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Heavy metal accumulation in wheat plant grown in soil amended with industrial sludge

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Abstract

The concentrations of different forms of Zn, Cu, Mn, Ni, Cd, Cr, Pb and Fe metals were determined for the roadside sludge collected from pickling-rolling and electroplating industrial area. In sludge the relative abundance of total heavy metals were Fe > Mn > Cr > Ni > Cu > Pb > Zn > Cd and DTPA-extractable metals were in the order – Fe > Ni > Mn > Cr > Cu > Zn > Pb > Cd.

Pot-culture experiment was conducted in soils amended with sludge (0%, 10%, 20%, 30%), pretreated with lime (0%, 0.5% and 1%). The soils were alkaline in nature (pH > 8.3) with organic carbon contents were 0.34% and 0.72%. The most abundant total and bio-available metal was Fe. Two wheat seedlings were grown in each pot containing 3 kg sludge-amended or control soil and the experiment was conducted till harvesting. Application of sludge increased both total and bio-available forms of metals in the soils, while lime application decreased the bioavailability of heavy metals in sludge-amended soils. The content of organic carbon showed positive correlation with all metals except Zn, Cr and Pb. CEC also showed a strong positive correlation ($R^2 > 0.7$) with Fe, Mn, Cu, Ni and Cd. Though wheat plants are not accumulators, the translocation efficiency was appreciably high. The translocation factor from shoot to grain was found smaller than that of root to shoot of wheat plants. This makes an implication that the heavy metal accumulation was proportionally lesser in grain than in shoot. In, 10% sludge with 0.5% lime-amended soils; each of these toxic heavy metals was found to be within permissible range (USEPA). Hence, on the basis of present study, the best possible treatment may be recommended.

Keywords: Industrial sludge; Metals; Bio-concentration factor; Translocation factor; Lime treatment; Wheat plants

1. Introduction

Disposal of sludge on land is an age-old practice throughout the world to avoid the higher cost of incineration. However, it leads to an increase in pollution load in the soil with numerous environmental consequences. The variable nature and concentrations of trace elements are largely dependent on the type and amount of urban and industrial discharges. The elements of primary concern are Cd, Zn, Cu, Pb, Ni which, when applied to the soil in excessive amount, may decrease plant yields or degrade quality of food or fiber products. Sludge should therefore be analyzed for nutrients and trace elements before applying on land.

The factors that generally affect the chemistry of metals in soil and their uptake by organisms are pH, organic matter and redox conditions; among these pH is considered to be the most important and easily manageable one (Förstner et al., 1991). Soil pH influences the availability and plant uptake of micronutrients. The grasses grown at the industrial waste site with a high pH have the lowest micronutrient concentrations. Liming on soil offers an approach for minimizing the risk of food chain contamination by reducing the plant uptake of sludge-born heavy metals (Jackson and Alloway, 1991; Smith, 1994). According to several studies, the efficiency of liming varies depending on the soil type, metal content, pH of the soil and particular crop species (Pepper et al., 1983; Eriksson, 1988).

Baker (1981) has distinguished three types of plants, viz. accumulators, excluders and indicators. In accumulator

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plants the ratio of the concentration of elements in the plant to that in the soil is ≫1. In excluder plants, metal concentration in aerial parts are maintained low and constant over a wide range of metal concentration in soil, up to a critical value above which the exclusion mechanism breaks down, resulting in unrestricted transport and toxicity, plant/soil concentration factors is <1. In indicator plants the uptake and transport of metals are regulated in such a way that the ratio of the concentration of element in the plant to that in the soil is >1. Bio-concentration factor (BCF) and translocation factor (TF) are important parameters in heavy metal uptake studies (Zayed et al., 1998; Marchiol et al., 2004).

In the present study, we focused on the safe disposal of metal contaminated acidic sludge, as well as heavy metal uptake and accumulation in different parts of wheat plants.

