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Levels of Cd, Pb, and Hg in Soil, Carica Papaya and Manihot Esculenta around Dangote Cement Factory Tse-Kucha, Gboko, Benue State

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Abstract The levels of heavy metals (Cd, Pb and Hg) in the soil and plant leaves of pawpaw (*Carica papaya*) and cassava (*Manihot esculenta*) around Dangote Cement Company Gboko were determined by Atomic Absorption Spectrophotometry (AAS). The aim of this study was to determine the extent of heavy metal contamination on soil and crops cultivated around the cement factory as well as establish a link between heavy metal contents of soil and their uptake by the plants. The mean concentration of the metals in the soil samples north of the company in µg g^{-1} were: Cd (0.003 ± 0.014), Pb (0.149 ± 0.128) and Hg (3.773± 3.590). For pawpaw leaves north of the company, the metal concentrations in µg g^{-1} were Cd (0.004 ± 0.002), Pb (0.068 ± 0.036) and Hg (6.612 ± 5.085) while the trend for cassava leaves north of the company in µg g^{-1} was Cd (0.012 ± 0.003), Pb (0.011 ± 0.002) and Hg (5.434 ± 5.591). In the southern part of the company, the mean values for soil samples in µg g^{-1} were Cd (0.002 ± 0.002), Pb (0.244 ± 0.578) and Hg (5.916 ± 6.057). The mean metal concentrations in pawpaw leaves south of the company in µg g^{-1} were Cd (0.086 ± 0.007), Pb (0.086 ± 0.032) and Hg (0.004±0.002) while values for cassava leaves in µg g^{-1} were Cd (0.145 ± 0.205), Pb (0.101 ± 0.266) and Hg (1.331 ± 0.433). The mean values of Cd and Pb were found to be within the normal background levels and below the permissible limits set by the World Health Organization (WHO). However, the values of Hg were above natural background levels and also above the permissible limits set by WHO. These results have important implications on the soil productivity as well as on human health because heavy metals taken up by plants accumulate along the food chain.

Keywords Heavy metals, soil productivity, vegetation, human health

Introduction

The environmental problems associated with heavy metals contamination are becoming more worrisome in the world particularly in developing countries [1-2]. This is because research efforts towards monitoring the environment have not been given the desired attention by the stake holders [2]. Generally, the natural concentration of heavy metals in agricultural soils, water and plant materials, is not sufficiently high to cause harm to human health [3]. However, the presence of high concentration of heavy metals in the ecosystem is of great concern because of their toxicity and non-biodegradability [1]. These heavy metals are introduced into the environment through natural and anthropogenic sources [5]. Human activities that could increase the concentration of heavy metals in the environment include combustion, mining, industrial processes, smelting, indiscriminate dumping of industrial and domestic wastes in landfill and water bodies without treatment and traffic activities [2, 6-7]. Industrial wastes are the major sources of environmental pollution that originates from mining industries, chemical industries, metal processing industries, electroplating, application of fertilizer and pesticides application [8-9]. These industrial wastes include a variety of chemicals like heavy metals, dust, smoke, harmful oxides, petrochemicals, and phenols [10].

One factor that has triggered the growth of industries is rapid growth in human population. Economic development, shortage of infrastructural materials, food and water has limited human lives and social development [11]. In order to meet up with the growing demands, man has to look for alternative sources such as increased industries and industrial processes, application of fertilizers, irrigation farming and other new developmental innovative [12]. These efforts have helped in solving some of the problems on one hand but on the other hand, have also created problems such as environmental pollution, heavy metal contamination, and disease outbreaks [10]. This is because the wastes generated from human activities such as farming, industrial processes and irrigation keep escaping into the environment [13]. Studies have shown that high concentrations of these heavy metals in the ecosystem could lead to adverse effects on human health [10, 14]. Also, crops grown on heavy metal contaminated areas may absorb and accumulate large quantities of these metals as ions in their roots, stems and leaves depending on the plant species as well as the physical and chemical conditions of the soil [11, 15]. Consumption of plants polluted by heavy metals is the primary pathway of the food chain, responsible for triggering cell mutation (cancer) and neurological disorders in human beings [16-18]. Since heavy metals are toxic and non-biodegradable, they persist in the environment for a very long time. The knowledge of metal-plant-animal relationship is also very important for a safe environment and good health [10]. Studies have also shown that early detection and remediation of heavy metals in soil and vegetation will ameliorate serious threats posed to human existence [8].

To maintain a healthy life style, food safety and quality are very important factors to consider [7]. The study therefore had a two-fold objective. The first was to determine the trace metal concentrations of soil and selected vegetation around the cement factory. This would help ascertain the consumption safety of the plants based on uptake of the heavy metals from the soil, hence the second objective of establishing a link between the trace metal levels in soil and plant samples.

