A COMPARATIVE STUDY OF ACCUMULATION OF HEAVY METALS (CADMIUM AND MERCURY) IN VEGETABLES IRRIGATED BY SEWAGE WATER, FRESH WATER AND RIVER WATER

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ABSTRACT: The comparison was made for the heavy metals (Cd and Hg) contents in the vegetables irrigated by sewage water, tube well water and river water. The study was carried out for the vegetables irrigated by sewage water around the suburban areas of Lahore and its comparison to the vegetables grown in fresh water. Five vegetables i.e. turnip, radish, coriander, spinach and brassica were selected. The Atomic Absorption analysisshowed theconcentration of cadmium in sewage irrigated vegetables was higher as compared to those irrigated by fresh water. The cadmium content in these vegetables was found to be 0.03-0.61mg kg^{-1} as compared to 0.03-0.53 mg kg^{-1} irrigated in tube well waterand 0.03-0.32 mg kg^{-1}irrigated in river water. Vegetables like spinach, and brassica were highly contaminated with cadmium above the permissiblelimits. The mercury accumulation in vegetables was below the maximum permissible limit 0.01mgkg^{-1}specified by FDA/WHO.

Key Words: Cd and Hg accumulation, Vegetables, Suburban Lahore, FDA/WHO limits

INTRODUCTION:

Edible parts of vegetables contain carbohydrates, proteins, vitamins, minerals and trace elements [1]. The excessive use of vegetables causes accumulation of these trace elements in human body [2]. The contents of heavy metals in vegetables are due to sewage water, soil, manure and the pesticides used for their growth [3, 4]. In many countries around the world vegetables are irrigated by sewage water [5-7]. The sewage water fulfil the shortage of irrigation water and deficiency of fertilizers [8]. Sewage water effect the growth of reddish or potatoes but not the leafy vegetables [9]. This water contains Sodium, Potassium, Nitrates, Nitrites and toxic heavy metals Cadmium, Lead, Arsenic, Chromium, Copper, Nickel, Zinc, Cobalt, Magnesium and Pathogens which accumulate in vegetables grown in this water [10-12]. Heavy metals Cadmium, Lead, Nickel, Aluminium, Chromium, Copper, Manganese, Zinc are abundantly used in industrial processes as catalysts, oxidants, dyes and have greater chances of accumulation in living systems [13, 14].

The heavy metals accumulation is a risk for plants and animal life [15, 16]. The accumulation of heavy metals, due to their mutagenicity, teratogenicity, carcinogenicity got global attention [17]. Their prolonged intake affect the human kidney and liver and cause cardiovascular and nervous problems [18]. Anthropogenic input of Cadmium to soils occurs by aerial deposition, sewage sludge, manureand phosphate fertilizer application to agricultural soils [19]. It ispresent in water as carbonates, hydroxides, chlorides, sulphates and organic humic acids complexes [20]. Cadmium is found at a distance of 50 km from its source when mixed with water [21]. The limiting concentration of Cd by NEQS (National Environmental Quality Standards) for irrigation water is 0.10 μgmL^{-1} [22]. United Nations standard for nutritional and agriculture materials set the maximum permissible level of 0.01 ppm for Cd in irrigational waters [23, 24]. According to WHO [25] maximum permissible limit for cadmium content in food products is 0.1 ugg^{-1}. United Nations standard for nutritional and agriculture materials [26] has determined the maximum permissible level of 7.0 ugg^{-1} of body weight for humans daily diet. The American Food Industries [27] has introduced a standard which permits a maximum amount of 92 μg per day for cadmium existing in human's daily diet. Human body systems are seriously affected due to increased dietary accumulation of heavy metals such as Lead and Cadmium [28]. Lacatusu et al [29] has reported that cadmium and mercury contaminated soil and vegetables have significantly reduced human life expectancy rate in Romania decreasing average age at death by 9–10 years. A disease named itai itai spread in Japan during 1950's when cadmium contaminated rice were eaten by women suffering from menopausal stage with low iron and zinc levels. Mercury is non-biodegradable having high mobility and bio-accumulative nature [30]. Annually 50 tons of mercury is emitted in atmosphere due to various anthropogenic and natural sources [31]. A large amount of mercury is produced by human activities [32]. Mercury accumulation is more in roots than seeds and shoots. It has been observed that monomethyl mercury has higher transport rates than other forms of mercury [33]. A permissible limit for Hg in irrigation water as specified by NEQS (National Environmental Quality Standards) is 0.01mg/L [22]. The maximum permissibl limit of 0.03 μgg^{-1} has been specified by WHO/ FDA [25] in foods and food stuff. Serious health problems may arise when the concentration of mercury supersedes the allowable dietary limits.

