ISSN-1996-918X

Cross Mark

Pak. J. Anal. Environ. Chem. Vol. 24, No. 1 (2023) 94 – 105

http://doi.org/10.21743/pjaec/2023.06.09

Assessment of Heavy Metal Contents and Their Risks in Vegetables Collected from District Ghotki, Sindh

Liaquat Ali Shar*, Shafique Ahmed Arain and Ghulam Qadir Shar

Institute of Chemistry, Shah Abdul Latif University, Khairpur, Sindh, Pakistan.

**Corresponding Author Email: liaquatalishar1978@gmail.com*

Received 30 May 2023, Revised 10 June 2023, Accepted 16 June 2023

Abstract

Vegetables are renowned for their nutritional value, as they are rich sources of dietary fiber, minerals, and vitamins offering a wide range of health benefits. They also possess antioxidative properties that contribute to overall well-being. The aim of this study was to evaluate the contamination of heavy metals like Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni), and Zinc (Zn) in the agriculture soil and most frequently consumed vegetables including; Sweet Potato (*Ipomoea batatas*), Turnip (*Brassica rapa*), Onion (*Allium cepa*), Carrot (*Daucus Carota*), Garlic (*Allium sativum*), Radish (*Raphanus sativus*), Lotus (*Nelumbo nucifera*), Potato (*Solanum tuberosum*), Beetroot (*Beta vulgaris*), and Ginger (*Zingiber officinale*) collected from various sites of District Ghotki, Sindh. The agriculture soil and vegetable samples were digested, and heavy metal levels were determined using Atomic Absorption Spectrophotometer (AAS). The Zn content was found higher in all vegetable samples. Cu, Fe, Mn, and Zn concentrations were found within the permissible levels of the Food and Agriculture Organization and World Health Organization (WHO/FAO). However, the concentrations of As, Cd, Cr, and Ni were found higher than the permissible limit suggested by WHO/FAO. Hazard index (HI), target hazard quotient (THQ), daily intake of metals (DIM), and estimated daily exposure to heavy metals (EDEM) were also measure. The hazard index (HI) values of As for all the vegetable samples were greater than 1, indicating potential health risks to those consuming these vegetables.

Keywords: Arsenic, Heavy metals, Vegetables, Target hazard quotient, Estimated daily exposure of Heavy metals.

Introduction

In recent years, the issue of heavy metals (HMs) contamination has become a global concern due to their non-biodegradable nature, bioaccumulation behavior, and the contamination of agricultural soils. The high levels of toxic metals in agricultural soil can negatively impact crop quality and reduce overall product yield. This contamination can also upset the structure and function of soil, leading to adverse environmental impacts. Furthermore, the transportation of these metals through the food chain can have serious implications for human health. The sources of HMs contamination in agricultural soils can be attributed to either anthropogenic or natural factors [1-4]. The concentrations of naturally occurring HMs in unpolluted agricultural soils are primarily governed by the geological composition of parent material, which influences their release and incorporation into the soil matrix [5]. Human activities can significantly impact the levels of HMs in soils, leading to potential environmental and health consequences. The use of chemical fertilizers and pesticides in agriculture, along with emissions from vehicles and industrial activities, can introduce high levels of toxic metals into the soil, altering its natural balance and contaminating crops and groundwater [6]. Furthermore, mining operations can release heavy metals into the soil and water, affecting nearby ecosystems and posing a risk to human health [7-10].

Vegetables are a vital component of a healthy diet for individuals of all ages, offering a rich source of minerals, fiber, and vitamins necessary for optimal bodily function and well-being [11-13]. However, it should be noted that vegetables can also contain high levels of HMs. This is because they can absorb these metals from polluted water and soil through their roots and subsequently transfer them to the edible portions of the plant [14, 15]. The presence of toxic metals in vegetables is a concern for human health as ingestion of these metals can have adverse effects on various bodily functions, which may be including cancer, developmental anomalies, hematological and reproductive effects, kidney and liver damage, cardiovascular diseases and nervous system disorders [16,17]. In recent years, numerous studies conducted worldwide by researchers have focused on investigating the potential risks of HMs on human health through the consumption of vegetables [18-23]. These studies analyze the levels of toxic metals in vegetables, such as lead, cadmium, arsenic, and mercury, and assess the potential health implications for individuals who consume them. The aim of this study is to determine the concentrations of arsenic and HMs in the common vegetables grown in the Ghotki district, Sindh province, and to compare the levels of HMs among the vegetables. Moreover, the health risks associated with HMs exposure through vegetable consumption will be assessed to create crucial data for public health protection.

Materials and Methods

Study Area

The headquarters of the Ghotki district is located in the city of Mirpur Mathelo in the Sindh province of Pakistan. The district was established in 1993, having previously been a part of the Sukkur district. The total area of the Ghotki district is 6975 square kilometers or 1,555,528 acres. A significant portion of this area, approximately 25,000 acres, is classified as deserted land, while 402,578 acres are flooded. Nevertheless, the cultivated area spans the district's desert and flooded regions. The Ghotki district includes the White Desert, also known as Achhro Thar, which is characterized by windblown hills. Additionally, a flooded area or Kacha stretches along the Indus River for approximately 87 kilometers and contains forests (Fig. 1). According to the 2017 census, the population of the Ghotki district was recorded as 1,648,708, with 21.89% residing in urban areas. The majority, 93.67% of the total population, follows Islam, while 6.19% practice Hinduism, including the Scheduled Castes. The district is home to people of different languages, including 1.05% Saraiki, 1.64% Punjabi, 2.49% Urdu, and 93.37% Sindhi. Notably, the historic Hindu temple, Shadani Darbar, is situated in this district.

