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IMPACT OF SEWAGE WATER ON VEGETABLES QUALITY WITH RESPECT TO HEAVY METALS IN PESHAWAR PAKISTAN

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Abstract

The present research study was conducted to analyze the impact of sewage water on vegetables quality with respect to heavy metals in Peshawar Pakistan. Forty samples each of soil, water and vegetables leaves and edible portions were collected from 40 different localities around Peshawar city. Water from Warsak Canal and Bara River, polluted with sewage or waste water, was being used as irrigation source in these localities. The water and soil samples were analyzed for pH, EC and heavy metals (Nickel, Cadmium, Lead and Chromium). All the water samples were slightly alkaline whereas only two water samples had EC above the safe limit. The concentrations of Cr was within the safe limit in all the water samples while that of Ni, Pb and Cd were found in toxic range in 18, 13 and 98% samples, respectively. All the sampled fields were alkaline in reaction and had no salinity problem. None of the soil samples had the heavy metals above the safe limit. The Ammonium Bicarbonate Di-ethylene Triamine Penta-acetic Acid (AB-DTPA) extractable Ni, Pb, Cd and Cr of soil had significant positive correlation with that of the irrigation water. Nickel, Pb and Cr were above the safe limit in 90, 10, 78 and 15% of the leaves samples, respectively. Heavy metals in leaves were in the order of Ni>Cd>Cr>Pb. The plant Cd had positive non-significant correlation with soil Cd whereas other heavy metals in leaves had significant positive correlation with the corresponding heavy metals in soil. The concentration of Ni, Pb, Cd and Cr in edible portions was above the safe limit in 90, 28, 83 and 63% of the samples, respectively. The heavy metals in edible portions were in the order of Ni>Cd>Cr>Pb. The vegetables tested were not safe for human use, especially those directly consumed by human beings.

Introduction

The volume of wastewater generated by domestic, industrial and commercial sources has increased with population, urbanization, improved living conditions, and economic development (Qadir *et al*., 2008). In urban areas of many (developing) countries, urban and peri-urban agriculture depends, at least to some extent, on wastewater as a source of irrigation water. The quality of the water and the conditions under which this water is used vary greatly. In poor countries this water may, in extreme cases, take the form of diluted raw sewage, even if this is considered illegal (Huibers *et al*., 2004). However, the quality of the wastewater used and the nature of its use vary enormously, both between and within countries. In many low-income countries in Africa, Asia, and Latin America, the wastewater tends to be used untreated, while in middle-income countries such as Tunisia and Jordan, treated wastewater is used (Faruqui *et al*., 2004).

It provides farmers with a nutrient enriched water supply (Ullah *et al*., 2011; Gosh *et al*., 2012) and society with a reliable and inexpensive system for wastewater treatment and disposal (Feigin *et al.*, 1991). In situations such as Dakar and Pakistan, farmers prefer wastewater even when freshwater is available, because they earn higher profits using wastewater. As both cases demonstrate, wastewater can be a more reliable source, both in terms of availability and volume, than either rain or freshwater supply from irrigation systems. In these cases, it also allows them to crop more than once a year, sometimes up to 3 crops per year, depending on the crop. In Pakistan (Ensink *et al.,* 2004), farmers using wastewater earned approximately US$300 per year more than those using freshwater. Furthermore, in addition to generating income for farmers, wastewater use in urban and peri-urban agriculture also provides jobs and income for merchants who sell the produce.

Waste waters are contaminated with trace elements like lead (Pb), copper (Cu), zinc (Zn), boron (B), cobalt (Co) chromium (Cr), arsenic (As), molybdenum (Mo), manganese (Mn) etc. many of which are non-essential and over time toxic to plants, animals and human beings (Kanwar & Sandha, 2000). Long-term application of treated and untreated waste water resulted in significant buildup of heavy metals in soil (Khan *et al*., 2008; Ullah *et al*., 2011; Gosh *et al*., 2012) and in vegetables and cereals and their subsequent transfer to food chain causing potential health risk to consumers (Singh *et al*., 2010; Gupta *et al*., 2011). Heavy metal concentrations in plants grown in wastewater-irrigated soils were significantly higher than in plants grown in the reference soil (Khan *et al*., 2008; Singh *et al*., 2010; Gupta *et al*., 2011). Sharma *et al*., (2006) concluded that the use of treated and untreated wastewater for irrigation had increased the contamination of Cd, Pb, and Ni in edible portion of vegetables causing potential health risk in the long term. Sachan *et al*., (2007) found that bioaccumulation of Pb and Cr in vegetables was above the critical concentrations for plant growth while Pb and Cd were above the prescribed limit in the diet of animals. Chary *et al.,* (2008) assessed Zn, Cr, Cu, Ni, Co and Pb in soils, forage grass, milk from cattle, leafy and non-leafy vegetables. Human risk was assessed in people known to consume these contaminated foods by analyzing metals concentrations in venous blood and urine. Results showed high amounts of Pb, Zn, Cr, and Ni compared to permissible limits.

The use of sewage-contaminated municipal water for irrigation of crops is an old practice in many big cities of Pakistan (Ullah *et al*., 2011). Peshawar, one of the densely populated and polluted cities of the country, is no exception. The problem of disposal of municipal, industrial and sewage effluent along with scarcity of irrigation water is severe. In order to provide food to the ever-increasing population and due to the unavailability and scarcity of irrigation water, sewage water is used for irrigation purpose, in Peshawar, which may cause soil pollution and contaminate the vegetables grown with it. The present study was undertaken to assess the heavy metal content/status of the sewage-water-irrigated soil and vegetables and to correlate the heavy metal concentration of sewage water to that of the soil and plants.

