Research Article

Accumulation of Heavy Metals in Vegetables Grown in Long Term Sewage Irrigated Soil of Allahabad Region and Its Impact on Human Health

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Abstract

In the present study, accumulation of Cr, Mn, Cu, Ni, Zn, Cd, Pb and Fe in sewage effluent was assessed. Similarly the accumulations of these heavy metals (Cr, Mn, Cu, Co, Ni, Zn, As, Se, Cd, Pb and Fe) in edible parts of five vegetables were also estimated. Concentration of the studied heavy metals in sewage water used for irrigation was much higher than permissible limits of WHO. Waste water contamination by heavy metals is of serious concern due to their toxicity and persistence in the environment. Generally, irrigation with wastewater elevates the heavy metal concentrations in soils. The mean contents of Cr, Mn, Cu, Ni, Zn, Cd, Pb and Fe in sewage effluent were 7.75, 0.41, 0.34, 0.29, 1.16, 0.04, 0.85 and 7.54 ppm, respectively. Concentration of heavy metals in spinach, potato, radish, cabbage and cauliflower were also very high and above permissible limits. The study concludes that the use of sewage effluent for irrigation has increased the contamination of heavy in edible portion of vegetables causing potential health risk in the long term from this practice. Importance of these findings will be discussed in relation to environmental management of the area.

Keywords: Heavy metals, Sewage effluent, Daily intake, vegetables, soil, accumulation, human health, industrial water, agricultural land, irrigation, contamination

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Introduction

Waste water and industrial waters are rich sources beneficial and harmful elements. Since some of the waste waters are rich source of nutrients, therefore soils provide the logical disposal sink. But most untreated as well as contaminated wastewater and industrial wastewater may have higher concentrations of many metals like Cd, Pb Ni, and Cr [1-2]. Their continuous accumulation on soils has resulted the soil sickness [3] and deposition of some toxic metals in agricultural soil [2, 4-12] which may cause serious animal and human health. Agricultural lands particularly in vicinity of towns, exhibit increasing load of metals because of continuous irrigation with metal-rich waste water and industries-waste waters. The accumulation and uptake of these metals in the edible parts of green tissues represent a direct pathway of incorporation of the metals into the animal human and food chain.

Material and methods

Area of Study

The sites selected for the present investigation are situated at Jamunapar region of Allahabad. There were 5 experimental sites namely Arail village (S1), Gangia village (S2), Mahewa village (S3), Dandi village (S4), Dabhau village (S5).Vegetables taken for analysis are Potato, Radish, Cauliflower, Cabbage, Spinach.

Plant Analysis

Edible parts of plants were washed with running tap water, acidified water, distilled water and double distilled water. These samples were then dried first at room temperature for several days and then in hot (60±5˚C) air over for 48 hrs.

The dried plant parts were then crushed and powdered separately in mortar and pestle. The powdered plant samples were then put separately in well washed, dried and suitably labeled flasks and these samples were then ready for digestion.

Table 1 Physico-chemical parameters of sewage effluent at different sites

Parameters	S_1	S_2	S_3	S_4	S_5
pH (W/V)	6.12	6.23	6.23	7.18	6.77
EC	0.69	0.653	0.653	0.68	0.782
DO (mg l^{-1})	5.24	5.33	5.33	4.3	3.73
BOD (mg l^{-1})	2.53	3.07	3.07	3.44	3.35
TDS (mg l^{-1})	417	385	385	680	623
Chloride (mg l^{-1})	274.11	265.17	265.17	281.98	317.34
OC (mg l^{-1})	0.39	0.36	0.41	0.37	0.42
COD (mg l^{-1})	367	361	325	354	319
NO_3 (mg l^{-1})	4.67	4.61	4.55	4.74	4.28

Table 2 Heavy metal content (ppm) in sewage effluent at different sites

Metals	S_1	S_2	S_3	S_4	S_5
Cr	7.13	8.18	8.38	7.80	7.28
Mn	0.27	0.36	0.38	0.63	0.39
Cu	0.39	0.31	0.39	0.27	0.33
Ni	0.27	0.25	0.30	0.33	0.30
Zn	1.118	1.17	1.18	1.15	1.16
Cd	0.047	0.036	0.039	0.046	0.046
Pb	0.097	0.88	1.25	1.116	0.89
Fe	6.37	8.14	6.66	8.36	8.18

The digestion mixture for biological sample was a diacid mixture. The mixture comprises of conc. HNO_3 and $HClO_4$. To one gram of plant material, 5ml of conc. HNO_3 was added and kept overnight. Next day 12ml of diacid 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. The plants samples slowly begin to dissolved and digest in di-acid mixture. After few hr the plant sample dissolved completely in the digestion mixture and the solution was then evaporated until only about 2 ml was left in the flask. The digested samples were then transferred into small tubes and were sent for analysis using the Atomic Absorption Spectrophotometer [13].

