

PHYTOREMEDIATION OF Pb, Cd AND As FROM URBAN SOLID WASTE COMPOST USING *TITHONIA DIVERSIFOLIA HEMNSL* AND *AGERATUM CONYZOIDES L*

Oyeyemi Adigun DADA¹, Olajumoke Oke FAYINMINNU², Temitope Opeyemi TAIWO¹

¹Department of Crop Production, Olabisi Onabanjo University, College of Agricultural Sciences, Yewa Campus, Nigeria

²Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria
Corresponding author e-mail: oadada247@yahoo.com

ABSTRACT

*Soil and water contaminated with heavy metals pose a major environmental and human health problem in Nigeria. This study was carried out to ascertain the presence of heavy metals in Urban Solid Waste Compost (USWC) and examined the potentials of *Tithonia diversifolia* and *Ageratum conyzoides* in remediating heavy metals constituents of USWC. The study was carried out in the crop garden of the Department of Crop Production, Olabisi Onabanjo University, College of Agricultural Sciences, Ayetoro. The trial was a completely randomized design with four replicates. The treatment was made of two plant species belonging to Compositae family and USWC obtained from three different dump site locations in Ayetoro and a control. Two seeds of the two plant species were sown in pots containing 20kg of USWC and grown for 12 weeks. Data were subjected to analysis of variance and means separated by LSD at $p \leq 0.05$. At the commencement of the trial, the concentration of Pb, Cd and As in the USWC from the three dumpsites averaged 15mg/kg, 0.53mg/kg and 0.15mg/kg respectively. Post trial analysis showed that Pb, Cd and As contents of the USWC was reduced by 97.99%, 75.90% and 11.69% respectively. Uptake of Pb ($t_{\alpha=0.05} = 0.36$), Cd ($t_{\alpha=0.05} = 0.64$), and As ($t_{\alpha=0.05} = 0.91$) by the two plant species were not significantly ($p < 0.05$) different. Partitioning of the pollutants was more in roots (Pb = 15.15 mg/kg, Cd = 0.57mg/kg and As = 0.13mg/kg) than shoots (Pb = 14.89mg/kg, Cd = 0.49mg/kg and As = 0.15mg/kg). The implication of the results for the quality of arables produced at urban and peri-urban roadside gardens as well as human health and environmental problems are discussed.*

KEYWORDS: heavy metals, urban solid waste compost, Compositae, phytoremediation

INTRODUCTION

Soil contamination is a major environmental concern resulting from disposal of industrial and urban wastes generated by human activities. Controlled and uncontrolled disposal of wastes, accidental and process spillage, mining and smelting of metalliferous ores, sewage sludge application to agricultural soils are responsible for the migration of contaminant into non – contaminated sites as dust or leachate compost which contribute towards contamination of our ecosystem. Heavy metals are important environmental pollutants and many of them are poisonous even at low concentrations.

Environmental pollution by heavy metals has accelerated since industrial revolution and it is one of the most important issues for human being (Memon *et al.*, 2001).

Chang (1992) reported bioaccumulation of lead in the human body is responsible for impaired respiration and also cause constipation, anaemia, swelling of the brain, paralysis and death, while that of cadmium is implicated in hypertension and cardiovascular diseases. Needleman *et al.* (1996) reported that Lead can have biochemical effects on the synthesis of haemoglobin and cause acute or chronic damage to the nervous system, reproductive system, kidney, joints, gastrointestinal tract and loss of 20% intelligence quotient (IQ) at blood level of 10-12 µg/dl in young children. Cadmium is reported to be biopersistent and has effect on renal dysfunction in human after a long-term exposure (CDC, 1991; Ahumada, 1998). Arsenic poisoning is related to heart disease (Tseng *et al.*, 2003), (hypertension related cardiovascular), cancer, (Smith *et al.*, 1992), stroke (cerebrovascular diseases) (Chiou *et al.*, 197), chronic lower respiratory diseases (Hendryx, 2009), and diabetes (Navas-Acien *et al.*, 2008, Kile and Christiani, 2008).

