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Advances in Applied Science Research, 2016, 7(3):20-27

ISSN: 0976-8610
CODEN (USA): AASRFC

Assessment of heavy metal contamination of soil and cassava plants within the vicinity of a cement factory in north central, Nigeria

Idakwoji Precious Adejoh

Department of Biochemistry, Faculty of Natural Sciences, University of Nigeria, Nsukka, Enugu State, Nigeria

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ABSTRACT

The study was conducted to determine the heavy metal concentration in the soils and cassava (Manihot esculentus) leaves within the vicinity of a cement factory in North Central, Nigeria. The concentrations of Cd, Cu, Ni, Pb and Zn were determined using Atomic Absorption Spectroscopy (AAS) technique. Samples of soil and cassava leaves were collected from sites located at a maximum 0.5- 1 km from the factory while control samples were collected on sites located 3 km from the factory. Mean Cd contents in the soil and control soil samples were 1.22 ± 0.34 and 0.78 ± 0.16 µg/ g respectively. Mean values for Cu, Ni, Pb and Zn concentrations in the soil samples were 3.42 ± 0.70, 0.07 ± 0.02, 8.40 ± 2.48 and 0.04 ± 0.01µg/ g respective ly while for the control sites, the mean values were 0.72 ± 0.09, 0.02 ± 0.07, 0.91 ± 0.04 and 0.02 ± 0.01respectivel y. Mean values for Cd, Cu, Ni, Pb and Zn concentrations in the cassava leaves were 0.02± 0.01, 0.93 ± 0.02, 0.39 ± 0.10, 0.30 ± 0.36 and 0.05 ± 0.02 µg/ g respective ly while for the cassava leaves from the control site, the mean values were 0.01 ± 0.01, 0.02 ± 0.01, 0.36± 0.10, 0 .02 ± 0.01 and 0.02 ± 0.01 µg/ g for Cd, Cu, Ni, Pb and Zn concentration respectively. With the exception of Ni and Pb, there were positive correlations between the soil and plant samples for all the metals in the investigated area. These relations were only significant for Ni which showed a negative correlation (r = - 0.78) (p< 0.05). Metal levels in both soil and cassava leaf samples were below the WHO/ FAO recommended limits.

Key words: Heavy metals, Contamination, Cement Factory, Soil, Cassava

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INTRODUCTION

Human activities such as industrial production, mining, agriculture and transportation, release high amounts of heavy metals into surface/ ground water, soils and ultimately to the biosphere. Environmental pollution by heavy metals has been on the rise in recent times. Cement manufacture is one of such activities that contribute to environmental pollution through the emission of gasses and cement dust [1]. Cement dust is largely made up of cement-kiln that is a by-product and it is usually stored as waste in open-pit and unlined landfills. This dust can spread over large areas through wind and rain and are accumulated in and on soils and plants [2]. Some of the metals usually found in the dust emissions from cement plants include arsenic, cadmium, lead, mercury and thallium [3]. Aluminum, beryllium, chromium, copper, manganese, nickel, lead and zinc among others [4]. Excessive accumulation of these heavy metals in agricultural soils, resulting in elevated heavy metal uptake by food crops, is of great concern because of potential health risk to man and animal [5].

Obajana is a small area in Kogi State, North central, Nigeria, where a cement factory is situated and it has been in operation for more than a decade. The people of Obajana are engaged in medium scale agriculture where rice, sweet potatoes, maize, millets, pepper, cassava and cowpea are the commonly cultivated crops. Within the vicinity of the cement plant which is the study area, cassava is the most common and important crop cultivated. Owing to the close proximity of these cassava farms to the cement factory, there is a possibility of the cassava crops been contaminated with heavy metals. A large variety of products (garri, fufu, abacha e.t.c) can be processed from the edible portion of the cassava tubers for human consumption. Thus, it constitutes one of the major ingredients in the local staple of the people of Obajana and by extension, Nigerians. It is well established that high exposure to trace metals like, As, Cr, Ni and Pb in cassava could result in an array of diseases to both human and animals. Apart from cassava, other vegetables can take up and accumulate heavy metals in quantities high enough to cause clinical problems to humans [6].

Food safety is an important aspect of a nation’s economic stability and due to previous reports on the degree of pollution of some food items [7], [8], this study was aimed at assessing the soil and cassava crops within the vicinity of the cement factory for the presence/ concentration of some heavy metals (Cd, Cu, Ni, Pb and Zn) as the toxicity of these elements have been reported extensively [9], [10].

