

## Influence of Sewage Sludge on the Mobility of Heavy Metals in *Inceptisol*

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**Abstract** Application of sewage sludge on agricultural field at soil science research farm led to the accumulation of DTPA-Pb from 0.35 to 0.98 ppm, DTPA-Cd from 0.05 to 0.98 ppm and DTPA-Ni from 0.32 to 0.53 ppm in surface soil (0–15 cm). A very low amount of Pb, Cd and Ni was observed in 30–45 cm depth in comparison to surface soil (0–15 cm) in the soil examined indicating less mobility of heavy metals in down depth. The DTPA-extractable Pb, Cd and Ni contents of sewage sludge applied soil decreased with increasing soil depth. The soil organic carbon content in sewage sludge soils was positively and significantly

affect soil properties like pH, electrical conductivity (EC), OC (%), available N, available P and available K exhibited positive relationship with DTPA-extractable Pb, Cd and Ni content in soil. The Pb, Cd and Ni contents in mustard grown crop on sewage sludge applied soil were higher as compared to grown on control soil. The treatments consisted of four sewage sludge levels (0, 4, 8 and 12 t ha<sup>-1</sup>) and four levels of inorganic fertilizer (0, 50, 75 and 100% RDF) was recorded significantly.

**Keywords** Sewage sludge, Pb, Cd, Ni, Movement.

### Introduction

The disposal of sewage sludge (city-waste) on soil as a fertilizer for agriculture or as a regenerative for soil is the most attractive application since the sludge act as a source of nutrient for crop production owing to the high content of organic matter. The application of sewage sludge into the agricultural soil can improve nutrient status of soil as well as physico-chemical parameter of this soil sewage sludge may be used in agriculture for increasing product yield. However, this practice has the potential to create environmental pollution problems because of the likely high contents of toxic heavy metals. Pollution problems may arise if toxic heavy metal are mobilized into the soil solution and are either taken by plants transported in drainage waters to associated water supplies. It can present high metal concentration (Cd, Cu, Ni, Pb and Zn) that can cause serious problems in plants and its

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**Table 1.** Effect of different levels of sewage sludge and inorganic fertilizers on soil pH and EC (dSm<sup>-1</sup>) at various depths (cm) harvest of mustard.