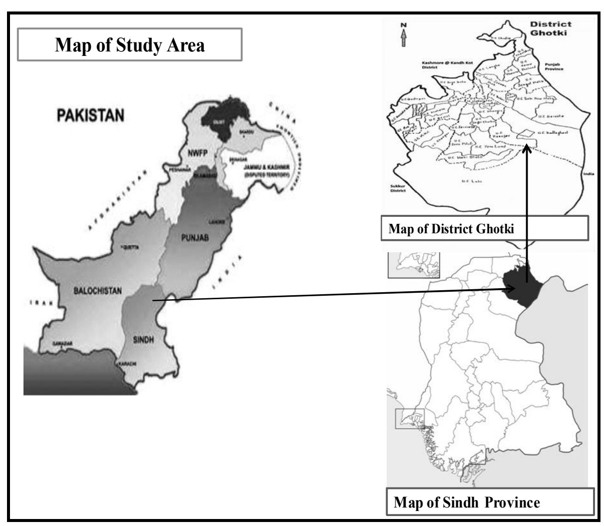

Figure 1. **Sampling area of district Ghotki**

Sample Collection

Five sites were selected for sample collection. At each site, one kg of each type of sample was collected depending on the ripeness of the vegetables in the field during sampling. In total ten types of vegetable samples were collected which included, Sweet Potato (*Ipomoea batatas*), Turnip (*Brassica rapa*), Onion (*Allium cepa*), Carrot (*Daucus Carota*), Garlic (*Allium sativum*), Radish (*Raphanus sativus*), Lotus (*Nelumbo nucifera*), Potato (*Solanum tuberosum*), Beetroot (Beta vulgaris), and Ginger (*Zingiber officinale*). For soil sample collection five spots were selected from where vegetable samples were collected. Collections of vegetable samples were made in triplicates. Samples were wrapped in neat and clean bags, properly labeled and shifted to the Laboratory, Institute of Chemistry, Shah Abdul Latif University, Khairpur, where samples were initially washed using tap water to eliminate dirt particles. Double distilled water was used to rinse vegetable samples, kitchen knife was used to cut into smaller pieces for drying purposes. Sliced vegetable samples were dried in an oven at temperatures below 100 °C for 5 to 7 h. Dried vegetable samples were properly labeled and shifted to the National Center of Excellence in Analytical Chemistry, University of Sindh, Jamshoro for heavy metal and As analyses.

Sample Preparation and Analyses

2 g of each vegetable sample was taken in a beaker containing nitric acid and perchloric acid in a 4:1 ratio. Contents were kept for digestion purposes overnight. Samples were heated using electric hot plates at different temperatures until the formation of a clear solution. Then samples were cooled and filtered using Whatman #42 filter paper. Double distilled water was used to dilute the samples to make up a volume of up to 50 mL in measuring flasks. Samples were kept at room temperature for further analysis. To evaluate the reproducibility of measurement, all analyses were repeated three times. The 2% HNO_3 solution was used to prepare 1000 ppm stock solutions of heavy metals from their salts. Double Distilled water was used for successive dilution from stock solutions. A hydride generation Absorption spectrophotometer was used to detect arsenic from the edible roots of vegetable samples. The quantity of arsenic and heavy metals was measured from the calibration curve of the respective HMs. Certified reference material obtained from International Atomic Energy Agency (IAEA) was used to analyze the accuracy of the analysis. A similar method was followed for the analysis of blank and calibration standard solutions.

Statistical analysis

For the analysis of statistics the SPSS (Statistical Package for the Social Science) version 18.0 was used. Descriptive statistics such as average, minimum, maximum, standard deviation, and correlation co-efficient were determined at a 5% level of confidence.

Risk Assessment

Daily intake of Heavy Metals (DIM) and Estimated Daily exposure (EDEM)

The ingestion of heavy metals in the samples depicted as daily intake of metals (DIM) was calculated using the following equation.

$$DIM = \frac{Cm \times D_{intake}}{BW}$$

Cm, D_{intake}, and BW stand for the concentration of HMs, daily ingestion of vegetables (166 g/person/day), and body weight (60 kg), respectively [24].

EDEM was determined using the following formula:

$$EDEM = \frac{DIM}{BW}$$

Where DIM and BW show daily intake of HMs and body weight, respectively.

Target Hazard Quotient

The target Hazard Quotient (THQ) depends on the consumption of common vegetables by the people of the study area. This procedure of evaluating risk using THQ is given in the USEPA region III risk dependent concentration and its equation is as follows [25]:

$$THQ = \frac{MC \times IR \times EF \times ED \times CF}{RFD \times BW \times ATn}$$

Where, MC, IR, EF, ED, CF RfD, BW and ATn are metal content, ingestion rate, exposure frequency (365 days/year), duration exposure (60 years), conversion factor (0.085), reference daily dose, body weight (60 kg) and average time exposure, respectively.

Hazard Index (HI)

The hazard index from THQs is denoted as the total of the hazard quotients as given in the following equation [24].