Reuse of organic wastes is considered desirable, in general, for resource management and nutrient cycling, while reuse is seen as a way for urban authorities to substantially reduce the amount of waste requiring disposal and treatment. All farmers recognize the need for organic soil amendments and most prefer organic matter (even if derived from municipal waste) to chemical fertilizers (Brook and Davila 2000). In many cases however, consumption of produce from crops that uptake heavy metals such as Pb, Cd and As in municipal solid waste compost has endangered human and livestock health.

Consequently, diverse methods are applied to reduce water and soil pollutants. However, most of the methods are expensive and time consuming and not sufficient for controlling the contamination. Several works have presented diverse means that could be used to stabilize, recover, or volatilize pollutants in contaminated soil (Novelli, 1997; Van Huysen *et al.*, 2004). One of such techniques is phytoremediation. Phytoremediation, an emerging cleanup technology for contaminated soils, groundwater, and wastewater that is both low-tech and low-cost, is defined as the engineered use of green plants (including grasses, forbs, and woody species) to remove, contain, or render harmless such environmental contaminants as heavy metals, trace elements, organic compounds, and radioactive compounds in soil or water. (Raskin *et al.*, 1994, Salt *et al.*, 1995, Salt *et al.*, 1998). This technology makes use of the naturally occurring processes by which plants and their microbial, rhizosphere flora degrade and sequester organic and inorganic pollutants (Lasat, 2000).

The ideal type of phytoremediator is a species that creates a large biomass, grows quickly, has an extensive root system, hyperaccumulators of a wide range of toxic metals and must be easily cultivated and harvested (Clemens *et al.*, 2002). Plants belonging to Asteraceae or Compositae family display tendencies synonymous to an

ideal phytoremediator species. Mexican sunflower (*Tithonia diversifolia* Hemsl.) and Goat weed (*Agerantum conyzoides* L.) are good examples of such plants belonging to this family, they are widely distributed in the tropics from Mexico to Brazil, and also found in Asia and Africa. Both plants are weeds of agricultural importance that are commonly classified as ruderals and agresters respectively. Much has been published, not only on systematics (at various levels), but on biology, chemistry, and economic and medical uses of Asteraceae worldwide (Samir *et al.*, 2009) but little is known on the phytoremediation capability of some members of this family.

It is therefore necessary for research into remediation potentials of some members of this plant family in cleaning up contaminated soils and making them available for useful purposes. Hence, this study was conducted to generate useful information on the utilization of these two weed plants of Compositae or Asteraceae family in the uptake of some heavy metals pollutants from compost derived from urban solid waste. The result from such researches like this may offer the remediation solution for various contaminated soils. The result may also be useful for peri-urban farmers on the need to remediate composted solid waste to be used for growing arable crops especially vegetables.

MATERIALS AND METHODS

The study was carried out in the Crop Garden of Department of Crop Production, the College of Agricultural Sciences, Olabisi Onabanjo University, Yewa Campus, Ayetoro. Ayetoro is located 35km northwest of Abeokuta on latitude 7^o12' N and longitude 3^o 0'E. The experiment was conducted in 2009. The plants were grown for 12 weeks between 2nd of May to 8th of July. The laboratory analysis lasted for 4 weeks in August 2009.

Collection of soil samples

Urban solid waste compost (USWC) was obtained from three purposively selected different dumpsites across Ayetoro environ where peri-urban farming are being practiced on yearly basis. A systemic sampling technique (equal probability method) was used to select the dumpsites. There were three categories comprising of densely, moderately and thinly populated areas. 20kg each of the USWC and fallowed agricultural field soil (Control) were collected from three dumpsites: (a). Joga – densely populated (b). Saala - moderately populated and (c) Oke-ola – thinly populated. Soil for the control study was obtained from a field at the Teaching and Research Farm of College of Agricultural Sciences. Plastic pots of 60 cm height, and 40cm width was used for the study. The pots were perforated at the base to allow drainage of excess water during watering. The pots were filled with the composted materials up to 58cm to allow watering.

Experimental design. The experimental design used for the study was a Completely Randomized Design (CRD). The pots were laid out in a CRD and replicated four times.

