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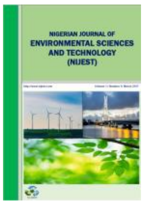

Determination of Heavy Metal Contamination in Soil and Accumulation in Cassava (*Manihot Esculenta*) in Automobile Waste Dumpsite at Ohiya Mechanic Village

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ABSTRACT

Human health challenges resulting from consumption of food contaminated by heavy metals necessitated the investigation of soil and cassava plants around automobile waste dumpsite at Ohiya mechanic village, Abia State, Nigeria. Soil and cassava samples collected randomly at the site were analyzed for cadmium (Cd), copper (Cu), lead (Pb) and chromium (Cr). The values of highest concentration of Cu and Pb in soil was recorded in 0-10 cm, Cr was obtained in 21-30 cm while Cd was in 11-20 cm soil depth. The concentration of Cd (0.11±0.00 to 0.26±0.00 mg/kg) in soil exceed maximum permitted level of 0.1 mg/kg (Cd) by FAO/WHO. The concentration of Pb (0.01±0.001 to 3.24±0.00 mg/kg) and Cd (0.07±0.00 to 2.08±0.00 mg/kg) in cassava plants exceed the permissible limit of 0.3 mg/kg (Pb) and 0.2 mg/kg (Cd) set by FAO/WHO. The Pearson correlation analysis show very strong positive relationship between Cu and Cu (r=0.996) and Pb and Pb (r=0.986) while strong negative relationship exist between Cr and Cr (r= -0.686) and Cd and Cd (r= -0.981) in soil and plant. Based on our findings, the concentrations of Cd in soil vis-à-vis Pb and Cd in plants which exceed maximum permitted level set by Codex Alimentarius Commission FAO/WHO will expose man and animals that relied on soil and cassava plants for food to serious health risks. Consequently, Abia State government should prevent farmers' access to the site by fencing round the automobile waste dumpsite.

Keywords: Automobile waste, dumpsite, heavy metals, soil, cassava plants, Ohiya

1.0. Introduction

The environment is continuously being contaminated by various human activities such as industrial production, agricultural processes, mineral exploitation, food processing, commercial, social, and domestic activities that generate contaminants like heavy metals (Ogbonna *et al*., 2018a). Continual loading of pollutants into the environment is of great concern to man since contaminants such as heavy metals persist in the environment due to its chemical structure (Ali *et al*., 2013; Hashem *et al*., 2017). Such contaminants include lead, cadmium, mercury and dioxin that never go away or degrade for long time. Over a long period of time, a large fraction of these contaminants may become buried in soil and even small residual amounts of these contaminants are a concern (Sakan and Dordevic, 2010).

Human health challenges in recent times have been attributed to consumption of food contaminated with heavy metals. Food contamination by human activities (Ogbonna *et al*., 2012; Ogbonna *et al*., 2013) is becoming very alarming due to quest to cope with high rate of food insecurity as well as other myriad of human needs in Nigeria. Cassava (*Manihot esculenta* Crantz) is considered the most essential staple root crop in the world and ranked as one of the most vital food crops grown in the tropics (Droppelmann *et al*., 2018; Olutosin and Barbara, 2019; Lawal *et al*., 2019). Besides playing a crucial role in food security, it is the cheapest source of industrial starch the world over (Zainuddin *et al*., 2019; Oyeyinka *et al*., 2019), alternative feedstock in many industrial applications like industrial baking flour, drug manufacturing, ethanol production among others due to its availability and low comparative cost (Anyanwu *et al*., 2015; Lawal *et al*., 2019). As a result of land hunger especially in the South east Nigeria, farmers are constrained to farming on lands adjoined to sources of pollution without considering the health implications of consuming crops grown on such lands (Ogbonna *et al*., 2018b). One of such adjoining sources of pollution is the mechanic village where automobile waste of various shapes, sizes and volumes are generated over a period of time (e.g. four years and above) and dumped at nearby lands. The corrosion of scrap metals as well as wear and tear due to rain (i.e. moisture) may release heavy metals into the soil. Plants growing on metal contaminated soil tend to absorb metals from soil solution via the roots and translocate it to the stems and the leaves (Ogbonna *et al*., 2018b). The use of plant parts is an effective indicator to monitor atmospheric pollution (Goodman and Robert 1971; Onder and Dursun 2006) but the distribution of heavy metals between soil and plants is a key issue in assessing the impact of anthropogenic activities, such as mechanic village on the ecosystem.

Quite a number of research on mechanic village or artisanal activities have been carried out in terms of heavy metal contamination in soil in Cape Coast metropolis, Ghana (Nyarko *et al*., 2019) Shashemane City, Ethiopia (Demie, 2015), Akure, Ondo State (Oguntimehin and Ipinmoroti, 2008), Imo river basin, Imo State (Nwachukwu *et al*., 2010), Gboko and Makurdi, Benue State (Pam *et al*., 2013; Luter *et al*., 2011), Anyigba, Kogi State (Ogunkolu *et al*., 2019), Abakaliki, Ebonyi State (Wilberforce, 2016), Port Harcourt, River State (Iwegbue *et al*., 2007), Okitipupa, Ondo State (Adebayo *et al*., 2017), Oghara, Delta State (Anegbe *et al*., 2018), Benin City, Edo State (Idugboe *et al*., 2014), soil and underground water (Owoso *et al*., 2017), soil and maize (*Zea mays*) Gwagwalada, Abuja (Okpanachi *et al*., 2016), pawpaw (*Carica papaya* Linn.) Port Harcourt metropolis, Rivers State (Eludoyin and Ogbe, 2017) in Nigeria. Despite the research, literature search show that no such work on heavy metal contamination of important root crop and staple food such as cassava has been carried out at any mechanic village site the world over. The objective of this study, therefore, is to investigate the level of concentrations of heavy metals in soil and their accumulation in cassava grown around automobile waste dumpsite at Ohiya mechanic village and compare the values with the maximum permissible limits of FAO/WHO, Dutch criteria for soil, the accepted limits of Federal Environmental Protection Agency (FEPA) and National Environmental Standards and Regulations Enforcement Agency (NESREA) of Nigeria. The results of this research will provide the background information on the levels of concentrations of heavy metals in the soil and plants and serve as an important document for proper dissemination of information to farmers by the Agricultural Development Programme (ADP), Abia State, thus, enhancing farmers knowledge on the possible health risk associated with farming on land in proximity with the mechanic village.

