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Research Article

Impact of Togo's Urbans Solids Wastes Sorting and Composting on the Total Content of Heavy Metals

[1]E.K. Koledzi, [2]K.N. Segbeaya, [1]M. Tcha-Thom, [2]G. Baba, [3]G. Matejka and [1]G. Tchangbedji

[1]Université de Lomé, FDS, Laboratoire GTVD (Gestion, Traitement et Valorisation des Déchets), B.P. 1515 Lomé, Togo
[2]Université de Kara, B.P. 404, Kara, Togo
[3]Université de Limoges, ENSIL, Groupement de Recherche Eau, Sol et Environnement (GRESE), 87068 Limoges Cedex, France

Abstract

Background and Objective: Metals may constitute problems in waste management because of their multiple sources and potentially high toxicity of some constituents. Processes of composting do not always guarantee acceptable quality of the compost in terms of hazardous metals. The aim of this study is to assess the balance of some heavy metals during the composting of different categories of urban waste. **Methodology:** Sorting and composting were used to separate the waste into different categories. Leaching test with EDTA solution were used to extract and study the speciation of Pb. The AFNOR recommendation were applied for determining the amount the heavy metals meet in Togo's waste and during composting. **Results:** The results showed that, the fraction of the super fines for example with a particle size of less than 10 mm, contributes 30-56% of the total and average contents of metals in compost. Sorting of waste into various fractions such as plastics, hazardous materials, glass, miscellaneous combustible material, metals and super fines lowers the metal contents in finished compost by about 80%. The remaining 20% can be washed during the fermentation of windrows or still better can be reduced by chemical complex formation in the compost as shown by the leaching adequate test. The average content of metals is classified as followed: Cd<Ni<Cu<Zn<Pb. Only the Pb content exceeds the level of the French standard (AFNOR). The higher the rate of organic matter is the lower rate of extraction. **Conclusion:** Thus, contamination can largely be avoided by separating the organic waste from other residues prior to composting. This, will provide the necessary arguments to convince the populations to subscribe to programs of management of specific waste as for example the elimination of super fines in the waste in the case of Lomé.

Key words: Waste sorting, composting, heavy metals, leaching test, lead extraction

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Corresponding Author: E.K. Koledzi, Université de Lomé, FDS, Laboratoire GTVD (Gestion, Traitement et Valorisation des Déchets), B.P. 1515 Lomé, Togo Tel: +228 90 19 85 35

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Metals contamination in solid waste cities, soil and groundwater is a worldwide problem, resulting from natural geologic activity and manmade sources such as mining, industrial manufacturing of various products (batteries, sprays, kitchenware, paints, ink and electronic components), semiconductor manufacturing and packaging materials (conjoint boxes, brick packages for milk and juice, paper, cardboard and plastics), forest products, landfill leachates, fertilizers, pesticides and sewage[1,2].

Heavy metal pollution of agricultural soils is one of the most important environmental problems on world scale[3]. Most of heavy metals are known as inhibitors exerting a variety of adverse effects on vegetables, which can lead to wider phytotoxic responses and reduce the yield and quality of agricultural crops[4-6], even cause threat to human and animals by inflowing the food chain. Kopyra and Gwozdz[4] and Atici *et al.*[5] reported that lead and other heavy metals induce the inhibitory effects on seed germination and seedling growth. Another important consequence of heavy metal stress in plants is the excessive generation of Reactive Oxygen Species (ROS) including hydrogen peroxide (H_2O_2). Increased ROS production can mediate antioxidative defense mechanisms[7]. On the other hand, accumulation of ROS induces secondary oxidative stress follow-on in a variety of harmful effects on normal metabolism in many plant cells or tissues[8,9].

In household waste, the contribution of metals varies according to the categories constituting the waste and in respect to individual metals. Tolerance limits for metals vary between countries[10,11]. In developing countries, the common processes of composting do not guarantee at present a sufficiently high quality of compost in terms of metals. If no regulatory standards are implemented, compost may contain metals in quantities greatly exceeding the limits established in developed countries[12].

The aim of this study was to improve the process of composting on the basis of a balance assessment of metals on the decentralized plant of a Non-Governmental Organization (NGO) in Lomé, Togo.

