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Mobility of Cadmium in Sewage Sludge Applied Soil and its Uptake by Radish (*Raphanus Sativus L*) and Spinach (*Spinacia Oleracea*)

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Abstract

An experiment was carried out in 2009 - 10 at the Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad to assess the mobility of cadmium in sewage sludge applied soil and its uptake by radish(Raphanus sativus L) and Spinach (Spinacia oleracea). In conjunction of sewage sludge with lime, fertilizer, Phosphate Solublizing Bacteria (PSB) and Plant Growth Promoting Rhizobacteria (PGPR) on the behavior of cadmium in soil profile (0-15), (15-30) cm, radish root and leaf and spinach leaf. The availability of cadmium increased with increase the quantity of sewage sludge in the treatment T_1 and T_2 but in the treatment (T_3) lime @ 20 kgha^{-1} + 10 tha^{-1} sewage sludge decreased the availability cadmium from (0.95) ppm to (0.71) ppm. There was an increased the availability of cadmium in the treatment T_4, T_5 and T_6, T_7 applied sewage sludge with fertilizer and sewage with PSB. However, there was decreased the availability of cadmium when applied sewage sludge with PGPR in the treatment T_8 and T_9 in compared to only sewage sludge applied soil. The availability of cadmium was found twice with the application of fertilizer, PSB and PGPR in the treatment T_{10} and T_{11} recording 1.97 ppm (T_{10}) and 2.12 ppm (T_{11}) as compared to only sewage sludge T_1 (0.95 ppm) and T_2(1.04 ppm).The main focus of present research paper to understand the absorption and desorption of cadmium in sewage sludge applied soil with different treatment combination for safely use of sewage sludge in agricultural land and human health.

Keywords: Sewage Sludge Allahabad (SSA),uptake, biotoxic, Adsorption, Desorption etc.

1. Introduction

Application of sewage sludge as manure to agricultural soil is a common practice because of availability of plant nutrients and its low costs. However, this practice can pose a threat to environment and the major concern arises from the fact that sewage sludge, especially those from the heavily urbanized and industrialized areas, contains a relatively high concentration of heavy metals. Thus application of sewage sludge to agricultural soil may result in elevated concentrations of toxic heavy metals like cadmium, lead and chromium, which may lead to food chain contamination and harmful for human health. In addition, metal adsorption on soils is strongly related to soil properties; it increased with increase in pH, organic matter and cation exchange capacity.

Cadmium is considered as one of the important soil and an environmental pollutant as it is the most potential biotoxic heavy metal that is readily absorbed by soil and enters into human food chain (Chang *et al.*, 1883). The greatest concern due to cadmium concentration is because of its occurrence in free ionic form. The adsorption of Cadmium mainly involve the free divalent cation Cd^{2+} (Neals and Sposito, 1986).

Cadmium is highly toxic to human health. After gaining entrance into the body cadmium is accumulated mainly in the soft tissues. More than half the body's burden of cadmium is found in the kidneys and liver. A disease especially associated with cadmium poisoning has been recognized in Japan known as "itai-itai". The International Agency for Research on Cancer has classified cadmium and its compounds in group 2B: limited evidence of carcinogenetic in animals and human being. The main focus of present research work to know the adsorption and desorption properties of cadmium ion in different amendments with sewage sludge applied soil.

2. Materials and Methods

The field experiment was conducted in the Department of Soil Science and Agricultural Chemistry farm, School of Forestry and Environment, SHIATS, Allahabad. In field experiment different dose of treatment combination such as 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 various depths (0-15) and (15-30) cm 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 depth (0-15) cm 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 cadmium 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 cadmium was estimated in sewage sludge applied soil before sowing and after harvesting of radish and spinach. Plant roots and 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 ($60\pm5^{\circ}$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 radish root, leaf and 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 Cadmium in Radish Grown Soil, Radish Root, Leaf and Spinach Grown Soil and Leaf

DTPA extractable cadmium in various depth of soil in radish and spinach grown plots is summarized in table 1. The cadmium content (ppm) of post harvested soil of radish and spinach grown plot in treatment T_1(0.95) ppmand T_2 (1.04) ppm tended to be higher than without sewage sludge applied soil (0.03) ppm in control plot 0-15cm soil depth. The data relevant cadmium 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. The availability of cadmium in soil showed decreases with increasing soil depths (0-15) to (15-30) cm in all treatment combination. The change in DTPA extractable cadmium in soil in case of radish grown plot and similar trend as given for spinach post harvest soil Sharma, *et al.,* 2009**.** The concentration of cadmium in radish root and leaf was increased T_1(0.02) and T_2(0.03) ppm in radish root and T_1 (0.03) and T_2 (0.04) ppm in radish leaf in comparison to control plot T_0 (0.02) ppm in root and 0.03 ppm in leaf). Similar results also showed in spinach leaf Hundal *et al.*, 2006, Hanc *et al* .,2006**.**

The DTPA extractable cadmium in the treatment T_3 @ 10 Tha^{-1} sewage sludge + 20 kg lime ha^{-1} was found (0.71) ppm in comparison to treatment T_1 @ 10 Tha^{-1} sewage sludge (0.95) ppm. The low mobility of cadmium in lime treated soil. The concentration of cadmium in the treatment T_3 (0.02) ppm in root and (0.03) ppm in leaf in comparison to T_1@ 10 Tha^{-1} sewage sludge (0.03) ppm in root and (0.04) ppm in radish leaf. 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). Similar result also observed in spinach grown soil and spinach leaf in the treatment T_3.

