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Status of Heavy Metals in Soil and Vegetables Grown in Peri-Urban Areas of Jabalpur District, Madhya Pradesh, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The contamination of soil and vegetables by heavy metals is a critical environmental and public health issue, particularly in regions where wastewater is utilized for irrigation. This study assesses the concentration of heavy metals, (Cr, Zn, Cd, Fe, Mn, Ni, Pb, As, Co and Cu) accumulated in soils and vegetables grown in *Peri*-urban areas which are mainly irrigated with wastewater.

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Place and Duration of Study: This study was conducted in Department of Soil Science and Agricultural Chemistry, JNKVV, Jabalpur, Madhya Pradesh during 2022-23.
Methodology: Heavy metal content was measured using an Inductively coupled plasma-Mass Spectroscopy. Few indices for human health were also studied. Ten sites were chosen for soil and plant samples for analysis of metal content.
Results: The study revealed that the metal content of soil samples were below the permissible limits except for soil collected from Khandari site which had Co above the permissible level (203.65 mg/kg) and slightly Cd contamination in Khurji site (0.09 mg/kg). In case of vegetables, brinjal collected from Regama and Kumhi site showed Fe and Cd contamination (735.67 mg/kg, 476.33 mg/kg) and (0.35 mg/kg, 0.34 mg/kg), respectively. Potato and cabbage collected from Khurji and Khandari sites showed Fe contamination of 455.67 mg/kg and 670.83 mg/kg, respectively. Further the result on transfer factor for vegetables was <1, except potato collected from Khandari site which had Cd accumulated in edible portion (11.70). Wheat crop collected from Khurji site also had Cd accumulated (24.66) in grain portion.
Conclusion: Despite few vegetables showed contamination by metals, health risk parameters *viz* Daily intake of metals, Health risk index and Metal pollution index but were found at safe levels. Thus, it can be concluded that there was no apparent risk for human beings after consumption in *Peri*-urban regions of Jabalpur district. Still to ensure quality of soil, vegetables and human health measures should be taken to regulate and address pollution of heavy metals in peri-urban areas.

Keywords: Heavy metals; vegetables; health risk index; peri-urban areas.

1. INTRODUCTION

The reserves of water are currently being depleted globally due to increased industrialization and population growth. In order to lessen the existing strain on these resources, it is necessary to implement techniques like recycling and reuse [1]. An estimated 80% of the vegetables consumed locally are grown using wastewater, and around 7% of all irrigated land worldwide is irrigated using wastewater in one way or another [2]. The World Health Organization (2006) [3] states that over 10% of people across the globe consume food that has been irrigated with wastewater.

Using wastewater to irrigate agricultural land is a frequent technique in underdeveloped countries [4]. The use of unconventional water sources, such as treated domestic wastewater (TWW), as a substitute water supply for crop irrigation in arid and semi-arid areas has drawn a lot of interest [5]. Due to a lack of organization and sewage treatment facilities, many enterprises release untreated wastewater onto nearby farms. This can cause a buildup of different organic and inorganic toxins [6].

Numerous studies have demonstrated that waste water irrigation increases inputs of nitrogen, phosphorous, potassium, and trace metals (Cu, Mn, Fe, and Zn) while also improving soil fertility and agricultural output [7]. On the other hand, prolonged, continued waste water irrigation may eventually harm the health of the soil in some unexpected ways. According to [8], heavy metals pose the greatest danger to the sustainability and quality of soil. Because these metals are neither biodegradable nor leachable, they are referred to as ubiquitous environmental contaminants. As a result, soil resources are depleted, plant development is hampered, and crop yields decline [9].

When wastewater is used negligently and irregularly to irrigate agricultural land, it can eventually cause these dangerous pollutants to settle in the soil [10]. Agriculture crops are impacted by the presence of heavy metals in the soil, which presents a serious risk to public health [11]. These pollutants then get absorbed by plants and accumulate in various human organs through plant consumption [12].

The main source of the risk factors for heavy metal contamination in food is agricultural products, such as cereals, crops, and vegetables. These supplies have affected many parts of the world, but only developing nations have been affected [13]. Leafy vegetables compared to grain or fruit crops have the highest metal uptake rate of any crop and serve as a bio-indicator of soil pollution, despite being one of the most popular daily diets due to their enrichment with nutritious elements (e.g., fiber, minerals, and vitamins) [14]. The edible portions of leafy vegetables have higher accumulations of trace elements. Vegetables might differ in the sequence in which trace elements concentrate and accumulate, as well as in the edible sections (root, stem, and leaf) of the vegetable [15]. As a result, vegetables contaminated with toxic metals are hazardous to human health. Previous research [16] revealed that consuming an excessive amount of heavy metal-contaminated vegetables may have carcinogenic, mutagenic, neurotoxic, and teratogenic effects on human health, posing a serious risk to health outcomes such as Alzheimer's in adults, intellectual disability in children, DNS (deviated nasal septum), insomnia, kidney, and liver diseases, among others. It is therefore, essential to consider the possible impacts of using TWW for irrigation on soil contamination by heavy metals (HM) [5].

To safeguard public and environmental health, the World Health Organization (WHO) has established maximum allowable limits for the amounts of heavy metals in water, crops, and soil [17-20]. Furthermore, precise information regarding the toxicity of heavy metals in crops grown in affected areas must be made accessible. The present investigation aimed to estimate the amounts of particular heavy metals (Fe, Co, Mn, Pb, Zn, Cr, Ni, Cu, As, and Cd) in soil, and vegetable samples in the areas surrounding the selected locations. Several factors were determined in order to calculate the health risk: transfer factor, Daily intake of metals, Health risk index, and Metal pollution index.

