enter our bodies through foods, drinks, water and air (Barron, 1990).

Furthermore, heavy metals are a member of loosely – defined subsets of elements that exhibit metallic properties and they mainly include the transition metals, some metalloids, lanthanides and actinides. Many different definitions have been proposed, some are based on density, some on atomic number or atomic weight, and some on chemical properties or toxicity (Agency for toxic substances and disease registry (ATSDR), 2005). Heavy metals are also chemical elements with a specific gravity that is at least 5 times the specific gravity of water. Specific gravity itself is a measure of density of a given amount of a solid substance when compared with an equal volume of water (ATSDR, 2005).

Bioaccumulation can be described as an increase in the concentration of a chemical substance in biological system overtime, compared to the chemical concentration in the environment (Specie *et al.*, 1995). It is also the accumulation of contaminants by species in concentrations that are in order of magnitude higher than the surrounding environment (Beek, 2000).

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.

In a study of the bioaccumulation of heavy metals in soil and cassava *(manihot esculenta cranzt)* cultivated in farms near dumpsites in nekede mechanic village owerri nigeria, Ejiogu et al, (2017) noted that the high levels of the heavy metals in the soil, 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.

They also observed that 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 immunocompromised individuals.

Against this backdrop therefore, there is need to investigate possible bioaccumulation of these heavy metals in paw-paw (*Carica papaya*) cultivated in farmlands near dumpsites in Nekede automobile, village, Owerri.

The objectives of this study shall include: (i) measurement of the levels of absorption of the heavy metals by the pawpaw plant, (ii) evaluation of the physicochemical properties of the garden soil near the dumpsites by comparing it with soil off the polluted environment (iii) assessment of the use of absorptive capacity of these crops in bioremediation of the dumpsites and (iv) determination of the effect of the heavy metals on the microbial population of the soil.

THE 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 $5^{0}26^{'}$ North, $7^{0}2^{'}$ East in Owerri West L.G.A (Fig 1).

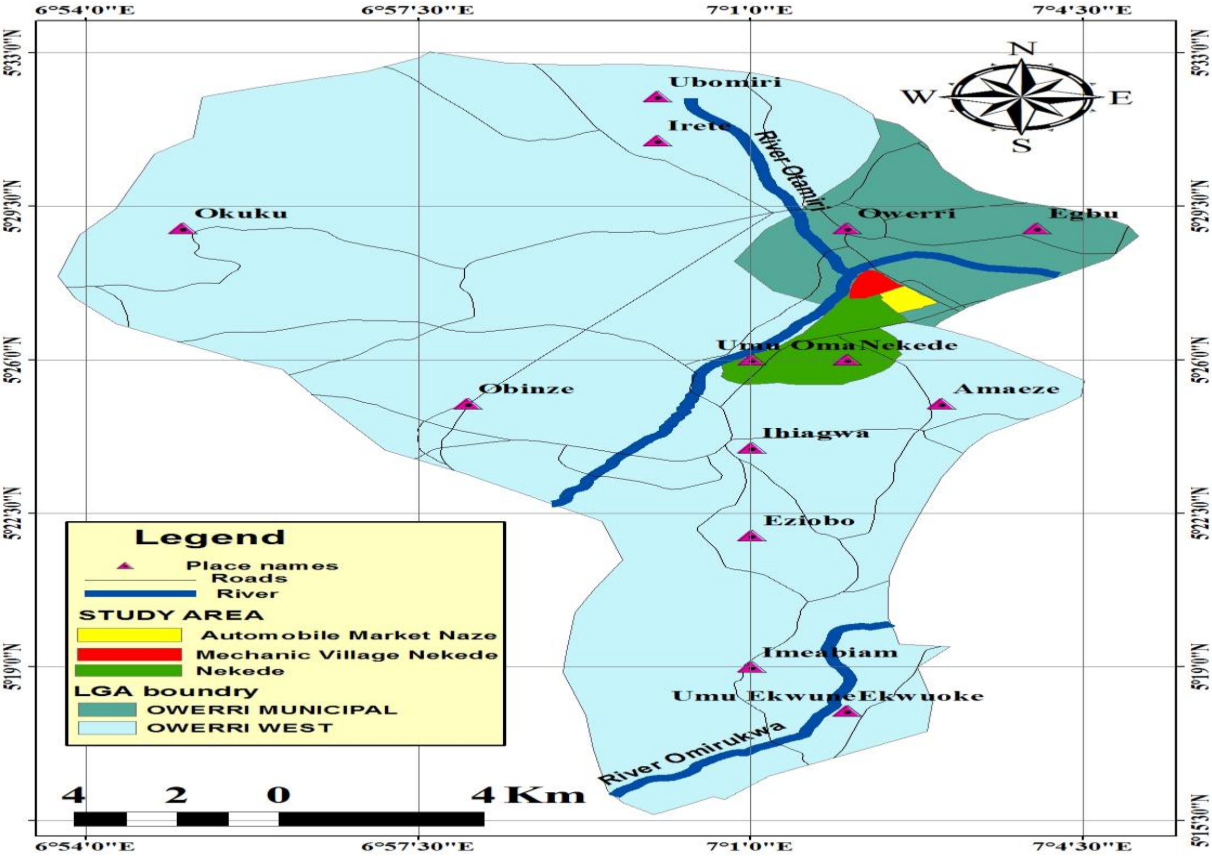

Fig 1. Location map of the study area

METHODOLOGY

Sample Collection

Samples of pawpaw (fruits, leaves and roots) 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 pawpaw 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 control samples were collected from farmlands at Ihiagwa that have no visible waste dump around them.

