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Tissues Accumulation of Heavy Metals by Maize (*Zea maize L.)* Cultivated on Soil Collected from Selected Dumpsites in Ekiti State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author EEA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors OSA and SSA managed the analyses of the study. Author SSA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The study examined the levels of heavy metals in tissues of maize (*Zea mays L*.), cultivated on four selected dumpsites in Ekiti State, Nigeria; with a view to discouraging constant cultivation of abandoned dumpsites.
Study Design: It is an analytical study.
Place and Duration of Study: The study was carried out in 2012 on selected dumpsites located in Ekiti State, Nigeria.
Methodology: Representative soil samples collected from four dumpsites located in Ekiti State were analyzed for pH, organic matter and heavy metals, prior to plant cultivation. After maturity, heavy metals concentrations were determined in various sections of plant, using flame absorption spectrophotometer. All determinations were carried out in triplicates using standard analytical procedures. The results obtained were subjected to statistical analyses.
Results: The results showed that these dumpsites were grossly polluted with heavy metals when

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compared with control sites in the range: Cd (21.9-138.0), Co (11.1-60.8), Cr (9.0-29.8), Cu (7.0-18.0), Fe (125.0-752.0), Pb (35.0-60.0), Mn (11.0-47.1), Ni (15.0-29.8), Sn (3.5-9.6) and Zn (63.0-80.2), all in mg/kg. Moderate values of soil pH and organic matter content revealed that maize could thrive well on mentioned dumpsites. However, the plant accumulated elevated concentrations of heavy metals in their shoot, when compared with the root, with Cr and Pb having higher concentration range of 101-104 mg/kg and 109.9-158.2 mg/kg respectively in its shoot at all dumpsites investigated.

Conclusion: Therefore, cultivation of arable crops on dumpsites should be discouraged as constant environmental monitoring is imperative.

Keywords: Heavy metals; maize tissues; soil; dumpsites.

1. INTRODUCTION

Attention has been given to heavy metals because of their long standing toxicity when exceeding specific thresholds. Their mobility in ecosystems and transfer in food chains are among the key issues in environmental research on heavy metals [1]. Technological development and the increased consumer use of heavy metal containing materials have resulted in increase in the extent of heavy metal contamination in the last fifty years [2]. Heavy metals contamination of the environment arises at all stages of metal utilization from mining of metallic ores to disposal of domestic and industrial wastes. Ultimately, these metals find their way in food chain and may subsequently be ingested by man [3].

In Nigeria, little progress has been made on waste management because of technological, financial and institutional constraints [4]. As a result, indiscriminate dumping of waste has become common practice; most dumpsites are located close to residential area, markets, roadside and farms [5]. Farmers have ignorantly cultivated some arable crops on abandoned dumpsites because of their fertility; most dumpsites have been reported to have high organic matter content which is one of the factors responsible for high soil fertility [5]. It is important to note that these crops tend to accumulate high levels of heavy metals when cultivated on contaminated soils when compared with uncontaminated soils [3,5,6]. Health risk leading to heavy metals ingestion has been widely reported [7-9].

Chaney et al. [10] indicated that subsistence farmers eating rice grain grown on contaminated sites throughout their lifetime are at risk from dietary exposure to cadmium. With greater awareness by the governments and the public of the implications of degraded environment on human and animal health, there has been increasing interest amongst the scientific community in the development of technologies to remediate contaminated sites [11]. Plants do not readily absorb large amount of heavy metals; the amount they absorb depends on their concentration, soil pH, species and variety of plant, the chemical composition of the soil, among other factors. Intake of vegetables and arable crops is an important path of heavy metals toxicity to human being. Dietary intake of heavy metals through contaminated arable crops may lead to various chronic diseases. Heavy metals bio-toxic effect depends upon their concentration and oxidation state, kind of sources and mode of deposition. Severe of cadmium may lead to pulmonary effects such as emphysema, brochiolitis and alveolitis [12]. Lead toxicity also caused reduction in heamoglobin synthesis, disturbance in functioning of kidney, joints, reproductive and cardiovascular systems and chronic damage to peripheral nervous system [13].