Growth experiments and uptake study

The field experiment conducted at the 5 different sites of Allahabad region in order to find out the effect of long term sewage effluent irrigation on uptake of heavy metals viz. Cd, Cr, Pb, Fe, As, Co, Se Ni, Mn, Cu and Zn by vegetables.

Daily intake of metals

The daily intake of metals (DIM) was determined by the following equation.

$$DIM = C_{metal} * C_{factor} * D_{food\ intake} / B_{average\ weight}$$

where C_{metal}, C_{factor}, $D_{food\ intake}$ and $B_{average\ weight}$ represent the heavy metal concentrations in plants (mg kg^{-1}), conversion factor, daily intake of vegetables and average body weight, respectively. The conversion factor 0.085 was used to convert fresh green vegetable weight to dry weight, as described by Rattan *et al*. [14]. The average daily vegetable intakes for adults and children were considered to be 0.345 and 0.232 kg $person^{-1}$ day^{-1}, respectively, while the average adult and child body weights were considered to be 55.9 and 32.7 kg, respectively, as used in previous studies [15,16].

Statistical analysis

The experiment was conducted in randomized block design having four treatments and three replications. The data recorded during the course of investigation was subjected to statistical analysis as per method of "Analysis of variance" [17].the significant and non-significant of treatment affect was judged with the help of 'F' variance ratio test calculated 'F' at 5% level of significance. Either effects was considered to be significant or non significant. The significant difference between the mean was tested against the critical difference at 5% level of significance. For testing of hypothesis, the following ANOVA table is used.

Results and Discussion

Heavy metal concentration in vegetables

The results in **Tables 3-7** indicate that the metal content in the vegetable samples of potato, spinach cauliflower, radish and cabbage were in the order of Fe>Zn>Mn>As>Ni>Cr>Co>Pb>Se>Cd>Cu,Fe>Mn>Zn>Co>Ni>As>Cr>Se>Pb>Cu>Cd,Fe>Mn>Zn>As>Ni>Co>Cr>Cu>Se>Pb>Cd,Fe>As>Se>Zn>Mn>Cr>Ni>Co>Cd>Cu>Pb,Mn>Fe>As>Se>Zn>Pb>Ni>Cr>Cu>Cd>Co respectively. The metal content in all the vegetables was higher than the permissible limit. A major cause for the occurrence of high content of metals in vegetables is due to the presence of high content of metals in the soil in which these vegetables are growing as these places were irrigated with sewage effluent from past many years. A major pathway of soil contamination is through various inputs such as fertilizers, pesticides, sewage sludge, organic manure and compost [18]. Additionally foliar uptake of atmospheric heavy metals from emission gas also been identified as an important pathway of heavy metal contamination in vegetable crops. Several studies have shown that vegetables, particularly leafy crops, grown in heavy metal contaminated soils have higher concentrations of heavy metals than those grown in uncontaminated soil [19, 20]. Humans who consume these vegetable parts are at serious health risk from the toxicity of these plants.

Table 3 Effect of Sewage effluent irrigation on heavy metal content in potato

Metals	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**
Cr	4.671	3.738	3.045	4.88	4.25
Mn	32.850	28.665	25.855	25.65	23.65
Cu	0.879	0.222	0.161	0.189	0.165
Co	2.198	8.618	1.164	1.568	2.54
Ni	5.328	5.042	4.518	3.889	4.58
Zn	76.800	70.870	65.070	66.039	64.55
As	14.180	14.465	9.543	8.958	8.36
Se	1.640	1.385	1.170	1.658	1.52
Cd	0.835	0.685	0.700	0.865	0.870
Pb	2.129	1.860	1.500	1.258	1.236
Fe	279.8	255.2	275.68	280.58	282.65
F-test	S				
S. Ed (±)	2.602				
C.D.at5%	5.258				

