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Bioaccumulation of Heavy Metals in Beans Plant Raised on Agricultural, Industrial, Residential and Dumpsites Soil in Sango Ota, Ogun State

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Abstract

Heavy metals contamination and accumulation in food plants constitute major threat which has brought about environmental devaluations around the world due to their toxicity, abundant sources and non-biodegradable properties. The accumulation of heavy metals into different part of bean plant raised on soils obtained from different locations reflecting different activity was studied. Soil samples were collected from each studied location (industrial, agricultural, residential and dumpsite) in Sango Ota. A portion of the soil samples was digested and the rest was used for planting beans seed which was harvested after three months and digested using aqua regia. The soil and plant digests were analyzed for heavy metals using atomic absorption spectroscopy. The concentration of Pb ranged from 31.67-

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71.67 mg/kg, 288.00-566.67 mg/kg for Mn, 28.00-44.17 mg/kg in Cr, 0.35-1.28 mg/kg for Cd and 4.13-9.15 mg/kg for Ni in the soil samples. The mean concentration of heavy metal accumulation into leaves, stem and root of beans plants shows Pb: 8.56, 7.38, 12.19 mg/kg; Mn: 40.94, 29.75, 70.81 mg/kg; Cr: 4.00, 4.13, 4.63mg/kg; Cd: 0.85, 0.84, 0.62 mg/kg and Ni: 20.25, 22.14, 20.03mg/kg respectively. The trend of accumulation observed across the three-soil source majorly follows: Root>Stem>Leaf>; thus, edible plants grown on contaminated soil may accumulate toxic metals hence, agricultural soils needs to be constantly monitored to prevent toxic metal accumulation into edible plant.

Keywords: heavy metals, soil sample, toxicity, non-biodegradable and atomic absorption spectroscopy

INTRODUCTION

Heavy metals accumulation in soil interrupt the normal functioning of soil ecosystem and plant growth *(*Khan *et al., 2008).* Plant absorbed various kinds of heavy metals when available in the soil or irrigation water (Ijeoma *et al.,* 2011). Soils are contaminated in the environment with a number of heavy metals by natural (weathering and erosion of parent rock material or ore deposits) or artificial (waste water, irrigation, mining activities) sources. The presence of one contaminant can increase or decrease the impact of others. Today, majority of studies have focus or investigated the effect of a single metals on plant species (Calkins, 2009).

Heavy metals in soil can threaten human health through consumption, and the chronic low-level intake of soil metals through ingestion or inhalation has a seriously negative effect on human health (Abulude *et al.,* 2007*).* For example, chronic exposure to cadmium can have harmful effects such as lung cancer, prostatic proliferation lesions, bone fracture, kidney dysfunction and hypertension (Jia *et al.,* 2010**).**

Some factors known to influence the levels heavy metals in soil samples, which have been reported, are traffic, industry and weathered materials **(**Kar *et al.,* 2008). Top soil and dusts in urban areas are indicators of heavy metal contamination from atmospheric deposition.

It has been noted that location close to roads are severally polluted by heavy metals such as Pb, Zn, Cu, Cd etc. from traffic (Pain, 2008). Soil is not only the key nutrient bearing environment for plant like (Hill, 2010) but also a supplier of many pollutants to plant can uptake toxic substance through their roots from soil (Jia *et al.,* 2007).

The existing farming practices explores high yielding varieties and intensive, cropping pattern that required higher use of external inputs such as irrigation, pesticides and extent of soil contamination with heavy metals to make sustainable management strategies for agricultural soils (Mico *et al.,* 2006). The main sources of heavy metals in agricultural fertilizers, pesticide organic manure, disposal of urban and industrial waste and atmospheric pollution from motor vehicles and combustion of fossil fuels (zhang, 2006). Toxic heavy metal is entering the ecosystem may lead to geo-accumulation, or bioaccumulation and bio magnification (Miculescu *et al.,* 2011).

Heavy metals can also be very quickly translocated through the environment by erosion of the soil particles to which they are adsorbed or bound and re-deposited elsewhere (Qishlaqi and Moore 2007). The transport, cycling, fate, bioavailability and toxicity of heavy metals are markedly influenced by their physicochemical forms in water, sediments and soil (Shafi, 2005). Whenever a heavy metal or its compound is introduced into an aquatic environment, it is subjected to a wide variety of physical, chemical and biological processes. (Adeleke and abegunde *et al., 2011).* These include hydrolysis, chelation, complexation, redox, biomethylation, precipitation and adsorption reactions. (Sherameti and Varma, 2010). Often, heavy metals experience a change in the chemical form as a result of these processes and so their distribution, bioavailability and other interactions in the environment are also affected. They can leach into living systems from natural ore deposits and other sources such as waste disposal of heavy metal containing waste. In fact, waste disposal accounts for higher percentage of most heavy metals including manganese in the environment (Bhandari et al., 2007).