Materials and Methods

Site selection: A thorough survey of the outskirts of Peshawar city was carried out and 40 different sites were identified where sewage water was used for irrigation of vegetables.

Water, soil and plant sampling: Forty samples of sewage water used for irrigation of vegetables on selected locations were collected during 2005. Soil samples were collected from the same fields from 0-30 cm depth. Forty samples each of leaves and edible portion of vegetables (coriander, mustard, tomato, squash, onion, garlic, chili, cabbage, cauliflower, radish, turnip, garden pea, sugar beet and lettuce) irrigated and grown on sewage water were collected from the locations. The leaves and edible portion samples were analyzed separately. However; as the leaves of coriander, cabbage, lettuce and mustard are used uncooked (salad) and cooked (*saag* etc); these were considered as the edible portion as well.

Chemical analysis: EC and pH of water were determined by the method described by Rhoades (1982) and Mclean (1982), respectively. Heavy metals (Ni, Cd, Pb and Cr) were determined by Atomic Absorption Spectrophotometer. Soil pH and EC were determined in 1:5 soil water suspension by the method of Mclean (1982) and Black (1965), respectively. AB-DTPA extractable heavy metals were determined by the method of Havlin & Soltanpour (1981). Similarly, ground plant samples were analyzed for heavy metals using wet digestion method (USDA Hand Book 60, 1954).

Statistical analysis: Computer programs MS Excel and SPSS were used for correlation of the analytical results.

Results and Discussion

Water pH, EC and heavy metals: All the water samples were alkaline in reaction, $pH_{1:5}$ ranged from 7.65 to 8.79 with an average value of 8.47. The slight variation in pH at different locations might be due to the effluent discharge to the canal water from the surrounding areas. Sheinberg & Oster (1985) reported that the pH of irrigation water is not an accepted criterion of water quality because it tends to be buffered by the soil and most crops can tolerate a wide pH range. The alkaline pH of the water samples are in line with the findings of Perveen *et al.,* (2006).

The EC of irrigation water varied from 0.38 to 4.17 dS m^{-1} with an average value of 1.24 dS m^{-1}. Ayers & Westcot (1984) suggested that water having EC higher than 3 dS m^{-1} are not safe for irrigation purpose. According to this criterion water of only 2 localities is above safe limits. Perveen *et al.,* (2006) reported that all of water samples (26) from upper Warsak gravity canal were within safe limit.

Average concentrations of Ni, Pb, Cd and Cr in water samples were 0.61, 0.25, 0.75 and 0.03 mg L^{-1}, respectively. The concentration of Cr was within the safe limit (Table 1) as compared to NEQS limits in industrial effluents and municipal wastes. Nickel, Pb and Cd were above the critical level in 18%, 13% and 98% of the samples, respectively. A comparison with USEPA (1999) irrigation water standard revealed that all the water samples contained Pb and Cd within the safe limit. Chromium and Ni were above the limit in 1 and 4 samples, respectively. These results are in accordance with the findings of Sarwar (2003) and Bano (2004). Gosh *et al.,* (2012) indicated that treated sewage water contained Cd, Cr and Ni in amounts well above the permissible limits for its use as irrigation water.

Soil pH, EC and heavy metals: All the sampled fields were alkaline in reaction having $pH_{1:5}$ ranged from 7.81 to 8.80. Of the total 40 sampled fields, pH of 31 (78%) were above pH 8.0. The alkaline pH of the sample fields were in line with the findings of Khan *et al.,* (1974), Nawaz (1975) and Ahmed *et al.,* (2008). Rusan (2007) evaluated the long term effect of wastewater irrigation of forage crops on soil and plant quality parameters. He analyzed soil and plant samples from sites irrigated with wastewater for 10, 5, and 2 years and site not irrigated. It was revealed that soil pH was not consistently affected.

The EC of soil varied from 0.13 to 1.65 dS m^{-1}, with a mean value of 0.32 dS m^{-1}. The EC of the soil samples revealed that all the fields had no salinity problem (EC<4.0 dS m^{-1}). The results are in accordance with the findings of Ahmed *et al.,* (2008).

The average concentration of AB-DTPA extractable Ni, Pb, Cd and Cr were 0.65, 2.58, 0.24 and 0.35 mg kg^{-1} (Table 2). Similar results have been reported by Rashid (2001) and Bano (2004). The results showed that all the heavy metals were within the safe limit in all the soil samples as compared to Linzon (1978 and Kabata-Pendias & Pendias (1985). The concentrations of heavy metals may be below the toxic limit due to high buffering capacity and calcareous nature of the soil. Latif *et al.,* (2008) reported that all the samples from ‘sewage irrigated vegetable fields’ and ‘untreated industrial effluents irrigated fields’ of Rawalpindi area were below the critical levels with respect to Pb, Cd, Cr and Ni contents. Rusan (2007) reported that wastewater irrigation had no significant effect on soil heavy metals (Pb and Cd) regardless of duration of wastewater irrigation. Rai *et al.,* (2011) studied the effect of sewage water and canal water irrigation by comparing their physicochemical properties and heavy metals concentration in soil. They reported that the observed concentration of Pb, Cu and Zn was below the Indian standards except Cd. The enrichment was moderate while pollution index values were lower than permissible pollution limit of 1.0. Gupta *et al.,* (2010) reported that the enrichment factor of the heavy metals in contaminated soil was in the sequence of Cd>Mn>Cr>Pb>Fe.