Health Critical Values (HCVs) specified by British Environment Agency [34] for Inorganic, elemental and methyl mercury compounds are summarized in Table 1 considering the kinetics, toxicity and exposure to each form.

The main target of mercury contamination is Central nervous System (CNS) that may cause hearing and mental retardation, vision loss and ultimately prove fatal to life. Birth defects, sperm damage and miscarriages have also reported. Chromosomal damage produces syndrome like mongolism [35].

Table 1: Health Criteria Values Recommended for Mercury

Parameter	Elemental Mercury	Inorganic Mercury	Methyl Mercury
Tolerable Daily Intake (ug/kg body weight per day)	Not derived	2	0.23
Mean Daily Intake oral, ug/day	negligible	1	0.5

MATERIAL AND METHODS:

Instruments

Atomic Absorption Spectrometer

A Perkin–Elmer Analyst 700 atomic absorption spectrometer (AAS) equipped with two fully integrated atomizers i.e. a burner system for flame atomization and a graphite furnace for electrothermal atomization and an autosampler model AS-800 and a cooling system were used. The assembly was operated from an interfaced computer running AA WinLab software. HGA (Heated Graphite Furnace Atomizer) bearing full stabilized temperature platform was used in all tests.

MHS-15 Mercury Hydride Generator

Mercury in the samples was analyzed by Perkin Elmer MHS-15 as Mercury Hydride Generator coupled with AAnalyst 700 atomic absorption spectrometer. MHS-15 offers detection limits upto ng range.

Graphite tubes

Pyrolytic graphite tubes with an integrated platform were used that provided STPF (Stabilized Temperature Platform furnace) conditions.

Hollow Cathode Lamp for Cadmium

Perkin Elmer *Lumina*^{R} Hollow Cathode Lamp having wavelength 228.8nm was used as line source. The lamp current settings were automatically set by the instrument software.

EDL(Electrodeless discharge lamp) for Mercury

Perkin Elmer Coded EDL with built in power supply for Hg having wavelength 253.7nm was used with AAnalyst 700 AAS for analysis of Mercury.

Hot Plates

STEDEC Rectangular Hot Plates (Temperature range 30 to 350^{o}C)

Electric Oven

Carbolite Electric Oven used for drying soil and vegetable samples (Temperature Range 0-1000^{o}C)

Analytical Balance

Shimadzu AUX 200 micro analytical balance capable of weighing 10mg to 220g.

Millipore Ultrapure Water Purification Unit

Millipore Simplicity UV system was used for production of the Type-I water having resistivity of 18.2Mohm-cm was used for production of Type-I ultrapure deionized water.

Teflon Beakers

Teflon Beakers 100mL were used for wet ashing of the soil and vegetable samples.

Auger Sampler

A standard stainless steel auger hand sampler for sampling at the depth of 10cm depth of soil.