MATERIALS AND METHODS

Physical characterization of waste: In order to estimate the global average content of metals, characterization of the waste was carried out. Sampling was realized according to the statistical law of Bernoulli. While in the AFNOR[13], 13 categories are defined; in this study the following 10 waste categories were distinguished: Organic food and yard waste, paper and cardboard, textiles, plastics, miscellaneous combustible material (misc. C) including leather, rubber and wood, glass, metals, miscellaneous inerts (misc. I) including gravel, ceramic, tile and stones, hazardous materials, fines (20-10 mm) and super fines (<10 mm).

Sample collection: Four samples were collected by taking 500 Kg of material from different places within the waste pile. Every sample was mixed and 1 kg of each material was collected from the mixture. Finally, 11 sub-samples were analyzed. The global study was conducted during 2012 and 2014.

Moisture content: The moisture content of a given sample (20-50 g) was determined by heating to 105°C in an oven for 24 h[14-17] and measuring a weight loss of the samples.

Metal contents: Six aliquots of 0.5 g of each sample category were taken for analysis. They were digested in vessel adding a mixture of 20 mL HCl and 10 mL HNO_3[18,19]. Metals were determined by atomic adsorption spectrometry, model SAA FlammeVARIAN SPECTR AA[20,21]. The limit detection of metals Cd, Pb and Ni are respectively 1, 20 and 50 µg L^{-1}.

Scheme of the process: The process often used in platforms is sorting-composting. In this study the sieving (10 mm) of the fine fraction was introduced into the process before the staking operation in windrows and after maturation (Fig. 1). The different steps of sorting-composting are notified by numbers 1-6 in dashed line circles. The fermentation step took 8 weeks and the maturation one took 12 weeks. The sieving is undertaking on waste only after maturation step.

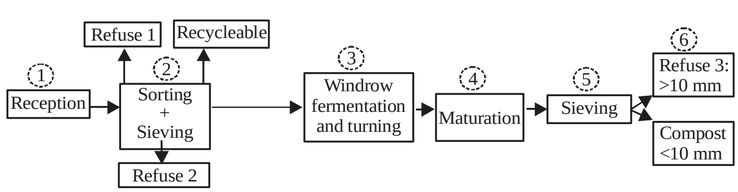

Fig. 1: Plan of the line in industrial scale composting, Refuse 1: >1 mm, no recyclable, Refuse 2: <10 mm and Refuse 3: >10 mm 90% of sand

Leaching test: The leaching test consisted of bringing a given mass of crushed waste in contact with a defined quantity of water for 24 h. The liquid fraction is then separate from solid fraction and centrifuged for 15 min at 4000 rpm, filtrated with cellulose acetate membrane 0.45 µm and analyzing the eluate. For this study, the assay was realized with a report liquid/solid = 10 (water: 100 mL, solid: 10 g). The leaching solution used was EDTA, 0.05 mol L^{-1} at pH 7 and the eluates were mineralized with 1/3 HNO_3+2/3 HCl) as AFNOR NF ISO 11460, June, 1995 recommend before the spectrophotometric analysis with SAA Flamme VARIAN SPECTR AA[2].

RESULTS

Moisture content: In the dry season and in the wet season the moisture contents of the categories vary: Organic 50-60%, paper and cardboard 16-43%, textiles 5-10%, plastics 5-18%, misc. C 3-30%, fines 15-33% and super fines 10-28%. The moisture contents of the following categories glass, metal, misc. I and hazardous materials were not determined as it was assumed that such non-porous material contents only negligible amount of water, which is adsorbed on the surface.

Metals in the waste of Lomé: After having determined the average composition of waste dry matter and using results of analysis of metals by category, the global average content of the waste in metals was determined. Based on the AFNOR recommendation of heavy metals in composts, the organic materials, paper/cardboard and glass don't contains high amounts of heavy metals. In opposite, metals, textiles and hazordous contains the high proportions of heavy metals followed by fractions such as misc. C, fines and super fines. It seems like, in wet season the amount of heavy metals is higher than dry season (Table 1).

Proportion of metals brought by each category: Table 2 gives the annual proportion of metals brought by every category in 1 kg of dry waste and as a consequence in a heap of waste. Super fines provide the highest metals contents varying from 33% to 56±2%. In the case of Ni this category evolves as following: Hazardous (17±1%), metals, plastics and textiles. For Cu, this element is followed by some metals (32±2%), textiles, fines and plastics, while for Zn, the source of contamination comes from textiles (12.7±3%) followed by fines, metals, misc. C, hazardous and plastics. In the case of Pb, super fines are followed by fines (17.5%) and metals. The Cd is also brought by plastics (23.8±1.1%), misc. C (15.2±.2%), fines (8.7%) and textiles (7.6%).