2. MATERIALS AND METHODS

2.1 Study Area

Jabalpur is located at the coordinates of 23°10′N 79°56′E. The humid subtropical climate in Jabalpur is typical of Madhya Pradesh and southern Uttar Pradesh in north-central India. Summer lasts from late March to early June. The hottest month is May, when average highs reach over 40 °C (104 °F). The southwest monsoon follows summer and lasts until early October. From July to September, it delivers 889 mm (35 in) of rain. Approximately 1,386 mm (54.6 in) of precipitation falls on average each year. Late November marks the start of the winter, which lasts until early March. The coldest month is January, when daily average temperatures hover around 15 °C (59 °F).

2.2 Description of Location

A total number of ten sites were chosen in the *Peri*-Urban area of Jabalpur district where wastewater was used for irrigation purposes. From these sites soil and plants grown in these soils were sampled and location was marked using GPS.

2.3 Collection and Preparation of Samples

Soil and Plant samples were collected from the above chosen sites. Soil samples were collected from top-soil using hand auger. Soil samples was first then air dried for 24 hours.

The sample was sieved using a 2-mm sieve, dried at 105 °C for 24 hours, and then crushed using a wooden pestle and mortar. Similarly, the plant samples collected from the sites were kept in a sampling bag and then were carefully washed with deionized water to remove any debris and thereafter washed with 0.1% trace metal grade HCl (JT Baker). After washing plant samples, they were first air dried and then oven dried at 80º C. After drying, they were homogenised and labelled, and stored properly in paper bags.

2.4 Analysis of Heavy Metal in Soil and Plant Samples

The dried samples were further used for heavy metal content analysis using ICP-MS after digestion. Acid used for digestion of samples was trace metal grade to avoid any metal contamination from reagents. 0.5 gm of properly homogenised soil and plant samples were taken which were acidified using HNO_3 and HF. For digestion of soil, 6ml of HNO_3 and 1.5 ml of HF was used, whereas, 8 ml of HNO_3 was used for plant samples. Closed vessel microwave digestion using Anton Paar was used for digesting plant and soil samples. Parameters used under microwave digestion were power at 1200 W, Ramp time of 15 minutes, Final temperature reaching upto 200ºC, Temperature hold time of 20 minutes and Cool down time of about 15-20 minutes.

After digestion, the samples were filtered using Whatman filter paper no. 42, and 50 ml volume makeup was done using ultra-pure water. The samples are ready for analysis in ICP-MS for heavy metals. Mixed-element reference solutions were prepared using 1000 mg/L single-element standard solutions (Agilent).

2.5 Heavy Metal Risk Assessment

2.5.1 Metal transfer factor

The potential bioavailability of a given metal at a certain plant portion is represented by the metal transfer factor (MTF) [23]. It is the ratio of the metal content in plant tissue (mg/kg Dw) such as the stem, leaf, and root, to the metal concentration in soil (mg/kg Dw) [24]. The metal transfer factor for Cr, Zn, Ni, Cd, and Cu was determined using the equation [25] that follows:

$$MTF = C_{Plant} / C_{Soil}$$

Where, C_{plant} is the amount of metal in plant tissue (mg/kg Dw), and Csoil is the amount of metal in soil (mg/kg Dw).

2.5.2 Metal Pollution Index (MPI)

The total metal load in every plant growing at a specific location is evaluated using the metal pollution index (MPI). MPI can also be defined as the geometric mean of the total concentration of all metals in the edible portion of the vegetable [26]. To determine the MPI of the plant samples following equation was used.

$$MPI = (C1 \times C2 \times . \times Cn)^{1/n}$$

Where, C_n = concentration of 'n′ number of metals in the samples (Here, n = 10).

2.5.3 Daily Intke of Metals (DIM)

The relative phyto-availability of metals is represented by the daily intake of metals (DIM). The daily intake of metals from vegetable diet was calculated using the following equation [27]:

$$DIM=(C_{metal}\times C_{factor}\times C_{intake}) / B_{weight}$$

Where, C_{metal}= the concentration of heavy metals in vegetables (mg/kg),

C_{factor}= conversion factor to convert the fresh weight of vegetables to dry weight,

C_{intake}= ingestion rate.

The ingestion rate of leafy vegetables was calculated in this study as 0.0385 kg/person/day (According to Consumption of food report, 2016) [28], the conversion factor (0.085) was used to the vegetable samples that were chosen [29], and Bweight—the average body weight—was calculated as 70 kg (adults) [30].

2.5.4 Health Risk Index (HRI)

The susceptible health risk resulting from ongoing exposure to heavy metals that eventually becomes a chronic hazard is represented by the health risk index (HRI) [31]. Higher numbers on the index indicate a higher level of risk. According to USEPA(US Environmental Protection Agency) [32], an index greater than one is deemed unsafe for human health.

The HRI for each leafy vegetable was computed using the equation that follows

$$HRI = DIM/RfD$$

Oral reference dose (RfD) used under this study are given below according to USEPA USEPA Region III risk-based concentration table [33].

3. RESULTS AND DISCUSSION

3.1 Heavy Metal Content in Soil and Plant of Pariyat Site

The heavy metal content of soil is given in Table 1. The Highest metal content present was iron (Fe) (22272.60 mg/kg), followed by Mangenese (Mn) (599.76 mg/kg), Zinc (Zn) (65.93 mg/kg), Copper (Cu) (58.46 mg/kg), Chromium (Cr) (39.38 mg/kg), Nickel (Ni) (23.99 mg/kg), Lead (Pb) (15.03 mg/kg), Cobalt (Co) (14.53 mg/kg), Arsenic (As) (2.7 mg/kg) and least amount was of Cadmium (Cd) (0.34 mg/kg). All the metals were below the permissible range.

The heavy metal content in plants is given in Table 2. In Pariyat site, the vegetable collected was potato. The metal content was in order of Fe>Zn>Cu>Mn>Ni>Co>As=Cr>Cd=Pb with values of 63.67 mg/kg, 24.44 mg/kg, 4.63 mg/kg, 3.76 mg/kg, 0.24 mg/kg, 0.20 mg/kg, 0.02 mg/kg, 0.02 mg/kg, 0.02 mg/kg, 0.01 mg/kg and 0.01 mg/kg respectively. All the metal content were below the permissible limits.

Thus, it can be concluded that soil and plant frown on Pariyat site is safe as metal content is concerned.

List 1. Oral reference dose (RfD) used under this study

As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
0.0003	0.001	0.0003	0.003	0.04	0.7	0.14	0.02	0.0035	0.3

Table 1. Description of the sampling sites

Name of Site (Nala)	Soil and Plant samples		Plants samples collected
	Latitude N	Longitude E	
Pariyat	23.2515	79.9726	Potato
Ricchai	23.2245	79.9651	Chilli
Regama	23.1995	79.8895	Brinjal
Moti	23.2176	79.9316	Cabbage
Urdhawa	23.2117	79.9593	Wheat
Kumhi	23.0508	79.0241	Brinjal
Karonda	23.0670	79.0265	Wheat
Khurji	23.1033	79.9923	Potato
Khandari	23.1278	79.9658	Cabbage
Dhobighat	23.1461	79.9618	Cauliflower

Table 2. Permissible limits of Heavy metals in soil and plants

Metal (mg/kg)	Permissible limit in soil	Reference	Permissible limit in plant	Reference
Cd	0.8	[21]	0.3	[21]
Zn	300	[22]	100	[22]
Cu	100	[22]	0.6	[21]
Cr	270	[21]	1.3	[21]
Ni	50	[21]	10	[21]
Co	50	[21]	50	[21]
Fe	50000	[21]	425.5	[21]
Pb	85	[21]	2	[21]
As	20	[21]	0.5	[21]
Mn	2000	[21]	500	[22]

Table 3. Metal content in soil and plant samples

	Soil (mg/kg)									
Sites	**Cr**	**Mn**	**Fe (%)**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Cd**	**Pb**
Pariyat	39.38	599.76	2.23	14.53	23.99	58.46	65.93	2.70	0.34	15.03
Ricchai	32.30	223.90	1.05	5.26	13.90	17.64	27.59	2.63	0.10	15.33
Regama	51.12	375.81	2.05	11.92	28.31	64.35	279.65	4.62	0.64	50.81
Moti	42.42	225.67	1.33	6.10	20.44	18.60	47.20	4.03	0.10	24.19
Urdhawa	64.39	76.80	2.71	26.07	44.44	79.79	53.00	1.69	0.10	5.68
Kumhi	74.59	735.66	3.16	2.37	47.38	80.88	50.85	5.23	0.12	9.22
Karonda	217.86	297.42	2.41	10.32	10.15	51.28	54.20	1.85	0.13	5.43
Khurji	31.68	596.51	2.13	18.88	26.22	78.13	50.83	0.62	0.09	2.85
Khandari	10.43	295.34	2.32	203.65	15.27	79.62	51.25	2.98	0.20	8.82
Dhobighat	26.79	144.90	0.65	3.58	8.43	39.84	96.44	1.74	0.18	46.36
Crops	Vegetables and wheat (mg/kg)									
	Cr	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Cd**	**Pb**
Potato	0.02	3.76	63.67	0.20	0.24	4.63	24.44	0.02	0.01	0.01
Chilli	0.06	5.17	241.33	0.32	0.13	5.42	12.37	0.08	0.05	0.70
Brinjal	0.17	6.80	735.67	0.31	0.10	7.46	39.38	0.33	0.35	1.53
Cabbage	0.04	1.62	38.83	0.07	0.05	2.31	12.02	0.04	0.03	0.43
Wheat	0.17	5.08	82.00	0.03	0.04	2.60	8.63	0.04	0.03	0.60
Brinjal	0.12	4.48	476.33	0.20	0.08	6.68	30.72	0.20	0.34	1.02
Wheat	0.02	2.93	61.17	0.04	0.06	3.33	7.75	0.01	0.02	0.60
Potato	0.11	11.06	455.67	0.41	0.07	5.12	35.18	0.15	2.22	1.14
Cabbage	0.16	14.16	670.83	0.52	0.13	6.23	28.71	0.20	2.34	1.80
Cauliflower	0.01	1.59	28.17	0.02	0.01	1.28	6.68	0.01	0.01	0.01

