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Cadmium Contamination of Soils and Crops by Long Term Use of Raw Effluent, Ground and Canal Waters in Agricultural Lands

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ABSTRACT

Water scarcity in agriculture sector forced farmers to use city wastewater without any regard of its quality effects on environment and resultant contamination of soils and plants, particularly with heavy metals. A survey of effluent, tube well and canal water irrigated areas in Faisalabad, Pakistan was conducted to appraise Cd concentration in these waters and soils, and its uptake by cereal and legume crops. Water, soil and plant (seeds, shoot & roots) samples were collected and analyzed for Cd concentration. Results illustrated that wastewater contained 11.0 and 3.7 times higher Cd than tube well and canal waters, respectively. Location-wise the lowest Cd concentration was 0.6 µg L^{-1} at Bypass Samandari Road (BSR) while the highest was 1.4 µg L^{-1} at Malkhanwala (MW). Maximum AB-DTPA extractable Cd (0.30 mg kg^{-1} & 0.248 mg kg^{-1}) was found in soil samples collected from 0-15 cm depths at Uchkera and Ghulam Muhammad Abad (GMA), respectively. It was the lowest (0.04 mg kg^{-1}) in soil samples collected from Chak No. 235/RB (C235) location. Long term effluent irrigation resulted in 248 and 260% increase in Cd contents at 0-15 cm depth of soils compared to tube well and canal waters irrigated soils, respectively. In all the cases, Cd was within safe limits. About 70% of the metal was deposited in upper 30 cm layers. Seeds of effluent irrigated chickpea acquired the highest concentration of Cd (0.177 mg kg^{-1}), while was the lowest in wheat seeds (0.034 mg kg^{-1}). Concentration of Cd was higher in mungbean shoots (0.62 mg kg^{-1}) than in wheat shoots. The order for Cd concentration in seeds was chickpea > maize > mungbean > wheat for wastewater irrigated crops. Similar trend of Cd concentration was observed in tube well and canal waters irrigated crops.

Key Words: Irrigation waters; Cd contamination; Uptake; Cereal; Legume

INTRODUCTION

Geographically, most of the area of Pakistan falls in arid and semi–arid zone, where water scarcity in agriculture sector forced farmers to use city effluent water for irrigation. Water shortage in agriculture sector alone has been estimated to be 33% (382.37 billion cubic meters) of the total requirement in 2025 (Anonymous, 2005). In Pakistan, 32500 ha land is being irrigated with city effluent (Ensink *et al.,* 2004). Many countries have developed guidelines and criteria for reuse of water and these guidelines mainly focus on the human health or environmental risk from microbial pathogens, nutrients, total soluble salts, SAR, RSC and toxic metals. Maximum limit of 0.01 mg L^{-1} for Cd for long term irrigation have been recommended (Bouwer & Idelovitch, 1987), while EC, SAR and RSC permissible limits were set as 1.0 dS m^{-1}, 10.0 (mmol $L^{-1})^{1/2}$ and 2.5 $mmol_c$ L^{-1}, respectively (Ayers & Westcot, 1985). Permissible upper limit of Cd is 20 mg kg^{-1} in soil and 10 mg kg^{-1} for animal feeds (FAO, 1998; USEPA, 1993). Critical plant tissue concentration of 5 mg kg^{-1} for Cd has been reported by Macnicol and Beckett (1985), while Kent and Everes (1990) reported normal range of Cd in wheat as 0.1 mg kg^{-1} and Walker (1988) reported Cd permissible limit of 0.05 mg kg^{-1} in all foodstuffs including wheat seeds.

Long term use of effluent for irrigation may result in the buildup of metals in soils (Qadir *et al.*, 1999). Movement of metals through soil profile is considered a slow process and the surface soil accumulate higher concentrations than lower horizon (Kuhad *et al.* 1989; Salmasi & Tavassoli, 2006; Lamy *et al.*, 2006; Murtaza *et al.*, 2008) and salinity and sodicity indicators (EC_e, SAR & RSC) were also relatively high in the effluent-irrigated soils (Ghafoor *et al.*, 1994, 2004; Qadir *et al.*, 1997; Yadav *et al.*,

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2002; Chattha *et al*., 2005; Bashir *et al.*, 2006; Ahmad, 2007; Murtaza *et al*., 2008) compared to canal or tube well water irrigated soils (Rattan *et al*., 2005).