HI=THQ(Cr)+THQ(Cu)+THQ(Cd)+THQ(Cr) +THQ(As)+THQ(CrFe)+THQ(Mn)+THQ(Ni) +THQ(Zn)

Results and Discussion

Daily Intake of Heavy Metals

The DIM range of heavy metals under study in vegetable samples was determined as Cr (0.069 - 0.270), Cu (0.163 - 0.866), Cd (0.044 - 0.087), As (0.013 - 0.023), Fe (0.047 - 0.135), Mn (0.070 - 0.140), Ni (0.052 - 0.079) and Zn (1.001 - 1.575) mg/kg/day (Table 1 & 2).

Table 1. **Daily Intake (DIM) and Estimated Daily Exposure of Trace Metals (EDEM) in different Vegetables collected from various locations of District Ghotki.**

HMs	Daily Intake of Heavy Metals (DIM) (mg/day, fresh weight)									
	Ginger	*Beet Root*	*Potato*	*Lotus*	*Radish*	*Garlic*	*Carrot*	*Onion*	*Turnip*	*Sweet Potato*
Cr	0.076	0.114	0.072	0.069	0.103	0.106	0.075	0.075	0.270	0.101
Cu	0.866	0.340	0.504	0.332	0.334	0.466	0.353	0.279	0.367	0.163
Cd	0.087	0.085	0.068	0.055	0.068	0.058	0.074	0.044	0.049	0.064
As	0.023	0.022	0.022	0.021	0.023	0.017	0.013	0.014	0.019	0.019
Fe	0.047	0.059	0.050	0.063	0.065	0.047	0.056	0.053	0.116	0.135
Mn	0.114	0.124	0.140	0.135	0.076	0.093	0.083	0.072	0.070	0.083
Ni	0.060	0.052	0.068	0.071	0.054	0.066	0.070	0.058	0.061	0.079
Zn	1.226	1.537	1.575	1.520	1.165	1.001	1.281	1.390	1.394	1.170
Estimated Daily Exposure of Heavy metals (EDEM) (mg/kg bw/day)										
Cr	0.0011	0.0016	0.0010	0.0010	0.0015	0.0015	0.0011	0.0011	0.0039	0.0014
Cu	0.0124	0.0049	0.0072	0.0047	0.0048	0.0067	0.0050	0.0040	0.0052	0.0023
Cd	0.0012	0.0012	0.0010	0.0008	0.0010	0.0008	0.0011	0.0006	0.0007	0.0009
As	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0003	0.0003
Fe	0.0007	0.0008	0.0007	0.0009	0.0009	0.0007	0.0008	0.0008	0.0017	0.0019
Mn	0.0016	0.0018	0.0020	0.0019	0.0011	0.0013	0.0012	0.0010	0.0010	0.0012
Ni	0.0009	0.0007	0.0010	0.0010	0.0008	0.0009	0.0010	0.0008	0.0009	0.0011
Zn	0.0175	0.0220	0.0225	0.0217	0.0166	0.0143	0.0183	0.0199	0.0199	0.0167

Table 2. **Descriptive Statistics of Daily Intake (DIM) and Estimated Daily Exposure of Heavy Metals (EDEM) in vegetables collected from different locations of district Ghotki.**

HMs	DIM (mg/day, fresh weight)				EDEM (mg/kg bw/day)			
	Max	*Min*	*Mean*	*SD*	*Max*	*Min*	*Mean*	*SD*
Cr	0.270	0.069	0.106	0.060	0.004	0.001	0.002	0.001
Cu	0.866	0.163	0.400	0.188	0.012	0.002	0.007	0.003
Cd	0.087	0.044	0.065	0.014	0.001	0.001	0.001	0.000
As	0.023	0.013	0.019	0.004	0.000	0.000	0.000	0.000
Fe	0.135	0.047	0.069	0.031	0.002	0.001	0.001	0.000
Mn	0.140	0.070	0.099	0.027	0.002	0.001	0.002	0.000
Ni	0.079	0.052	0.064	0.008	0.001	0.001	0.001	0.000
Zn	1.575	1.001	1.326	0.189	0.023	0.014	0.018	0.003

Estimated Daily Exposure of Heavy Metals (EDEM)

However, EDEM values of heavy metals from same samples were measured as Cr (0.001 - 0.0039), Cu (0.0023 - 0.0124), Cd (0.0006 - 0.0012), As (0.0002 - 0.0003), Fe (0.0007 - 0.0019), Mn (0.001 - 0.002), Ni (0.0007 - 0.0011) and Zn (0.0143 - 0.0225) mg/kg/day (Table 1 & 2).

Target Hazard Quotient

The maximum value of THQ of Cr was found in Turnip samples, whereas minimum THQ was found in Lotus samples. The HI of Cr was measured as 0.33 which is less than unity. Similarly, THQ values were found in the range of 0.0115 - 0.0613 minimum in sweet potato and ginger samples (Table 3).

Health Indexes

The HI value greater than one shows possible health hazard which was displayed only by arsenic. HI greater than 1 increases the level of distress to the population consuming the vegetables from the study area; while HI values less than 1 concludes that the population is protected. Since HI value greater than one (1.83) was found for Arsenic. All other metals displayed HI values of less than one (Table 3). The order of HI for heavy metals was found as follows; As > Cd > Cr > Cu > Mn > Zn > Fe (Table 3).