2. Materials and methods

2.1. Sites sludge and soil

The study site, Wazirpur industrial area, is located in northwest part of Delhi, India. The main polluting industries are electroplating, pickling-rolling and textiles. Due to the large number of the small-scale industries and their unmonitored level of pollution, now that area has emerged as one of the major polluted industrial zones of Delhi. Samples were collected from different locations of the industrial area for each season (summer, monsoon and winter) from an open dumping ground and roadside dumps in accordance with the standard methods.

The two sampling sites for soil were Jawaharlal Nehru University (JNU) campus and Chhattarpur farmland. JNU soil is free of any kind of perturbation by agricultural, industrial or any such activities. JNU is covered by thick greenery with rich flora and fauna. The soil collected from Chhattarpur farmland has already been exposed to fertilizers, pesticides and many other pollutants. JNU soil is in the natural state and that of Chhattarpur is disturbed by anthropogenic activities. Soil samples were collected from 5 different spots from JNU as well as from Chhattarpur and were homogenized separately. Sampling was done once during the study period.

Soon after the collection of sludge and soils, the pH, electrical conductivity (EC), water holding capacity (WHC) and moisture content (MC) were measured and remaining samples were kept for drying at room temperature. Then air-dried sludge samples were ground and passed through 2 mm sieve and homogenized to make a representative sample. Following the same methods also processed soil samples.

2.2. Preparation for glass house experiment

As the sludge was acidic (pH 3.05) the pre-treatment was necessary to neutralize the pH. So, the homogenized sludge was treated with two different dosages of lime (0.5% and 1% by dry weight basis). The lime treated and control sludge (0% lime) was mixed with soils (Chhattarpur and JNU) separately at the rate of 0%, 10% 20% and 30% (dry weight basis). Then the sludge-amended and control soils were kept in earthen pots (3 kg/pot).

The wheat grains (HD1553) were collected from National Seed Corporation (NSC), Pusa, New Delhi. Then the plants were grown in two pots with the two soils separately. Two wheat seedlings of 7-day-old were transferred in the earthen pot containing sludge-amended or control soil. Distilled water was given to the plants to maintain 50% moisture of WHC through out the experiment. Whole experiment was carried out in a glass house maintaining the temperature at 20–30 °C. The experiment was performed with three replicates and was continued from January to April 2004.

2.3. Collection of soil and plant samples

Plant and soil samples were collected from the pots in different stages of plant growth, viz. planting, tillering, flowering, grain formation and harvesting. At each harvest, plants were removed carefully and washed first with tap water followed by de-ionized water. Root and shoot were separated and lengths were measured. Then kept in oven at 80 °C for 48 h. After drying, weight of root and shoot was taken. Weight of the grains collected after final harvest was also measured. At each step, care was taken to minimize any kind of contamination.

2.4. Chemical analysis

Both, the soil and the plant samples, were analyzed for their chemical composition by following methods mentioned below:

Organic carbon (OC) by Walkey and Black (1934), cation exchange capacity (CEC) by direct distillation method (Jackson, 1975), total nitrogen (TN) by kjeldahl method (Bremner, 1960), bio-available metal by DTPA extraction method (Lindsay and Narvell, 1978), total metal by tri-acid digestion method (Agemian and Chau, 1976) and heavy metal of plants by wet digestion method (Allen, 1974).

AAS used for Cu, Zn, Mn, Ni, Cd, Cr, Pb and Fe detection was AA-6800 model (SHIMADZU). Air-acetylene gas was used as fuel.

2.5. Data analysis

2.5.1. ANOVA (analysis of variance)

In the present study, different chemical parameters for the soils (treated with different proportion of lime and sludge) were monitored on five growth stages of plants (days). Similarly, different physico-chemical parameters for the plants were also monitored on the four growth stages of plants. These parameters were studied for root and shoot separately. Each set of data was arranged to execute two sets of 2-factor ANOVA ($p < 0.05$) as follows: