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Accumulation of heavy metals on soil and vegetable crops grown on sewage and tube well water irrigation

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Consumption of food crops contaminated with heavy metals is a major food chain route for human exposure. In the present study, vegetables grown in the sewage and tube well water irrigation are *Raphanus sativus*, *Daucus carrota* and *Brassica rapa*. Concentration of Cd, Pb and Ni was significantly higher in sewage irrigated soil at all the four depths (0-15, 15-30, 30-45 and 45-60 cm), respectively. Cadmium, Lead and Nickel concentration are higher at the surface horizons and it decreases sharply with depth in both tube well and sewage irrigated soils. Extent of heavy metal built up in sewage irrigated soils was significant in both 0-15 and 15-30 cm depth. Higher concentration of Pb, Cd and Ni, were observed in the roots of all crops grown in sewage irrigated soils compared to that of crops grown on tube well irrigated soils. Sewage water irrigation has a great potential to contaminate the soil which may lead to the accumulation of heavy metals in crop plants and may cause harmful effect on animals and plants. Results, indicate that, long term and indiscriminate application of sewage water, which contains heavy metals may cause accumulation of heavy metals in surface and sub-surface soils and the buildup of heavy metals on soil profile may prove harmful not only to plants, but also to consumers of the harvested crops.

Key words: Crops, heavy metals, water, sewage, tube well.

INTRODUCTION

Protection of environment is the most vital issue today. Explosive population growth, rapid progress in science and technology, massive industrialization and use of various chemicals in agriculture and most importantly, human activities are the factors threatening the very quality of life (Sharma et al., 2000). Tremendous progress in every sphere of science and technology has lead ultimately to environmental impact resulting in extreme unhygienic conditions, modifying our living environment. Environmental disturbances in the ecosystem against the backdrop of rapid population growth, uncontrolled urbanization of unregulated industrialization are mainly reflected by changes in the chemical element concentration pattern. Environmental degradation by trace metal accumulation in eco-friendly systems caused by over exploitation of resource materials and human imposed interactions are the few unending problems encountered which threaten the very basic economy of a nation and individuals by affecting both the progress of the nation as well as the health of the human beings.

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The biggest problem of environmental pollution on account of essential industrial growth is, in practical terms the problem of disposal of industrial waste, whether solid, liquid or gaseous. All the three types of wastes have the potentiality of ultimately polluting water. Polluted water in addition to other effects, directly affects soil, not only in industrial areas but also in agricultural fields, as well as the beds of rivers, creating secondary sources of pollution (De et al., 1980, 1985; Ray and Banerjee, 1983; Kisku et al., 2000; Barman et al., 2001). The major environmental effect on crops is due to air pollutants or water pollutants having high concentration of heavy metals (Lager Werff and Specht, 1970; Friberg et al., 1971). Usually, the pollutants come out through industrial mining, milling and nuclear waste (Francis and Rush, 1973). Such contamination of soil, air and water with increased industrialization is a threat to the continuous existence of countless species of plants and animals of the ecosystem and may ultimately become the greatest hazard to human population (Kumar et al., 1996).

Out of the 112 elements in nature, about 80 are metals, most of which are found only in trace amounts in the biosphere and in biological materials. There are at least some twenty metals or metal like elements which do give rise to well organized toxic effects in man and his ecological associates (Friberg et al., 1979). These elements include Arsenic, Antimony, Beryllium, Cobalt, Chromium, Lead, Manganese, Mercury, Molybdenum, Nickel and Tin. These metals have been known to be toxic to man for centuries, and their carcinogenic activities have also been reviewed by Frust (1977). Among the different pollutants heavy metals have received escalating attention due to their possible injurious effects to man, animal and plants as these are recorded to be cytotoxic, mutagenic and carcinogenic. Heavy metals are conventionally defined as elements with metallic properties such as ductility, conductivity, stability as cations, legends specificity etc. and atomic number greater than 20. The most common heavy metal contaminants are Cadmium, Chromium, Copper, Mercury, Lead, Zinc, Arsenic, Nickel and Vanadium. Heavy metals form the major group of toxic pollutants among the other pollutants, as these metals temper the harmony of the ecosystem (Rao and Patnaik, 1999).