Depth (cm)	Treatments (2010)															CD at <i>F</i> (5%)	test	
	T <sub>0</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>	T <sub>7</sub>	T <sub>8</sub>	T <sub>9</sub>	T <sub>10</sub>	T <sub>11</sub>	T <sub>12</sub>	T <sub>13</sub>	T <sub>14</sub>	T <sub>15</sub>		
Soil pH																		
0-15	8.32	8.24	8.94	8.23	8.15	8.23	8.36	8.29	8.22	8.42	8.25	8.18	8.14	8.14	8.25	8.25	0.33	S
15-30	8.27	8.13	8.16	8.12	8.20	8.13	8.23	8.33	8.11	8.22	8.20	8.14	8.11	8.11	8.17	8.17	0.18	NS
30-45	8.07	8.05	8.05	8.04	8.18	8.03	7.96	8.13	8.07	8.20	8.10	8.11	8.01	8.09	8.06	8.11	0.18	NS
Depth (cm)	Treatments (2011)															CD at <i>F</i> (5%)	test	
	T <sub>0</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>	T <sub>7</sub>	T <sub>8</sub>	T <sub>9</sub>	T <sub>10</sub>	T <sub>11</sub>	T <sub>12</sub>	T <sub>13</sub>	T <sub>14</sub>	T <sub>15</sub>		
Soil pH																		
0-15	8.30	8.23	8.69	8.30	8.22	8.29	8.36	8.33	8.25	8.39	8.26	8.20	8.14	8.10	8.29	8.23	0.24	S
15-30	8.29	8.21	8.49	8.14	8.20	8.16	8.22	8.30	8.11	8.11	8.02	7.80	8.02	7.58	8.11	8.11	0.27	S
30-45	8.28	8.09	8.42	8.05	8.13	8.05	7.83	8.07	7.83	8.85	7.58	8.52	7.45	7.37	7.93	8.04	0.24	S
Depth (cm)	Treatments (2010)															CD at <i>F</i> (5%)	test	
	T <sub>0</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>	T <sub>7</sub>	T <sub>8</sub>	T <sub>9</sub>	T <sub>10</sub>	T <sub>11</sub>	T <sub>12</sub>	T <sub>13</sub>	T <sub>14</sub>	T <sub>15</sub>		
EC (dSm <sup>-1</sup> )																		
0-15	0.39	0.42	0.41	0.44	0.48	0.45	0.50	0.53	0.55	0.56	0.56	0.52	0.57	0.58	0.61	0.63	0.02	S
15-30	0.34	0.37	0.34	0.40	0.43	0.18	0.44	0.46	0.49	0.51	0.49	0.46	0.50	0.53	0.57	0.56	0.02	S
30-45	0.29	0.33	0.31	0.37	0.39	0.16	0.41	0.44	0.46	0.48	0.42	0.39	0.38	0.48	0.49	0.45	0.02	S
Depth (cm)	Treatments (2011)															CD at <i>F</i> (5%)	test	
	T <sub>0</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>	T <sub>7</sub>	T <sub>8</sub>	T <sub>9</sub>	T <sub>10</sub>	T <sub>11</sub>	T <sub>12</sub>	T <sub>13</sub>	T <sub>14</sub>	T <sub>15</sub>		
EC (dSm <sup>-1</sup> )																		
0-15	0.18	0.24	0.29	0.28	0.26	0.14	0.16	0.37	0.28	0.25	0.21	0.23	0.36	0.38	0.41	0.43	0.00	S
15-30	0.15	0.16	0.27	0.26	0.16	0.17	0.14	0.16	0.19	0.19	0.15	0.20	0.28	0.29	0.32	0.36	0.02	S
30-45	0.14	0.12	0.15	0.15	0.13	0.16	0.12	0.16	0.16	0.14	0.13	0.16	0.21	0.24	0.28	0.30	0.02	S

consumers, the metal may then enter in the human food chain through the consumption of such plants or through intake of contaminated water. Sewage sludge usually brings to the soil elevated amount of potentially toxic elements, such as As, Cd, Pb and Zn. The plant availability of these elements can be affected by the source of sludge, pH, redox condition, humidity and preoccupation of sludge. In addition, the sludge treatment can alter the elements distribution into main soil fractions according to individual soil, high concentration of metals can change plant biological processes, such as photosynthesis, respiration, enzyme activity and growth, which may result in a lower production.

Many studies have been conducted to determine the effects of sewage sludge application on crop and plant yield and soil properties [1] lastly the apply of

sewage sludge as fertilizer sources is the major factor in the maintenance of soil fertility and substitute of mineral fertilizers.

## Materials and Methods

The study was carried from 2010 and 2011 on field of Department of Soil Science, School of Agriculture, SHIATS- Deemed to be-University, Allahabad. The samples of sewage sludge were collected from the sewage sludge treatment plant in the town of Naini, Allahabad. The collected soil sample from different depth (0-15, 15-30 and 30-45 cm) were analyzed for DTPA-TEA CaCl<sub>2</sub> (pH 7.3) extractable Pb, Cd and Ni [2] analyzed by atomic absorption spectrophotometer having flame. Soil pH, EC were analyzed by standard procedure and organic carbon determined by

**Table 2.** Effect of different levels of sewage sludge and inorganic fertilizers on soil OC (%) at various depths (cm) harvest of mustard.

