ChemTech

International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.8, No.12 pp 178-186, 2015

The Proficiency of Different Mature Compost in Suppressing the Uptake of Heavy Metal by *Jatropha curcas* L., Castor Bean and Sunflower Plants

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Abstract: The presence of non-biodegradable and high level of toxic heavy metals in the sewage sludge frequently hinders agricultural land application. Composting is considered to be the cheapest and most reliable technique for stabilization of heavy metals in sewage sludge and resemble soil conditioner in agricultural applications. A field study was performed to evaluate the different composting media proficiency in decline heavy metals transfer to the edible parts of three cultivated plants (*Jatropha curcas* L. , Castor Bean and Sunflower).The results cleared that there are significant differences in heavy metal concentrations in root and shoot in the different plant types. The amounts of accumulated lead ions in roots were higher than the translocate amount into shoots for *Jtropha curcas* L., Castor Bean and Sunflower seedlings.
Keywords : Bio Concentration Factor (BCF), Castor Bean, Compost, Heavy metals, *Jatropha curcas* L. ,Sunflower, Translocation Ratio (TR) and Transfer Factor (TF).

1. Introduction

Sewage sludge disposal in non harmful manners and minimizes their health risks are of a great environmental concerns. Landspreading considered to be one of the most beneficial and economical routs for sewage sludge disposal, where it increases soil fertility, plant yield and improving soil physical and chemical properties[1-6]. On the country, the presences of pathogenic microorganisms and heavy metals pollutants are of a great dangerous as it may poses risk to human health[7-10]. Therefore, sewage sludge in order to be used as fertilizer it must be fulfilled with national and international legislation limits. Plants take heavy metals from soils through different reactions, such as, absorption, ionic exchange, redox reactions, precipitation and dissolution. The solubility of metals depends on several factors like existing minerals (carbonates, oxide, hydroxide), soil organic matter (humic acids, fulvic acids, polysaccharides and organic acids), soil pH, redox potential, clay content, organic matter content, cationic exchange capacity, soil temperature and humidity[11]. Composting technique is one of possible and efficient route for stabilization of heavy metals in sewage sludge, reduces sewage sludge volume by 40-50% and destroy microbial pathogens[12]. Composted sewage sludge can improves structure, porosity, density, water holding capacity and cation exchange capacity of soil and provides soil with array of nutrients, suitable organic matter and beneficial microorganisms[13]. For studying the role of composting technique in stabilizing and fixing several heavy metals in contaminated sewage sludge, three multipurpose plants (Sunflower, Castor Bean and *Jatropha curcas* L.), that contains high amount of oil in its seeds which can be converted to biodiesel and also their ability to grow successfully in different soil types, were examined. Furthermore, the responses of plants root and shoot for heavy metal uptake from the soil were also studied.

2. Materials and Methods

Plantation experiments are performed using uniform amounts of six mature compost mixtures. It was proceed using six triangular composting windrow piles with.1: 1 ratio of sewage sludge : bulking agents (dry weight sewage sludge: dry weight bulking agents). The six mixtures for different composting piles were mixed using sewage sludge: rice straw (SS:RS), sewage sludge: faba bean straw (SS:FS), sewage sludge: wheat straw (SS:WS), sewage sludge: faba bean straw: wheat straw (SS:FS:WS), sewage sludge: rice straw: wheat straw (SS:RS:WS) and sewage sludge: rice straw: faba bean straw (SS:RS:FS).

A pot experiment was conducted to determine the stability of metals in the six mature composted sewage sludge mixtures using three oily plants *Jatropha curcas* L., Castor Bean and Sunflower. The three plants seeds were supplied from the Agriculture Research Centre (ARC), Giza, Egypt.

2.1. Soil Preparation for Plantation

A composted sandy soil was prepared for a plantation experiment, where, the collected sand, from distinct land, was treated by washing for several times with deionized water then air-dried in order to be sure that there is no contamination with heavy metals. A uniform 600 g of sand is combined and mixed with 300 g of each composted mixture to perform six composted sandy soils. For each performed soil about 300 g of combined mixture was taken and put in each pot to perform three similar pots as shown in Table (1). Finally, the eighteen pots are well equipped and then divided into three groups as represented in Table (2) for germination process. Triplicates of each group were planted as flowing; the first pots group (GP1) was planted with two *Jatropha curcas* L.seeds for each pot. The second pots group (GP2) was planted with two Castor Bean seeds for each pot. The third pots group (GP3) was planted with two Sunflower seeds for each pot. The pots were then watered lightly to submerge the mixtures in the pots then seeds were planted in each pot at a depth of 3cm. Pots were placed on a sun place at an average temperature of 38°C in sunlight (April to May, 2014). Furthermore, pots locations were rotated periodically to ensure uniform light intensity to all the pots. Pots were watered three times per week with tap water to keep the water level above the soil surface. After 60 days of growth, all plants were harvested and collected then placed in plastic bags, labeled carefully and brought to the laboratory for analysis.