Plants grown with effluent irrigation tends to accumulate higher amount of metals in their tissues. Large differences in accumulation of heavy metals by cereal and legume crops have been reported (Kumar *et al*., 1995; Cieslinski *et al*., 1996). Some plants develop strategies to control metal absorption at soil-root interface. Selection of cereal varieties with respect to restricted metal absorption may add to safer crop production on heavy metal contaminated soils (Chamon *et al*., 2005). Dicotyledonous crop plants tend to accumulate more metals than monocotyledonous crops (Kabata-Pendias *et al*., 1993). Metals transport to grain tissues is restricted in plants (Baker, 1981; Kabata-Pendias *et al*., 1993). Among wheat cultivars, 2.5 times variation of Cd concentration in seed was observed (Wenzel *et al*., 1996). In the seeds of effluent-irrigated wheat, concentration of Cd was found above permissible levels recommended by WHO for foodstuff sampled at Gandakhue, Mulkhanwala, Awanwala and Khanuwala along Satiana road drain, Faisalabad, Pakistan (Farid, 2003).

Increased use of raw city effluent for irrigation and metal accumulation in soils and plants necessitated this study to be carried out under local field conditions to assess Cd accumulation in different crops grown in soils irrigated with raw effluent in comparison with canal or tube well waters.

MATERIALS AND METHODS

Selection of sites: This survey study was conducted at selected locations in peri-urban area of Faisalabad, Pakistan where raw city effluent is used for irrigation of cereal, millets, fodder and vegetables for more than 25 years. The sites were located at villages Uchkera, Marzipura (MP), Malkhanwala (MW), Bypass Samandari Road (BSR), Chak No. 218/RB (C218), Ghulam Muhammad Abad (GMA) and Chak No. 235/RB (C235).

Sample collection and preparation: Effluent, tube well and canal irrigated fields were selected in the same area or from the adjoining area from urban area of Faisalabad. Effluents samples were collected fortnightly for five months during November 2006 to March 2007. The water samples were filtered through Whatman filter paper 42 and two drops of sodium hexa-meta-phosphate per 100 mL samples were added in each bottle to check the precipitation of salts during storage. In duplicate bottles of these samples, concentrated HNO_3 @ 0.25 mL per 100 mL sample was added and stored for metal ion determination.

Plant samples: Shoot and root samples of wheat, maize, chickpea and mungbean were collected at maturity from selected areas and washed with tap water followed by thorough washing with 1% HCl solution and distilled water. Samples were separated into roots, shoots and seeds and were air-dried in shade followed by oven-drying at 65±2°C to constant weight. Oven-dried samples were ground in a Wiley mill fitted with stainless steel blades.

Soil samples: Soil samples were collected from 0−15, 15−30, 30−60, 60−90 and 90−120 cm depths from the close vicinity of plant sampling sites with stainless steel auger. Five sub-samples were collected from the place of plants sampling, which were composited as one sample (about 1 kg) after mixing thoroughly. Soil samples were air-dried, ground and passed through a 2 mm sieve and stored in plastic containers and analyzed for texture and chemical properties (pH_s, EC_e, soluble cations & anions).

Chemical analysis: Water samples were analysed within 10 days of collection for pH, EC, carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), chloride (Cl^-), sulphate (SO_4^{2-}), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) following methods described by the US Salinity Laboratory Staff (1954). From this basic analyses, SAR [$SAR = Na^+/\{(Ca^{2+} + Mg^{2+})/2\}^{1/2}$] and RSC [$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$] were computed and metals were determined by atomic absorption spectrophotometer (AA solar series). Soil samples were extracted with ammonium bicarbonate-diethylene triamine pentaacetic acid (AB-DTPA) solution and Cd concentration in aliquots was determined according to the methods described by Soltanpour (1985). Chemical analyses of soils for pH_s, EC_e and soluble ions were performed, from which sodium adsorption ratio (SAR) was computed following US Salinity Laboratory Staff (1954). Shoot, root and grain samples were digested with di-acid (HNO_3+$HClO_4$) and Cd was determined from the digests by method explained by AOAC (1990) with atomic absorption spectrophotometer (Model Thermo Electron S-Series). Each sample was run in duplicate.

