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Research Article

Heavy Metals in Sewage Effluent Water Irrigated Vegetables and their Potential Health Hazard Risks to Consumers of Aligarh

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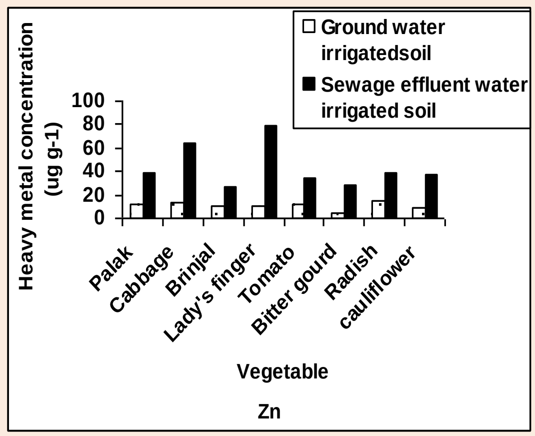
Abstract

In this study concentration of heavy metals (Zn, Cu, Ni, Pb, Cr and Cd) in vegetables grown on ground water and sewage effluent irrigated soils of Aligarh were studied. The concentration of heavy metals in vegetables obtained from sewage effluent water irrigated soil was in the order Zn>Cu> Cr> Ni>Pb> Cd. Continuous application of sewage effluent water for a long period causes accumulation of heavy metals in soils and in the vegetables grown on such soils. The concentration of heavy metals in sewage effluent water irrigated soils was in the order Zn> Cr>Pb> Cu> Ni> Cd. The results of this study also indicate that concentration of Cd, Pb and Ni in the vegetables grown on such soils had exceeded the safe permissible limits for human consumption. The contributions of these vegetables to dietary intake of Zn, Cu, Ni, Cr, Pb and Cd were 11, 24,58, 8, 63 and 67%respectively of provisional tolerable daily intake. Target hazard quotient showed health risk to the local population associated with Cd, Ni and Pb contamination of vegetables. The study concludes that in order to reduce the health risk and extent of heavy metal contamination steps must be taken for efficient treatment of sewage effluent. A regular monitoring of heavy metals in the vegetables grown on such soils is also mandatory.



Keywords: Contamination, heavy metal, transfer factor, target hazard quotient, sewage effluent water.

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Introduction

Mining, industrial processing, pesticide and chemical fertilizer, and automobile exhaust are the main sources of heavy metal contamination in the environment [1-2].Heavy metal accumulation in soils is of great concern in agricultural production due to the adverse effects on food quality, crop growth[3-4] and environmental health. These metals may accumulate to a toxic concentration level which can lead to impairment in the quality of human life [5]. Metals such as Pb, Cd, Cr and Co are considered hazardous contaminants and may accumulate in the human body, with a relatively long half-life [6]. For example, Cd has a half-life of 10 years in the human body [7].Women are more susceptible to the adverse effects of Cd and have higher body burdens due to the long half life of Cd and increased dietary absorption of Cd is long-lived in the body and low-level cumulative exposure has been associated with changes in renal function and bone metabolism [8]. In India, there is a gradual decline in freshwater availability for agricultural fields so sewage and other industrial effluents are being used for irrigation to agricultural fields particularly in periurban areas. The indiscriminate disposal of industrial and sewage effluents on agricultural lands is becoming a major source of heavy metal contamination in irrigated soils and ground water [9-10]. The uptake of heavy metals from contaminated soils by plants comprises a major path for such elements to enter the human and animal food chain [9].Heavy metal bioaccumulation in the food chain can be highly dangerous especially to human health. These metals enter the human body mainly through two routes, *viz.*, inhalation and ingestion, and ingestion being the main route of exposure to these elements in human population. Heavy metals such as As, Cd, Pb, Cr, Ni, Co and Hg are of concern primarily because of their potential to harm soil organisms, plants, animals and human beings. When agricultural soils get polluted, these heavy metals are taken up by plants and consequently accumulate in their tissues [11]. These heavy metals may also enter the body system when these plants are directly or indirectly consumed, also through air and water and may bioaccumulate over a period of time[12-13]. The objective of this study was to investigate concentrations of Pb, Cd, Ni, Cr, Zn and Cu in some vegetables grown in periurban areas of Aligarh in the soils irrigated by sewage effluent water, and to assess the associated potential health risk to local inhabitants through consumption of these vegetables. Health risk was ascertained through calculation of different hazard quotients.