Samples Preparations

The pawpaw samples were washed and peeled. A grater was used to grind the samples into pastes and placed into different clean containers.

After grinding, 70 g wet weight of each of the samples were dried using the hot air oven. After drying, the samples were also weighed to determine the dry weight. The samples were milled using mortar and pestle into fine powder.

A mesh sieve of 1mm size was used to sieve the ground powdered samples which were then poured into different clean labeled containers for digestion. The leaves and roots also were washed dried using the hot air oven, after which they were ground into finer substances using mortar and pestle for digestion.

Microbiological analyses of soil samples

Media prepared included nutrient agar, MacConkey agar and Saboraund dextrose agar for the study and their preparations were done according to the manufacturer's specifications. The diluent used was distilled water. The media and diluent prepared were sterilized at 121^0C for 15 minutes with an autoclave.

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). Parameters determined include: pH and soil conductivity, nitrate phosphate and sulphate

Determination of heavy metals using Atomic Absorption Spectrophotometer (AAS)

Atomic Absorption Spectrophotometer (AAS) model FS240AA was used for analyzing the aforementioned heavy metals.

Statistical methods used

Statistical methods employed were: descriptive statistics (Mean, Standard error, and Range), correlation analysis, one-way analysis of variance (ANOVA), Duncan multiple range test (post-hoc test), variation plots (graphs) and principal component analysis. Microsoft excel 2010 version and Statistical Package for Social Sciences (SPSS) version 22 were used in analyzing the data realized.

RESULTS

Result of Microbial Count

The results of the microbial counts of the various soil samples from the agricultural farmlands near the dumpsites in Nekede mechanic village and the control site are presented in Table 1. The total bacterial counts (TBC) of the top soil samples ranged from $6.2x10^7$ to $1.0x10^8$cfu/g while the TBC for the subsoil samples ranged from $2.8x10^7$ to $7.0x10^8$cfu/g. The total heterotrophic fungal (THF) counts of the topsoil samples ranged from $4.0x10^4$ to $1.1x10^5$cfu/g while the THF for the sub-soils ranged from $1.3x10^4$ to $7x10^4$cfu/g. The total coliform counts (TCC) of the topsoil's was of the range $4.0x10^5$ – $6.0x10^5$ cfu/g while the TCC for the sub-soil samples was $1.1x10^5$ - $2.1x10^5$ cfu/g.

Table 1: Total microbial counts (colony forming unit per gram) of the different soil samples from farms 4m away from dumpsites in Nekede mechanic village Owerri .

Soil Samples	TBC cfu/g	THF cfu/g	TCC cfu/g	TFC cfu/g
TS_1	$1.0x10^8$	$6.0x10^4$	$6.0x10^5$	$3.0x10^5$
TS_2	$9.0x10^7$	$1.1x10^5$	$4.0x10^5$	$1.1x10^5$
TS_C	$6.2x10^7$	$4.0x10^4$	$4.0x10^5$	$9.0x10^4$
SS_1	$7.0x10^8$	$1.3x10^4$	$1.4x10^5$	$9.0x10^4$
SS_2	$5.2x10^7$	$7.0x10^4$	$2.1x10^5$	$1.0x10^5$
SS_C	$2.8x10^7$	$3.0x10^4$	$1.1x10^5$	$8.0x10^4$

TBC = Total bacterial count, THF =Total heterotrophic fungi, TCC = Total coliform count, TFC = Total faecal coliform, cfu/g =Colony forming unit per gram
TS_1= Top soil site 1, TS_2= Top soil site 2, TS_c=Top soil control, SS_1= Sub-soil site 1, SS_2= Sub-soil site 2 and SS_c= Sub-soil control.

The colonial and biochemical characteristics of the bacterial isolates from the different top soil samples in the farms near mechanic waste dumpsites and control site are shown in Table 2.
The following bacteria were isolated and identified: *Enterobacter, Escherichia*, *Staphylococcus*, *Pseudomonas*, *Bacillus*, *Vibrio* and *Citrobacter*.

Table 2: Colonial and biochemical characteristics of bacterial isolates from the different top soil samples from farmlands 4m away from dumpsites in Nekede mechanic village Owerri