Metals contents in compost: Contents in three metals (Ni, Pb, Cd) were determined on raw compost without elimination of sand and on compost obtained from the process appearing at Fig. 1. Table 3 presents the contents of Ni, Pb and Cd in five composts obtained without primary screening. The characterization showed that, Pb values varies between 290 and 480 mg kg^{-1} dry mass in all the raw composts, which is two times higher compare to AFNOR[12] recommendations. On the contrary, the concentrations of Ni and Cd were lower than AFNOR recommended.

With the sorting of the unwanted materials (plastics, metals, hazardous, misc. C, misc. I, glass and textiles). The amount of heavy metals rises significantly. Ni vary from 2-14 mg kg^{-1} dry mass, Zn fluctuate between 10-50 mg kg^{-1} dry mass, Pb from 3-7 mg kg^{-1} dry mass and Cu was <16 mg kg^{-1} dry mass. The Cd was not detected.

Metals speciation: Case of Pb: The results of Pb concentration in the EDTA leachate was presented in Fig. 2. As it is seen every

Table 1: Composition of waste (dry mass) according to category and average metal contents

	Percentage		*Metal contents (mg kg^{-1} dry mass)				
Waste category	Dry season	Wet season	Ni	Cu	Zn	Pb	Cd
Organic	13.2	8.1	9.1	67.3	148	154	1.8
Paper and cardboard	4.5	8.7	11.8	38.1	112.1	26.1	1.4
Textiles	5.1	6.8	37.7	766	1220	99.2	6.8
Plastic	13.0	7.8	45.2	296	376	161	12.1
Glass	1.2	0.6	19.6	14.6	58	373	1.3
Metals	0.7	1.3	481	1554	507	905	7.9
Misc. C	7.3	4.2	19.6	497	867	184	14.0
Misc. I	3.3	2.1	23.3	21.2	558	641	1.0
Hazardous materials	1.7	1.8	388	21.7	2391	412	15.8
Fines-(20-10 mm)	10.9	19.6	26.8	299	441	746	3.0
Super fines (<10 mm)	39.0	38.9	34.1	465	553	931	4.5
	Dry season		38.3±1.1	453.1±2.1	559.5±2.1	604.7±3.2	5.7±1.1
	Wet season		41.3±1.2	554.9±2.2	595.5±2.1	695.4±2.1	5.0±0.1
	Average		39.8±1.1	504.0±2.1	577.5±2.1	650.0±2.6	5.3±0.6

*Ademe[11], Misc. C: Miscellaneous combustible and Misc. I: Miscellaneous inerts

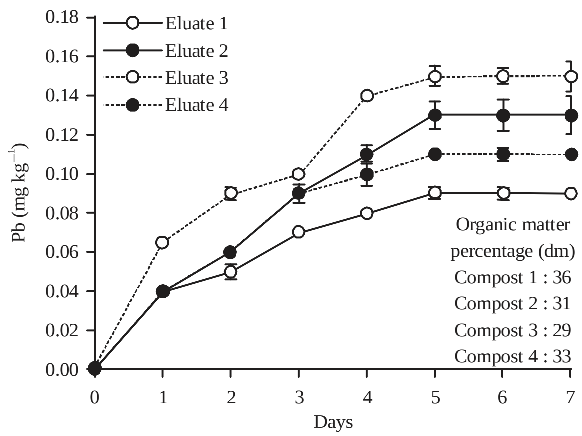

Fig. 2: Extraction of Pb with EDTA (0.05 M) pH = 7

Table 2: Annual average proportion of metals brought by every category on the total dry mass

