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Effect of Sewage Sludge on Phytoextraction of Heavy Metal by Wheat (*Triticum aestivum* L.)

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***Abstract:** A pot experiment was conducted to study the effect of sewage sludge on phytoextraction of heavy metal by wheat. The treatment consisted of sewage sludge @ 10, 20, 40 & 80 t ha-1, keeping 120:60:40 NPK as a standard application rate. It may be recommended that sewage sludge application of 4 t/ha was safe but application of 80 t ha^{-1} sewage sludge increased heavy metals accumulation in plant parts. However, the values were within permissible limits.*

***Keywords:** "sewage sludge, heavy metals, wheat, phytoextraction"*

1. Introduction

Sewage sludge application may lead to the accumulation of a number of potentially harmful components such as heavy metals in soil and crops. The presence of heavy metals in the applied sludge can result in phytotoxic effects, soil and water contamination and accumulation of heavy metal in food supplies. Problems exist because sewage sludge and effluents may contain high amount of toxic heavy metals such as Pb, Cd, Ni, Cr, Hg etc. due to the mixing of industrial wastewater with sewage. The average concentration of some heavy metals are as follows, Pb (26-154 ppm), Ni (12-596 ppm), Cr (66-1098 ppm), Cd (2-9 ppm), Hg (7-32 ppm) and As (8-23 ppm) which may limit their long term use in agriculture because of phytotoxicity and environmental deterioration. Besides heavy metals, other harmful toxics such as pharmaceuticals, detergents, various salts, pesticides, toxic organics, flame retardants and hormone disruptors can also be present in the sewage sludge.

Phytoextraction has emerged as a novel approach to clean up metal-polluted soils in which plants are used to transfer toxic metals from soils to shoots. During the accumulation of heavy metal, the antioxidant defense system helps the plant to protect itself from the damage caused by heavy metals. The use of plants to remove toxic metals from soil (phytoremediation) is emerging as a potential strategy for cost-effective and environmentally sound remediation of contaminated soils. The success of phytoremediation is dependent on several factors. Plants must produce sufficient biomass while accumulating high concentrations of mental. The metal-accumulating plants also need to be responsive to agricultural practices to allow repeated planting and harvesting of the metal-rich tissues .The ability to cultivate a high biomass plant with a high content of toxic metals on a contaminated soil will be a determining factor in the success of phytoremediation.. Land application of sewage sludge for crop production provides a feasible and cost effective disposal alternative and has a positive effect on the yield of wheat crop Owing to all above points the present investigation was carried out to study the effect of heavy metal contaminated sewage sludge on growth and yield and phytoextraction capacity of wheat.

2. Method and materials

The pot experiment was conducted in the Net house of Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, B.H.U. Varanasi U.P. The treatments

were T_1-Control, T2-10t/ ha Sludge, T3-20t/ ha Sludge, T4-40t/ ha Sludge, T5-80t/ ha Amounts of sewage sludge applied to the soil in pots were equivalent to 10, 20, 40 and 80 t ha^{-1}. Eight healthy seeds of wheat crop were sown on 21st November 2010, after germination of seeds number of plant were minimized to four plants per pot and were allow to grow to maturity pots were timely irrigated with deionized water at regular intervals to maintain moisture of the soil. Crop was harvested on 20th February 2011. The harvested plant material was put in paper bags, air dried and oven dried at 65± 2 ^{o}C to a constant weight. Thereafter dry weight of above ground plant parts was recorded. Plant materials grounded in grinder, mixed and stored in polythene bags for chemical analysis**.** The content of Cd, Cr, Pb and Ni in the plant and seed sample was

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digested and determined by using atomic absorption spectrophotometer (UNICAM – 969) as per procedure outlined by Tandon (2001).