Table 4. Transfer factor

Name of sites	**Pariyat**	**Ricchai**	**Regama**	**Moti**	**Urdhawa**	**Kumhi**	**Karonda**	**Khurji**	**Khandari**	**DhobiGhat**
Metal (mg/kg)	**Potato**	**Chilli**	**Brinjal**	**Cabbage**	**Wheat**	**Brinjal**	**Wheat**	**Potato**	**Cabbage**	**Cauliflower**
Cr	0.00051	0.00186	0.00333	0.00094	0.00264	0.00161	0.00009	0.00347	0.01534	0.00037
Mn	0.00627	0.02309	0.01809	0.00718	0.06615	0.00609	0.00985	0.01854	0.04794	0.01097
Fe	0.00286	0.02298	0.03586	0.00291	0.00302	0.01506	0.00253	0.02142	0.02893	0.00436
Co	0.01376	0.06084	0.02601	0.01148	0.00115	0.08439	0.00388	0.02172	0.00255	0.00559
Ni	0.01000	0.00935	0.00353	0.00245	0.00090	0.00169	0.00591	0.00267	0.00851	0.00119
Cu	0.07920	0.30726	0.11593	0.12419	0.03259	0.08259	0.06494	0.06553	0.07825	0.03213
Zn	0.37070	0.44835	0.14082	0.25466	0.16283	0.60413	0.14299	0.69211	0.56020	0.06927
As	0.00741	0.03042	0.07143	0.00993	0.02367	0.03824	0.00541	0.24194	0.06711	0.00575
Cd	0.02941	0.50000	0.54688	0.30000	0.30000	2.83333	0.15385	24.66667	11.70000	0.05556
Pb	0.00067	0.04566	0.03011	0.01778	0.10563	0.11063	0.11050	0.40000	0.20408	0.00022

Table 5. Daily intake of Metals

Name of sites (mg/kg)	**Pariyat**	**Ricchai**	**Regama**	**Moti**	**Urdhawa**	**Kumhi**	**Karonda**	**Khurji**	**Khandari**	**DhobiGhat**
	Potato	**Chilli**	**Brinjal**	**Cabbage**	**Wheat**	**Brinjal**	**Wheat**	**Potato**	**Cabbage**	**Cauliflower**
Cr	0.000000935	0.000002805	7.95E-^{06}	0.00000187	N/A	0.00000561	N/A	5.14E^{-06}	0.00000748	4.68E^{-07}
Mn	0.00017578	0.000241698	0.0003179	0.000075735	N/A	0.00020944	N/A	0.000517055	0.00066198	7.43E^{-05}
Fe	0.002976573	0.011282178	0.034392573	0.001815303	N/A	0.022268428	N/A	0.021302573	0.031361303	0.00131695
Co	0.00000935	0.00001496	1.45E-05	3.27E^{-06}	N/A	0.00000935	N/A	1.92E^{-05}	0.00002431	9.35E^{-07}
Ni	0.00001122	6.08E^{-06}	0.000004675	2.34E-06	N/A	0.00000374	N/A	3.27E^{-06}	6.08E^{-06}	4.68E^{-07}
Cu	0.000216453	0.000253385	0.000348755	0.000107993	N/A	0.00031229	N/A	0.00023936	0.000291253	0.00005984
Zn	0.00114257	0.000578298	0.001841015	0.000561935	N/A	0.00143616	N/A	0.001644665	0.001342193	0.00031229
As	0.000000935	0.00000374	1.54E^{-05}	0.00000187	N/A	0.00000935	N/A	7.01E^{-06}	0.00000935	4.68E^{-07}
Cd	4.68E^{-07}	2.34E^{-06}	1.64E^{-05}	1.40E^{-06}	N/A	0.000015895	N/A	0.000103785	0.000109395	4.68E^{-07}
Pb	4.68E^{-07}	0.000032725	7.15E^{-05}	2.01E^{-05}	N/A	0.000047685	N/A	0.000053295	0.00008415	4.68E^{-07}

Table 6. Health risk index

Name of sites (mg/kg)	Pariyat Potato	Ricchai Chilli	Regama Brinjal	Moti Cabbage	Urdhawa Wheat	Kumhi Brinjal	Karonda Wheat	Khurji Potato	Khandari Cabbage	DhobiGhat Cauliflower
Cr	0.000311667	0.000935	0.002649167	0.000623333	N/A	0.00187	N/A	0.001714167	0.002493333	0.00015583
Mn	1.26E-03	1.73E-03	2.27E-03	5.41E-04	N/A	1.50E-03	N/A	3.69E-03	4.73E-03	5.31E-04
Fe	4.25E-03	1.61E-02	4.91E-02	2.59E-03	N/A	3.18E-02	N/A	3.04E-02	4.48E-02	1.88E-03
Co	0.031166667	0.049866667	0.048308333	0.010908333	N/A	0.031166667	N/A	0.063891667	0.081033333	0.00311667
Ni	0.000561	0.000303875	0.00023375	0.000116875	N/A	0.000187	N/A	0.000163625	0.000303875	2.3375E-05
Cu	0.005411313	0.006334625	0.008718875	0.002699813	N/A	0.00780725	N/A	0.005984	0.007281313	0.001496
Zn	3.81E-03	1.93E-03	6.14E-03	1.87E-03	N/A	4.79E-03	N/A	5.48E-03	4.47E-03	1.04E-03
As	0.003116667	0.012466667	0.051425	0.006233333	N/A	0.031166667	N/A	0.023375	0.031166667	0.00155833
Cd	0.0004675	0.0023375	0.0163625	0.0014025	N/A	0.015895	N/A	0.103785	0.109395	0.0004675
Pb	0.000133571	0.00935	0.020436429	0.005743571	N/A	0.013624286	N/A	0.015227143	0.024042857	0.00013357

Table 7. Metal pollution index

Pariyat Potato	Ricchai Chilli	Regama Brinjal	Moti Cabbage	Urdhawa Wheat	Kumhi Brinjal	Karonda Wheat	Khurji Potato	Khandari Cabbage	DhobiGhat Cauliflower
0.372915652	0.94773593	2.058870604	0.407471895	0.517323774	1.501686905	0.348784721	2.01214606	2.624086824	0.12258012

3.1.1 Heavy metal content in soil and plant of Ricchai site

The heavy metal content in soil of Ricchai site was in order Fe>Mn>Cr>Zn> Cu>Pb>Ni>Co>As>Cd with value of 10502 mg/kg, 223.9 mg/kg, 32.30 mg/kg, 27.59 mg/kg, 17.64 mg/kg, 15.33 mg/kg, 13.9 mg/kg, 5.26 mg/kg, 2.63 mg/kg, and 0.1 mg/kg, respectively. All the metals were found withen range.

