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Adsorption of Heavy Metal Cations in Sewage Sludge Applied Soil and its Behavior in Spinach (*Spinacia Oleracea*)

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Abstract

An investigation was carried out on “Adsorption of heavy metal cations in sewage sludge applied soil and its behavior in spinach (Spinacia oleracea)” at research farm, SHIATS, Allahabad during 2010. The experiment was designed in Randomized Block Design with three replicates. The amendments included lime, NPK fertilizers, phosphate solublizing bacteria and plant growth promoting rhizobacteria with two rates of sewage sludge. The availability and mobility of heavy metals in soil and spinach leaf increased with increase the quantity of sewage sludge application in the treatment T_1 and T_2 in soil and spinach leaf both compared to control plot (To). Adding lime with sewage sludge in the treatment T_3 raised soil pH and significantly reduced availability and mobility of heavy metals, while phosphatic fertilizer (NPK) in the treatment (T_4,T_5) and phosphate solublizing bacteria treatment (T_6,T_7) showed lower soil pH resulted increased the availability and mobility of heavy metals in soil and spinach leaf. Adding plant growth promoting rhizobacteria with sewage sludge in the treatments (T_8, T_9) also raise the soil pH and reduced the availability of heavy metals in soil and spinach leaf. The availability of heavy metals were found twice in the treatment $T_{10,}$ and T_{11} (sewage sludge, NPK ,PSB and PGPR) in soil as compared to only sewage sludge application but in spinach leaf the concentration of heavy metals decreased as compared to only sewage sludge application. Heavy metals in sewage sludge, soil and spinach leaf were below the internationally recommended (WHO) maximum permissible limits except Cadmium. The results of investigation, we advise to farmers, don’t apply sewage sludge, in agricultural land due to high level of cadmium in sewage sludge and its availability in soil and spinach.

Keywords: Heavy metals, adsorption, desorption, sewage sludge etc.

1. Introduction

Increasing volume of sewage sludge, environmental constrains and cost associated with alternative methods are factors that what led to an increased interest in utilizing or disposing sewage sludge as fertilizer on agricultural land. (Alloway *et al.,* 1991). The application of sewage sludge to land provide significant benefit through the addition of organic matter, nitrogen, phosphorus and certain essential trace elements to the soil. (Change *et al.,* 1987) .However, as sludge may also contain higher concentration of pollutants, depending on the source and treatment of the waste, utilization as cheap fertilizer on cropland also raise the risk of soil pollution. In particular, the accumulation of heavy metals in soil and potential transfer into food chain .There is however, concern that heavy metals in soil amended with sewage sludge may increase after termination of sludge application creating a so called “time bomb effect” (McBride, 1995). On the other hand it has also been suggested that heavy metals released due to organic matter mineralization are maintained in chemical forms and are not readily bio-available i.e. the “plateau effect” .

2. Materials and Methods

An experiment was conducted in the Department of Soil Science and Agricultural Chemistry farm, School of Forestry and Environment, SHIATS, Allahabad. The amendments included lime, NPK fertilizers, phosphate solublizing bacteria and plant growth promoting rhizobacteria with two rates of sewage sludge viz, treatment combination, T_0 (control), T_1 (S.S.A.@ 10 Tha^{-1}), T_2 (S.S.A.@ 20Tha^{-1}), T_3(S.S.A.@ 10 Tha^{-1} + 20 kg lime ha^{-1}), T_4 (S.S.A. @ 10Tha^{-1} + RDF), T_5 (S.S.A. @ 20Tha^{-1}+ RDF), T_6 (S.S.A. @ 10Th^{-1}+ RDF +PSB @ 2kg ha^{-1}), T_7 (S.S.A. @ 20Th $^{-1}$+ RDF + PSB @ 2kg ha^{-1}) T_8 (S.S.A.@ 10Th^{-1} + RDF + PGPR@2kg ha^{-1}) T_9 (S.S.A.@ 20Th^{-1}+ NPK + PGPR @ 2kg ha-1), T_{10} (S.S.A.@ 10Th^{-1}+ RDF+PSB@ 2kg ha-1+ PGPR@2kg ha^{-1}) and T_{11} (S.S.A. @ 20Th^{-1} + RDF + PSB@2kg ha^{-1} + PGPR@2kg ha^{-1}). Before sowing of crops representative soil samples were collected from each of the selected places. The soil samples were collected from (0-15) cm depth with the help of a stainless steel tube auger. The representative soil samples were transferred into tight polythene bags and brought into laboratory for proper processing. The soil sample were found sandy loam, bulk density 1.25 Mgm^{-3} particle density 2.85 $Mgm^{-3}$and available cadmium 0.15ppm in soil depth (0-15) cm . The chemical composition of soil viz, pH 7.3 , EC 0.20 dSm^{-1} organic carbon 5.5 gkg^{-1} ,available nitrogen 120 kgh^{-1}, available phosphorous 9 kgh^{-1} and available phosphorous 150 kgh-1.

