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 T₁ and T₂ but in the treatment (T₃) lime @ 20 kg ha⁻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 T₄, T₅ and T₆, T₇ 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 T₈ and T₉ 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 T₁₀ and T₁₁ recording 1.97 ppm (T₁₀) and 2.12 ppm (T₁₁) as compared to only sewage sludge T₁ (0.95 ppm) and T₂(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 Cd²⁺ (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 T₀ (control), T₁ (S.S.A. @ 10 Tha⁻¹), T₂ (S.S.A. @ 20Tha⁻¹), T₃(S.S.A. @ 10 Tha⁻¹ + 20 kg lime ha⁻¹), T₄ (S.S.A. @ 10Tha⁻¹ + RDF), T₅ (S.S.A. @ 20Tha⁻¹ + RDF), T₆ (S.S.A. @ 10Th⁻¹ + RDF + PSB @ 2kg ha⁻¹), T₇ (S.S.A. @ 20Th⁻¹ + RDF + PSB @ 2kg ha⁻¹) T₈ (S.S.A. @ 10Th⁻¹ + RDF + PGPR@2kg ha⁻¹) T₉ (S.S.A. @ 20Th⁻¹+ NPK + PGPR @ 2kg ha⁻¹), T₁₀ (S.S.A. @ 10Th⁻¹+ RDF+PSB@ 2kg ha⁻¹+ PGPR@2kg ha⁻¹) and T₁¹ (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
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depth (0-15) cm pH 7.3, EC 0.20 dSm⁻¹, organic carbon 5.5 g kg⁻¹, available nitrogen 120 kgh⁻¹, available phosphorus 9 kgh⁻¹ and available phosphorus 150 kgh⁻¹.

The available cadmium in the soil was determined by extracting the soil with DTPA–TEA–CaCl₂ (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±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 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 1m². The crop was sown in the second week of September 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 T₁ (0.95) ppm and T₂ (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 T₁ (0.02) and T₂ (0.03) ppm in radish root and T₁ (0.03) and T₂ (0.04) ppm in radish leaf in comparison to control plot T₀ (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 T₃ @ 10 Tha⁻¹ sewage sludge + 20 kg lime ha⁻¹ was found (0.71) ppm in comparison to treatment T₁ @ 10 Tha⁻¹ sewage sludge (0.95) ppm. The low mobility of cadmium in lime treated soil. The concentration of cadmium in the treatment T₃ (0.02) ppm in root and (0.03) ppm in leaf in comparison to T₁ @ 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 T3.

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.

<table>
<thead>
<tr>
<th>Treatments combinatio n</th>
<th>Cd (ppm) in radish grown plot (0-15 cm)</th>
<th>Cd (ppm) in radish grown plot (15-30 cm)</th>
<th>Cd (ppm) in radish root</th>
<th>Cd (ppm) in radish leaf</th>
<th>Cd (ppm) in spinach grown plot (0-15 cm)</th>
<th>Cd (ppm) in radish grown plot (15-30 cm)</th>
<th>Cd (ppm) in spinach leaf</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0</td>
<td>0.03</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
<td>0.05</td>
<td>0.03</td>
<td>0.07</td>
</tr>
<tr>
<td>T1</td>
<td>0.95</td>
<td>0.10</td>
<td>0.02</td>
<td>0.03</td>
<td>0.64</td>
<td>0.14</td>
<td>0.13</td>
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<tr>
<td>T2</td>
<td>1.04</td>
<td>0.40</td>
<td>0.03</td>
<td>0.04</td>
<td>0.90</td>
<td>0.28</td>
<td>0.13</td>
</tr>
<tr>
<td>T3</td>
<td>0.71</td>
<td>0.33</td>
<td>0.02</td>
<td>0.03</td>
<td>0.65</td>
<td>0.31</td>
<td>0.19</td>
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<tr>
<td>T4</td>
<td>1.56</td>
<td>0.30</td>
<td>0.03</td>
<td>0.05</td>
<td>1.24</td>
<td>0.27</td>
<td>0.17</td>
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<tr>
<td>T5</td>
<td>1.25</td>
<td>0.25</td>
<td>0.04</td>
<td>0.04</td>
<td>0.99</td>
<td>0.20</td>
<td>0.22</td>
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<tr>
<td>T6</td>
<td>1.42</td>
<td>0.47</td>
<td>0.04</td>
<td>0.06</td>
<td>0.61</td>
<td>0.48</td>
<td>0.14</td>
</tr>
<tr>
<td>T7</td>
<td>1.12</td>
<td>0.34</td>
<td>0.03</td>
<td>0.05</td>
<td>1.58</td>
<td>0.35</td>
<td>0.14</td>
</tr>
<tr>
<td>T8</td>
<td>0.90</td>
<td>0.24</td>
<td>0.04</td>
<td>0.06</td>
<td>0.73</td>
<td>0.19</td>
<td>0.13</td>
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<tr>
<td>T9</td>
<td>0.68</td>
<td>0.21</td>
<td>0.03</td>
<td>0.05</td>
<td>0.76</td>
<td>0.20</td>
<td>0.11</td>
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<tr>
<td>T10</td>
<td>1.97</td>
<td>0.51</td>
<td>0.04</td>
<td>0.07</td>
<td>2.05</td>
<td>0.65</td>
<td>0.09</td>
</tr>
<tr>
<td>T11</td>
<td>2.12</td>
<td>0.63</td>
<td>0.06</td>
<td>0.08</td>
<td>2.16</td>
<td>0.74</td>
<td>0.12</td>
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<tr>
<td>F-test</td>
<td>S</td>
<td>S</td>
<td>NS</td>
<td>NS</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>S.Em (+)</td>
<td>0.12</td>
<td>0.10</td>
<td>0.01</td>
<td>0.02</td>
<td>0.08</td>
<td>0.07</td>
<td>0.02</td>
</tr>
<tr>
<td>C.D (P=0.05)</td>
<td>0.28</td>
<td>0.23</td>
<td>0.02</td>
<td>0.04</td>
<td>0.18</td>
<td>0.18</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Application of sewage sludge with RDF had significant effect in the availability of cadmium content in radish grown plot in the treatment T4 (1.56) ppm and T5 (1.25) ppm in compassion to T1 (0.95) (ppm) and T2 (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 T4 (1.50) ppm in comparison to T5 (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 T4 (0.03) and in the treatment T5 (0.04) ppm in compassion to T1 (0.03) ppm and T2 (0.04) ppm and radish.
leaf T₄ (0.06) and in the treatment T₅ (0.04) ppm in compassion to T₁ (0.04) ppm and T₂ (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 T₆ (1.42) ppm and T₇ (1.12) ppm in compassion to T₁ (0.95) ppm and T₂ (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 T₆ (0.04) ppm and T₇ (0.03) ppm and in leaf T₆ (0.06) ppm and T₇ (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 T₈ (0.90), ppm and treatment T₉ (0.68) ppm respectively in comparison to T₁ (0.95) ppm and T₂ (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 (T₈sand T₉) 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 T₁₀ (1.88) ppm and treatment T₁₁ (2.06) ppm respectively in comparison to treatment T₁ (0.95) ppm and T₂ (1.04), ppm at 0-15 cm depth (Thongavel and Subbhuraam 2004). The interaction between sewage sludge+RDF+PSB+PGPR (T₁₀ and T₁₁)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.
References