Chemicals

Hydrofluoric Acid 40% BDH Analar Grade, Perchloric Acid 70% BDH Analar. Grade, Nitric Acid 67%BDH Spectroscopy Grade, Sulphuric Acid 98% Panreac Spectroscopy Grade, Deionized Water Type-I, Potassium Permanganate Merck Extrapure, Potassium Persulphate ($K_2S_2O_8$)Fluka Puriss, Sodium Chloride Fluka Puriss, Hydroxylamine Sulphate Merck Extrapure, Tin Chloride $SnCl_2.2H_2O$ Merck Extrapure, BDH Stock Standard Solutions of 1000mg/L of Cd and Hg for Atomic Absorption Spectrometry

Sampling

The samples were taken from the agriculture farms of three different sampling areas of Saggian Khuda Yar, Nain Sukh Lahore, and River Ravi near Saggian Bridge irrigated by fresh, sewage and River Ravi water respectively.The sampling was done in the months of January and February 2012 from the selected fields.

Collection and Preparation of Water Samples

Water samples were collected in accordance with methods described by EPA [36] in triplicate separately from fresh tubewell, river Ravi at the points where it is taken for irrigation and from sewage water. The collected samples were acidified with 0.5N Nitric Acid to maintain pH<2.

Collection and Preparation of Soil Samples

Vegetable and soil samples were collected by Radojevic and Bashkin method [37].Soil samples were taken diagonally from opposite corners of each field in triplicate with the help of auger sampler at the depth of 10 cm. The collected soil samples were dried in an electric oven at 110^{o}C for 8 hours, grinded using Tema Mill to pass a 200 mesh sieve. For mercury analysis, the grinding was avoided and soil samples were homogenized using conning and quarting technique.

Collection and Preparation of Vegetable Samples

Three leafy vegetables, coriander, spinach and brassica and two root vegetables, turnip and radish were chosen for sampling. The vegetable samples were taken diagonally from opposite corners of each field in triplicate. At laboratory the each sample was washed with Type-I water and treated as the method given. The edible portions of the samples were chopped with knife and air dried for 48 hours under shade. The samples were grinded using a commercial food chopper and allowed to pass through the 2 mm sieve. The homogenized samples were dried in an oven at 105 ^{o}C for 18 hours [38]and then processed for analysis of Cadmium. However, for mercury analysis the homogenized samples were processed as such.

Determination of Cadmium

Cadmium was determined in the samples using Graphite Atomic Absorption Spectrometry (GFAAS).

The collected water samples were prepared using an EPA 3005a [39] method for surface and ground waters.

Cadmium in soil samples was analyzed using Graphite Furnace Atomic Absorption Spectrometric method [40].

Various acid digestion procedures have been reported [41].A method reported by Ganje and Page [42] adopted in the present study is a wet ashing acid digestion procedure using mixture of conc. $HClO_4$ acid, conc. HNO_3 acid and conc. H_2SO_4 acid

Preparation of Calibration Standards

Stock Solution A (10ppm Cd)

1ml of 1000ppm cadmium chloride solution (BDH Atomic spectrometry Grade) was taken in a precalibrated 100mL volumetric flask and volume was made upto mark with Type-I water.

Stock Solution B (10ppb Cd)

100ul of stock solution A was diluted to 100mL with Type-I water.

Preparation of Working Standards and Calibration Curve

Automatic Dilution Technique of Perkin Elmer Autosampler AS-800 was utilized for the preparation of working standards ranging from 2ppb to 10ppb.

The calibration curve recorded is given in fig 1.

Table 2: Instrumental Settings for Cadmium Analysis

Instrumental Parameter	Setting
Wavelength(nm)	228.8
Slit width (nm)	0.7L
Lamp current (mA)	4 mA
Sample volume (µL)	20
Signal type:	AA-BG
Measuring Signal:	Peak Area
Detection Limit(mg/Kg)	0.001
Injection Temperature	20^{o}C

Table 3: Graphite Furnace Temperature Program

	Temp(^{o}C)	Ramp Time (Sec)	Hold Time (Sec)	Internal Flow ml/min
Drying 1	100	5	20	250
Drying 2	140	15	15	250
Ashing	850	20	20	250
Atomization	1650	0	5	0
Cleaning	2600	1	5	250