The available heavy metals in the soil was determined by extracting the soil with DTPA–TEA–$CaCl_2$ (pH 7.3) as outlined by (Lindsay And Vorvell 1978). DTPA extractable heavy metals were estimated in sewage sludge applied soil before sowing and after harvesting of spinach. Plant leaf were washed thoroughly with tap water, acidified water distilled water and double distilled water. These samples were then dried first at room temperature for several days and then in hot (60$\pm$5˚C) air oven for 48 hrs. The dried plant parts were then crushed and powdered separately in mortar & pestle. The powdered plant samples were then kept separately in well washed, dried and suitably labeled flasks for various analytical parameters. The digested samples spinach leaf were transferred into small tubes for total concentration of cadmium using by Atomic Absorption Spectrophotometer.

The experiment was laid in randomized block design with 3 replications. The net cultivated area of each plot being $1m^2$. The crop was sown in the second week of October and harvested after 45 days. The experiment included the following treatments combination. The statistical analysis as per method of “Analysis of variance”. The significant and non significant of treatment effect was judged with the help of ‘F’ variance ratio test calculated ‘F’ at 5% level of significance.

3. Results and Discussion

3.1 Concentration of Heavy Metals in Spinach Grown Soil and Leaf

DTPA extractable heavy metals in soil and its uptake by spinach were summarized in table 1. The heavy metals content (ppm) of post harvested soil of spinach grown plot in treatment T_1 cadmium (0.64) ppm, lead (0.77), chromium (1.92) ppm and treatment T_2, cadmium (0.90) ppm, lead (0.83), chromium (2.14) ppm, tended to be higher than without sewage sludge applied soil (T_0), cadmium (0.05) ppm, lead (0.58), chromium (0.35) ppm respectively. Similar trends was observed in spinach leaf (concentration of heavy metals) in treatment T_1 and T_2 as compared to control. The data relevant heavy metals content increased gradually with increasing dose of sewage sludge application. It might be due to fact the concentration of heavy metals in sewage sludge emanating from different sources in many folds higher than control (Sharma, *et al.*, 2009). The concentration of heavy metal in spinach leaf were also higher in treatment T_1 and T_2 as compared to control plot (Hanc *et al* .,2006**).**

In the treatment T_3 (@ 10 Tha^{-1} sewage sludge + 20 kg lime ha^{-1}) showed , cadmium (0.65) ppm, lead (0.64), chromium (1.46) ppm, tended to be lower as compare to trématent T_1(@ 10 Tha^{-1} sewage sludge), cadmium (0.64) ppm, lead (0.77), chromium (1.92) ppm respectively. The concentration of heavy metal in spinach leaf were also lower in treatment T_3 as compared to control plot. This might be to high pH of soil and formation of insoluble hydroxide and carbonate was prime research for low uptake of this metal in plants (Yada and Kawasakil 2008 and Yassen *et al.,* 2006).

Application of sewage sludge with RDF had significant effect in the availability of cadmium content in spinach grown plot in the treatment T_5, cadmium (0.99) ppm, lead (0.48), chromium (1.53) ppm in comapaerd to control , cadmium (0.05) ppm, lead

(0.58), chromium (0.35) ppm respectively. This might be due to phosphatic fertilizers contain heavy metal as impurity. The concentration of heavy metal in spinach leaf were also higher in treatment T_5 as compared to control plot.