Soil Samples	Colonial Appearance	Microscopic Characteristics	Gram Stain	Slant	Butt	Gas	H_20	Catalase	Coagulase	Methyl Red	Voge Proskeur	Indole	Motility	Oxidase	Sucrose	Glucose	Lactose	Probable Organism
TS_1	a. Rhizoid-like smooth colourless and translucent colony	Short rods	-	A	A	+	-	+	-	+	-	-	+	-	AG	AG	AG	*Enterobacter spp.*
	b. Pink on MacConkey agar, creamy colony on nutrient agar with smooth entire edge.	Slender rods	-	A	A	+	-	+	-	+	-	+	+	-	AG	AG	AG	*Escherichia spp.*
	c. Golden yellow on nutrient agar	Cocci in Clusters	+	A	A	-	-	+	+	-	-	-	-	-	-	A	A	*Staphylococcus spp.*
TS_2	a. Dully creamy colony on nutrient agar.	Short rods	-	B	B	-	-	+	-	+	-	-	+	+	-	A	-	*Pseudomonas spp.*
	b. Round white glossy raised membranous growth.	Short rods	+	B	A	-	-	-	-	+	-	-	+	+	A	A	-	*Bacillus spp.*
	c. Creamy colony nutrient agar.	Short rods	-	B	A	-	-	+	-	+	-	+	+	+	AG	AG	A	*Vibrio spp.*
	d. Pink on MacConkey agar, creamy on nutrient agar with smooth edge.	Scattered small rods	-	A	A	+	-	+	-	+	-	+	+	+	AG	AG	AG	*Escherichia spp.*
TS_C	a. Round creamy colony on nutrient.	Small rods	-	A	A	-	-	+	-	+	-	+	+	+	A	A^0	AG	*Citrobacter spp.*
	b. Pink on MacConkey agar, creamy on nutrient agar.	Small	-	A	A	+	-	+	-	+	-	+	+	+	AG	AG	AG	*Escherichia spp.*
	c. Rhizoid-like smooth colourless and translucent colony.	Short rods	-	A	A	+	-	+	-	+	-	-	+	+	AG	AG	AG	*Enterobacter spp.*

Key: A = Acid production , A^0 = Small acid production ,AG = Acid and gas production, + = Positive , B = Alkaline , - = Negative, TS_1= Topsoil site 1 , TS_2 =Topsoil site 2, and TS_c= Topsoil control

The results of the characterization of the fungal isolates from top soil samples from farms near dumpsites in Nekede mechanic village and control site are shown in Table 3.
The fungal isolates include *Aspergillus flavus, Aspergillus fumigatus, Candida spp Epicoccum spp* and *Fusarium spp.*

Table 3: Morphological microscopic appearance and identification of probable fungal isolates from top soil samples in farmlands 4m away from dumpsites in Nekede mechanic village Owerri

Soil Samples	Cultural Morphology	Microscopic Characteristics	Most Probable Organisms
TS_1	a. Granular creamy colony that turns bluish green on aging.	Hyphae is septate and conidiophores arise from thick walls.	*Aspergillus fumigatus*
	b. The aerial mycelium is well developed, presenting a cottony surface that develops a yellow colour.	Hyphae distinctively septate with irregular sized spores clustered together.	*Epicoccum spp.*
TS_2	a. Granular creamy colony that turns bluish green.	Hyphae is septate and the conidiophores arise from the thick wall.	*Aspergillus fumigatus*
	b. Fluffy colonies with blackish yellow colour.	Conidiophores borne as short branches from the aerial hyphae with condensed spores surrounding them.	*Aspergillus flavus*
	c. Colony grows as white patches with a glossy surface.	Clamydospores are numerous, borne singly.	*Candida spp.*
TS_C	a. Colonies are initially white and later purple-red pigment was observed at its edge.	Hyphae are hyaline and sepatate microconidia is 2µm in diameter.	*Fusarium spp.*
	b. Colonies grow as white patches with a glossy surface.	Clamydospores are numerous, borne singly.	*Candida spp.*

The following fungi were isolated from sub-soil samples from farms near dumpsites in Nekede mechanic village and control site as shown in Table 4. They include: *Candida spp, Aspergillus spp, Penicillium spp,* and *Fusarium spp.*

Table 4: Morphology, Microscopic Appearance and Identification of probable fungal isolates from sub-soil samples in farmlands 4m away from dumpsites in Nekede mechanic village Owerri

.Soil Samples	Cultural Morphology	Microscopic Characteristics	Most Probable Organisms
SS_1	a. Colony grew as white patches with glossy surface.	Clamydospore are numerous borne singly.	*Candida spp.*
	b. Fluffy colonies with blackish yellow colour.	Conidiosphores borne as short branches from the aerial hyphae with condensed spores surrounding them.	*Aspergillus spp.*
SS_2	a. White fluffy colony that turned green later.	Bluish spore bearing structure, conidia in chains.	*Penicillium spp.*
SS_C	a. Colonies grow as white patches with a glossy surface.	Clamydospores are numerous, borne singly.	*Candida spp.*
	b. Colonies were initially white and later turned to purple-red.	Hyphae are hyaline and septate microconidia are 2µm in diameter.	*Fusarium spp.*

Result of Physicochemical Analysis

The results of the physicochemical parameters of the various soil samples determined are shown in Table 5. 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 subsoils 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 5: 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	TS_1	5.8	184.0	93.0	60.8	70.0
2	TS_2	6.6	45.0	32.8	16.4	10.0
3	TSc	4.5	20.0	43.0	2.6	0.0
4	SS_1	6.5	462.0	192.0	29.6	160.0
5	SS_2	6.5	45.0	7.1	16.7	0.0
6	SS_c	5.0	10.0	0.9	7.7	0.0

The result of the mean concentration of heavy metals analyzed in the various pawpaw samples are shown in Table 6.

In the pawpaw fruit (PF) parts, the mean concentration of heavy metals ranged from 0.00 ± 0.00 to 6.20 ± 0.08 $mgkg^{-1}$ dry weight, in the order As > Al > Hg > Zn > Ni > Cu > Cd > Pb with Ag, Fe and Cr recording zero concentration.