A comprehensive understanding of the heavy metal pollution in soil and plants have been conducted on several countries (singh, 2012) but few studies have been performed to assess the pollution grades of heavy metals in soil-food human chain and the health risk caused by heavy metals in soil. Therefore, the objectives of this study is to determine the contamination level of five heavy metals in soils and their translocation movement and bio-accumulation of these metals in beans plant.

MATERIALS AND METHODS

Study area

Sango Ota (6.7077 N 3.2560 E) is located in Ogun State, the south-western part of Nigeria. It is located at a distance of about 16.83km north of Lagos (Nigeria). The 2016 population projection reveals that there is about 733,400 people living in that town. The four main locations which were considered are agricultural, industrial, residential, and dump sites (figure 1).

Sample collection

A total of eight (8) soil samples were collected from areas representing agricultural, residential, industrial, and dump site in Sango. These samples were collected with the aid of clean hand trowel at 20 cm below the top soil, samples were then placed in a well labelled polyethene bags and was taken to the laboratory for treatment and analysis. The samples were air dried then sieved using a 2 mm mesh sized sieve. The sieved soils were transferred into polythene bags prior to laboratory analysis (Atiemo *et al.,* 2005). Some portions of the soil were used in planting beans seeds, which were carefully raised for three months, after they were harvested, the beans plants were separated into different parts (leaves, stems and root), The plant parts (leaves, stems, roots and seeds) samples were properly rinsed with water and then with deionized water to remove any attached soil particles. Afterwards they were being cut into smaller portion and placed in large clean crucibles and air dried at room temperature in enclosed chamber for about two weeks and then pulverized to fine powder using grinder. Powdered plant samples were collected in well labelled polythene bags and placed in a desiccator awaiting laboratory analysis (Nollet, 2011). 1g of samples (plants parts and soil) were weighed in a different 50 ml conical flask, then 10ml of aqua Regia mixture (HNO_3 and HCl ratio 1:3) was added to digest the samples and the mixture filtered and the filtrate made up to 50 ml mark, stored in previously cleaned respective plastic bottles in preparation for instrumental analysis of heavy metals with Atomic Absorption Spectrophotometer (Singh, 2012).

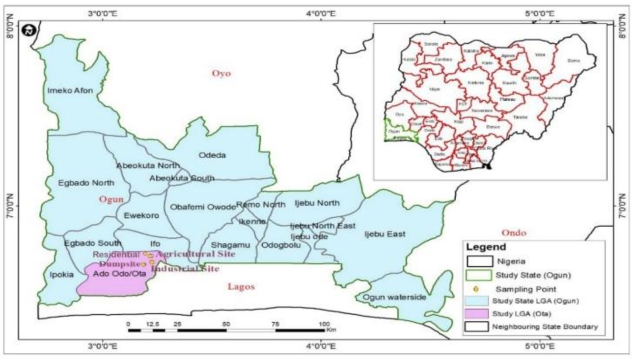

Figure 1: Map showing the studied locations and sampling point

RESULTS AND DISCUSSION

Assessment of Heavy Metals on the Soil Samples

The results of the heavy metals in the soil samples collected from agricultural, residential, industrial, and dump site in Sango are presented in Figure 2 to Figure 4. The results show that Pb ranged from 31.67-71.67 mg/kg, 288.00-566.67 mg/kg for Mn, 28.00-44.17 mg/kg for Cr, 0.35-1.28 mg/kg for Cd and 4.13-9.15 mg/kg for Ni.

Comparative Concentration of Heavy Metals on the Soil Samples

Results from the analysis of variance suggests that the concentration of Pb, Cr, Mn, Cd and Ni obtained across the locations are comparable thus, the difference between them are not statistically significant ($p>0.05$). On the other hand, significant difference exists in the manganese concentration across the levels with the highest level found in the dumpsite soil which is significantly different from the levels obtained in the other locations. Comparison of the concentration of the metals obtained as shown in the Figure 2 to Figure 4 with recommended standard shows that the soil samples from all location except the industrial location exceeded the WHO permissible limits for lead in soil; while the levels of chromium, cadmium, nickel and manganese in all the soil samples from the four locations were within the recommended limits. The elevated levels of some of the metals above recommended standard may pose a great threat to organisms in the soil and quality of human life surrounding the areas.

Conversely, the concentrations of all heavy metals (Lead, chromium, cadmium, nickel and manganese) recorded in soil samples from industrial site were within the WHO permissible limit; this could be attributed to the possible treatment of industrial effluents which by law industries are obliged to ensure to be below certain permissible limit before release into the environment.