Study area

Dangote Cement Factory Plc (formerly known as Benue Cement Company), Gboko is located in Tse-Kucha, 72 km along Makurdi-Gboko road and 8 km from Gboko town [19]. The factory is located at 7°24′ 42.45″ N and 8°58′ 31.28″E and is about 532 feet above mean sea level [19-20]. The area is located within a sub-humid tropical region with average annual temperature range of 23 – 34 °C and is characterized by two seasons; the rainy and dry seasons [20-21[. The siting of this factory in this location could be possibly due to the presences of limestone- the major raw material for cement production. The map showing the location of the cement factory and its surrounding settlements is shown in Fig. 1.

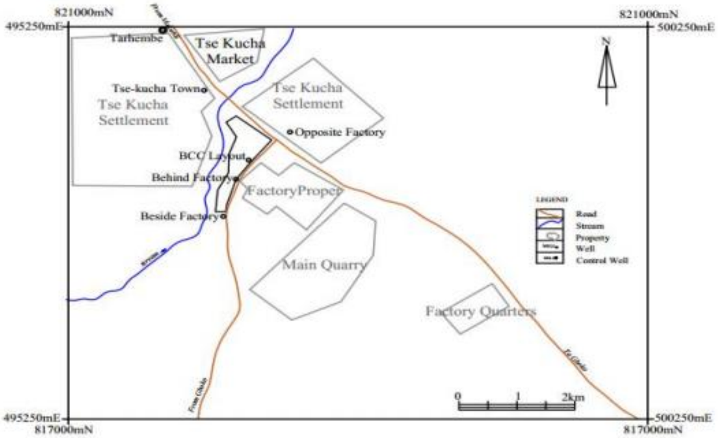

Figure 1: Map showing Dangote Cement Factory and other settlements around the factory [20-22]

Materials and methods

Materials

Nitric acid (ACS, 70% purity), distilled water, hot plate, weighing balance, beakers, watch glass, sieve, filter paper, measuring cylinder, porcelain mortar and pestle, volumetric flask, Atomic absorption spectrophotometer AAS (210 VGP, Buck Scientific, USA).All chemicals used for this research were of analytical grade, purchased from Sigma Aldrich and used without further purification.

Sample collection and storage

The soil and plant samples were collected at north and south cardinal points of Dangote Cement Factory. Three soil samples and two plant (cassava and pawpaw) leaves were collected up to three kilometers away from the factory at each cardinal point. These samples were collected at each kilometer giving a total of 14 samples. The samples were collected into polythene bags, labeled appropriately, tightly sealed to prevent interaction with air and light and taken to the chemistry laboratory of Benue State University Makurdi for analysis. Polythene bags were chosen for sample storage because they do not react with the samples and as such will not alter their chemical composition.

All the samples (soil and plants) were collected in September 2017 and preserved in a cupboard at ambient conditions. The leaves were washed to remove dust and soil particles, oven dried and ground to powder using a porcelain mortar and piston. The powdered plant and soil samples were sieved separately to obtain finer particles.

Digestion of plant and soil samples

5 g of the soil sample was measured and transferred into a beaker containing 50 mL of distilled water and 5 mL of conc. HNO_3 was added. The mixture in the beaker was heated on a hot plate for 1 hour during which the solution was allowed to evaporate to about 20 mL of the total volume. Concentrated HNO_3 (5 mL) was added again and the beaker was covered with a watch glass to obtain a gentle refluxing action. The solution was allowed to boil for about 1 hour and 5 mL of conc. HNO_3 was added and heating continued. The heating continued until a light-coloured, clear solution was observed which indicated complete digestion. The content of the beaker was allowed to cool and 2 mL of conc. HNO_3 was added to dissolve any remaining residue. The digested sample was then transferred into a 100 mL volumetric flask and the beaker rinsed into the volumetric flask. The solution was diluted to the 100 mL mark, filtered using Whatman No. 1 filter paper and stored for metal analysis [23]. The same digestion procedure was repeated for the plant samples. The analyses were carried out using Atomic Absorption Spectrophotometer, AAS Model 210 VGP of Buck Scientific, USA.

