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Studies on heavy metals status and their uptake by vegetables in adjoining areas of Hudiara drain in Lahore

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Abstract

Pakistan has a population of over 150 million and is one of the few countries that is almost completely dependant on a single river system for all its agricultural water demands. The Indus river and its tributaries provide water to over 16 million hectares of land, situated in the mainly arid and semi-arid zones of the country. A rapidly growing population, saline groundwater, a poorly performing irrigation distribution system and recurrent droughts have led to increased water shortages. Under these conditions, the use of untreated waste water being more nutritious for crops and free of cost is becoming a common and widespread practice. Hudiara drain originates from India and enters Pakistan near Hudiara village on Pakistan side and serves as a source of free water for growing crops especially vegetables on both side of the drain. This study was conducted to investigate the heavy metal contents in Hudiara drain water and their uptake by vegetables irrigated by the drain water in the adjoining area of this drain. This might serve as an indication of the future risks to humans and animals from the movement of these heavy metals in food chain by the consumption of vegetables produced using polluted water. The results indicated that Hudiara drain water in routine water analysis parameters is fit for irrigation but unfit in relation to heavy metals contents. Soil irrigated by this water is also having higher DTPA-extractable metals contents than canal irrigated and the vegetables under study were also having metal contents far high than Indian standards for safe consumption of vegetables. Highest metals contents were observed in spinach and lowest in bringals, others in between, indicating that these vegetables should be consumed carefully if produced using the polluted drain water.

Key words: Hudiara, heavy metals, arsenic, metal transfer factor, vegetables

Introduction

The area under waste water irrigation has increased significantly with about 20 million hectares producing nearly 40% of the food produced worldwide (WHO, 1997). In Pakistan, about 32,500 ha are presently irrigated using waste water (Saleem, 2005). Farming communities in water-scarce regions increasingly practice the use of waste water in agriculture. Untreated waste water is generally considered unacceptable for direct use because of potential health risks. Among the greatest threats to human health by the use of this waste water is the presence of high levels of heavy metals in waste water.

In the low concentrations, many metals are essential to life. In excess, the same chemicals can be poisonous. Lead poisoning in children causes neurological damage leading to a reduction in intelligence, loss of short term memory, learning disabilities and problems with coordination. Prenatal exposure can cause reduced birth weight and immune suppression or oversensitisation, which could explain why some children develop asthma and allergies (Day, 1998: Masters, 1998) and that it can contribute to tooth decay (Gil *et al*., 1996). High concentrations of arsenic in water have been documented in specific parts of Argentina, Canada, Chile, China, Japan, Mexico, Philippines and USA. The problem is particularly acute in West Bengal and Bangladesh, where an estimated 30 million people are drinking arsenic-poisoned water (WHO, 1997). Some 62% of wells supply arsenic contaminated water above WHO's limits with some containing as much as 400 times the limit (Bagla *et al*., 1996). The effects of arsenic include cardiovascular problems, skin cancer and other skin effects, peripheral neuropathy and kidney damage (WHO, 1997). Cadmium exposure occurs mainly through cereals and vegetables grown on soils contaminated by mining activities and use of phosphorus fertilizers. The principal health risks associated with mercury are damage to the nervous system, with such symptoms as uncontrollable shaking, muscle wasting, partial blindness, and deformities in children exposed in the womb. At levels well below WHO limits, it can damage the fetal and embryonic nervous systems with consequent learning difficulties, poor memory and shortened attention spans (Jorgensen *et al*, 1997). Low level exposures can also adversely affect male fertility (Dickman *et al*., 1998).

Hudiara Drain, which is a natural storm water channel, originates from Batala in Gurdaspur District, India and after flowing nearly 55 km on Indian side at village Laloo enters

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Pakistan at Hudiara village on Pakistan side. After flowing for nearly 63 km inside Pakistan, it joins the River Ravi. The river Ravi has serious pollution problems. There are around 100 industries located adjacent to the Hudiara drain on the 55 kilometers Indian side, so it is already quite polluted when it enters Pakistan (WWF, 2006). There are 112 small industries located next to the drain on Pakistani side as it travels 63 kilometers through the Punjab into the Ravi. The water is used for irrigation along the length of the drain. The villagers even use water from wells dug close to the drain, which are exposed to the pollution through seepage. With growing water scarcity for agriculture and increasing waste water volume in drains, farmers around these drains find it convenient to irrigate the fields with easily accessible and free of cost drains water. Untreated water, when used for irrigation, seeps into the soil and facilitates the entry of a number of pathogens and heavy metals into the food chain. Vegetables and other crops grown with polluted water may cause diseases when consumed by the people raw or cooked.

