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Research Article

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Depth wise Distribution of Cd, Cr, Ni and Pb in soil and accumulation of heavy metals in vegetable Crops grown on sewage irrigated soils of Aligarh District: A five year study

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ABSTRACT

A field study was undertaken to investigate the effect of continuous application of sewage-effluent irrigation on the DTPA-extractable Cd, Ni, Cr and Pb in soils and crops for five years. For this purpose, periurban agricultural lands irrigated by different sewage effluent, from a point of entering the effluents to a distance of nearly 1.5 km and irrigated by ground water from different parts of Aligarh district were selected where vegetable crops have successfully been grown. The data indicated that the concentration of these metals in sewage effluent irrigated soils became four to six folds in comparison to ground water irrigated soil. The data also denote that with increasing soil depth and distance from sewage entry point the concentration of these metals decreased indicating a low mobility of these metals in soils.Significant accumulation of heavy metals occurs in 0-15 and 15-30 cm depth. Soil properties viz organic carbon, pH, EC and CEC exhibited positive relationship with DTPA- extractable metal content, while clay content showed a negative relationship. The concentrations of Cd, Ni, Cr and Pb in different vegetable crops grown on sewage effluent irrigated soils were higher (beyond permissible limit) as compared to those grown on ground water irrigated soils. The maximum accumulations of these metals were in potato followed by maize except for Pb. These results also denote that potato and maize is good accumulator of metals hence growing of potato and maize on such soils should be avoided. Higher concentration of heavy metals Cd, Ni, Cr and Pb due to more accumulation probably may cause phytotoxicity which result in decrease of crop yield. Based on these results, it can be concluded that proper management of water irrigation and periodic monitoring of soil and plant quality parameters are required to ensure successful, safe and long term sewage effluent irrigation.

***Keywords**: Sewage effluent, Soils,Crops, Heavy metals, Crops.*

INTRODUCTION

Water is an indispensable for the growth and development of agricultural crops. About 300-1000 litre of water is necessary for production of a kilo of plant dry matter. Soil water is the great regulator of physical, chemical and biological activity of soil.Rapid growth of urbanization and industrialization in the last three decades has caused adverse effect on land and water[1-3]. In Asian countries including India, as there is a gradual decline in freshwater availability for agricultural fields so sewage and other industrial effluents are being used for irrigation of agricultural fields particularly in periurban areas.Mining, industrial processing, pesticide and chemical fertilizer, and automobile exhaust are the main sources of heavy metal contamination in the environment[4,5]. Heavy metal accumulation in soils is of great concern in agricultural production due to the adverse effects on food quality, crop growth[6,7] and environmental health. These metals may accumulate to a toxic concentration level which can lead to impairment in the quality of human life[8]. The indiscriminate disposal of industrial and sewage effluents on agricultural land for a long term is becoming a major source of heavy metal contamination in irrigated soils and groundwater[9].

The metals present in this available water arrive in plant tissue with water and accumulates in various parts of plant bodies. The sewage water use in agriculture thus target human and animal health, soil health and crop production[10]. Plant uptake of metals from sewage treated soils is related to the soil exchange capacity, pH of soil as well as the sewage contamination[11].

The objectives of this work was to study partition and translocation of Cd, Cr, Ni and Pb in soil and vegetable crops grown on the fields irrigated with untreated sewage water and ground water for a period of five years (2009-2014).

