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EFFECT OF INDUSTRIAL SLUDGE ON CONCENTRATION AND DISTRIBUTION PATTERN OF LEAD, CADMIUM AND NICKEL IN ROOT, STEM AND LEAF OF RED AMARANTH (*AMARANTHUS GANGETICUS* L.) IN SILTY CLAY LOAM SOIL

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Abstract

A pot experiment was carried out to evaluate the concentration and distribution of Lead, Cadmium and Nickel in industrial sludge. The test crop was Red Amaranth (*Amaranthus gangeticus* L.). Nitrogen was applied comprising the five combinations of different proportion of urea and industrial sludge and a control. Red Amaranth was harvested at 30 and 42 Days after sowing (DAS). Different physical and chemical analysis of soil, sludge, root, stem and leaf of the plant were carried out as required. Heavy metals concentration indicated the trends of Pb>Ni>Cd and distribution pattern of Pb, Cd and Ni were identified Leaf> root> stem, Root> leaf> stem and Root> leaf> stem respectively, both at 30 and 42 DAS with little exception. Industrial sludge had a significant influence on heavy metal concentration and distribution and contaminant food chain, although the data were below the maximum acceptable level.

Key Words: Industrial sludge, Concentration, Distribution pattern, Lead, Cadmium, Nickel, Red Amaranth

Introduction

In recent time environmental pollution is a global problem and a great threat to the existence of living world, the pollution being continuously aggravated. Heavy metals in sludge and soil are generally present in a variety of forms exhibiting different degrees of bioavailability and mobility (Salim *et al.* 1996). The corollary to the studies on the form of metals in sewage is that the metals coming from raw sludge determine their presence in the first instance. It is known that metals may be present as inorganic forms such as oxides, hydroxides, sulfides (Mosey *et al.* 1971) or as loose organic complex such as with humic acid or polysaccharides (Holtzclaw *et al.* 1970). Most system of controlling sludge application to the land involve the use of total metal concentration in sludge but in developing criteria to evaluate metals in sludge is essential to understand the nature of fraction present in the soil (Matthews 1984). Stover *et al.* (1976) has examined metal fractions in digested sludge by using a sequential extraction procedure for the separation of metals. Nevertheless, the procedure used by Stover *et al.* (1976) to rank the different forms of metal in digested sludge is as follows: Lead, carbonates>organic- bond>sulfides

>adsorbed>exchangeable;Cd,carbonates>sulfides>organic-ond>adsorbed=exchangeable; Ni, carbonates>organic-bond>exchangeable>adsorbed>sulfide.

Heavy metals such as zinc, copper, cadmium, chromium, nickel, mercury and lead can be phytotoxic. They accumulate in aquatic and terrestrial habitats and simultaneously contaminate the animal and human food chains, and hence will also cause diseases in human (Chaney 1983). Plants take up high level of nickel easily which cause toxicity to plants. However, Ni is an essential micronutrient to plant which is required by urease enzyme to hydrolyze urea formed in plants and avoid NH_3 toxicity (Salisbury and Ross 1992). Lead is also micronutrient in plant, but can cause damage to central and peripheral nervous systems, kidney and highly toxic to infants and pregnant women. Lead, Cd, Ni etc. in fertilizers and pesticides are important factors causing pollution. In contrast to most pollutants, these are not biodegradable. The result of pollutants undergoing global ecological cycles causes severe environmental pollution.

Many vegetables are grown in Bangladesh. Red Amaranth is one of them and grown in wide range in the country including industrial effluent contaminated lands too. Farmers use industrial sludge as a nutrient supplement without knowing its nutrient or toxic metal concentration. The crop may contain toxic or heavy metals from the effluent and sludge, which may be harmful to food chain. So, it is important to investigate the concentration and distribution pattern of heavy metals by the different parts of plant collected from sludge and effluent. The information could be helpful for developing techniques to handle such types of wastes and people would be concern about use of waste (sludge/effluent) for the crops and vegetables production. The main objectives of the study was to determine the concentration and distribution pattern of selected heavy metals in different parts of red amaranth, so as to assess the safety and feasibility of consuming red amaranth grown in area contaminated with industrial sludge.

