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Bioavailability of Heavy Metals (Cd, Cr, Ni, Pb) to French Marigold (*Tagetes patula*) in relation to Soil properties

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Abstract

After one month of incubation of soils with Cd,Ni,Pb and Cr at the rate of 5,10,20 and 30mg/kg, it was found that maximum DTPA extractable concentration was 8.78mg/kg (Sewage sludge), 0.483mg/kg (Alkali soil), 18.59mg/kg (Sewage irrigated soil) and 20.54mg/kg (Sandy Soil), respectively. Coorelation study showed a highly positive significant coorelation of Cd with organic carbon (r=0.883**), Pb with clay (r=0.726*), Cr with sand (r=0.789*) and significant negative coorelation of Ni with $CaCO_3$ (r=0.813*). Marigold crop could not survive in sandy soil and Alkali soil might be due to the Cr toxicity and adverse physical condition, respectively. Highest uptake of Cd was noticed in red soil while that of Cr and Ni is sewage irrigated soil. Lead was less bio available. Concentration of Cr and Ni was recorded in flowers where as Cd and Pb were not detectable. The pH had a significant negative coorelation (r=-0.741*) with Cd uptake whereas a significant positive coorelation of organic carbon(r=0.882**) was noted with Cr uptake. It was further observed that dry matter yield had positive coorelation with uptake and negative coorelation with content of heavy metas in plants. The DTPA extractable Ni was almost not detectable in post harvest soils.

Keywords: Heavy metals; Contaminated soil; Phytoremediation; Bioavailability; Alluvial soil; Alkali soil; River clay soil; Sandy soil; Black soil; Garden soil; Sewage irrigated soil

Introduction

Heavy metals are among one of the pollutants which pose severe threats to environment and their occurrence in soil indicates the presence of natural or anthropogenic sources. Soil physico-chemical properties are adversely affected by high concentration of heavy metal, rendering contaminated soil unsuitable for crop production [1,2]. The heavy metals may be transported through soil to reach ground waters or may be taken up by plants .It has been observed that only a small fraction of the total soil concentration of metals is potentially toxic [3]. This fraction is known as the mobile or bioavailable fraction which is of concern due to its potential leaching in to ground water and/or entering the food chain through plants [4]. Impact of heavy metals contamination on agricultural soils depends not only on type and amount of contaminants but also on soil properties. Variation in soil properties may significantly influence the distribution as well as the bioavailability of heavy metals to plants [5]. Keeping the above facts in view, a study was initiated during 2008-09 to assess the impact of various soil properties on bioavailability of heavy metals (Cd,Cr,Ni, Pb) taking French marigold as a test crop .

Methods

To conduct pot experiment, nine soils viz: Alluvial soil, Alkali soil, River clay soil, Sandy soil, Black soil, Garden soil, Sewage irrigated soil and Sewage sludge were collected from different locations of Varanasi and Mirzapur districts .Soil properties indicated a variation in pH 4.7 to 9.5, EC 0.10 to 2.59 dSm^{-1}, OC 0.03 to 14.24%, $CaCO_3$ 0.5 to 10.5% and clay 8.79 to 44.56%. Pots lined with polythene sheet were filled with 4kg of air dried soils. Soils in the pots were treated with the dominant heavy metals present in sewage sludge such as Cd,Ni,Pb and Cr at the rate of 5,10,20 and 30mg/kg, respectively. The soils were irrigated to field capacity and kept in the net house for one month to allow added metals to equilibrate before planting. Two plants of French Marigold (*Tagetes patula*) Variety: Honey Comb was planted. Nine soils were taken as treatments and replicated thrice in a Completely Randomized Block Design. Fertilizer dose of N, P_2O_5, K_2O was applied at the rate of 100,45,45mg/kg soil. Plants were harvested at flowering stage i.e. 90 days after transplanting. Plant samples were washed sequentially with 0.2% soap solution, 0.1 N HCl and finally with distilled water. Dried and ground plant samples were subjected for analysis. Soil properties were analysed following standard analytical procedures. Soils after one month of incubation were extracted by DTPA as per procedure developed by Lindsay & Norvell [6] and plant samples were digested in di acid. The content of Cd,Ni,Pb and Cr in soil extract and plant digest was determined using atomic absorption spectrophotometer (UNICAM-969).

Results

It is evident (Table 1) that Cd,Cr,Ni and Pb concentration in metals treated soils after one month of incubation ranged between 2.44 (river clay soil) to 8.78 (sewage sludge), 0.32 (sewage sludge) to 20.54 (sandy soil), 0.023 (river clay soil) to 0.483 (Alkali soil) and 6.73 (sewage sludge) to 18.59mg/kg (sewage irrigated soil), respectively. Cadmium availability showed positive and significant correlation with organic matter (r=0.883**). It appears that organic matter likely to promote the extractability of Cd in soil by supplying soluble organic complexing agents which could reduce the Cd fixation in soil [2]. The Ni extractability in treated soils showed a significant negative correlation(r=0.813*) with $CaCO_3$ which could be due to precipitation of $CaCO_3$ that bind the Ni in unavailable fractions [7].

Table 1: Heavy metals status (mg/kg) in soils.