Table 1. Heavy metals concentration of irrigation water.

S. No.	Locality	Heavy metals (mg L^{-1})			
		Ni	Pb	Cd	Cr
1.	Sardar Colony	1.15*	0.09	0.68*	0.02
2.	Latif Abad	0.02	0.72*	0.77*	0.02
3.	Shinwari Town	2.26*	0.73*	0.44*	0.04
4.	Ghari Rahimdad	1.03*	0.13	0.56*	0.04
5.	Pakha Ghulam	0.86	0.02	0.48*	0.03
6.	Khanam Abad	0.84	0.53*	0.27*	0.04
7.	Hazar Khani	0.01	0.07	0.90*	0.03
8.	Khamosh Colony	0.86	0.02	0.11*	0.08
9.	Rahman Baba Chowk	0.33	0.72*	0.43*	0.08
10.	Qamar Din Ghari	0.84	0.32	0.79*	0.03
11.	Landi Arbab	0.17	0.10	1.43*	0.03
12.	Landi Argajoon	0.25	0.42	0.52*	0.09
13.	Imran Abad	0.93	0.37	0.96*	0.02
14.	Yousaf Abad	0.52	0.42	0.83*	0.02
15.	Chowk Akhmadak	0.90	0.03	0.84*	0.03
16.	Upper Pistakhara	0.37	0.20	1.31*	0.07
17.	Achini	0.75	0.03	0.76*	0.02
18.	Kagawala	0.53	0.33	0.98*	0.10
19.	Bazid Khel	0.73	0.06	0.91*	0.02
20.	Ahmed Khel	1.15*	0.08	1.19*	0.01
21.	Gugan Khel	1.36*	0.60*	0.06	0.06
22.	Malang Abad	0.23	0.30	0.81*	0.01
23.	Mera	0.33	0.27	1.18*	0.05
24.	Haji Hassan Camp No2	1.39*	0.03	0.48*	0.03
25.	Paroan	0.30	0.38	0.53*	0.01
26.	Shah Muhammad Khan	0.27	0.04	0.43*	0.01
27.	Paroan 2	0.11	0.34	1.04*	0.01
28.	Haseeb Abad	1.3*	0.47	1.23*	0.04
29.	Mama Khel	0.82	0.27	1.38*	0.04
30.	Wakeel Kala	0.13	0.14	0.39*	0.03
31.	Janey Khuwar	0.16	0.03	0.94*	0.01
32.	Mamakhel No. 2	0.20	0.29	0.80*	0.01
33.	Mirza Abad	0.71	0.18	0.68*	0.03
34.	Majeed Abad	0.02	0.40	0.57*	0.04
35.	Balizai Khel	0.54	0.33	0.24*	0.03
36.	Masho	0.06	0.04	1.14*	0.03
37.	Haji Khel Mera	0.91	0.11	1.03*	0.01
38.	Gul Bara	0.81	0.23	1.03*	0.02
39.	Suleman Khel	0.02	0.14	0.24*	0.04
40.	Mashoo Gagar	0.19	0.02	0.76*	0.01
Minimum		0.01	0.02	0.06	0.01
Maximum		2.26	0.73	1.43	0.10
Average		0.61	0.25	0.75	0.03
Standard Deviation		0.49	0.21	0.35	0.02
No. of samples above safe limit		7	5	39	0

* = above safe limit

Table 2. AB-DTPA extractable heavy metals in soil.

S. No.	Locality	Heavy metals (mg kg^{-1})			
		Ni	Pb	Cd	Cr
1.	Sardar Colony	0.94	2.82	0.07	0.13
2.	Latif Abad	0.23	6.24	0.28	0.09
3.	Shinwari Town	1.11	7.52	0.28	0.12
4.	Ghari Rahimdad	0.88	4.14	0.17	0.29
5.	Pakha Ghulam	0.63	0.02	0.35	0.15
6.	Khanam Abad	0.12	4.56	0.20	0.15
7.	Hazar Khani	0.02	2.24	0.07	0.27
8.	Khamosh Colony	0.49	3.06	0.29	1.05
9.	Rahman Baba Chowk	0.67	5.16	0.26	1.23
10.	Qamar Din Ghari	0.61	4.44	0.23	0.28
11.	Landi Arbab	0.51	3.51	0.37	0.27
12.	Landi Argajoon	0.54	3.52	0.37	1.90
13.	Imran Abad	0.81	2.68	0.09	0.12
14.	Yousaf Abad	0.50	4.48	0.34	0.18
15.	Chowk Akhmadak	0.42	2.82	0.19	0.18
16.	Upper Pishtakhara	0.91	3.82	1.17	1.19
17.	Achini	0.81	3.62	0.02	0.19
18.	Kagawala	0.42	3.46	0.29	1.92
19.	Bazid Khel	0.52	3.88	0.27	0.24
20.	Ahmed Khel	0.82	2.06	0.36	0.21
21.	Gugan Khel	1.00	4.82	0.18	1.19
22.	Malang Abad	0.99	3.24	0.25	0.07
23.	Mera	0.87	0.86	0.30	0.17
24.	Haji Hassan Camp 2	0.64	1.16	0.13	0.13
25.	Paroan	0.86	1.58	0.22	0.10
26.	Shah Muhammad Khan	0.36	1.12	0.17	0.18
27.	Paroan 2	0.60	1.14	0.32	0.04
28.	Haseeb Abad	1.10	1.66	0.31	0.06
29.	Mama Khel	0.73	1.20	0.17	0.18
30.	Wakeel Kala	0.85	1.20	0.13	0.21
31.	Janey Khuwar	0.81	1.34	0.20	0.40
32.	Mamakhel No. 2	0.33	1.30	0.21	0.19
33.	Mirza Abad	0.46	1.92	0.17	0.14
34.	Majeed Abad	0.03	1.36	0.14	0.24
35.	Balizai Khel	0.68	2.34	0.26	0.17
36.	Masho	0.69	1.78	0.30	0.23
37.	Haji Khel Mera	1.03	0.80	0.20	0.05
38.	Gul Bara	1.03	0.12	0.08	0.18
39.	Suleman Khel	1.10	0.18	0.08	0.04
40.	Mashoo Gagar	0.73	0.02	0.31	0.08
Minimum		0.02	0.02	0.02	0.04
Maximum		1.11	7.52	0.37	1.92
Average		0.65	2.58	0.24	0.35
Standard Deviation		0.29	1.75	0.17	0.47
No. of samples above safe limit		0	0	0	0