MATERIALS AND METHODS

For the present study ten agricultural fields (S_1- S_{10}) out of which four were irrigated only by sewage effluent; four were partially irrigated by sewage effluent and two were irrigated by ground water from different parts of Aligarh district were selected. Soil samples at the depths 0-15, 15-30, 30-45 and 45-60 cm were collected bimonthly for five years (April 2009- March 2014) from these sites. The soil samples were air dried, crushed and grounded to pass through <70 mesh sieve before use. The physio-chemical properties were determined by usual laboratory methodology. The values are given in Table 1. The soil samples collected from different sites and depths were analyzed for pH, EC, organic carbon, DTPA-TEA-$CaCl_2$ extractable Cd, Ni, Cr and Pb [12]. From these fields during the study five plant species including the root with 4 replications namely cauliflower, radish, eggplant, potato and maize, common at all the selected sites were sampled. Crop samples were thoroughly washed successively with tap water, distilled water and 0.01 N HCl solutions for removing the impurities. The samples were dried with air circulation at 65^{o}C and pulverized in a warming blender to make them homogeneous to be used for chemical analysis. The samples were digested in diacid mixture containing HNO_3: $HClO_4$ (3:1). The digested mixture was heated over a hot plate till brown fumes ceased. It was then dissolved in 5 mL of 2M HCl and the supernatant was analyzed for Cd, Ni, Cr and Pb by atomic absorption spectrophotometer (Systronics, 1200).

RESULTS AND DISCUSSION

Soil pH, EC and organic matter

The average values of soil pH, EC and organic carbon at various depths are given in Table 2. The data of Table 2 denoted that pH decreases with increasing depth which may be due to downward movement of organic acid, humic and fulvic acid (present in sewage effluent). Electrical conductivity (EC) of soils increased (Table 2) with sewage effluent irrigation, while EC decreased with depth suggesting a slow downward movement of ions. Table 2 also denoted that soils treated with sewage effluent have a higher concentration of organic carbon as compared to ground water irrigated soils and the organic carbon content in soils varied significantly from one site to the other depending on the distance from the point of discharge of effluent. The organic carbon content at all the sites decreased with increasing depth. The higher concentration of organic carbon content in sewage effluent irrigated soils may be due to accumulation of sewage effluent organic carbon in the soils. Our preliminary studies have also shown that accumulation of organic carbon occurs mainly in top (0-15 cm) layer. Similar results are also reported by Samaras *et al.*,[13] and Kumar *et al.*,[14], Kabirinejad and Hoodaji[15].

DTPA-extractable Cd, Ni, Cr and Pb

The concentration of DTPA- extractable Cd, Ni, Cr and Pb in sewage effluent treated soils at various depths are given in Table 3.The examination of Table 3 denote that the concentrations of DTPA-extractable Cd, Ni, Cr and Pb in sewage effluent treated soils build up continuously as compared to ground water treated soils. The concentration of DTPA-extractable metals in sewage effluent irrigated soils was 2-3.6 times for Cd; 2- 3.7 times for Ni; 2.8-6 times for Cr and3- 5.5 times for Pb than ground water treated soils. The higher concentration of DTPA extractable metals in sewage effluent irrigated soils may be due to accumulation of heavy metals present in sewage effluent in the soils.The concentration of metals decreased with depth and with increasing distance from effluent discharge point (the concentration of DTPA-extractable Cd, Ni, Cr and Pb throughout the period of study and at different depth in ground water irrigated soil (S_{10}) was almost same). The concentration of DTPA-extractable metals at various depths in sewage irrigated soils ranged; Cd from 0.450 to 0.138; Ni from 9.72-1.92; Cr from 26.4-7.3 and Pb from 18.8-6.8.

The DTPA-extractable Cd, Ni, Cr and Pb in surface soil exhibited a significant correlation (Table 4) with soil pH (r = 0.874-0.938), soil EC (r = 0.904-0.965), organic carbon (r = 0.872- 0.914), CEC (r = 0.886-0.942) and clay content (r = -0.824- -0.914), indicating that pH, EC, organic carbon, CEC and clay content significantly influence the availability of Cd, Ni, Cr and Pb in soil.

The higher concentration of Ni, Cr and Pb in soils 1, 2, 3 and 4 may be due to addition of Ni, Cr and Pb in the form of gasoline, personal care products and aerosol by urban population as these sites are close to urban residential area.

The concentration of DTPA-extractable metals declined with depth which may be due to lower permeability and vertical movement of the metals. The results also indicate that organic carbon plays a major role in mobility and transport of Cd, Ni, Cr and Pb in the sewage effluent treated soils. The immobilization of metals might have been due to adsorption and occulation on the surface by hydroxides and oxides in soils and tend to remain in the zone of incorporation[16].

