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# STUDY ON HEAVY METAL ACCUMULATION IN THE PLANTS GROWN IN THE SOIL AMENDED WITH CETP SLUDGE IN DIFFERENT COMPOSITIONS

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**Abstract**
Present study was carried out to demonstrate the utility of sludge generated from a CETP of Delhi as a resource and its use as a soil supplement with special emphasis on heavy metal accumulation in plants. Sludge collected from Wazirpur CETP was analyzed for certain heavy metals. Soil was amended with sludge in 5%, 10%, 20% and 30% to grow experimental plants, in duplicates. The plants were allowed to grow for 45 days and then analyzed for heavy metals using ICP-OES. Results concluded that the addition of sludge in soil do not affects the plant growth in general, but heavy metal content in plant parts increased appreciably after 10% sludge addition. Bioaccumulation Factor (BAF) of more than 1 in case of Cr and Pb in Desi chana and of Cr, Cu, Ni and Pb in Indian mustard indicate that the plants are accumulators of the above-mentioned metals and they may be evaluated for phytoremediation. Sewage sludge contains good amount of nutrients, but due to high concentration of toxic metals, it cannot be applied for land application in considerable amount. However, sewage sludge can still be considered as a beneficial alternative, in order to supplement the organic fertilizers, after suitable chemical characterization and risk assessment.

**Keywords:** Soil; Sewage sludge; amendment; heavy metals; Bioaccumulation; Phytoremediation.

## INTRODUCTION

Priorities in environmental management of wastes are changing with time. In India, the ongoing development of wastewater treatment facilities with improved efficiencies is leading to a notable escalation in the daily generation of sewage sludge, also known as biosolids. It is predicted that around 132 billion liters of wastewater per day would be generated in India by 2050, with a potential to meet 4.5 per cent of the total irrigation water demand [1]. In the upcoming years, overall water management highlights a dual challenge to cope with the surge in wastewater and biosolid production, attributed to the escalating population and industrialization. One of the biggest environmental concerns, worldwide, is about the safe disposal of the sewage sludge [2]. The decision regarding disposal and reclamation of sludge, requires an understanding of the behavior of toxic metals, organic contaminants and other pollutants, specific to local conditions which include climate, mineralogy, geochemistry and topography. Although, landfill disposals of hazardous wastes are still considered to be the main alternative, the escalation in the prices of land and growing population makes it difficult to find new landfill sites. Incineration is another common method to manage sludge but it is costly and difficult to adopt as a regular practice on a large scale or urban set ups. Bioremediation of sludge facilitates in reducing BOD, COD, TSS, Coliform and also reduces odor problem but it is still under nascency.

Use of industrial sewage sludge on agricultural soil seems attractive because of increasing energy requirements and cost associated with alternative disposal methods and benefits gained from recycling of plant nutrients present in these

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wastes. It was also reported that due to green revolution high yield of agriculture production has led to depletion of micronutrients from our croplands. With relation to our recent environmental problems, studies of waste characteristics are the key for the successful, safe and suitable management of our wastes. [3] Utilizing sewage sludge in agriculture emerges as a favorable choice for its secure disposal, presenting an approach to enhance soil physical, chemical and biological attributes, facilitated by the substantial organic matter content in sewage sludge, offering an opportunity to recycle essential plant nutrients such a nitrogen (N), phosphorus (P), potassium (K), secondary nutrients and micronutrients. Contrary to the previously mentioned point, the composition of sewage sludge varies based on its origin, and it frequently harbours elevated levels of potentially toxic heavy metals, prolonged and excessive use of sewage sludge can lead to an increased bioavailability of these metals in the soil, ultimately resulting in contamination of the food chain. [4]

The objective of this work is to study the accumulation of heavy metals in plants grown in different mixtures of soil and Wazirpur CETP sludge. On the basis of calculated Bioaccumulation Factor, the two species may also be classified as excluder and accumulator.

