

Effect of Chelating Agents on Distribution of Lead in Soil after Harvest of *Brassica juncea*

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Abstract

An experiment was conducted under screen house conditions to evaluate the effect of chelating agents on distribution of Pb in soil at 180 mmol/kg soil and farm yard manure (FYM) at 3% with *Brassica juncea* as test crop in the sewage sludge unamended and amended soils. Addition of chelating agents increased the exchangeable fraction highlighting their utility in increasing its available pool in the soils. The dominant Pb fraction was organic followed by Fe, carbonate, manganese oxide, exchangeable and reserve Pb fractions. Significantly higher content of Exch-Pb was observed in sewage sludge unamended than amended soil. Significantly low content of Exch-Pb was observed in soil at 80 days after sowing (DAS) than that at 50 DAS of *B. juncea*. Highest amount of exchangeable Pb at 50 DAS was observed in NTA treated soil whereas CDTA was more effective at 80 DAS.

Key words : Chelating agents, Lead in soil, Distribution, Harvest, *Brassica juncea*.

Heavy metals are ubiquitous environmental contaminants in an industrialized society. A gradual increase in accumulation of heavy metals in soils of many agricultural fields owing to discharge of industrial and municipal residual wastes has caused a serious problem to the crop production and hazards to human and animal health. Use of sewage sludge continuously may increase heavy metals in soil but organic matter, present in the sludge can complex/immobilize Pb and decrease their bioavailability (1). Addition of chelating agents such as nitrilotriacetic acid (NTA), diethylenetriaminepentaacetic acid (DTPA), cyclohexanediaminetetraacetic acid (CDTA) and citric acid have been reported to increase the exchangeable fraction of Pb in the solution phase (2). Hence, higher extractability of Pb due to chelating agents may lead to their excessive accumulation in plants. Hence, the study was carried out to study the effect of chelating agents on distribution of Pb in soil.

Methods

The bulk surface sample (0—15 cm) collected from the experimental area, CCS Haryana Agricultural University, Hisar, Haryana was processed and used for laboratory and screen house studies. The processed soils were divided into two portions. The

first part treated with Pb using Pb NO_3 at 180 mg/kg soil and second portion treated with Pb at 180 mg/kg and sewage sludge at 3%. After incubation soils were mixed thoroughly and filled in 72 earthen pots at the rate of 5 kg soil/pot. the experiment was carried out in a completely randomized design, arranged in a (2 × 6 × 6 = 72) factorial, two soils (sewage sludge unamended and amended); six amendment (control, four chelating agents and FYM) and six replications. Ten healthy seeds of the *B. juncea* cultivar were sown in each pot in third week of October, 2005. After emergence of seedling, only four plants per pot were allowed to grow. Four chelating agents namely, CDTA, citric acid, DTPA and NTA were applied at rate of 3 mmol/kg soil (1 mmol daily for 3 days in 3 split doses) 40 DAS. The FYM at 3% was uniformly mixed in portion of Pb spiked and Pb spiked sewage sludge treated soil 10 weeks before sowing. Ten days after application of chelating agents half of the mustard crop (i.e. 3 replications out of 6) were harvested and remaining 3 replications were harvested 80 DAS. Then at workable moisture content, representative soil samples (covering full depth of soil in pot) were taken with the help of a stainless steel tube auger, air dried, ground, sieved and kept in polyethylene bags for fractionation studies.

Sequential chemical fractionation of soil Pb fol-

Table 1. Effect of chelating agents on distribution of Pb in soil samples after harvest of *B. juncea* in Pb enriched soil.