Also, in the pawpaw root (PR) samples, the mean concentration of heavy metals ranged from 0.00 ± 0.00 to 5.18 ± 1.31 $mgkg^{-1}$ dry weight, in the order As > Al > Hg > Cu > Zn > Pb > Cd > Ni > Ag with Fe and Cr recording zero concentration.

However, the mean concentration of the heavy metals in the pawpaw leaf (PL) samples ranged from 0.00 ± 0.00 to 5.33 ± 1.14 $mgkg^{-1}$ dry weight, in the order Cu > As > Al > Hg > Fe > Zn > Ni > Cd > Pb with Ag and Cr recording zero concentration.

Table 6: Concentration of heavy metals in Paw-Paw samples from farmlands 4m away from dumpsites in Nekede mechanic village Owerri

Paw-paw Sample $mgkg^{-1}$	Cu	Cd	Zn	Al	Pb	Ni	As	Hg	Ag	Fe	Cr
PF_1	0.697	0.056	0.729	6.276	0.000	0.875	6.090	2.435	0.000	0.000	0.000
PF_2	0.013	0.142	1.020	2.758	0.160	0.000	6.310	2.100	0.000	0.000	0.000
$PF_{(mean)}$	0.36±0.24	0.10±0.03	0.88±0.10	4.02±0.89	0.08±0.06	0.44±0.32	6.20±0.08	2.27±0.12	0.00±0.00	0.00±0.00	0.00±0.00
PF_c	0.00	0.07	0.48	2.76	0.00	0.01	4.55	2.62	0.00	0.00	0.00
PR_1	1.231	0.058	0.843	4.746	0.049	0.000	3.330	2.570	0.027	0.000	0.000
PR_2	0.000	0.159	0.207	2.607	0.175	0.052	7.020	0.000	0.000	0.000	0.000
$PR_{(Mean)}$	0.62±0.44	0.11±0.04	0.53±0.23	3.68±0.76	0.11±0.05	0.03±0.03	5.18±1.31	1.29±0.90	0.01±0.01	0.00±0.00	0.00±0.00
PR_C	0.00	0.14	0.19	3.40	0.09	0.02	5.54	2.37	0.00	0.00	0.00
PL_1	3.714	0.092	0.873	4.090	0.000	0.875	3.960	3.542	0.000	0.740	0.000
PL_2	6.946	0.197	0.451	5.035	0.148	0.021	6.310	0.002	0.000	0.000	0.000
$PL_{(Mean)}$	5.33±1.14	0.15±0.04	0.66±0.15	4.56±0.33	0.07±0.05	0.45±0.31	5.14±0.83	1.77±1.25	0.00±0.00	0.87±0.62	0.00±0.00
PL_C	0.00	0.18	0.29	3.29	0.21	0.65	2.75	3.65	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, PF_1= Pawpaw fruit site 1, PF_2= Pawpaw fruit site 2, PF_C= Pawpaw fruit control, PR_1 =Pawpaw root site 1, PR_2= Pawpaw root site 2, PR_C= Pawpaw root control, PL_1=Pawpaw leaf site 1, PL_2= Pawpaw leaf site 2, PL_C= Pawpaw leaf control

NA = Not Available

The results of the mean concentration of heavy metals in soil samples are shown in Table 7. 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 7: Concentration of heavy metals in soil sample from farmlands 4m away from dumpsites in Nekede mechanic village Owerri

Soil Sample $mgkg^{-1}$	Cu	Cd	Zn	Al	Pb	Ni	As	Hg	Ag	Fe	Cr
TS_1	2.608	0.254	0.425	37.297	0.362	0.110	8.990	2.000	0.000	63.436	0.000
SS_1	3.985	0.168	1.319	33.601	0.707	0.326	10.000	0.000	0.000	63.105	0.000
Mean Conc. Site 1	3.30±0.49	0.21±0.03	0.87±0.33	35.45±1.31	0.54±0.12	0.22±0.09	9.50±0.36	1.00±0.71	0.00±0.00	63.27±0.12	0.00±0.00
TS_2	6.113	0.202	1.424	26.742	1.139	0.275	9.340	0.000	0.000	64.576	0.000
SS_2	17.972	0.168	4.800	22.412	1.170	0.376	9.230	1.000	0.000	65.761	0.000
Mean Conc. Site 2	12.04±4.19	0.19±0.01	3.11±1.19	24.58±1.53	1.16±0.01	0.32±0.05	9.29±0.04	0.50±0.35	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±0.04	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±0.05	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 SS_C =Sub soil sample control.