Statistical analysis: The data was analyzed by using statistical/analytical software ”Statistix 8, version 8.1” by applying descriptive statistics and least significant difference (LSD) test.

RESULTS AND DISCUSSION

Irrigation waters: Average concentration of Cd was 1.1, 0.1 and 0.3 mg L^{-1} in effluent, tube well and canal water, respectively. The Cd concentration ranged from traces to 4.7 μg L^{-1}. Raw effluent contained 11.0 and 3.7 times higher amount of Cd than tube well and canal waters, respectively. The Cd concentration was close to the concentration reported by Qadir *et al.* (1997) for Judgewala (JW), Marzipura (MP) and Uchkera locations. Khan *et al.* (1994) reported the Cd concentration of 0.051-0.054 mg L^{-1} for effluents used for growing vegetables at Chak 219 and 220/RB, Tehsil Faisalabad, Pakistan while Farid (2003) reported that Cd concentration was above permissible limit at Malkhanwala along Satiana road drain. However, in the present study, Cd concentration was within permissible limits. The observed concentration of Cd was also towards

Table I: EC (dS m^{-1}), pH and Cd concentration (µg L^{-1}) of effluent, tube well and canal waters used for irrigation at different locations

Location	Parameter	Effluent	Canal	Tube well
Uchkera	EC	2.95 ± 0.18	0.28 ± 0.04	2.15 ± 0.48
	pH	7.48 ± 0.17	7.26 ± 0.36	8.57 ± 0.14
	Cd	1.30 ± 1.00	0.1 ± 0.01	0.08 ± 0.13
Marzipura	EC	3.10 ± 0.14	0.33 ± 0.03	2.93 ± 0.27
	pH	7.90 ± 0.01	7.4 ± 0.10	8.80 ± 0.10
	Cd	1.20 ± 1.00	0.1 ± 0.01	0.07 ± 0.05
Judgewala	EC	3.70 ± 0.17	0.284 ± 0.02	3.00 ± 0.27
	pH	7.56 ± 0.24	7.18 ± 0.29	8.60 ± 0.20
	Cd	1.4 ± 1.20	0.30 ± 0.20	Tr ± 0.00
Malkhanwala	EC	4.3 ± 0.20	0.29 ± 0.01	3.10 ± 0.7
	pH	8.20 ± 0.20	7.24 ± 0.18	7.7 ± 0.60
	Cd	1.42 ± 1.00	1.0 ± 0.20	Tr ± 0.00
Bypass	EC	5.60 ± 0.06	0.29 ± 0.02	3.73 ± 0.22
Samandari	pH	7.52 ± 0.07	7.24 ± 0.09	8.43 ± 0.5
Road	Cd	0.60 ± 0.03	0.20 ± 0.15	0. 1 ± 0.5
Chak No.	EC	3.10 ± 0.40	0.31 ± 0.02	3.30 ± 0.90
218/RB	pH	7.60 ± 0.10	7.30 ± 0.22	8.10 ± 0.60
	Cd	1.20 ± 1.00	0. 40 ± 0.03	Tr ± 0.00
Ghulam	EC	3.29 ± 0.85	0.29 ± 0.01	2.30 ± 0.71
Muhammad	pH	7.51 ± 0.14	7.13 ± 0.12	8.40 ± 0.28
Abad	Cd	1.30 ± 1.00	0.20 ± 0.44	0.11 ± 0.00
Chak No.	EC	5.00 ± 0.60	0.28 ± 0.02	3.00 ± 1.40
235/RB	pH	8.00 ± 0.12	7.40 ± 0.26	8.03 ± 0.50
	Cd	0.30 ± 1.00	0.10 ± 0.08	0.10 ± 0.08
Waters Mean	EC	3.84** (1210)	2.87 (880)	0.293
	pH	7.7 (5)	8.3 (14)	7.3
	Cd	1.1** (266)	0.1 (67)	0.3

n=10 for each location; Tr= traces, SD= Standard deviation; Values in parentheses indicate % increase or decrease over canal irrigation water; ** Significant at P = 0.01

Table II: The EC (dS m^{-1}), pH, SAR, RSC (mmol$_c$ L^{-1}) and Cd concentration (µg L^{-1}) of effluent at different locations