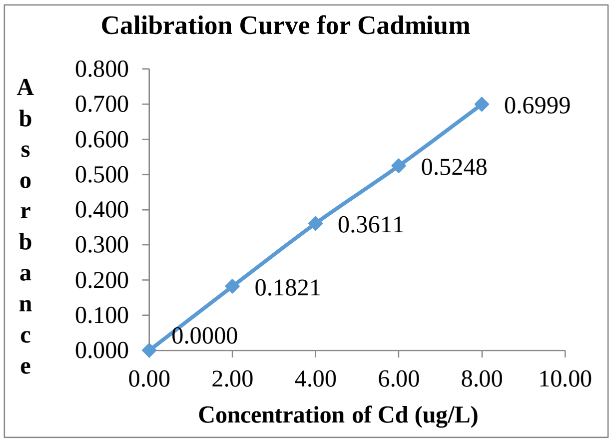

Figure 1: Calibration Curve of Cadmium by Graphite Furnace AAS

Measurement of the samples

The absorption signal of the prepared samples was then recorded against calibration curve (fig.1) using IAEA-140 (fucus sp) as a Standard Reference Material

Determination of Mercury

Cold Vapour Atomic Absorption Spectrometry was used for determination of mercury in the collected samples. The absorption signals were measured at 253.7nm by Perkin Elmer AAnalyst700 AA Spectrometer. A standard dissolution method [43] was employed for determination of total mercury in soil and vegetable samples.

Preparation of Water Samples

The collected water samples were prepared using an EPA method [44] for determination of total mercury in surface and ground waters. The sample blank was prepared similarly by above method.

Preparation of Working Standards and Calibration Curve

BDH Mercury Stock Solution1000 mg/L Hg for AA spectroscopy

Mercury Standard Solution (A) = 1 mg Hg/L

Diluted 100uL of above standard solution in 100mLof 1.5% HNO_3 and stabilized by the addition of a few drops of 5% $KMnO_4$ solution.

0.15 mol/L (1.5% V/V) hydrochloric acid

1 mol/L (10% V/V) Hydrochloric acid

0.22 mol/L (1.5% V/V) nitric acid

5% (W/V) $KMnO_4$ solution

5% (W/V) $SnCl_2$ solution (Dissolved 50 g tin (II) chloride dehydrate ($SnCl_2$. $2H_2O$) in 10% HCl solution and volume made upto 1000 mL with 10% HCl solution)

Preparation of Calibration Curve

Three working calibration standards of 2.5, 5.0 and 10 ug/L of Hg were prepared to get calibration curve. The instrumental and analytical settings were made as given in table 4 and absorbance reading for each working standard appeared on the calibration curve as shown in Fig 2.

RESULTS AND DISCUSSIONS

Cadmium

Cadmium in Water Samples

The cadmium content in Ravi River water irrigating the vegetable fields in Saggian Bridge area was found to be 1.22$\pm$0.01 µg/L (Table-5). These values are within the safe limits of NEQS for irrigation water [27]. The sewage water used to irrigate the fields of Nain Sukh Area showed higher Cadmium concentrations i.e.3.23$\pm$0.19 µg/L (Table-5). These values are highbut within safe limits of United Nations standard for nutritional and agriculture materials [28]. The ground water samples from the tube wells irrigated field showed the lowest Cadmium concentrations i.e.1.50$\pm$0.01 µg/L within permissible levels.

Table 4:Instrumental Parameters for MHS-15 and AAnalyst700 for Hg

Lamp Current	185 mA
Analytical wavelength	253.6 nm
Slit width and height	0.7 nm
Radiation source	EDL for Hg.
QTA heating	No flame required.
Prepared measurement volume	10 mL
Pre-reaction purge time	5 sec
Reaction Time	30 sec
Post-reaction purge time	50 sec
Carrier Gas Used	Argon

Measurement of the samples

Prepared samples were then analyzed against this calibration curve using IAEA-140 (fucus sp) as standard reference material.