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 Fig 2-10

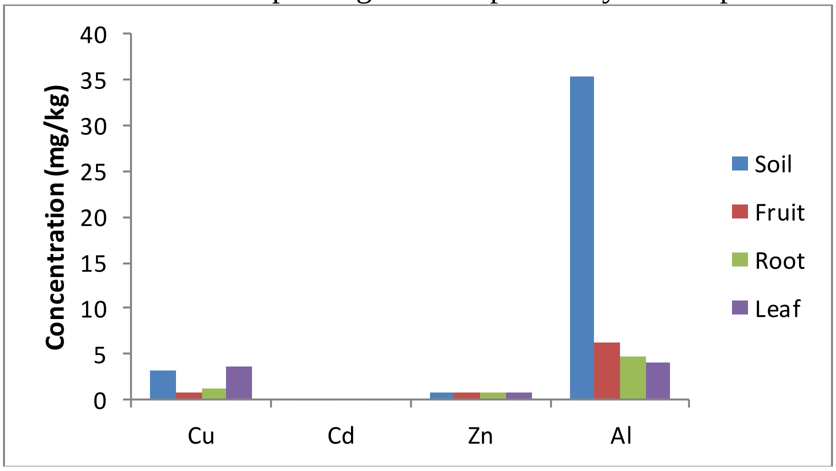

Fig. 2 Mean Concentrations of Cu, Cd, Zn, and Al in Soil and Pawpaw Parts Sampled in Site 1.

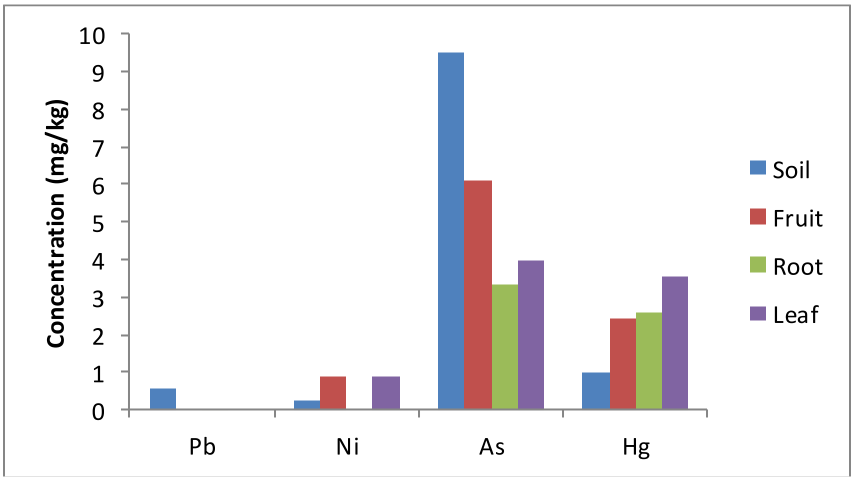

Fig. 3 Mean Concentrations of Pb, Ni, As, and Hg in Soil and Pawpaw Parts Sampled in Site 1.

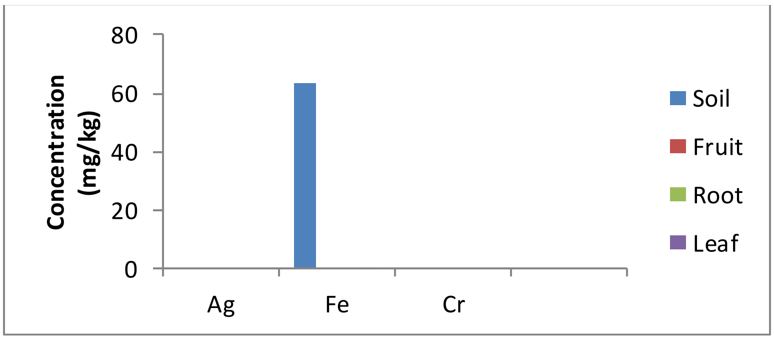

Fig. 4 Mean Concentrations of Ag, Fe, and Cr in Soil and Pawpaw Parts Sampled in Site 1.

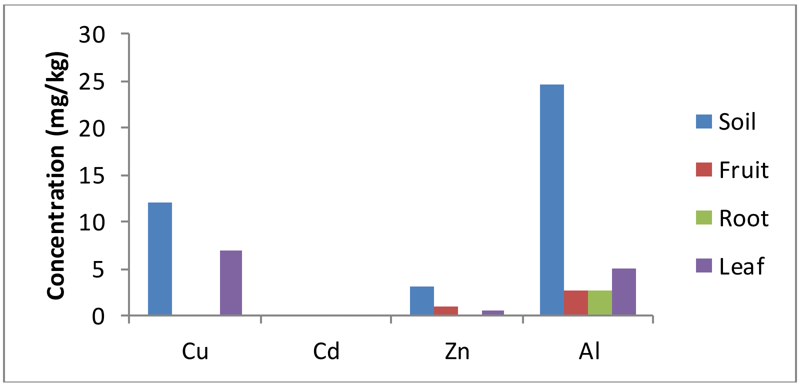

Fig. 5. Mean Concentrations of Cu, Cd, Zn, and Al in Soil and Pawpaw Parts Sampled in Site 2.

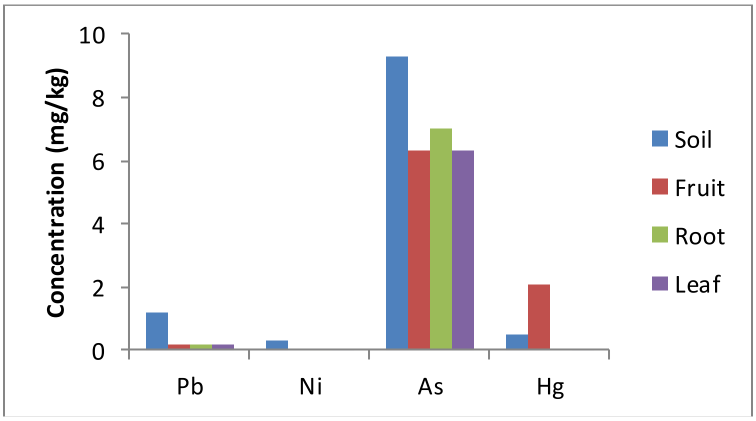

Fig. 6 Mean Concentrations of Pb, Ni, As, and Hg in Soil and Pawpaw Parts Sampled in Site 2.