Materials and Methods

The experiment was carried out in pot in a net house of the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. The experimental site was located at latitude 24°05′N, longitude 90°16′E and altitude 8.4 m AMSL. Soil was silty clay loam belonging to Chiaata series in the Bangladesh soil classification system (Brammer and Saheed 1984). Industrial sludge was collected from ‘Islam dyeing’ and ‘Dundy dyeing’ industry at Konabari, Gazipur and Badsha, Niki and Combined dyeing industry at Katchpur, Narayanganj. The test crop was Red Amaranth (*Amaranthus gangeticus* L.), variety “BARI Lalshak-1”. The experiments were designed to provide nutrient and heavy metals to red amaranth using different ratios of urea and industrial sludge. Six treatment combinations were prepared as T1.UN_{100} + SN_0 (100% urea-N + 0% sludge-N), T2. UN_{75} + SN_{25} (75% urea-N + 25% sludge-N), T3. UN_{50} + SN_{50} (50% urea-N + 50% sludge-N), T4. UN_{25} + SN_{75} (25% urea-N + 75% sludge-N), T5. UN_0 + SN_{100} (0% urea-N +100% sludge-N) and T6. Control (0% urea-N + 0% sludge-N). The experiment was conducted in completely randomized design (CRD) with four replications. Phosphorous (P) and potassium (K) were applied at the rate of 40 and 112.5 kg/ha, respectively as per fertilizer recommendation guide-2005. Accordingly, each pot (5.0 kg of oven dry soil) was given approximately 0.09 g P and 0.25 g K using triple super phosphate (19.78% P) and muriate of potash (50% K). Nitrogen was applied at the rate of 250 kg/ha and each pot received 0.6 g of N in the combinations of urea and sludge, depending upon the treatments.

Soil samples were collected initially, intermittently and after harvesting the crop. Three soil columns were collected from each pot using a core sampler to the depth of 20 cm. These samples were then mixed to make a composite sample, air-dried, ground, sieved and stored in labeled polythene bags for laboratory analysis. Plant height was measured at 30 and 42 DAS, i.e. just prior to harvesting, in which the height of every plant in each pot from the soil level up to the apical bud was measured and average plant height was calculated and recorded. The plants were then uprooted (when soil was moist), properly washed and leaves, stems and roots were separated. Both fresh and oven dry weights were recorded after drying in an oven for 72 hours at 70 ^{0}C. These samples were separately ground, labelled and stored for laboratory analysis.

The Particle-size analysis of the soil was made by combination of sieving and hydrometer method as described by Day (1965) and textural classes were determined by Marshall’s Triangular Coordinate curve. In both soil and industrial sludge samples, pH was determined with distilled water (1:2.5) by Metrohm 691 digital pH meter (Jackson 1973). Organic carbon was determined using the dry combustion method, for which the LECO Model C 200 analyzer was used. The organic matter concentrations in samples were computed by multiplying the organic carbon concentration with 1.72 (Nelson and Sommers 1982). Total N was estimated by Micro-kjeldhal method (Jackson 1973).

Later, soil and industrial sludge extracts were prepared by ammonium acetate extraction method for determination of available K, DTPA extraction method for available Zn, Pb, Cd and Ni and Olsen method for available P (Jackson 1973). Plant extracts were prepared, by nitric (HNO_3) acid (68%) digestion method using a specified weight of ground materials for computing total amount of selected elements including Pb, Cd and Ni. From the above soil, industrial sludge and plant extracts, P was determined colorimetrically (using spectrophotometer UV-Model lamda 11), K flame emission spectrophotometrically (using flame photometer Model Jenway pfp-7), Pb, Cd, Ni and Zn Atomic Absorption Spectrophotometrically.

Results and Discussion

The physical and chemical parameters of soil are tested and shown in Table1. The test results confirm that the soil did not have traceable levels of Pb, Cd and Ni. The total N, labile P and Zn were at low levels; K and organic matter concentrations were at medium levels while S was at high level. The pH was 6.7, which indicates that the soil was slightly acidic to neutral.

Table 1. Selected parameters of background soil used in the experimental pot.