Therefore, the present study has been undertaken to assess the status of heavy metals contamination of Hudiara drain water and soil irrigated with this drain water, to investigate the uptake of heavy metals by crops grown in soil irrigated with this drain water and to determine DTPA-extractable metals in soil.

Materials and Methods

This study was conducted to investigate the heavy metals status in Hudiara drain water and their uptake by crops due to irrigation with this drain water in the adjoining area of this drain. For this purpose water samples were collected from three specific points with 10 replications in each month from April to June in 2007. Plant samples (vegetable crops) of okra (*Hibiscus esculentus*), “Tar” (*Cucumis sativus*), “Ghia Tori” (*Cucurbita pipo*), Green chilies (*Capsicum annuum*), Bringals (*Solanum melongena*) and Spinich (*Spinacea oleracea)* were collected with 20 replications. Soil samples from 0-6 and 6-12 inches depth were also collected from the corresponding spots. For the purpose of studying heavy metals in water samples, water was filtered using Whatman No. 42 filter paper and was analysed directly using ICP-OES Optima 5300 DV from Perkin Elmer using CRMs having traceability to NIST supplied by Perkin Elmer, USA. For studying heavy metals contents in plant samples, oven dried ground plant material (0.25 g) was digested using 10 mL of tri-acid mixture of HNO_3, $HClO_4$ and H_2SO_4 in 2:1:1 ratio on temperature controlled hot plate. When the volume was reduced to about 2-3 mL upon heating with clear digested solution, the contents were allowed to cool and transferred to a 50 mL volumetric flask. The volume was made upto the mark. The solution was filtered and stored in plastic bottles for analysis using ICP-OES 5300 DV from Perkin Elmer USA in the same manner as described for water analysis. For soil analysis, 0.005 M DTPA was used. Twenty gram soil was extracted with 40 mL DTPA for two hour continuous shaking and filtering through Whatman No. 42. These were then directly analyzed using ICP-OES (same as previous). The instrument was run under the following conditions: Torch: Type 2 Quartz–Slotted Extension, Power: 1350 Watts, Plasma Flow: 15 L min^{-1}, Aux. Flow: 1.0 L min^{-1}, Nebulizer Gem Tip Cross-flow with flow rate 1.0 L min^{-1}, Injector pump rate: 1.0 mL min^{-1}, Spray Chamber Ryton Scott Type Double-pass and Pumped drain. All chemicals used during study were ICP-OES and HPLC grade. Water used during study was deionized from distilled water having EC less than 4 µS m^{-1}. Argon and nitrogen gas used was from Fine Gas, Pakistan. Temperature of the laboratory was maintained at 25 $\pm$ 3 ^{o}C and RH was 50-55% during the analysis. Calibrated 1000 µL and 5 mL micro pipettes with standard tips were used for sample dilutions. All glass ware used during the study was A class.

Transfer factor for each metal was calculated according to the following formula:

$$TF = Ps\ (\mu g\ g^{-1}\ \text{dry weight}) / St\ (\mu g\ g^{-1}\ \text{dry weight})$$

where Ps is the plant contents originating from soil and St is the DTPA-extractable metal contents in soil (Chamberlain, 1983; Harrison and Chirgawi, 2000).

Results and Discussion

The problem of environmental pollution due to toxic metals has begun to cause concern now in most areas where water for irrigation is becoming scarce and people are using the drain water for irrigation. The toxic heavy metals entering the ecosystem may lead to geoaccumulation, bioaccumulation and biomagnification. Heavy metals like Fe, Cu, Zn, Ni and other trace elements are important for proper functioning of biological systems and their deficiency or excess could lead to a number of disorders. Food chain contamination by heavy metals has become a burning issue in recent years because of their potential accumulation in biosystems through contaminated water, soil and air.