2.0. Materials and Methods

2.1. Study area

This study was carried out at the automobile waste dumpsite at Ohiya mechanic village in Umuahia South, Abia State, Nigeria. The Ohiya mechanic village was commissioned by the Abia State government on 6th Novermber, 2014. Umuahia is the capital city of Abia State in Southeastern Nigeria and it has an area of 140 km² and a population of 138,570 at the 2006 census (NPC, 2006). Ohiya is within the lowland rainforest zone of Nigeria (Keay, 1959; Ogbonna *et al*., 2018c) which lies on latitude 05°28'N and longitude 07°26'E. The area has a mean annual rainfall of 2133 mm distributed over eight months of rainy season period (March to October) with bimodal peak in July and September. The soil is ultisol while the minimum and maximum temperature is 21°C and 30°C respectively, with relative humidity of 60-70%. The main food crops grown by farmers include cassava, maize, yam, vegetables as fluted pumpkin, bitter leaf, okra; cash crops such as oil palm fruits, groundnuts among others.

2.2. Collection of samples and analysis

Soil samples were collected with Dutch soil auger from nine (9) different sampling points (A_1, A_2, A_3; B_1, B_2, B_3, C_1, C_2, and C_3) at 0 - 10, 11 - 20, 21 - 30, 31 - 40 and 41 - 50 cm soil depth in three sampling positions (i.e. three sampling points each at entry point (A_1, A_2 and A_3), middle point (B_1, B_2 and B_3), and exit point (C_1, C_2 and C_3)) of the 64 m x 87 m dump site. The control sample was collected in an upland two (2) years bush fallow "at Uzo-Okpulo" which is about 1.5 km from the automobile waste dumpsite where there was no visible source of contamination. Samples from each particular soil depth (e.g., 0-10 cm at entry point, middle point and exit point) were bulked together to form a composite sample and were placed in cellophane bags (about 35 g) well labelled, placed in a wooden box and covered to avoid contamination from external sources. The samples in the wooden box were transferred to the laboratory for pre-treatment and analysis. Each bulked soil sample was freed from foreign objects (roots, pebbles, etc.) and air-dried to a constant weight in an oven of 30^0C with a circulating air. The samples were subjected to crushing, grinding and then homogenized using a porcelain pestle and mortar. The homogenized soil samples were sieved through a 2.0 mm sieve pore, giving rise to the actual workable samples, which were then placed in their labelled cellophane bags respectively and stored at room temperature for the next level of the analytical process (Garcia *et al.*, 2004). Two (2 g) of the dried samples each was weighed out into a digestion flask and added 20 ml of the acid mixture (650 ml conc HNO_3; 80 ml perchloric acid; 20 ml conc. H_2SO_4), then allowed for about 20 min. The digestion flask containing the weighed out soil sample was heated until a clear digest is obtained. The clear digest was allowed to cool for 10 min, filtered into 50 ml standard flask with Whatman No. 41 filter paper, and then diluted with deionized water to the 100 ml mark (Adrian, 1973) and analysed for Pb, Cd, Cr, and Cu. In order to check for background contamination by the reagents, blanks were prepared from only reagents without sample. Triplicate digestion of each sample was carried out. The digested samples were then subjected to analysis of heavy metals (Pb, Cd, Cr, and Cu) using the Atomic Absorption Spectrophotometer (Model: Perkin Elmer, USA).

Cassava samples for determination of heavy metals content was collected from fifteen (15) months old Cassava plant grown about 1 m away from the dumpsite. Control cassava samples were collected from a farmland about 1.5 km away from the experimental farmland where there was no visible source of contamination. Samples of cassava were collected randomly in the month of September from the 54 m x 72 m farmland, using well cleaned secateurs at various sampling points, three (3) points at each sampling positions (entry point (within 5 m from the dumpsite, middle point (25 m away from the dumpsite) and exit point (50 m away from the dumpsite)) in the farmland. Samples were bulked together and separated into roots, stems and leaves, well labelled and transferred to the laboratory for pre-treatment and analysis.

Samples were cleaned with deionized water to remove dust and debris after which they were oven-dried at 60^oC for 72 hr. The roots, stems and leaves of the cassava plant samples were milled separately with Thomas Wiley milling machine to fine powder. The oven-dried, ground and sieved samples were accurately weighed and digested in a 1:1 mixture of concentrated nitric acid and perchloric acid (Oyelola *et al.*, 2009). A 5 ml of the mixture of concentrated nitric acid (HNO_3) and per chloric acid (HCL_4) was added to 2 g of each sample and heated on a hot plate at 105^oC for an hour to dryness, allowed to cool for 10 mins, and then transferred to a volumetric flask. Exactly 1 M HNO_3 was added to make up the solution to the mark of 50 ml volumetric flask. The solution was centrifuged for 45 min and transferred to sampling bottles for analysis. In order to check for background contamination by the reagents, blanks were prepared from only reagents without sample. Triplicate digestion of each sample was carried out. The digested samples were then subjected to analysis of heavy metals (Pb, Cd, Cr, and Cu) using the Atomic Absorption Spectrophotometer (Model: Perkin Elmer, USA).