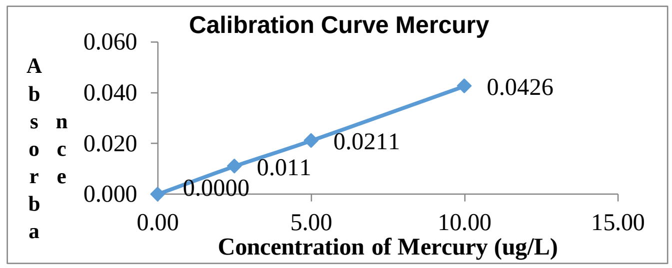

Figure 2: Calibration Curve of Mercury using Perkin Elmer MHS-15.

Cadmium in Soil Samples

Table 6, 7 and 8 depict that cadmium concentrations in soils irrigated by fresh water, sewage water and river water were found to be 0.01-0.06 mg kg^{-1} , 0.01-0.09 mg $kg^{-1}$and $\leq$0.01 mg kg^{-1} respectively. The comparison of the soil samples depicted in Figure 3 clearly shows that the sewage water irrigated soils of Nain Sukh Area are more contaminated with cadmium than the soils of Saggian Bridge irrigated by river water and ground water

Table 5: Concentration of Cadmium in Water Samples

Sample I.D	Specification	Cadmium ug/L	Mercury ug/L
GW-1	Ground Water	1.49	ND
GW-2	Ground Water	1.51	ND
GW-3	Ground Water	1.53	ND
SW-1	Sewage Water	3.37	ND
SW-2	Sewage Water	3.59	ND
SW-3	Sewage Water	3.23	ND
RW-1	River Water	1.23	ND
RW-2	River Water	1.21	ND
RW-3	River Water	1.22	ND

ND= less than 2.5ug/L

Cadmium in Vegetable Samples

Table 9, 10 and 11 show results for concentration of cadmium in five vegetable samples i.e. Turnip, Radish, coriander, spinach and brassica leaves irrigated by fresh, river and sewage water respectively. The vegetables grown on soils irrigated by fresh water contained cadmium from 0.03-0.53 mg kg^{-1}. The leafy vegetables such as brassica showed the highest concentration upto 0.53 mg kg^{-1} which were well above the limits specified by WHO/FDA that is 0.1mg kg^{-1}. On the other hand root vegetable like turnip containing the lowest concentration upto 0.03 mg kg^{-1}.

Table 6: Concentration of Cadmium in soil samples irrigated by fresh water

Sample Identity	Irrigation Water	Vegetable Name	Sampling Site	Cadmium*mg/kg	Mercury*mg/kg
S_1	Fresh Water	Turnip	Saggian	0.05	0.029
S_2	Fresh Water	Turnip	Saggian	0.06	0.025
S_3	Fresh Water	Radish	Saggian	0.01	0.014
S_4	Fresh Water	Radish	Saggian	0.01	0.033
S_5	Fresh Water	Coriander	Saggian	0.01	0.051
S_6	Fresh Water	Coriander	Saggian	0.01	0.286
S_7	Fresh Water	Spinach	Saggian	0.03	0.033
S_8	Fresh Water	Spinach	Saggian	0.03	0.037
S_9	Fresh Water	Brassica	Saggian	0.01	ND
S_{10}	Fresh Water	Brassica	Saggian	0.01	ND

***Mean average of three readings ND= less than 0.01mg kg^{-1}**

Table 7: Concentration of Cadmium in soil samples irrigatedby Sewage water

Sample Identity	Irrigation water	Vegetable grown	Sampling Site	Cadmium *mg/kg	Mercury *mg/kg
SS-1	Sewage Water	Turnip	Nain Sukh	0.01	0.136
SS-2	Sewage Water	Turnip	Nain Sukh	0.01	0.085
SS-3	Sewage Water	Radish	Nain Sukh	0.07	0.043
SS-4	Sewage Water	Radish	Nain Sukh	0.06	0.091
SS-5	Sewage Water	Coriander	Nain Sukh	0.02	0.094
SS-6	Sewage Water	Coriander	Nain Sukh	0.02	0.045
SS-7	Sewage Water	Spinach	Nain Sukh	0.01	0.024
SS-8	Sewage Water	Spinach	Nain Sukh	0.01	ND
SS-9	Sewage Water	Brassica	Nain Sukh	0.08	ND
SS-10	Sewage Water	Brassica	Nain Sukh	0.09	0.023