Maize *(Zea mays* L.*)*, or corn is a versatile cereal crop that is grown widely throughout the world in a range of agro-ecological environments. Maize is the most important cereal crop in sub-Saharan Africa (SSA) and an important staple food for more than 1.2 billion people in SSA and Latin America [14,15]. In Nigeria, maize is the most important staple cereal after sorghum and millet with the widest geographical spread in terms of production and utilization among the cereals [14,16]. Maize is grown in all parts of the country, though it is grown slightly more in the savannah belt of the country. About 50 species exist and consist of different colours, textures and grain shapes and sizes. White, yellow and red are the most common types. Maize is capable of continuous phytoextraction of metals from contaminated soils by translocating them from roots to shoots [17]. The maize plant has been even shown to accumulate certain heavy metals such as Cd [18] and Pb [19] above levels that define metal hyperaccumulation. Based on its capability of heavy metal uptake and sensitivity to high metal pollution, Máthé-Gáspár and Anton [20] have grouped maize as an accumulator and a metal tolerant plant especially for Cd and Zn.

Therefore the aim of this study was to determine the levels of heavy metals in tissues of maize cultivated on selected dumpsites in Ekiti State, with a view of discouraging the practice of cultivating on abandoned dumpsites.

2. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

The soil samples used in this study were collected in October, 2012 from four selected dumpsites; Aba Egbira (7.41° 288 ^{1}N; 5.15° 661^{1}E), Atikankan (7.37º 032^{1}N, 5.13º 263^{1}E) at Ado Ekiti and Igbehin street (7.29º 729^{1}N; 5.13º 263^{1}E), Moshood road (7.39º 363^{1}N; 5.13º 931^{1}E) at Ikere Ekiti, Ekiti State, Nigeria. The dumpsites were selected considering the volume and nature of waste, closeness to agricultural settlements and their age. They were randomly collected from top of each dumpsite (0-15 cm) to make a total of 40 samples (10 from each dumpsite). Control samples were also taken 500 m away from each dumpsite. The samples were characterized as sandy loam soil before air-drying and later mixed with mechanical shaker. They were made to pass through 4 mm mesh size to remove fibre and non-soil particulate in the soil samples. The pH of soil samples was determined immediately, after sample preparation and organic matter content of soil was also determined prior to planting [21].

In the determination of organic matter content of soil, 2 g of air-dried soil was placed into a porcelain dish which mass had already been determined. The dish and the content were placed in a muffle furnace and the temperature monitored until about 440℃ to constant weight. It was later transferred into desiccators, where it was allowed to cool overnight. The organic matter content of soil was calculated by difference.

The pH meter for the analyses was standardized using potassium hydrogen phthalate and ammonium buffer solution. 2 g of the soil sample was weighed into a 50 ml beaker and 20 ml of distilled water was added. The beaker was allowed to stand for 30 minutes during which it was stirred with a glass rod occasionally. The electrode of the pH was inserted to measure the pH and the value recorded.

Plastic pots 15 cm high and 25 cm wide was leached with 0.01M HNO_3: this was done to remove external heavy metals, after which previously sieved soil samples were added. Plant seeds for this experiment; bought from a local market were planted in each pot after proper identification by Plant Science Department Herbarium of Ekiti State University, Ado Ekiti. The pots were placed in green house, where they were constantly watered to field capacity on a daily basis and no fertilizer was added until maturity. The pots were placed on individual trays on which leached water are re-added to the bags in case of any loss to prevent heavy metals from leaching away. On maturity, the plants were harvested for onward laboratory analyses [21].

2.2 Soil and Plant Analysis

Harvested plants were immersed in 0.01M HNO_3 to remove external heavy metals and rinsed with distilled/de-ionized water for 1 min. They were subsequently separated into parts: root, stem, leaf and fruit, which were air-dried and later oven-dried at 70℃ until complete dryness. Plant samples were ashed in a furnace at 1200ºC, after digestion with dil. HNO_3while 3:1 conc. HNO_3:$HClO_4$ was added to soil samples and placed on hot plate, where digestion took place for 3 hours. Heavy metals concentrations in plant and soil samples were determined with flame atomic absorption spectrophotomer (Perkin Elmer, model 306) [3,5].

2.3 Data Analysis

All determinations were performed in triplicate. Statistical analyses were conducted using Analysis of Variance (ANOVA) procedures and the mean value separated by Duncan's Multiple Range Test (DMRT) using SPSS 15.0. Significant difference was observed between multiple treatments by LSD test, mean and standard deviation was also calculated. The soil-plant transfer factor, expressed as the ratio of plant metal concentration divided by the total metal concentration in soil and translocation factor, the ratio of contaminant concentration in shoot to roots were calculated.