Figure 1: Map of Nigeria showing Abia State (Source: GIS Lab., Department of Geography, University of Nigeria, Nsukka (2018))

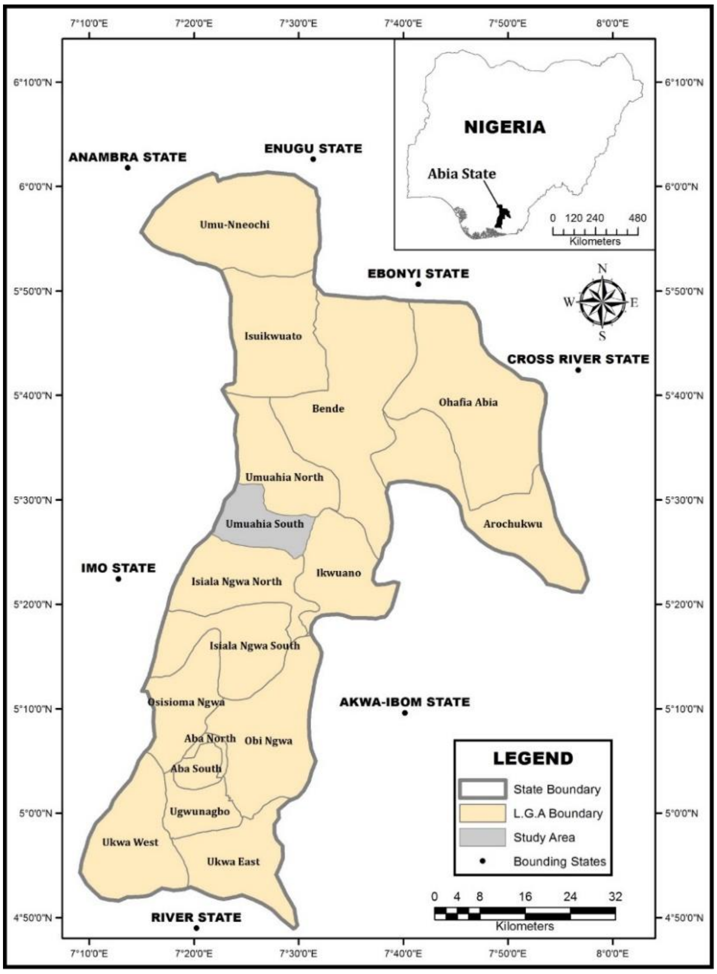

Figure 2: Abia State showing Umuahia South (Source: GIS Lab., Department of Geography, University of Nigeria, Nsukka (2018))

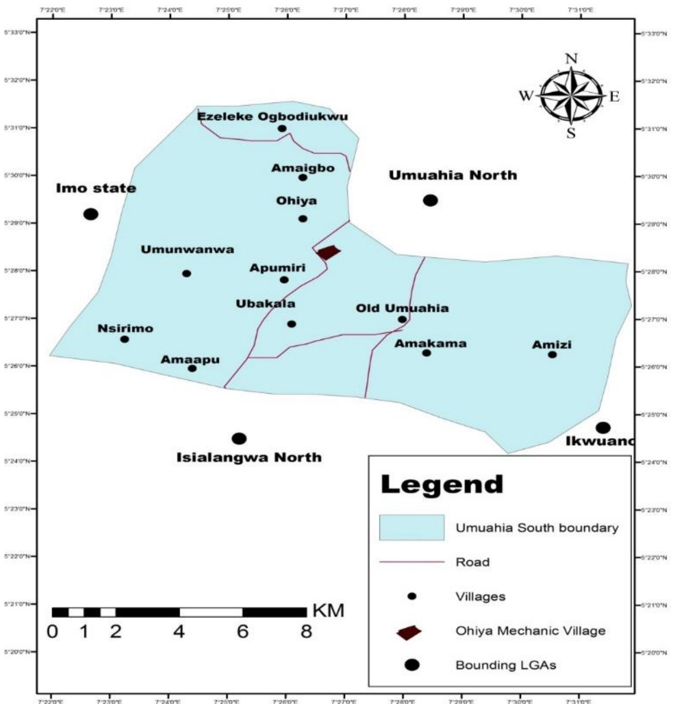

Figure 3: Map of Umuahia South LGA showing Umuahia mechanic village (Source: GIS Lab., Department of Geography, University of Nigeria, Nsukka (2018))

2.3. Analysis of heavy metals

Digested soil and plant samples was conducted using Agilent FS240AA Atomic Absorption Spectrophotometer according to the method of American Public Health Association, APHA (1995). Atomic absorption spectrophotometer's working principle is based on the sample being aspirated into the flame and atomized when the AAS's light beam 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. Some metals have their own characteristic absorption wavelength, a source lamp composed of that element is used, making the method relatively free from spectral or radiational interferences. The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample. The instrument settings and operational conditions were in accordance with the manufacturer's specifications. The instrument was calibrated with analytical grade standard metal solutions.

2.4. Statistical analysis and experimental design

A simple factorial experiment was conducted in a randomized complete block design with five replications in soil depth. Data generated from the experiment were subjected to one way analysis of variance (ANOVA) using special package for social sciences (SPSS) v. 16 and means were separated (Steel and Torrie, 1980) at $P<0.05$ using Duncan Multiple Range Test (DMRT) while Correlation analysis was used to determine the relationship between the means of the parameters analysed in soil and cassava plant.