MATERIALS AND METHODS

Roots of the plant species namely *Raphanus sativus* commonly called Radish, *Brassica rapa* commonly called Turnip and *Daucus carrota* commonly called Carrot, were chosen for chemical analysis.

Chemical analysis

Sampling and analysis of sewage water and underground water

Composite sample of waste water were collected from sewage channel carrying sewage mixed with untreated industrial effluents. Manual sampling from sewage surface was carried out by plastic bottle fastened by a rope. Container was rinsed twice with the sample to be examined before being finally filled. 2000 ml of sewage sample was collected in polyethylene bottle rinsed with 20% HNO_3 followed by distilled water. Water samples from deep tube well were also collected. High grade plastic bottles of 2000 ml capacity were thoroughly cleaned and were rinsed with the water being sampled. Samples were collected after running the water for 15 min from the source so as to avoid error due to water contained within the pipes. 100 ml of the thoroughly mixed sewage water sample was transferred to a 250-ml beaker. 100 ml sewage water sample was evaporated to dryness on steam bath and digested with 5 ml of perchloric acid ($HClO_4$) and 25 ml nitric acid (HNO_3) mixture (1 : 4) on hot plate to the lowest volume (15-20 ml). Each digest was made up to 50 ml with the addition of double distilled water (APHA, 1975). Cd, Pb and Ni, were determined in the digest by AAS (Atomic Absorption spectrophotometer).

Soil sampling and analysis

Before sowing of crops, representative soil samples were collected from Research field of Allahabad Agricultural University. Soil samples were collected at the depths (0-15, 15-30, 30-45 and 45–60 cm), respectively with the help of a stainless steel tube auger. The representative soil samples were transferred into air tight polythene bags and brought into the laboratory.

Soil samples were dried at 40°C for 48 h in hot air oven and crushed to pass through a 2 mm nylon sieve. A di-acid mixture was used to find out the heavy metals Cd, Pb, Cu in the soil. A known amount (5 g) oven dry soil was weighed and transferred into 100-ml beaker to which 25 ml of concentrated HNO_3 and 5 ml of perchloric acid was added. [25 ml conc. HNO_3 and 5 ml of $HClO_4$ (5:1)]. Mixture was placed on a hot plate at 105°C for one hour and then temperature was increased up to 140°C until the sample was completely dry. After cooling, the solution was mixed and filtered through Whatman No. 42 filter paper into a 50-ml volumetric flask. Digested samples were then analyzed for Cd, Pb, and Ni on AAS (Atomic Absorption spectrophotometer).

Plant sampling and analysis

Plant root samples of different crops were collected from fields irrigated with sewage water, as well as tube well water. Root samples of Radish (*R. sativus*), Turnip (*B. rapa*), Carrot (*D. carota*) were collected at the time of harvest. Plant root samples were washed successively with tap water, acidified water, distilled water and double distilled water. These samples were then dried, first at room air temperature for several days and then in hot (60 + 5°C) air oven for 48 h. Dried plant parts were then crushed and powdered separately in mortar and pestle. Powdered plant samples were then put separately in well washed, dried and suitably labeled flasks and these samples were then ready for digestion. Digestion mixture for biological sample was a di-acid mixture. Mixture comprised concentrated HNO_3 and $HClO_4$. To one gram of plant material, 5 ml of concentrated HNO_3 was added and kept overnight. The next day, 12 ml of di-acid mixture (conc. HNO_3 +$HCLO_4$ in the ratio 3:1) was added and digested on hot plate till white reddish brown fumes of perchloric acid comes out. Plant samples slowly begin to dissolve and digest in di-acid mixture. After a few hours, plant sample dissolved completely in the digestion mixture and solution was then evaporated until only about 2 ml was left in the flask. Digested samples were then transferred into small tubes for analysis using Atomic Absorption spectrophotometer (Jackson, 1973).

Table 1. Heavy metal concentration (mg^{-l}) in sewage and tubewell water.