***Mean average of three readings ND= less than 0.01mg kg^{-1}**

Table 8: Concentration of Cadmium in soil samples irrigatedby river water

Sample Identity	Irrigation Water	Sampling Site	Vegetable Grown	Cadmium *mg/Kg	Mercury *mg/Kg
RS-1	Ravi Water	Saggian Bridge	Turnip	ND	0.045
RS-2	Ravi Water	Saggian Bridge	Turnip	ND	0.054
RS-3	Ravi Water	Saggian Bridge	Radish	ND	ND
RS-4	Ravi Water	Saggian Bridge	Radish	ND	0.112
RS-5	Ravi Water	Saggian Bridge	Coriander	ND	ND
RS-6	Ravi Water	Saggian Bridge	Coriander	ND	0.307
RS-7	Ravi Water	Saggian Bridge	Spinach	ND	0.305
RS-8	Ravi Water	Saggian Bridge	Spinach	ND	0.276
RS-9	Ravi Water	Saggian Bridge	Brassica	0.01	0.215
RS-15	Ravi Water	Saggian Bridge	Brassica	0.01	0.284

***Mean average of three readings ND= less than 0.01mg kg^{-1}**

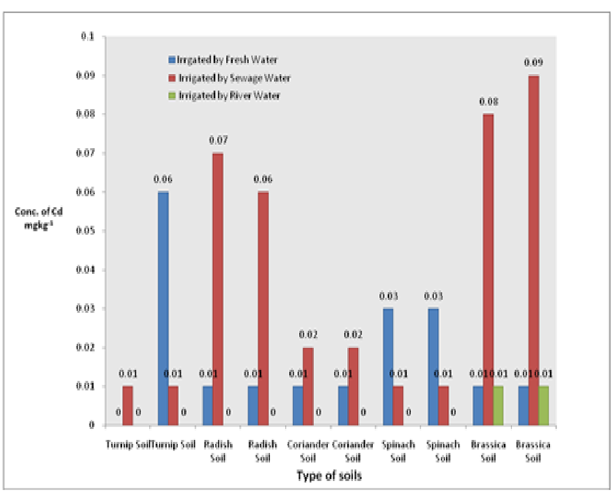

Figure 3:Comparison of Cadmium Concentration in soils irrigated by Fresh Water, River water and Sewage Water

The vegetables grown on soils irrigated by river water contained cadmium from 0.03-0.32 mg kg^{-1}. The spinach showed the highest concentration upto 0.32mg kg^{-1} while turnip contained the concentration as low as 0.03 mg kg^{-1}.

The vegetables grown on soils irrigated by sewage water contained cadmium from 0.03-0.61mg kg^{-1}. The brassica leaves showed the highest concentration upto 0.61mg kg^{-1} while turnip contained the concentration as low as 0.13 mg kg^{-1}.

The comparison of these vegetables according to the quality of water used for irrigation is given in Figure 4. The results showed that the uptake of cadmium depends upon the type of the plant as the spinach showed higher cadmium uptake in samples irrigated by river water than in sewage water. However the brassica leaves showed higher concentration of cadmium in fields irrigated by sewage water than in river water. From all the results it was found that cadmium uptake was higher in the vegetables irrigated by sewage water and river water as compared to those irrigated by fresh ground water.

