Available online at www.elixirpublishers.com (Elixir International Journal)

Pollution

Elixir Pollution 70 (2014) 24135-24139

ISSN: 2229-712X

Heavy metals distribution and bioavailability in soil and plant (*Cassia occidentalis*) of jega, jega local government kebbi state, Nigeria

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ARTICLE INFO

Article history:

Received: 4 March 2014;

Received in revised form: 25 April 2014;

Accepted: 7 May 2014;

Keywords

Heavy metals,

Bioavailability,

Cassia occidentalis,

Jega.

ABSTRACT

The levels of heavy metals (Cr, Cd, Pb, Cu, Co, Ni and Zn) in soil nd plant (cassia occidentalis) of jega town were determined using atomic absorption spectrophotometry. The sample area was divided into five units (JE, JC, JW, JN and JS) using stratified random sampling method. Results revealed significant ($p<0.05$) difference between the samples in terms of Cr, Pb, Cu, Co, Ni and Zn contents in soil with Cd showing no significance at 5% level of significance. Cr, Cd and Zn levels are of no significance ($p>0.05$) between the samples. However, high significance different ($p<0.05$) exists between the samples for the remaining metals. Pearson Product Moment Correlation showed that Pb in plant correlated positively with all other metals in the soil; with higher significance correlation at 1% level of significance between Pb in soil. However, Co and Cr in plant showed significant correlation with Pb and Zn in soil at 5% level of significance. However, results indicated that the area is moderately polluted based on the US EPA standard of heavy metals in soils.

Introduction

Heavy metal pollution in soil is one of the main ecological problems in the whole world (Gardea-Torresday *et al.,* 2005; Claus *et al.*, 2007). Soil, whether in urban or rural areas, represent a major sink for metals released into the environment from a variety of anthropogenic activities. Some of these metals will persist because of their immobile nature; others will be more mobile migrating to either ground water or plants (Nwajei and Iwegbue, 2007). Heavy metals are persistent contaminants of soils, coastal waters and sediments (Osakwe, 2009). Due to their non-degradability, they may persist for a long period in both aquatic and terrestrial environment. They may percolate through soil to reach groundwater, or may absorb by plants, including agricultural crops (Boularbah *et al.*, 2006).

As human activities began to undergo industrialization, the amount of waste known into the environment increased tremendously (Inuwa, 2004). Njoku and Ibe (2009) reported that "the industrialization of the world has increased the environmental 'load' of heavy metal toxins". The combination of population explosion and increasing level of industrialization and urbanization has significantly led to environmental pollution (Filazi *et. al.*, 2003).

Trace metals are introduced into the environment through a number of sources, some of which are; geological weathering, mining effluents, industrial effluents, domestic and urban rain water run-off , emission from vehicles, organic manuring, agricultural fertilizer and pesticide, air borne dust from industries and natural disaster (Liebemberg, 1972; Ndiokwere *et. al.*, 2006; Obahiagbon *et. al.*, 2007).

Soil serves as both a medium for contaminant accumulation and mobility. Upon getting into soil through dust, precipitation or other ways, contaminants accumulate in different combinations. From soil, they can enter plants and through them, the food chain. They can also migrate to surface, ground and underground waters and spread at large distances, re-enter food chains and poison organisms (Idzelis *et al.*, 2004). Heavy metals can disturb soil processes and sometimes cause soil degradation (Baltrenas *et al.*, 2003; Poszyler-Adamska and Czerniak, 2007).

Dahiru (2005) reported that the increased level of heavy metals in urban soil was related to the intensity of human activities and traffic volume. While NdioKwere*et. al* (2006) and Ekwumembo and Audu (2006) reported that the used of organic amendments (organic manure, inorganic fertilizer, pesticides and other agrochemicals) by man as a substitute to conventional fertilizer in agricultural land to enhance soil quality also contributed to the increase levels of heavy metals in soil.

The uptake of toxic heavy metals from contaminated soils by food and forage plants comprises a prominent path for such elements to enter the food chain and finally ingested by human. Ingestion and eventually accumulation of toxic heavy metals poses a threat to human health and should therefore, be minimized (Dieckmanni*et al.*, 2002). Plant growing in polluted environment can accumulate the toxic metals at high concentration causing serious risk to human health when consumed (Osakwe, 2009). The sources of heavy metals in plant are their growth medium (soil, air and nutrients) from which heavy metals are been taken up by roots or foliage (Okoronkwo *et. al.*, 2005).