Table 4 Effect of Sewage effluent irrigation on heavy metal content in spinach

Metals	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**
Cr	1.145	5.111	0.500	0.485	0.465
Mn	62.022	90.555	76.500	77.85	77.99
Cu	0.092	0.036	0.045	0.065	0.059
Co	1.238	9.206	4.806	4.58	4.69
Ni	6.648	4.025	1.821	1.98	1.70
Zn	32.970	29.190	35.690	35.85	38.46
As	2.735	1.450	1.040	1.65	2.65
Se	1.136	0.890	0.522	0.595	0.615
Cd	0.165	0.207	0.147	0.135	0.185
Pb	0.961	0.912	0.731	0.765	0.791
Fe	282.2	276.4	264.4	266.36	268.25
F-test	S				
S. Ed (±)	2.640				
C.D.at 5%	5.336				

Table 5 Effect of Sewage effluent irrigation on heavy metal content in cauliflower

Metals	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**
Cr	10.103	10.36	11.432	10.60	11.35
Mn	49.45	49.35	47.025	47.65	45.65
Cu	2.720	2.35	2.450	2.65	2.15
Co	13.808	13.85	12.835	12.35	12.36
Ni	11.240	12.36	12.986	12.36	12.65
Zn	47.390	48.65	44.800	43.65	44.65
As	29.025	29.28	32.940	33.15	31.65
Se	1.435	0.88	1.935	1.17	1.25
Cd	0.558	0.565	0.417	0.436	0.517
Pb	0.978	0.789	0.826	1.361	1.65
Fe	178.4	169.65	171.46	170.65	170.98
F-test	S				
S. Ed (±)	0.968				
C.D.at 5%	1.957				

Table 6 Effect of Sewage effluent irrigation on heavy metal content in Radish

Metals	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**
Cr	5.838	7.106	7.938	8.052	8.15
Mn	17.235	15.155	12.700	10.570	14.25
Cu	0.578	0.501	0.443	0.311	0.514
Co	1.511	1.364	1.950	1.669	1.36
Ni	2.655	2.187	2.235	2.311	2.32
Zn	24.065	23.190	21.650	20.300	22.15
As	28.380	28.815	35.940	33.540	32.12
Se	26.700	35.190	26.495	20.415	25.00
Cd	1.308	0.450	1.830	1.217	1.25
Pb	0.418	0.247	0.170	0.108	0.161
Fe	142.2	128.7	93.5	89.5	128.3
F-test	S				
S. Ed (±)	4.625				
C.D.at 5%	9.348				

Table 7 Effect of Sewage effluent irrigation on heavy metal content in Cabbage

Metals	**S1**	**S2**	**S3**	**S4**	**S5**
Cr	7.5	8.750	6.95	6.85	7.31
Mn	166.80	156.300	156.95	154.38	158.23
Cu	5.099	3.116	4.407	4.58	4.42
Co	0.261	0.469	0.105	0.327	0.310
Ni	50.670	51.235	48.985	52.28	52.14
Zn	50.25	41.36	60.36	53.18	55.65
As	145.35	138.750	121.20	125.21	123.23
Se	119.10	126.800	117.40	117.38	120.18
Cd	0.953	0.159	0.385	0.325	0.348
Pb	43.980	52.605	58.560	54.65	55.27
Fe	146.2	137.39	127.11	132.8	132.24
F-test	S				
S. Ed (±)	3.280				
C.D.at 5%	6.628				

Daily intake of heavy metals by human

Ingestion of vegetables containing heavy metals is one of the main ways in which these elements enter the human body. Once entered, heavy metals are deposited in bone and fat tissues, overlapping noble minerals. Slowly released into the body, heavy metals can cause an array of diseases. Due to the non-biodegradable and persistent nature, heavy metals are accumulated in vital organs in the human body such as the kidneys, bones and liver and are associated with numerous serious health disorders. Individual metals exhibit specific signs of their toxicity. In order to observe the health risk of any pollutant, it is very important to estimate the level of exposure, by detecting the routes of exposure to the target organisms. There are several possible pathways of exposure to humans but amongst them the food chain is the most important pathway. The daily intake of metals was estimated according to the average vegetable consumption for both adults and children (**Tables 8** and **9**). The DIM values for heavy metals were high when based on the consumption of vegetables grown in wastewater- irrigated soils. The intakes of Fe was highest while lowest intake was for Co from the consumption of Potato, Cauliflower, Spinach, Cabbage, Radish respectively, for both adults and children, grown in wastewater-irrigated soils. Chronic low-level intakes of heavy metals have damaging effects on human beings and other animals, since there is no good mechanism for their elimination. Metals such as lead, mercury, cadmium and copper are cumulative poisons.