Parameters	background soil [1/]	Interpretation of Soil test values [2/]
Texture	Silty clay loam	-
pH	6.7 ± 0.091	Slightly alkaline to neutral
Moisture Concentration (%)	20.6 ± 0.072	-
Organic C (%)	1.81 ± 0.063	Medium class
Total N (%)	0.11 ± 0.010	Low
Labile P (ppm)	10.1 ± 0.082	Low
Available K (meq/100g soil)	0.17 ± 0.011	Medium
Available S (ppm)	28.9 ± 1.04	Optimum
Available Zn (ppm)	0.8 ± 0.032	Low
Available Pb (ppm)	1.05 ± 0.012	Below max. Accept. level
Available Cd (ppm)	0.06 ± 0.032	Below max. Accept. level
Available Ni (ppm)	0.46 ± 0.042	-

[1/] Soil used for the experiment. [2/] Source: Anon, 2005.

The physical and chemical parameters of industrial sludge are shown in Table 2. Industrial sludge contained optimum, high and very high levels of K, Organic carbon and Zn, respectively. Labile P concentration was very low. Total N and S were considered to be available at moderate concentrations.

Table 2. Selected parameters of industrial sludge used in the experimental pot.

Parameters	Industrial sludge [1/]	Interpretation of Sludge test values [2/]
pH	7.8 ± 0.08	Slightly alkaline
Moisture Concentration (%)	28.8 ± 0.08	-
Organic C (%)	2.6 ± 0.08	High class
Total N (%)	0.2 ± 0.02	Medium
Labile P (ppm)	14.5 ± 0.09	Low
Available K (meq/100g soil)	0.36 ± 0.01	Optimum
Available S (ppm)	19.9 ± 0.92	Medium
Available Zn (ppm)	47.0 ± 1.28	Very high
Available Pb (ppm)	3.9 ± 0.01	Below max. Accept. level
Available Cd (ppm)	0.2 ± 0.03	Below max. Accept. level
Available Ni (ppm)	1.2 ± 0.04	-

[1/] Industrial sludge used as a proportion of treatment in exp. [2/] Source: Anon, 2005.

Lead concentration and distribution

Root: The highest Pb concentration (3.36mgkg^{-1}) in root was recorded in T_4 receiving 75% N from industrial sludge and 25% N from urea at 30 DAS (Table 3). The effect of this treatment was statistically similar to T_5 but superior to T_1, T_2, T_3 and T_6. The lowest Pb concentration (1.92mgkg^{-1}) in root was observed in T_6 (control). Highest Pb concentration (3.30mgkg^{-1}) in root was recorded in 42 DAS (Treatment T_4). Lead concentration found in treatment T_5 rank second in position. Treatment T_2 and T_3 identical to each other, rank third in position and superior to control.

Stem: The highest Pb concentration (2.73mgkg^{-1}) in stem was recorded in T_5 receiving 100% N from industrial sludge and 0 % N from urea at 30 DAS (Table 3). Lead concentration found in treatment T_4 rank second in position which was followed by T_3. Treatment T_1 and T_2 were identical to each other and superior to control (1.91mgkg^{-1}). The highest Pb concentration (2.47mgkg^{-1}) was also recorded in stem at 42 DAS (Treatment T_5). Lead concentration found in treatment T_4 rank second in position and the effect of this treatment was identical to T_2 and T_3, but superior to control. The lowest Pb concentration (1.32mgkg^{-1}) in stem was observed in T_6 (control).

Leaf: Similar to stem the highest Pb concentration (3.99mgkg^{-1}) in leaf was noted in T_5 at 30 DAS (Table 3). The rank of treatment T_4 was second in position and that was identical to T_2 and T_3 but superior to T_1 and T_6 like as 30 DAS. Treatment T_5 showed highest Pb concentration (3.36mgkg^{-1}) in leaf at 42 DAS. In treatment T_1 and T_2 recorded Pb concentration was statistically similar and inferior from T_3 and T_4, but superior to T_6. The lowest Pb concentration was identified in control (1.89mgkg^{-1}). Increasing sludge concentration in the treatment showed higher Pb concentration in root, stem and leaf of red amaranth.