Materials and Methods

Study area: The present study was carried out in the periurban areas of Aligarh city ((27°54'30"N, 78°4'26" E) around sewage discharge system (which also contain effluent of small scale industries). Two areas following different irrigation sources demarcated at the experimental sites. Ground water (GW) from deep bore well (>100m) is used for irrigation at ground water irrigation site (GWI) whereas sewage effluent water (SW) was used for irrigation at the other site (SWI).

Water samples (GW and SW) used for irrigation were collected in a 100 mL polypropylene bottles. One mL of HNO_3 was added to these samples to avoid microbial activities. The soil obtained from experimental site was alluvial. The surface soil (0-30 cm depth) was collected, air dried, crushed and grounded to pass through <70 mesh sieve before use. The physico-chemical properties of soils and water samples were determined by usual methods [14] and values are given in **Table 1**.

Table 1 Heavy metals content in sewage effluent, ground water (mg L^{-1}) and in soils (mg kg^{-1}) irrigated by sewage effluent and ground water.

Metals	Water		Permissible limit (Indian standard)	Soil		
	Ground water	Sewage effluent water		Ground water irrigated	Sewage effluent water irrigated	Permissible limit (Indian standard)
Zn	0.336±0.034 (0.24-0.40)	1.18±0.06 (1.04-1.30)	2.0	34.6±0.36 (33.1-37.4)	62.3±1.8 (53.1-79.4)	300
Cu	0.434±0.024 (0.40-0.50)	1.72±0.14 (1.44-2.02)	0.20	11.1±0.12 (9.44-12.42)	22.4±0.92 (20.2-26.4)	140
Ni	0.056±0.002 (0.05-0.08)	0.368±0.014 (0.34-0.40)	0.1	9.98±0.064 (9.14-11.84)	18.2±0.24 (16.6-20.2)	75
Cr	0.076±0.002 (0.06-0.09)	0.484±0.024 (0.42-0.56)	0.2	9.66±0.124 (8.94-10.62)	27.6±0.82 (24.4-33.3)	100
Pb	0.076±0.002 (0.07-0.09)	0.366±0.014 (0.34-0.40)	5.0	8.98±0.042 (8.62-9.84)	23.2±0.64 (20.2-28.6)	300
Cd	0.022±0.002 (Tr-0.04)	0.124±0.006 (0.11-0.14)	0.01	0.142±0.002 (0.105-0.162)	0.39±0.006 (0.344-0.432)	3

Edible parts of major vegetables grown in the area were also collected randomly from experimental sites. The collected vegetables were palak (*Beta vulgaris* L.*cv*.allgreen), cabbage (*Brassica oleracea* L. *var*. capitata), cauliflower (*Brassica oleracea* L. *var*. botrytis), lady's finger (*Albelmoschus esculentus* L.), brinjal (*Solanum melongena*L.), tomato (*Lycopersicon esculentum* L.), bitter gourd *(Momordic acharantia* L.) and radish (*Raphanus sativus* L.). The samples were washed with tap water to remove soil particles. After washing the vegetables were oven dried at 80^0C to constant weight. The dried samples were ground and sieved through a 2 mm sieve and analyzed. 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 analysed for Zn, Cd, Cu, Ni, Cr and Pb by atomic absorption spectrophotometer (Model Varian AA 975).

Appropriate quality assurance procedure and precautions were taken to ensure the reliability of results. Samples were carefully handled to avoid contamination. Glasswares were properly cleaned and reagents were of analytical grade. Deionized water was used throughout the study. Reagents blanks were also used. For validation of the analytical procedure, analyses of the samples were repeated against internationally certified plant standard reference material (SRM-1570), the results were found within ± 2% of standard values.

Data analyses

***Transfer of heavy metal from soil to vegetables*:** As the vegetables are the sources of human consumption. Therefore the soil to plant transfer quotient is the main source of human exposure. Transfer factor was calculated as [15].
Transfer factor (TF) = concentration of metal in edible part/ concentration of metal in soil.