Sample	Cd	Pb	Ni
	Sewage water		
SW_1	0.15	0.34	0.22
SW2	0.12	0.35	0.20
SW3	0.16	0.61	0.24
SW4	0.13	0.23	0.17
SW5	0.17	0.52	0.17
SW6	0.10	0.30	0.19
Mean	**0.14**	**0.39**	**0.19**
	Tubewell water		
TW1	0.0008	0.014	0.0003
TW2	0.0002	0.013	0.0003
TW3	0.0005	0.02	ND
TW4	0.0003	0.016	0.0002
TW5	ND	0.014	0.0002
TW6	0.0002	0.021	ND
Mean	**0.0004**	**0.016**	**0.0002**

RESULTS AND DISCUSSION

Concentration of heavy metals in sewage contaminated water and tube well water

Cadmium

Concentration of Cd was significantly higher in sewage contaminated water than the tube well water. In tube well water Cd concentration varied from 0.0002 to 0.0005 (mean 0.0004 mg l^{-1} water) But the concentration of Cd in sewage water ranged from 0.10 to 0.17 (mean 0.14 mgl^{-1} water). In sewage water the values of mean concentration of Cd were 350 times than that of tubewell water. Sewage water near the discharge point contained appreciably high amount of Cd and gradually decreased as distance from the discharge point increased. Khan et al. (2001) also reported that water in areas near to source of effluent discharge was more contaminated, as compared to the areas away from the sources. Increase in Cd concentration was also due to availability of different organic sources in sewage water.

Lead

A wide range in concentration of Pb was found in sewage and tube well water (Table 1). Its concentration varied from 0.23 to 0.61 mgl^{-1} (mean 0.39). In tube well water its concentration varied from 0.013 to 0.020 mgl^{-1} (mean 0.016). Thus, in sewage water mean Pb concentration was 24.37 folds greater than its concentration in tube well waters.

Nickel

Nickel concentration of water samples exhibited a wide range of variations in Gangia. In tubewell water Ni concentration varied from 0.0002 to 0.0003 mg l^{-1} (mean 0.0002). But concentration of Ni in sewage water ranged from 0.17 to 0.19 mg l^{-1} (mean 0.9). In sewage water values of mean concentration of Pb were 950 folds higher than that of tube well water. Sharma and Shukla (2013) have reported that physicochemical analysis of waste water and soil samples have heavy load of metals resulting into continuous addition to the agricultural fields.

Accumulation of Cd, Pb and Ni in sewage and tube well irrigated soils

The extent of contamination due to anthropogenic activity is generally judged by making comparisons of the metal contaminated soils with adjacent non polluted ones as there is no direct reference level due to wide variations in naturally occurring heavy metals in soils. Same criteria have been followed in present study to determine the distribution and extent of heavy metal pollution in sewage irrigated soil as compared to tube well irrigated soils.

Data on Cd, Pb and Ni in soils are presented in Table 2. Concentration of these metals in sewage and tubewell irrigated soils varied markedly.

Cadmium

Manifold increase in Cd was found in sewage irrigated soils than tube well irrigated soils. In sewage fed soils of site (Gangia) Cd content in 0-15, 15-30, 30-45 and 45-60

Table 2. Depth wise distribution of cadmium (mg/kg) in sewage and tubewell irrigated soil.

Sample	Sewage irrigated				Tubewell irrigated			
	Depth of Sampling (cm)				Depth of Sampling (cm)			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
S_1	0.78	0.38	0.1	0.12	0.14	0.12	0.08	0.07
S_2	0.86	0.12	0.16	0.11	0.15	0.13	0.08	0.07
S_3	0.88	0.58	0.18	0.09	0.13	0.09	0.1	0.08
S_4	0.6	0.6	0.12	0.1	0.09	0.07	0.08	0.1
S_5	0.63	0.42	0.14	0.1	0.07	0.11	0.08	0.09
S_6	0.7	0.4	0.16	0.1	0.15	0.1	0.07	0.09
Mean	**0.74**	**0.41**	**0.14**	**0.10**	**0.12**	**0.10**	**0.08**	**0.08**

Table 3. Depth wise distribution of Lead (mg/kg) in sewage and tubewell irrigated soil.