		Proportion of metals percentage (dm)				
Waste category	Percentage (dm)	Ni	Cu	Zn	Pb	Cd
Organic	10.6±0.2	2.4±0.2	1.4±0.1	2.7±0.1	2.5±0.1	3.6±0.1
Paper and cardboard	6.6±0.1	2.0±0.1	0.5±0.0	1.3±0.0	0.3±0.0	1.7±0.1
Textiles	6.0±0.1	5.6±0.1	9.1±0.1	12.6±0.2	0.9±0.0	7.6±0.2
Plastic	10.4±0.2	11.8±0.2	6.1±0.2	6.8±0.1	2.6±0.1	23.8±0.5
Glass	0.9±0.0	0.4±0.0	0.0±0.0	0.1±0.0	0.5±0.0	0.2±0.0
Metals	1.0±0.0	12.6±0.3	32.0±0.6	9.1±0.2	14.5±0.3	1.5±0.0
Misc. C	5.7±0.1	2.8±0.1	5.7±0.1	8.6±0.1	1.6±0.0	15.2±0.3
Misc. I	2.7±0.1	1.6±0.0	0.1±0.0	2.6±0.1	2.7±0.1	0.5±0.0
Hazardous	1.8±0.0	17.1±0.3	0.1±0.0	7.2±0.2	1.1±0.0	5.2±0.1
Fines (20-10 mm)	15.3±0.3	10.3±0.2	9.1±0.1	11.7±0.2	17.5±0.4	8.7±0.2
Super fines (<10 mm)	39.0±0.8	33.4±0.6	35.9±0.7	37.3±0.7	55.8±1.0	33.1±0.6

dm: Dry mass, Misc. C: Miscellanous combustible and Misc I: Miscellanous inerts

Table 3: Concentration of metals in raw compost (mg kg^{-1} dm)

Elements	Compost 1	Compost 2	Compost 3	Compost 4	*NFU 44 051
Ni	40±1.00	14±1.00	20±1.00	18.0±1.00	60
Pb	460±2.00	380±2.00	480±2.00	290.0±2.00	180
Cd	1±0.02	1±0.01	2±0.03	2.0±0.03	3

dm: Dry mass, *AFNOR[12]

compost sample released lead into the solution. The amount of Pb extracted increases slowly with time of contact and the concentration rise rate ranged from 0.01-0.016 mg/kg/day up to 5 days, when the equilibrium was reached. The maximal values of Pb concentration in the leachates (equilibrium) eluted from studied compost samples (No. 1-4) were 0.09, 0.13, 0.15 and 0.11 mg kg^{-1}, respectively.

DISCUSSION

Moisture content: The moisture content varies according to the category. Water is necessary for the microorganisms. Its content determines the start of the composting process and the creation of a favorable course of biological biotope processes. Therefore, the decomposition of organic matter is not inhibited in dry and rainy season due to the high moisture content.

Metals in the waste of Lomé: The global average distribution of waste by category shows the high super fines content with an average rate of 39±1% dry waste. Previous studies of Koledzi *et al.*[22] showed that this category contains 9-10% of organic matter and that the rest is only sand. This justifies the choice of the process for eliminating sand on the first table of sorting. This category is followed by the 20-10 mm fines (10-20%) with an average content of 30±2% in organic matter[22]. Other constituents vary slightly with regard to the others with a minimum of 0.7% for the fraction of metals. The categories such as plastic, glass bottles and metals generally were got back throughout the sector of collection. In spite of recycling, some elements as plastics still represent a part which cannot be negligible. When added to the total mass of dry waste, their proportion still remains included between 7 and 13%. The evolution of

Table 4: Composition of metals in composts obtained by process (mg kg^{-1} dm)

Elements	Compost 1	Compost 2	Compost 3	Compost 4	Compost 5	*NFU 44 051
Ni	10±1	5.0±1	2.0±0.1	LQ	14±1	60
Cu	LQ	8.0±1	10±1	LQ	15±1	300
Zn	50±1	10±1	40±1	30±1	30±1	600
Pb	5.0±1	LD	6.0±1	7.0±1	3.0±0.1	180
Cd	1.0±0.01	LD	LD	LD	LD	3

LD: Limit of detection, LQ: Limit of quantification, dm: Dry mass and *AFNOR[12]

textiles amount is few, their total degradation is supposed to be reached after 60 years according to the literature. The average content of metals is classified as followed: Cd <Ni<Cu<Zn<Pb.