Table 3. **Target hazard quotient (THQ) for different heavy metals, their hazard index (HI) from consumption of various types of vegetables collected from different locations of district Ghotki.**

HMs	Ginger	Beet Root	Potato	Lotus	Radish	Garlic	Carrot	Onion	Turnip	Sweet Potato	HI
Cr	0.0240	0.0360	0.0227	0.0217	0.0324	0.0334	0.0235	0.0237	0.0849	0.0317	0.33
Cu	0.0613	0.0241	0.0357	0.0235	0.0236	0.0330	0.0250	0.0197	0.0260	0.0115	0.28
Cd	0.0493	0.0480	0.0387	0.0309	0.0385	0.0331	0.0419	0.0248	0.0277	0.0364	0.37
As	0.2211	0.2117	0.2085	0.1975	0.2179	0.1583	0.1207	0.1364	0.1819	0.1772	1.83
Fe	0.0002	0.0002	0.0002	0.0003	0.0003	0.0002	0.0002	0.0002	0.0005	0.0005	0.00
Mn	0.0230	0.0250	0.0283	0.0272	0.0154	0.0188	0.0169	0.0146	0.0141	0.0168	0.20
Ni	0.0086	0.0074	0.0096	0.0100	0.0077	0.0094	0.0099	0.0083	0.0087	0.0111	0.09
Zn	0.0116	0.0145	0.0149	0.0144	0.0110	0.0095	0.0121	0.0131	0.0132	0.0111	0.13

Heavy Metal Concentration in Studied Vegetables

The Cr content range in various vegetable samples was found as 0.416 and 1.625 mg/kg in Turnips and Lotus, respectively, while The WHO/FAO limit is 1.5 mg/kg. Vegetable samples of Turnips showed alarming levels of Cr, whereas all other vegetable samples declared chromium within allowable levels (Table 4 & 5) & (Fig. 2). Cr is extremely significant for DNA transcription as well as insulin activity. Although an intake of less than 0.02 mg/day may reduce the cellular responses to insulin [26].

The highest and lowest amount of 5.216 and 0.981 mg/kg of Cu was found in vegetables of Ginger and Sweet Potato, respectively. The safe level of Cu was found in all vegetable samples than the allowable level of 10 mg/kg (Table 4 & 5). The interaction of Cu with the atmosphere is complicated; it may be observed from the research that a major part of Cu introduced into the atmosphere may readily become stable which cannot pose a health problem. Cu is very important for the development of animals and plants and therefore is considered a micronutrient element. It helps in the production of human blood haemoglobin, while in plants Cu is extremely significant in water regulation, disease resistance, and seed production. High levels of Cu may cause intestinal and stomach irritation, kidney and liver damage and anaemia as well. Increased oxidative damage may be caused to DNA, lipids and proteins by copper. Tubular necrosis in kidney and liver cirrhosis may also be caused due to chronic Cu toxicity [27, 28].

Table 4. **Mean content of heavy metals (mg/kg) in different vegetables collected from various locations of District Ghotki.**

HMs	Ginger (n = 5)	Beet Root (n = 5)	Potato (n = 5)	Lotus (n = 5)	Radish (n = 5)	Garlic (n = 5)	Carrot (n = 5)	Onion (n = 5)	Turnip (n = 5)	Sweet Potato (n = 5)
Cr	0.46	0.688	0.434	0.416	0.62	0.639	0.449	0.454	1.625	0.606
Cu	5.216	2.046	3.036	2.002	2.01	2.808	2.128	1.678	2.211	0.981
Cd	0.524	0.51	0.411	0.329	0.409	0.352	0.445	0.264	0.295	0.387
As	0.141	0.135	0.133	0.126	0.139	0.101	0.077	0.087	0.116	0.113
Fe	0.286	0.356	0.303	0.382	0.393	0.285	0.338	0.322	0.700	0.816
Mn	0.684	0.744	0.843	0.811	0.457	0.559	0.502	0.436	0.421	0.501
Ni	0.364	0.315	0.408	0.426	0.326	0.399	0.423	0.351	0.37	0.473
Zn	7.386	9.259	9.485	9.159	7.017	6.028	7.718	8.373	8.397	7.050

Table 5. **Descriptive statistics, maximum contaminant level and reference Dose (RfD) of heavy metals for vegetables collected from different locations of District Ghotki.**

HMs	Max: (mg/kg)	Min: (mg/kg)	Mean (mg/kg)	SD.	WHO/FAO Limit	RfD (mg/kg/day)
Cr	1.625	0.416	0.639	0.361	1.5	1.5000
Cu	5.216	0.981	2.412	1.134	10	0.0400
Cd	0.524	0.264	0.393	0.086	0.1	0.0050
As	0.141	0.077	0.117	0.022	0.1	0.0003
Fe	0.816	0.285	0.418	0.185	150	0.7000
Mn	0.843	0.421	0.596	0.160	2.5	0.0140
Ni	0.473	0.315	0.386	0.049	0.10	0.0200
Zn	9.485	6.028	7.987	1.137	20	0.3000

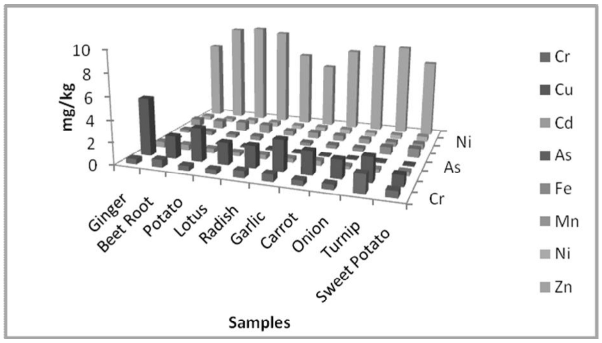

Figure 2. **Heavy metals (mg/kg) in different vegetables collected from various locations of District Ghotki**