Soil Types	Initial Soil				Metals Treated Soil			
	Cd	Cr	Ni	Pb	Cd	Cr	Ni	Pb
Red soil	*ND	0.009	0.364	2.34	3.22	1.41	0.407	12.08
Black soil	0.285	ND	0.255	2.24	5.31	1.4	0.449	15.64
Alluvial soil	ND	0.027	ND	2.63	3.88	2.39	0.196	9.76
River clay soil	0.205	0.58	0.05	3.01	2.44	2.28	0.023	10.11
Sewage irrig. soil	0.644	0.055	0.39	12.16	5.81	0.72	0.273	18.59
Garden soil	ND	0.072	ND	4.75	4.22	0.37	0.388	12.17
Sewage sludge	7.53	0.237	0.066	8.41	8.78	0.32	0.058	6.73
Sandy soil	ND	0.043	0.368	0.7	5.75	20.54	0.138	12.74
Alkali soil	ND	0.109	ND	3.24	3.52	3.12	0.483	15.56

*Not Detectable

As regards to the heavy metals content in initial soil (Table 1), maximum content of DTPA extractable Cd,Cr,Ni and Pb was noticed in Sewage sludge (7.53mg/kg), River clay soil (0.58mg/kg), Sandy soil (0.36mg/kg), and sewage irrigated soil (12.16mg/kg), respectively. All the heavy metals under study were present in sewage sludge and sewage irrigated soils. Plant of marigold could not survive in Alkali soil due to high pH and adverse physical condition and in Sandy soil because of very high concentration of Cr (20.54mg/kg) recorded after treatment of heavy metals which was used for growing crop.

The concentration of heavy metals in dry matter (Table 2) indicates that maximum content of Cd,Cr,Ni and Pb was in Red soil (158.58mg/kg), Alluvial soil (22.41mg/kg), Sewage irrigated soil (29.64mg/kg), Black soil (12.25mg/kg), respectively. Lead concentration was not detectable in plants grown in Red soil, Alluvial soil, River clay soil and Garden soil. The Cd concentration in plants showed negative and significant correlation (r= -0.81*) with $CaCO_3$ content of soil. The concentration of Cr and Ni in flower ranged from 6.76 to 10.80 and 12.52 to 29.86mg/kg, respectively across the soils whereas concentration of Cd and Pb in flowers was not detectable.

The uptake pattern of French marigold grown in different soils revealed (Table 2) that maximum uptake of Cd,Cr,Ni and Pb was found in Red soil (0.683mg/kg), Sewage irrigated soil (0.084mg/kg), Sewage irrigated soil (0.14mg/kg) and Black soil (0.061mg/kg), respectively. A significant negative correlation was recorded with soil pH (r=-0.741*) and $CaCO_3$ (r=-0.804*) content of soil to that of uptake of Cd by plants whereas highly significant positive correlation was noticed with Organic carbon(r=0.882**) and Sand (r=0.783*) content of soil to that of Cr uptake by plants. It has also been reported that Cd uptake had a negative correlation with soil pH [8] and Cr uptake had a significant positive correlation with organic matter content of soil [9,10].

Table 2: Dry matter yield, concentration and uptake of heavy metals.

Soil Types	Dry Matter (g/pot)	Concentration(mg/kg)				Uptake(mg/pot)			
		Cd	Cr	Ni	Pb	Cd	Cr	Ni	Pb
Red soil	4.3	158.5	10.43	14.29	*ND	0.683	0.045	0.062	ND
Black soil	5	56.85	16.19	2.61	12.25	0.284	0.081	0.013	0.061
Alluvial soil	3.36	57.37	22.41	3.06	ND	0.192	0.075	0.01	ND
River clay soil	2.37	ND	20.21	2.91	ND	ND	0.048	0.007	ND

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Sewage irrig. soil	4.73	5.84	17.9	29.64	3.12	0.03	0.084	0.14	0.015
Garden soil	4.83	62.32	17.17	21.04	ND	0.303	0.083	0.102	ND
Sewage sludge	3.87	21.67	19.97	28.81	8.72	0.084	0.077	0.111	0.034
Sem±	0.14	1.26	0.45	0.31	0.08	0.004	0.001	0.001	-
C D(p=0.05)	0.43	3.85	1.37	0.95	0.24	0.013	0.004	0.114	0.001

Plants grown in heavy metals treated soils showed decline in growth and biomass yield as compared to control (untreated) but Swage treated soil and River clay soil did not have any adverse effect of heavy metals treatment on biomass yield. This may be due to the fixation of heavy metals in these soils. The content of most of the heavy metals showed negative relation with content and uptake of other metals. It was noticed that with increase in dry matter yield, the uptake of heavy metals by plants was found to increase but the concentration of metals in plant decreased.

The DTPA extractable Ni content of post harvest soil was not detectable except in Sewage irrigated soil (0.26mg/kg) and Sewage sludge (0.45mg/kg).This might be due to high content of $CaCO_3$ in these soils which precipitated and bound Ni in unavailable fractions. A negative significant correlation (r= -0.813*) between $CaCO_3$ and Ni availability of soil corroborate this result.

Conclusion

It is concluded that soil properties significantly influence the distribution and bioavailability of heavy metals (Cd,Cr,Ni,Pb) in soil and thus concept of bioavailability in determining the critical content of heavy metals should be adopted for all soils.

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