Depth (cm)	Treatments (2010)															CD at <i>F</i> (5%) test		
	T <sub>0</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>	T <sub>7</sub>	T <sub>8</sub>	T <sub>9</sub>	T <sub>10</sub>	T <sub>11</sub>	T <sub>12</sub>	T <sub>13</sub>	T <sub>14</sub>		T <sub>15</sub>	
Soil OC (%)																		
0-15	0.37	0.41	0.60	0.65	0.45	0.57	0.65	0.68	0.48	0.46	0.60	0.68	0.38	0.55	0.75	0.76	0.04	S
15-30	0.31	0.17	0.38	0.35	0.41	0.55	0.43	0.48	0.22	0.38	0.27	0.65	0.32	0.51	0.35	0.37	0.01	S
30-45	0.08	0.14	0.07	0.29	0.16	0.38	0.09	0.25	0.09	0.23	0.18	0.38	0.07	0.43	0.26	0.22	0.04	S
Depth (cm)	Treatments (2011)															CD at <i>F</i> (5%) test		
	T <sub>0</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>	T <sub>7</sub>	T <sub>8</sub>	T <sub>9</sub>	T <sub>10</sub>	T <sub>11</sub>	T <sub>12</sub>	T <sub>13</sub>	T <sub>14</sub>		T <sub>15</sub>	
OC (%)																		
0-15	0.40	0.44	0.63	0.66	0.47	0.58	0.66	0.68	0.51	0.48	0.62	0.69	0.39	0.56	0.76	0.77	0.01	S
15-30	0.32	0.21	0.41	0.36	0.42	0.56	0.44	0.50	0.24	0.39	0.28	0.66	0.33	0.52	0.36	0.38	0.00	S
30-45	0.09	0.13	0.10	0.28	0.17	0.39	0.08	0.26	0.11	0.24	0.19	0.38	0.10	0.44	0.27	0.24	0.01	S

standard method [3].

## Results and Discussion

### Soil pH and electrical conductivity

The data on soil pH and electrical conductivity (EC) of experimental site at various depths are presented in Table 1. Soil pH decreased slightly with increasing depth. Such change in pH may be attributed to downward movement of sewage- sludge containing organic acid, humic and fluvic acid in the soil. Application of sewage sludge for cultivation a higher EC. Such change in pH and EC were also reported earlier [4]. The effects of depth and soils and their interaction were significant on pH and EC.

### Organic carbon

Table 2 shows that percentage organic carbon of harvested soil of mustard grown plot was significant at various depths in both experimental years 2010 and 2011. The mean percent organic carbons of post harvest soil of the mustard grown plot were recorded at

0-15, 15-30 and 30-45 cm depth in various depths. The percentage of organic carbon of post-harvested soil of mustard plot in (T<sub>14</sub> and T<sub>15</sub>) is tended to be significantly greater than remaining treatments and it decreased with increasing soil depths. The increased organic matter and the retention of dissolve organic matter led to change in per cent organic carbon in soil profile of post harvest soil of mustard grown plot. Similar finding was also reported earlier [1].

### Available macronutrient in soil

Table 3 shows that available nitrogen of harvested soil of mustard grown plot was significant in different depth in both experimental years 2010 and 2011. The mean available nitrogen of post harvest soil of mustard grown plot recorded at 0-15, 15-30 and 30-45 cm depth. Available nitrogen of post harvest soil of mustard grown plot in the treatment (T<sub>14</sub> and T<sub>15</sub>) tended to be higher than control plot and it further decreased with increasing soil depths, because sewage sludge contained appreciable amount of nitrogen therefore, brought it significant increase in available nitrogen of post harvested soil of mustard similar finding was also reported earlier [5].

The available phosphorus of harvested soil of

**Table 3.** Effect of different levels of sewage sludge and inorganic fertilizers on soil available N, P, and K kg ha<sup>-1</sup> at various depths (cm) harvest of mustard.