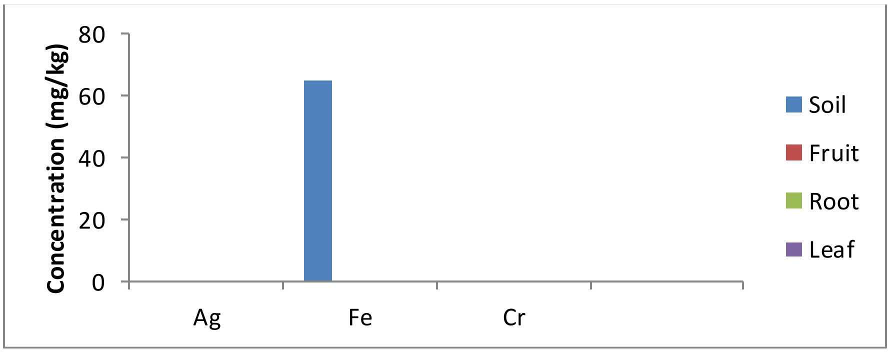

Fig. 7 Mean Concentrations of Ag, Fe, and Cr in Soil and Pawpaw Parts Sampled in Site 2.

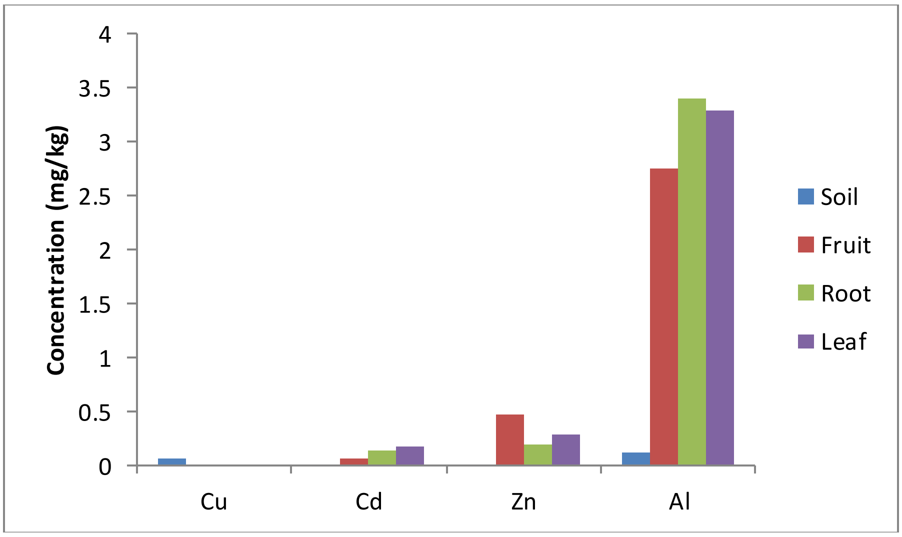

Fig.8. Mean Concentrations of Cu, Cd, Zn, and Al in Soil and Pawpaw Parts Sampled in Site 3 (Control).

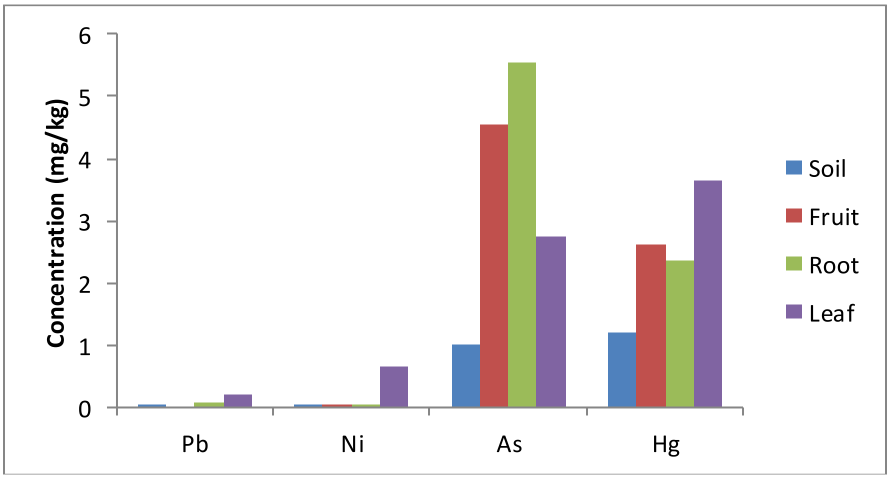

Fig.9. Mean Concentrations of Pb, Ni, As, and Hg in Soil and Pawpaw Parts Sampled in Site 3 (Control).