Results and Discussion

Results

Table 1: Mean concentration in µg g^{-1} (±standard deviation) of heavy metals in soil and plant samples north of the factory

	Heavy metals/µg g^{-1}		
Samples	**Cd**	**Pb**	**Hg**
Soil	0.003 ± 0.014	0.149 ± 0.128	3.773 ± 3.590
Pawpaw	0.004 ± 0.002	0.068 ± 0.036	6.612 ± 5.085
Cassava	0.012 ± 0.003	0.091 ± 0.002	5.434 ± 5.591

Table 2: Mean concentration in µg g^{-1} (±S.D) of heavy metals in soil and plant samples north of the factory

	Heavy metals/µg g^{-1}		
Samples	**Cd**	**Pb**	**Hg**
Soil	0.002 ± 0.002	0.244 ± 0.578	5.916 ± 6.057
Pawpaw	0.086 ± 0.007	0.086 ± 0.032	0.004 ± 0.002
Cassava	0.145 ± 0.205	0.101 ± 0.226	1.331 ± 0.433

Table 3: Computed Pearson correlation coefficient between heavy metal levels of soil and plant samples in the investigated area

Correlation between metals	**r_c values**
Correlation between soil and cassava plant for Cd (north location)	0.998
Correlation between soil and pawpaw plant for Cd (north location)	0.981
Correlation between soil and cassava plant for Cd (south location)	-0.844
Correlation between soil and pawpaw plant for Cd (north location)	-0.561
Correlation between soil and cassava plant for Pb (north location)	1.000
Correlation between soil and pawpaw plant for Pb (north location)	-1.000
Correlation between soil and cassava plant for Pb (south location)	-0.871
Correlation between soil and pawpaw plant for Pb (south location)	0.961
Correlation between soil and cassava plant for Hg (north location)	-1.000
Correlation between soil and pawpaw plant for Hg (north location)	-1.000
Correlation between soil and cassava plant for Hg (south location)	0.772
Correlation between soil and pawpaw plant for Hg (south location)	-1.000

Table 4: Student T-test (one sample statistics and one sample test) computed

	Variables	**$T_{calculated}$**	**t_{table}**	**df**	**Mean**	**Standard deviation**
North (Cd)	CL	5.000	12.71	1	0.0125	0.00354
	Soil	1.195	4.303	2	0.0103	0.01498
	PL	3.000	12.71	1	0.0045	0.00212
	Soil	1.195	4.303	2	0.0103	0.01498
South (Cd)	CL	1.000	12.71	1	0.0145	0.02051
	Soil	1.309	4.303	2	0.0020	0.00265
	PL	5.182	12.71	1	0.0285	0.00778
	Soil	1.309	4.303	1	0.0020	0.00265
North (Pb)	CL	2.615	12.71	1	0.0680	.03677
	Soil	1.918	4.303	2	0.1423	.12851
	PL	3.000	12.71	1	0.0045	.00212
	Soil	1.918	4.303	2	0.1423	.12851
South (Pb)	CL	6.312	12.71	1	0.1010	0.02263
	Soil	1.648	4.303	2	0.5500	0.57816
	PL	3.739	12.71	1	0.0860	0.03253
	Soil	1.648	4.303	2	0.5500	0.57816
North (Hg)	CL	1.839	12.71	1	6.6120	5.08551
	Soil	1.828	4.303	2	3.7900	3.59038
	PL	1.374	12.71	1	5.4340	5.59180
	Soil	1.828	4.303	2	3.7900	3.59038
South (Hg)	CL	4.344	12.71	1	1.3315	0.43346
	Soil	1.692	4.303	2	5.9163	6.05744
	PL	3.000	12.71	1	0.0045	0.00212
	Soil	1.692	4.303	2	5.9163	6.05744

CL = cassava (*Manihot esculenta*) leaves, PL= pawpaw (*Asimina triloba*) leaves.

Discussion

This research was carried out to determine the heavy metal concentrations in the soils and plants collected at varying distances around Dangote Cement Factory. The mean concentrations of the heavy metal concentrations are shown in Tables 1and 2 while the correlation coefficients are in Table 3. The concentration of Cd in the soil and plant samples, north of the factory showed mean concentration values of 0.003 ± 0.014, 0.012 ±0.003 and 0.004 ± 0.002 µg/g for soil, cassava and pawpaw respectively. The mean values of 0.002 ± 0.002, 0.145 ± 0.205 and 0.086 ± 0.007 µg/g were obtained for soil; cassava and pawpaw respectively south of the factory. These values were below the permissible limits set by the World Health Organization (WHO) for soils around industrial areas. The correlation coefficient computed for Cd indicated a positive correlation between the soil and plants, north of the factory and negative for the samples, south of the factory. This result of positive correlation is in agreement with the findings of Voutsa *et al.*, [24], thus indicating that plants take up nutritional elements from the soil through their roots to their leaves [25-26]. However, the negative correlation results indicated gave a strong suspicion 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 due to the fact that only the upper layer (horizon A) of the soil was sampled [27]. Cd is not an essential element for human health with a high biological toxicity. It accumulates mainly in the surface soil, and enters the body majorly through the digestive system [11]. Although the levels of Cd detected was within the normal range for soils and plants, continual consumption of crops grown on these soils could lead to accumulation and adverse health implication [6, 9].