MATERIALS AND METHODS

2.1 Study Area

Obajana town is situated in Koton karfi, Kogi state, Nigeria. Its geographical coordinates are 7° 55' 0" North and 6° 26' 0" East. It is about 45km from Lokoja and 220 km southwest of the Federal Capital Territory (FCT). Obajana town is bounded by nearby towns such as Zariagi, Lokoja, Oshokoshoko and Kabba. Though the place was hitherto barely known, but with its present status as the home of the Dangote cement, it has since assumed international recognition [11].

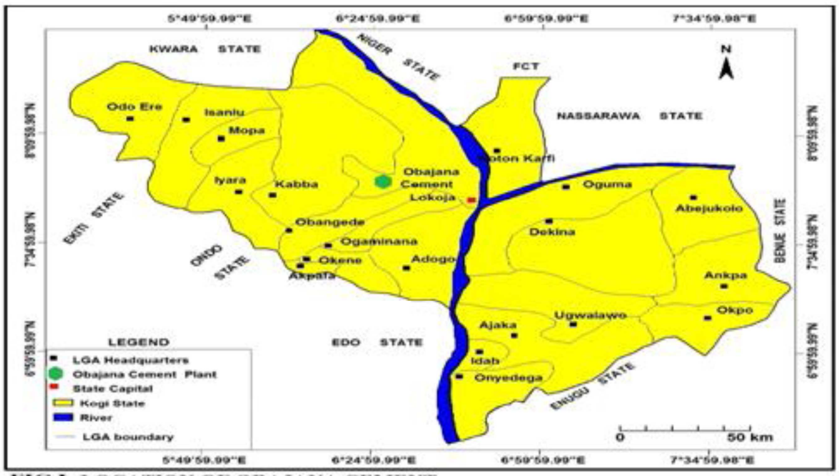

FIG I: LOCATION OF OBAJANA CEMENT

Source : Modified from Kogi State Administrative Map

Figure 1: Location of Obajana Cement Factory

According to 1991 census, the population of Obajana by early 2003 was expected to be 500 people but by January 2003 respondents put this value at about an average of 780 people. By June 2004, the population increased to about 1500 made up of 63.2% strangers and 46.8% indigenes according to a survey and by September 2004 respondents put the population of Obajana at 3,000 and 3,500 during the day, and between 1400 and 1800 at night [12]. The reported higher population during the day is due to an influx of factory workers and job speculators residing outside Obajana, but despite the fact that no recent census could ascertain the current figure, field observation shows that the population would have grown to about 20,000, especially with the influx of thousands of truck drivers in the village on a weekly basis [13].

The people of Obajana are involved in a number of occupations which include cattle rearing, rain-fed farming, hunting and petty trading. The agricultural system is more of an intensive smallholder rain-fed agriculture which consists of small plot farms (0.5 to 2ha) growing mostly rice, sweet potatoes, maize, millets, pepper, cassava and cowpea. Tree crops such as cashew and palm tree are also found in swampy areas. The people of Obajana also engage in Fadama agricultural system (flood plain cropping) in some parts of the study area. Irrigation farming is not practiced in this area since the only source of water – the River Oinyi- dries up during the dry season.

Road transport is the most predominant means of movement in Obajana town. The intra city road structures are not well paved while the town is linked to the major Kabba – Lokoja expressway for its intercity movements. The road transport system is mainly by the use of bicycles, motor bicycles, motor cars, buses, trucks, and trailers. These vehicles travel to various parts of the state and country. Dangote Obajana cement airstrip facility serves as the gateway for air travelers from and to the town. The town is not linked by railway and waterways services [13].

2.2 Sample Collection/ Preparation

To provide a satisfactory environmental representation of the study area, the soil samples were obtained from eight (8) sampling sites representing the north (SITE I), north-east (SITE II), east (SITE III), south-east (SITE IV), south (SITE V), south-west (SITE VI), west (SITE VII) and north-west (SITE VIII) directions of the factory while the cassava plant samples were also obtained from eight (8) farms around the factory in the same directions as above.