A better understanding of heavy metal sources, their accumulation in the soil and the effect of their presence in water and soil on plant systems seem to be particularly important issues of present-day research on risk assessments. The main sources of heavy metals to vegetable crops are their growth media especially drain water if used for irrigation and even the air pollution from which these are taken up by the roots or foliage.

Heavy metals in soil

The physico-chemical properties of soil in the adjoining area of Hudiara drain are presented in Table 1. The results of the analysis indicated that the metals contents of the soil are some what higher from the normal concentration of these metals in the soil samples collected from those fields which were never irrigated with drain water. This might be developed as a result of the application of contaminated drain water used for growing crops and vegetables in the drain adjoining area for years.

Zn and Cu contents in all crops were within the Indian standard limits except for "Ghia Tori". Zn concentration in "Ghia Tori" was 10 times higher than safe levels. Bringals and Spinach contained Fe in higher concentration than the stated guidelines. Mn content was the double of the safe level in "Ghia Tori" but its concentration in other vegetables were within the safe limits. Nickle contents in all the crops except for bringals was higher than the safe levels. Cadmium concentration in all the plants except for "Tar" exceeded the safe limit. Cadmium is relatively easily taken up by the food crops especially by vegetables in addition to foliar absorption of Cd from atmospheric deposition on plant leaves (Mido and Stake, 2003). Spinach contained 1.5 times higher Cr concentration than that of the Indian standard limits. Lead contents in okra and spinach were higher but in chilli and bringals were lower in comparison with the stated limits. The order of toxic heavy metal contamination or transfer factor in vegetables studied was found to be : spinach > Ghia Tori > Okra > Green chillies >Tar> Bringals.

Table 1. General properties and heavy metal contents of soil in the adjoining area of Hudiara drain

Property			**Value**	
Textural class			clay loam to loam	
Saturation (%)			45 - 48	
pH_s			7.9 - 8.1	
EC_e (dS m^{-1})			2.1- 2.6	
Organic matter (%)			0.65 – 0.91	
Total N (%)			0.034	
Available P (ppm)			7 – 9	
Available K (ppm)			180-210	
	Non-drain irrigated soil		**Drain water irrigated soil**	
	0-6 inches	6-12 inches	0-6 inches	6-12 inches
Zn (ppm)	18.43	22.10	24.90	32.01
Cu (ppm)	6.20	7.50	9.41	11.07
Fe (ppm)	34.10	40.20	51.44	75.70
Mn (ppm)	14.00	10.82	27.30	12.33
Cd (ppm)	0.31	0.32	0.61	1.10
Cr (ppm)	ND	ND	0.002	ND
Ni (ppm)	0.55	0.58	1.07	1.03
Pb (ppm)	1.20	0.91	3.75	3.11

- Values are average of 140 soil samples.