3. RESULTS AND DISCUSSION

Table 1 presents the concentration of heavy metals on soil collected from selected dumpsites and control sites. Information from this Table revealed that the concentration of heavy metals were found in the following range; Cd (21.9-138.0), Co (11.1-60.8), Cr (9.0-29.8), Cu(7.0-18.0), Fe (125.0-752.0), Pb (35.0-60.0), Mn (11.0-47.1), Ni (15.0-29.8), Sn (3.5-9.6) and Zn (63.0-80.2), all in mg/kg. Fe has the highest concentration in all dumpsites investigated as well as in control sites. However, higher concentration of Fe has been reported in Nigeria soils [3,5]. These metals were not all detected in control sites, as they were lesser than the values observed in all dumpsites, where they were detected. This observation could be as a result of contribution of dumping activities to heavy metals content of dumpsites. Adefemi and Awokunmi [3] also reported that municipal solid waste disposal has contributed to the increase in heavy mIetals content of soil. pH and organic matter content of dumpsites were observed to be higher that of control site with the following values; pH (6.0-7.4, 5.5-5.6) and (7.7-9.8, 5.0-6.6), respectively. The higher values of organic matter content of dumpsites when compared to control sites were responsible for their higher pH values [22]. Fernandes and Henriques [12] reported that heavy metals are bioavailable mostly at lower pH.

Concentration of heavy metals in the tissues of maize (*Zea maize L.*) cultivated on soil collected from selected dumpsites in Ekiti State are presented in Table 2. The results revealed that heavy metals were accumulated mostly in the shoot of the plant when compared with root. The plant accumulated very high concentration of Cr; 101-104 mg/kg and Pb; 109.9-158.2 mg/kg in its shoot. The plant at Abaegbira dumpsite has the highest concentration of heavy metals when compared to other dumpsites; this could be as a result of moderately higher organic matter content of the dumpsite. Heavy metals accumulation pattern of maize was in sequence of root<stem<fruit<leaf, the highest concentration was observed in leaf. High heavy metals accumulating ability has been reported for cereal crop such as sorghum (*Shorghum bicolor*), alfalfa (*Medicago sativa L.*) [23]. Though the accumulating tendencies or efficiencies of these plants has been employed recently in environmental restoration [5,24,25], but peasant farmer are not encouraged from cultivating such plant on dumpsites for consumption as heavy metals may eventually enter food chain. The health risks that such habit could pose to plant and animals had been documented [7,8,13]. The results also showed significant differences in the concentration of heavy metals in tissues of plant on these dumpsites when subjected to LSD test at $p \leq 0.05$).

The results of heavy metals accumulation efficiencies of maize are presented in Tables 3 and 4. Information obtained from Table 3 revealed that all heavy metals were transferred from soil to plant on all dumpsites investigated with Cr, Pb and Cu having comparatively higher transfer factors. It was also revealed from Table 4 that all heavy metals investigated were translocated from root to shoot. Therefore, the higher the values of translocation factor, the more the tendencies for the plant to accumulate heavy metals in their tissues, most especially the fruit which is the edible part. Transfer and translocation factors are not only responsible for accumulation affeciencies as a particular plant may have varying accumulation efficiencies, which may depend on the overall physical and chemical properties of soil [23].

Table 1. Concentration of metals in the soil samples collected from selected dumpsites (mg/kg)

Metal	AB	CON	AT	CON	IG	CON	MO	CON
Cd	138.0	ND	60.0	ND	58.0	ND	21.9	ND
Co	60.8	ND	47.0	ND	51.0	ND	11.1	ND
Cr	23.0	ND	29.8	2.0	21.2	ND	9.0	ND
Cu	11.5	10.2	7.6	0.1	7.0	1.8	18.0	1.1
Fe	752.0	122.1	700.1	35.0	125.0	66.0	159.0	111.0
Pb	40.3	ND	60.0	ND	59.0	ND	35.0	ND
Mn	41.3	2.1	47.1	2.3	11.0	2.0	20.2	ND
Ni	25.2	1.8	29.8	2.0	21.2	ND	15.0	ND
Sn	9.6	1.6	7.6	1.8	7.0	2.0	3.5	2.0
Zn	80.2	3.6	73.5	0.8	63.0	0.9	71.1	ND
pH	6.8	5.6	6.5	5.5	6.0	5.5	7.4	5.6
OMC	9.8	6.6	8.7	5.5	7.7	5.0	8.9	6.2