Soil analysis. USWC and Soil samples obtained from the various locations were taken to laboratory for chemical analysis to determine the composition of the Pb, Cd and As in the samples before planting. Post planting soil analysis was carried out to determine heavy metal composition after tested plant species had been harvested.

Planting and maintenance

The seeds for the study were obtained from uncontaminated sites to be sure that the seeds were free of pollutants. Seeds of the plants were sown by broadcasting into each pots. 14 days after emergence Mexican sunflower plant was thinned to one plant per pot while Goat weed plant was thinned to two plants per pot. The plants were grown till they flower. The pots were adequately watered as required and unwanted plants were constantly rouged from each pot regularly.

Determination of heavy metal composition (Pb, Cd and As)

Determination of heavy metal composition was carried out at the Central Laboratory Unit of Institute of Agriculture Research and Training, Ibadan (IAR&T). Shoots and roots were further dried in a ventilated oven for approximately 78 hours at 60°C to constant weight and later ground. The ground materials were ashed in a muffle furnace at 600°C for 3 hours. The digest of the ash of each sample was washed in 100 ml volumetric flask with deionised water made up to mark. This diluents was aspirated into the Buck 200 Atomic Absorption Spectrophotometer (AAS) through the suction tube. Each of the elements was read at their respective wavelengths with their respective hollow cathode lamps using appropriate fuel and oxidant combination.

Data analysis

The data collected were statistically analysed using Analysis of Variance (ANOVA) as described by Gomez, and Gomez (1984) and t-test. Differences in means were separated using Least Significant Difference (LSD) at P = 0.05.

RESULTS

Table 1 presents the results of pre-study analysis of USWC and control soil from four different locations. The results showed that there is significant ($P \leq 0.05$) difference in heavy metal composition in the USWC across the different locations in the study area. Composted materials collected from Joga and Saala had significantly higher concentrations (mg/kg) of Pb (20.58 and 19.15), and Cd (0.79 and 0.61) respectively. However, soil obtained from College of Agricultural Sciences field which served as the control had the lowest concentration of heavy metals. Lead, Cadmium and Arsenic were detected in all USWC samples analyzed at the commencement of study including control samples.

Accumulation of heavy metals from urban solid wastes compost by *A. conyzoides* and *T. diversifolia* is presented in Table 2. The results show that there is no significant different in uptake of Pb, Cd and As by the two plant species. However, highest concentration of Pb (16.86mg/kg), Cd (0.50mg/kg) and As (0.12mg/kg) uptake was observed in *Ageratum conyzoides*.

Figure 1 revealed that uptake of these metals was more in the roots than shoots of the plant species investigated in this trial. Meanwhile Pb concentration was higher in the root and shoot of *T. diversifolia* than *A. conyzoides* (Fig.2). However, *A.conyzoides* accumulated highest concentration (mg/kg) of Cd and As in both shoot and root portions.

Results in Table 3 presents the post study composition of heavy metals in urban solid wastes compost collected from three locations and a fallow field in Ayetoro. Post planting soil compost analysis reveals that compost collected from Joga had significantly higher concentration (mg/kg) of heavy metals than any other location. The concentration (mg/kg) of heavy metals from Joga dump sites was significantly higher in Pb (0.23) but not higher than that observed in Oke-oyinbo compared to Joga dump sites. Control (Soil from fallow field) had the least concentration (mg/kg) of Pb (0.41), Cd (0.08), as well as As (0.07).

TABLE 1. Pre-study analysis of heavy metals in of urban solid wastes compost obtained from three dump sites and control soil

Dump sites	Heavy metals (mg/kg)		
	Pb	Cd	As
Control soil	9.05b	0.34b	0.09 b
Joga	20.58a	0.79a	0.22a
Saala	19.15a	0.61 a	0.13b
Oke-oyinbo	11.26b	0.38b	0.12b
LSD (p = 0.05)	9.81	0.40	0.07
SE (±)	2.64	0.11	0.22

Figures with similar alphabets along the column are not significantly different at P=0.05

TABLE 2. Accumulation of heavy metals from uswc by *Ageratum conyzoides* and *Tithonia diversifolia*