Location	EC	pH	SAR	RSC	Cd
Uchkera	2.95	7.46	12.50	2.00	1.21
Marzipura	3.08	7.93	12.43	2.50	1.16
Judgewala	3.68	7.54	13.50	1.83	1.56
Malkhanwala	4.29	8.24	12.07	1.57	0.70
Bypass Samandari Road	5.63	7.53	18.60	12.20	0.46
Chak No. 218/RB	3.11	7.51	10.43	0.57	0.87
Ghulam Muhammad Abad	3.16	7.58	11.03	1.50	0.66
Chak No. 235/RB	4.70	7.50	14.2	9.27	0.32
LSD	0.44	0.19	2.79	2.19	1.27

lower range than that reported by Ahmed (2007) and Chattha *et al.* (2005) who collected effluent samples at main gate of factories. This difference may be due to sampling of effluent at point sources, temporal variation and closure of industrial units due to energy and economic crises as well as use of alternatives for common metals in Pakistan for the last couple of years. In the present study, sampling was done at field outlet and further dilution at downstream was observed with domestic wastewater and lot of metal concentration may be absorbed by soil in the water course.

The effluent contained considerable amount of Cd but it was below the critical limit proposed by various agencies (Ayers & Westcot, 1985; Bouwer & Idelovitch, 1987; USEPA, 1993; FAO, 1998). Although raw effluent had higher Cd concentration compared to that in tube well or canal waters, they were still within permissible limit for use as irrigation water. However, long term use may cause build up of Cd in the soils.

Lowest mean Cd concentration of 0.60 µg L^{-1} was recorded at BSR while the maximum concentration was of 1.42 µg L^{-1} at MW in effluents. There were significant spatial variations in quality parameters of water at different sites. Location wise differences for canal and tube well waters were non-significant but Cd in effluent samples significantly varied.

The electrical conductivity (EC) of raw effluents varied from 2.5 to 5.7 dS m^{-1}. The EC of all samples of effluent and tube well waters exceeded 1.0 dS m^{-1}. Effluent EC was statistically higher from other sources of irrigation water. The values of residual sodium carbonate (RSC) in effluent water ranged from traces to 12 (Table II) and about 46% effluent samples had RSC above 1.25 mmol$_c$ L^{-1}, while the canal waters low in RSC (data on canal & tube well waters not shown). Sodium adsorption ratio (SAR) was high at all the effluent sampling sites and 60% of the tube well water samples were high in SAR suitable limit of 10. Long term use of these effluents may cause Na^+ hazard in soils due to precipitation of Ca^{2+} by high concentration of HCO_3^- ions. More than 60% of the tube wall water samples had RSC more than 1.25 mmol$_c$ L^{-1}. These results are in line with those of Ibrahim and Salmon (1992), Gafoor *et al.* (1994 &1996), Chattha *et al.* (2005). Results indicated that all the waters were alkaline in reaction having average pH from 7.3 to 8.3 (Table I). The pH of mixed city effluent (7.66) was lesser than ground water collected from different tube wells in nearby area (8.33).

Characteristics of soils: The soils at different locations were texturally different while the soils of adjacent locations belong to same textural class (not shown). The soil pH ranged from 7.30 to 8.22 with mean values of 7.90 in effluent irrigated soils collected from 0-15 cm depth. The pH did not vary with the depth of soils. High concentration of AB-DTPA extractable Cd in effluent irrigated soils over tube well or canal waters irrigated soils was recorded (Table III). Maximum AB-DTPA extractable Cd was found in soil samples collected from 0-15 cm depth at Uchkera (0.30 mg kg^{-1}) followed by GMA (0.248 mg kg^{-1}). Effluent irrigation resulted in 248% increase in Cd contents of surface soils compared with that of tube well irrigated soils while increase over canal irrigated soils was 260%. Critical levels of AB-DTPA/DTPA extractable metals in soil leading to health problems are 0.31 mg kg^{-1} for Cd (MacLean *et al.*, 1987). The Cd level has reached at critical level at Uchkera site. So there is health concern which was also observed in plant samples of legume crops. At Uchkera intensive cultivation of vegetables is practiced and more effluent application may be the reason for higher concentration of Cd. The mean concentration of Cd is high than normal soils irrigated with un-contaminated ground water. These findings conform to results reported by Ghafoor *et al.*