Daily Intake (DIR): The daily intake of heavy metals through the consumption of the vegetables was calculated according to given equation:

DIR (ug/day) = [Daily vegetable consumption x vegetable heavy metal concentration]

Daily vegetable consumption was obtained through a formal survey of 25 families each having > 4 members conducted in the studied area.

Target hazard quotient (THQ): Risk of intake of metal-contaminated vegetables to human health was characterized by target hazard quotient (THQ). THQ is the ratio of determined dose to the reference dose. There is no risk if ratio is less than 1, and if it is greater than 1, the population is expected to health hazard risk. Following equation was used to calculate HQ [16]: $HQ = [\{W_{plant} x M_{plant}\} / R_fD \times B]$, where W_{plant} is the dry weight of vegetable consumed (mg d^{-1}), $M_{plant}$is the concentration of metal in vegetable (mg kg^{-1}), R_fD is the food reference dose for the metal (mg d^{-1}) and B is the average body mass (55.9kg).

Results and Discussion

Heavy metals in ground water, sewage effluent and soils: The amount of heavy metals (ug mL^{-1}) in ground and sewage effluent water is given in **Table 1**. The concentration of heavy metals in sewage effluent water was higher by 3.5 to 5.5 times than in ground water. The higher concentration of heavy metals in sewage effluent water may be due to discharge of untreated effluent of small scale industries such as electroplating, metal surface treatment and battery. Similar results are also reported by other workers [10, 17].

The concentration of heavy metals (ug g^{-1}) in soils irrigated by sewage effluent water ranged from 53.1 to 79.4 for Zn; 20.2 to 26.4 for Cu; 16.6 to 20.4 for Ni; 24.4 to 33.3 for Cr; 20.2 to 28.6 for Pb and 0.344 to 0.432 for Cd (**Table 1**). Heavy metal content in sewage effluent irrigated soils was higher in tune of 1.8 times of Zn; Cu 2.0; Ni 1.82; Cr 2.85; Pb.67 and Cd 2.75 than ground water irrigated soils. Amongst the studied heavy metals Zn was maximum and of Cd minimum. But even the upper limits of heavy metal concentrations were below the upper permissible limits of PFA standards.