Heavy metals	Plant types	concentration (mg/kg)	SEM (±)	$t_{\alpha = 0.05}$	
Lead	<i>Tithonia diversifolia</i>	15.42	3.15	0.36	NS
	<i>Ageratum conyzoides</i>	16.86	2.46		
Cadmium	<i>Tithonia diversifolia</i>	0.41	0.10	0.64	NS
	<i>Ageratum conyzoides</i>	0.50	0.11		
Arsenic	<i>Tithonia diversifolia</i>	0.09	0.03	0.91	NS
	<i>Ageratum conyzoides</i>	0.12	0.03		

NS= not significant SEM = Standard error of mean (±)

DADA *et al*: Phytoremediation of Pd, Cd and As from urban solid waste compost using *Tithonia diversifolia* Hemnsl. and *Ageratum conyzoides* L.

TABLE 3. Post- planting analysis of heavy metals in of urban solid wastes compost obtained from three dump sites and control soil

Dump sites	Heavy metals (mg/kg)		
	Pb	Cd	As
Control soil	0.14c	0.08c	0.07c
Joga	0.23a	0.15a	0.21a
Saala	0.18ab	0.12b	0.13bc
Oke-oyinbo	0.21ab	0.13ab	0.15ab
LSD (p = 0.05)	0.08	0.02	0.08
SE (\pm)	0.01	0.01	0.02

Figures with similar alphabets along the column are not significantly different at $p = 0.05$

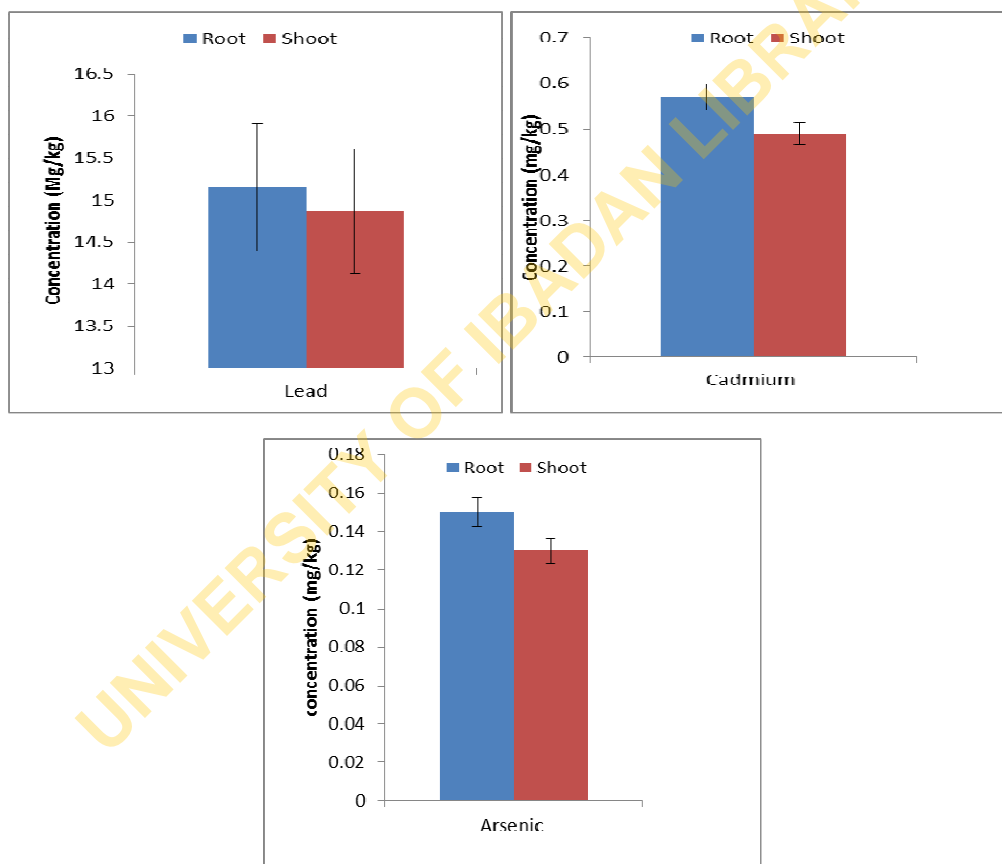


FIG.1. Concentration (mg/kg) of heavy metals in root and shoot of plants use for remediating UWSC
 \bar{I} = Standard error bar (5%)