Table 1: DTPA extractable Cadmium (ppm) radish and spinach grown plot at various depths 0-15,15-30 cm in soil and uptake of cadmium (ppm)in radish root, leaf and spinach leaf.

Treatments combination	Cd (ppm) in radish grown plot (0-15 cm)	Cd (ppm) in radish grown plot (15-30 cm)	Cd (ppm) in radish root	Cd (ppm) in radish leaf	Cd (ppm) in spinach grown plot (0-15 cm)	Cd (ppm) in radish grown plot (15-30 cm)	Cd (ppm) in spinach leaf
T_0	0.03	0.02	0.02	0.03	0.05	0.03	0.07
T_1	0.95	0.10	0.02	0.03	0.64	0.14	0.13
T_2	1.04	0.40	0.03	0.04	0.90	0.28	0.13
T_3	0.71	0.33	0.02	0.03	0.65	0.31	0.19
T_4	1.56	0.30	0.03	0.05	1.24	0.27	0.17
T_5	1.25	0.25	0.04	0.04	0.99	0.20	0.22
T_6	1.42	0.47	0.04	0.06	0.61	0.48	0.14
T_7	1.12	0.34	0.03	0.05	1.58	0.35	0.14
T_8	0.90	0.24	0.04	0.06	0.73	0.19	0.13
T_9	0.68	0.21	0.03	0.05	0.76	0.20	0.11
T_{10}	1.97	0.51	0.04	0.07	2.05	0.65	0.09
T_{11}	2.12	0.63	0.06	0.08	2.16	0.74	0.12
F-test	S	S	NS	NS	S	S	S
S.Em ($\underline{+}$)	0.12	0.10	0.01	0.02	0.08	0.07	0.02
C.D (P=0.05)	0.28	0.23	0.02	0.04	0.18	0.18	0.05

Application of sewage sludge with RDF had significant effect in the availability of cadmium content in radish grown plot in the treatment T_4 (1.56) ppm and T_5 (1.25) ppm in compassion to T_1 (0.95) (ppm) and T_2 (1.04) ppm at 0 -15 depth this might be due to phosphatic fertilizers contain cadmium metal as impurity. In this treatment higher concentration of cadmium in the treatment T_4 (1.50) ppm in comparison to T_5 (0.78) ppm this might be due to increase dose of sewage sludge highly contain organic carbon which reduce the availability of cadmium in soil with similar dose of RDF. The concentration of cadmium content in radish root in the treatment T_4 (0.03) and in the treatment T_5 (0.04) ppm in compassion to T_1 (0.03) ppm and T_2 (0.04) ppm and radish leaf T_4 (0.06) and in the treatment T_5 (0.04) ppm in compassion to T_1 (0.04) ppm and T_2 (0.05) ppm. Similar result also showed in spinach grown plot (soil) and spinach leaf.

The interaction between sewage sludge+RDF+PSM increased the availability of cadmium in the treatment T_6 (1.42) ppm and T_7 (1.12) ppm in compassion to T_1 (0.95) ppm and T_2 (1.04) ppm at 0-15 cm depth increase the soluble form of phosphorous increased availability of cadmium it might be due to increase the cadmium contained phosphetic fertilizer increase the availability of cadmium in the treatment in root T_6 (0.04) ppm and T_7 (0.03) ppm and in leaf T_6 (0.06) ppm and T_7 (0.05) ppm, this might be due to because that the PSB showed intrinsic ability of growth promoting and attenuation of toxic affect of heavy cadmium could be exploited for remediation of heavy metal from heavy metal contaminated sight. Similar result also showed in spinach grown plot (soil) and spinach leaf.

The interaction between sewage sludge +RDF+PGPR decreased the amount of extractable cadmium in the treatment T_8 (0.90), ppm and treatment T_9 (0.68) ppm respectively in comparison to T_1 (0.95) ppm and T_2 (1.04), ppm at 0-15 depth 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 extractable cadmium 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. Similar result also showed in spinach grown plot (soil) and spinach leaf.

The interaction between sewage sludge+RDF+PSB+PGPR had showed highly desorption property of cadmium ion in radish grown plot in the treatment T_{10} (1.88) ppm and treatment T_{11} (2.06) ppm respectively in comparison to treatment T_1(0.95) ppm and T_2 (1.04), ppm at 0-15 cm depth (Thongavel and Subbhuraam 2004). The interaction between sewage sludge+RDF+PSB+PGPR (T_{10} and T_{11})showed 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 plant raddish 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

Sewage sludge obtained from sewage treatment plant, Naini was not applicable in agricultural land due to high concentration of cadmium. As is evident from the present investigation to restore degraded soil and vegetation with the use of such soil amendments which metallic cation might have a strong potential remediation approach and technology for metal contaminated soil also.

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