In July, 2014, a total of 32 soil samples were collected from the sites with a small plastic shovel from the upper 5 cm of the soil and scrapped into labeled plastic cylindrical containers of approximately 90 cm^3. Large stones and foreign objects were removed from the soil specimens and air–dried for seventy-two hours, ground in a mortar, passed through a 0.005 mm sieve and stored in clean acid treated polythene bags. Also, thirty- two (32) cassava plant (*M. esculentus*), samples were collected from 4 locations each on eight (8) different farms around the factory at 50 m interval by cutting at a height 5 cm from the surface of the soil using a stainless steel knife. The plant specimens obtained were washed with deionized water, air dried to a constant weight at a temperature of 105^oC in an oven. Samples were ground into powder, passed through a 0.02 mm sieve, mixed to homogenize and stored in similar plastic containers as the soil samples until analysis.

The reference soil used was obtained from a sparsely populated area which is 3 km away from the factory. This area has low traffic and no industrial activity taking place.

2.3 Sample Analysis

Tessier *et al.* [14] method for total metal analysis was carried out by digesting 1g (<0.005 mm) of soil sample with a mixture of 5 ml HF and 1 ml $HClO_4$. The extract was analyzed using AAS. Same procedure was carried out on soil reference sample. Soil pH was determined using a soil-water ratio 1:2.5 (w/v). Soil organic matter was determined using the Walkey-Black wet oxidation method [15]. Soil particle size distribution was done using hydrometer method and soil carbonate was determined by the concentrated HCl acid method [15]. For the cassava plant samples, the method of 4:1 mixture of HNO_3 and $HClO_4$ by [16] was used for plant digestion. Reagent blank was prepared in similar manner.

2.4 Quality Assurance

To ensure accurate determination of concentration by the AAS, various standards of the heavy metals of interest were used and blank samples made from only reagents without sample were analyzed to get rid of any background concentration metals in the system.

2.5 Data Analysis

Concentrations of heavy metals were expressed as mean ± SD (Standard Deviation). The calculation of Means, standard deviations and all other statistical analyses were carried out with GraphPad version 5.0 with values for $p < 0.05$ considered significantly different.

RESULTS AND DISCUSSION

3.1 physico-chemical properties of soil

The physico-chemical properties of the studied soil are shown on Table 1. The soil is mainly sandy, slightly acidic and moderately high in carbonate with low percentage of organic matter.

3.2 Concentration of heavy metals in the soil and cassava leaves

Heavy metals have maximum permissible level in soils and plants specified by different bodies. In this study, the standard used by WHO/FAO was adopted. Therefore a comparison and interpretation of the results of analysed soils and vegetables is based on the control values and standards set by WHO/FAO.

Cadmium (Cd)
The estimated concentration of Cd in the soil samples ranged from 0.95– 1.83 µg/g (Table 2) with a mean value of 1.22 µg/ g (Table 4). The recorded Cd concentration in the soil was below the maximum permissible concentration of 3.0 µg/ g set by W.H.O but higher than the control site with a mean value of 0.78 µg/ g (Table 4). For the cassava from farms around the factory, the estimated concentration of Cd ranged from 0.01- 0.03 µg/ g (Table 3) with a mean value of 0.02 µg/ g (Table 5). This concentration observed is higher than that of the cassava leaves from the control which has a mean concentration of 0.01 µg/ g (Table 4) but below the maximum permissible concentration of 3.0 µg/ g set by WHO.

The estimated concentrations of Cd in the soil and cassava samples even though below the WHO permissible limit, were slightly higher than those from the control sites. With this observation, there is no fear of acute toxicity when the plants are consumed since the concentration is below the WHO permissible limits. In the long term, toxicity might however, arise from chronic accumulation of Cd if these plants are continuously consumed. The kidneys and liver store about 50 to 85% of Cd in the body with 30 to 60% being stored in the kidneys [10]. Cd has no known biological functions in the body but it interferes with some essential function of Zn, thereby inhibiting enzyme reactions and nutrient utilization. It catalyzes oxidation reactions, generating free-radical tissue damage [17]. Zinc, an essential trace element is more toxic in salt form than in elemental form. Its ingestion causes gastrointestinal toxicity, pulmonary toxicity, nephrotoxicity and neurotoxicity [18], [19]. Though there has been paucity of information on reported carcinogenicity by oral route, most classifications are based on occupational exposure to cadmium with inhalation as the primary route of exposure. A study also reported an association between environmental exposure to cadmium and cancer via inhalation exposure (Nawrot *et al.* [20]. These authors also compared cancer incidence in an area contaminated with cadmium (geometric mean cadmium soil concentration 7.97 mg/kg) with incidence in an area with low exposure to cadmium (geometric mean cadmium soil concentration 0.81 mg/kg). Nawrot *et al.* [20] also found a significant relationship between cadmium concentration in the soil, or residence in a high-exposure area, and lung cancer even after adjustment for age, sex, smoking and exclusion of cadmium-exposed workers.