The higher and lower concentration of Cd was measured from Ginger (0.524 mg/kg) and Carrot (0.264 mg/kg) greater than permissible limit of 0.1 mg/kg of the WHO guideline. The mean Cd content (0.393 mg/kg) was also greater than the allowable limit (Table 4 & 5). Contaminated water and food are the main Cd exposure for humans, while Cd may be inhaled through cigarette smoke. Cd toxicity is because of its buildup in animals and plants for about 25 to 30 years. Cd may be removed from food by one of the effective methods like microbial fermentation [29, 30]. Phosphate fertilizers and waste incineration procedure is another main source of Cd in the atmosphere. There may be a large difference in blood Cd levels between non-smokers and smokers of cigarettes. Toxic effects may be found on the gastric system and may lead to lung cancer, breast cancer, gastric cancer, as well as renal cancer. The reference daily dose for Cd as established by EPA is 0.001 mg/kg/day for food and 0.0005 mg/kg/day for water [31].

The range of As content was determined as 0.077 to 0.141 mg/kg in vegetables of Carrot and Ginger, respectively. The allowable As level is mentioned as 0.1 mg/kg, although average arsenic concentration of 0.117 mg/kg was greater than the permissible limit. Only carrot and onion displayed safe As level. The all remaining vegetables showed As content at an alarming level (Table 4 & 5). As is not a metal but a metalloid but because of its carcinogenic and toxic nature, it is therefore presented along with heavy metal toxicity. Various researchers have discussed the health effects of arsenic disclosure to humans. Foods, groundwater, and atmospheric air are responsible for As exposure for majority of the population [32]. As damages reproductive, renal, endocrine, and cardiovascular systems. But in numerous parts of the globe such as Bangladesh, India and Pakistan it was observed that groundwater is the main source of As exposure. According to the reports of the researchers, the major source of As exposure in Pakistan and Bangladesh is groundwater [33, 34]. Groundwater contamination of As in Bangladesh may be due to the intensive use of agrochemicals for agricultural purposes. Chronic exposure of inorganic As may cause "black-foot disease" which is illustrated by a constant failure of circulation in feet and hands, causing eventually gangrene and necrosis.

The WHO/FAO allowed Fe level given as 150 mg/kg, while all samples collected from the study area showed a safe limit of Fe. The lowest and the highest level of 0.285 and 0.816 mg/kg of Fe were determined from Garlic and Sweet Potato, respectively. The mean Fe content was measured as 0.418 mg/kg from vegetable samples of the study area (Table 4 & 5). Fe sufficiency may enhance the rate of estrogen–induced kidney tumors in Syrian hamsters; it also enhances the carcinogen–induced mammary cancer in mice. Fe adequacy also caused a variety of estrogen–induced cancers in humans. For an extensive range of metabolic purposes, Fe plays a function as a catalytic center [35]. However, Fe deficiency also causes anaemia. Numerous signals of Fe deficiency are observed like, spoiled cognitive role, less ability of hearing, exhaustion, reduced physical fitness, decreased work efficiency, enhanced distractibility, itching, reduced coordination and reactivity, failure to normalize body temperature and ingestion pica [36, 37].

WHO/FAO maximum contaminant point of Mn for vegetables is suggested as 2.5 mg/kg, while data shows a safe limit of Mn in all vegetables in the study area. The utmost and smallest Mn content was determined as 0.843 and 0.421 mg/kg in samples of Potato and Turnip, respectively. The average Mn concentration in samples collected from Ghotki district was found as 0.596 mg/kg (Table 4 & 5).

Mn is toxic at a high level while it is an essential metal for the nutrition of animals as well as plants. Mn is present in various foods of the human diet like oysters, green beans, olive oil, nuts, eggs, soya beans, rice, grains, herbs, tea and spinach. The brain and respiratory tract in human is mostly affected due to Mn toxicity, indications include nerve damage, figment of the imagination and absentmindedness. Bronchitis, lung embolism, and Parkinson's disease are also caused by Mn [38]. Deficiency of Mn may cause impaired growth and reproduction. Its symptoms include neurological symptoms, birth effects, skeleton disorders, skin problems, lowered cholesterol levels, blood clotting, weight gain and glucose intolerance. The Ni content range was found as 0.315 and 0.473 mg/kg in vegetables Onion and Sweet Potato, respectively. The average Ni content of 0.386 mg/kg is greater than the allowable level of 0.1 mg/kg suggested by WHO/FAO. All vegetable samples displayed alarming levels of Ni in the study area of district Ghotki (Table 4 & 5). No specific function of Ni has been observed in humans, but for some microbial intestine enzymes, it acts as a co – factor. Higher levels of Ni may cause damage to cell and DNA structures, which should be less than 0.1 mg/day [39, 40].

The maximum, minimum and mean values of Zn in vegetables were determined as 9.485, 6.028 and 7.987 mg/kg. All samples declared Zn content below the allowable level of 20 mg/kg as suggested by WHO/FAO (Table 4 & 5) & (Fig. 2). Zn insufficiency in humans' diet may be more harmful to health because it is an essential element. Health effects related to Zn deficiency include dermatitis, immune puzzlements, deferred wound healing, growth retardation, damaged neuropsychological functions, oligospermia and neurosensory changes. For men and women the recommended dietary allowance (RDA) for Zn is 11 and 8 mg/day, respectively, while for women during pregnancy and lactation higher RDAs are recommended [41, 42]. The concentration of HMs in vegetables reported in the literature in Pakistan and worldwide is provided in Table 6.