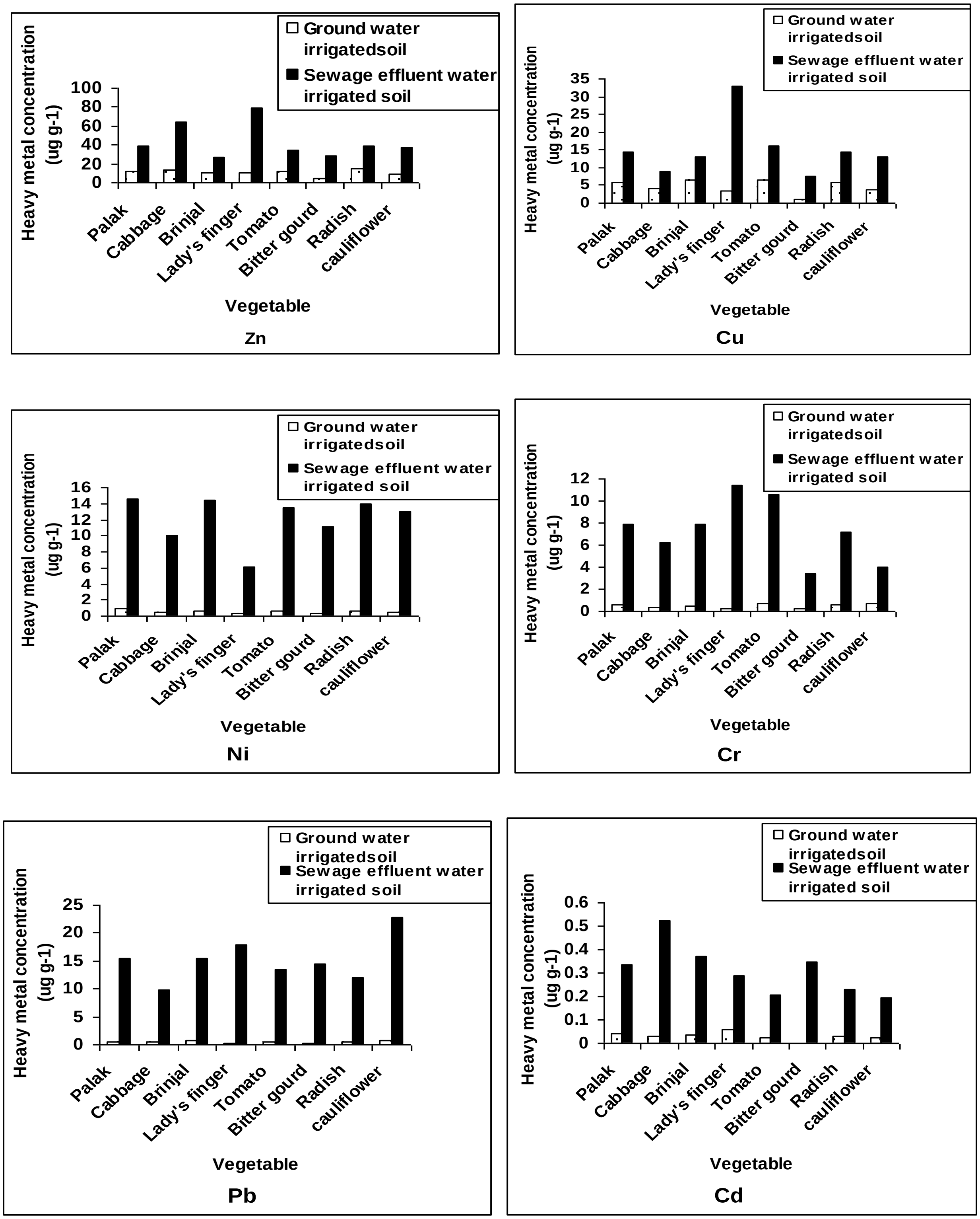

Figure 1 Concentration of heavy metals (ug g^{-1}) in different vegetables

Heavy metals in vegetables: The heavy metal concentration varied among the vegetables (**Figure 1**) which may be attributed to differential absorption capacity of studied vegetables for different heavy metals. Concentration of all the studied heavy metals in vegetables grown in sewage effluent irrigated soils were several fold higher in vegetables grown in ground water irrigated soils. Similar results were also found by other researchers [16, 18-19].

The mean concentration of Zn was highest in all the studied vegetables (**Figure 1**) and followed the order Zn>Cu>Pb>Ni> Cr> Cd. The maximum concentration of Zn, Cu and Cr was found in lady's finger while Ni in palak, Pb in cauliflower and Cd in cabbage while Ni was minimum in lady's finger, Zn, Cu and Cr in bitter gourd, Pb in cabbage and Cd in cauliflower. Variation in heavy metal concentrations in edible parts of vegetables may be due to variation in absorption of metals in plants through roots and their further translocation within the plants parts. It was also found that in the vegetables grown on sewage effluent irrigated soils the concentration of Zn in cabbage and lady's finger; Cu in lady's finger; Ni and Pb in all the studied vegetables were higher than the permissible limits of Indian standards.

Transfer Factor: Transfer factor for all the metals in ground water irrigated sites was lower (ND-0.640) than sewage effluent irrigated sites (0.124-1.464). Transfer factor for Zn, Cu was highest for lady's finger followed by cabbage. Maximum transfer factor for Cd was for cabbage. Variations in transfer factor among different vegetables may be attributed to differential absorption capacity of studied vegetables for different heavy metals. It was also found that the minimum transfer factor was for Cr.

Table 2 Transfer factors of heavy metals through different vegetables at ground water and sewage effluent irrigated sites

Vegetable	Zn		Cu		Ni		Cr		Pb		Cd	
	Ground water irrigated	Sewage water irrigated	Ground water irrigated	Sewage water irrigated	Ground water irrigated	Sewage water irrigated	Ground water irrigated	Sewage water irrigated	Ground water irrigated	Sewage water irrigated	Ground water irrigated	Sewage water irrigated
Palak	0.365	0.622	0.524	0.646	0.096	0.802	0.066	0.284	0.055	0.666	0.312	0.868
Cabbage	0.404	1.024	0.366	0.392	0.046	0.554	0.042	0.226	0.044	0.424	0.228	1.342
Brinjal	0.285	0.424	0.586	0.575	0.066	0.795	0.044	0.286	0.084	0.666	0.245	0.944
Lady's Finger	0.312	1.264	0.312	1.464	0.033	0.336	0.026	0.414	0.036	0.777	0.044	0.742
Tomato	0.333	0.544	0.596	0.714	0.068	0.744	0.074	0.384	0.062	0.586	0.164	0.522
Bitter gourd	0.111	0.444	0.096	0.332	0.032	0.614	0.022	0.124	0.016	0.625	Nd	0.896
Radish	0.422	0.624	0.514	0.644	0.062	0.766	0.062	0.262	0.058	0.516	0.204	0.588
Cauli-flower	0.245	0.608	0.333	0.586	0.050	0.714	0.070	0.144	0.084	0.982	0.182	0.505