Heavy metal in vegetables: The mean concentrations of Ni, Pb, Cd and Cr in leaves samples were 30.78, 15.58, 12.37 and 3.74 mg kg^{-1}, respectively (Table 3). A comparison of the data with the criterion laid out by Kabata-Pendias & Pendias (1985) for the approximate concentrations of heavy metals in mature leaf tissue, revealed that Ni was in excessive or toxic concentrations in 36 (90%), Pb in 4 (10%), Cd in 31 (78%) and Cr in 6 (15%) of the leaves samples.

Table 3. Heavy metals concentration in vegetables leaves.

S. No.	Vegetable	Heavy metals (mg kg^{-1})			
		Ni	Pb	Cd	Cr
1.	Coriander	42.2*	12.6	1.02	1.52
2.	Cabbage	12.8*	48.8*	16.72*	1.12
3.	Cauliflower	56.0*	50.0*	1.60	1.24
4.	Mustard	40.1*	22.8	15.8*	3.52
5.	Garlic	27.6*	0.80	21.8*	2.56
6.	Pea	9.20	30.4*	10.12*	1.36
7.	Mustard	0.40	11.2	0.52	3.12
8.	Squash	18.0*	20.0	21.4*	12.68*
9.	Coriander	30.8*	36.1*	16.24*	12.8*
10.	Cauliflower	23.6*	22.4	5.80*	3.12
11.	Squash	24.2*	21.2	19.6*	3.32
12.	Cauliflower	20.0*	21.6	24.8*	2.32
13.	Mustard	36.4*	16.2	24.1*	3.21
14.	Pea	23.6*	26.8	5.40*	3.21
15.	Pea	7.60	11.2	21.16*	1.92
16.	Pea	43.6*	21.6	8.52*	12.02*
17.	Garlic	41.6*	21.6	3.04	12.65*
18.	Chilly	20.4*	20.8	1.25	14.24*
19.	Pea	29.6*	23.6	5.28*	3.25
20.	Onion	49.6*	12.4	11.16*	2.44
21.	Mustard	43.2*	20.3	5.60*	13.25*
22.	Garlic	43.2*	17.2	7.80*	1.12
23.	Cauliflower	39.6*	2.60	22.24*	1.68
24.	Tomato	30.8*	9.30	10.25*	2.40
25.	Tomato	43.08*	8.92	2.52	1.88
26.	Tomato	16.8*	6.80	13.56*	2.12
27.	Squash	36.1*	9.20	24.36*	1.08
28.	Garlic	36.0*	7.40	24.92*	1.08
29.	Radish	42.4*	7.80	26.30*	1.76
30.	Radish	37.6*	9.60	6.56*	1.80
31.	Squash	43.2*	7.80	23.04*	2.12
32.	Squash	13.2*	9.40	16.25*	2.36
33.	Turnip	24.4*	7.60	6.88*	2.08
34.	Sugar Beet	1.20	7.10	4.80	2.60
35.	Pea	25.2*	16.4	14.36*	1.64
36.	Radish	31.8*	8.80	8.40*	1.76
37.	Lettuce	47.6*	2.20	15.24*	1.08
38.	Garlic	34.4*	2.40	0.28	2.08
39.	Radish	49.2*	9.60	0.92	2.36
40.	Pea	34.8*	0.80	25.4*	1.60
Minimum		0.40	0.80	0.28	1.08
Maximum		56.0	50.0	26.30	14.24
Average		30.78	15.58	12.37	3.74
Standard Deviation		13.73	11.46	8.59	3.98
No. of samples above safe limit		36	4	31	6

* = above safe limit

Edible portions of vegetables had average concentrations of Ni, Pb, Cd and Cr as 30.14, 27.49, 27.67 and 7.56 mg kg^{-1}, respectively (Table 4). The data, compared with Kabata-Pendias & Pendias (1985), showed that 36 (90%) edible portion samples had Ni above the safe limit while Pb, Cd and Cr were above the limit in 11 (28%), 33 (83%) and 25 (63%) samples, respectively. Rusan (2007) stated that plant Pb and Cd increased with wastewater irrigation and the longer the period of wastewater irrigation the higher the concentration of heavy metals. Singh (2006) collected samples of vegetables (spinach and okra), soil and irrigation water from 5 peri-urban sites of New Delhi to monitor their heavy metal loads. It was concluded that while heavy metal load of the irrigation water were above the maximum allowable limit, it was lower in soils and higher in vegetable samples. The spinach and okra samples showed Zn, Pb and Cd levels higher than the WHO limits. Though the wastewater contains low levels of the heavy metals, the plant samples showed higher values due to accumulation (Gupta *et al*., 2010).