Vegetables

Table 5 which denote the Cd, Ni, Cr and Pb concentration in crops grown on sewage irrigated soils showed that concentration of metals in vegetables grown on sewage effluent irrigated soils ranged : Cd from 0.63-5.68: Ni from 5.54-29.32: Cr from 5.38 – 21.22 and Pb from 9.32.-20.24 mg $kg^{-1,}$ whilein ground water irrigated soil it ranged from 0.25-0.98;1.88-7.86;1.94-4.64;2.84-5.04 mg kg^{-1} for Cd, Ni, Cr and Pb respectively. The maximum accumulation of these metals was in potato followed by maize except for Pb. Similar results are also reported by Brar *et al.,*[17]. The metal concentrations in vegetables were significantly positively correlated with soil DTPA-extractable metal concentration. A linear relationship between Cd, Ni, Cr and Pb concentration in plant species and DTPA-extractable Cd, Ni, Cr and Pb were noted. The relationship for Cd is as below:

Cauliflower-Cd = 3.59 DTPA-Cd -0.342 (r = 0.95); Radish-Cd = 3.36 DTPA-Cd -0.060; (r = 0.87); Eggplant-Cd = 7.38 DTPA-Cd -1.10; (r = 0.82); Potato-Cd =13.82 DTPA-Cd -1.44; (r = 0.85); Maize-Cd = 9.58 DTPA-Cd -0.78; (r = 0.88);

The relationship for Ni is as follows:

Cauliflower-Ni = 1.34 DTPA-Ni -2.06; (r = 0.93); Radish-Ni = 1.31DTPA-Ni -2.24; (r = 0.90); Eggplant-Ni = 1.62 DTPA-Ni -1.69; (r = 0.86); Potato-Ni =2.54 DTPA-Ni -2.08; (r = 0.86); Maize-Ni = 1.96DTPA-Ni-1.45; (r = 0.91)

For Cr the linear relationship is as:

Cauliflower-Cr = 0.47DTPA-Cr +1.16; (r = 0.92); Radish-Cr = 0.40DTPA-Cr +1.58; (r = 0.90); Eggplant-Cr = 0.48DTPA-Cr +0.23; (r = 0.95); Potato-Cr =0.76DTPA-Cr +1.28; (r = 0.84); Maize-Cr = 0.59DTPA-Cr+2.56; (r = 0.82)

The concentration of Pb in crops and soil can be related as:

Cauliflower-Pb= 1.38DTPA-Pb-0.54; (r = 0.83); Radish-Pb = 1.25DTPA-Pb -0.60; (r = 0.87); Eggplant-Pb = 1.22DTPA-Pb +0.39; (r = 0.91); Potato-Pb =1.50DTPA-Pb+0.89; (r = 0.88); Maize-Pb = 0.75DTPA-Pb+0.018 (r = 0.76)

Thus the metal concentration in various vegetable crops may be predicted by estimation of DTPA-extractable metals in soils.

These results suggest that sewage effluent disposal on agricultural land enhanced the Cd, Ni, Cr and Pb concentration in soils and in crops as compared to ground water irrigated soils. Uptake of heavy metals by crops were positively correlated with soil organic matter, suggesting that there is a formation of metal-humic acid complex in soil by application of sewage effluent for longer period and these forms of metal get transferred into the plants grown on these soils[7].