Daily Intake Rate: The degree of toxicity of heavy metals to human being depends on their daily intake. From the estimated daily intake rate of studied heavy metals through the consumption of vegetables (**Table 3**) it can be suggested that the consumption of average amount of these contaminated vegetables does not pose a health risk for the consumers as the values are below the FAO/WHO limit for heavy metals intake based on the body weight of an average adult (55.9 kg). The present study also showed that the contributions of studied vegetables to daily intake of Zn, Cu, Ni, Cr, Pb and Cd were 11, 24, 58, 8, 63 and 67 of provisional tolerable daily intake (PTDI) respectively.

Table 3 Daily intake rate (ug person^{-1} day^{-1}) of heavy metals through consumption of sewage effluent water irrigated vegetables

Vegetable	Zn	Cu	Ni	Cr	Pb	Cd
Palak	426	159	161	86.2	170	3.72
Cabbage	829	114	131	81.1	128	6.80
Brinjal	607	296	332	181	355	8.46
Lady's Finger	944	393	73.4	137	216	3.47
Tomato	949	448	379	297	380	5.68
Bitter gourd	277	144	139	34.2	145	3.49
Radish	544	202	195	101	168	3.20
Cauliflower	795	275	273	83.4	478	4.14

Table 4 Target hazard quotient (THQ) for different heavy metals due to consumption of vegetables grown on sewage effluent irrigated soils.

Vegetable	Zn	Cu	Ni	Cr	Pb	Cd
Palak	1.12	1.39	2.56	0.16	1.24	3.42
Cabbage	1.94	0.82	2.12	0.12	0.66	4.16
Brinjal	1.42	1.74	3.85	0.28	2.14	5.96
Lady's Finger	2.25	1.86	0.75	0.22	1.38	3.38
Tomato	1.84	1.48	3.86	0.52	2.52	4.58
Bitter gourd	0.42	0.45	0.98	0.12	0.96	1.71
Radish	1.08	0.72	2.04	0.46	1.08	2.46
Cauliflower	1.84	0.86	3.16	0.18	2.78	2.98

Target hazard quotient (THQ): The results of target hazard quotient calculations showed that Ni, Pb and Cd contamination in plants had potential to pose health risk to consumer. Target hazard quotient for Cd was more than 1 for all the studied vegetables; THQ for Pb was more than 1 in palak, brinjal, lady's finger, tomato and cauliflower; THQ for Ni was more than 1 for all the studied vegetables except lady's finger and bitter gourd; values of Cu THQ were more than 1 in palak, brinjal, lady's finger and tomato and Zn THQ was more than 1 for all the vegetables except bitter gourd. Values of Cr THQ were less than 1 for all the vegetables. Higher THQ values for Pb, Ni and Cd were due to presence of higher amount of these metals in sewage effluent water due to small scale industries.

Conclusions

Waste water irrigation led to the accumulation of heavy metals in soils and consequently in the vegetables. The present study has generated data on heavy metals pollution in and around Aligarh city and associated risk assessment for consumer's exposure to the heavy metals. Concentration of heavy metals varied among the studied vegetables which may be due to difference in their uptake capability and translocation to edible portion of the plants. Cadmium, Pb and Ni concentration were above the national and international permissible limit in most of the studied vegetables. Target hazard quotient of heavy metals also suggest that the Cd, Pb and Ni concentration in most of the vegetables had potential for human health risk due to consumption of plants. Consumption of these vegetables with high amount of heavy metals will lead to high level of body accumulation causing related health disorders. In order to prevent excessive buildup of these heavy metals in food chain regular monitoring of heavy metal contamination in the vegetables grown at sewage effluent water irrigated area is necessary and consumption of contaminated vegetables must be avoided.

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