Table 8 Daily intake of Metals (mg) in Adults

Metals	Potato	Cauliflower	Spinach	Cabbage	Radish
Cr	0.0021	0.0057	0.0008	0.0039	0.0038
Mn	0.0144	0.0251	0.0408	0.0838	0.0080
Co	0.0002	0.0013	0.0001	0.0024	0.0003
Ni	0.0017	0.0068	0.0026	0.0002	0.0008
Cu	0.0024	0.0066	0.0017	0.0271	0.0012
Zn	0.0359	0.0246	0.0182	0.0277	0.0121
As	0.0058	0.0166	0.0010	0.0688	0.0166
Se	0.0008	0.0006	0.0006	0.0628	0.0143
Cd	0.0004	0.0003	0.0001	0.0002	0.0007
Pb	0.0009	0.0006	0.0004	0.0273	0.0001
Fe	0.1452	0.0914	0.1419	0.0709	0.0626

Table 9 Daily Intake of metals (mg) in children

Metals	Potato	Cauliflower	Spinach	Cabbage	Radish
Cr	0.0024	0.0066	0.0010	0.0045	0.0044
Mn	0.0165	0.0289	0.0469	0.0963	0.0092
Co	0.0002	0.0015	0.0001	0.0027	0.0003
Ni	0.0020	0.0078	0.0030	0.0002	0.0009
Cu	0.0028	0.0076	0.0019	0.0311	0.0014
Zn	0.0413	0.0283	0.0210	0.0318	0.0139
As	0.0066	0.0190	0.0012	0.0791	0.0191
Se	0.0010	0.0007	0.0007	0.0722	0.0164
Cd	0.0005	0.0003	0.0001	0.0003	0.0008
Pb	0.0011	0.0007	0.0005	0.0314	0.0001
Fe	0.1670	0.1050	0.1632	0.0815	0.0720

Daily intake of heavy metals by human

Ingestion of vegetables containing heavy metals is one of the main ways in which these elements enter the human body. Once entered, heavy metals are deposited in bone and fat tissues, overlapping noble minerals. Slowly released into the body, heavy metals can cause an array of diseases. Due to the non-biodegradable and persistent nature, heavy metals are accumulated in vital organs in the human body such as the kidneys, bones and liver and are associated with numerous serious health disorders. Individual metals exhibit specific signs of their toxicity. In order to observe the health risk of any pollutant, it is very important to estimate the level of exposure, by detecting the routes of exposure to the target organisms. There are several possible pathways of exposure to humans but amongst them the food chain is the most important pathway. The daily intake of metals was estimated according to the average vegetable consumption for both adults and children (Tables 8 and 9). The DIM values for heavy metals were high when based on the consumption of vegetables grown in wastewater- irrigated soils. The intakes of Fe was highest while lowest intake was for Co from the consumption of Potato, Cauliflower, Spinach, Cabbage, Radish respectively, for both adults and children, grown in wastewater-irrigated soils. Chronic low-level intakes of heavy metals have damaging effects on human beings and other animals, since there is no good mechanism for their elimination. Metals such as lead, mercury, cadmium and copper are cumulative poisons.

Conclusions

Results from present and previous studies [21-23] demonstrate that the plants grown on wastewater-irrigated soils are generally contaminated with heavy metals, which pose a major health concern. Regular monitoring and study of metals from sewage effluents, in crops and other edible food is necessary for preventing its entrance in food web [24].The results of the present research regarding Daily metal intake limit of (DIM) value suggested that consumption of these crops grown in waste water effluent or wastewater-contaminated-soils is high, but is nearly free from major risks, because its intake limits of some metals such as Mn, Fe, Zn, and Cu in adults range from 2.0 to 20.0 mg, 10.0 to 50.0 mg, 5.0 to 22.0 mg and 1.2-3.0 mg, respectively. However, there may also various other sources of metals exposure, for example dust inhalation, dermal contact, and ingestion of heavy metal-contaminated soils, which were taken into account in the present study. So, further detailed studies are required to completely understand the problem and risks.

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