Depth (cm)	Treatment <sup>f</sup> (2010)															CD at (5%)	F test	
	T <sub>0</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>	T <sub>7</sub>	T <sub>8</sub>	T <sub>9</sub>	T <sub>10</sub>	T <sub>11</sub>	T <sub>12</sub>	T <sub>13</sub>	T <sub>14</sub>	T <sub>15</sub>		
Available N (kg ha <sup>-1</sup> )																		
0-15	192.7	197.9	199.1	200.0	194.9	198.6	217.2	250.9	203.9	280.3	299.0	327.9	205.3	339.2	358.1	365.2	0.51	S
15-30	181.6	186.8	186.2	192.9	177.1	178.8	184.0	184.0	194.0	207.2	222.0	206.1	196.0	303.1	317.0	316.0	0.08	S
30-45	171.0	163.6	171.9	185.3	162.4	149.1	166.0	172.9	184.1	195.1	198.9	188.8	175.0	187.1	112.1	104.4	8.2	S
Depth (cm)	Treatments (2011)															CD at (5%)	F test	
	T <sub>0</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>	T <sub>7</sub>	T <sub>8</sub>	T <sub>9</sub>	T <sub>10</sub>	T <sub>11</sub>	T <sub>12</sub>	T <sub>13</sub>	T <sub>14</sub>	T <sub>15</sub>		
Available N (kg ha <sup>-1</sup> )																		
0-15	193.2	198.1	199.6	219.1	195.8	199.2	218.1	252.3	208.1	284.6	308.1	329.2	207.3	341.1	359.3	366.3	0.49	S
15-30	183.0	188.0	187.2	194.1	178.1	181.1	185.3	185.1	195.1	208.1	223.1	207.1	197.1	304.1	318.1	217.1	0.07	S
30-45	179.0	167.6	181.9	185.3	161.0	151.1	166.0	176.9	184.1	197.1	199.9	189.8	175.0	189.1	114.1	107.4	0.26	S
Depth (cm)	Treatments (2010)															CD at (5%)	F test	
	T <sub>0</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>	T <sub>7</sub>	T <sub>8</sub>	T <sub>9</sub>	T <sub>10</sub>	T <sub>11</sub>	T <sub>12</sub>	T <sub>13</sub>	T <sub>14</sub>	T <sub>15</sub>		
Available P (kg ha <sup>-1</sup> )																		
0-15	8.9	9.8	10.4	11.8	13.9	14.8	15.1	15.5	16.8	16.9	18.2	18.5	18.8	19.4	20.5	24.0	1.51	S
15-30	7.1	6.9	5.9	7.8	7.9	11.0	9.0	8.1	11.0	9.9	10.6	12.0	12.9	13.7	12.8	16.0	2.98	S
30-45	3.6	4.9	5.8	6.9	6.9	10.0	8.1	7.9	9.0	8.0	8.0	7.1	9.4	10.6	10.3	10.1	1.84	S
Depth (cm)	Treatments (2011)															CD at (5%)	F test	
	T <sub>0</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>	T <sub>7</sub>	T <sub>8</sub>	T <sub>9</sub>	T <sub>10</sub>	T <sub>11</sub>	T <sub>12</sub>	T <sub>13</sub>	T <sub>14</sub>	T <sub>15</sub>		
Available P (kg ha <sup>-1</sup> )																		
0-15	9.6	10.8	11.1	12.6	14.7	15.8	16.2	16.3	17.8	17.8	18.1	19.5	19.7	19.8	20.8	24.9	0.40	S
15-30	7.8	8.0	8.9	9.5	9.2	10.4	8.4	10.8	12.3	12.0	13.2	13.5	13.8	14.6	11.5	16.5	1.52	S
30-45	5.0	6.3	6.4	6.7	7.0	5.7	6.7	7.3	8.9	8.1	8.5	8.8	11.1	12.4	9.7	10.5	2.29	S
Depth (cm)	Treatments (2010)															CD at (5%)	F test	
	T <sub>0</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>	T <sub>7</sub>	T <sub>8</sub>	T <sub>9</sub>	T <sub>10</sub>	T <sub>11</sub>	T <sub>12</sub>	T <sub>13</sub>	T <sub>14</sub>	T <sub>15</sub>		
Available K (kg ha <sup>-1</sup> )																		
0-15	216.3	225.6	228.8	240.7	242.8	243.8	245.0	241.7	245.9	246.2	247.1	229.8	245.6	247.1	247.7	249.1	1.74	S
15-30	214.5	217.7	221.4	228.7	234.7	221.9	226.8	217.7	227.9	229.6	219.5	212.2	220.0	223.3	230.5	233.6	1.79	S
30-45	213.4	213.5	215.9	213.8	218.7	210.8	208.8	206.0	211.7	213.5	212.4	212.8	205.0	208.0	211.8	225.9	1.44	S
Depth (cm)	Treatments (2011)															CD at (5%)	F test	
	T <sub>0</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>	T <sub>7</sub>	T <sub>8</sub>	T <sub>9</sub>	T <sub>10</sub>	T <sub>11</sub>	T <sub>12</sub>	T <sub>13</sub>	T <sub>14</sub>	T <sub>15</sub>		
Available K (kg ha <sup>-1</sup> )																		
0-15	216.8	227.7	229.9	241.5	243.6	244.8	246.3	242.8	247.4	247.7	247.8	231.5	246.9	248.2	248.2	249.9	1.09	S
15-30	214.7	218.7	221.7	229.6	236.4	222.5	227.8	218.7	228.9	231.4	220.8	213.3	220.7	223.8	231.5	234.9	0.60	S
30-45	213.8	213.4	216.8	215.2	219.7	212.3	210.5	208.5	212.5	213.8	214.4	212.8	206.8	209.6	212.8	226.8	0.68	S