The metal content in plants followed the order of Fe>Zn>Cu>Mn>Pb>Co>Ni>As>Cr>Cd with values of 241.33 mg/kg, 12.37 mg/kg, 5.42 mg/kg, 5.17 mg/kg, 0.70 mg/kg, 0.32 mg/kg, 0.13 mg/kg, 0.08 mg/kg, 0.06 mg/kg, and 0.05 mg/kg. All the metals were found withen acceptable range.

Thereby, Ricchai site can be classified as safe for metals in both soil and plants grown into it.

3.1.2 Heavy metal content in soil and plant of Regama site

The heavy metal content in soil of Regama site followed the order of Fe>Mn>Zn>Cu>Cr>Pb>Ni> Co>As>Cd with values of 20514.9 mg/kg, 375.81 mg/kg, 279.65 mg/kg, 64.35 mg/kg, 51.12 mg/kg, 50.81 mg/kg, 28.31 mg/kg, 11.92 mg/kg, 4.62 mg/kg, and 0.64 mg/kg, respectively. All the metals were within the permissible limits.

Plant content for heavy metals were in order of Fe>Zn>Cu>Mn>Pb>Cd>As>Co>Cr>Ni with values of 735.67 mg/kg, 39.38 mg/kg, 7.46 mg/kg, 6.80 mg/kg, 1.53 mg/kg, 0.35 mg/kg, 0.33 mg/kg, 0.31 mg/kg, 0.17 mg/kg, and 0.10 mg/kg, respectively. All the metals except Fe and Cd were within the permissible limits.

According to [34] the result of growing levels of Fe in plants was the ongoing usage of sewage water. It is common for brinjal to collect Cd [35], even when grown on lightly contaminated soil [36].

3.1.3 Heavy metal content in soil and plant of Moti site

Heavy metal content of Moti site in soil is as follows Fe>Mn>Zn>Cr>Pb>Ni>Cu>Co>As>Cd with values of 13324 mg/kg, 225.67 mg/kg, 47.20 mg/kg, 42.42 mg/kg, 24.19 mg/kg, 20.44 mg/kg,18.60 mg/kg, 6.10 mg/kg, 4.03 mg/kg, and 0.10 mg/kg, respectively. All metals were within range.

The metal content in plant samples were in order of Fe >Zn>Cu>Mn>Pb>Co>Ni>As=Cr>Cd with values of 38.83 mg/kg, 12.02 mg/kg, 2.31 mg/kg, 1.62 mg/kg, 0.43 mg/kg, 0.07 mg/kg, 0.05 mg/kg, 0.04 mg/kg,0.04 mg/kg, and 0.03 mg/kg, respectively. All the metals were found within allowable range.

3.1.4 Heavy metal content in soil and plant of Urdhawa site

Heavy metal content in soil of Urdhawa site is as follows Fe>Cu>Mn>Cr>Zn>Ni>Co>Pb>As>Cd with values of 27139 mg/kg, 79.79 mg/kg, 76.80 mg/kg, 64.39 mg/kg, 53 mg/kg, 44.44 mg/kg, 26.07 mg/kg, 5.68 mg/kg, 1.69 and 0.1 mg/kg, respectively. All the metals were found within acceptable range.

Heavy metal content in Wheat sample collected from Urdhawa site were in order of Fe>Zn>Mn>Cu>Pb>Cr>As=Ni>Cd=Co with values of 82 mg/kg, 8.63 mg/kg, 5.08 mg/kg, 2.60 mg/kg, 0.60 mg/kg, 0.17 mg/kg, 0.04 mg/kg, 0.04 mg/kg, 0.03 mg/kg, and 0.03 mg/kg, respectively. All the metals were found under permissible limits.

3.1.5 Heavy metal content in soil and plant of Kumhi site

The metal content of soil is in order of Fe>Mn>Cu>Cr>Zn>Ni>Pb>As>Co>Cd having values of 31630.1 mg/kg, 735.66 mg/kg, 80.88 mg/kg, 74.59 mg/kg, 50.85 mg/kg, 47.38 mg/kg, 9.22 mg/kg, 5.23 mg/kg, 2.37 mg/kg, and 0.15 mg/kg, respectively. All metals were found within permissible limits.

In brinjal plant collected from Kumhi site the heavy metal content was found in order of Fe>Zn>Cu>Mn>Pb>Cd>As=Co>Cr>Ni with values of 476.33 mg/kg,30.72 mg/kg, 6.68 mg/kg, 4.48 mg/kg, 1.02 mg/kg, 0.34 mg/kg, 0.20 mg/kg, 0.20 mg/kg, 0.12 mg/kg, and 0.08 mg/kg,respectively. All metals except Cd were within the allowable range. As explained before, brinjal has its intrinsic nature to absorb more Cd even if soil has Cd below permissible levels [36]. Also heavy metals such as Cd can be easily absorbed by the roots of vegetables and transported to the edible parts of the plants, even though the metal content in soil is low [37,38]. Vegetables can also absorb metals like Cd, Pb, Zn, Cr from their aerial surfaces due to aerosols [39].

3.1.6 Heavy metal content in soil and plant of Karonda site

Heavy metal content of soil was as follows Fe>Mn>Cr>Zn>Cu>Co>Ni>Pb>As>Cd with values of 24138.8 mg/kg, 297.42 mg/kg, 217.86 mg/kg, 54.2 mg/kg, 51.28 mg/kg, 10.32 mg/kg, 10.15 mg/kg, 5.43 mg/kg, 1.85 mg/kg, and 0.13 mg/kg, respectively. All metals were found within permissible limits.