Table 6. **The concentration (mg/kg) of heavy metals in vegetables on reported in the literature in Pakistan and worldwide.**

HMs	Ginger	Beet Root	Potato	Lotus	Radish	Garlic	Carrot	Onion	Turnip	Sweet Potato
Cr	3.17 [43]	7.61 [44]	5.87 [45]	17.27 [46]	10.11 [45]	7.89 [45]	16.32 [45]	22.18 [45]	2.70 [47]	16.7 [48]
Cu	65.14 [43]	10.94 [44]	14.35 [45]	32.18 [46]	24.85 [45]	18.76 [45]	28.40 [45]	6.25 [45]	8.10 [47]	3.3 [48]
Cd	4.60 [43]	0.00 [44]	0.280 [45]	1.52 [46]	0.77 [45]	0.00 [45]	0.96 [45]	0.13 [45]	0.10 [47]	18.8 [48]
As	-	-	0.073 [44]	4.82 [46]	0.073 [44]	-	0.148 [44]	-	-	16.6 [48]
Fe	78.64 [43]	80.52 [44]	66.78 [45]	-	59.81 [45]	65.21[45]	80.51[45]	182.4 [45]	93.53 [47]	20.5 [48]
Mn		16.22 [44]	15.87 [45]	-	-	13.65 [45]	14.76 [45]	20.15 [45]	11.10 [47]	8.9 [48]
Ni	7.01 [43]	2.16 [44]	3.90 [45]	-	3.41[45]	8.21 [45]	3.37 [45]	0.54 [45]	0.00 [47]	10.3 [48]
Zn	16.74 [43]	34.18 [44]	26.52 [45]	88.4 [46]	39.48 [45]	24.83 [45]	29.20 [45]	23.94 [43]	50.95 [45]	15.9 [48]

Correlation Coefficient

The correlation coefficient was determined with the help of SPSS Software version 18. This shows that only Fe – Cr declared a strong positive correlation. None of the other pair displayed either a positive or negative strong or weak correlation coefficient among HMs of the studied area (Table 7).

Table 7. **Correlation coefficient among heavy metals determined from study area.**

Correlations								
	Cr	***Cu***	***Cd***	***As***	***Fe***	***Mn***	***Ni***	***Zn***
Cr	1							
Cu	-.090	1						
Cd	.026	.274	1					
As	.173	.058	-.080	1				
Fe	.799**	-.423	-.184	.189	1			
Mn	-.389	.205	-.268	.429	-.283	1		
Ni	-.066	-.216	-.326	-.235	.424	.000	1	
Zn	-.050	-.338	-.505	.167	.087	.567	.015	1

**. Correlation is significant at the 0.01 level (2-tailed).

Conclusion

Heavy metals were determined from the vegetable samples collected from district Ghotki. The average concentration of Chromium, Cadmium, Arsenic and Nickel showed alarming levels in collected vegetable samples of district Ghotki. The average content of Copper, Iron, Manganese and Zinc were found within the allowable limit of FAO/WHO guidelines in root vegetables of the study area. Food plants especially root vegetables are the major dietary source being consumed all over the world. They play a significant role in nutritious commitment to the customers. Target Hazard Quotient (THQ) associated with the assessed heavy metals exposure via consumption of root samples for adults were below 1 in all samples. However, health indices of all heavy metals were below 1 except arsenic which was above 1. To avoid risks to human health, strict enforcement must be followed for the maximum allowable ingestion of heavy metals. The nutritional value of vegetables is decreased due to heavy metal contamination. It is recommended that the intake of vegetables by animals and humans must be avoided from those sites which are contaminated by arsenic and heavy metals. Order of the average concentration of heavy metals was found as, Ginger Zn > Cu > Mn > Cd > Cr > Ni > Fe > As, Beet Root as, Zn > Cu > Mn > Cr > Cd > Fe > Ni > As, Potato as, Zn > Cu > Mn > Cr > Cd > Ni > Fe > As, Lotus as, Zn > Cu > Mn > Cr > Ni > Fe > Cd> As, Radish as, Zn > Cu > Cr > Mn > Cd > Fe > Ni > As, Garlic as, Zn > Cu > Cr > Mn > Ni > Cd > Fe > As, Carrot as, Zn > Cu > Mn > Cr > Cd > Ni > Fe > As, Onion as, Zn > Cu > Cr > Mn > Ni > Fe > Cd > As, Turnip as, Zn > Cu > Cr > Fe > Mn > Ni > Cd > As and Sweet Potato as, Zn > Cu > Fe > Cr > Mn > Ni > Cd > As. It is therefore suggested that heavy metals and arsenic must be regularly monitored in common vegetables in the study area.

Conflict of Interest

The authors declare that there is no conflict of interest.