mustard grown plot, was significant at different in both experimental years 2010 and 2011 (Table 3). The mean available phosphorus of post harvest soil of the mustard grown plot were recorded at 0-15, 15-30 and 30-45 cm depth in both the experimental years. The treatment (T<sub>14</sub> and T<sub>15</sub>) caused significantly higher

than control and it is decreased with increasing soil depth, because sewage sludge contained appreciable amount of phosphorus. Therefore, it brought significant increase in available phosphorus of post harvest soil of mustard. It is accordance with the similar finding reported earlier [6].

Available potash of harvested soil of mustard grown plot was significant at different in both experimental years 2010 and 2011 (Table 3). The available potash  $\text{kg ha}^{-1}$  of post-harvested soil of mustard grown plot in the treatment  $T_1$  and  $T_2$  are significantly higher than control and it is decreased with increasing soil depths. This is also due to higher content of potash in sewage sludge thus brought significant increase in available potash of potash harvested soil of mustard. Similar results also reported earlier [6].

DTPA extractable heavy metals (Pb, Cd and Ni) (ppm) at various depths (cm) at harvest

DTPA extractable lead in various depths of soil is summarized in Fig. 1. The statistical analysis was found to be significant at various depth in both the experimental years 2010 and 2011. The Pb (ppm) of post-harvested soil of mustard grown plot treatment  $T_4$  @ 4 ton sewage sludge and  $T_9$  @ 8 ton sewage sludge had significantly effect on Pb status of post harvest soil of mustard as shown in Fig. 1. and graphically represented in Fig. 1. The extractable Pb increase with increasing quantity of sewage sludge. Similar finding had also reported earlier [7]. The interaction between sewage sludge + inorganic fertilizers (NPK) had significant effect on extractable Pb in mustard grown plot as compared to control plot the application of sewage sludge ( $T_{14}$  and  $T_{15}$ ) showed highly extractable Pb then they remain treatments. Similar finding had also reported earlier [8].