The uptake of heavy metals by plants depends significantly on factors such as;

i. The concentration and chemical speciation of the metals in the soil solution
ii. The movement of the metals from a bulk soil to the root by diffusion or convection
iii. Metals absorption by the root
iv. Metals translocation within the plants and

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v. Some soils parameters such as; pH, soil organic matter (SOM), cat ion exchange capacity (CEC) etc.

Significant and positive correlation between cadmium in the soil and vegetables grown on the soil contaminated with the heavy metals has been reported (Algeria*et. al*., 1991).

Soil as a component of terrestrial ecosystems, being essential for the growth of plants is a dynamic system and subject to short term fluctuations, such as variation in moisture status, pH and release conditions and also undergoing gradual alterations in response to changes in management and environmental factors.(Abubakar *et. al.*, 2004)

Contamination of heavy metals in the environment is of major concerned, because of their toxicity, threat to human life and the environment. Therefore, the levels of these metals in soils require constant monitoring. The aim of the present work was to investigate relationsbetween contents of metals in soil and their accumulationin plant.

Materials and methods

All the reagents used were of analytical grade (Analar) and all the glassware used, containers and tools were washed with liquid detergent first, rinsed with 20% (v/v) nitric acid and finally rinsed with distilled water. The containers and glassware were kept in an oven at 105 ^{0}C until needed. Distilled water was used throughout the work.

Description of the Study Area

Jega town is the head quarter of Jega local government of Kebbi state. The local government is located in the Sudan and Guinea savanna zone of the central part of the state. Birnin Kebbi local government relatively bound it to the north, Kalgo local government to the west, Aliero local government to the east and Maiyama local government to the south. Geographically, Jega is located within the latitude of 12^0C 11^I 24^{II} N and longitudes 4^0 23^I 50^{II} E, with a population of approximately 200,000 inhabitants that are predominantly Hausa and Fulanis (Population census, 2006). Their major occupation are farming (Crop production and Animal rearing), blacksmithing, trading and other modern activities like welding, carpentering, automobile repairing with small percentage as civil servants (Yandaki and Suleiman, 2008).

Sampling and sample treatment

Soil Sampling

Stratified random sampling method was used. Each sampling area was divided into ten smaller units and from each unit; ten (10) samples were collected randomly at a depth of 10cm, mixed and homogenized. Cone and quartered method was used until a required (representative) sample was obtained. Clean polythene bags were used to transport the sample for laboratory analysis (Radojevic and Bashkin, 1999). The sampling areas were labeled as follows:

JE = Jega East
JW = Jega West
JN = Jega North
JS = Jega South
JC = Jega Central

Plant Sampling

The plant (*Cassia occidentalis*), was obtained from the same site where the soil sample was obtained using a method described in Radojevic and Bashkin, (1999) and Onomrerhinor, (2010).

Sample Treatment

Soil was air dried for 5 days. Foreign and non-soil materials were removed and the soil was crushed using pestle and mortar, passed through a 1.5mm mesh sieve. 1g of each soil sieved soil was put in a digestion tube. 10cm^3 of conc. H_2SO_4, 2cm^3 of 60% HClO4 and 1cm^3 HNO_3 were added to the sample. The digestion tube were placed in a block digester, heated to 105^{0}C until a clear fumes was obtained. The digest was then splashed with distilled water and allowed to cooled, filtered into a 50cm^3 volumetric flask and diluted to the mark with distilled water (Radojevic and Bashkin, 1999; Onomrerhinor, 2010; Orhue and Uza, 2010).

The plant samples were washed several times with distilled water and oven dried at 80^{0}C to constant weight. The plant was later homogenized using pestle and mortar and passed through a 1.5mm sieve. 2g of the sieved plant was digested in the same way as the soil (Osakwe, 2009; Onomrerhinor, 2010). The digested samples were used for metals analysis using flame atomic absorption spectrophotometer (AA6500).

Statistical Analysis

Data obtained were statistically analyzed using one-way analysis of variance (ANOVA) with SPSS version 10.0 statistical packages and reported as mean $\pm$ standard error of mean of six and three replicate analysis for soil and plant respectively. LSD test was applied to determine the direction of the differences between mean values at 5% level.

Results and discussion

The results of the heavy metals content in the soil is presented in table 1.