Table 4. Heavy metals concentration in vegetables edible portions.

S. No.	Vegetable	Edible portions	Heavy metals (mg kg^{-1})			
			Ni	Pb	Cd	Cr
1.	Coriander	Leaves	42.2*	12.6	1.02	1.52
2.	Cabbage	Leaves	51.0*	43.0*	3.9	11.0*
3.	Cauliflower	Curd	18.0*	92.0*	10.4*	3.6
4.	Mustard	Leaves	40.1*	22.8	15.8*	3.52
5.	Garlic	Bulb	42.3*	37.2*	34.1*	14.6*
6.	Pea	Seed	18.2*	48.0*	26.4*	13.0*
7.	Mustard	Leaves	0.40	11.2	0.52	3.12
8.	Squash	Fruit	6.80	11.4	14.2*	9.0*
9.	Coriander	Leaves	30.8*	36.1*	16.24*	12.8*
10.	Cauliflower	Curd	32.3*	32.2*	13.1*	6.6*
11.	Squash	Fruit	28.0*	20.0	67.1*	4.8
12.	Cauliflower	Curd	29.3*	27.4	67.8*	16.0*
13.	Mustard	Leaves	36.4*	16.2	24.1*	3.21
14.	Pea	Seed	28.1*	15.71	27.6*	5.8*
15.	Pea	Seed	19.6*	39.3*	8.30*	5.0*
16.	Pea	Seed	17.9*	24.0	24.0*	6.2*
17.	Garlic	Bulb	22.1*	32.0*	0.40	5.2*
18.	Chili	Fruit	53.0*	24.2	9.70*	16.6*
19.	Pea	Seed	16.8*	24.3	3.80	6.6*
20.	Onion	Bulb	9.20	9.50	4.20	7.2*
21.	Mustard	Leaves	43.2*	20.3	5.60*	13.2*5
22.	Garlic	Bulb	57.0*	37.3*	0.45	4.1
23.	Cauliflower	Curd	48.0*	39.0*	5.40*	3.4
24.	Tomato	Fruit	29.7*	11.1	8.40*	12.2*
25.	Tomato	Fruit	30.0*	13.0	48.2*	16.2*
26.	Tomato	Fruit	36.0*	17.2	61.4*	11.8*
27.	Squash	Fruit	26.0*	10.0	41.6*	2.6
28.	Garlic	Bulb	49.1*	12.1	63.4*	6.6*
29.	Radish	Root	34.1*	17.4	21.8*	6.0*
30.	Radish	Root	28.3*	21.6	37.2*	6.8*
31.	Squash	Fruit	26.1*	28.7	37.1*	7.0*
32.	Squash	Fruit	32.0*	28.9	55.6*	7.6*
33.	Turnip	Root	38.0*	22.0	28.4*	6.2*
34.	Sugar Beet	Root	8.80	15.6	22.2*	4.6
35.	Pea	Seed	39.0*	28.3	57.4*	4.2
36.	Radish	Root	30.0*	21.5	46.9*	6.6*
37.	Lettuce	Leaves	47.6*	2.20	15.24*	1.08
38.	Garlic	Bulb	40.0*	13.6	11.4*	4.8
39.	Radish	Root	11.6*	86.3*	15.8*	3.6
40.	Pea	Seed	38.4*	3.60	35.6*	4.2
Minimum			0.40	0.80	0.28	1.08
Maximum			67.80	50.00	26.30	14.24
Average			30.14	27.49	27.67	7.56
Standard Deviation			13.09	19.22	21.22	4.02
No. of samples above safe limit			36	11	33	25

* = above safe limit

Percentage of leaves and edible portions samples containing Ni higher than the safe limit was the same. Furthermore average concentration of Ni was almost the same in leaves and edible portions. Average concentrations of Pb, Cd and Cr were higher in edible portions than in leaves. Edible portions had a greater number of samples having Pb and Cr above the safe limit as compared to leaves samples. High levels of heavy metals in vegetables irrigated with sewage water were because of the fact that the sewage water was enriched with heavy metals, thus polluting the soil and consequently the vegetables.

Various scientists in Pakistan reported elevated levels of heavy metals in sewage and industrial effluents-irrigated vegetables. Zaidi *et al*., (1997) collected vegetables and pulses samples from market in Rawalpindi and Islamabad and reported them unsafe for eating due to heavy metals enrichment. All vegetable samples irrigated with sewage in Rawalpindi area were above the critical levels with respect to Pb, Cd, Cr and Ni contents (Latif *et al.*, 2008). Similarly, all vegetable samples irrigated with untreated industrial effluents were above the critical levels for eating regarding Pb, Cd, Cr and Ni contents. Spinach, eggplant, okra, bitter gourd and pumpkin collected from Faisalabad city were polluted with heavy metals and were unsafe for eating (Farid, 2003). Lone *et al.*, (2003) revealed the same in sewage irrigated okra and spinach leaves and fruits in Attock area. Ronaq *et al.,* (2005) collected spinach and turnip samples from market and found them unsafe for eating due to toxic heavy metal concentrations. Similarly, Butt *et al*., (2005) obtained the same results in spinach, potato, squash, turnip, tomato and coriander.