The comparison and interpretation of the results of different parts of *Manihot esculenta* (cassava) analyzed in this study is based on the control values, the values of concentration of heavy metals in plants in similar studies, standards set by international agency such as Codex Alimentarius Commission as well as national agencies such as Federal Environmental Protection Agency (FEPA) and National Environmental Standards and Regulations Enforcement Agency (NESREA) of Nigeria.

3.0. Results and Discussion

3.1. Concentration of heavy metals in soil

The values of the concentration of heavy metals in the different soil depths in automobile waste dumpsite at Ohiya mechanic village are summarized in Table 1. Heavy metal concentration in soil in this study were raised to different levels and the significant differences was evidenced amongst the different soil depths at study site. The various anthropogenic activities such as panel beating, servicing of car engines and changing of electrical component of vehicles among other resulted to generation of heavy metal contaminated materials that are discarded at the dumpsite. The results indicate that the highest and lowest heavy metal concentrations in soil were obtained at the scrap metal dumpsite and control site, respectively for Cd, Pb, Cu and Cr. Some pollution surveys showed that soil within or around source of pollutants had high concentrations of heavy metals (Davila *et al*., 2006; Nwachukwu *et al*., 2010; Ogbonna *et al*., 2013; Ogbonna *et al*., 2018a). Since there were no other sources of contamination in the area, the high concentrations of heavy metals in soil of the automobile waste dumpsite (unlike the control) may be attributed to leaching of the heavy metals (Cd, Pb, Cu and Cr) from the large volume of waste from Ohiya mechanic village waste dumpsite.

The concentration of heavy metals was observed to peak within 21-30 cm depth for Cr while Cd had its concentration within 11-20 and 21-30 cm depths unlike Cu and Pb that had their highest concentrations in 0-10 cm depth. The pattern of leaching or migration of heavy metals in the soil suggest that Cr and Cd were relatively more mobile than Pb and Cu at the study site. Cadmium is known to be highly mobile in soil (Ogbonna and Okeke, 2011) and its mobility at the automobile waste dumpsite peaked within 11-20 and 21-30 cm depths. The high concentrations of Pb and Cu in 0-10 cm depth may be attributed to presence of organic matter since heavy metals are bound to topsoil by organic matter (Sukkariyah *et* *al*., 2005) hence reducing the leaching of heavy metals into the lower depths (Ogbonna *et al*., 2018b). Organic matter waste residue from effluent oil and oil spills adds organic matter and carbon to the soil (Anegbe *et al*., 2018).

The highest concentration of Cd (0.26±0.00 mg/kg) was jointly recorded in 11-20 and 21-30 cm depths, and the value is significantly (P<0.05) higher than values observed for Cd in 0-10 cm (0.3±0.00 mg/kg), 31-40 cm (0.20±0.00 mg/kg), 41-50 cm (0.11±0.00 mg/kg) and control (0.16±0.03, 0.15±0.01, 0.05±0.00, 0.02±0.00 and 0.00±0.00 mg/kg, respectively for 0-10, 11-20, 21-30, 31-40 and 41-50 cm). The heavy metals from the scrap metal at the dumpsite may have provided a source for continued dispersion and have resulted to various degree of contamination of Cd in the soil depths. For instance, Ogbonna and Okezie (2011) in their study of roadside soils reported that Cd is released from the wearing of paints on the metal parts of vehicles. The values of the concentration of Cd in automobile waste dumpsite soils of Ohiya mechanic village was 0.11±0.00 to 0.26±0.00 mg/kg, which is well below 31.5 to 47.5 mg/kg (Nwachukwu et al., 2010), 26.0 to 48.0 mg/kg (Iwegbue *et al*., 2007), 19.86 to 21.421 mg/kg (Idugboe *et al*., 2014) and 0.87 to 2.55 mg/kg (Anegbe *et al*., 2018) but higher than 0.01 to 0.12 mg/kg (Adebayo *et al*., 2017) in their studies of heavy metals in soils. The low concentration of Cd in soils of Ohiya mechanic village may be attributed to short period of time of its existence (i.e. 015 till date) as well as the type and volume of waste at the automobile dumpsite. Nwachukwu *et al*. (2010) opined that the type of automobile waste at dumpsite, volume of waste and length of time the dump has been in use influence the release of metals. The concentration of Cd (0.26±0.00 mg/kg) in 11-20 and 21-30 cm depth was found to be 1.13, 1.30, 2.36 times higher than its values in 0-10, 31-40 and 41-50 cm at the dumpsite and 1.63, 1.73, 5.2, 13 and 26 times higher than 0-10, 11-20, 21-30, 31-40 and 41-50 cm at the control site, respectively.