Table (1) Three Groups of Soil Mixtures with Six Mature Compost Mixtures

(300:600 g)(Compost : Sand)	Composted Sandy Soil Mixtures		
SS:RS/Sand	A1	B1	C1
SS:FS/Sand	A2	B2	C2
SS:WS/Sand	A3	B3	C3
SS:FS:WS/Sand	A4	B4	C4
SS:RS:WS/Sand	A5	B5	C5
SS:RS:FS/Sand	A6	B6	C6

Table (2) Three Planted Groups in Six different Composted Soil Mixtures

Planted Groups	Group no.	Groups Names					
Jatropha curcas L.	GP1	A1	A2	A3	A4	A5	A6
Castor Bean	GP2	B1	B2	B3	B4	B5	B6
Sunflower	GP3	C1	C2	C3	C4	C5	C6

2.2. Analysis of Soil and Plant

All plant parts were collected from each pot, washed with running tap water and rinsed with deionized water to remove any soil or sediment particles attached to the plant surfaces, then dried in oven at 70 ºC till the plant tissue be completely dried. Prepared composted sandy mixtures samples and dried plant parts (shoot and roots) were grounded, digested, and then physical properties, metals, cations, anions and bacterial count were determined according to APHA [14].

2.3. Translocation Ratio (TR), Transfer Factor (TF) and Bio Concentration Factor (BCF)

Calculations of both (TR & TF) parameters are necessary for predicting agricultural crops pollutant which indirectly estimating dose intake by person[15]**.** TR is calculated by the relation between the ratio of concentration of metal in the shoot to the concentration of metal in the roots (Equation, 1) [16-18]**.**

$$TR = \{\text{Concentration of metals}\}_{shoot} / \{\text{Concentration of metals}\}_{root} \qquad \text{Eq. (1)}$$

The transfer factor (TF) is used to evaluate the impact of routine or accidental releases of pollutant into the environment. TF is given by the relation between the ratio of the concentration of metal in the shoots to the concentration of metals in the soil (Equation, 2) [17-22]. If the TF ratios >1 the plants have high ability to accumulate metals, the ratios around 1 indicate that the plants are not influenced by the metals and ratios < 1 show that plants exclude the metals from the uptake[23]

$$TF = \{\text{Concentration of metals}\}_{shoot} / \{\text{Concentration of metals}\}_{soil} \qquad \text{Eq. (2)}$$

The Bio Concentration Factor (BCF) is used to evaluate the plant's ability to accumulate metals from soils and it is defined as the ratio of metals concentration in plant roots to the soil metals concentration (Equation, 3) [24-27]

$$BCF = \{\text{Concentration of metals}\}_{root} / \{\text{Concentration of metals}\}_{soil} \qquad \text{Eq. (3)}$$

3. Results and Discussion

Characteristics of the Mature Compost Mixtures that use for Germination Study

Several indicators for the six mature compost mixtures are measured to certify the maturation of compost as shown in Table (3), where the pH was neutral and ranged from 7.2 to 7.5 for all composted mixtures. There is an indicative for an acceptable composting maturity from changes in total organic carbon : total nitrogen ratio (TOC:TN) which are 14.64, 15.31, 12.69, 12.46, 13.9 and 14.30 for SS:RS, SS:FS, SS:WS, SS:FS:WS, SS:RS:WS and SS:RS:FS, respectively. The pathogenic communities in the six mixtures are within the limited values presented in (Table 5), where the *Salmonella* spp are not detected and both of total coliform and fecal coliform are less than 10 MPN/100g DS for all mature compost mixtures.