References

1. M. Varol, K. Gündüz and M.R. Sünbül, *Environ. Res., 202* (2021) 111806. https://doi.org/10.1016/j.envres.2021.111806
2. C. Tokatlı and M. Varol, *Environ. Res.*, 201 (2021) 111571.

https://doi.org/10.1016/j.envres.2021.111571
3. G. Qin, Z. Niu, J. Yu, Z. Li, J. Ma and P. Xiang, *Chemosphere*, *267* (2021) 129205. https://doi.org/10.1016/j.chemosphere.2020.129205
4. A. Alengebawy, S.T.Abdelkhalek, S.R. Qureshi and M.Q. Wang, *Toxics*, *9* (2021) 42. https://doi.org/10.3390/toxics9030042
5. J. K. Saha, R. Selladurai, M. V. Coumar, M. L. Dotaniya, S. Kundu, A. K. Patra, J. K. Saha, R. Selladurai, M. V. Coumar, M. L. Dotaniya and S. Kundu, *Soil Poll. Emer. Thre. Agric.*, 10 (2017) 155. https://doi.org/10.1007/978-981-10-4274-4_7.
6. C. Chaza, S. Rayane, N. Sopheak, B. Moomen and O. Baghdad, *Int. J. Environ. Res.*, 12 (2018) 631. https://doi.org/101007/s41742-018-0120-0
7. L. Joanne Slavin and B. Lloyd, *Adv. Nutr.*, 3 (2012) 506. https://doi.org/10.3945/an.112.002154
8. C. Luo, C. Liu, Y. Wang, X. Liu, F. Li, G. Zhang, and X. Li, *J. Hazard. Mat.*, *186* (2011) 481. https://doi.org/10.1016/j.jhazmat.2010.11.024
9. N. Munir, M. Jahangeer, A. Bouyahya, N. El Omari, R. Ghchime, A. Balahbib, S. Aboulaghras, Z. Mahmood, M. Akram, S. M. Ali Shah and I. N. Mikolaychik, *Sustainability*, 14 (2022) 161. https://doi.org/10.3390/su14010161
10. Z. Xu, M. Shi, X. Yu and M. Liu, *Int. J. Environ. Res. Public Health*, 19 (2022) 9835. doi: 10.3390/ijerph19169835
11. F. Noli and P. Tsamos, *Sci. Total Environ.*, 563 (2016) 377. https://doi.org/10.1016/j.scitotenv.2016.04.098
12. N. Shaheen, N. M. Irfan, I. N. Khan, S. Islam, M. S. Islam and M. K. Ahmed, *Chemosphere*, 152 (2016) 431. https://doi.org/10.1016/j.chemosphere.2016.02.060
13. V. Antoniadis, S. M. Shaheen, J. Boersch, T. Frohne, G. Du Laing and J. Rinklebe, *J. Environ. Manag.*, *186* (2017) 192. https://doi.org/10.1016/j.jenvman.2016.04.036
14. K. ur Rehman, S. M. Bukhari, S. Andleeb, A. Mahmood, K. O. Erinle, M. M. Naeem and Q. Imran, *Agric. Water Manag.*, *226* (2019) 105816. https://doi.org/10.1016/j.agwat.2019.105816
15. F. A. Rutigliano, R. Marzaioli, S. De Crescenzo and M. Trifuoggi, *Sci. Total Environ.*, 691 (2019) 195. https://doi.org/10.1016/j.scitotenv.2019.07.037
16. A. Guadie, A. Yesigat, S. Gatew, A. Worku, W. Liu, F. O. Ajibade and A. Wang,. *Sci. Total Environ.*, 761 (2021) 143302. https://doi.org/10.1016/j.scitotenv.2020.143302
17. N. Gupta, K. K. Yadav, V. Kumar, S. Krishnan, S. Kumar, Z. D. Nejad, M. M. Khan, and J. Alam, *Environ. Toxicol. Pharmacol.*, 82 (2021) 103563. https://doi.org/10.1016/j.etap.2020.103563
18. J. Wang, L. Wang, Y. Wang, D. C. Tsang, X. Yang, J. Beiyuan, M. Yin, T. Xiao, Y. Jiang, W. Lin and Y. Zhou, *Environ. Inter.*, *146* (2021) 106207. https://doi.org/10.1016/j.envint.2020.106207
19. S. Park, L. Zhao, S. H. Lee, H. C. Hamner, L. V. Moore, D. A. Galuska and H. M. Blanck, *Nutrients*, 15 (2023) 274. https://doi.org/10.3390/nu15020274