The highest concentration of Pb (2.57±0.00 mg/kg) and Cu (1.28±0.00 mg/kg) were recorded in 0-10 cm depth and the values are significantly (P<0.05) higher than their corresponding values in 11-20 cm (1.34±0.00 and 0.50±0.00 mg/kg), 21-30 cm (1.92±0.00 and 0.57±0.00 mg/kg), 31-40 cm (0.93±0.00 and 0.27±0.00 mg/kg), 41-50 cm (0.93±0.00 and 0.41±0.00 mg/kg) and control (1.36±0.01 and 1.03±0.01, 0.59±0.00 and 0.01±0.00, 0.79±0.00 and 0.32±0.02, 0.31±0.01 and 0.03±0.00, 0.23±0.02, and 0.01±0.00 mg/kg, respectively for Pb and Cu in 0-10, 11-20, 21-30, 31-40 and 41-50 cm depths). The concentration of Pb in soil may be attributed to lead-acid batteries, adhesion of lead halides from petroleum motor spirit (PMS) and spent lubricating oil used for cleaning engines and other vehicular parts during servicing and are discarded at the automobile dumpsite. Lead (Pb) is part of the composition of lubricating oil and galvanized parts of vehicles (Falahi-Ardakani, 1984; Zechmeister *et al*., 2005). It (Pb) is also released from babbit metal bushings (Oguntimehin and Ipinmoroti, 2008) that are discarded at automobile waste dumpsite in Ohiya mechanic village. The concentration of Pb in 0-10 cm depth (2.57±0.00 mg/kg) was found to be 1.92, 1.34, 2.76 times higher than its corresponding values in 11-20, 21-30, 31-40, 41-50 cm depth at the study site and 1.89, 4.36, 3.25, 8.29 and 11.7 times higher than its values in 0-10, 11-20, 21-30, 31-40 and 41-50 cm depths at the control site, respectively. The concentration of Pb in soils of the automobile dumpsite at Ohiya mechanic village was 0.93±0.00 to 2.57±0.00 mg/kg, which is higher than 0.01 to 0.80 mg/kg (Adebayo *et al*., 2017) but well below 283.7±127 to 665±912 mg/kg (Pam et al., 2013), 0.055±0.008 to 21,200±90 mg/kg (Owoso *et al*., 2017), 18.25 to 15,100 mg/kg (Adelekan and Abegunde, 2011), 268.12±46.8 to 664.62±52 mg/kg (Wilberforce *et al*., 2016) and 1.66 to 172.76 mg/kg (Luter *et al*., 2011).

The high concentration of Cu in soil at the dumpsite (unlike the control plot) may be attributed to presence of car brake and metal bearing at the automobile waste dumpsite. Copper is included in car brake (Falahi-Ardakani, 1984) and metal bearing (Oguntimehin and Ipinmoroti, 2008) which are gradually released and leached into the soil at the Ohiya mechanic village dumpsite. Copper in soil may also be attributed to automobile wastes containing electrical and electronic parts like copper wires and pipes, electrodes and alloys from corroding vehicle scraps (Pam *et al*., 2013) that are leached into the soil (Nwachukwu *et al*., 2011; Adebayo *et al*., 2017). The concentration of Cu in soils of Ohiya mechanic village was 0.41±0.00 to 1.28±0.00 mg/kg, which is well below 375 to 1,281 mg/kg (Nwachukwu *et al*., 2010), 28.26 to 44.35 mg/kg (Anegbe *et al*., 2018), 16.270 to 22.83 mg/kg (Idugboe *et al*., 2014) and 210 to 630.1 mg/kg (Adebayo *et al*., 2017) in their studies of heavy metals in soils of mechanic villages. The concentration of Cu in 0-10 cm (1.28±0.00 mg/kg) was found to be 2.56, 2.25, 4.74 and 3.12 times higher than its corresponding values in 11-20, 21-30, 31-40 and 41-50 cm depth at the study site and 1.24, 128, 4, 42.67 and 128 times higher than its values in 0-10, 11-20, 21-30, 31-40 and 41-50 cm depth at the control site, respectively.

Table 1: Heavy metals concentration (mg/kg) in soil

Soil depths (cm)	Cr	Cu	Pb	Cd
0 – 10	$0.01^{e} \pm 0.00$	$1.28^{a} \pm 0.00$	$2.57^{a} \pm 0.00$	$0.23^{b} \pm 0.00$
11 – 20	$0.05^{c} \pm 0.00$	$0.50^{d} \pm 0.00$	$1.34^{c} \pm 0.00$	$0.26^{a} \pm 0.00$
21 – 30	$0.13^{a} \pm 0.00$	$0.57^{c} \pm 0.00$	$1.92^{b} \pm 0.00$	$0.26^{a} \pm 0.00$
31 – 40	$0.04^{cd} \pm 0.00$	$0.27^{g} \pm 0.00$	$0.93^{d} \pm 0.00$	$0.20^{c} \pm 0.00$
41 – 50	$0.08^{b} \pm 0.00$	$0.41^{e} \pm 0.00$	$0.93^{d} \pm 0.00$	$0.11^{f} \pm 0.00$
C. 0 – 10	$0.00^{f} \pm 0.00$	$1.03^{b} \pm 0.01$	$1.36^{c} \pm 0.01$	$0.16^{d} \pm 0.03$
C. 11 – 20	$0.03^{d} \pm 0.01$	$0.01^{i} \pm 0.00$	$0.59^{f} \pm 0.00$	$0.15^{e} \pm 0.01$
C. 21 – 30	$0.11^{ab} \pm 0.02$	$0.32^{f} \pm 0.02$	$0.79^{e} \pm 0.00$	$0.05^{g} \pm 0.00$
C. 31 – 40	$0.01^{e} \pm 0.00$	$0.03^{h} \pm 0.00$	$0.31^{g} \pm 0.01$	$0.02^{h} \pm 0.00$
C. 41 – 50	$0.03^{d} \pm 0.00$	$0.01^{i} \pm 0.00$	$0.23^{h} \pm 0.02$	$0.00^{i} \pm 0.00$

Note: Values are mean ± standard deviation of 3 replicates; ^{a,b,c,d,e,f,g,h,i} means in the same column with different superscripts are significantly different (P<0.05) and C = mean of the Control plot