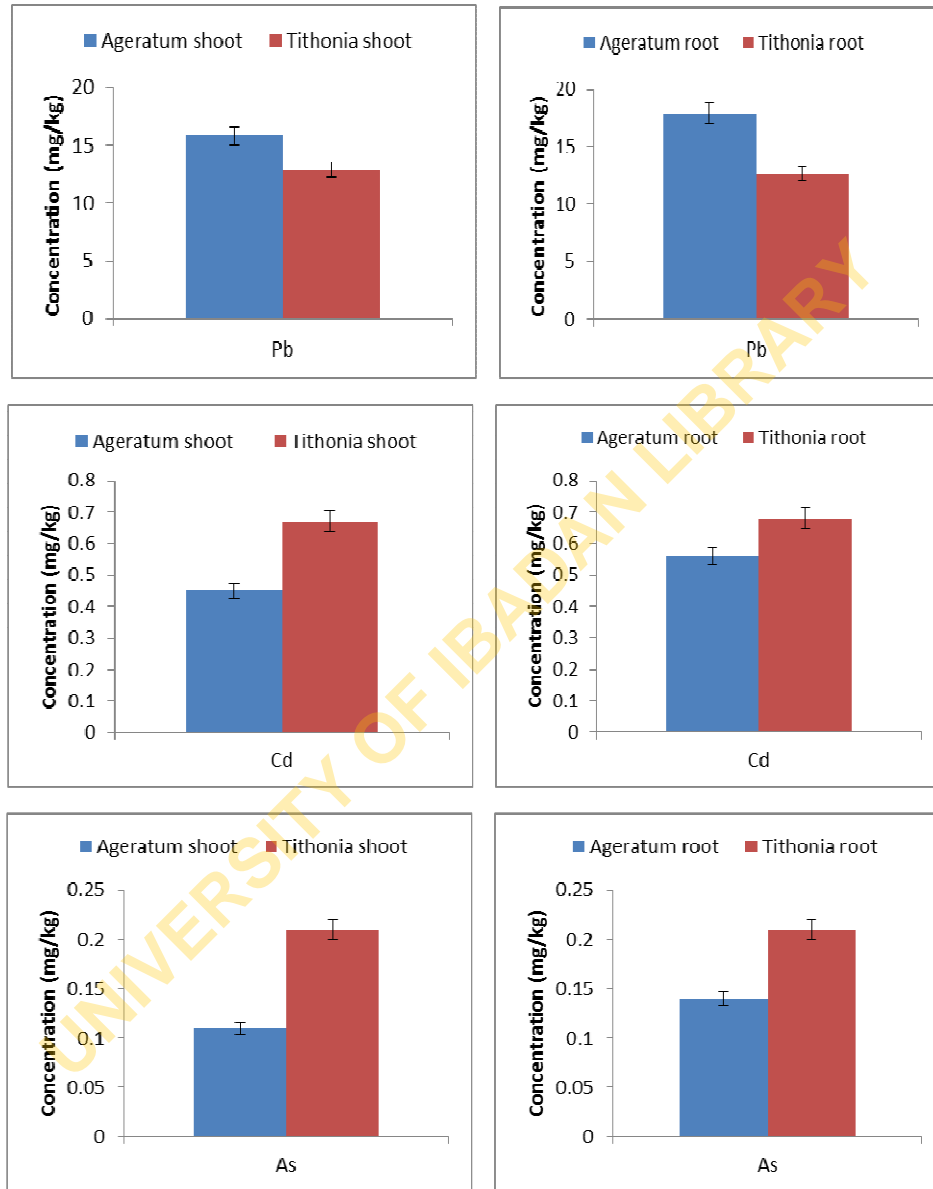


FIG 2. Concentration of heavy metals in shoot and root of two plant species grown on uswc
 \bar{I} = Standard error bar (5%)