Total Heavy Metals Concentrations in the Prepared Composted Sandy Soil Mixtures

The total heavy metals concentrations were detected for the six composted sandy soil mixtures (SS:RS:Sand, SS:FS:Sand, SS:WS:Sand, SS:FS:WS:Sand, SS:RS:WS:Sand and SS:RS:FS:Sand). This results in Table (4) indicating that, all heavy metals concentration of the six composted sandy soil mixtures are within the permitted Egyptian limits for sewage sludge agriculture use (**Decree No. 214/1997**) (Table (5)) [28]**,** except lead ions (Pb) which have higher concentrations for all prepared composted sandy soil mixtures which reached to 2540, 2385, 2560, 2500, 2750, 3000 mg/Kg for SS:RS: Sand, SS:FS: Sand, SS:WS: Sand, SS:FS:WS: Sand, SS:RS:WS: Sand and SS:RS:FS: Sand respectively. Therefore, our current study focused on studying the mobility of lead ions to shoot and root of three different plant (*Jatropha curcas* L., Castor Bean and Sunflower) as plant species are vary in their capacity to uptake and accumulate heavy metals[29-,30].

Plant uptake of heavy metals from soil occurs either passively with the mass flow of water into the roots, or through active transport crosses the plasma membrane of root epidermal cells[25]**. Friedland (1989)** [31] said that heavy metals accumulation and distribution in plant tissues are important to evaluate the effect of contaminated soil with heavy metals on plant. In our study the distribution of lead ions concentration in different plants parts (roots and shoots) after two months from the plantation are represented in Table (6).

3.1. Lead ions Accumulation in different Plant Parts of *Jatropha curcas* L. (GP1).

Lead ions concentration in the *Jatropha curcas* L. parts were significantly variable among prepared composted sandy mixtures, where the roots exhibited higher absorption compared with the above ground part (shoot), the Pb ions root accumulation from sandy mixture A4 (SS:FS:WS/Sand) was significantly higher with compared to other composted sandy mixtures which reached to (84.14 mg/Kg). On the contrary, the sandy mixture A1 (SS:RS/Sand) has the lowest root lead ions accumulation (36.9 mg/Kg). It was also noted that lead ions concentration does not reached to the shoots from sandy mixtures (A1, A2, A5 and A6) with respect to A3 sandy mixture (3.0 mg/Kg) and A4 (6.12 mg/Kg). From these results it is obtained that type (A1) sandy mixture represents the most stabilized composted sandy soil mixture.

Table (3) Basic Characteristics of the Six Mature Compost Mixtures

Parameters	Unit	Compost Mixtures					
		SS:RS	SS:FS	SS:WS	SS:FS:WS	SS:RS:WS	SS:RS:FS
pH	-----	7.48	7.61	7.35	7.38	7.2	7.5
Electrical conductivity	ds/m	11.9	10.64	9.05	10.72	11	9.84
Moisture content	%	42.77	38	41.51	42.2	43.24	46.81
Dry matter	%	57.23	62	58.49	57.8	56.76	53.19
Total organic carbon	%	21.37	19.29	20.3	20.93	19.74	19.59
Total nitrogen	%	1.46	1.26	1.6	1.68	1.42	1.37
TOC:TN	-----	14.64	15.31	12.69	12.46	13.9	14.30
Organic matter	%	36.84	33.26	35	36.08	34.04	33.78
Ammonia (NH_4)	mg NH_4^+-N/Kg	212	204	185	110	195	185
Nitrates (NO_3^-)	mg NO_3^- -N/Kg	1644	1847	1315	1458	1602	1381
Total Phosphorous	%	1.22	1.57	1.53	1.6	2.24	1.07
***Salmonella* spp**	MPN/100g DS	N.D	N.D	N.D	N.D	N.D	N.D
Total coliform	MPN/100g DS	< 10	< 10	< 10	< 10	< 10	< 10
Fecal coliform	MPN/100g DS	< 10	< 10	< 10	< 10	< 10	< 10
Nickel	mg/Kg	34.2	29.4	30.75	27.7	27.2	32.75
Copper		280	235	245	244	241.54	265
Chromium		79.3	70	78.6	61.5	65	81
Lead		10500	9980	10600	9640	9370	10740
Cadmium		2	1.2	1.5	1.2	1.3	2
Zinc		365	355	360	358	345	365

N.D : Not Detected. DS: dry solid MPN: Most probable number.

Table (4): Total Heavy Metals Concentrations in the different Composted Sandy Soil Mixtures

Parameters	mg/Kg					
	Zn	Cd	Pb	Cr	Cu	Ni
Sand	5	0.1	13	1	2	1.5
SS:RS: Sand	153	0.25	2540	20	46.5	5.75
SS:FS: Sand	210	0.45	2385	31	57	6.5
SS:WS: Sand	286	0.9	2560	42	101	9
SS:FS:WS: Sand	170	0.5	2500	24	62.5	7.5
SS:RS:WS: Sand	194	0.5	2750	26.3	65	7.5
SS:RS:FS: Sand	250	0.6	3000	34	83.5	8.5