Sample	Sewage irrigated				Tubewell irrigated			
	Depth of Sampling (cm)				Depth of Sampling (cm)			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
S_1	5.1	2.6	0.16	0.32	0.6	0.7	0.12	0.27
S_2	4.38	1.6	0.54	0.22	1.02	0.4	0.88	0.34
S_3	3.76	1.42	0.32	0.26	0.8	1.1	0.3	0.06
S_4	2.9	2.42	0.72	0.38	1.42	0.85	0.53	0.1
S_5	5.12	2.48	0.68	0.16	1.64	0.13	0.7	0.26
S_6	3.36	2.1	0.36	0.2	0.66	0.68	0.44	0.32
Mean	**4.10**	**2.10**	**0.46**	**0.26**	**1.02**	**0.64**	**0.47**	**0.22**

cm depth varied from 0.60 to 0.88 mg Cd kg^{-1} soil (mean 0.74 mg Cd kg^{-1}soil), 0.12 to 0.60 mg Cd kg^{-1} soil (mean 0.41 mg Cd kg^{-1} soil), 0.10 to 0.18 mg Cd kg^{-1} soil (mean 0.14 mg Cd kg^{-1} soil), and 0.09 to 0.12 mg Cd kg^{-1} soil (mean 0.10 mg Cd kg^{-1} soil).

Mean values of Cd in tube well irrigated soils in the 0-15, 15-30, 30-45 and 45-60 cm depth respectively were 0.12, 0.10, 0.08, and 0.08 mg Cd kg^{-1}. Difference in Cd between sewage and tube well irrigated soils was restricted largely to the 0-15 and 15-30 cm soil depths and there was particularly no difference in Cd beyond 30 cm depth. In 0-15 and 15-30 cm soil depth, the respective Cd in sewage irrigated soils was 6.16 and 4.1 over the tube well irrigated soils among the sewage irrigated soils. Mitra and Gupta (1999) and Khurana et al. (2004) also reported higher concentration of heavy metals in sewage irrigated soils than soil irrigated with uncontaminated water.

Lead

A perusal of the data in Table 3 indicated that, concentration of Pb was higher in sewage irrigated soils than in tube well irrigated soils at all the four depths (0-15, 15-30, 30-45 and 45–60 cm). Concentration of Pb in the surface (0-15 cm) and sub-surface soils (15-30 cm) respectively varied from 2.90 to 5.12 (mean 4.10) and 1.42 to 2.60 (mean 2.10 mg Pb kg^{-1} soil).

Concentration of Pb decreased with depth in both tube well and sewage irrigated soils .The extent of lead built up in sewage irrigated soils was significant in both 0-15 and 15-30 cm depth. This might be due to the fact that, concentration of heavy metals in sewage effluents emanating from different sources is manifolds higher than that of tube well water. A gradual decline in its concentration was recorded with increase in distance from the point of sewage discharge and down the profiles. Data further indicated the enrichment of Pb due to discharge of sewage water and sludge mostly in the surface layer with very little mobility down the profile. Datta et al. (2000) reported that, soils of IARI farm receiving sewage water of mostly domestic origin for more than three decades has only marginally increased the concentration of Pb from 1.2 to 1.6 mg kg^{-1} soil. These results are also in tune with Mosleh and Almagrabi (2013) who reported that high level of Zn and Pb was found in soils (11.24 and 8.32 mg kg^{-1}) respectively.

Nickel

The data on Ni content of different depths in soils are presented in Table 4. In sewage irrigated surface soils it varied from 1.54 to 2.18 mg Ni kg^{-1} soil with the mean value of 1.94 mg Ni kg^{-1}) soil and in tube well irrigated

Table 4. Depth wise distribution of Nickel (mg/kg) in sewage and tubewell irrigated soil.

Sample	Sewage irrigated				Tubewell irrigated			
	Depth of sampling (cm)				Depth of sampling (cm)			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
S_1	2.18	0.5	0.12	0.02	0.44	0.2	0.08	0.03
S_2	2.14	0.57	0.18	0.02	0.54	0.2	0.09	0.03
S_3	1.76	0.2	0.18	0.02	0.46	0.18	0.01	0.02
S_4	2.02	0.42	0.1	0.04	0.36	0.13	0.01	0.02
S_5	2	0.62	0.01	0.04	0.78	0.28	0.04	0.07
S_6	1.54	0.18	0.07	0.08	0.38	0.16	0.09	0.05
Mean	**1.94**	**0.40**	**0.11**	**0.04**	**0.49**	**0.19**	**0.06**	**0.04**

surface soils it varied from 0.36 to 0.78 mg Ni kg^{-1} soil with mean value of 0.49 mg Ni kg^{-1}. Thus the mean value of Ni in 0-15 cm soil layer was 3.96 fold in sewage irrigated soil over the tub well irrigated soils. In other two soil depths, that is, 30-45 and 45-60 cm the differences were not of much significance. As stated above for Cd and Pb, concentration of Ni also decreases with the depth in both tube well and sewage irrigated soils.