DISCUSSION

The presence of heavy metals in this USWC samples obtained from different dumpsites suggests that these sites are potentially unsuitable for peri-urban farming

has they portend health and environmental hazard for human and livestock who consume crop grown on these sites. Ogunyemi *et al.* (2003a) reported accumulation of Pb and Cd in the shoots and roots of *Amaranthus cruentus* grown in soils from landfill sites with concentration higher than the optimum allowed by FAO/WHO for dietary consumption (FAO/WHO, 1978). Consequently such sites must be cleansed off these toxic pollutants before they could be suitable for farming activities. Detection of heavy metals in the control soil suggests that deposition is likely to be from vehicular exhaust, agrochemicals such as herbicides, insecticides, fertilizers, etc. and domestic erosion from adjoining community might have added the heavy metals to the soil. This is in consonance with the reports of Egunjobi (1989) and Ogunyemi *et al.* (2003b).

The similarity in the concentration of heavy metals in the tissues of the two plant species is a pointer to the fact that plants belonging to Compositae family possess traits that has the ability to accumulate heavy metal from contaminated soil. This is possibly owing to effectiveness of these species to translocate metal from the roots to the harvestable shoots. This agrees with the submission of Dollhopf (2000).

The two plant species seems to employ phytoaccumulation principles in accumulation metallic pollutants. Wenzel (2005) described phytoaccumulation as process where fast growing species and pollutant-accumulating plants are used to remove metals or organics from soils by concentrating them in the harvestable parts. Also, it appeared as if *A. conyzoides* is more efficient in accumulation of heavy metals than *T. diversifolia* especially lead accumulation where higher concentration (mg/kg) was observed in the shoot portion. Our observation agrees with that of Arthur *et al.* (2005), who reported that it is preferable to have the metal accumulated in the shoots of metal accumulating plants than in the roots.

Significantly higher concentration of heavy metal in compost collected from Joga after planting suggests that time needed to clean up a polluted site differs depending on the quantity of pollutants in the composted materials. This suggests that heavy metals retention period is likely to be higher for compost collected from this site. This is in line with the observation of Fritioff and Greger (2003) where they observed that availability of dissolved metals for uptake depend on the amount of organic in the system, retention time, pH, redox likelihood and particle bound metals. Hence the need for further remediation of such USWC before it could be put to agricultural uses.

CONCLUSION

The USWC investigated contains Pb, Cd and As which makes crops grown on this sites unfit for human and livestock consumption because of harmful effect of these pollutants on human health. Although, the contamination levels in all the treatments were below the hazardous threshold of 250 ppm for Pb and 3.0 ppm for Cd and 70 to 200 mg or 1 mg/kg/day for arsenic (DOE/NWC, 1981, and Dart, (2004) but the level of pollutants in the USWC could attain dangerous level over time if left unremediated.

Pollutant constituents could perhaps biomagnify in the living tissue of humans and livestock when crops grown on it are consumed. The two plant species belonging to Compositae family reduced the pollutants concentration appreciably whereby Pb, Cd and As contents of the USWC was reduced by 97.99%, 75.90% and 11.69% respectively. Uptake of pollutants was more in root than shoot of both plants. *Ageratum conyzoides* accumulated heavy metals in than *Tithonia diversifolia*. Both plant species could be used in phytoremediation of Pb, Cd and As contaminated composted solid waste before being used for growing crops.

ACKNOWLEDGEMENTS

The authors acknowledge the staff and management of Analytical Laboratory of IAR&T Ibadan for their contributions in the area of soil and plant analysis.