Copper (Cu):
Cu concentration in the soil samples ranged from 2.19– 4.18 µg/g (Table 2) with a mean value of 3.42 µg/ g (Table 4) which is below the maximum permissible concentration of 100.0 µg/ g set by W.H.O but higher than the control site with a mean concentration of 0.72 µg/ g (Table 4). The estimated concentration of Cu in the samples of the cassava leaves ranged from 0.79- 1.01 µg/ g (Table 3) with a mean value of 0.93 µg/ g (Table 5). This concentration is below the maximum permissible concentration of 73.0 µg/ g set by W.H.O and slightly higher than the control with a mean concentration of 0.02 µg/ g.

Copper is an essential trace metal, vitally important for both physical and mental development in human, usually found in many food types particularly vegetarian foods such as nuts, seeds and grains. It is important for energy production in cells and is required for women's fertility in relation to estrogen metabolism amongst others. This study did not reveal any risk of acute Cu toxicity but there is a possibility of chronic toxicity. Cu accumulates easily in the body hence, chronic low level intakes have damaging effects on human beings and other animals, since there is no good mechanism for their elimination. Conditions associated with increased copper body burden are arthritis, fatigue, insomnia, scoliosis, osteoporosis, heart disease, cancer, migraine, heart seizures, gum diseases, skin and hair problems. Reported also are mental and emotional disorders such as depression mood swings, fears, anxiety, panic attacks, violence and memory loss [19], [21].

Nickel (Ni)
The W.H.O maximum permissible concentration of Ni in the soil is 50 µg/ g. The estimated concentration of Cu in soil samples obtained around the factory ranged from 0. 04- 0.09 µg/ g (Table 2) with a mean value of 0.07 µg/ g (Table 4). This is less than the WHO permissible concentration stated above. It is however, above that of the control site which stands at a mean concentration of 0.02 µg/ g (Table 4). For the cassava, the estimated concentration of Cu in the samples ranged from 0.25- 0.52 µg/ g (Table 3) with a mean value of 0.39 µg/ g (Table 5). This concentration is below the maximum permissible concentration of 67µg/ g set by W.H.O and slightly higher than the control with a mean concentration of 0.36 µg/ g.

Nickel is also an essential trace element. It is contained in many body tissues but its role is not well understood. Ordinarily, nickel is not known to be toxic to the body as the body does not readily absorb it [22]. However, nickel can combine with carbon monoxide (CO) to form a complex, nickel tetracarbonyl (Ni (CO) $_4$), which is extremely poisonous, even more than CO, which is one of its precursor. Elevated dietary intake of the metal is associated with increased thyroid problems, cancer and heart disease [23]. Though this study did not reveal any risk of acute toxicity, the slight increase in the concentration of Ni in the soil and cassava plants around the factory represents a risk in the future.

Lead (Pb)

The permissible limit of Pb in the soil recommended by WHO is 100 µg/ g. In the soil samples the concentration of lead was recorded below the permissible limit. The estimated concentration of Pb in the samples ranged from 5.09-11.08 µg/ g (Table 2) with a mean value of 8.04 µg/ g (Table 4). This concentration of Pb around the factory is however, above that of the control site with a mean concentration of 0.91 µg/ g (Table 4). The estimated concentration of Pb in the cassava samples ranged from 0.03- 1.00 µg/ g (Table 3) with a mean value of 0.30 µg/ g (Table 5). This concentration is the same with the maximum permissible concentration of 0.30 µg/ g set by W.H.O but higher than the control with a mean concentration of 0.20 µg/ g.

This study revealed that the concentration of Pb in the cassava plants is the same with WHO recommended permissible limit. This concentration however, is not enough to cause acute toxicity. High Pb concentration in edible plants that are cultivated in areas that are contaminated can potentially pose a health risk to consumers. The absorption of Pb is influenced by food intake with higher rates of absorption after fasting than when it is ingested with a meal. Age is also another factor that influences Pb absorption. The absorption rate in infants is five times greater than that of adults. After Pb absorption and distribution in blood, it is initially distributed to soft tissues throughout the body. Eventually, bone accumulates Pb over much of the human life span and may serve as an endogenous source of Pb. The half-life for Pb in blood and other soft tissues is about 28-36 days, but it is much longer in the various bone compartments. The percentage retention of Pb in body stores is higher in children than adults. Lead that is not distributed is mainly excreted through the kidney [24].