Table 9: Sampling data for vegetable samples irrigated by Fresh water

Sample Identity	Vegetable Name	Irrigation Water	Sampling Site	Cadmium *mg/Kg	Mercury*mg/Kg
V-1	Turnip	Fresh Water	Saggian	0.03	ND
V-2	Turnip	Fresh Water	Saggian	0.03	ND
V-3	Radish	Fresh Water	Saggian	0.10	ND
V-4	Radish	Fresh Water	Saggian	0.10	ND
V-5	Coriander	Fresh Water	Saggian	0.08	ND
V-6	Coriander	Fresh Water	Saggian	0.06	ND
V-7	Spinach	Fresh Water	Saggian	0.47	0.020
V-8	Spinach	Fresh Water	Saggian	0.53	0.02
V-9	Brassica	Fresh Water	Saggian	0.27	ND
V-10	Brassica	Fresh Water	Saggian	0.32	ND

*Mean average of three readings ND= less than 0.01mg kg^{-1}

Table 10: Sampling data for vegetable samples irrigated by River Ravi water

Sample Identity	Vegetable Name	Irrigation Water	Sampling Site	Cadmium *$mgkg^{-1}$	Mercury*$mgkg^{-1}$
VR-1	Turnip	River Ravi	Saggian Bridge	0.06	ND
VR-2	Turnip	River Ravi	Saggian Bridge	0.12	ND
VR-3	Radish	River Ravi	Saggian Bridge	0.13	ND
VR-4	Radish	River Ravi	Saggian Bridge	0.12	ND
VR-5	Coriander	River Ravi	Saggian Bridge	0.26	ND
VR-6	Coriander	River Ravi	Saggian Bridge	0.32	ND
VR-7	Spinach	River Ravi	Saggian Bridge	0.27	ND
VR-8	Spinach	River Ravi	Saggian Bridge	0.32	ND
VR-9	Brassica	River Ravi	Saggian Bridge	0.03	ND
VR-10	Brassica	River Ravi	Saggian Bridge	0.03	ND

*****Mean average of three readings ND= less than 0.01mg kg^{-1}

Table 11: Sampling data for vegetable samples irrigated by sewage water.

Sample Identity	Name of Vegetable	Irrigation Water	Sampling Site	Cadmium *mg/Kg	Mercury *mg/Kg
VS-1	Turnip	Sewage Water	Nain Sukh	0.03	ND
VS-2	Turnip	Sewage Water	Nain Sukh	0.17	ND
VS-3	Radish	Sewage Water	Nain Sukh	0.08	ND
VS-4	Radish	Sewage Water	Nain Sukh	0.24	ND
VS-5	Coriander	Sewage Water	Nain Sukh	0.02	ND
VS-6	Coriander	Sewage Water	Nain Sukh	0.08	ND
VS-7	Spinach	Sewage Water	Nain Sukh	0.45	0.02
VS-8	Spinach	Sewage Water	Nain Sukh	0.59	0.02
VS-9	Brassica	Sewage Water	Nain Sukh	0.41	ND
VS-10	Brassica	Sewage Water	Nain Sukh	0.61	ND

***Mean average of three readings ND= less than 0.01mg kg^{-1}**

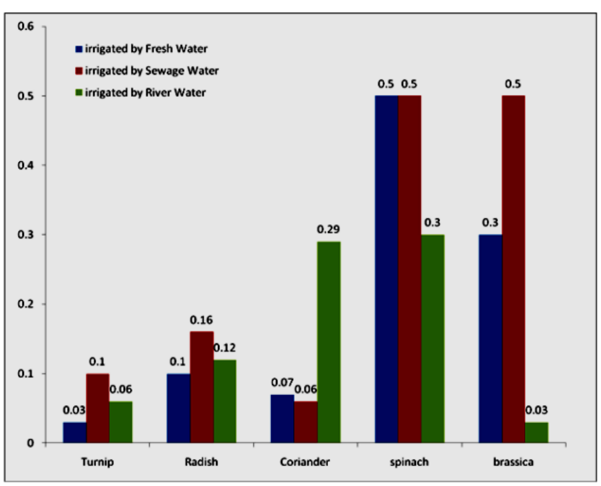

Figure 4:Comparison of Mean Cadmium Concentration in vegetables irrigated by Fresh Water, River water and Sewage Water

Mercury

Mercury in Water Samples

Table 5 shows that mercury content in fresh, sewage and river water was found to be < 2.5 ug/L which depicts that the water quality with respect to mercury concentration is within the safe permissible limit of 10 ug/L specified by NEQS and WWF in 2007.