## MATERIAL AND METHODS

### Study area

The study was conducted using sludge collected from Wazirpur Industrial CETP, located in Delhi. Influent coming to the CETP is heterogenous in nature as it is discharged from different kind of industries, including rolling, pickling, electroplating, textiles, anodizing, soap, rubber plastics, candles, and engineering. As per Delhi State Industrial and Infrastructure Development Corporation Ltd (DSIIDC), out of 1939 industries, 1222 industries are connected to Wazirpur CETP. 3-4 tons of sewage sludge is generated per day and from 2006-2020, 13000 to 15000 tons of sludge was still stored inside the premises during present study. During the monsoon period, many industrial sites experience flooding with acidic wastewater and garbage, reflecting the challenge of managing toxic waste generated by numerous small-scale industries.

### Soil and sludge preparation

Soil from the designated area was collected, sealed, and sun-dried. It was ground to a fine consistency using a pestle and mortar and then sieved through a 0.7mm sieve. Sewage sludge, obtained from the Wazirpur CETP, was air-dried, crushed and mixed with soil to create five sludge soil mixtures, representing 0%, 5%, 10%, 20% and 30% of the total mixture.

### Selection of Plant material

The seeds of two common plant species, namely, *Brassica juncea* (Black Indian mustard) *and Cicer arietinum* (Desi chana or chick pea) were chosen for the study. Since the species are fast growing and appropriate with the study season, they have been selected.

### Pot Experimental Setup

Total 20 experimental pots (10 pots for each plant species), each of inner diameter 6 inches, had been included in the present study. 0%, 5%, 10%, 20% and 30% of sewage sludge was mixed with the soil and each dosage was in duplicate. Each pot was filled with 900g of soil. No sludge was added in the soil of control. No fertilizer or manure was added to the experimental and control pots. All the pots were watered at the same time with appropriate amount of tap water, as required and were kept at a place such that all received uniform sunlight.

Small sprouts were observed in Indian mustard within one week of sowing, while in chickpea, sprouts emerged after 10 days as can be seen in Fig 1(1a & 1b). During initial growth phase, it was observed that the plant growth decreased as the amount of sludge increased in the pots (Figure 2). However, the difference in plant growth disappeared over the next 10-15 days and at the end of growth period (45 days) all plants had same growth (Figure 3). The plants were harvested. Stem and root samples were collected separately, dried in oven and powdered for further analysis (Figure 4).

1a 1b

**Figure 1: Appearance of sprouts in Indian mustard (1a) and chickpea (1b) within 7 and 10 days of sowing respectively**

**Figure 2: Effect of increasing sludge amount on growth pattern in plants of Indian mustard and chickpea from control to 30% mixture**
**Front row: chick pea (10 pots); Back row: Indian mustard (10 pots)**


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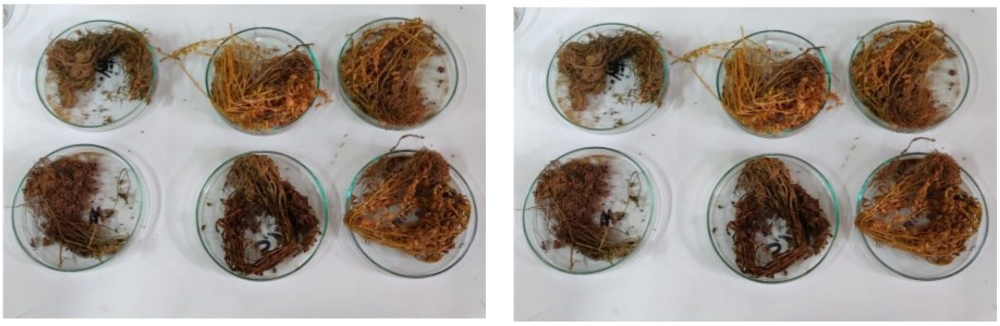