In potato plant collected from Karonda site the metals were in following order Fe>Zn>Cu>Mn> Pb>Ni>Co>Cd=Cr>As having values of 61.17 mg/kg, 7.75 mg/kg, 3.33 mg/kg, 2.93 mg/kg, 0.60 mg/kg, 0.06 mg/kg, 0.04 mg/kg, 0.02 mg/kg, 0.02 mg/kg, 0.01 mg/kg, respectively. All the metals were found within range.

3.1.7 Heavy metal content in soil and plant of Khurji site

Heavy metal content in soils of Khurji site were in order of Fe>Mn>Cu>Zn>Cr>Ni>Co>Pb>As>Cd having values of 21275 mg/kg, 596.51 mg/kg, 78.13 mg/kg, 50.83 mg/kg, 31.68 mg/kg, 26.22 mg/kg, 18.88 mg/kg, 2.85 mg/kg, 0.62 mg/kg, and 0.09 mg/kg, respectively.Cd pollution can be a result of irrigating agriculture with water polluted by industrial effluents [40]. Another important factor contributing to the buildup of Cd in agricultural soils is fertilizers based on phosphorus [41].

Heavy metal content in Potato plant collected from Khurji site was in order Fe>Zn>Mn>Cu>Cd>Pb>Co>As>Cr>Ni with values of 455.67 mg/kg, 35.18 mg/kg, 11.06 mg/kg, 5.12 mg/kg, 2.22 mg/kg, 1.14 mg/kg, 0.41 mg/kg, 0.15 mg/kg, 0.11 mg/kg, and 0.07 mg/kg, respectively. All metal content except iron were under permissible limits. Excessive heavy metals like iron, buildup in plants is the result of continuous wastewater irrigation and use of fertilizers [16].

3.1.8 Heavy metal content in soil and plant of Khandari site

Heavy metal content in soils of Khandari site were in order of Fe>Mn>Co>Cu> Zn>Ni>Cr>Pb>As>Cd with values of 23187.50 mg/kg, 295.34 mg/kg, 203.65 mg/kg, 79.62 mg/kg, 51.25 mg/kg, 15.27 mg/kg, 10.43 mg/kg, 8.82 mg/kg, 2.98 mg/kg, and 0.20 mg/kg, respectively. The metals were found to be under permissible limits except Co.

According to Khanet al. [42] Co enters in soil through wastewater, phosphate fertilizer and industrial waste.

In plant sample collected from the site the metal contamination level was in order Fe>Zn>Mn >Cu>Cd>Pb>Co>As>Cr>Ni with values of 670.83 mg/kg, 28.71 mg/kg, 14.16 mg/kg, 6.23 mg/kg, 2.34 mg/kg, 1.80 mg/kg, 0.52 mg/kg, 0.20 mg/kg, 0.16 mg/kg, and 0.13 mg/kg, respectively. The plant has Co content below permissible limits as in root cells calcium ions binds with cobalt binding sites which decreases its toxicity in plants [43]. All the samples were found to be within range when heavy metal is considered.

3.1.9 Heavy metal content in soil and plant of Dhobighat site

The heavy metal content of soil was in order of Fe>Mn>Zn>Pb>Cu>Cr>Ni>Co>As>Cd with values of 6460.97 mg/kg, 144.90 mg/kg, 96.44 mg/kg, 46.36 mg/kg, 39.84 mg/kg, 26.79 mg/kg, 8.43 mg/kg, 3.58 mg/kg, 1.74 mg/kg, and 0.18 mg/kg, respectively. All the metals were within permissible range.

Heavy metal content in cauliflower was in sequence of Fe>Zn>Mn>Cu>Co>Cr= Ni=As= Cd=Pb, with values of 28.17 mg/kg, 6.68 mg/kg, 1.59 mg/kg, 1.28 mg/kg,0.02 mg/kg, and 0.01 mg/kg, respectively. All the metals were found within range.

3.2 Risk Assessment Parameters

3.2.1 Transfer Factor (TF)

The highest TF was found under wheat crop collected from Khurji nala for Cd (24.66), followed by Zn (0.69) and Cu (0.65). Apart from wheat crop, highest TF was obtained for potato collected from Khandari nala for Cd (11.70) followed by As (0.06). Next to potato, chilli showed high TF of 0.54, followed by Zn (0.14). Lowest TF was found in brinjal collected from Karonda site for Cr (0.00009), followed by Cauliflower collected from Dhobighat nala for Pb (0.00022).

3.2.2 Daily Intake of Metals (DIM)

The daily intake of metal (DIM) is a measure of how much the body is exposed to heavy metals through food [44]. Highest DIM was observed for Fe under Brinjal collected from Regama site followed by Zn, Cu, Mn, Pb, Cd, As, Co, Cr then

Ni. Lowest DIM was obtained from Cauliflower collected from Dhobighat site for Pb followed by Cr, Ni, As, and Cd having equal values of DIM, then Co, Cu, Mn, Zn and Fe.

3.2.3 Health Risk Index (HRI)

The health risk index assesses the likelihood of any health risks resulting from eating foods that are contaminated [45]. Since all the vegetables had HRI index of less than one therefore, they were safe to consume. Although, Cabbage from Khandari site showed the highest HRI for Cd (0.10) followed by Co (0.08).

3.2.4 Metal Pollution Index (MPI)

Since all the vegetables showed the MPI value less than five, thus they are safe to consume. Among the vegetables, highest MPI was showed by cabbage collected from Khandari site (2.62), Brinjal from Regama (2.05), Potato from khurji site (2.01).