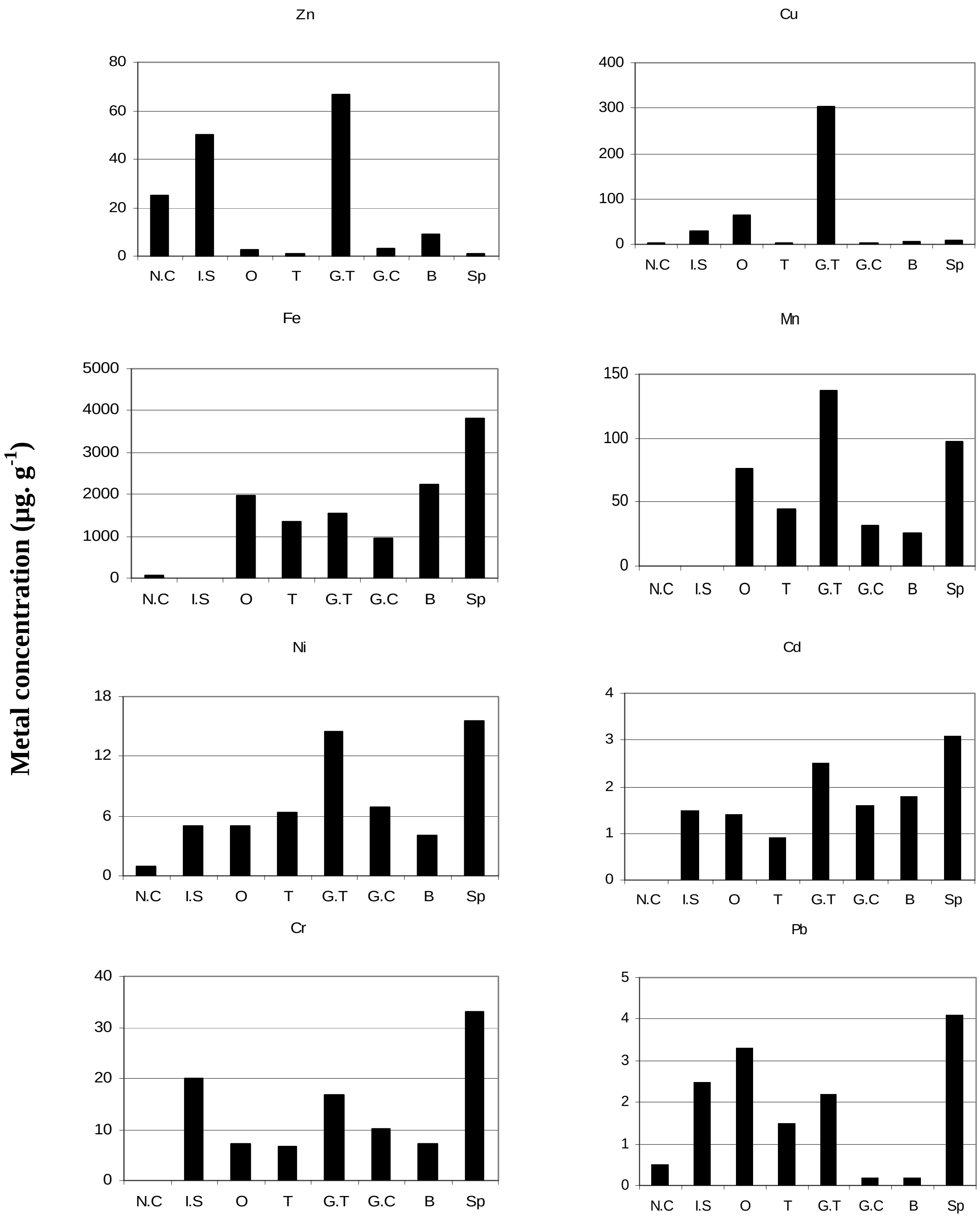
Heavy metals in Hudiara drain water

The general properties and heavy metals contents in Hudiara drain water are presented in Table 3. Data indicated that EC, SAR and RSC values of Hudiara drain water are within the limits of irrigation water quality guidelines as suggested by WWF, Pakistan 2006 (Table 2). However, the contents of heavy metals except for Pb and Zn were higher than the guideline limits. The concentration of Cu, Fe, Mn, Cd, Cr and Ni were about 2, 1.5, 4, 18, 7 and 5 times higher, respectively, than the guideline limits.

Metal Contents in different vegetables

The data regarding metals concentrations in different plants grown with drain water is presented in Figure 1. The results indicated that different metals were found at higher concentrations than Indian standards of these metals in different vegetables (Lokeshwari and Chandrapa, 2006).

The transfer factors (TF) of different heavy metals (Figure 2) from soil to vegetation is one of the key components of human exposure to metals through the food chain. The highest TF values (1.6 and 1.2 respectively) are found for Cd and Zn because these metals are more mobile in nature. One of the reasons for these results is that Cd occurs with Zn in nature and Cd (II) is retained less



(N.C= natural conc. I.S= Indian standard O= Okra T= Tar. G.T= Ghia Tori G.C = Green chilies B=Bringals Sp= Spinach) (Lokeshwari and Chandrapa, 2006).