- Values were presented as mean ± standard error of mean of six replicate analysis
- Values within the same column with different superscripts are significantly ($p<0.05$) different

KEY

BDL = Beyond Detection Limit

The results indicated no significance ($p>0.05$) in between the sample in terms of chromium concentrations with JC having the highest concentration of 27.78±1.26mg/kg. The high value of chromium in JC may not be unconnected with the fact that the area is the commercial nerve centre of the town. Vehicular emission, waste dumping could also be sources in addition to natural factors due to its usage in dyes, paper and textile (Grubinger and Ross, 2012). The values from this work were far less than the values reported by Ekwumemgbo and Audu, (2006) and Mweghoha and Kihampa, (2010) in similar works.

The results revealed no significant ($P>0.05$) different in terms of cadmium concentration between the sample with the exception of sample JN which was significantly ($P<0.05$) different from other samples. The cadmium sources could be dumping of cadmium containing substances due its usage in plating, soldering and battery (Cranston, 1983). The known function of cadmium in the body has not yet established due to its toxicity. Cadmium have been considered more toxic than either lead or mercury. It is toxic at levels one-tenth that of lead. It inhibits release of acetylcholine, probably by interfering with calcium metabolism (Nriagu, 1984). However, cadmium concentration are within the normal range (0.1–11 mg kg−1) reported for the worlds soils (Sanchez-Camazano *et al*., 1994).All the samples have high concentration but lower compared to the value reported by Onomrerhinor, (2010) in similar work. The results showed no significance ($P>0.05$) difference between the samples except sample JE which was significantly ($P<0.05$) different. All the values fall within the range of 30-100mg/kg for urban agricultural soils (Webber, 1984).

The concentration of copper in all sample were low compared with the finding of Amusan *et. al.*, (2003) and Mweghoha and Kihampa, (2010) in similar works.

Table 1: Results of Heavy Metals Contents of Soil in Jega Town

Samples	Metals Concentration (Mg/Kg) Cr	Cd	Pb	Cu	Co	Ni	ZN
JE	21.76±2.69[ab]	3.38±0141[b]	5.09±0.76[ab]	3.18±0.59[ab]	20.30±1.10	1.52±0.01[a]	181.07±3.17
JW	25.91±1.65[b]	3.36±0.33[b]	12.00±3.07[c]	3.05±0.67[ab]	4.20±1.24	1.74±0.79[a]	100.37±2.37
JC	27.78±1.26[b]	3.48±0.39[b]	11.09±2.54[bc]	6.52±2.09[bc]	33.35±3	4.10±1.61[abc]	122.10±9.04
JN	23.12±1.89[ab]	1.16±0.26[a]	6.88±1.33[abc]	1.85±0.04[a]	BDL	4.44±1.85[abc]	56.63±1.10
JS	25.88±2.39[b]	3.01±0.31[b]	12.30±2.79[c]	1.57±014[a]	11.49±3.07	4.85±1.27[abc]	10.98±0.28

Table 2: Results of Heavy Metals Contents of in Plant (*Cassia occidentalis*) of Jega Town

Samples	Metals Concentration (Mg/Kg) Cr	Cd	Pb	Cu	Co	Ni	ZN
JE	16.17±2.77[b]	2.80±0.35[b]	2.50±0.50	4.61±0.11	6.06±2.52[ab]	12.66±2.27[c]	45.47±0.33[ab]
JW	2.87±1.61[a]	2.94±0.33[b]	0.50±0.00	2.54±0.05	1.87±0.00[a]	0.93±0.00[a]	40.76±0.55[a]
JC	5.83±1.91[a]	1.24±0.56[a]	5.17±1.74	4.28±0.89	17.00±5.00[abc]	1.92±0.50[a]	49.53±0.17[ab]
JN	4.91±0.73[a]	2.17±0.39[ab]	5.00±0.89	4.46±0.25	BDL	2.58±0.73[a]	45.47±0.17[ab]
JS	4.99±0.62[a]	2.83±0.55[b]	7.26±0.43	3.62±0.06	10.02±0.32[bc]	12.79±1.99[c]	47.03±0.09[ab]

Table 3: Pearson Product Moment Correlation Coefficients between Metals Levels in Soil and Plant (*Cassia occidentalis*)