4. CONCLUSION

This study was conducted to assess the heavy metal contamination in soil irrigated with wastewater and its effect on cultivated plants. Ten heavy metals *viz* Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd and Pb were studied in both soil and plants and the results showed that the metal content in the soil under study was below the permissible limits except for Coin the Khandari and Cd in Khurji site. The vegetables grown on these soils did not show much contamination level except for Fe content in brinjal, potato and cabbage grown on Regama, Kumhi, Khurji and Khandari site and Cd for brinjal grown on Regama and Kumhi site. Tendency to accumulate metals in edible parts was only shown by wheat for Cd grown on Khurji site and potato grown on Khurji site. Despite of the presence of contamination level none of the vegetables showed health risk hazard, thus it can be said that consumption of these vegetables might not pose any significant health hazard but in order to protect human health the implementation of appropriate management and mitigation measures to reduce heavy metals to a safer level should be employed.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gupta N, Yadav KK, Kumar V, Prasad S, CabralPinto MMS, Jeon BH, Kumar S, Abdel MH Attif AKD. Alsukaibia, Investigation of heavy metal accumulation in vegetables and health risk to humans from their consumption Front. Environ. Sci. 2022;10.
2. Elliethy M, Ragab AA, Bedair R, Khafagi OM. Assessment of nutrients and heavy metals content in soil and some vegetables cultivated in agricultural land around El-Khashab canal (Helwan-El Saff area). International Journal of Theoretical and Applied Research. 2022; 1(1):27-37.
3. WHO-World Health Organization. Guidelines for the safe use of wastewater, excreta and greywater wastewater use in agriculture (2nd ed.); 2006.
4. Haroon B, Ping A, Pervez A, Irshad F. Characterization of heavy metal in soils as affected by long-term irrigation with industrial wastewater J. Water Reuse Desalin. 2019;9:47-56.
5. Abidi M, Bachtouli S, Ali ZI. Soil contamination by heavy metals through irrigation with treated wastewater in a semi-arid area. Environ Earth Sci. 2024;83, 25.
6. Gupta K, Srivastava A, Srivastava S, Kumar A. Phyto-genotoxicity of arsenic

contaminated soil from Lakhimpur Kheri, India on *Vicia faba* L Chemosphere. 2020;241.

7. Tahtouh J, Mohtar R, Assi A, Schwab P, Jantrania A, Deng Y, Munster C.Impact of brackish groundwater and treated wastewater on soil chemical and mineralogical properties Sci. Total Environ. 2019;647:99-109.
8. Rezapour S, Atashpaz B, Moghaddam SS, Damalas CA.Heavy metal bioavailability and accumulation in winter wheat (*Triticum aestivum* L.) irrigated with treated wastewater in calcareous soils Sci. Total Environ. 2019; 656:261-269.
9. Liu H, Zhang Y, Yang J, Wang H, Li Y, Shi Y, Li D, Holm PE, Ou Q, Hu W. Quantitative source apportionment, risk assessment and distribu. tion of heavy metals in agricultural soils from southern Shandong Peninsula of China Sci. Total Environ. 2021;767.
10. Barakat A, Ennaji W, Krimissa S, Bouzaid M.Heavy metal contamination and ecological-healthrisk evaluation in peri-urban wastewater-irrigated soils of Beni-Mellal city (Morocco) Int. J.Environ. Health Res. 2020;372-387.
11. Al-Nasir FM, Jiries AG, Al-Rabadi GJ,Alu'datt MH, Tranchant CC, Al-Dalain SA, Alrabadi N,Madanat OY, Al-Dmour RS. Determination of pesticide residues in selected citrus fruits and vegetables cultivated in the Jordan Valley LWT. 2020; 123.
12. Bonanno G, Vymazal J, Cirelli GL.Translocation, accumulation and bioindication of trace elements in wetland plants Sci. Total Environ. 2018;631–632: 252-261.
13. Baghaie AH, Fereydoni M. The potential risk of heavy metals on human health due to the daily consumption of vegetables. Environ. Health Eng. Manage. 2019;6(1):11–16.
14. Singh A, Prasad SM. Effect of agro-industrial waste amendment on Cd uptake in Amaranthus caudatus grown under contaminated soil: an oxidative biomarker response. Ecotoxicol. Environ. Saf. 2014; 100:105–113.
15. Islam A, Teo SH, Ahmed MT, Khandaker S, Ibrahim ML, Vo DVN, Abdulkreem-Alsultan G, Khan AS. Novel Micro-structured Carbon-based Adsorbents for Notorious Arsenic Removal from Wastewater Chemosphere. 2021;272.
16. Salman MS, Znad H, Hasan MN, Hasan MM. Optimization of innovative composite sensor for Pb (II) detection and capturing from water samples Microchem. J., 2021;160.
17. Singh PK, Yadav JS, Kumar I, Kumar U, Sharma RK.Carpet industry irrigational sources risk assessment: Heavy metal contaminated vegetables and cereal crops in northern India Toxicol. Rep. 2022; 9:19 06-1919.
18. O. Amour K, Mohammed NK. Heavy metal concentrations in soil and green vegetables (*Vigna unguiculata*) around Volcanic Mountain of Oldoinyo Lengai, Arusha, Tanzania. J. Exp. Agric. Int. 2015;8(3):178-85.

    Accessed on: 2024 Jun. 2

    Available:https://journaljeai.com/index.php/JEAI/article/view/650
19. Swetha TN, Rajasekar B, Hudge BV, Mishra P, Harshitha DN. Phytoremediation of Heavy Metal Contaminated Soils Using Various Flower and Ornamentals. Int. J. Plant Soil Sci. 2023;35(18):747-52.