3. Results and discussion

3.1 Heavy metal content in wheat grain and straw

The data pertaining to Cd content in wheat grain (Table 1) experienced significant increase with graded levels of sewage sludge. The Cd content in wheat grain increased from 0.53 mg kg^{-1} to 2.7mg kg^{-1}. Maximum (2.70 mg kg^{-1}) being in treatments 80 t ha^{-1} metal contaminated sewage sludge and minimum (0.53 mg kg^{-1}) in control. Treatments 80 t ha^{-1} sewage sludge have shown 5 times increase in Cd content over control (0.53 mg kg^{-1})The data pertaining to Cd content in wheat straw (Table 2) with sewage sludge. The maximum (4.42 mg kg^{-1}) was recorded in T5 treatment and minimum (1.95 mg kg^{-1}) was observed in control. The data pertaining to Cr content in wheat grain (Table 1) showed a significant increase with graded application sewage sludge. The Cr content in wheat grain increased from 0.68 to 2.23 mg kg^{-1}. application of 80 t ha^{-1} sewage sludge increased Cr content by about 4 times in wheat grain over control (0.68 mg kg^{-1})..The data pertaining to Cr content in wheat straw (Table 2) revealed significant increase with the application of graded levels of sewage sludge. Chromium content in wheat straw varied from 0.83 (control) to 2.87 mg kg^{-1}(T5). Addition of 80 t ha^{-1} sewage sludge increased Cr content in wheat straw by 3 times over control. The normal range of Cr in plants is considered 0.03-14.00 mg kg^{-1}, while the toxic concentrations fall between 5-30 mg kg^{-1} (Alloway and Ayers, 1997). This suggests that plant Cr in this study was in the normal range.

Nickel content in wheat grain ranged from 1.25 to 4.36 mg kg^{-1}(Table 1). The treatments 80 t ha^{-1} sewage sludge increased Ni content in wheat grain by 4 times over control (1.25 mg kg^{-1}).. The Ni content in wheat straw varied from 8.73 to 21.6 mg kg^{-1},application of 80 t ha^{-1} sewage sludge and 80 t ha^{-1} metal contaminated sewage sludge were 2.5 times higher over control (8.73 mg kg^{-1}).

A careful perusal of data (Table 1) showed that Pb content in wheat grain experienced similar significant effect as wheat straw. The Pb content in wheat grain ranged from 0.07 to 1.15 mg kg^{-1}. Maximum (1.15 mg kg^{-1}) was recorded in treatment 80 t ha^{-1} which was significant higher than control (0.07 mg kg^{-1}). The data pertaining to Pb content in wheat straw (Table 2) varied from 0.40 to 2.62mg kg^{-1}. Application of 80 t ha^{-1} sewage sludge was 6 times higher over control. A significant increase in Pb content in wheat straw was observed with increase in sewage sludge doses.

Singh and Agrawal (2010) reported that sewage sludge amendment rates above 4.5 kg m^{-2} though increased the yield of rice, but caused risk of food chain contamination as concentrations of Ni and Cd in rice grains were found to be above the Indian safe limits (1.5 mg kg^{-1}) of human consumption above 4.5 kg m^{-2} sewage sludge and Pb (2.6 mg kg^{-1}) above 6 kg m^{-2} sewage sludge amendment. Above ground parts also showed higher concentration than the permissible levels of Ni, Cd and Pb at 4.5 kg m^{-2} sewage sludge. The accumulation of heavy metals by plants depends on various factors such as soil physico–chemical properties, sewage sludge composition sludge application rate, plant species, climatic factors and chemical speciation of metals .Wheat grown in sewage sludge (2–10 kg m^{-2}) amended Sandy Loam and Silty Loam soils of USA showed significant higher concentrations of Zn, Cd and Ni in wheat grains at increasing sewage sludge amendment rates in soil. (Tadesse *et al.*, 1991).El – Naim *et al.* (2004) recorded varying levels of increments in heavy metals concentration in wheat and corn grains, peanut seeds, onion, guava and top part of clover under application of dried sewage sludge. The variations in heavy metal concentrations in various parts of plants have been ascribed to compartmentalization and translocation through the vesicular system (Kim *et al.* 2003).

3.2. Heavy metal uptake by wheat grain and straw

The Cd uptake in wheat grain ranged between 0.016 to 0.085 mg $pot^{-1)}$ (Table1). Maximum uptake (0.085 mg pot^{-1}) was recorded in 80 t ha^{-1} heavy metal contaminated sewage sludge which was 5 times higher than control. Lowest (0.016 mg pot^{-1}) was recorded in control A significant variation in uptake of Cd by wheat straw by application of sewage sludge was noticed.

The Cd uptake by wheat straw varied from 0.07 to 0.19 mg pot^{-1}. (Table1). The minimum value (0.07 mg pot^{-1}) was recorded in control. Application of 80 t ha^{-1} sewage sludge resulted in

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2.5 times increase over control in case of wheat straw and 5 times increase in uptake of Cd by wheat grain over control. The Cr uptake in wheat straw increased from 0.03 to 0.37 mg pot^{-1}(Table 2). The maximum uptake (0.37 mg pot^{-1}) was recorded in 80 t ha^{-1} heavy metal contaminated sewage sludge which was about 12 times higher than control. The maximum Cr uptake (0.179 mg pot^{-1}) was recorded with 80 t ha^{-1} heavy metal contaminated sewage sludge which was 2.5 and 9 times increase than 80 t ha^{-1} sewage sludge and control, respectively. Minimum Cr uptake (0.179 mg pot^{-1}) was recorded with control. (Table1). The Ni uptake in wheat straw ranged between 0.30 to 0.92 mg pot^{-1}. Application of 80 t ha^{-1} sewage sludge dose resulted 3 times increase in uptake of Ni by wheat straw over control.