AB: Aba Egbira; AT: Atikankan; IG: Igbehin MO: Moshood; CON: Control; OMC: Organic matter content

Table 2. Concentration of heavy metals in tissues of *Zea mays* (mg/kg)

		Root	Stem	Leaf	Fruit	Shoot	Total
Cd	AB	4.3_{a}	6.2_{a}	8.0_{a}	6.2_{a}	20.4	24.7
	AT	4.0_{a}	7.8_{a}	10.0_{ab}	6.4_{a}	24.2	28.2
	IG	3.2_{ab}	5.0_{a}	7.6_{a}	6.0_{a}	18.6	21.8
	MO	2.4_{ab}	5.6_{a}	4.8_{a}	5.2_{a}	15.6	18.0
Cr	AB	13.4_{a}	25.6_{a}	56.7_{a}	22.6_{a}	104.9	118.3
	AT	13.0_{ab}	24.8_{a}	56.2_{a}	22.4_{ab}	103.4	116.4
	MO	24.4_{b}	23.8_{ab}	55.6_{c}	22.3_{ab}	101.7	126.1
Fe	AB	9.1_{a}	10.1_{a}	14.5_{a}	9.6_{a}	34.2	43.3
	AT	8.2_{ab}	10.1_{ab}	14.5_{a}	9.6_{a}	34.2	42.4
	IG	20.1_{bc}	20.0_{c}	22.1_{ab}	9.8_{ab}	51.9	72.0
	MO	19.8_{c}	19.2_{ab}	17.2_{c}	17.2_{b}	53.6	73.4
Mn	AB	6.8_{a}	5.6_{a}	6.8_{a}	3.0_{a}	15.4	22.2
	AT	5.2_{ab}	5.2_{ab}	6.0_{ab}	3.0_{a}	14.2	19.4
	IG	4.8_{ab}	5.2_{ab}	6.0_{ab}	3.0_{a}	14.2	19.0
	MO	3.2_{b}	4.8_{c}	5.2_{b}	2.8_{a}	12.8	16.0
Pb	AB	16.2_{a}	46.2_{a}	76.0_{a}	36.0_{a}	158.2	174.4
	AT	14.2_{ab}	42.1_{ab}	72.1_{ab}	$36._{ab}$	150.2	164.4
	IG	10.2_{b}	30.0_{b}	69.1_{ab}	30.4_{ab}	129.5	139.5
	MO	9.8_{c}	19.2_{c}	58.6_{b}	32.1_{c}	109.9	119.7
Zn	AB	5.6_{a}	21.0_{a}	32.4_{a}	18.2_{a}	71.6	77.2
	AT	4.8_{b}	17.4_{ab}	30.6_{ab}	17.4_{ab}	65.4	70.2
	IG	3.2_{c}	17.0_{ab}	20.0_{b}	16.0_{b}	53.0	56.2
	MO	3.2_{d}	16.8_{b}	18.4_{c}	16.0_{b}	51.2	54.4
Ni	AB	3.3_{a}	5.2_{a}	7.0_{a}	5.2_{a}	17.4	20.7
	AT	3.0_{ab}	6.8_{ab}	9.1_{ab}	3.2_{ab}	19.1	22.1
	IG	2.7_{ab}	4.0_{b}	7.6_{a}	4.0_{bc}	15.6	18.3
	MO	1.4_{c}	4.6_{b}	3.8_{b}	3.2_{c}	11.6	13.0
Cu	AB	9.1_{a}	10.1_{a}	14.5_{a}	9.6_{a}	34.2	43.3
	AT	8.2_{ab}	10.1_{a}	14.0_{ab}	9.6_{a}	33.7	41.9
	IG	8.1_{ab}	10.0_{a}	13.8_{b}	8.0_{ab}	31.8	39.9
	MO	8.0_{ab}	9.1_{ab}	12.2_{c}	8.0_{ab}	29.3	37.3
Co	AB	1.2_{a}	3.8_{a}	4.8_{a}	3.2_{a}	11.8	13.0
	AT	2.4_{ab}	3.8_{a}	3.2_{ab}	3.1_{a}	10.1	12.5
	IG	1.0_{a}	2.4_{ab}	3.2_{ab}	3.1_{a}	8.7	9.7
	MO	1.8_{ab}	2.4_{ab}	3.0_{ab}	2.8_{ab}	8.2	10.0
Sn	AB	1.2_{a}	2.5_{a}	3.5_{a}	1.8_{a}	7.8	9.0
	AT	1.0_{a}	2.2_{a}	5.6_{ab}	1.4_{a}	9.2	10.2
	IG	1.0_{a}	4.0_{b}	2.0_{b}	1.3_{ab}	7.3	8.3
	MO	1.0_{a}	1.8_{ab}	1.8_{c}	1.3_{ab}	4.9	5.9