Table III: Vertical distribution of AB-DTPA extractable Cd (mg kg^{-1}) in effluent, tube well and canal waters irrigated soils

Location	0-15 cm	15-30 cm	30-60 cm	60-90 cm	90-120 cm
Effluent water					
Uchkera	0.300 ± 0.23	0.960 ± 0.80	0.300 ± 0.23	0.22 ± 0.17	0.160 ± 0.13
Marzipura	0.080 ± 0.01	0.020 ± 0.01	0.020 ± 0.01	0.02 ± 0.01	Tr ± 0.00
Judgewala	0.080 ± 0.02	0.080 ± 0.01	0.040 ± 0.01	0.060 ± 0.03	0.040 ± 0.01
Malkhanwala	0.020 ± 0.01	0.002 ± 0.00	0.004 ± 0.00	0.002 ± 0.0	0.000 ± 0.00
Bypass Samandari Road	0.200 ± 0.08	0.060 ± 0.02	0.002 ± 0.00	Tr ± 0.00	Tr ± 0.00
Chak No. 218/RB	0.120 ± 0.06	0.060 ± 0.01	0.020 ± 0.01	0.020 ± 0.01	Tr ± 0.00
Ghulam Muhammad Abad	0.240 ± 0.17	0.060 ± 0.02	0.040 ± 0.01	0.020 ± 0.01	0.020 ± 0.01
Chak No. 235/RB	0.040 ± 0.020	0.020 ± 0.011	0.020 ± 0.01	Tr ± 0.00	Tr ± 0.00
Mean	0.135	0.158	0.056	0.043	0.028
Tube well water					
Uchkera	0.056 ± 0.03	0.038 ± 0.02	0.024 ± 0.01	0.042 ± 0.02	0.002 ± 0.00
Marzipura	0.056 ± 0.02	0.026 ± 0.01	0.024 ± 0.01	0.024 ± 0.01	0.010 ± 0.01
Judgewala	0.060 ± 0.03	0.044 ± 0.02	0.054 ± 0.03	0.048 ± 0.02	0.032 ± 0.001
Malkhanwala	0.026 ± 0.01	0.016 ± 0.01	0.028 ± 0.01	0.022 ± 0.01	0.020 ± 0.001
Bypass Samandari Road	0.020 ± 0.01	0.020 ± 0.01	0.014 ± 0.01	0.004 ± 0.00	0.026 ± 0.01
Chak No. 218/RB	0.008 ± 0.00	0.006 ± 0.00	0.004 ± 0.00	0.024 ± 0.01	0.024 ± 0.01
Ghulam Muhammad Abad	0.064 ± 0.03	0.062 ± 0.03	0.066 ± 0.02	0.004 ± 0.00	0.006 ± 0.00
Chak No. 235/RB	0.020 ± 0.01	0.018 ± 0.01	0.002 ± 0.00	0.002 ± 0.00	0.024 ± 0.01
Mean	0.039	0.029	0.027	0.021	0.018
Canal water					
Uchkera	0.020 ± 0.01	Tr ± 0.00	Tr ± 0.00	0.000 ± 0.00	Tr ± 0.00
Marzipura	0.040 ± 0.02	0.020 ± 0.01	0.020 ± 0.01	0.020 ± 0.01	0.020 ± 0.01
Judgewala	0.040 ± 0.02	0.040 ± 0.01	0.020 ± 0.01	Tr ± 0.00	Tr ± 0.00
Malkhanwala	0.020 ± 0.01	0.020 ± 0.01	Tr ± 0.00	Tr ± 0.00	Tr ± 0.00
Bypass Samandari Road	0.080 ± 0.03	0.060 ± 0.02	Tr ± 0.00	Tr ± 0.00	Tr ± 0.00
Chak No. 218/RB	0.040 ± 0.02	0.020 ± 0.02	0.002 ± 0.00	Tr ± 0.00	Tr ± 0.00
Ghulam Muhammad Abad	0.040 ± 0.02	0.001± 0.00	0.001 ± 0.00	0.020 ± 0.00	Tr ± 0.00
Chak No. 235/RB	0.020 ± 0.01	0.020 ± 0.01	0.020 ± 0.01	0.020 ± 0.01	Tr ± 0.00
Mean	0.038	0.023	0.008	0.008	0.003