REFERENCES

- Ahumada H. T., 1998. Health condition in population living near waste recycling plant in Mexico. *Pan A.M.J. Public Health* 3:15-30.
- Brook R, Julio D. 2000. *The Peri-Urban Interface: A Tale of Two Cities*. Bethesda (Wales): University of Wales and University College London.
- Centre for Disease Control (CDC). 1991. *Preventing lead poisoning in young children*. U.S. Department of Health and Human Service. Atlantic GA. Public Health Service Centres for Disease Control.
- Chang L.W., 1992. The concept of direct and indirect neuro toxicity and concept of toxic metal/essential element interactions as a common biomechanism underlying metal toxicity, In: *The vulnerable brain and environment risk*, Vol. 2, Toxins in Food. Plenum Press, New York. Pp. 61.
- Chiou HY, Huang WI, Su CL, Chang SF, Hsu YH, Chen CJ, 1997. Dose-response relationship between prevalence of cerebrovascular disease and ingested inorganic arsenic. *Stroke* 28 (9): 1717–23.
- Clemens S, Palmgren M. G., Kramer U. 2002. A long way ahead: understanding and engineering plant metal accumulation. *TRENDS in Plant Science* 7(7), 309-31.
- Dart R. C. 2004. *Medical toxicology*. Philadelphia: Williams & Wilkins. pp. 1393–1401.
- DOE/NWC, 1981. *Report of the sub-committee on the disposal of sewage sludge to land*. Standing Tech. Committee Report No. 2, Dept. of Environment. London.
- Dollhopf D.J., 2000. Plant growth on saline and acidic borrow soils. *Bozeman Montana. Reclamation Research Unit. MSU, Bozeman*. P.89.
- Fritioff A, Gregger M. 2003. Aquatic and terrestrial plant species with potentials to remove heavy metals from stormwater. *International Journal of Phytoremediation* 5(3) 211 – 224.
- Gomez A. K., A. A. Gomez. 1984. *Statistical procedure for Agricultural Research*. 2nd Edn. pp: 680.
- Hendryx M, 2009. Mortality from heart, respiratory, and kidney disease in coal mining areas of Appalachia. *Int Arch Occup Environ Health* 82 (2): 243–9.
- Kile M.L, Christiani D.C. 2008. Environmental arsenic exposure and diabetes. *JAMA* 300 (7): 845–856.
- Lasat M.M. 2000. Phytoextraction of metals from contaminated soil: a review of plant/soil/metal interaction and assessment of pertinent agronomic issues. *Journal of Hazardous Substance Research* 2, 1-25.
- Navas-Acien A, Silbergeld E.K, Pastor-Barriuso R, Guallar E, 2008. Arsenic exposure and prevalence of type 2 diabetes in US adults. *JAMA* 300 (7): 814–822.

DADA et al: *Phytoremediation of Pd, Cd and As from urban solid waste compost using Tithonia diversifolia Hemnsl. and Ageratum conyzoides L.*

- Needleman H. L., Riess J. A., Tobin M. J., Biesecker G. E., Greenhouse J. B., 1996. Bone lead level and delinquent behavior. *Journal of American Medical Association* 275: 363-369.
- Novelli L.R. 1997. Phytoremediation - What It Is and What It Does. *Scrap* 54(2):173-181.
- Ogunyemi S., Awodoyin R. O., Opadeji T., 2003b. Urban Agricultural Production: Heavy metal contamination of *Amaranthus cruentus* L. grown in domestic refuse landfill in Ibadan, Nigeria. *Emirates Journal of Agric. Sc.* 15(2): 87-94
- Ogunyemi S., Bamgbose O. O., Awodoyin R.O., 2003a. Heavy metal contamination of some leafy vegetables growing within Ibadan metropolis, Southwestern Nigeria. *Tropical Agricultural Research and Extension*, 6:71-76.
- Raskin I., Ensley B.D. 2000. *Phytoremediation of Toxic Metals. Using Plants to Clean Up the Environment* – John Wiley & Sons, Inc., New York; pp 53-70
- Samir A. M. Abdelgaleil, Neama Abdel-Razeek, Salah A. Soliman. 2009. Herbicidal activity of three sesquiterpene lactones on wild oat (*Avena fatua*) and their possible mode of action *Weed Science* 57(1):6-9.
- Smith A.H, Hopenhayn-Rich C, Bates M.N, 1992. Cancer risks from arsenic in drinking water. *Environ. Health Perspect.* 97: 259–67.
- Tseng C.H, Chong C.K, Tseng CP, 2003. Long-term arsenic exposure and ischemic heart disease in arseniasis-hyperendemic villages in Taiwan. *Toxicol. Lett.* 137 (1-2): 15–21.
- Wenzel, W. 2005. Mycorrhizal function under heavy metal pollution. Institute of soil Science, University of Agricultural Sciences, Vienna, BOKU, Australia. <http://www.rhizo.at/default.asp?id=759&lid=2>.