Statistical analysis

Correlation between water and soil: The correlation results between water and soil contents are summarized in Table 5. The r-values for Ni, Pb, Cd and Cr were 0.40, 0.61, 0.33 and 0.86, respectively. The data showed that AB-DTPA extractable Ni, Pb, Cd and Cr of soil had significant positive correlation with that of the irrigation water i.e. increasing heavy metal contents of irrigation water showed increasing amounts of heavy metals in the respective soils (Figs. 1-4).

Correlation between plants leaves and soil: The correlation results between plants leaves and soil contents are given in Table 5. The r-values for Ni, Pb, Cd and Cr were 0.92, 0.95, 0.17 and 0.87, respectively. The data showed that the plant Cd had positive non- significant correlation with soil Cd. Other heavy metals like Ni, Pb and Cr of leaves samples had significant positive correlation with the given heavy metals in soil (Figs. 5-8).

Table 5. Soil-water and plants-soil correlation.

S. No	Independent variable (water)	Dependent variable (Soil)	r-value	Independent variable (Soil)	Dependent variable (Plant leaves)	r-value
1.	Ni	Ni	0.404*	Ni	Ni	0.923*
2.	Pb	Pb	0.605*	Pb	Pb	0.951*
3.	Cd	Cd	0.327*	Cd	Cd	0.172
4.	Cr	Cr	0.864*	Cu	Cu	0.874*

* = Significant

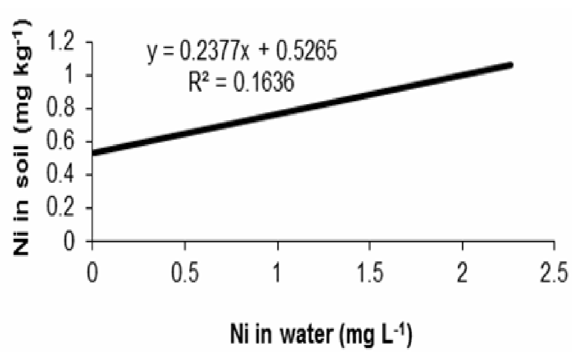

Fig. 1. Correlation between Ni in water and soil.

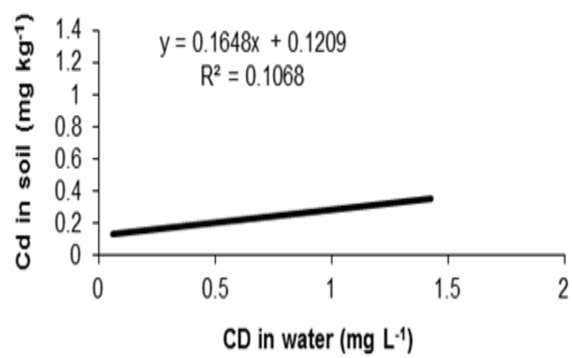

Fig. 3. Correlation between Cd in water and soil.

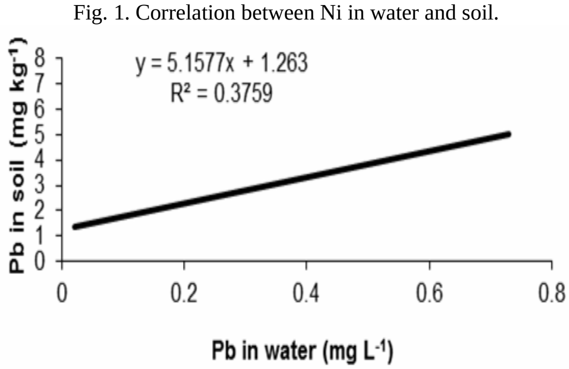

Fig. 2. Correlation between Pb in water and soil.

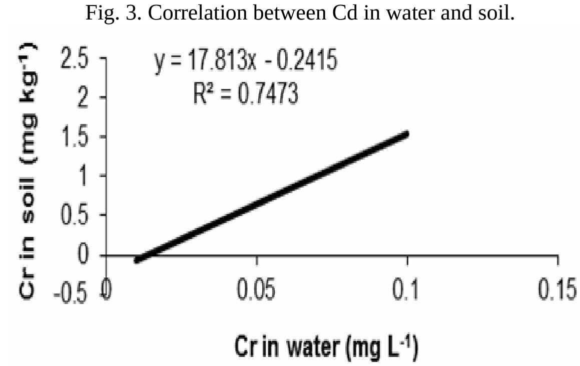

Fig. 4. Correlation between Cr in water and soil.

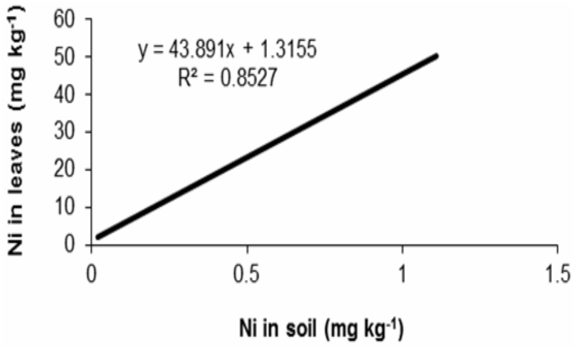

Fig. 5. Correlation between Ni in soil and leaves.

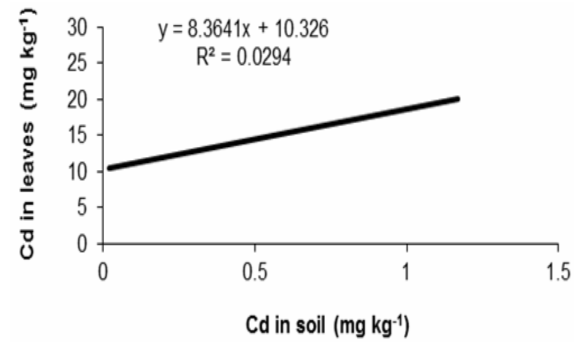

Fig. 7. Correlation between Cd in soil and leaves.