Ni decreased progressively with soil depth and increase in distance from the point of sewage discharge. Organic matter has been reported to bind various heavy metals (Singer and Navrot, 1976) and is responsible for their accumulation and movement in soils depending on nature of organic matter.

Thus, it may be concluded from the present study that, application of waste waters has resulted in appreciable accumulation of Cd, Pb and Ni in soils; most of the accumulation of these metals was restricted up to 30 cm depth. The continuous cultivation of these lands for food and fodder crops may result in greater uptake of metals by crops, resulting in health hazard to animals and human beings.

Cd, Pb and Ni content of plants grown on sewage and tube well irrigated soils

Crops are one of the principal sinks for accumulation of the heavy metals and these metal contaminated edible portions act as poisons for human being and other living organisms. This is a matter of serious concern as vegetables, being prolific accumulators of heavy metals provide easy entry into food chain to these dreaded metals.

Cadmium

Cadmium content of the plant samples exhibited a wide range of variations. In plants collected from tube well irrigated soils the Cd content varied from 0.66 to 0.60 (mean 0.82 mg kg^{-1} dry matter). But sewage irrigation increased the accumulation of Cd in different crop species. It varied from 1.10 to 1.61 (mean 1.32 mg kg^{-1} dry matter), 0.95 to 1.47 (mean 1.15 mg kg^{-1} dry matter). In sewage irrigated crops the values of mean content of Cd were 1.67 times than the tube well irrigated plants. Results showed that sewage water led to the buildup of heavy metals in crop plants grown in that soil. However, Cd concentration in plants grown in tube well irrigated soils indicated safe background levels.

Chitdeshwari et al. (2002) reported that increased levels of sewage water increased the uptake of heavy metals including Cd and Cr in Amaranthus crop. The greater accumulation of Pb in roots of crops were observed. Breckle and Kahle (1992) demonstrated that Pb is captured in the root apoplast and hence, its translocation to the shoot was restricted.

Lead

A wide range in plant concentration of Pb was found in sewage and tubwell irrigated soils (Table 5). Its concentration varied from 0.84 to 3.72 mg kg^{-1} dry matter (mean 1.93). In sewage irrigated plants its concentration varied from 2.45 to 9.87 mg kg^{-1} dry matter (mean 7.07). Thus, in sewage irrigated soils the mean Pb concentration of plants was 2.99 folds than its content in the tube well irrigated soils.

Brar et al. (2000) also reported higher accumulation of metals in tubers of potato grown on sewage irrigated soils as compared to those grown on tube well water irrigated soils.

On comparison of heavy metal concentration with respect to initial concentration, concentration was below the critical concentration range which is 25 to 85 g/g for Pb (Macnicol and Beckett, 1985), indicating safe background levels. Similar results were reported by Mosleh and Almagrabi (2013) who reported Pb concentration (0.21, 0.26 and 0.32 $mgkg^{-1}$) in leaves of lettuce, squash and garden rocket respectively.

High metal concentrations in soil are one of the important environmental concerns (Lamali et al., 2007).

Table 5. Heavy metal concentration (mg/kg) in plants grown in sewage and tubewell irrigated soils.

Plant sample	Sewage water irrigated			Tubewell water irrigated		
	Cd	Pb	Ni	Cd	Pb	Ni
Carrot	1.49	8.88	6.14	1.12	3.70	2.20
Carrot	1.61	6.30	6.55	1.16	2.12	1.52
Turnip	1.43	6.15	5.10	0.60	2.16	2.00
Turnip	1.17	5.20	5.34	1.00	1.68	2.02
Radish	1.10	5.02	3.23	0.39	1.06	0.82
Radish	1.10	6.21	3.10	0.65	0.84	0.66
Mean	**1.32**	**7.07**	**4.78**	**0.82**	**1.93**	**1.50**

Heavy metal contents in plants can be predicted easily for elements, which are bounded with low binding strength to the soil (Malla et al., 2007). Malla et al. (2007). have reported an improvement in the fertility status of the soils but with buildup of metallic cations in the soil upon sewage water irrigation.