Table 1: Physico-chemical properties of soils

Properties	Soils									
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S9	S_{10}
pH	8.42	8.38	8.35	8.40	8.30	8.32	8.25	8.24	8.10	8.06
EC (dS m^{-1})	1.36	1.24	1.20	1.18	1.16	1.14	1.10	1.02	1.06	0.64
Org. C (g $kg^{-1)}$	22.4	20.8	15.1	13.2	14.8	12.6	11.5	10.7	10.5	5.8
CEC [cmol(p+) $kg^{-1]}$	30.6	27.4	24.8	20.6	21.0	18.0	17.0	15.0	13.4	12.2
Clay (%)	16.5	12.4	18.7	17.2	20.1	21.6	22.4	20.5	23.7	27.5
Silt (%)	33.3	41.5	47.5	40.3	35.5	50.5	38.4	44.5	52.2	47.5
Sand (%)	50.2	46.1	33.5	42.5	44.4	27.9	39.2	35.0	24.1	25.0
DTPA- Extractable (mg $kg^{-1)}$										
Cd	0.442	0.406	0.388	0.362	0.394	0.350	0.302	0.264	0.244	0.122
Ni	9.64	9.06	8.72	8.34	7.08	6.22	6.54	5.92	5.22	2.64
Cr	25.4	21.4	22.1	20.2	14.6	12.8	15.8	13.4	10.2	4.4
Pb	18.2	15.5	16.6	13.7	14.2	12.2	12.8	10.8	11.0	3.4

Table 2: Mean values of pH, in the partial sewage effluent, sewage effluent and ground water irrigated soils pH

Depth (cm)	Soils										
	S_1 (SI)	S_2 (SI)	S_3 (SI)	S_4 (SI)	S_5 (PSI)	S_6 (PSI)	S_7 (PSI)	S_8 (PSI)	S_9 (GW)	S_{10} (GW)	Mean
0-15	8.48 (8.34-8.60)	8.42 (8.30-8.52)	8.38 (8.30-8.46)	8.44 (8.34-8.50)	8.33 (8.20-8.40)	8.24 (8.14-8.32)	8.28 (8.18-8.36)	8.27 (8.16-8.34)	8.12 (8.0-8.17)	8.07 (8.00-8.12)	8.30
15-30	8.03 (7.94-8.11)	8.04 (7.94-8.12)	8.08 (8.0-8.16)	7.94 (7.88-7.99)	7.92 (7.84-7.98)	7.84 (7.80-7.90)	7.82 (7.74-7.89)	7.87 (7.80-7.92)	7.65 (7.62-7.68)	7.61 (7.56-7.64)	7.88
30-45	7.74 (7.68-7.92)	7.66 (7.58-7.72)	7.72 (7.66-7.78)	7.65 (7.58-7.70)	7.60 (7.56-7.64)	7.60 (7.58-7.62)	7.62 (7.54-7.68)	7.74 (7.68-7.82)	7.41 (7.38-7.45)	7.37 (7.34-7.40)	7.61
45-60	7.40 (7.36-7.44)	7.36 (7.32-7.40)	7.40 78.34-7.46)	7.32 (7.28-7.36)	7.46 (7.40-7.52)	7.42 (7.36-7.48)	7.36 (7.32-7.42)	7.60 (7.54-7.66)	7.28 (7.26-7.30)	7.26 (7.24-7.28)	7.39
Mean	7.91	7.88	7.90	7.83	7.83	7.78	7.77	7.87	7.61	7.58	
CD (5%)	Soil = 0.038; Depth= 0.022										
EC											
0-15	1.40 (1.32-1.45)	1.27 (1.20-1.31)	1.34 (1.26-1.40)	1.32 (1.23-1.40)	1.16 (1.08-1.21)	1.13 (1.06-1.18)	1.09 (1.02-1.16)	1.04 (1.0-1.08)	0.70 (0.64-0.74)	0.65 (0.62-0.68)	1.11
15-30	1.09 (1.03-1.12)	1.05 (1.0-1.10)	1.07 (1.0-1.11)	1.06 (1.0-1.12)	0.95 (0.88-0.98)	0.92 (0.88-0.95)	0.94 (0.88-0.98)	0.88 (0.83-0.91)	0.58 (0.54-0.64)	0.55 (0.52-0.58)	0.91
30-45	1.02 (0.95-1.06)	0.92 (0.85-0.98)	0.99 (0.93-1.02)	0.93 (0.86-0.98)	0.88 (0.80-0.92)	0.84 (0.78-0.88)	0.82 (0.77-0.85)	0.78 (0.74-0.81)	0.51 (0.47-0.53)	0.49 (0.46-0.51)	0.82
45-60	0.92 (0.87-0.97)	0.82 (0.77-0.86)	0.90 (0.85-0.95)	0.86 (0.81-0.89)	0.79 (0.75-0.84)	0.75 (0.72-0.78)	0.77 (0.74-0.80)	0.69 (0.66-0.72)	0.47 (0.44-0.49)	0.45 (0.43-0.47)	0.74
Mean	1.11	1.02	1.07	1.04	0.94	0.91	0.90	0.85	0.57	0.54	
CD (5%)	Soil = 0.015; Depth= 0.009										