**Figure 4: Oven dried stem and roots samples of Indian mustard and Chickpea**

## Analysis of the soil and plant samples

pH, Electrical conductivity, soluble cations, particle size distribution, bulk density, particle density, porosity and Water Holding Capacity (WHC) have been determined in soil samples using recommended standard methods. Heavy metal analysis of soil, sludge and plant samples has also been performed. 1 gm of soil or sludge samples were digested using 20 ml of aqua regia in microwave digester (Make: CEM Mars one model) [5] [6]. Final volume was 100 ml. 0.5 gm of plant samples were digested with 5 ml of nitric acid and 3 ml of hydrogen peroxide in the microwave digester, with make-up volume of 50 ml. The samples were filtered using Whatman No.4 filter followed by 0.22 micron syringe filter. Prepared samples for heavy metal estimation were ran on

ICP-OES (M/s Teledyne Leeman Labs) with calibration standards ranging from 1-10 ppm for soil and sludge samples. The range of calibration standards for plant samples was 200-1000 ppb. The metal concentration was reported in mg/Kg for all the samples.

## RESULTS AND DISCUSSION

Characterization of soil is presented in Table 1. The soil is of sandy-loam texture and slightly alkaline in nature. Table 2 presents the heavy metal (Cd, Cr, Cu, Fe, Ni and Pb) data of soil and sludge. Concentration of heavy metals in sludge is found to be much higher than in the soil. Present heavy metal data has been compared with the limit values prescribed by Council of the European Commission (CEC) on protection of Environment [7], the concentration of Cd, Cr, Cu, Ni and Pb in soil are much below the limit values whereas in sludge only Cd and Zn are found below the limit values. The limit values of heavy metals in sludge prescribed by ECE suggests that the suitability of the sludge to be mixed with agricultural soil.

**Table 1: Characteristics of soil.**

| Parameter | Value |
|---|---|
| pH | 8.4 |
| Electrical conductivity | 0.321 mS/cm |
| Texture | Sandy loam |
| Soluble cations (meq/L) | $Ca^{2}$+=122, $Mg^{2}$+=60, $Na^{+}$=6.91, $K^{+}$ =31.12 |
| Particle size distribution | sand=74.8%, silt = 6.8%, clay = 8.4% |
| Bulk density | 0.159 g/cc |
| Particle density | 0.318 g/cc |
| porosity | 50% |
| Water holding capacity | 37.34% |

**Table 2: Composition of heavy metals in soil and sewage sludge**

| | Cd | Co | Cr | Cu | Fe | Mn | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|
| Soil | 1.2 | 8.3 | 34 | 16 | 17089 | 315 | 22 | 2.8 | 54 |
| Sludge | 6.4 | 65 | 11764 | 1912 | 104427 | 7525 | 1271 | 2050 | 105 |

(All the values are in mg/kg)

**Table 3: Limit value for heavy metals in soil and sludge as per Council of European Commission (CEC)**

| Heavy metal | CEC limits in soil (mg/kg) | CEC limits in Sewage sludge(mg/kg) |
|---|---|---|
| Cd | 1-3 | 20 |
| Cr | 100-150 | 1200 |
| Cu | 50-140 | 1200 |
| Ni | 30-75 | 200 |
| Pb | 50-300 | 1200 |

### Metal content in stems of Desi Chana (DC) and Indian Mustard (IM) and their comparison

Table 4 presents the concentration of heavy metals in stems of DC and IM and their comparison. As obvious, concentration of all heavy metals is found to increase as the sludge amount increased in sludge-soil mixtures. Concentration of Cr, Ni and Pb is found to be BDL in both the control samples as well as in all sludge-soil mixture. Cd was also analyzed, but it was found to be BDL in all samples including control, hence not reported in table. On comparison of metal content in the stems of DC and IM, it is found that concentration of Cr, Cu, Fe, Ni and Pb in both the plant species differ significantly. Metal content is found to be higher in the stem of IM than in the DC in all the soil-sludge mixtures and this difference in concentrations is most pronounced in case of Cr and Pb. Their concentration in the stem of IM is found to be more than 100 times than that found in the stem of DC in 10% sludge-soil mixture The difference in the concentration of metals in both type of plants may be attributed to the plant species, the level of the metals in the sludge amended soil, surrounding air, speciation state of heavy metals in soil, their bioavailability, soil parameters like pH, CEC, vegetation period and other factors.