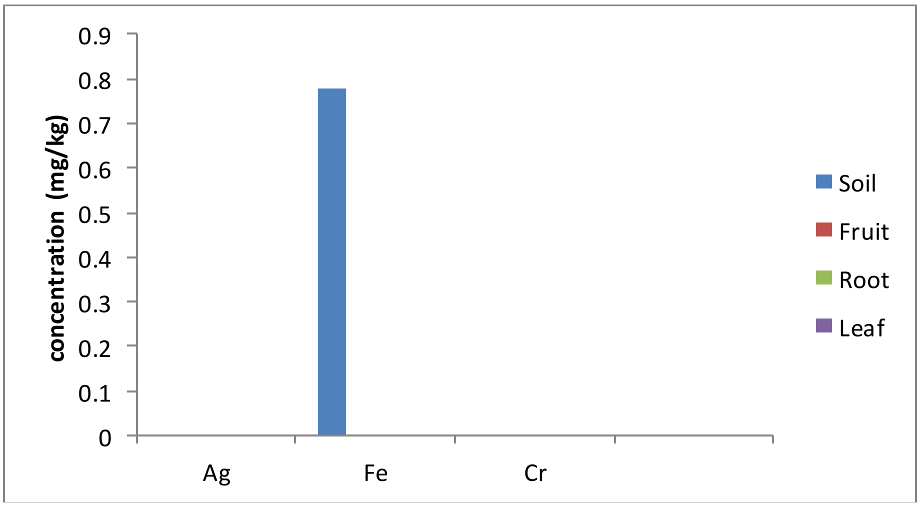

Fig. 10. Mean Concentrations of Ag, Fe, and Cr in Soil and Pawpaw Parts Sampled in Site 3 (Control).

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 SL_2 and other locations, the levels of Cd, Ni and As differed between SL_3 and the other locations, and the levels of Al, Pb and Fe differed in all the locations (Table 8).

Table 8: 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	3.297^b	12.043^a	0.055^b
Cd	0.211^a	0.185^a	0.009^b
Zn	0.872^b	3.112^a	0.009^b
Al	35.449^a	24.577^b	0.131^c
Pb	0.535^b	1.155^a	0.009^c
Ni	0.218^a	0.324^a	0.002^b
As	9.495^a	9.285^a	1.007^b
Hg	1.000^a	0.500^a	1.200^a
Fe	63.271^b	65.169^a	0.778^c

Values with same superscripts along same row are not significantly different at P<0.05
SL_1=Sample location 1, SL_2= Sample location 2 and SL_3=Sample location 3 (control).

PAWPAW SAMPLES

The One-way Analysis of Variance (ANOVA) Test revealed that the significant values of F; Cd (0.521), Zn (0.264), Al (0.574), Pb (0.796), Ni (0.319), As (0.540) and Hg (0.658) were not significantly different across the sampling locations. However, the levels of Cu (0.002) differed significantly across the sampling locations (SL) at $P<0.05$. The Post-hoc Duncan Multiple Range Test as presented in Table 4.13 on pawpaw samples across the sampling locations showed that the levels of Cu differed between SL_3 and and the other locations, whilst the levels of Cd, Zn, Al, Pb, Ni, As, Hg, Ag and Fe were not significantly different across the sampling locations.

Table 9: Mean separation in concentration of heavy metals in Pawpaw 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	0.355^b	0.617^b	5.330^a
Cd	0.099^a	0.109^a	0.145^a
Zn	0.875^a	0.525^a	0.662^a
Al	4.017^a	3.677^a	4.563^a
Pb	0.080^a	0.112^a	0.074^a
Ni	0.0438^a	0.026^a	0.448^a
As	6.200^a	5.175^a	5.135^a
Hg	2.264^a	1.285^a	1.772^a
Ag	0.000^a	0.014^a	0.000^a
Fe	0.000^a	0.000^a	0.870^a

Values with same superscripts along same row are not significantly different at P<0.05
Subscript "s" refers to concentrations of heavy metal in soil samples
Subscript "p" refers to concentration of heavy metals in pawpaw samples

The Pearson correlations (r) between levels of the heavy metals in soil and cassava parts sampled are shown in Table 10. 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 10: Correlation (r) matrix between the concentration of heavy metals in soil and pawpaw samples from farmlands 4m away from dumpsites in Nekede mechanic village, Owerri

The relationship between heavy metals and microorganisms in soils from the waste dumpsite as explored with the Pearson Correlation (r) is shown in Table 11. At P<0.05, Al ions

	Cu_s	Cd_s	Zn_s	Al_s	Pb_s	Ni_s	As_s	Hg_s	Ag_s	Fe_s
Cu_p	-0.615									
Cd_p		-0.572								
Zn_p			-0.589							
Al_p				-0.236						
Pb_p					0.364					
Ni_p						-0.599				
As_p							0.231			
Hg_p								-0.541		
Ag_p									0.635	
Fe_p										0.001

correlated positively with Total Coliform Counts (TCC) (r = 0.905). At P<0.01, Pb correlated negatively with TCC (r = -0.962).

Table 11: Correlation (r) matrix between the heavy metals and microorganisms measured in soils 4m away from dumpsites in Nekede Mechanic Village, Owerri.