Table 2: Comparison with international and national standards

Source	Cr	Cu	Pb	Cd
This study	0.01 – 0.13	0.41 – 1.28	0.93 – 2.57	0.11 – 0.06
Dutch criteria (target value), mg/kg	100	36	85	0.8
FAO/WHO 2001, 2006, 2007	100	100	50	0.1
FEPA 1999	NA	70-80	1.6	0.01
NESREA 2011 standard, mg/kg	100	100	NA	3
*UK	400	135	300	3
*Netherlands	30	40	40	0.5
*France	150	100	100	2
*Sweden	60	40	40	0.4

**Source: ECDGE (2010); NA = Not available*

The highest concentration of Cr (0.13±0.00 mg/kg) was recorded for 21-30 cm depth and the value is significantly (P<0.05) higher than values recorded for Cr in 0-10 cm (0.01±0.00 mg/kg), 11-20 cm (0.05±0.00 mg/kg), 31-40 cm (0.04±0.00 mg/kg), 41-50 cm (0.08±0.00 mg/kg) and control (0.00±0.00, 0.03±0.01, 0.11±0.02, 0.01±0.00 and 0.03±0.00 mg/kg, respectively for Cr in 0-10, 11-0, 21-30, 31-40 and 41-50 cm depths). The concentration of Cr in 21-30 cm depth (0.13±0.00 mg/kg) was found to be 13, 2.6, 3.25 and 1.63 times higher than its corresponding values in 0-10, 11-20, 31-40 and 41-50 cm depths at the automobile waste dumpsite and 13, 4.33, 1.18, 13 and 13 times higher than its values in 0-10, 11-20, 21-30, 31-40 and 41-50 cm depth at the control site, respectively. The concentration of Cr in soils of the automobile waste dump at Ohiya mechanic village was 0.01±0.00 to 0.13±0.00 mg/kg, which is well below 3.313 to 9.92 mg/kg (Idugboe *et al*., 2014), 1.14±0.12 to 6.18±0.18 mg/kg (Wilberforce *et al*., 2016), 40.98 to 57.28 mg/kg (Luter *et al*., 2016), 0.219±0.003 to 4,850±17 mg/kg (Owoso *et al*., 2017), 2.00 to 29.75 mg/kg (Adelekan and Abegunde, 2011), 6.98 to 21.10 mg/kg (Iwegbue *et al*., 2007), 16.8 to 38 mg/kg (Nwachukwu *et al*., 2010) and 0.01 to 0.42 mg/kg (Adebayo *et al*., 2017). In this study, it was observed that the highest value of Cr at the control site was obtained in 21-30 cm depth (0.11±0.02 mg/kg), which is similar to the highest value (0.13±0.00 mg/kg) obtained in soils at the automobile waste dumpsite. This indicate that the level of Cr in soil may be attributed to natural processes rather than anthropogenic activities at the mechanic village.

The concentration of Pb, Cu, and Cr in automobile waste dumpsite soils of Ohiya mechanic village in Umuahia south, Abia State, Nigeria were 0.93±0.00 to 2.57±0.00, 0.41±0.00 to 1.28±0.00 and 0.01±0.00 to 0.13±0.00 mg/kg, respectively, which are well below the accepted limits (i.e. target value) and maximum permitted levels of 85 and 50 mg/kg (Pb), 36 and 100 mg/kg (Cu) as well as 100 and 100 mg/kg (Cr) as described by Dutch criteria (Ogbonna *et al.*, 2018b) and established by the Codex Alimentarius Commission (FAO/WHO, 2001) (Table 2), respectively. Similarly, the concentrations of Cu (0.41±0.00 to 1.28±0.00 mg/kg) and Cr (0.01±0.00 to 0.13±0.00 mg/kg) in this study are well below the accepted limits of 100 and 100 mg/kg as described by National Environmental Standards and Regulations Enforcement Agency (NESREA, 2001) of Nigeria for Cu and Cr, respectively. However, the concentration of Cd (0.11±0.00 to 0.26±0.00 mg/kg) in soil at the automobile waste dumpsite is above the maximum permitted level of 0.1 mg/kg (Cd) established by the Codex Alimentarius Commission (FAO/WHO, 2001) and 0.01 mg/kg (Cd) set by the Federal Environmental Protection Agency (FEPA, 1991) of Nigeria. The level of Cd in soils at the automobile waste dumpsite can pose a serious health risk to living organisms. For instance, earthworms are important bait in fishing as well as food material for fish production in south eastern Nigeria (Ogbonna *et al*., 2013; Ogbonna *et al*., 2019), prey to many amphibian, reptile, bird, and mammalian species (OECD, 2004). Hence, heavy metal pollution of earthworm at the study site can trigger death of animals living within and around the vicinity of the automobile waste dumpsite of Ohiya mechanic village, *inter alia,* decimation of fauna species along the food chain. It can also lead to decline in ecological processes taken place at the site since earthworm plays vital role in organic matter decomposition. The order of abundance of the four (4) heavy metals tested in this study that may be causing soil pollution within and around the automobile waste dumpsite at Ohiya mechanic village are as follows: Pb>Cu>Cd>Cr.

3.2. Concentration of heavy metals in cassava plants

The concentration of four (4) heavy metals in different parts of *Manihot esculenta* sampled from the automobile waste dumpsite and control site of Ohiya mechanic village, Umuahia south are summarized in Table 3. The results indicate that heavy metal concentrations differed significantly ($P<0.05$) among the different parts of *Manihot esculenta* tested in this study and that the highest and the lowest heavy metal concentrations in cassava plants were recorded for the automobile waste dumpsite and control site, respectively. The highest values of Cr (0.051±0.002 mg/kg), Cu (4.01±0.00 mg/kg), Pb (2.08±0.00 mg/kg) and Cd (3.24±0.00 mg/kg) recorded in cassava root sampled at the automobile waste dumpsite were significantly ($P<0.05$) higher than the highest corresponding values of Cr (0.011±0.002 mg/kg in stem), Cu (1.01±0.002 mg/kg in root), Pb (1.12±0.002 mg/kg in root) and Cd (1.00±0.002 mg/kg) in root) at the control site. The highest values of Cr, Cu, Pb and Cd in *M. esculenta* collected from the automobile waste dumpsite exceeded their corresponding values at the control site by 4.64, 3.97, 1.86 and 3.24 times, respectively. The result corroborates with the findings of Okpanachi *et al*. (2016) and Eludoyin and Ogbe (2017) who reported that the concentration of heavy metals in plants at mechanic workshops and village is higher than the concentration in plants at the control sites.