Table 3. Lead concentration in root, stem and leaf of red amaranth as influenced by urea and sludge-N at 30 and 42 DAS.

Treatment	Pb (mgkg^{-1}dry matter)					
	Root		Stem		Leaf	
	30DAS[1/]	42 DAS	30 DAS	42 DAS	30 DAS	42 DAS
T1. $UN_{100} + SN_0$	2.55d	2.57d	2.00d	1.36c	2.69c	2.66d
T2. $UN_{75} + SN_{25}$	2.70c	2.65c	2.04d	2.00b	3.37b	2.69d
T3. $UN_{50} + SN_{50}$	2.99b	2.69c	2.21c	2.09b	3.33b	2.76c
T4. $UN_{25} + SN_{75}$	3.36a	3.30a	2.59b	2.21b	3.47b	3.31b
T5. $UN_0 + SN_{100}$	3.32a	2.98b	2.73a	2.47a	3.99a	3.36a
T6. Control	1.92e	1.94e	1.91e	1.32c	1.96e	1.89e
LSD (P=0.05)	0.067	0.057	0.055	0.22	0.19	0.033
CV%	1.54	1.37	1.63	7.54	3.81	0.78

U_N – Nitrogen from urea; S_N – Nitrogen from industrial sludge; 1/ DAS – Days after seeding; Means followed by common letter (s) in a column are not significantly different at 5% level by DMRT.

Cadmium concentration and distribution

Root: The highest amount of Cd (0.04mgkg^{-1}) was recorded in T_5 in root at 30 DAS (Table 4). The effect of this treatment was statistically similar to T_2, T_3 and T_4, but superior to $T_{1,}$ and $T_{6.}$ The lowest Cd concentration (0.01mgkg^{-1}) in root was observed in T_6 (control). The highest Cd concentration (2.06mgkg^{-1}) was recorded in T_4 in root at 42 DAS. Cadmium concentration found in treatment T_5 rank second in position. Treatment T_2 and T_3 were identical to each other and rank third in position and superior to control.

Stem: Treatment T_5 recoded the highest Cd concentration (0.02mgkg^{-1}) in stem at 30DAS (Table 4). The effect of this treatment was statistically similar to T_3, and T_4, but superior to $T_{1,}$ T_2 and $T_{6.}$ The lowest Cd concentration (0.01mgkg^{-1}) in stem was observed in T_6 (control). The highest Cd concentration (1.85mgkg^{-1}) in leaf was recorded in T_5 at 42 DAS. The rank of treatment T_4 was second in position and that was identical to T_2 and T_3, but superior to T_1 and T_6.

Leaf: The highest Cd concentration (0.03mgkg^{-1}) in leaf was recorded in T_5 at 30 DAS (Table 4). The effect of this treatment was statistically similar to T_4, but superior to rest of the treatments. Treatment $T_{1,}$ T_2, and T_6 were identical in respect of Cd concentration. The lowest Cd concentration (0.01mgkg^{-1}) in leaf was observed in T_6 (control). The highest Cd concentration (1.84mgkg^{-1}) was recorded in T_4 at 42 DAS that was statistically similar to T_5 but superior to $T_{1,}$ T_2, T_3 and $T_{6.}$ It was found that cadmium concentration was higher at 42 DAS compared to 30 DAS in all plant parts and higher values were in roots. Higher Cd concentration was also found in the treatment where N was given by 100 % sludge only.

Table 4. Cadmium concentration in root, stem and leaf of red amaranth as influenced by urea and sludge-N at 30 and 42 DAS.