Nickel

A substantial increase in mean Ni concentration of plants from 1.50 mg kg^{-1} in tubewell irrigated soils of site (Gangia) to 4.78 mg kg^{-1} in sewage irrigated soils was observed. This may be due to the fact that sewage water contains municipal, domestic and hospital wastes. Wastes of these sources contain lot of Ni. Tiwana et al. (1987) also observed a Nickel concentration varying from 1.0 to 3.0 g^{-1} in waste water from electroplating industries of Ludhiana city. Anderson and Nilson (1976) reported that the use of sludge had elevated the level of Ni, Cd, Zn and Cu in soils as well as the crops. Similar findings have earlier been observed by Singh and Kansal (1983). However, due to genetic characteristics, plant species and even varieties differed in their susceptibility and tolerance to Nickel The preceding results indicated that heavy metal enriched sources affected the soil and plant metal concentration directly by serving as a source of trace metals and indirectly by altering the soil chemistry. Therefore irrigating agricultural fields by sewage water, chemical composition of sewage water especially heavy metal concentration should be tested properly as sewage water contains higher concentration of potentially toxic elements. Therefore the accumulation of heavy metals, in soils and their subsequent uptake by plants is a major concern for soil, plant, animal and human health.

The results obtained in present study are also in agreement with previous studies showing increased levels of heavy metals in edible food crops grown in wastewater irrigated soils (Gupta et al., 2008; Liu et al., 2006). These reports demonstrate that the plants grown on waste-water irrigated soils are generally contaminated with heavy metals, posing a major health concern (Liu, 2006). Arora et al. (2008) have reported accumulation of metals in the range of 116-378, 12-69, 5.2-1 6.8 and 22-46 mg kg’ for iron, manganese, copper and zinc, respectively. The variation in the percent buildup of metallic cations in the soils and vegetable crops may be attributed to a greater variation in the initial values of the metallic cations in the soil prior to experimentation and preferential absorbance of a particular cation by different vegetable and reports confirming the flux of heavy metals from crops under study (Arora, 2008). Our results are also in agreement with Akan et al. (2013) who reported that leaves contained much higher concentrations of heavy metals and anions than roots and stems. The concentrations of Cr detected in the vegetable samples ranged from 0.23 to 3.22 mg/kg; 0.23 to 3.43 mg/kg Mn; 0.23 to 3.45 mg/kg Fe; 0.21 to B 3.54 mg/kg Ni; 0.25 to 4.56 mg/kg Pb; 0.87 to 8.34 mg/kg Zn; 0.34 to 5.44 mg/kg Cd and 0.21 to 3.22 mg/kg Cu. Previous studies carried out by other researchers (Kumar et al., 2009; Rosborg et al., 2009) show that Cd were found higher than our results. Our results are also in conformity with Delbari and Kulkarni (2013) who reported maximum Cd, Pb and Fe were observed in spinach.

Conclusion

Results revealed that, sewage water was polluted with Cd, Pb, and Ni due to disposal of house hold, commercial and hospital wastes into the sewage drain. The concentrations of heavy metals were significantly higher in sewage water than tube well water. Cd, Pb and Ni concentration in sewage water were above the permissible limits for their disposal on agricultural land and mean total Cd, Pb, and Ni concentration in tube well water are safe background levels.

The concentration of Cd, Pb and Ni was significantly higher in all sewage irrigated soils at all the four depths (0-15, 15-30, 30-45 and 45–60 cm), respectively. The pattern of distribution of heavy metals is uniform. However, Cadmium, Lead and Nickel concentration are higher at the surface horizons and it decreases sharply with depth in both tube well and sewage irrigated soils. The extent of heavy metal built up in sewage irrigated soils was significant in both 0-15 and 15–30 cm depth, respectively. Data further indicated enrichment of heavy metals due to the discharge of sewage water and sludge mostly in the surface layer with very little mobility down the profile.

Vegetables commonly grown in the sewage and non sewage irrigated area, are radish, carrot and turnip etc. higher concentration of Pb, Cd and Ni, were observed in the roots of all crops grown in sewage irrigated soils compared to that of crops grown on tube well irrigated soils. Results of this study, therefore, indicate that long term and indiscriminate application of sewage water which contains heavy metals may cause accumulation of heavy metals in surface and sub-surface soils and the buildup of heavy metals on soil profile may prove harmful not only to plants, but also to consumers of the harvested crops.

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