The concentration of Pb was 0.07±0.000 (stem) to 2.08±0.00 mg/kg (root), which is well below 5.48± to 33.28 mg/kg in maize plant (Okpanachi *et al*., 2016) and 18.40 to 80.30 mg/kg in pawpaw plant (Eludoyin and Ogbe, 2017) at mechanic workshop and village, respectively. The concentration of Cd was 0.01±0.001 (stem) to 3.24±0.00 mg/kg (root) and this is well below 1.75 to 10.56 mg/kg in maize plant (Okpanachi *et al*., 2016) and 2.3 to 18.0 mg/kg in pawpaw plant (Eludoyin and Ogbe, 2016). Similarly, the values of the concentration of Cu was 0.01±0.000 (leaf) to 4.01±0.00 mg/kg (root), which is well below 25.38 to 79.42 mg/kg in maize (Okpanachi *et al*., 2016) and 15.6 to 88.0 mg/kg in pawpaw (Eludoyin and Ogbe, 2017) while the values of the concentration of Cr was 0.001±0.000 (root) to 0.051±0.002 mg/kg (root). The low values of the concentration of Pb, Cd, Cu and Cr in this study may be attributed to the short length of time the automobile waste dumpsite at Ohiya mechanic village has been in use.

Table 3: Means and Standard deviation of heavy metals content (mg/kg) in *Manihot esculenta*

Plant parts	Cr	Cu	Pb	Cd
Root	$0.051^a \pm 0.002$	$4.01^a \pm 0.00$	$2.08^a \pm 0.00$	$3.24^a \pm 0.00$
Stem	$0.018^b \pm 0.001$	$0.17^c \pm 0.00$	$0.82^d \pm 0.00$	$0.21^c \pm 0.00$
Leaf	$0.020^b \pm 0.001$	$0.10^d \pm 0.00$	$1.23^b \pm 0.00$	$0.20^c \pm 0.00$
C. Root	$0.001^e \pm 0.000$	$1.01^b \pm 0.002$	$1.12^c \pm 0.002$	$1.001^b \pm 0.002$
C. Stem	$0.011^c \pm 0.002$	$0.03^e \pm 0.000$	$0.07^e \pm 0.000$	$0.01^f \pm 0.001$
C. Leaf	$0.002^d \pm 0.001$	$0.01^f \pm 0.000$	$072^e \pm 0.001$	$0.02^e \pm 0.001$

Values are mean ± standard deviation of 3 replicates; [a,b,c,d,e,f,g,h,i] Means in the same column with different superscripts are significantly different (P<0.05) and C = mean of the Control plot

Table 4: Comparison with international and national standards

Source	Cr	Cu	Pb	Cd
This study	0.001 – 0.051±0.002	0.01 – 4.01	0.07 – 2.08	0.01±0.001 – 3.24
Similar studies (Eludoyin & Ogbe (2017))	NA	15.60 – 88.0	18.40 – 80.30	2.30 – 18.0
Similar studies (Okpanachi *et al.* (2016))	NA	25.38 – 79.42	5.48 – 33.28	1.75 – 10.56
FAO/WHO 2001, 2006, 2007	2.3	40	0.3	0.2
FEPA 1999	NA	NA	NA	NA
NESREA 2011	NA	NA	NA	NA

NA = Not available

In comparing the concentration of heavy metals in soil with the values of the concentration in cassava plants, the results indicate that the concentration of Pb (2.57±0.00 mg/kg) and Cr (0.13±0.00) were higher in soil than in cassava plants for Pb (2.08±0.00 mg/kg) and Cd (0.051±0.002 mg/kg). The concentration of Pb and Cr in soil were 1.24 and 2.55 times higher than their corresponding values in cassava plants, respectively. In contrast, the values of the concentration of Cu (4.01±0.00 mg/kg) and Cd (3.24±0.00 mg/kg) in cassava roots were higher than their values in soil (1.28±0.00 mg/kg and 0.26±0.00 mg/kg). The concentrations of Cu and Cd in cassava roots were 3.13 and 12.46 times higher than their corresponding values in soils of the automobile waste dumpsite at Ohiya mechanic village. The soil is implicated for the concentrations of Pb and Cr in cassava plants while inherent ability of cassava roots to absorb and store Cd and Cu over time may be responsible for the higher concentration of Cd and Cu in cassava plants. The shallow root system of cassava plants might have facilitated the absorption of the heavy metals (Cu and Cd) in soil solution and accumulation in cassava roots since Cu and Cd recorded the highest values of their concentrations in soil within 0-10 and 21-30 cm depths, respectively. The rate of movement of heavy metal in plant tissues varies depending on plant organ, age and element involved (Kabata-Pemdias, 2000). The concentration of Cd increased from 0.01±0.001 in cassava stem to 3.24±0.00 mg/kg in cassava root, which is well above the permissible limit (PL) of 0.2 mg/kg set by Codex Alimentarius Commission (FAO/WHO, 2007) (Table 4) for vegetables and root crops. The values of the concentration of Pb increased from 0.07±0.000 in cassava stem to 2.08±0.00 mg/kg in cassava root and the level is well above the permissible limit (PL) of 0.3 mg/kg set by Codex Alimentarius Commission (FAO/WHO, 2001). The utilization of cassava roots at the automobile waste dumpsite for man and animal consumption could be a route of entry of Cd and Pb in man as well as livestock that will be fed with the peels from such metal contaminated cassava roots. For instance, serious systemic adverse health consequences develop from excessive dietary accumulation of toxic metals in humans (Oliver 1997; Li *et al*., 2009). The prevalence of upper gastrointestinal cancer in the