According to Rahnama *et al.*[23], there are two groups of metals: the "main things" (e.g., Cu and Zn) and the "non-main things" (e.g., Ni, Pb and Cd). The first biochemists who elaborated this study topic distinguished these metals on the basis of their ligand affinity. The Cd and Pb have an affinity for the sulfur, which allowed to identify proteins "which precipitate heavily" or easily give salts. On the other hand, both metals also have some physico-chemical characteristics:

- They do not destroy themselves, although they transport themselves or change their chemicals
- They have a high electric conductivity, which explains their use in numerous industries
- Especially, they present certain human toxicity, entailing in particular more or less grave neurological hurts, whereas all the others have a given utility in determined biological process
- They are only toxic elements

Proportion of metals brought by each category: The superfine and fine fractions represent an average of 50% in the dry season against 59% in the wet season. The rate of organics decreases during the wet season, possibly due to a change in food and to onset of waste degradation in the transfer site into fine elements. Informal waste recycling is carried out in order to generate income and at times contributing towards everyday survival. Waste collectors often go from door to door to collect sorted dry recyclable materials, such as metals, from householders. The misc. C component is constituted for the greater part by charcoal, as the majority of households use only wood or charcoal as a source of heat for cooking.

The first screening does not only eliminate sand but also a very important proportion of metals. Except for the primary screening the sorting of hazardous, misc. C, metals, plastics and textiles would also eliminate 50±3% of Ni, 53±2% of Cu, 44.3±1.1% of Zn, 20.7±2.1% of Pb and 53.3±2.1% of Cd. This process of composting would thus allow the removal of around 80±2% of metals.

The valorization of raw waste through composting directly on the dumping site features a considerable drawback: the high percentage of minerals (sand and gravel). Mixed municipal solid waste may contain heavy metals, although featuring a low content in the organic fraction. Thus, contamination can largely be avoided by separating the organic waste from other residues prior to composting.

Metals contents in compost: Only the Pb content exceeds the level of the French standard[12] because it is brought by super fines in a 55.8% ratio in the waste. The metals contents in super fines and thus in compost could result from the layer of humus, from some steppe black soil of gardens[24-27] and therefore, in households waste. The city of Lomé is located on a sandy soil and household's keepers have a few knowledge of the waste management. Household wastes are put down at first on the ground before being swept thus bringing the quantity of sand found in the waste.

Table 4 shows that the contents of metals in compost obtained after the sorting and the primary screening are very low with regard to the standard. The question is to know if these small quantities could be transferred to plants after amendment of grounds by these compost and thus to food chain. The leaching test and thus the speciation of metals were realized to determine the potential of release of the element in compost. This parameter allows the evaluation of the easily soluble pollution.

Metals speciation: Case of Pb: According to the previous works of Koledzi *et al.*[2] on methods developed for simple extractions with different solvents (water, $CaCl_2$ and EDTA), only EDTA seems to have a strong effect on the release of lead. The chosen solution was thus EDTA 0.05 mol L^{-1} at pH = 7 to test the retention of Pb in compost obtained by the process. This leaching test realized on compost allowed to determine the maximal capacity of release from the solid matrix towards the solution (leachate) corresponding to the pollution susceptible to be remobilized and transferred to plants in short or medium-term.

The classification of the retention potency appears to be: Compost 3<compost 2<compost 4<compost 1. Two hypotheses are possible: Either the compost is rich in metallic hydroxides and thus participates in the retention of lead by cation exchange or by absorption or it is sufficiently rich in organic matter for entrapping or retaining the metal by chemical complexes formation. The study for the content in organic matter by ignition gives 36% for compost 1, 31% for compost 2, 29% for compost 3 and 33% for compost 4. The higher the rate of organic matter is the lower is the rate of extraction. The retention of Pb is strong when the fraction of organic matter is high. The major part of Pb seems bound to the organic matter as shown by the results obtained after the fourth day of extraction (Fig. 2). Complexation by organic matter would lead to a stable fixation state, leading to low mobility of Pb.

The retention of Pb can occur not only on organic matter but also on metallic hydroxides, either by cation exchange or by fixation on carbonates. In natural ecosystems, particularly in soil, chemical speciation of metals is depending on numerous physico-chemical and/or biological parameters, which can be subject to wide variations. The chemical speciation of an element is defined as including all the chemical forms/sorts of this element in a natural environment. Some ligands (inorganic or organic) are able to condition the speciation of this element by the formation of more or less stable complexes. It was shown that the toxicity of metal is dependent on its speciation and that the free ionic metal (Cu^{2+} and Pb^{2+} etc.) speciation is one the most reactive form with the neutral species, because more easily assimilated by the alive organisms[28]. This metal (Ni, Cu, Zn, Pb and Cd) speciation is also dependent on a large number of physical parameters (temperature, pressure) and chemical ones (pH, ionic strength, concentrations in major elements, complexing ligands).