Table 1: DTPA extractable heavy metals (ppm) spinach grown plot at (0-15 cm) depths in soil and uptake of heavy metals (ppm) in spinach leaf.

Treatments combination	*DTPA extractable heavy metals (ppm) in soil*			*Uptake of heavy metals (ppm) in spinach leaf*		
	Cadmium	Lead	Chromium	Cadmium	Lead	Chromium
T_0	0.05	0.58	0.35	0.07	0.09	0.09
T_1	0.64	0.77	1.92	0.13	0.12	0.12
T_2	0.90	0.83	2.14	0.13	0.13	0.14
T_3	0.65	0.64	1.46	0.19	0.11	0.11
T_4	1.24	0.61	1.49	0.17	0.16	0.16
T_5	0.99	0.48	1.53	0.22	0.14	0.13
T_6	0.61	0.43	1.53	0.14	0.25	0.18
T_7	1.58	0.46	1.68	0.14	0.17	0.18
T_8	0.73	0.44	1.62	0.13	0.17	0.17
T_9	0.76	0.44	1.80	0.11	0.14	0.14
T_{10}	2.05	1.60	2.05	0.09	0.17	0.17
T_{11}	2.16	1.63	2.74	0.12	0.19	0.18
F-test	S	S	S	S	S	S
S.Em (±)	0.08	0.30	0.16	0.02	0.02	0.01
C.D (P=0.05)	0.18	0.74	0.39	0.05	0.06	0.04

The interaction between sewage sludge+RDF+PSM increased the availability of heavy metals in soil and spinach leaf in the treatment T_6 and T_7 in compassion to T_1. This might be due to because that the PSB showed intrinsic ability of growth promoting and attenuation of toxic affect of heavy metal could be exploited for remediation of heavy metal from heavy metal contaminated sight. The interaction between sewage sludge +RDF+PGPR decreased the amount of extractable heavy metals in the treatment T_8 and treatment T_9 in comparison to T_1 this might be due to plant growth promoting rhizobacteria producing Indo acitic acid (Vivas *et al* 2003) The interaction between sewage sludge+RDF+PGPR ($T_8$and T_9) decreased the amount of uptake heavy metals observed by plants when expressed on a root weight basis because of increase root biomas due to production of indol acitic acid. Similar finding had reported by Vivas *et al* 2003.

The interaction between sewage sludge+RDF+PSB+PGPR had showed highly desorption property of heavy metals in spinach grown plot in the treatment T_{10} , cadmium (2.05) ppm, lead (1.60), chromium (2.05) ppm and T_{11}, cadmium (2.16) ppm, lead (1.63), chromium (2.74) ppm as compared to control , cadmium (0.05) ppm, lead (0.58), chromium (0.35) ppm respectively. The concentration of heavy metals in spinach leaf showed not higher as like as in soil. This might be a positive correlation between invitro1-aminocyclopropane-1 carboxylate (ACC) deaminase activity of the bacteria and their simulating effect on root elongation suggest the utilization of ACC is an important bacteria trait determining root growth promoting. The isolated bacteria promise as innoculant to improved growth of metal accumulating sinach in presence of toxic Heavy metal concentration for the development of plant innoculant system useful for phytoremediation of polluted soil. Khuda and Hassan 2005.

4. Conclusion

Adding lime with sewage sludge raised soil pH and significantly reduced availability and mobility of heavy metals in soil and spinach leaf, while (NPK) and phosphate solublizing bacteria showed lower soil pH resulted increased the availability and mobility of heavy metals in soil and spinach leaf. The availability of heavy metals were found twice in the interaction between sewage sludge + RDF + PSB + PGPR in soil as compared to only sewage sludge application but in spinach leaf the concentration of heavy metals decreased as compared to only sewage sludge application. In ours finding all heavy metal found bellow the permissible limit in soil and plants except cadmium element, showed greater values than permissible limit (WHO).

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