Table (5): The permitted heavy metals concentrations in the sludge for agriculture application in Egypt (Decree No. 214/1997)

Pollutant	Concentration Limit(Safe Sludge) (mg/Kg (dry solids basis)
Zinc (Zn)	2800
Copper (Cu)	1500
Nickel (Ni)	420
Cadmium (Cd)	39
Lead (Pb)	300
Mercury (Hg)	17
Chromium (Cr)	1200
Molybdenum (Mo)	18
Selenium (Se)	36
Arsenic (As)	41
Microbial pathogens	**Concentration limits**
***Salmonella* spp**	Less than 3 cells per 100 ml at a sludge concentration of 4% dry solids.
Fecal coliform	Less than 1000 cells per 1g dry

Table (6) Lead ions concentration in roots and shoots of *Jatropha curcas* L. , Castor Bean and Sunflower Plants after two months of plantation

Groups	Mixtures	Pb ions in Mixtures mg/Kg	Lead ions conc. in plant mg/Kg				
			Root	Shoot	TR	TF	BCF
GP (1)	A1	2540	36.9	0.0	0.0	0.0	0.015
	A2	2385	40	0.0	0.0	0.0	0.017
	A3	2560	50.4	3.0	0.06	0.001	0.02
	A4	2500	84.14	6.12	0.073	0.002	0.03
	A5	2750	45.3	0.0	0.0	0.0	0.016
	A6	3000	46.15	0.0	0.0	0.0	0.015
GP (2)	B1	2540	46.7	15	0.32	0.006	0.018
	B2	2385	86.7	15.4	0.18	0.006	0.036
	B3	2560	117	21.7	0.19	0.008	0.046
	B4	2500	192.5	26.6	0.14	0.01	0.08
	B5	2750	105	15.9	0.15	0.006	0.038
	B6	3000	108.3	17.8	0.16	0.006	0.036
GP (3)	C1	2540	101.6	19.3	0.2	0.008	0.04
	C2	2385	105	21.7	0.21	0.009	0.044
	C3	2560	192.3	27	0.14	0.011	0.075
	C4	2500	198.5	31	0.16	0.012	0.08
	C5	2750	141	23	0.163	0.008	0.051
	C6	3000	159.6	24.6	0.15	0.008	0.053

3.2. Lead ions Accumulation in different Plant Parts of Castor Bean (GP2)

The fates of lead ions accumulation in Castor Bean roots and shoots were significantly variable among prepared composted sandy mixtures. Where the roots exhibited higher absorption compared with the above ground part from shoot. The root accumulation of Pb ions in mixture B4 (SS:FS:WS/Sand) was significantly higher with compared to other composted sandy mixtures which reached to (192.5 mg/Kg) . On the contrary, the mixture B1(SS:RS/Sand) has the lowest lead ions accumulation in root (46.7 mg/Kg). It was also noted that sandy mixture B1 represent the lowest shoot lead ions accumulation (15 mg/Kg) compared with other composted sandy mixtures. The recorded results indicated that the sandy soil (B1) has least ability to transfer lead ions from soil to other plant parts.

3.3. Lead ions Accumulation in different Plant Parts of Sunflower (GP3)

There are significant differences in Pb ions transportation from prepared composted sandy mixtures to plant parts. The accumulation of lead ions in Sunflower roots are 101.6, 105, 192.3 , 198.5, 141 and 159.6 mg/Kg and lead ions translocation in the shoot will be reduced to 19.3, 21.7, 27, 31, 23 and 24.6 mg/Kg for composted sandy mixtures C1, C2, C3, C4, C5 and C6 respectively. These displays results indicated that there are several differences exist between plants in their abilities for lead ions accumulation in the root and translocation to the shoot. The maximum accumulation of lead ions were found in the root and shoot of sandy mixture (C4) and the minimum accumulation of lead ions were represented in sandy mixture (C1). These showed results prove that, the prepared composted sandy mixture (SS:RS/Sand) (A1,B1,C1) has the lowest shoot and root lead ions translocation and accumulation in the three trial plants (*Jatropha curcas* L., Castor Bean and Sunflower).

The composted sandy mixtures which immobilized transportation of lead ions to the plants were increases in the following order:

GP1: A4 < A3 < A6 < A5< A2< A1
GP2: B4 < B3 < B6 < B5 < B2 < B1
GP3: C4 < C3 < C6 < C5 < C2 < C1

The plants shoot and root lead ions accumulation were increase in the following order:

***Jatropha curcas* L. < Castor Bean < Sunflower**

3.4. Translocation Ratio (TR), Transfer Factor (TF) and Bio concentration Factor (BCF) of Heavy Metals

As (TR) and (TF) are predicting the extent of accumulated pollutants in agriculture crops, therefore it is important to calculate the variations of TR and TF values in the three planted groups.