CONCLUSION

The implementation of data relative to the potential pollution capacities of metals by category is an essential stage in the management of waste with the aim of mitigation of the impact of these elements on the human health and the environment. This is mostly important in the developing countries, where serious reflections hare to be led in this frame. So, that allows directing surrounding areas of management, adapted to the context by optimizing their contribution in the reduction of the specific quantities of waste intended for the final discharge. This study allowed determining the origin of Ni, Cu, Zn, Pb and Cd in compost to make the balance assessment quantity by metal and by category and to realize the balance assessment on these metals in the process of composting. This study on a decentralized plant will have to allow the actors implication (decision-makers, local authorities and companies etc.) in the management of household waste. It also will be helpful for and conceiving effective programs. It will provide the necessary arguments to convince the populations to subscribe to programs of management of specific waste as for example the elimination of super fines in the waste in the case of Lomé.

So, for example, a reduction of the plastic and super fines, which are the main sources of Cd in the household waste would appreciably contribute to the reduction of the rates in this element. Furthermore, the sorting of textiles, metals, misc. C would lead to a significant reduction of Ni, Cu, Zn, Pb and Cd. The sanitary and environmental stake in these toxic elements is particularly important when it is taken into account their half-life period, which can vary from a few days to some thousand years according to the matrix.

ACKNOWLEDGMENTS

The French associations Gevalor and GoodPlanet are carrying out a project called "Africompost", which started in 2011. It is founded by the French AFD and FFEM and aims at supporting the development of already operational composting units to generate good quality compost and selling carbon credits thus generated by reduction of methane emissions from landfill disposed waste. Another target is to empower the local project partners. The project shall provide environmental and economic as well as social benefits by generating around one hundred new workplaces for persons with a low education level.

SIGNIFICANT STATEMENT

The aim of this study is to assess the balance of some heavy metals during composting of different categories of urban waste of Togo because metals, especially lead is found in a high amount in wastes without sorting used to produce compost for soils amendment. This lead can be transfer in vegetable plant and occurs diseases. Thus, contamination can largely be avoided up to 80% by separating the organic waste from other residues prior to composting. This will provide the necessary arguments to convince the populations to subscribe to programs of management of specific waste as for example the elimination of super fines in the waste in the case of Lomé.