Van region of Turkey has been linked to metal pollution in soil, fruits and vegetables (Turkdogan *et al*., 2003). Soil and vegetables polluted with Pb and Cd in Romania significantly decreased human life expectancy by reducing the average age at death by 9–10 years (Carafa *et al*., 2009) while in the city of Kabwe, Zambia, mining and smelting operations led to widespread Pb and Cd contamination of soil (Fulekar and Jadia, 2009) and children living in the vicinity of a former smelter had high blood Pb levels in France (Pruvot *et al*., 2006) and Brazil (Bosso and Enzweiler, 2008). Lead and Cd are potential carcinogens and are associated with adverse effects on blood, kidneys, bone, as well as cardiovascular, and nervous system (Jarup, 2003).

Similarly, the dependent of wild animals such as *Thryonomis swinderianus* (grasscutter), *Cricetomys gambianus* (African giant pouched rat), *Francolinus squamatus* (Scaly francolin) among others on such contaminated cassava roots in farm at Ohiya mechanic village may lead to bio-magnification of Cd and Pb in the food chain with the concomitant effect of possible ecological imbalance in the natural environment. Copper increased from 0.01±0.000 in cassava leaf to 4.01±0.00 mg/kg in root. The level of Cu in cassava plants is well below the permissible limit (PL) of 40 mg/kg (FAO/WHO, 2006) for vegetables and root crops. Chromium increased from 0.001±0.000 in root to 0.051±0.002 in cassava root but the level of Cr in cassava plants is well below the permissible limit (PL) of 2.3 mg/kg (FAO/WHO, 2006). The order of abundance of the four heavy metals tested in various parts of cassava plant in this study is as follows: Cu>Cd>Pb>Cr.

3.3. Pearson correlation analysis between heavy metals in soil and plants

The result of the Pearson correlation analysis of heavy metals in soil and plants is summarized in Table 5. The result show very strong positive relationship as well as strong negative relationship between heavy metals in soil and plants. For instance, very strong positive relationship exist between Cu in soil and Cu in plants (r=0.996, p<0.05) and Pb in soil and Pb in plants (r=0.986, p<0.05) which suggest that increase in Cu and Pb in soil might have resulted to their (Cu and Pb) increase in cassava plants. Strong negative relationship exist between Cr in soil and Cr in plants (r= -0.686, p<0.05) and Cd in soil and Cd in plants (r= -0.981, p<0.01). However, there were strong positive relationship between Cu in soil with Cr in plants (r=0.997, p<0.01), Cu in soil with Pb in plants (r=0.970, p<0.01) and Cu in soil with Cd in plants (r=0.997, p<0.01) while strong negative relationship occurred between Cd in soil with Cr in plants (r= -0.990, p<0.01), Cd in soil with Cu in plants (r= -0.979, p<0.01) and Cd in soil with Pb in plants (r= -0.987, p<0.01).

Table 5: Correlation result between heavy metals in soil and heavy metals content in *Manihot esculenta*

	Cr (soil)	Cu (soil)	Pb (soil)	Cd (soil)	Cr (plant)	Cu (plant)	Pb (plant)	Cd (plant)
Cr (soil)	1	-.445	-.163	-.002	-.686*	-.738*	-.473	-.731*
Cu (soil)		1	.926**	.341	.997**	.996**	.970**	.997**
Pb (soil)			1	.576*	.904**	.875**	.986**	.880**
Cd (soil)				1	-.990**	-.979**	-.987**	-.981**
Cr (plant)					1	.995**	.961**	.995**
Cu (plant)						1	.943**	1.000**
Pb (plant)							1	.947**
Cd (plant)								1

**Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed).*

4.0. Conclusion

The investigation of heavy metals contamination in soil and cassava plants at automobile waste dumpsite in Ohiya mechanic village, Abia State, Nigeria showed that artisanal activities generate wastes that release contaminants such as heavy metals. The values of highest concentration of heavy metals (Cd, Cu, Pb and Cr) occurred within 0 to 30 cm depth. The heavy metals that are leached into the soil profile are taken up by cassava plant, especially the root. The values of the concentration of Cd in soil exceed maximum permitted level set by Codex Alimentarius Commission (FAO/WHO) while the values of the concentration of Pb and Cd in cassava plants exceed the permissible limit set by Codex Alimentarius Commission (FAO/WHO). The level of Cd in soil and Pb and Cd in cassava plant is a serious concern to man and animals' health as well as ecological processes taken place in the soil ecosystem. Therefore, it is recommended that rural farmers are informed the consequences of using such adjoining lands for farming activities. More so, efforts should be geared towards using wire gauze to fence round the dumpsite so that animals may not have access to the polluted soil and plants. Abia State Environmental Protection Agency and the leadership of the Automobile and Technician Association should monitor the activities of artisans to ensure strict compliance to industrial and environmental laws and regulations. For example, collection and recycling of spent oil and proper disposal of spent electrolyte to reduce heavy metal contamination in soil and biomagnification in flora and fauna.

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