**Table 4: Comparison of heavy metal concentration in the stem of Desi Chana and Indian Mustard.**

| | Cr | Cu | Fe | Ni | Pb |
|---|---|---|---|---|---|
| **DESI CHANA STEM** | | | | | |
| CON DC S | BDL | 0.55 | 786 | BDL | BDL |
| 5% DC S | BDL | 3 | 819 | BDL | BDL |
| 10% DC S | 0.54 | 3 | 1323 | BDL | 0.07 |
| 20% DC S | 13 | 3 | 1366 | 5 | 0.67 |
| 30% DC S | 53 | 12 | 2075 | 9 | 8.2 |
| **INDIAN MUSTARD STEM** | | | | | |
| CON IM S | BDL | BDL | 2250 | BDL | BDL |
| 5% IM S | 4 | 4 | 1146 | BDL | BDL |
| 10% IM S | 105 | 19 | 3787 | 8 | 11 |
| 20% IM S | 141 | 42 | 6124 | 11 | 37 |
| 30% IM S | 252 | 54 | 7834 | 34 | 45 |

**(CON = Control, DC = Desi Chana, IM = Mustard, S = stem, BDL = Below Detection Limit) (All the values are in mg/kg)**

**Metal content in roots of Desi Chana (DC) and Indian Mustard (IM) and their comparison**

Table 5 presents the concentration of heavy metals in the roots of DC and IM and their comparison. As obvious, concentration of all heavy metals is found to increase as the sludge amount increased in sludge-soil mixtures. There are differences in the concentration of Cr, Cu, Fe, Ni and Pb in the roots of BC and IM but the difference is not so significant as found in their respective stems. On comparison of metal content in the stems of Desi chana and Indian Mustard, it is found that concentration of Cr, Cu, Fe, Ni and Pb in both the plant species differ greatly. Figure 6(a) to 6(e) present the comparison. Metal content is found higher in the roots of Indian mustard than the Desi chana in most soil-sludge mixtures. The difference in the concentration of metals in both type of plants may be attributed to the plant species, the level of the metals in the sludge amended soil, surrounding air, speciation state of heavy metals in soil, their bioavailability, soil parameters like pH, CEC, vegetation period and other factors.

**Table 5: Comparison of heavy metal concentration in the roots of Desi Chana and Indian Mustard.**

| | Cr | Cu | Fe | Ni | Pb |
|---|---|---|---|---|---|
| **DESI CHANA ROOT** | | | | | |
| CON DC R | 8 | 3 | 4433 | BDL | BDL |
| 5% DC R | 25 | 7 | 2917 | BDL | 1 |
| 10% DC R | 196 | 58 | 4940 | 29 | 55 |
| 20% DC R | 260 | 71 | 5539 | 37 | 64 |
| 30% DC R | 363 | 76 | 8235 | 39 | 74 |
| **INDIAN MUSTARD ROOT** | | | | | |
| CON IM R | 4 | BDL | 6115 | BDL | BDL |
| 5% IM R | 3 | 7 | 1469 | BDL | 3 |
| 10% IM R | 60 | 18 | 6558 | 9 | 8 |
| 20% IM R | 389 | 77 | 7376 | 45 | 71 |
| 30% IM R | 1189 | 239 | 13412 | 149 | 233 |

**(CON = Control, DC = Desi Chana, IM = Mustard, R = Root, BDL = Below Detection Limit) (All the values are in mg/kg)**

**Bioaccumulation Factor (BAF) of heavy metals**

Table 6 presents the BAF for the heavy metals. In case of DC, BF >1 is found only in 30% sludge-soil mixture for Cr and Pb which suggests that DC accumulates metals when they are at very high concentrations in growing media. Cu, Fe and Ni do not accumulate significantly at any sludge-soil amendment in DC.