20. D. Romero-Estévez, G. S. Yánez-Jácome, K. Simbaña-Farinango and H. Navarrete, *Foods*, 8 (2019) 330. https://doi.org/10.3390/foods8080330
21. M. Harmanescu, L. M. Alda, D. M. Bordean, I. Gogoasa and I. Gergen, *Chem. Cent. J.*, 5 (2011) 1. https://doi.org/10.1186/1752-153X-5-64
22. A. Margenat, V. Matamoros, S. Díez, N. Cañameras, J. Comas and J. M. Bayona, *Environ. Int.*, 124 (2019) 49. https://doi.org/10.1016/j.envint.2018.12.013
23. G. Mustatea, E. L. Ungureanu, S. C. Iorga, D. Ciotea and M. E. Popa, *Foods*, 10 (2021) 581. https://doi.org/10.3390/foods10030581
24. F. A. O. WHO. Joint Expert Committee on Food Additives and World Health Organization (2011). World Health Organization. https://apps.who.int/iris/bitstream/handle/10665/44520/?sequence=1
25. M. Bamuwamye, P. Ogwok and V. Tumuhairwe, *J. Environ. Pollut. Human Health*, 3 (2015) 24. doi:10.12691/jephh-3-2-1
26. F. Guerra, A. R. Trevizam, T. Muraoka, N. C. Marcante and S. G. Canniatti-Brazaca, *Sci. Agric.*, 69 (2012) 54. https://doi.org/10.1590/S0103-90162012000100008
27. M. Rehman, L. Liu, Q. Wang, M. H. Saleem, S. Bashir, S. Ullah and D. Peng, *Environ. Sci. Poll. Res.*, 26 (2019). 18003. https://doi.org/101007/s11356-019-05073-6
28. W. Hermann, *Annals Trans. Med.*, 7 (2019) 1. doi: 10.21037/atm.2019.02.07
29. G. Genchi, M. S. Sinicropi, G. Lauria, A. Carocci and A. Catalano, *Inter. J. Environ. Res. Pub. Health*, 17 (2020) 3782. https://doi.org/10.3390/ijerph17113782
30. M. Ebrahimi, N. Khalili, S. Razi, M. Keshavarz-Fathi, N. Khalili and N. Rezaei, *J. Environ. Health Sci. Eng.*, 18 (2020) 335 https://doi.org/10.1016/j.toxrep.2021.05.015
31. K. Fatema, S. S. Shoily, T. Ahsan, Z. Haidar, A. F. Sumit and A. A. Sajib, *Toxicol. Rep.*, *8* (2021) 1109. https://doi.org/10.1016/j.toxrep.2021.05.015
32. C. W. Chang, C. H. Ou, C. C. Yu, C. W. Lo, C. Y. Tsai, P. Y. Cheng, Y. T. Chen, H. C. Huang, C. C. Wu, C. C. Li and H. Y. Lee, *BMC Cancer*, 21 (2021) 1. https://doi.org/10.1186/s12885-021-07799-4
33. H. Ur Rehman, S. Ahmed, M. Ur Rahman and M.S. Mehmood, *Environ. Sci. Pollut. Res.,* 29 (2022) 49796. https://doi.org/10.1007/s11356-022-19405-6
34. F. Karahan, I. I. Ozyigit, I. A. Saracoglu, I. E. Yalcin, A. H. Ozyigit and A. Ilcim, *Biol. Trace Elem. Res.,* 197 (2020) 316. https://doi.org/10.1007/s12011-019-01974-2
35. A. Atamaleki, A. Yazdanbakhsh, Y. Fakhri, F. Mahdipour, S. Khodakarim and A. M. Khaneghah, *Food Res. Inter.*, 125 (2019) 108518. https://doi.org/10.1016/j.scitotenv.2020.143302.
36. C. Wong, *Paediatr. Child Health*, 27 (2017) 527. https://doi.org/10.1016/j.paed.2017.08.004
37. K. M. Erikson, M. Aschner, *Met. Ions Life. Sci.,* 19 (2019) 253. https://doi.org/10.1515/9783110527872-016
38. R. C. Balachandran, S. Mukhopadhyay, D. McBride, J. Veevers, F. E. Harrison, M. Aschner, E. N. Haynes and A.B. Bowman, *J. Biol. Chem.*, 295 (2020) 6312. https://doi.org/10.1074/jbc.REV119.009453

39. F. Karahan, I. I. Ozyigit, I. A. Saracoglu, I. E. Yalcin, A. H. Ozyigit and A. Ilcim, *Biol. Trace Elem. Res.*, 197 (2020) 3169. https://doi.org/10.1007/s12011-019-01974-2
40. S. T. Khan and A. Malik, Microbial Biofertilizers and Micronutrient Availability (*Springer Cham, Switzerland)* (2021). https://doi.org/10.1007/978-3-030-76609-2
41. C. T. Chasapis, P. S. A. Ntoupa, C. A. Spiliopoulou and M.E. Stefanidou, *Arch. Toxicol.*, 94 (2020) 1443. https://doi.org/10.1007/s00204-020-02702-9
42. N. N. F. Sheet, *National Food Policy Plan of Action and Country Investment Plan, Government of the People's Republic of Bangladesh* (2011) 1. https://faolex.fao.org/docs/pdf/bgd163029.pdf
43. F. Ali, M. Israr, S. Ur Rehman, A. Azizullah, H. Gulab, M. Idrees, R. Iqbal, A. Khattak, M. Hussain and F. M. Al-Zuaibr, *Plos One*, 16 (2021) e0255853. https://doi.org/10.1371/journal.pone.0255853.
44. N. Hussain, shafiq, M. Ahmed and S.M Hussain, *Saudi J. Biol. Sci.*, 29 (2022) 1813. https://doi.org/10.1016/j.sjbs.2021.10.043
45. M. A. Fazili, N. Ahmad, J. M. War, R. Nazir and M. Akram, *Res. Square,* PREPRINT (Version 1) (2022) 1. https://doi.org/10.21203/rs.3.rs-1814291/v1
46. I. Ashraf, F. Ahmad, A. Sharif, A. R. Altaf and H. Teng, *Appl. Sci.*, 3 (2021) 1. https://doi.org/10.1007/s42452-021-04547-y
47. N. Gupta, K. K. Yadav, V. Kumar, S. Prasad, M. Cabral-Pinto, B. H. Jeon, S. Kumar, M. H. Abdel Latif and A. K. D Alsukaibia, *Front. Environ. Sci.*, (2022) 40. doi: 10.3389/fenvs.2022.791052
48. R. Sultana, R. U. Tanvir, K. A. Hussain, A. S. Chamon and M. N. Mondol, *Environ. Syst. Res.,* 11 (2022) 15. https://doi.org/10.1186/s40068-022-00261-9