3.4.1. Translocation Ratio (TR)

The results for plantation of (*Jatropha curcas* L., Castor Bean and Sunflower) in different composted sandy soil mixtures show that, the translocation ratios of composted sandy mixture (SS:RS/Sand) are zero in (A1), B1(0.32) and C1(0.2). As observed the TR levels for all of them are less than 1 which indicating that the three plant species were not able to translocate lead ions from the roots to the shoots. This mainly attributed to the form of lead ions which are poorly mobile that cannot translocate from root to shoot[32]**.** By comparing the TR values of the three plant groups (*Jatropha curcas* L., Castor Bean and Sunflower) we noted that, all plants TR values are less than 1 which indicating that the three plant groups can be labeling as trace metal excluder.

3.4.2. Transfer Factor (TF)

The variations in Pb ions transfer factor (TF) for the three groups (GP1, GP2 and GP3) are presented in Table (6). Where the TF values for GP2 (Castor Bean) are 0.006 for mixtures B1, B2, B5 and B6, 0.008 for B3 and 0.01 for B4. As observed the TF values for all GP2 mixtures are less than 1 as well as both GP1 and GP3 mixtures. The obtained results indicate that the uptake and transport of lead ions were regulated in a way that the ratio of the concentration of lead ions in the plant shoots to that in the soil < 1, therefore, these plants are labeling as excluder plants [23]**.**

3.4.3. Bio Concentration Factor (BCF)

The variations in BCF for plant species under different formed composted sandy soil mixtures are shown in Table (6). Where the lowest BCF values observe at composted sandy mixture (SS:RS/Sand) which are (0.015, 0.018 and 0.04) for A1, B1 and C1 respectively. These represented data indicated that BCF values less than 1 for all prepared composted sandy soil mixtures, which refers to the restriction of even high Pb ions concentration to transfer from soil to root.

3.5. Relation between Translocation Ratio (TR) and Bio Concentration Factor (BCF).

By comparing BCF and TR, we can compare the ability of different plants in taking up metals from soils and translocating them to the shoots. The plants with both bio concentration factor and translocation ratio greater than one (TR and BCF > 1) have the potentiality to accumulate metal. While, plants with bio concentration factor greater than one and translocation ratio less than one (BCF > 1 and TR < 1) indicating that, these plants have the potentiality for phytostabilization of metals. In contrast plants with bio concentration factor less than one and translocation ratio less than one (BCF < 1 and TR < 1) are metal excluder plants (non accumulating) [33]**.** By comparing BCF and TR in Table (6), it was observed that the ability of different plants in taking up Pb ions from soils and translocating them to the shoots are varied. These growing plants are capable of translocating Pb ions to roots, but all of them had low TR and BCF values, which means limited ability of Pb ions accumulation and translocation by the plants. Therefore, it is expected that the Pb ions translocation from shoot to leaves be decline to extent less than that observed in shoots which is agrees with **Raphael, *et al.* (2010)** [34] who found that most of metals are concentrate in the roots of the food crops more than in the stems and leaves.

All these represented results indicating that the three plant species growing on the contaminated composted mixtures were tolerant to lead ions, especially *Jatropha curcas* L. which has high ability for excluding lead ions from accumulation in different plant part with compared to other two plant types. **Verkleij and Schat (1989)** [35] mentioned that, the restriction of upward movement from roots into shoots can be considered as one of the tolerance mechanism. From our results we recommended that *Jatropha curcas* L. is one of more suitable plants that can be planted in heavy metal contaminated compost especially when it is remediated with rice straw.

4. Conclusion

The study are focused on the proficiency of different mature composted mixtures in stabilizing the heavy metals and preventing it's transportation to three oily plants (*Jatropha curcas* L., Castor Bean and Sunflower). In order to investigate the mobility and translocation of lead ions from soil to different plant parts different factors were investigated (TR, TF and BCF), the values of the three calculated factors are less than 1, which indicating that, there are restriction of lead ions to transfer from composted sandy soil mixtures to the plants root and shoot. By comparing the different composted sandy mixtures, we can concluded that the composted sandy mixtures with rice straw having the lowest ability for transportation of lead ions to the plant parts compared to the other composted sandy mixtures. *Jatropha curcas* L. considered to be the most lead ions excluder plant than the other germinated plants.

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