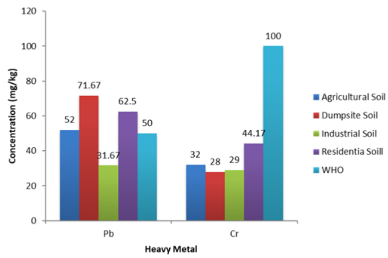

Figure 2. Comparative Concentration of Lead and Chromium in the Soils from Four Sources

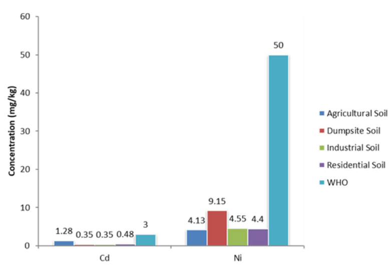

Figure 3. Comparative Concentration of Cadmium and Nickel in the Soils from Four Sources

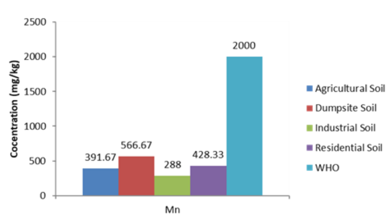

Figure 4. Comparative Concentration of Manganese in the Soils from Four Sources

Accumulation of Heavy metals in Bean Plant Tissues Raised on Different Soil Sources

The accumulation of heavy metals into the tissues of bean plant raised on soils collected from different sources was further assessed; data collected were presented as mean ± standard deviation of duplicate measurement (Table 1). A two-way analysis of variance and Duncan multiple range tests were used to assess the variation in the accumulation of heavy metals into the plants while considering the soil source and the plant parts as factors (Table 2). Similarly, metal accumulation was compared with the WHO (2001) standards for heavy metals in plants. Results from the analysis of variance revealed an interaction effect observed only in the concentration of Pb and Mn which suggests that the mean levels of the metal accumulated from each soil source is not consistent across the various plant's part and vice versa. Thus, Table 1 presents the mean concentration of heavy metals accumulated by the bean plant as influenced by the source of soil. The Pb accumulation ranged from 6.25-11.42 mg/kg where the root of the bean plant grown on the residential soil accumulated the highest level of Pb which is comparable with the level uptake in different parts of the plants grown in other soil source. Also, the concentration of Mn ranged from 16.50-76.75 mg/kg where the root of the plant raised in the agricultural soil accumulated the highest amount also comparable to that accumulated by the root of the plant raised on the dumpsite soil. The concentration of Cr ranged from 2.67-8.08 mg/kg; Cd ranged from 0.56-0.98 mg/kg and Ni ranged from 14.11-29.06 mg/kg. The mean concentrations accumulated by these three metals are consistent across both the soil source and plant parts. (Table 2 and Table 3).

Table 1. Mean Concentration of Heavy Metal Accumulation in Bean Plant Grown in Different Soils

Soil Source	Pb(mg/kg)	Mn(mg/kg)	Cr(mg/kg)	Cd*(mg/kg)	Ni(mg/kg)
Industrial	11.17±3.61	16.50±5.09	2.67±0.75^{a}	0.56±0.54	14.11±5.81^{a}
Dumpsite	6.25±5.68	66.08±32.17	3.58±1.02^{a}	0.81±0.22	22.39±4.72^{b}
Agricultural	8.67±3.60	76.75±36.20	8.08±1.86^{b}	0.98±0.67	29.06±2.32^{c}
Residential	11.42±2.56	29.33±12.36	2.67±1.47^{a}	0.74±0.49	17.67±1.10^{ab}
WHO	0.30	500.00	2.30	0.10	67.00

*** Not significant; means with the same superscript in same column are not significantly different (p>0.05)**

The level of uptake of cadmium from the soils from the four locations shows comparable levels which are not significantly different from each other. The accumulation of chromium suggests that the metal uptake by the plant was more intense in the agricultural soil where higher uptake was observed which is significantly different from the uptake in the other soil sources, similar trend was observed in the uptake of nickel by the plant, while the pattern of the uptake of lead and manganese was dependent on the soil source and the plant tissue accumulating the metals.

Accumulation of Heavy metals in Bean Plant Tissues as affected by Different Soil Sources

The result of the concentration of heavy metals in the three tissues (Leaves, stem, root) of bean plant as affected by four soils source shows that only the accumulation of Pb and Mn was dependent on the soil type and the tissue of the plant where Pb ranged from ND-14.25 mg/kg and Mn ranged from 11.25-122.00 mg/kg (Table 2). It was observed that lead accumulation into the root was highest in the residential soil which was similarly mirrored in the industrial soil. Trends in the manganese uptake show that the roots of the plants raised on the agricultural soil and dumpsite soil gave comparably highest manganese accumulation compared with the others. The levels of heavy metal uptake show that lead, chromium and cadmium were accumulated into the tissues of the bean plant at levels which exceeded the recommended limit for heavy metals in plant which may pose danger to both the plant and the potential consumers of the plant.