Treatment	Cd (mgkg^{-1}dry matter)					
	Root		Stem		Leaf	
	30 DAS[1/]	42 DAS	30 DAS	42 DAS	30 DAS	42 DAS
T1. $UN_{100} + SN_0$	0.01b	1.70cd	0.01b	1.06c	0.01c	1.08d
T2. $UN_{75} + SN_{25}$	0.02ab	1.84bc	0.01b	1.27b	0.01c	1.28c
T3. $UN_{50} + SN_{50}$	0.03ab	1.88b	0.02ab	1.21b	0.02b	1.54b
T4. $UN_{25} + SN_{75}$	0.04a	2.06a	0.02ab	1.30b	0.02ab	1.84a
T5. $UN_0 + SN_{100}$	0.04a	1.94ab	0.02a	1.85a	0.03a	1.82a
T6. Control	0.01b	1.61d	0.01b	0.05d	0.01c	0.76e
LSD (P=0.05)	0.176	0.176	0.0063	0.136	0.005	0.164
CV%	6.29	6.37	3.04	9.44	21.05	7.86

U_N – Nitrogen from urea; S_N – Nitrogen from industrial sludge; 1/ DAS – Days after seeding; Means followed by common letter (s) in a column are not significantly different at 5% level by DMRT.

Nickel concentration and distribution

Root: The highest Ni concentration (0.53mgkg^{-1}) in root at 30 DAS (Table 5) was recorded in T_5. Treatment T_3 was second in position and that was identical to T_1, T_2 and T_4 but superior to T_6. The lowest Ni concentration (0.26mgkg^{-1}) in root was observed in T_6. The highest Ni concentration (2.48mgkg^{-1}) in root was recorded in T_5 at 42 DAS (Table 5). Treatment T_4 was second in position and that was statistically similar to T_3 but superior to T_1, T_2 and T_6.

Stem: The highest Ni concentration (0.42mgkg^{-1}) in root was noted in T_5 at 30 DAS (Table 5). Treatment T_4 rank second in position and that was identical to T_3 but superior to T_1 T_2 and T_6. The highest Ni concentration (1.72mgkg^{-1}) in stem was recorded in T_5 at 42 DAS (Table 5). Treatment T_4 was second in position and that was statistically similar to T_2 and T_3, but superior to T_1 and T_6.

Leaf: The highest Ni concentration (0.56mgkg^{-1}) in leaf was recorded in T_5 at 30 DAS (Table 5). Treatment T_4 was second in position and that was statistically similar to T_3, but superior to T_1, T_2 and control. The lowest Ni concentration (0.27mgkg^{-1}) in leaf was recorded in T_6 at 30 DAS (Table 5). The highest Ni concentration (2.12mgkg^{-1}) in leaf was observed in T_5 at 42 DAS. Treatment T_4 was second in position. Treatment T_2 rank third in position and statistically similar to T_3 but superior to T_1 and T_6. From above discussion, it is revealed that higher amount of Ni was found at 42 DAS compared to 30 DAS in all parts of plant and higher values were in roots. Nickel is considered as a micronutrient in plants (Salisbury and Ross 1982). This nutrient is considered in many plants to be essential in order to avoid urea toxicity by acting as a co-factor for the urease enzyme to hydrolyze urea formed.

Table 5. Nickel concentration in root, stem and leaf of red amaranth as influenced by urea and sludge-N at 30 and 42 DAS.

Treatment	Ni (mgkg^{-1}dry matter)					
	Root		Stem		Leaf	
	30 DAS$^{1/}$	42 DAS	30 DAS	42 DAS	30 DAS	42 DAS
T1. $UN_{100} + SN_0$	0.31b	2.06d	0.23bc	0.99c	0.31c	1.29d
T2. $UN_{75} + SN_{25}$	0.32b	2.16c	0.24bc	1.02bc	0.32c	1.41c
T3. $UN_{50} + SN_{50}$	0.34b	2.23b	0.25b	1.02bc	0.33bc	1.40c
T4. $UN_{25} + SN_{75}$	0.32b	2.23b	0.26b	1.06b	0.35b	1.51b
T5. $UN_0 + SN_{100}$	0.53a	2.48a	0.42a	1.72a	0.56a	2.12a
T6. Control	0.26c	1.96e	0.21c	0.96c	0.27d	1.10e
LSD (P=0.05)	0.032	0.058	0.031	0.062	0.03	0.074
CV%	6.16	1.77	7.64	3.66	5.6	3.36

U_N – Nitrogen from urea; S_N – Nitrogen from industrial sludge; 1/ DAS – Days after seeding; Means followed by common letter (s) in a column are not significantly different at 5% level by DMRT.

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