					Organic matter						
0-15	23.1 (20.6-25.1)	21.4 (18.9-23.2)	17.8 (15.7-19.1)	19.4 (17.7-20.4)	12.5 (11.0-14.0)	13.0 (11.9-13.9)	11.8 (10.8-12.8)	10.9 (10.0-11.8)	6.4 (5.9-7.0)	5.9 (5.5-6.0)	14.2
15-30	14.4 (13.0-15.5)	13.9 (12.4-15.1)	12.9 (12.0-13.7)	13. 7 (12.3-16.2)	9.8 (8.8-10.6)	9.9 (9.4-10.4)	9.2 (8.5-9.8)	8.7 (8.1-9.3)	4.5 (4.0-5.0)	4.0 (3.8-4.2)	10.1
30-45	10.4 (9.8-11.0)	9.8 (9.4-10.2)	9.5 (8.9-9.8)	9.7 (9.2-10.2)	7.4 (6.7-7.9)	7.6 (7.2-8.2)	7.2 (6.6-7.6)	6.7 (6.2-7.1)	3.7 (3.3-4.0)	3.2 (3.0-3.3)	7.5
45-60	9.5 (9.1-9.8)	9.0 (8.6-9.3)	8.5 (8.0-8.8)	8.5 (8.0-8.7)	6.3 (6.2-6.7)	7.1 (6.8-7.4)	6.6 (6.4-6.8)	6.2 (6.0-6.4)	3.1 (3.0-3.3)	2.7 (2.6-2.8)	6.75
Mean	14.35	13.5	12.2	12.8	9.0	9.4	8.65	8.1	4.4	3.95	
CD (5%)	Soil = 0.047; Depth= 0.026										

Table 3: Mean values of DTPA-extractable cadmium (g kg^{-1}) in the partial sewage effluent, sewage effluent and ground Water irrigated soils