The concentration of Pb in the soil and plant samples analyzed showed mean values of 0.149 ± 0.128, 0.091 ± 0.002 and 0.068 ± 0.036 µg/g for soil, cassava and pawpaw respectively, north of the factory and mean values of 0.244 ± 0.578, 0.101 ± 0.226 and 0.086 ± 0.032 µg/g for soil, cassava and pawpaw samples respectively, south of the factory. These values as observed for Cd above are below the permissible limits set by WHO for soils and plants around industrial areas but fall within normal background levels of soil and plant composition. The correlation coefficient r, for Pb is rather irregular with a positive correlation between soil and cassava plant from the northern geographical area of the factory and negative correlation for soil and cassava plants, south of the factory. A similar pattern was observed for pawpaw plant. This may be as a result of abnormality in the results of the concentrations. At one point, the highest levels of Pb occurred closer to, and at varying directions from the factory. In another instance, the peak levels of Pb were observed further away in varying directions. For instance, for the soil samples, the highest level of Pb was observed at a radius distance (rd) of 2 km southwards of the factory and another peak at 1 km away from the factory towards the northern direction.

The concentration of Hg in the soil and plant samples analyzed showed mean concentration values of 3.773 ±3.590, 5.434 ± 5.591 and 6.612 ± 5.085 µg/g for soil, cassava and pawpaw respectively north of the factory and a mean concentration of 5.916±6.057, 0.004±0.002 and 1.331±0.433 µg/g for soil, cassava and pawpaw; south of the factory. These values were above the permissible limits set by WHO for soils around industrial areas and even higher normal range of soil and plant composition. As similarly observed for Pb, the correlation coefficient for Hg is rather irregular, perhaps as result of an anomaly in the results of concentration. At one point the highest levels of Hg occurred in plants closer to, and at varying directions from the factory. In another instance, the peak levels of Hg were observed further away in varying directions. This result of Hg accumulation is in excess of natural background and critical limits for soils and plants. The high concentration of Hg in the soil and plant samples might be attributed to the soil type and the effluent from the cement company around the vicinity. Due to the excessive concentration of Hg in the study area, residents of Tse-Kucha and Amua community who consume these crops grown on the soil are at risk of mercury poisoning which can lead to the disturbance and inhibition of numerous essential biological functions; symptoms include ataxia and extensive damage to many internal organs including the brain, heart, intestine and kidneys and eventually death [27].

From Table 4, the T-test conducted for all the samples above showed that there is no significant difference between metal concentrations in the various samples ($t_{\text{calculated}} < t_{\text{table}}$) and hence a link between the concentration in the soil and plant samples. Generally as stated above, a close observation from the available data reveals a number of irregular distributions in the metal concentrations of the samples with respect to distance and direction. The situation can be linked to the cement factory as a major source responsible for the metal distribution pattern due to uneven dispersal of exhaust effluent into the atmosphere. Furthermore, the highest levels of these elements in plants have differing distances and directions which cannot be described even with the understanding of the three main prevailing wind directions in the area (north, north-east and east). These discrepancies in concentration are associated with each metal in the soil and vegetation samples. Several industrial studies, particularly in the cement and municipal solid waste incinerator industrial facilities involving similar studies have observed similar phenomena [26, 28].

Correlation analysis of the Cd metal levels in the soil and plant samples suggested a positive correlation for samples collected north of the factory and a negative correlation for samples on the southern direction. Correlation analyses of Pb and Hg were of irregular pattern. While the Pb contents of soil and cassava north of the factory are perfectly positively correlated, the lead contents of cassava, pawpaw and the soil in the southern part of the factory are negatively correlated.This relationship between the trace metal elemental contents of the soil and vegetation samples in relation to distance and direction from the cement factory is rather complicated and may depend on several factors.

Among these factors are; possible variations that may have occurred in the raw materials mix in the factory. This can affect metal emissions from the kilnand their subsequent deposition on the soil and plants. Others include the meteorological conditions of the area, the sampling season and non-homogeneity of the samples.

Conclusion

The results of the study indicated the presence of cadmium, lead and mercury in the soil and plant samples. The concentrations of Cd and Pb were within the normal background levels while the levels of Hg were above the background and critical limits in all the samples. Due to the high toxicity of Hg, it is suggested that the inhabitants of this community should not consume the crops cultivated near the factory as they risk being exposed to Hg poisoning

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