DTPA extractable cadmium in various depth of soil is summarized in Fig. 1. Statistical analysis was found to be significant at various depths in both the

experimental years 2010 and 2011. The Cd content (ppm) of post harvested soil of mustard grown plot in treatment  $T_4$  and  $T_5$  treatment tended to be higher than control treatment. The concentration Cd decreased with increasing depths in both experimental years. The concentration of Cd in 2011 was higher in comparison to the concentration of Cd in 2010. The content relevant as Cd content increased gradually with increasing level of sewage sludge application as compared to control plot. Similar finding has also been reported earlier [9]. The interaction between sewage sludge and inorganic fertilizers (NPK)  $T_{14}$  and  $T_{15}$  had significant effect on extractable Cd in mustard grown plot as compared to control plot the application of sewage sludge ( $T_{14}$  and  $T_{15}$ ) showed highly extractable Cd then they remain treatments.

The Ni content of post harvested soil of mustard grown plot in treatment  $T_4$  and  $T_5$  treatment tended to be higher than control treatment. The concentration of Ni decreased with increasing depths in both experimental years. The concentration of Ni in 2011 was higher in comparison to the concentration of Ni in 2010. The content relevant as Ni content increased gradually with increasing level of sewage sludge application as compared to control plot. Similar finding has also been reported earlier [10]. The interaction between sewage sludge and inorganic fertilizers (NPK)  $T_{14}$  and  $T_{15}$  had significant effect on extractable Ni in mustard grown plot as compared to control plot. The application of sewage sludge ( $T_{14}$  and  $T_{15}$ ) showed highly extractable Ni.

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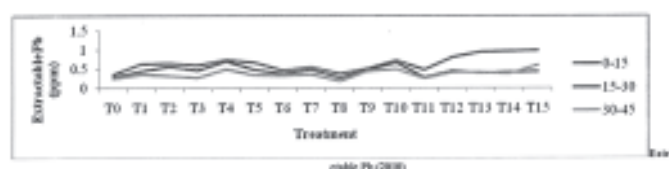
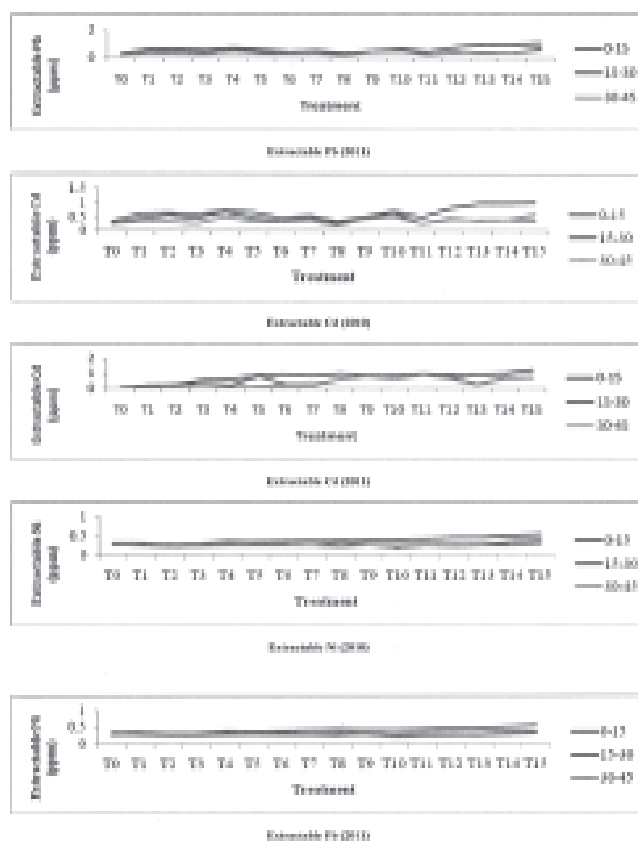


Fig. 1A.



**Fig. 1A, 1B.** Effect of different level of sewage sludge and inorganic fertilizers on soil DTPA extractable heavy metals (Pb, Cd and Ni) (ppm) at various depths (cm) at harvest of mustard.

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