Lead is a classical chronic or cumulative poison. In humans, Pb is known to cause a lot effects in the body system depending on the level and duration of exposure. Many of the effects observed in humans ranges from hematological, neurological, behavioral; renal to cardiovascular effects. Due to the rapid rate of absorption in children, they are often more vulnerable to the effects of lead than adults. Pb has been implicated in the impairment of neurobehavioral functioning in children and this is thought to be the most critical effect [22].

Zinc (Zn)

Zinc is one of the important trace elements that play a vital role in the physiological and metabolic process of many organisms. Nevertheless, higher concentrations of zinc can be toxic to man. The concentration of Zn in the soil samples ranged between 0.04 to 0.05 µg/ g (Table 2). The permissible limit of zinc in soil according to WHO standards is 300 µg/ g. In all the collected soil samples, the concentration of Zn was recorded below the permissible limit. For the cassava samples, the concentration of Zn ranged between 0.02 to 0.07 µg/ g (Table 3). The mean concentration of 0.05 µg/ g estimated for the soil around the factory is below the permissible limit of 100 µg/ g set by W.H.O but higher than the concentration (0.02 µg/ g) in the control sample (Table 5).

Among all heavy metals, zinc is the least toxic and an essential element in human diet as it is required to maintain the functioning of the immune system. The deficiency of Zn may be more fatal to human health than the excess of it [25] In human, high levels of zinc cause acute effects such as vomiting and gastrointestinal irritation (nausea, cramps, diarrhoea), weakness, anorexia, anaemia, diminished growth, loss of hair, lowered food utilization, changes in the levels of liver and serum enzymes, morphological and enzymatic changes in the brain, and histological and functional changes in the kidney. Chronic elevated intake of Zn could also result to impaired Cu uptake in humans. This implies that some of the effects of Zn may be secondary to impaired copper utilization [26].

Table 1: Average Physico- Chemical Parameters of the Soil around the Cement Factory

SITE	SAND %	SILT %	CO_3^{2-} %	CLAY %	TOM %	P^H
Studied	86.9	9.83	3.29	11	2.98	5.8
Control	78.24	7.28	4.72	14.48	3.17	8.3

TOM = Total Organic Matter

Table 2: Concentration of Heavy Metals in the Soil Samples obtained from the Surrounding of the Cement Factory

SITE	Cd (µg/ g)	Cu (µg/ g)	Ni (µg/ g)	Pb (µg/ g)	Zn (µg/ g)
I	0.98	4.18	0.08	5.09	0.04
II	1.17	3.20	0.06	8.07	0.03
III	1.08	3.16	0.09	10.07	0.05
IV	1.04	4.13	0.08	9.07	0.03
V	1.83	2.19	0.08	6.06	0.02
VI	1.66	3.14	0.07	6.10	0.02
VII	1.03	3.15	0.04	11.08	0.04
VIII	0.95	4.17	0.09	10.90	0.05
MEAN	1.22	3.42	0.07	8.40	0.04
SD	0.34	0.70	0.02	2.48	0.01
CONTROL 1	0.92	0.71	0.02	1.01	0.02
CONTROL 2	0.61	0.81	0.01	0.97	0.01
CONTROL 3	0.81	0.63	0.03	0.93	0.02
MEAN	0.78	0.72	0.02	0.97	0.02
SD	0.16	0.09	0.01	0.04	0.01

SD= Standard Deviation

Table 3: Concentration of Heavy Metal in the Cassava Leaves Samples obtained from the Surrounding of the Cement Factory

SITE	Cd (µg/ g)	Cu (µg/ g)	Ni (µg/ g)	Pb (µg/ g)	Zn (µg/ g)
I	0.01	0.95	0.03	0.50	0.05
II	0.03	1.01	0.50	0.60	0.06
III	0.01	0.97	0.25	0.03	0.04
IV	0.01	0.89	0.33	0.05	0.02
V	0.02	0.79	0.39	0.07	0.07
VI	0.01	0.82	0.52	1.00	0.03
VII	0.03	0.96	0.48	0.08	0.04
VIII	0.01	1.01	0.31	0.07	0.06
MEAN	0.02	0.93	0.39	0.30	0.05
SD	0.01	0.08	0.10	0.36	0.02
CONTROL 1	0.01	0.03	0.45	0.01	0.02
CONTROL 2	0.01	0.02	0.39	0.03	0.01
CONTROL 3	0.01	0.02	0.25	0.01	0.02
MEAN	0.01	0.02	0.36	0.02	0.02
SD	0.00	0.01	0.10	0.01	0.01