Mercury in Soil Samples

Table 9, 10 and 11 show the results of mercury in soil samples irrigated by Fresh water, sewage water and river water respectively. The results showed that most of the soil samples irrigated by the river water, sewage water and fresh water contained mercury concentrations 0.045-0.284 $mgkg^{-1}$, 0.023-0.136 $mgkg^{-1}$, and 0.014-0.286 $mgkg^{-1}$ respectively. The comparison of the soil samples depicted in Figure 5 clearly shows that soils irrigated by river water seem to be more contaminated with mercury than the soils irrigated by sewage water and ground water despite the fact that the mercury content of sewage water, river water and fresh water were well below the permissible safety standards. It is the evidence that the Hg is collected from the irrigation water in the soil and remains there for a long time to contaminate the crops grown in that soil.

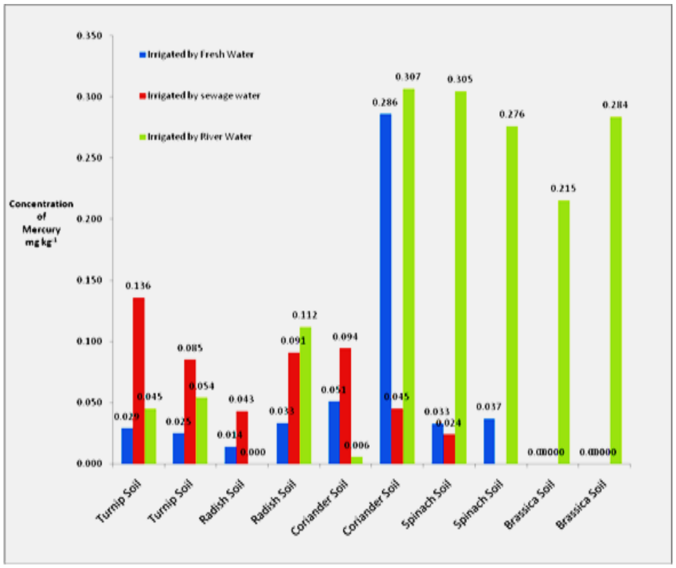

Figure 5:Comparison of Mercury Concentration in soils irrigated by Fresh Water, River water and Sewage Water

Mercury in Vegetable Samples

Results for concentration of mercury in five vegetables i.e. Turnip, Radish, coriander, spinach and brassica leaves irrigated by fresh water, river water and sewage water respectively are shown in Tables 9, 10, 11.

This study showed that mercury content was below the detection limit i.e. 0.01mg kg^{-1} in all the vegetables except the spinach irrigated by fresh water and river water that contained 0.020mg kg^{-1}. Thus the mercury content in all the vegetable samples collected in triplicate was within permissible safety limits of WHO/FDA.

CONCLUSION

Objective of this study was to monitor the levels of toxic heavy metals (Cd and Hg) in vegetables with respect to the quality of water used for irrigation, in particular, the sewage water being used for vegetable growth around periphery of Lahore in the areas like the Saggian Bridge and Nain Sukh.

Present study shows that the concentration of cadmium and mercury were comparatively high in leafy vegetable such as spinach and brassica. TheCadmium concentration was higher than the permissible limits of WHO i.e. $0.1mg.kg^{-1}$ in leafy vegetables like spinach and brassica leaves. However, the mercury concentrations in both vegetable and soils were found to be within the permissible limits given by W.H.O/ F.A.O (1999) and safe in consumption point of view. The results have revealed that the sewage water causes more cadmium accumulation to the soil and vegetables as compared to the river water and tube well water.

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