Depth (cm)	Soils										
	S$_1$ (SI)	S$_2$ (SI)	S$_3$ (SI)	S$_4$ (SI)	S$_5$ (PSI)	S$_6$ (PSI)	S$_7$ (PSI)	S$_8$ (PSI)	S$_9$ (GW)	S$_{10}$ (GW)	Mean
					Cd						
0-15	0.450 (0.412-0.476)	0.412 (0.388-0.430)	0.394 (0.374-0.406)	0.398 (0.380-0.412)	0.354 (0.334-0.372)	0.292 (0.276-0.308)	0.306 (0.288-0.320)	0.266 (0.248-0.282)	0.145 (0.136-0.156)	0.123 (0.120-0.125)	0.314
15-30	0.374 (0.348-0.402)	0.338 (0.322-0.356)	0.310 (0.292-0.320)	0.324 (0.308-0.342)	0.278 (0.264-0.290)	0.220 (0.204-0.230)	0.234 (0.220-0.252)	0.202 (0.188-0.226)	0.117 (0.112-0.122)	0.109 (0.104-0.112)	0.250
30-45	0.306 (0.292-0.318)	0.288 (0.278-0.295)	0.276 (0.262-0.288)	0.290 (0.276-0.302)	0.256 (0.248-0.266)	0.185 (0.178-0.194)	0.208 (0.198-0.219)	0.165 (0.150-0.182)	0.106 (0.100-0.110)	0.100 (0.098-0.104)	0.218
45-60	0.266 (0.256-0.272)	0.253 (0.246-0.260)	0.241 (0.232-0.248)	0.258 (0.248-0.264)	0.231 (0.226-0.238)	0.152 (0.148-0.156)	0.189 (0.186-0.192)	0.138 (0.136-0.140)	0.096 (0.094-0.098)	0.094 (0.093-0.095)	0.192
Mean	0.349	0.321	0.305	0.318	0.280	0.212	0.234	0.193	0.116	0.1065	
CD (5%)	Soil = 0.002; Depth= 0.001										
					Ni						
0-15	9.72 (9.24-10.14)	9.16 (8.34-9.44)	8.78 (8.32-9.16)	8.38 (7.94-8.66)	6.26 (5.88-6.56)	6.06 (5.88-6.34)	5.56 (5.22-5.92)	5.94 (5.64-6.32)	3.14 (2.78-3.36)	2.67 (2.52-2.74)	6.57
15-30	6.92 (6.44-7.16)	6.38 (6.02-6.74)	6.22 (5.98-6.34)	5.88 (5.58-6.10)	3.78 (3.60-3.96)	3.68 (3.50-3.82)	3.74 (3.54-3.74)	3.57 (3.34-3.80)	2.49 (2.32-2.60)	2.29 (2.20-2.38)	4.49
30-45	4.14 (4.02-4.32)	3.76 (3.54-3.96)	3.62 (3.48-3.74)	3.42 (3.28-3.54)	2.30 (2.18-2.39)	2.36 (2.28-2.44)	2.60 (2.48-2.74)	2.21 (2.06-2.32)	2.11 (2.06-2.16)	2.06 (2.0-2.14)	2.86