**Table 6: Bioaccumulation Factor for different metals.**

| | Cr | Cu | Fe | Ni | Pb |
|---|---|---|---|---|---|
| **DESI CHANA (C shoot / C soil)** | | | | | |
| CON DC | - | 0.034 | 0.046 | - | - |
| 5% DC | - | 0.193 | 0.047 | - | - |
| 10% DC | 0.016 | 0.233 | 0.077 | - | 0.024 |
| 20% DC | 0.38 | 0.243 | 0.079 | 0.208 | 0.237 |
| 30% DC | 1.57 | 0.76 | 0.121 | 0.399 | 2.907 |
| **INDIAN MUSTARD (C shoot / C soil)** | | | | | |
| CON M | - | - | 0.131 | - | - |
| 5% M | 0.11 | 0.25 | 0.067 | - | - |
| 10% M | 3.09 | 1.22 | 0.221 | 0.507 | 0.498 |
| 20% M | 4.16 | 2.65 | 0.358 | 0.345 | 13.3 |
| 30% M | 7.43 | 3.40 | 0.458 | 1.5 | 16.2 |

**(CON = Control, DC = Desi Chana, IM = Indian Mustard)**

In case of IM, significant accumulation of Cr, Cu, Ni and Pb is found in the shoot. Cr and Cu showed accumulation in all sludge-soil amendment except 5% whereas Ni showed accumulation only in 30% amendment. Maximum BAF (13.3 and 16.2) is found for Pb in 20% and 30% amendments indicating very high concentration of Pb, contributed by sludge (2050 mg/Kg).

Plants have been classified as excluder and accumulator, depending on BAF. When BAF <1, the plant is classified as excluder and the plant only absorbs the trace metal but does not accumulate. When BAF >1, the plant is an accumulator which means the plant has the ability to accumulate one or more heavy metals in its tissues. This makes plant useful in phytoremediation of metal contaminated soil by accumulating one or more heavy metals. In the present study, BAF of Cr, Cu, Ni and Pb is more than 1 in IM, indicating that IM is an accumulator for them and it can be used for the phytoremediation of soil containing excess of Cr, Cu, Ni and Pb. In case of DC, the plant may be used as an accumulator for Cr and Pb.

## CONCLUSION

In the present study, 10% sludge mixture seemed to be appropriate for growing plants, while 20% and 30% sludge mixtures show appreciable accumulation of toxic metals in the plants, which is not favorable for the well-being of plant and its consumers. On the other hand, the study also concludes that *Brassica juncea* (Black Indian mustard) *and Cicer arietinum* (Desi chana or chick pea) are accumulators and they may be used in phytoremediation of the soil contaminated with Cr, Cu, Ni and Pb. Addition of sludge directly in soil for growing plants may be one way of using the CETP sludge without involving any cost for sludge treatment. However, pretreatment of the sludge for removing excess toxic metals before adding into the soil will further enhance the use of sludge in growing plants. This needs an additional study in which sludge nutrient (NPK) profile, presence of organic contaminants, organic matter content etc. must be undertaken. Appropriate dosage of sludge (after necessary characterization) in soil may increase its use in agricultural soil, thus making a judicious use of tons of sludge without any processing.

The application of sewage sludge from the Wazirpur CETP Plant suggests that the sludge may be applied in the soil in appropriate dosage. Growing plants in sludge-soil amendment did not affect the growth of the plants, as evident from the present study, although an alteration in the levels of heavy metals in the soil and plants may occur. Escalating fertilizer costs, coupled with unbalanced and inefficient utilization, pose significant challenges within the agricultural sector. Thus, sewage sludge can be considered as a beneficial alternative in order to supplement the organic fertilizers. However, after risk assessment and proper characterization of the sludge, its use for agricultural purposes should be ecologically evaluated so as to prevent contamination in the soil-plant-animal-continuum.

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