(Values are mean of 5 samples each)

(1996) and Midrar-ul-Haq *et al.* (2003) where canal irrigated soils had low Cd concentration compared to effluent irrigated soils. However, at present contamination of soils due to effluent irrigation was much lower than

Table IV: Mean Cd concentration (mg kg^{-1}) in crops grown on soils irrigated with effluent, canal and tube well waters

Crop	Concentration (mg kg^{-1}) Effluent	Canal	Tube well
Seed			
Wheat	0.034 ± 0.01	0.013 ± 0.01	0.010 ± 0.002
Chickpea	0.177 ± 0.03	0.128 ± 0.08	0.122 ± 0.05
Maize	0.133 ± 0.01	0.007 ± 0.003	0.009 ± 0.002
Mungbean	0.071 ± 0.04	0.041 ± 0.01	0.046 ± 0.01
Shoot			
Wheat	0.123 ± 0.02	0.019 ± 0.01	0.016 ± 0.005
Chickpea	0.240 ± 0.02	0.138 ± 0.01	0.152 ± 0.01
Maize	0.273 ± 0.11	0.013 ± 0.01	0.019 ± 0.01
Mungbean	0.623 ± 0.30	0.297 ± 0.14	0.329 ± 0.12
Root			
Wheat	0.208 ± 0.17	0.026 ±0.012	0.028 ± 0.01
Chickpea	0.599 ± 0.30	0.297 ± 0.10	0.228 ±0.11
Maize	0.747 ± 0.35	0.385 ± 0.10	0.438 ± 0.02
Mungbean	0.828 ± 0.46	0.402 ± 0.12	0.507 ± 0.12

permissible upper limits of total Cd i.e., 20 mg kg^{-1} for soil as recommended by FAO (1998) or USEPA (1993). There seems gradual build up of Cd in soils, which are under irrigation for more than 25 years.

Distribution of Cd in soil along depth: About 70% of AB-DTPA extractable Cd has accumulated in the upper 30 cm of soil surface (Table III). Cadmium was high in 15-30 cm soil depth at Uchkera, which may be due to its vertical movement in well drained moderately coarse textured sandy loam soil and seepage from neighboring ponds constructed by Water and Sanitation Agency (WASA), Faisalabad for sewage treatment mainly through settling of suspended material. High Cd concentration in surface soil layers has also been reported by Murtaza *et al.* (2008), Ahmad (2007), Butt *et al.* (2005), Midrar-ul-Haq *et al.* (2003), Ghafoor *et al.* (1996 & 2004) in Pakistan and Sutapa and Bhattacharyya (2008), Rattan *et al.* (2005), Yadav *et al.* (2002), Kuhad *et al.* (1989) in India. The clay fractions can adsorb high amount of Cd (Lee, 1997) and accumulation in surface soil is supported by the contents of organic matter higher in surface than sub soils (Singh & Singh, 1994). Further vertical movement of metals in coarse textured soils has been reported by (Salmasi & Tavassoli, 2006; Lamy *et al.*, 2006; Van Oort *et al.*, 2006).

Cadmium in Plants

Wheat: The mean Cd concentration in seeds, shoots and roots was 0.034, 0.123 and 0.208 mg kg^{-1} at the effluent irrigated locations, while the corresponding values were 0.013, 0.019 and 0.026 mg kg^{-1} at canal irrigated sites and 0.010, 0.015 and 0.025 mg kg^{-1} in tube well irrigated areas, respectivly (Table IV). Cadmium ranged from traces to 0.047 mg kg^{-1} in seeds, 0.078 to 0.165 mg kg^{-1} in shoots and 0.171 to 0.269 mg kg $^{-1}$ in roots receiving effluent for irrigation. Maximum concentration of Cd in seeds (0.047 mg kg^{-1}) and roots (0.296 mg kg $^{-1}$) was recorded at Uchkera and 0.165 mg kg^{-1} in shoots at MW sampling site. Effluent irrigated wheat accumulated 2.4, 7.2 and 7.3 times more Cd in seeds, shoots and roots than canal irrigated and 3.4 times more than tube well irrigated plants. Factors like pH, presence of complexing agents, high concentration of Ca, K and Mg and organic matter could complex Cd in soils and may change metal concentration in plants in a given soil environment. In most of the annual crops, tissue concentration of Cd frequently correlates with concentration of metals in soil solution.