	Cu	Cd	Zn	Al	Pb	Ni	As	Hg	Fe
TBC	-0.194	0.108	-0.236	-0.179	0.327	-0.039	-0.056	-0.452	0.082
THF	-0.050	-0.333	0.035	0.292	-0.336	0.194	0.552	0.021	-0.350
TCC	-0.664	0.638	-0.655	0.905*	-0.962**	-0.751	-0.019	0.655	-0.778
TFC	-0.417	0.798	-0.466	0.600	-0.688	-0.798	-0.501	0.786	-0.385

* = significant at P<0.05, ** = significant at P<0.01, TBC = Total Bacteria Count, THF = Total Heterotrophic Fungi, TCC = Total Coliform Count, TFC = Total Faecal Coliform

DISCUSSION

The results of the microbial counts of the various soil samples from agricultural farmlands near the dumpsites in Nekede mechanic village showed that there were higher counts of the various microorganisms both in the top and sub- soil samples when compared with soil samples from the control farm at Ihiagwa.

This may be attributed to the availability of nutrients in the dumpsites. Apart from the dumping of auto-mechanic waste, faeces and other domestic waste are also disposed of in such dumpsites, and these contain high level of nutrients that would support the proliferation of these microorganisms such as the members of the family *Enterobacteriacae*, faecal coliforms and some saprophytic fungi that feed on dead decaying organic materials.

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 whereas 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 microorganism.

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).

In the pawpaw samples, for contaminated sites the fruits had heavy metal accumulation in decreasing order as As>Al>Hg>Zn>Ni>Cu>Cd>Pb while the control site was, As>Al>Hg>Zn>Cd>Ni which is similar to the order in contaminated sites.

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

The accumulation order of the heavy metals for pawpaw leaf samples in contaminated sites was Cu>As>Al>Hg>Fe>Zn>Ni>Cd>Pb decreasingly while the control site had the order was Hg>Al>As>Ni>Zn>Pb>Cd.

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 same 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 automechanic 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 plot, the concentration of Cu in the soil was higher than those accumulated by the plant parts with pawpaw parts accumulating more than cassava parts.
Al ions correlated positively with Total Coliform Count ($r=0.095$) at $P<0.05$, and Pb correlated highly negatively with TCC at $P<0.01$ ($r = -0.962$). This means that the presence of Al seems to support the growth of the coliform microorganisms while Pb had inhibitory effects on the coliform organisms.

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.
This study indicated that the micro-organisms in the soil samples were in quantum indicating high proliferation due the presence of other nutrients in the dumpsites, and some of their ability to utilize the trace metals as nutrients.
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. Hence, strict adherence to proper disposal of auto-mechanic wastes should be followed, while farmers in such areas are advised to 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.

REFERENCES

Agency, for Toxic Substances and Disease Registry (ATSDR) (2005). US Department of Health and Human Services. Division of Toxicology and Environmental Medicine Arsenic.

Alloway B.J. (1990).Soil processes and the behaviour of metals. In: Heavy metals in soils, B.J Alloway. Blackie and Son Ltd Glasgow

Arias, M.E., Gonzalez-perez J.A., Gonzalez-Villa F.J. & Ball A.S. (2005).Soil: A new challenge for Microbiologists and chemists. *Microbio*., 8:13-21.

Barron, M.A. (1990). "Bioconcentration" will Water Born Organic Chemical Accumulate in Aquatic Animals? In: *Environmental Science and Technology*. 24(2): 1612-1618.

Beek, B. (2000). Bioaccumulation; New Aspects and Developments. In: Handbook of Environmental Chemistry, vol. 2 Reactions and Processes. New York: Springer – Veriag, 21-22.

Elaigwu, S.E., Ajibola, V.O. & Folaranmi, F.M. (2007). Studies on the impact of municipal waste dumps on surrounding soil and air quality of two cities in Northern Nigeria. *Journals of Applied Science*, 7:421-425.

Gupta A.K. & Sinha S. (2006).Chemical fractionation and heavy metal accumulation in the plant of *Sesamum indicum* (L.) Var T55 in soil amended with tannery Sludge; Selection of single extractants. *Chemosphere*, 64:161-173.

Idodo−Umeh, G. & Ogbeibu, A.E. (2010). Bioaccumulation of heavy metals in cassava tubers and plantain fruits grown in soil impacted with petroleum and non−petroleum activities. *Research Journal of Environmental Science*. 4:33−41.

Karaca A. (2004).Effect of organic wastes on the extractability of cadmium, copper, nickel and zinc in soil.*Geoderma*,122:297-303.

Lenntech W. (2009).Chemical properties, Health and Environmental effects of copper. Lennitech water treatment and purification Holding B.V. www.lenntech.com/periodic/elements/cu.htm

Resaee, A., Derayat, J., Mortazari, S.B., Yamini, Y. & Jafarzadeh, M.T. (2005). ″Removal of Mercury from chlor-alkali industry waste water using Acetobacter Xylium Cellulose″. *American Journal of Environmental Sciences*, 1(2):102-105.

Sautra, S.C. (2008). Metals in the Environment, In: Environmental Science, 2nd Ed. New Central Book Agency, Kolkaka. 450-465.

Singer M.J. & Munns D.N.(199).Soil: An introduction.4th_Edn Prentice –Hall ;Inc ;New Jersey, U.S.A 1-254

Uba, S., Uzairu, A., Harrison, G.F.S., Balarabe, M.L. & Okunola, O.J. (2008). Assessment of heavy metals bioavailability in dumpsites of Zaria Metropolis, Nigeria. *African Journal of Biotechnology*, 7:122-130.