| Treatment | 50 DAS | | 80 DAS | | Mean |
|---------------------------|-----------------------------|------------------------------|--|-------------------|-------|
| | Without SS | With SS | Without SS | With SS | |
| Exchangeable-Pb | | | | | |
| Pb ₁₈₀ | 22.68 | 19.84 | 21.04 | 18.52 | 20.52 |
| Pb ₁₈₀ + CDTA | 31.72 | 29.76 | 29.42 | 27.90 | 29.70 |
| Pb ₁₈₀ + CA | 27.84 | 25.68 | 25.28 | 24.26 | 25.77 |
| Pb ₁₈₀ + DTPA | 29.86 | 28.64 | 27.92 | 26.28 | 28.18 |
| Pb ₁₈₀ + NTA | 37.00 | 34.24 | 26.78 | 24.90 | 30.73 |
| Pb ₁₈₀ + FYM | 24.26 | 22.68 | 22.68 | 20.66 | 22.57 |
| Mean | 28.89 | 26.81 | 25.52 | 23.75 | |
| CD (0.05) | Soil=0.84 S × T = 1.18 | Time = 0.84 S × CA = NS | Chelating agents = NS T × CA = 2.04 | S × T × CA = NS | |
| Carbonate Bound-Pb | | | | | |
| Pb ₁₈₀ | 36.66 | 30.82 | 33.36 | 30.40 | 32.81 |
| Pb ₁₈₀ + CDTA | 31.28 | 20.42 | 24.64 | 24.46 | 25.20 |
| Pb ₁₈₀ + CA | 31.66 | 29.72 | 30.00 | 27.88 | 29.82 |
| Pb ₁₈₀ + DTPA | 32.24 | 30.92 | 25.68 | 27.28 | 29.03 |
| Pb ₁₈₀ + NTA | 28.64 | 28.94 | 29.96 | 27.56 | 28.78 |
| Pb ₁₈₀ + FYM | 34.24 | 30.42 | 31.86 | 31.92 | 32.11 |
| Mean | 32.45 | 28.54 | 29.25 | 28.25 | |
| CD (0.05) | Soil=0.76 S × T = 1.08 | Time = 0.76 S × CA = 1.86 | Chelating agents = 1.32 T × CA = 1.86 | S × T × CA = 2.64 | |
| MnO Bound-Pb | | | | | |
| Pb ₁₈₀ | 27.84 | 27.06 | 24.72 | 24.46 | 26.02 |
| Pb ₁₈₀ + CDTA | 27.36 | 25.66 | 24.20 | 23.68 | 25.23 |
| Pb ₁₈₀ + CA | 29.26 | 28.26 | 28.38 | 25.78 | 27.92 |
| Pb ₁₈₀ + DTPA | 28.08 | 29.56 | 25.72 | 26.40 | 27.44 |
| Pb ₁₈₀ + NTA | 26.62 | 24.42 | 26.86 | 23.06 | 25.24 |
| Pb ₁₈₀ + FYM | 28.20 | 27.28 | 26.00 | 29.06 | 27.64 |
| Mean | 27.89 | 27.04 | 25.98 | 25.41 | |
| CD (0.05) | Soil=0.65 S × T = 0.92 | Time=0.65 S × CA = 1.59 | Chelating agents = NS T × CA = NS | S × T × CA = NS | |
| Organic Bound-Pb | | | | | |
| Pb ₁₈₀ | 50.62 | 52.20 | 58.68 | 61.28 | 55.70 |
| Pb ₁₈₀ + CDTA | 50.86 | 51.28 | 56.68 | 59.12 | 54.49 |
| Pb ₁₈₀ + CA | 52.32 | 53.16 | 56.46 | 59.28 | 55.31 |
| Pb ₁₈₀ + DTPA | 49.62 | 51.42 | 52.22 | 61.26 | 53.63 |
| Pb ₁₈₀ + NTA | 50.84 | 51.26 | 54.24 | 57.78 | 53.53 |
| Pb ₁₈₀ + FYM | 48.80 | 55.80 | 58.80 | 63.26 | 56.67 |
| Mean | 50.51 | 52.52 | 56.18 | 60.33 | |
| CD (0.05) | Soil = 0.81 S × T = 1.15 | Time = 0.81 S × CA = 2.00 | Chelating agents = 1.41 T × CA = 2.00 | S × T × CA = 2.82 | |
| FeO Bound-Pb | | | | | |
| Pb ₁₈₀ | 35.28 | 39.64 | 35.08 | 38.18 | 37.05 |
| Pb ₁₈₀ + CDTA | 34.24 | 37.68 | 38.04 | 35.20 | 36.29 |
| Pb ₁₈₀ + CA | 35.28 | 30.22 | 33.40 | 35.66 | 33.64 |
| Pb ₁₈₀ + DTPA | 34.64 | 30.28 | 34.84 | 37.88 | 34.41 |
| Pb ₁₈₀ + NTA | 34.42 | 30.12 | 35.62 | 36.80 | 34.24 |

Table 1. Continued.

| Treatment | 50 DAS | | 80 DAS | | Mean |
|--------------------------|-------------------------|--------------------------|--------------------------------------|-----------------|-------|
| | Without SS | With SS | Without SS | With SS | |
| Pb ₁₈₀ +FYM | 34.80 | 39.88 | 33.00 | 29.08 | 34.19 |
| Mean | 34.78 | 34.64 | 35.00 | 35.47 | |
| CD (0.05) | Soil=NS S × T=0.96 | Time=NS S × CA=1.66 | Chelating agents=2.35 T × CA=1.66 | S × T × CA=0.35 | |
| Residual-Pb | | | | | |
| Pb ₁₈₀ | 12.84 | 13.84 | 11.24 | 8.48 | 11.6 |
| Pb ₁₈₀ + CDTA | 10.60 | 10.80 | 9.54 | 7.02 | 9.49 |
| Pb ₁₈₀ + CA | 10.64 | 11.26 | 9.64 | 7.88 | 9.86 |
| Pb ₁₈₀ + DTPA | 10.56 | 9.82 | 9.80 | 6.80 | 9.25 |
| Pb ₁₈₀ + NTA | 8.20 | 6.56 | 8.42 | 7.04 | 7.56 |
| Pb ₁₈₀ + FYM | 10.64 | 10.20 | 9.62 | 6.86 | 9.33 |
| Mean | 10.58 | 10.41 | 9.71 | 7.35 | |
| CD (0.05) | Soil=0.26 S × T=0.36 | Time=0.26 S × CA=0.62 | Chelating agents=0.44 T × CA=0.62 | S × T × CA=0.88 | |