Chickpea: Seed Cd ranged from 0.010-0.350, 0.05-0.201 and 0.095-0.019 mg kg^{-1} in effluent, tube well and canal irrigated soils, respectively (Table IV). Mean concentration of Cd in seeds was 0.177 mg kg^{-1} for effluent, 0.122 mg kg^{-1} for tube well and 0.128 mg kg^{-1} for canal irrigated crop. The decreasing order of Cd concentration was root (0.599 mg kg^{-1}) > shoot (0.024 mg kg^{-1}) > seed (0.177 mg kg^{-1}) for effluent irrigated crop.

Mungbean: Seed-Cd ranged from 0.02-0.15, 0.01-0.07 and 0.02-0.06 mg kg^{-1} in effluent, tube well and canal irrigated crops, respectively (Table IV). Mean seed concentration of Cd was 0.07 mg kg^{-1} for effluent, 0.04 mg kg^{-1} for tube well and 0.41 mg kg^{-1} for canal irrigated crops. The decreasing order of Cd concentration was root (0.83 mg kg^{-1}) > shoot (0.62 mg kg^{-1}) > seed (0.07 mg kg^{-1}) for effluent irrigated crop.

Maize: Seed Cd ranged from 0.004-0.040, 0.002-0.02 and 0.002-0.020 mg kg^{-1} in effluent, tube well and canal irrigated soils, respectively. Mean seed concentration of Cd was 0.133 mg kg^{-1} for effluent, 0.009 mg kg^{-1} for tube well and 0.007 mg kg^{-1} for canal irrigated crops. The decreasing order of Cd concentration was root (0.0.747 mg kg^{-1}) > shoot (0.274 mg kg^{-1}) > seed (0.133 mg kg^{-1}) for effluent irrigated crop. Among crops, chickpea seeds acquired maximum Cd (0.217 mg kg^{-1}) followed by maize (0.133 mg kg^{-1}). The order for Cd accumulation in seeds was chickpea > maize > mungbean > wheat for effluent irrigated crops, while similar pattern of Cd accumulation was in tube well and canal irrigated crops.

The results are in line with Kent and Everes (1990) who reported 0.1 mg kg^{-1} Cd concentration in wheat seed as normal whereas Walker (1988) stated that the permissible limit for Cd in all foodstuffs is 0.05 mg kg^{-1}. Cadmium concentration was found higher in chickpea, mungbean and maize than the limits proposed by Walker (1988). Crops grown on sandy soils and having low organic matter tend to absorb greater amount of a certain heavy metal particularly Cd and Zn (Alloway, 1995). Effluent irrigated mungbean contained the highest concentration of Cd in shoots (0.62 mg kg^{-1}) and lowest in wheat crop (0.123 mg kg^{-1}). Yuruk and Bozkurt (2006) reported normal Cd concentration in seeds of mungbean and chickpea as 0.05 and 0.07 mg kg^{-1}, respectively.

Crop species differentially acquired Cd concentration in their tissues. Similar observations were recorded by Rattan *et al.* (2005) for wheat, maize, rice and fodder crops. The concentration of Cd varied widely in different parts of the cereal and legume crops.

Differential metal accumulation in plants were also accounted due to differences in soil properties, plant physiology, pollution inputs, agricultural management practices, prevailing climate (McLaughlin *et al*., 1997; Jansson & Oborn, 2000) and rhizosphere (Martino *et al*., 2000; Saleh Al‒Garni, 2006). All these factors modify the solubility, speciation, mobility and uptake of metallic Cd as well as of pollutant metals by roots (Walter, 2005). Low Cd concentration in seeds suggests that it is known to be poorly transported to seeds due to binding in roots (Baker 1981; Kabata-Pendias *et al*., 1993).

CONCLUSION

This study showed that although Cd was in permissible limit for their use as irrigation, the effluent water was unsafe for irrigation with respect to Na hazards. Plant analysis showed that roots retained most of the absorbed Cd from soil with a little transfer to shoots and least into the seeds of all crops. Effluent irrigated chickpea seeds acquired the highest Cd. It seems better to prefer cereal cultivation over leguminous crops on effluent irrigated soils to reduce the hazard of Cd contamination.

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