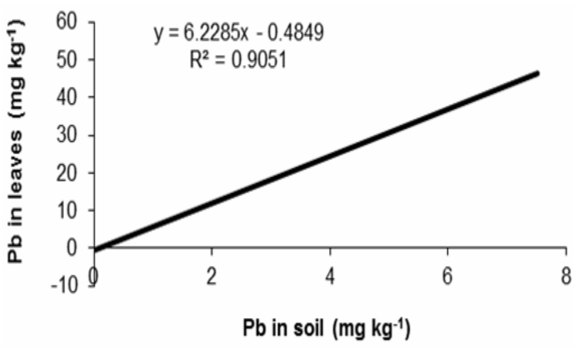

Fig. 6. Correlation between Pb in soil and leaves.

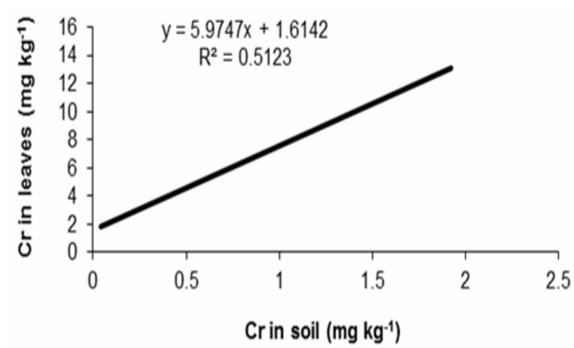

Fig. 8. Correlation between Cr in soil and leaves.

Conclusion

The water of Warsak canal and Bara river containing excessive amounts of certain heavy metals, should not be used for irrigation of those vegetables which are directly consumed uncooked by human beings e.g. lettuce, cabbage, beets, coriander, radishes, carrots, spinach and parsley etc. These sources of water should not be used for drinking purpose of livestock as the heavy metals present in it may cause a number of abnormalities in animals.

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References

Ahmed, M., R.A. Khattak and D. Mohammad. 2008. Soil evaluation of Kafoor Dheri farm for crop production. *Soil & Environ*., 27(1): 43-51.

Ayers, R.S. and D.W. Westcott. 1984. Water quality for agriculture and drainage diversion. *Rome*. Paper 29. pp. 173.

Bano, D. 2004. *Spatial and temporal variation of heavy metals in industrial effluents of Hayatabad and its effect on soil*. M.Sc. (Hons). Thesis. Deptt. Soil Environ. Sci. NWFP Agric. Uni. Peshawar.

Black, C.A. 1965. *Methods of soil analysis*. Agronomy. No. 9. Part 2: Amer. Soc. Agron. Inc., Madison, WI. USA.

Butt, M.S., K. Sharif, B.E. Bajwa and A. Aziz. 2005. Hazardous effects of sewage water on the environment; focus on heavy metals and chemical composition of soil and vegetables. *Manag. Environ. Quality*. 16(4): 338-346.

Chary, N.S., C.T. Kamala and D.S. Raj. 2008. Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. *Ecotoxicol. Environ. Safety*, 69(3): 513-524.

Ensink, J.H.J., T. Mahmood, W. Van der Hoek, L. Raschid-Sally and F.P. Amera-singhe. 2004. A nation-wide assessment of wastewater use in Pakistan: an obscure activity or a vitally important one? *Water Policy*, 6: 1-10.

Farid, S. 2003. Toxic elements concentration in vegetables irrigated with untreated city effluents. *Sci. Technol. Dev*., 22(4): 58-60.

Faruqui, N.I, C.A. Scott and L. Raschid-sally. 2004. *Confronting the realities of waste water in irrigated agriculture: lessons learned and recommendations*. IDRC Books Free online. http://www.idrc.ca.

Feigin, A., I. Ravina and J. Shalhevet. 1991. Irrigation with Treated Sewage Effluent. Management for Environmental Protection. Advanced Series in Agricultural Sciences. 17. Springer-Verlag. pp. 224.

Ghosh, A.K., M.A. Bhatt and H.P. Agrawal. 2012. Effect of long-term application of treated sewage water on heavy metal accumulation in vegetables grown in northern India. *Environ. Monit. Assess*., 184(2): 1025-1036.

Gupta, N., D.K. Khan and S.C. Santra. 2011. Heavy metal accumulation in vegetables grown in a long-term wastewater-irrigated agricultural land of tropical India. *Environ. Monit. Assess*., Epub. ahead of print. http://www.ncbi.nlm.nih.gov/pubmed/22131014.

Gupta, S., S. Satpati, S. Nayek and D. Garai. 2010. Effect of wastewater irrigation on vegetables in relation to bioaccumulation of heavy metals and biochemical changes. *Environ. Monit. Assess*., 165(1-4): 169-177.

Havlin, J.L. and P.N. Soltanpour. 1981. Evaluation of the NH_4HCO_3 DTPA Soil test for Fe, Zn, Mn, Cu. *Soil Sci. Soc. Amer. J*., 45: 70-77.

Huibers, F.P., O. Moscoso, A. Duran and J.B.V. Lier. 2004. *The use of waste water in cochabamba, Bolivia: a degrading environment*. IDRC Books Free online. http://www.idrc.ca.