lowed the method of Berti et al. (3) used in previous studies. The method we used had six fractions. viz. exchangeable Pb (Exch-Pb), carbonate-bound Pb (Carb-Pb), Mn oxide-bound Pb (MnOx-Pb), organically complexed Pb (Org-Pb), Fe oxide-bound Pb (FeOx-Pb), residual Pb (Res-Pb), Lead in all soil extracts were measured using Atomic absorption spectrophotometer.

Results and Discussion

Table 1 reveals that the transformation of Pb to different fractions in sludge unamended and amended soils was influenced differentially by different chelating agents. The fraction wise description is given below.

Exchangeable-Pb (Exch-Pb)

Application of chelating agents caused more increase in the exchangeable Pb as compared to control (Pb₁₈₀) (Table 1). Though the overall effect of chelating agents was non-significant on the amount of Exch-Pb but its maximum value was observed in NTA treated soil and the least in control (Pb₁₈₀). The Exch-Pb increased from 20.52 in control (Pb₁₈₀) to 30.73 mg/kg soil in NTA treated soil. The mean content of Exch-Pb decreased significantly with increasing time in both soils. However, slightly higher content of Exch-Pb was observed in sewage sludge unamended than

amended soil. The possible reason for higher value of Exch-Pb fraction in chelate treated soils may be due to their role in mobilizing Pb to this form from other fractions (4).

Carbonate Bound -Pb (Carb-Pb)

The mean content of Carb-Pb decreased significantly in chelating agents treated soil (Table 1). The Carb-Pb was relatively higher in control (Pb₁₈₀) but it decreased with the application of chelating agents. The mean Carb-Pb was 32.45 and 28.54 mg/kg in sewage sludge unamended and amended soil, respectively at 50 DAS. The mean Carb-Pb also decreased with increasing time due to addition of chelating agents.

Manganese oxide Bound Pb (MnO-Pb)

The mean content of MnO-Pb varies from 26.02 to 27.92mg/kg soil. Significantly lower content of MnO-Pb was observed at 80 DAS than 50 DAS. The MnO-Pb fraction in CDTA treated soil was 27.36 and 25.66 mg/kg, respectively in sewage sludge unamended and amended soils at 50 DAS of *B. juncea*. Similar trend was also observed at 80 DAS.

Organic Bound-Pb (Org-Pb)

The Org-Pb fraction increased significantly with

increased levels of sewage sludge from 0 to 3%. The organic bound Pb significantly increased from 50.51 to 52.52 and 56.18 to 60.33 mg/kg soil at first and second stage of growth with an increased level of sewage sludge from 0 to 3% respectively, on the other hand Org-Pb also increased with increased in time.

Ferrous Bound Pb (Fe-Pb)

The mean content of Fe-Pb increased from 34.78 to 35.00 in sewage sludge unamended and 34.64 to 35.47 mg/kg in amended soil after 50 and 80 DAS, respectively. The mean content of Fe-Pb decreased due to addition of chelating agents. Citric acid decreased Fe-Pb fraction from 35.28 to 30.22 mg/kg soil with an increase in sewage sludge level from 0 to 3% at 50 DAS. But reverse trend was observed in soil samples drawn 80 DAS.

Reserve-Lead (Res-Pb)

It reveals that Res-Pb decreased with increased time and addition of chelating agents (Table 1). The Res-Pb in sewage sludge amended soil decreased from 10.41 to 7.35 mg/kg with an increase in time from 50 to 80 DAS. It was also observed that NTA was more effective in decreasing Res-Pb than any other chelating agent. The mean Res-Pb fraction decreased from 10.58 to 10.41 mg/kg at 50 DAS and similar trend was observed at 80 DAS.

Thus, it is evident from the Table 1 that dominant Pb fraction was organic followed by Fe, carbonate,

manganese oxide, exchangeable and reserve Pb fractions. Application of chelating agents increased the exchangeable fraction causing an increase in its availability in the soils. It may be concluded that application of chelating agents caused an increase in the exchangeable fraction of Pb. Wang et al. (5) and Indoria (6) reported that in sewage sludge treated soil most part of the total Pb in soil was in carbonate and organic matter fractions.

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