Same trend of significance was observed for Ni in wheat grain as influenced by application of sewage sludge. The data showed that the uptake of Pb was very less in wheat straw (Table 1). The uptake of Pb in wheat straw was significantly increased with application of graded doses of sewage sludge. The maximum Pb uptake by wheat straw was 0.11 mg pot^{-1}. Lowest (0.01 mg pot^{-1}) was recorded in control. Almost similar trend was observed for uptake of Pb in wheat grain increased from 0.002 to 0.36 mg pot^{-1}. The total Cd, Cr, Ni and Pb uptake by wheat crop also increased with application of sewage sludge (Table 3). In wheat crop maximum uptake values were 0.27, 0.19, 1.05 and 0.15 mg pot^{-1} for Cd, Cr, Ni and Pb respectively in T5 treatment which was significantly higher than controls.

4. Conclusion

Study clearly indicated that application of sewage sludge slightly increased the concentration and uptake of Ni, Cd, Pb and Cr in wheat except for Pb which was not bio-available. It has also been observed that Ni and Cd could be readily taken up and accumulated by plants depending on soil conditions and especially from soils containing elevated levels of these elements.

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Table.-1 Effect of sewage sludge on heavy metal content (mg kg^{-1}) and uptake (mg pot^{-1}) by Wheat grain

Treatments	Heavy metal content (mg kg^{-1})				Heavy metal uptake (mg pot^{-1})			
	Cd	Cr	Ni	Pb	Cd	Cr	Ni	Pb
T_1-Control	0.53	0.68	1.25	0.07	0.016	0.020	0.04	0.002
T_2-10t/ ha Sludge	0.96	1.39	3.28	0.21	0.029	0.042	0.10	0.006
T_3-20t/ ha Sludge	1.84	1.64	3.68	0.45	0.057	0.051	0.11	0.014
T_4-40t/ ha Sludge	2.35	1.95	4.07	0.89	0.076	0.063	0.13	0.029
T_5-80t/ ha Sludge	2.70	2.23	4.36	1.15	0.085	0.070	0.14	0.036
SEM ±	0.19	0.05	0.15	0.07	0.005	0.004	0.010	0.004
CD (P=0.01)	0.75	0.20	0.58	0.26	0.019	0.017	0.037	0.016

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Table.-2 Effect of sewage sludge on heavy metal content (mg kg^{-1}) and uptake (mg pot^{-1}) by Wheat straw.

Treatments	Heavy metal content (mg kg^{-1})				Heavy metal uptake (mg pot^{-1})			
	Cd	Cr	Ni	Pb	Cd	Cr	Ni	Pb
T_1-Control	1.95	0.83	8.73	0.40	0.07	0.03	0.30	0.01
T_2-10t/ ha Sludge	2.64	1.42	15.95	1.07	0.10	0.05	0.59	0.04
T_3-20t/ ha Sludge	3.03	1.86	16.66	1.31	0.12	0.07	0.65	0.05
T_4-40t/ ha Sludge	3.98	2.48	19.93	2.02	0.17	0.10	0.83	0.08
T_5-80t/ ha Sludge	4.42	2.87	21.60	2.62	0.19	0.12	0.92	0.11
SEM ±	0.19	0.17	0.35	0.07	0.010	0.008	0.022	0.004
CD (P=0.01)	0.77	0.66	1.39	0.28	0.038	0.031	0.088	0.017

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Table.3: Effect of heavy metal contaminated sewage sludge on heavy metal (mg pot^{-1}) uptake by wheat crop.

Treatments	Heavy metal uptake (mg pot^{-1})			
	Cd	Cr	Ni	Pb
T_1-Control	0.08	0.05	0.34	0.02
T_2-10t/ ha Sludge	0.13	0.09	0.68	0.05
T_3-20t/ ha Sludge	0.18	0.12	0.77	0.07
T_4-40t/ ha Sludge	0.24	0.17	0.96	0.11
T_5-80t/ ha Sludge	0.27	0.19	1.05	0.15
SEM ±	0.01	0.01	0.02	0.01
CD (P=0.01)	0.04	0.04	0.09	0.02