Correlation

	Cr	Cd	Pb	Cu	Co	Ni	Zn
Cr	-0.09	0.18	0.219	-0.313	-0.262	-0.553	0.206
	0.655	0.368	0.273	0.111	0.187	0.003	0.302
Cd	0.179	-0.195	0.156	0.05	-0.065	0.195	0.155
	0.372	0.329	0.436	0.805	0.748	0.329	0.441
Pb	0.008	-0.058	0.715**	-0.084	0.446*	0.08	-0.047
	0.967	0.773	0	0.676	0.02	0.691	0.817
Cu	0.219	-0.12	0.322	0.004	0.13	-0.019	-0.186
	0.274	0.551	0.102	0.986	0.518	0.926	0.353
CO	0.248	-0.227	0.082	0.223	0.034	0.052	0.162
	0.213	0.254	0.684	0.264	0.867	0.797	0.42
Ni	-0.313	0.097	0.103	0.043	0.334	0.272	0.164
	0.112	0.632	0.609	0.83	0.088	0.17	0.413
Zn	0.384*	0.115	0.064	-0.094	-0.109	-0.139	-0.006
	0.048	0.569	0.753	0.043	0.588	0.491	0.975

* Correlation is significant at 5% level

** Correlation is significant at 1% level

The results are similar (p>0.05) in all the sample with the exception of samples JC. This could be linked to the used of copper containing substances especially by black smithers around the area

The concentration of cobalt ranges from 4.20 to 33.53mg/kg. The high concentration of cobalt was observed in sample JC. However, in JN either the metal was absent or it is below the detection limit of the machine. The sources of this metal could be due to wearing a way of cobalt alloys, tyres, and exhaust from vehicles and generating set (Adams, 2011). All the values were above the values reported by Marjanovic *et al.*, (2010) in similar work.

Even though nickel in soil occur naturally. The concentration found in this work was low when compared with the regulatory limit adopted by US EPA in soil (US EPA, 1993). The resultsrevealed high significance (P<0.05) difference between individual sample. The highest concentration of 181.07±3.12mg/kg was observed in JE with JS having the lowest concentration of 18.18±1.13mg/kg. The highest concentration in JE could be because of building construction taking place at the area due to the discharged of scrap zinc sheet to an open environment. The results tally with the finding of Ekwumemgbo and Audu, (2006).

- Values were presented as mean ± standard error of mean of three replicate analysis
- Values within the same column with different superscripts are significantly (p<0.05) different

KEY

BDL = Beyond Detection Limit

The chromium concentration in all the samples are similar (p>0.05) with the exception of JE which is significantly (p<0.05) different from the remaining samples.

Cadmium concentration was also found to exhibit no significance (p>0.05) between the samples. The results was in agreement with the finding of Ozores-Hampton, *et. al.*, (2005) and deviated from the results obtained by Howard *et. al.*, (2009) in similar works.

The concentration of lead was found to ranged between 0.17-7.26mg/kg in plant sample with JS having the highest concentration of 7.26±0.43mg/kg followed by JC and JN with 5.17±1.74 and 5.00±0.89mg/kg respectively. The high value of Pb in JS could be attributed to the dumping of refuge containing lead in the area, vehicular exhaust and emission from diesel/generator engine due to the use of lead (tetraethyl lead) as additive in petroleum (Tangahu, *et.al.*, 2011). The values obtained in this work were far greater than the value obtained by Howard *et. al*, (2009) in similar works. Accumulation of lead in the body has been linked to several disease which includes; anaemia, kidney and CNS dysfunction (Chilsholm, 1971). The lead concentration in the range of 100 – 1000mg/kg is required to causes visible toxic effects in plants (Aksoy, *et. al.*, 2000).

Copper concentration shows no significance (p>0.05) between the samples. Cobalt concentration ranges from 1.87-17.00mg/kg with the highest concentration observed in sample JC. While the cobalt was either, absent or beyond the detection limit of the machine in JN. Hence, no significant (p>0.05) difference exist between the samples. The nickel concentration are similar (p>0.05) between JN, JC and JW. Zinc concentrations are also similar (p>0.05) in plant between the samples

Results of correlation studies between the metals in soil and plant uptake showed positive correlation between the metals in almost all the metals. However, Cr correlated negatively between the metals with exception of Cd, Pb and Ni. Zinc also correlated negatively with the metals apart from Cr, Cd and Pb. The significance positive correlation was observed between Pb-Pb at 1% level of significance. Pb-Co and Zn-Cr also showed significance positive correlation at 5% level of significance.

Conclusion

The present research revealed that all the metals analysed were present in all the sampling area in both soil and plant (*Cassia occidentalis*). In addition, they metals were distributed differently in soil and plant of the sampling areas. In addition, the results revealed that there were significant (p<0.05) different in the distribution of some of the metals analysed. The research also revealed that the area is moderately polluted when compared with the US EPA maximum concentration of the heavy metals in soil. With all the metals having lower concentration compared with the US EPA standard.

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