SD= Standard Deviation

Table 4: Average Concentration of Heavy Metals in the Soil around the Cement Factory

SOIL	Cd (µg/ g)	Cu (µg/ g)	Ni (µg/ g)	Pb (µg/ g)	Zn (µg/ g)
TEST	1.22 ± 0.34	3.42 ± 0.70	0.07 ± 0.02	8.40 ± 2.48	0.04 ± 0.01
CONTROL	0.78 ± 0.16	0.72 ± 0.09	0.02 ± 0.07	0.91 ± 0.04	0.02 ± 0.01
MPL (WHO/ FAO)	3.00	100.00	50.00	100.00	300.00

Results Presented as Mean ±Standard Deviation
MPL = Maximum Permissible Limit
WHO= World Health Organization
FAO = Food and Agriculture Organization

Table 5: Average Concentration of Heavy Metals in the Cassava Leaves around the Cement Factory

CASSAVA	Cd (µg/ g)	Cu (µg/ g)	Ni (µg/ g)	Pb (µg/ g)	Zn (µg/ g)
TEST	0.02± 0.01	0.93 ± 0.02	0.39 ± 0.10	0.30 ± 0.36	0.05 ± 0.02
CONTROL	0.01 ± 0.00	0.02 ± 0.01	0.36± 0.10	0.02 ± 0.01	0.02 ± 0.01
MPL (WHO/ FAO)	0.10	73.00	67.0	0.30	100.00

Results Presented as Mean ±Standard Deviation
MPL = Maximum Permissible Limit
WHO= World Health Organization
FAO = Food and Agriculture Organization

3.3 Correlation between the Concentration of Heavy Metals (µg/g) in the Soil and Cassava Samples

As seen from Table 6, with the exception of Ni and Pb, there are positive correlation between soil and plant for all the metals in the investigated area. These relations were only significant for Ni which showed a negative correlation (r = - 0.78), but not significant for the rest of the metals examined. The results of positive correlation between soil and plants have been supported by earlier findings [27], [28]. Thus, indicating that plants take nutritional elements from soil through their roots [29]. However, the negative correlation results indicated by Ni and Pb gives credence to the fact that some elements might be assimilated through other organs of the plants other than their roots or some plants may have high affinity of assimilation of some elements directly from atmospheric deposition. Another good reason may be linked to the fact that only the upper layer (A soil horizon) of soil was sampled [30]. Generally, the mean concentration levels in soil are higher than that of the plant samples (Table 4 and 5). However, Ni was an exception to this observation, indicating that the mean soil concentration of Ni (0.07 μg/g) is lower than mean concentration of 0.39 μg/g for the plants which might have led to the negative correlation result for the metal.

Table 6: Computed Pearson Correlation Coefficient between Heavy Metal Levels in the Soil and Plant Samples in the Investigated Area

Correlation between metals	r_c Value
Correlation between soil and plants for Cd	0.07
Correlation between soil and plants for Cu	0.52
Correlation between soil and plants for Ni	-0.78*
Correlation between soil and plants for Pb	-0. 61
Correlation between soil and plants for Zn	0.04

**significant at p <0.05*

CONCLUSION

The concentrations of Cadmium, Copper, Nickel, Lead and Zinc in the soil were found to be below the WHO/ FAO permissible limit but above that of the control site while for the cassava crop, all the metals were found to be in concentrations below WHO/ FAO recommended permissible limit (but higher than that of the control site) except Lead that was at the same level with the WHO/ FAO limit. The soil and cassava crop may be said to be slightly contaminated with these toxic metals. The contamination of the soil may be due to the close proximity of the farm lands to the cement factory while the cassava crops might have been contaminated by direct uptake of the heavy metals from the soil via the roots and/or aerial uptake.

Though, the concentration of the heavy metals like Cd, Cu, Ni and Zn in the farm soil and crops were found to be below the FAO/WHO safe limits, safe limits of metals based on acute evaluations alone may be misleading as concentrations judged to be low as not to cause any deleterious effect at that point in time may accumulate incidentally thereby leading chronic toxicity. Hence, regular monitoring and evaluation of the soil and the crops cultivated around Obajana Cement Company is encouraged to check the elevated concentrations of these metals. The data from such assessment could serve as index on which remediation variables in modeling could be anchored.

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