Figure 1. Concentration of metals in different crops

Table 2. Irrigation water quality guidelines

Substance or condition	Unit	Maximum recommended value
Total dissolved solids (TDS)	mg L^{-1}	1000
EC at 25^{o}C	dS m^{-1}	1.5
SAR	(m mol $L^{-1})^{1/2}$	8
RSC	me L^{-1}	1.25
Boron	mg L^{-1}	1.0
Chloride	mg L^{-1}	100
pH	-	6.5-8.4
Aluminum	mg L^{-1}	5.0
Arsenic	mg L^{-1}	0.10
Beryllium	mg L^{-1}	0.10
Cadmium	mg L^{-1}	0.01
Chromium	mg L^{-1}	0.01
Cobalt	mg L^{-1}	0.05
Copper	mg L^{-1}	0.20
Cyanide	mg L^{-1}	1.0
Fluoride	mg L^{-1}	1.0
Iron	mg L^{-1}	5.0
Lead	mg L^{-1}	0.1
Lithium	mg L^{-1}	2.5
Manganese	mg L^{-1}	0.20
Mercury	mg L^{-1}	0.01
Molybdenum	mg L^{-1}	0.01
Nickel	mg L^{-1}	0.20
Selenium	mg L^{-1}	0.02
Vanadium	mg L^{-1}	0.10
Zinc	mg L^{-1}	2.0

WWF-National Surface Water Classification Criteria, Irrigation water Quality Guidelines for Pakistan, WWF-February, 2007.

strongly by the soil than other toxic cations. Overall, TF values of Zn, Cu, Pb and Cd are found to be significant and it supports the findings that accumulation of Cr, Ni and Pb is comparatively less while that of Cd, Cu and Zn is more in plants (Lokeshwari and Chandrappa, 2006)

Conclusion

From this study, it was concluded that Hudiara drain water in routine water analysis is fit for irrigation, whereas from heavy metals analysis point of view, it may be a main source of pollution and irrigation with this water containing variable amounts of heavy metals may lead to increase in concentration of heavy metals in the soil. The soil where drain water is used for irrigation has higher DTPA-extractable metals contents as compared to the canal irrigated area. The vegetables grown using this polluted water also have much higher concentration of heavy metals than the safe standard limits (up to the time no standards for safe limits of metals in vegetables has been established in Pakistan so Indian standards were used for safe limits). This study will provide a baseline data and there is a need for intensive sampling of the same for quantification of the results. Soil, plant and water quality monitoring, together with the prevention of metals entering the plant, is a prerequisite in order to prevent potential health hazards of irrigation with Hudiara drain water.

Table 3. Water analysis of the of Hudiara drain

Property		Value
EC at 25^o C	(µS cm^{-1})	1050
Ca+Mg	(meL^{-1})	6.4
Na	(meL^{-1})	3.1
CO_3^{--}	(meL^{-1})	ND
HCO_3^-	(meL^{-1})	7.5
Cl	(meL^{-1})	2.3
SAR	(m mol $L^{-1})^{1/2}$	1.7-1.9
RSC	(me L^{-1})	1.1-1.2
Zn	(ppm)	1.7
Cu	(ppm)	0.45
Fe	(ppm)	7-9
Mn	(ppm)	0.85
Cd	(ppm)	0.18
Cr	(ppm)	0.07
Ni	(ppm)	0.93
Pb	(ppm)	0.03

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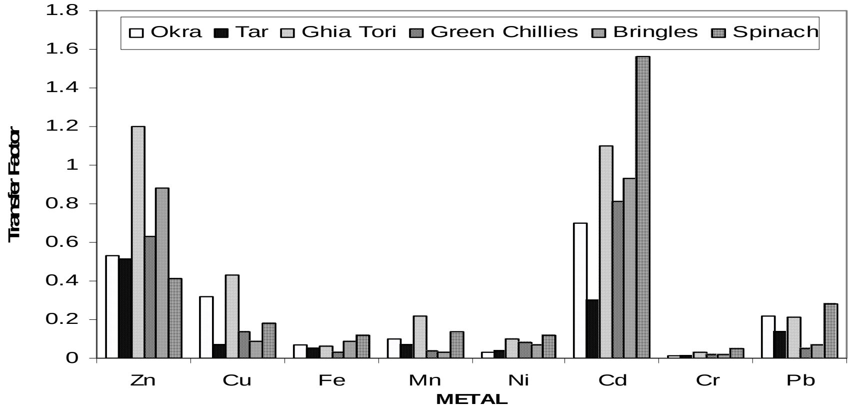

Figure 2. Transfer factor of metals in different vegetables

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