    Accessed on: 2024 Jun. 2

    Availablehttps://journalijpss.com/index.php/IJPSS/article/view/3341
20. Huang SW, Jin JY. Status of heavy metals in agricultural soils as affected by different patterns of land use. Environmental monitoring and assessment. 2008;139: 317-27.
21. FAO. WHO.Codex general Standard for Contaminants and Toxins in food. Joint Food Standard Programme, Codex Alimentarious Commission, Rome, Italy; 1996.
22. Chiroma TM, Ebewele RO, Hymore FK. Comparative assessment of heavy meta levels in soil, vegetables and urban grey waste water used for irrigation in Yola and Kano. International Refereed Journal of Engineering and Science. 2014;3(2):1-9.
23. Gebrekidan A. Toxicological assessment of heavy metals accumulated in vegetables and fruits grown in Ginfel river near Sheba Tannery, Tigray, Northern Ethiopia. Ecotoxicol. Environ. Saf. 2013; 95:171–178.

24. Rahmani GNH, Stenberg SPK.Bioremoval of Lead from Water Using Lemna Minor. Biores.Tech. 1999;70:225–230.
25. Shen ZJ, Chen YS, Zhang Z. Heavy metals translocation and accumulation from the rhizosphere soils to the edible parts of the medicinal plant Fengdan (*Paeonia ostii*) grown on a metal mining area, China. Ecotoxicol. Environ. Saf. 2017;143:19–27.
26. Usero J, Gonzalez-Regalado E, Gracia I. Trace metals in the bivalve mollusks *Ruditapes decussatus and Ruditapes phillippinarum* from the Atlantic coast of Southern Spain. Environ Int. 1997;23(3):291–298.
27. Chary NS, Kamala C, Raj DSS. Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. Ecotoxicol. Environ. Saf. 2008;69(3):513–524.
28. Consumption of food: Final report on household income and expenditure survey 2016, Bangladesh bureau of statistics, statistics and informatics division, ministry of planning, Bangladesh. 2019 ;45.
29. Ur Rehman K. Ecological risk assessment of heavy metals in vegetables irrigated with groundwater and wastewater: the particular case of Sahiwal district in Pakistan. Agric. Water Manag. 2019;226.
30. Sarkar T. Assessment of heavy metals contamination and human health risk in shrimp collected from different farms and rivers at Khulna-Satkhira region, Bangladesh. Toxicol. Rep. 2016;3:346–350.
31. Singh A. 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. 2010;48(2):611:619.
32. USEPA (US Environmental Protection Agency), Region 9, Preliminary Remediation Goals; 2002.
33. USEPA. USEPA Region III risk-based concentration table: technical back-ground information. Unites States Environmental Protection Agency, Washington,2006.
34. Sandeep G, Vijayalatha K, Anitha T. Heavy metals and its impact in vegetable crops. Int J Chem Stud. 2019;7 (1):1612–21.
35. Shen C, Huang YY, Liao Q, Huang BF, Xin JL, Wang L, Fu HL. Characterization of Cadmium accumulationmechanism between eggplant (*Solanum melongela L*) cultivars. Front Plant Sci.2023;13: 1097998.
36. Yuan H, Sun L, Tai P, Liu W, Li X, Hao L. Effects of grafting on root-to-shoot cadmium translocation in plants of eggplant (*Solanum melongena*) and tomato (*Solanum lycopersicum*). Sci. Total Environ. 2019;652:989–995.
37. Yang Y, Zhang FS, Li HF, Jiang RF. Accumulation of Cadmium in edible parts of six vegetables species grown in Cd-contaminated soils. J. Environment Manag. 2009;90:1117:1122.
38. Jolly YN, Islam A, Akbar S. Transfer of metals from soil to vegetables and possible health risk assessment. Springerplus. 2013;2:385-391.
39. Tem-merman and Hoenig. Vegetable crops for biomonitoring lead and cadmium deposition. Journal of Atmospheric Chemistry. 2004;49,121-135.
40. Rahim HU, Akbar WA, Alatalo JM. A Comprehensive literature review on cadmium (Cd) status in the soil environment and its immobilization by biochar-based materials. Agronomy. 2022; 12(4):877.
41. Taylor M. Accumulation of cadmium derived from fertilisers in New Zealand soils. *Sci.* Total Environ. 1997;208:123–126.
42. Khan ZI, Liu W, Mubeen I, Alrefaei AF, Alharbi SN, Muhammad FG, Ejaz A, Ahmad K, Nadeem M, Shoukat J, Ashfaq A, Mahpara S, Siddique K, Ashraf MA, Memona H, Batool AI, Munir M, Malik IS, Noorka IR, Ugulu I. Cobalt availability in the soil plant and animal food chain: A study under a peri-urban environment. Braz J Biol. 2023;3:83.
43. Lwalaba JL, Louis LT, Zwobgo G, Richmond ME, Fu L, Naz S, Mwamba M, Mundende RP, Zhang G.Physiological and molecular mechanism of cobalt and copper interaction in causing phyto-toxicity in two Barley genotypes differing in Co tolerance. Ecotoxicology and Environment safety. 2020;187.
44. Daniele L. Chemical composition of Chilean bottled waters: Anomalous values

and possible effects on human health. Sci. Total Environ. 2019;689:526–533.

45. Ahmed S, Fatema-Tuj-Zohra, Mahdi MM, Nurnabi M, Alam MZ, Choudhury TR. Health risk assessment for heavy metal accumulation in leafy vegetables grown on tannery effluent contaminated soil. Toxicol Rep. 2022;10; 9:346-355.

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