Values followed by different letters differ at p≤0.05 (LSD test); AB: Aba Egbira; AT: Atikankan; IG: Igbehin; MO: Moshood

Table 3. Transfer factors of heavy metals in *Zea mays* cultivated on selected dumpsites

	Cd	Cr	Fe	Mn	Pb	Zn	Ni	Cu	Co	Sn
AB	0.2	5.1	0.1	0.5	4.3	1.0	0.8	3.8	0.2	0.9
AT	0.5	3.9	0.1	0.4	2.7	1.0	0.7	5.5	0.3	1.3
IG	0.4	5.4	0.6	1.7	2.4	0.9	0.9	5.7	0.2	1.2
MO	0.9	4.0	0.5	0.8	3.4	0.8	0.9	2.0	0.9	1.7

AB: Aba Egbira; AT: Atikankan; IG:Igbehin street; MO: Moshood road

Table 4. Translocation factors of heavy metals in *Zea mays* cultivaated on selected dumpsites

	Cd	Cr	Fe	Mn	Pb	Zn	Ni	Cu	Co
AB	4.7	7.8	3.8	2.3	9.8	12.7	5.3	3.8	9.8
AT	6.1	8.0	4.2	2.7	10.6	13.6	6.4	4.1	4.2
IG	5.8	8.0	2.6	3.0	12.7	16.6	5.8	3.9	8.7
MO	6.5	4.2	2.7	4.0	11.2	16.0	8.3	3.7	4.5

AB: Aba Egbira; AT: Atikankan; IG: Igbehin street; MO: Moshood road

4. CONCLUSION

The study revealed that dumpsites are sinks for elevated levels of heavy metals. Maize has ability for accumulation of higher heavy metals levels in their shoots. It is important to note that if peasant farmers continue to cultivate maize and other arable crops on abandoned dumpsites, this will increase the levels of heavy metals which may eventually enter food chain and as a result mankind may experience possible health risk. However, regular environmental monitoring and restoration is imperative.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Coskun M, Steinnes E, Viladimirovna M, Sjobakk T, Demkina S. Heavy metal pollution of surface soil in the Thrace region, Turkey. Environ. Monit. Assses. 2006;119:545-556.
2. Majid A, Argue S. Remediation of heavy metal contaminated solid waste using agglomeration technniques. Miner Eng. 2001;14(11):1513-1525.
3. Adefemi OS, Awokunmi EE. Uptake of heavy metals by tomato (*Lycopersicum esculentus)* grown on soil collected from dumpsites in Ekiti State, South West, Nigeria. Int. J. of Chem. 2013;5(3):70-75.
4. Ojeshina OA. Sanitary and hazardous waste: Landfill as a waste disposal strategy for Nigerian settlement. A paper presented at a one day workshop as part of the activities to mark FEPA's 10th year anniversary, Nigeria; 1999.
5. Awokunmi EE, Asaolu SS, Ajayi OO, Adebayo AO. The role of EDTA on heavy metals phytoextraction by *Jatropha gossypifolia* grown on soil collected from dumpsites in Ekiti State, Nigeria. British Journal of Environment and Climate Change. 2012;2(2):153-162.
6. Eriyamremu GE, Asagba SO, Akpoboro Akpoboro A, Ojeaburu SI. Evaluation of lead and cadmium levels in some commonly consumed vegetables in Niger Delta oil area of Nigeria. Bulletin of Environmental Contamination and Toxicology. 2005;75:278-283.
7. Baker AJM, McGrath SP, Reeves RD, Smith JAC. Metal hyperaccumulator plants: A review of the ecology and physiology of a biochemical resource for phytoremediation of metal-polluted soils. In: Phytoremediation of Contaminated Soil and Water. N. Terry and G. Banuelos (eds.) Lewis Publ. Boca Raton, FL. 2000;85–107.
8. Duruibe JO, Ogwuegbu MDC, Egwurugwu JN. Heavy metals pollution and human biotoxic effects, International Journal of physical science. 2007;2:112-118.
9. Claire LC, Adriano DC, Sajwan KS, Abel SL, Thoma DP, Driver JT. Effects of selected trace metals on germinating seeds of six plant species. Water Air Soil Pollut. 1991;59:231-240.
10. Chaney RL, Reeves PG, Ryan JA, Simmons RW, Welch RM, Angle JS. An improved understanding of soil Cd risk to humans and low cost methods to phytoextract Cd from contaminated soils to prevent soil Cd risks. BioMetals. 2005;17:549–553.
11. Bolan NS, Ko BG, Anderson CWN, Vogeler I. Solute interactions in soils in relation to bioavailability and remediation of the environment, 5th International Symposium. Pucón, Chile; 2008.
12. Fernandes JC, Henriques FS. Biochemical, physiological, and structural