REFERENCES

1. Roberto, F.F., J.M. Barnes and D.F. Bruhn, 2002. Evaluation of a GFP reporter gene construct for environmental arsenic detection. Talanta, 58: 181-188.
2. Koledzi, K.E., G. Baba, N. Segbeaya, G. Tchangbedji and K. Kili *et al*., 2011. [Valorization of urban waste in agriculture: Ecological impact study of composts]. Journal Societe Ouest-Africaine Chimie, 32: 27-42, (In French).
3. Reddy, A.M., S.G. Kumar, G. Jyothsnakumari, S. Thimmanaik and C. Sudhakar, 2005. Lead induced changes in antioxidant metabolism of horsegram (*Macrotyloma uniflorum* (Lam.) Verdc.) and bengalgram (*Cicer arietinum* L.). Chemosphere, 60: 97-104.
4. Kopyra, M. and E.A. Gwozdz, 2003. Nitric oxide stimulates seed germination and counteracts the inhibitory effect of heavy metals and salinity on root growth of *Lupinus luteus*. Plant Physiol. Biochem., 41: 1011-1017.
5. Atici, O., G. Agar and P. Battal, 2005. Changes in phytohormone contents in chickpea seeds germinating under lead or zinc stress. Biologia Plantarum, 49: 215-222.
6. Faheed, F.A., 2005. Effect of lead stress on the growth and metabolism of *Eruca sativa* M. seedlings. Acta Agronomica Hungarica, 53: 319-327.
7. Ruciska-Sobkowiak, R. and P.M. Pukacki, 2006. Antioxidative defense system in lupin roots exposed to increasing concentrations of lead. Acta Physiologiae Plantarum, 28: 357-364.
8. Shalata, A. and M. Tal, 1998. The effect of salt stress on lipid peroxidation and antioxidants in the leaf of the cultivated tomato and its wild salt-tolerant relative *Lycopersicon pennellii*. Physiologia Plantarum, 104: 169-174.
9. Shah, K., R.G. Kumar, S. Verma and R.S. Dubey, 2001. Effect of cadmium on lipid peroxidation, superoxide anion generation and activities of antioxidant enzymes in growing rice seedlings. Plant Sci., 161: 1135-1144.
10. Lagier, T., 2000. Study of macro molecules leachate: Characterization and behavior metals. Ph.D. Thesis, University of Limoges, France.
11. Ademe, 1999. The storage of household and similar waste: Technical and recommendations. Editions ADEME-1999, Page: 106.
12. AFNOR., 2010. Organic amendments-denominations, specifications and marking-compiled text of NF U44-051 in April 2006 and its amendment 1 December 2010. Editions AFNOR-2010. AFNOR., Paris, France.
13. AFNOR., 1996. Waste characterization of a sample of household and similar waste. Editions AFNOR-1996, AFNOR., Paris, France, pp: 30-408.
14. Charnay, F., 2005. Composting of municipal solid waste in developing countries: Methodological approach for a sustainable production of compost. Ph.D. Thesis, University of Limoges, France.
15. Garcia, A.J., M.B. Esteban, M.C. Marquez and P. Ramos, 2005. Biodegradable municipal solid waste: Characterization and potential use as animal feedstuffs. Waste Manage., 25: 780-787.
16. Aloueimine, S.O., G. Matejka, C. Zurbrugg and M.E.O. Sidi Mohamed, 2006. Characterization of waste in nouakchott-part 2: Results in the dry season and wet season. Waste-Revue Francophone Industrial Ecology, No. 44.
17. Yobouet, Y.A., K. Adouby, A. Trokourey and B. Yao, 2010. Cadmium, copper, lead and zinc speciation in contaminated soils. Int. J. Eng. Sci. Technol., 2: 802-812.
18. Bustamante, M.A., C. Paredes, F.C. Marhuenda-Egea, A. Perez-Espinosa, M.P. Bernal and R. Moral, 2008. Co-composting of distillery wastes with animal manures: Carbon and nitrogen transformations in the evaluation of compost stability. Chemosphere, 72: 551-557.
19. Belyaeva, O.N. and R.J. Haynes, 2009. Chemical, microbial and physical properties of manufactured soils produced by co-composting municipal green waste with coal fly ash. Bioresour. Technol., 100: 5203-5209.
20. Koffi, L.C.K., K. Adouby, E.N. Wandan, B. Yao and K.P. Kotchi, 2010. Sorption and desorption of Pb(II) from aqueous solution using *Triplochiton scleroxylon* sawdust as sorbent. J. Applied Sci., 10: 1536-1544.
21. Shokrzadeh, M. and S.S. Saeedi Saravi, 2010. The study of heavy metals (zinc, lead, cadmium and chromium) in sediments sampled from Gorgan coast (Iran), spring 2008. Toxicol. Environ. Chem., 92: 67-69.
22. Koledzi, E.K., Y. Kpabou, G. Baba, G. Tchangbedji and K.A. Kili *et al*., 2011. Composition of municipal solid waste and perspective of decentralized composting in the districts of Lome, Togo. Waste Manage., 31: 607-609.
23. Rahnama, R., A. Javanshir and A. Mashinchian, 2010. The effects of lead bioaccumulation on filtration rate of zebra mussel (*Dreissena polymorpha*) from Anzali Wetland-Caspian sea. Toxicol. Environ. Chem., 92: 107-114.
24. Nilsson, I., 1972. Accumulation of metals in spruce needles and needle Litter. Oikos, 23: 132-136.
25. Coughtrey, P.J., C.H. Jones, M.H. Martin and S.W. Shales, 1979. Litter accumulation in woodlands contaminated by Pb, Zn, Cd and Cu. Oecologia, 39: 51-60.
26. Veeken, A. and B. Hamelers, 2002. Sources of Cd, Cu, Pb and Zn in biowaste. Sci. Total Environ., 300: 87-98.
27. Koledzi, K.E., G. Baba, G. Tchangbedji, K. Agbeko, G. Matejka, G. Feuillade and J. Bowen, 2011. Experimental study of urban waste composting and evaluation of its agricultural valorization in Lome (Togo). Asian J. Applied Sci., 4: 378-391.
28. Lai, Y.L., M. Thirumavalavan and J.F. Lee, 2010. Effective adsorption of heavy metal ions (Cu^{2+}, Pb^{2+}, Zn^{2+}) from aqueous solution by immobilization of adsorbents on Ca-alginate beads. Toxicol. Environ. Chem., 92: 697-705.