45-60	2.66 (2.56-2.70)	2.43 (2.34-2.54)	2.33 (2.26-2.38)	2.22 (2.18-2.26)	2.02 (1.78-1.96)	1.95 (1.88-2.02)	2.12 (2.02-2.20)	1.92 (1.82-2.0)	1.94 (1.86-2.00)	1.92 (1.88-1.98)	2.15
Mean	5.86	5.43	5.24	4.98	3.59	3.51	3.50	3.41	2.42	2.23	
CD (5%)	Soil = 0.372 Depth= 0.228										

Cr											
0-15	26.2 (22.2-30.2)	22.2 (19.2-24.0)	22.7 (19.4-25.8)	20.8 (17.8-23.0)	15.0 (12.8-17.0)	13.3 (11.0-15.2)	14.3 (11.9-16.3)	12.8 (10.8-14.8)	5.4 (4.8-6.2)	4.5 (4.0-4.9)	15.7
15-30	19.3 (16.8-21.4)	16.1 (14.1-17.8)	16.6 (14.8-18.6)	14.8 (13.0-16.8)	11.2 (9.6-12.4)	10.4 (9.1-11.6)	10.5 (9.4-12.1)	9.7 (8.4-11.2)	4.5 (3.8-5.2)	4.0 (3.4-4.6)	11.7
30-45	15.6 (14.0-17.0)	13.5 (12.2-15.0)	14.1 (12.9-15.2)	12.9 (11.8-14.1)	9.4 (8.4-10.0)	8.8 (7.7-9.6)	8.8 (7.9-9.8)	8.3 (7.5-8.9)	3.9 (3.5-4.5)	3.6 (3.2-4.2)	9.9
45-60	13.8 (13.0-14.6)	12.3 (11.5-13.2)	12.5 (12.0-13.3)	10.9 (10.5-11.4)	8.5 (8.0-8.7)	8.2 (7.7-8.5)	7.7 (7.3-8.3)	7.3 (7.0-7.8)	3.5 (3.2-3.8)	3.2 (2.9-3.5)	8.8
Mean	18.7	16.0	16.5	14.8	11.0	10.2	10.3	9.5	4.3	3.8	
CD (5%)	Soil = 0.422; Depth= 0.292										
Pb											
0-15	18.8 (16.6-20.8)	16.1 (14.1-17.6)	17.1 (14.9-18.5)	15.6 (13.7-16.8)	13.6 (12.7-14.9)	12.6 (11.0-14.0)	13.1 (11.5-14.4)	11.1 (9.8-12.2)	4.2 (3.5-4.5)	3.5 (2.9-3.9)	12.6
15-30	13.8 (11.8-15.4)	11.8 (10.0-13.1)	12.4 (10.8-13.8)	11.9 (10.8-12.5)	10.3 (8.8-11.4)	9.7 (8.4-10.8)	9.3 (8.2-10.5)	8.9 (8.0-9.8)	3.3 (3.0-3.6)	3.1 (2.7-3.5)	9.5
30-45	10.5 (9.4-11.6)	9.6 (8.1-10.8)	10.2 (9.0-11.1)	9.4 (8.5-10.2)	8.4 (7.5-9.2)	8.2 (7.2-8.9)	7.7 (7.0-8.5)	7.4 (6.5-8.2)	3.1 (2.8-3.3)	2.8 (2.5-3.2)	7.7
45-60	9.3 (8.6-9.6)	8.9 (8.1-9.7)	9.8 (9.5-10.0)	8.2 (7.8-8.5)	7.7 (7.3-8.2)	7.5 (7.1-7.8)	7.2 (6.7-7.5)	6.8 (6.5-7.2)	2.4 (2.3-2.6)	2.4 (2.2-2.6)	7.0
Mean	13.1	11.6	12.4	11.3	10	9.5	9.3	8.5	3.25	2.95	
CD (5%)	Soil = 0.378; Depth= 0.268										