effects of excess copper in plants. Bot. Rev. 1991;57:246-273.
13. Gardea-Torresdey JL, Polette L, Arteaga SK, Tiemann J, Bibb JJ, Gonzalez H. Determination of the content of hazardous heavy metals on *Larrea tridentata* grown around a contaminated area, Proceedings of the Eleventh Annual EPA Conf. On Hazardous Waste Research, Edited by Erickson LR, Tillison DL, Grant SC, McDonald JP, NM: 1996;199:660.
14. The Nippon Foundation: Feeding the future, Newsletter of the Sasakawa Africa Association. 18:1 – 20. 2002. Available: http://www.saatokyo.org/english/newsletter/pdf/issue18.pdf.
15. International Institute of Tropical Agriculture, IITA Crops: Maize. Available: http://www.iita.org/crops/maize. 2010.
16. Omoloye AA. Field accumulation risks of heavy metals and uptake effects on the biology of *Sitophilus zea maize* (Coleoptera:Curculionide). African Scientist. 2009;10(2):75–88.
17. Nascimento CWA, Xing B. Phytoextraction: A review on enhanced metal availability and plant accumulation. Sci. Agric. (Piracicaba, Braz.). 2006;63(3):299–311.
18. Kimenyu PN, Oyaro N, Chacha JS, Tsanuo MK.The potential of *Commelina bengalensis*, *Amaranthus hybridus*, *Zea mays* for phytoremediation of heavy metals from contaminated soils. Sains Malaysiana. 2009;38(1):61–68.
19. Pereira BFF, de Abreu CA, Romeiro S, Lagôa AMMA, Paz-González A. Pb-Phytoextraction by maize in a Pb-EDTA treated oxisol. Sci. Agric. (Piracicaba, Braz.) 2007;64(1):52–60.
20. Máthé-Gáspár G, Anton A. Phytoremediation study: Factors influencing heavy metal uptake of plants. Acta Biologica Szegediensis. 2005;49(1–2):69–70.
21. Muchuwiti MJ, Birkett W, Chinyanga E, Zvauya R, Scrimshaw MD, Lester JN. Heavy metals content of vegetable irrigated with mixture of waste water and sewage sludge in Zimbabwe, Implications for Human health, Agriculture, Ecosystem and Environment. 2006;112:41-48.
22. Ogwuegbu MOC, Muhanga W. Investigation of lead concentration in the blood of people in copper belt province of Zambia, J. Environ. 2005;1:66-75.
23. Vijayarengan P. Nitrogen and potassium status of greengram (*Vigna radiata*) cultivars under nickel stress. Nature Environ. Pollut. Tech. 2005;4:65–69.
24. Sun YB, Zhou QX, Wang L, Liu WT. The influence of different growth stages and dosage of EDTA on Cd uptake and accumulation in Cd-hyperaccumulator (*Solanium nigrum L.).* Bull. Environ. Contam. Toxicol. 2009;348-353.
25. Yuebing S, Qixing Z, Yingming X, Vingming X, Lin W. Xuefeng L. The role of EDTA on cadmium phytoextraction in a cadmium-hyperaccumulator *Rorippa globosa*. J. of Environ and Eco. 2011;3(3):45-51.

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