Heavy Metals Accumulation into the Various Plant Parts

The mean heavy metals accumulated into leaves, stem, and roots of the bean plant grown in different soil revealed that Pb accumulation ranged from 7.38-12.19 mg/kg; Mn ranged from 29.75-70.81 mg/kg; Cr ranged from 4.00-4.63 mg/kg; Cd ranged from 0.62-0.85 mg/kg while Ni ranged from 20.03-22.14 mg/kg (Table 3). The root was found to accumulate more of Pb, Mn and Cr. This is in agreement to the trend previously reported in soya beans (Zhuang *et al.,* 2013).

Comparable level of uptake was observed in Cr, Cd and Ni, the observed metal accumulation into the plant tissues shows that Pb, Cr, and Cd accumulated in different parts which are significantly above the

WHO permissible limits, thus, also highlighting the danger of heavy metal contaminated plants.

Table 2. Mean Concentration of Heavy metals in Bean Plant Tissues as Affected by Different Soil Source

Soil *Source*	Plant Part	Pb(mg/kg)	Mn(mg/kg)	Cr*(mg/kg)	Cd*(mg/kg)	Ni*(mg/kg)
Industrial	Leaves	12.25±3.18^{def}	21.25±1.06^{ab}	2.00±0.71	0.28±0.04	16.43±10.22
	Stem	8.00±4.24^{bcd}	11.25±3.89^{a}	3.00±0.71	1.25±0.07	14.45±5.94
	Root	13.25±2.47^{ef}	17.00±3.54^{a}	3.00±0.71	0.15±0.07	11.45±2.05
Dumpsite	Leaves	ND^{a}	46.75±13.79^{cd}	3.00±1.41	0.90±0.14	20.15±3.54
	Stem	6.25±1.77^{bc}	45.25±10.25^{cd}	4.25±1.06	0.73±0.11	25.30±7.85
	Root	12.50±1.41^{def}	106.25±6.01^{e}	3.50±0.71	0.80±0.42	21.73±3.08
Agricultural	Leaves	12.50±0.71^{def}	59.75±13.08^{d}	9.25±1.77	1.13±0.81	27.80±3.68
	Stem	4.75±1.06^{b}	48.50±8.49^{cd}	7.50±1.41	0.48±0.32	30.28±0.67
	Root	8.75±1.77^{bcde}	122.00±6.36^{e}	7.50±2.83	1.33±0.81	29.10±2.62
Residential	Leaves	9.50±2.12^{bcdef}	36.00±1.41^{bc}	1.75±0.35	1.10±0.28	16.63±1.24
	Stem	10.50±1.4^{cdef}	14.00±1.41^{a}	1.75±0.35	0.93±0.46	18.53±0.74
	Root	14.25±1.06^{f}	38.00±7.07^{bc}	4.50±0.71	0.20±0.14	17.85±0.49
WHO		0.30	500.00	2.30	0.10	67.00

*** Not significant; means with the same superscript in same column are not significantly different (p>0.05)**

Table 3. Mean Concentration of Heavy Metal Accumulation into Different Tissues of Bean Plant

Plant part	Pb(mg/kg)	Mn(mg/kg)	Cr*(mg/kg)	Cd*(mg/kg)	Ni*(mg/kg)
Leaves	8.56	40.94	4.00	0.85	20.25
Stem	7.38	29.75	4.13	0.84	22.14
Root	12.19	70.81	4.63	0.62	20.03
WHO	0.30	500.00	2.30	0.10	67.00

*** Not significant**

Comparative of Bioaccumulation of Heavy Metals into the Plants Tissues with WHO Standard

Comparison of the bioaccumulation of the heavy metals into the plants with WHO standards for heavy metals in plants shows that the amount of lead, chromium and cadmium accumulated into the plant tissues exceeded the WHO (2007) permissible limit for heavy metals in plants, same observation for the chromium accumulated from the agricultural soil; these suggest that soil samples that exceeded set limit for heavy metals may be a sink through which edible plants may translocate toxic metals into their tissue parts thus, posing danger to both the plant and the humans/animals that consumes such plant (lokeshappa et al., 2008). Furthermore, the high level of Pb, Cr and Cd recorded in agricultural site could also be attributed to the excessive usage of fertilizers, herbicides and other agrochemicals for plant growth, this result is similar to the previous work done by (Mohammed and Folorunsho, 2015)

CONCLUSION

This study has demonstrated the potential danger in cultivating edible plants on heavy metal contaminated soil; it further highlighted the need to constantly monitor the environment to prevent cases of contamination. Results from this study has shown that soils from our surroundings especially agronomic soil could be contaminated, while plant can also absorb these metals at levels above safe limit into their tissues. It is therefore essential to discourage cultivation of food product on potentially polluted soil sources, while agricultural soils need to be constantly monitored.

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