Table 4 : Correlation coefficients of cadmium, nickel, chromium and lead with soil Properties

Parameters	DTPA-Cd	DTPA-Ni	DTPA-Cr	DTPA-Pb
pH	0.932	0.938	0.938	0.874
EC	0.963	0.944	0.904	0.965
Org. C	0.912	0.914	0.894	0.872
CEC	0.934	0.942	0.934	0.886
Clay content	-0.852	-0.914	-0.870	-0.824

Table 5:Distribution of DTPA-extractable metal ions($g\ kg^{-1}$) in different crops grown in the sewage effluent irrigated soils

Vegetable crop	Soils										
	S_1 (SI)	S_2 (SI)	S_3 (SI)	S_4 (SI)	S_5 (PSI)	S_6 (PSI)	S_7 (PSI)	S_8 (PSI)	S9 (GW)	S_{10} (GW)	Mean
Cd											
Cauliflower	1.52±0.14	1.30±0.14	1.25±0.09	1.12±0.13	0.80±0.07	0.75±0.04	0.70±0.07	0.63±0.06	0.34±0.04	0.25±0.02	0.87
Radish	1.88±0.20	1.74±0.16	1.49±0.14	1.36±0.12	1.06±0.11	0.94±0.09	0.88±0.05	0.80±0.09	0.50±0.08	0.44±0.06	1.11
Egg Plant	2.22±0.24	2.20±0.19	1.94±0.16	1.76±0.17	1.60±0.20	1.48±0.11	1.24±0.09	1.14±0.12	0.64±0.05	0.52±0.06	1.47
Potato	5.68±0.30	4.96±0.26	4.22±0.22	3.68±0.28	3.14±0.20	2.82±0.24	2.44±0.22	2.20±0.22	0.98±0.10	0.94±0.12	3.11
Maize	3.64±0.18	3.18±0.16	3.10±0.15	2.76±0.22	2.50±0.14	2.22±0.15	1.98±0.14	1.84±0.10	0.82±0.08	0.74±0.10	2.28
Mean	2.95	2.67	2.40	2.13	1.82	1.64	1.48	1.33	0.66	0.58	-------
CD (5%)	Soil = 0.26; Crops= 0.15										
Ni											
Cauliflower	12.98±0.64	10.68±0.48	9.72±0.28	8.52±0.16	7.62±0.14	6.98±0.20	6.34±0.14	5.54±0.16	2.98±0.12	2.48±0.12	7.38
Radish	12.04±0.68	10.24±0.32	9.54±0.28	8.64±0.26	6.94±0.20	6.36±0.16	6.12±0.14	5.78±0.30	2.22±0.14	1.88±0.06	6.96
Egg Plant	17.12±0.84	12.64±0.54	12.62±0.42	11.86±0.54	8.92±0.18	9.26±0.32	8.62±0.28	8.26±0.40	2.72±0.12	2.42±0.12	9.44
Potato	29.32±1.48	22.48±1.08	19.06±0.96	16.98±0.96	13.86±0.42	14.58±0.52	13.54±0.62	12.84±0.56	7.86±0.26	6.98±0.14	15.75
Maize	18.24±0.84	16.42±0.66	15.58±0.54	15.44±0.60	10.54±0.34	11.68±0.38	11.26±0.34	10.62±0.34	3.52±0.18	2.88±0.10	11.62
Mean	19.94	14.54	13.30	12.29	9.58	9.77	9.18	8.61	3.86	3.33	------
CD (5%)	Soil = 0.94; Crops= 0.66										
Cr											
Cauliflower	15.26±0.44	13.86±0.62	11.98±0.38	10.74±0.34	8.54±0.16	9.24±0.28	8.32±0.18	7.96±0.24	2.76±0.14	2.58±0.08	9.12
Radish	13.74±0.60	11.98±0.28	10.74±0.28	9.62±0.22	6.88±0.16	8.42±0.22	7.88±0.22	7.48±0.34	2.32±0.08	2.16±0.08	8.10
Egg Plant	11.94±0.52	10.84±0.38	9.94±0.36	11.62±0.58	8.72±0.16	6.88±0.28	6.34±0.20	5.58±0.24	2.14±0.12	1.94±0.08	7.59
Potato	21.22±1.16	19.14±0.98	17.14±0.56	15.94±0.74	13.52±0.44	12.58±0.36	11.32±0.60	9.98±0.44	4.64±0.22	4.44±0.20	13.00
Maize	16.98±0.54	14.96±0.56	14.08±0.38	13.94±0.68	10.66±0.38	11.44±0.28	10.98±0.42	10.52±0.28	3.22±0.18	2.96±0.06	10.97
Mean	15.83	14.16	12.78	12.37	9.66	9.71	8.97	8.30	3.02	2.82	------
CD (5%)	Soil = 1.08; Crops= 0.74										
Pb											
Cauliflower	24.26±0.66	22.58±0.46	20.98±0.58	19.96±0.28	17.64±0.32	17.14±0.38	16.48±0.38	15.68±0.54	3.84±0.16	3.44±0.08	16.20
Radish	22.16±0.74	21.22±0.68	19.96±0.40	19.22±0.38	16.74±0.60	16.52±0.34	15.62±0.52	14.42±0.38	3.38±0.10	2.98±0.14	15.22
Egg Plant	20.22±0.62	19.46±0.52	18.66±0.62	18.06±0.46	15.54±0.32	16.24±0.42	15.34±0.44	14.68±0.44	3.32±0.16	2.84±0.16	14.44
Potato	30.24±1.02	27.28±0.96	25.72±1.06	25.12±0.52	21.52±0.62	22.08±0.54	20.98±0.96	20.32±0.52	5.04±0.26	4.58±0.14	20.29
Maize	14.36±0.40	13.38±0.34	12.54±0.22	11.78±0.38	10.34±0.36	10.32±0.38	9.48±0.38	9.32±0.36	3.08±0.16	2.46±0.08	9.71
Mean	22.25	20.88	19.57	18.83	16.36	16.46	15.58	14.88	3.73	3.26	------
CD (5%)	Soil = 1.14; Crops= 0.76										

CONCLUSIONS

From this study it is evident that continuous use of sewage effluent for irrigation on agricultural land is increasing the concentration of DTPA- extractable Cd, Ni, Cr and Pb in soils and crops grown on such soils beyond their toxic limit. The study also revealed that maximum accumulation of heavy metals is in potato a most commonly used vegetable in India. These results also denote that potato and maize is good accumulator of metals hence growing of potato and maize on such soils should be avoided. Higher concentration of heavy metals Cd, Ni, Cr and Pb due to more accumulation probably may cause phytotoxicity which result in decrease of crop yield. If the non –judicious use of sewage effluent is not stopped it will not only harm the consumer of the crops but also retard the soil fertility and crop yield.

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