Kabata-Pendias, A and H. Pendias. 1985. *Trace elements in soil and plants*. pp. 57-59.

Kanwar, J.S. and M.S. Sandha. 2000. Waste water pollution injury to vegetable crops, a review. *Agric. Review*., 21(2): 133-136.

Khan, G.S., T.K. Khattak and A. Rashid. 1974. Physicochemical properties of representative soils of Peshawar valley. *Pak. J. Soil Sci*., 26: 77-80.

Khan, S., Q. Cao, Y.M. Zheng, Y.Z. Huang and Y.G. Zhu. 2008. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Environ. Pollution*, 152(3): 686-692.

Latif, M.I., M.I. Lone and K.S. Khan. 2008. Heavy metals contamination of different water sources, soils and vegetables in Rawalpindi area. *Soil & Environment*, 27(1): 29-35.

Linzon, S.N. 1978. *Phytotoxicology Excessive Levels for Contaminants in Soil and Vegetation*, Report of Ministry of the Environment, Ontario, Canada.

Lone, M.I., S. Saleem, T. Mahmood, K. Saifullah and G. Hussain. 2003. Heavy metal contents of vegetables irrigated by Sewage/Tube well water. Intern. *J. Agric. Biol*., 15(4): 533-535.

Mclean, E.O. 1982. Soil pH and lime requirement. In: *Methods of soil analysis*. (Eds.): A.L. Page, R.H. Milelr and D.R. Keeney. Part 2. 2nd ed. *Agron*. 9: 209-223.

Nawaz, M. 1975. *Studies on the relationships of physicochemical properties of two important series of Peshawar valley*. M.Sc. (Hons). Thesis. Deptt. Soil Sci. Agric. Uni. Peshawar.

Perveen, S., W. Nazif, Rahimullah and H. Shah. 2006. Evaluation of water quality of Upper Warsak Gravity Canal for irrigation with respect to heavy metals. *J. Agric. Biol. Sci*., 1(2): 19-24.

Qadir, M., D. Wichelns, L. Raschid-Sally, P.G. McCornick, P. Drechsel, A. Bahri and P.S. Minhas. 2008. *The challenges of wastewater irrigation in developing countries*. Agric. Water Manag. http://www.sciencedirect.com.

Rai, S., A.K. Chopra, C. Pathak, D.K. Sharma, R. Sharma and P.M. Gupta. 2011. Comparative study of some physicochemical parameters of soil irrigated with sewage water and canal water of Dehradun city, India. *Arch. Appl. Sci. Res*., 3(2): 318-325.

Rashid, A. 2001. *Soil Science*. (Eds.): E. Bashir and R. Bantal. National Book Foundation. Islamabad. pp. 357-373.

Rhoades, J.D. 1982. Soluble salts. In: *Methods of soil analysis*. (Eds.): A.L. Page, R.H. Miller and D.R. Keeney. Part 2. American Society of Agronomy, Inc., Madison, WI. USA. pp. 167-178.

Ronaq, R.N., I. Haider, M. Qadir and N. Hasnain. 2005. Studies on the distribution of heavy and toxic metals (Copper, Lead, Zinc and Cadmium) in different vegetables using Atomic Absorption Spectroscopy. Proceedings of 5th National Chemical Conference, Islamabad, Pakistan. pp. 63-64.

Rusan, M.J.M., S. Hinnawi and L. Rousan. 2007. Long term effect of wastewater irrigation of forage crops on soil and plant quality parameters. *Desalination*, 215(1-3): 143-152.

Sachan, S., S.K. Singh and P.C. Srivastava. 2007. Buildup of heavy metals in soil-water-plant continuum as influenced by irrigation with contaminated effluent. *J. Environ. Sci. Eng*., 49(4): 293-296.

Sarwar, S. 2003. *Evaluation of Jehlum river water quality for irrigation and dirking purposes at district Muzaffarabad (AJK)*. M.Sc. (Hons). Thesis. Deptt. Soil and Enviro. Sci. NWFP Agric. Uni. Peshawar.

Sharma, R.K., M. Agrawal and Fiona Marshall. 2006. Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. *Ecotoxicol. Environ. Safety*, 66(2): 258-266.

Sheinberg, I. and J.D. Oster. 1985. Quality of irrigation water. International irrigation information centre. pp. 8.

Singh, A., R.K. Sharma, M. Agrawal and F.M. Marshall. 2010. Health risk assessment of heavy metals via dietary intake of foodstuffs from the wastewater irrigated site of a dry tropical area of India. *Food Chem. Toxicol*., 48(2): 611-619.

Singh, S. and M. Kumar. 2006. Heavy metal load of soil, water and vegetables in Peri-Urban Delhi. *Environ. Monit. Assess*., 120(1-3): 79-91.

Ullah, H., I. Khan and I. Ullah. 2011. *Impact of sewage contaminated water on soil, vegetables and underground water of peri-urban Peshawar*, Pakistan. Environ. Monit. Assess. Epub. ahead of print. http://www.ncbi.nlm.nih.gov/pubmed/22203410.

U.S. Salinity Lab. Staff. 1954. Diagnosis and improvement of saline and alkali soils. U.S.D.A. Hand Book No. 60. Washington D.C.

Zaidi, Z.H., M. Arif, I. Fatima, S. Ahmed and I.H. Qureshi. 1997. Rapid RNAA procedures for the determination of some toxic elements in food materials. In: *Proceedings of national symposium on modern trends in contemporary chemistry on environmental pollution*. (Eds.): J. Hanif and M.I. Hanif. February 24-26, 1997. pp. 219-233.

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