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Heavy Metal Accumulation in Goosefoot (*Chenopodium album* L.) Irrigated With Wastewater

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Abstract

Wastewater sources contain enormous amounts of nutrients for plant growth. This study aimed to define the metal accumulation in the goosefoot plant (*Chenopodium album* L.) of wastewater use in agricultural irrigation and to evaluate the risks of this accumulation to human health. The present research was performed in field conditions in Khushab, Pakistan. The Cd, Cu, Cr, Fe, Zn, Ni, and Mn concentrations were determined with the analysis performed using Atomic Absorption Spectrophotometer-AAS. Heavy metal concentrations in goosefoot samples irrigated with groundwater (GWI), canal water (CWI) and sugar mill water (MWI) ranged from 0.84 to 1.08, 0.55 to 0.78, 0.23 to 0.70, 2.09 to 5.56, 2.84 to 13.53, 0.53 to 1.13 and 0.32 to 0.39 mg/kg for Cd, Cr, Cu, Fe, Ni, Zn, and Mn, respectively. According to the statistical analyses, wastewater applications had a non-significant effect on Cr, Cu, and Zn concentrations in *C. album* samples collected from three sites, and a significant effect on Cd, Fe, Mn, and Ni concentrations ($p>0.05$). The results also showed that the health risk index value of cadmium was higher than 1. According to these results, long-term consumption of *C. album* samples grown in the study area may cause an accumulation of Cd in the human body and diseases in many tissues and organs.

Keywords: Biomonitoring, Goosefoot, Vegetable, Trace Metal

Introduction

Wastewater sources contain enormous amounts of nutrients for plant growth. For this reason, wastewater is used in many parts of the world to irrigate crops in urban and suburban lands [1-3]. Another reason for using wastewater in agricultural irrigation is that many countries do not have facilities for the non-toxic disposal of wastewater. For this reason, vegetables in urban areas of many countries are mostly irrigated with industrial and urban wastewater [4-7]. These wastewaters contain a variety of contaminants, including both inorganic and organic hazardous chemicals, medical wastes, and nutrients [8-13].

Industrial and domestic wastewater enters the soil and water system through agricultural irrigation and introduces potentially toxic metals [14-15]. Therefore, the concentrations of heavy metals increase in the soil due to the intensive usage of wastewater. These metals can affect plant growth and the health of living things as well as negatively affect nutritional value [16-20]. The accumulation of these toxic compounds in the food chain may cause various problems in the health of all living things in the ecosystem, including humans and animals. The intake of hazardous substances such as trace metals causes serious diseases in humans [21-22]. Heavy metal toxicity can have acute or chronic effects [23-25].

Irrigation of agricultural soil by wastewater for a long period may lead to the accretion of metals in agricultural soils and plants. Potential health risks and food safety problems make this one of the most alarming environmental aspects [26]. Consumption of food crops grown in soils irrigated with contaminated water having a high amount of heavy metals can exert a direct impact on human health [27]. Crops of rice contaminated with Cd on a farm in Asia provide a strong indication that dysfunction of the human renal tubule is due to Cd as a heavy metal [13]. It has been indicated that crops have different capacities to translocate and accumulate harmful material and heavy metals in their different parts. It is also described that there is an extensive discrepancy in the uptake and absorbance of metals between different species of plants and even between cultivars of identical species [28].

Many Chenopodium species are traditionally used in indigenous systems of medicine for the treatment of numerous ailments. Chenopodium album, a plant widely distributed in Asia, North America, and Europe, is grown as a food crop in parts of Asia and Africa [22]. Many studies have been reported on a wide variety of chemical components such as aldehydes, alkaloids, apocarotenoids, and flavonoids in the structure of the plant, and the antifungal and antioxidant properties of the plant. Examples of the reported benefits of the herb on its use for phytotherapeutic purposes: appetite enhancer, anthelmintic, laxative, diuretic, biliary, and beneficial against abdominal pain and eye diseases [29].

Agricultural activities in Pakistan stand out as one of the most important economic activities of the country [16]. On the other hand, Pakistan, which can be described as an agricultural country, has a great problem in terms of clean water resources [19]. For this reason, a significant part of the water required for agricultural irrigation is obtained by mixing wastewater such as industrial wastewater and sewage water with groundwater. Studies have shown that irrigation with wastewater is effective in metal accumulation in agricultural products, since the water used for agricultural irrigation is not made clean by advanced treatment methods [22]. Literature studies on the subject have shown that studies on heavy metal accumulation in *C. album* samples irrigated with wastewater and the effects of these plants on health are not sufficient. For this reason, the main aim of this study is to define the metal accumulation in the *C. album* plant of wastewater use in agricultural irrigation and to evaluate the risks of this accumulation for human health.

Materials and Methods

Study Area

The present research was performed in field conditions in Khushab, Pakistan (Fig. 1). Khushab district of the province of Punjab is placed in Pakistan country (GPS coordinates: 31° 52' 42.4956'' N and 71° 53' 55.0896'' E). The maximum temperature measured in the region in the summer is about 50 °C, and the lowest in the winter is about 12 °C. Due to this temperate feature, the city of Khushab offers a favourable environment for agricultural applications.

Figure 1. **The map of the study area**

Plant Cultivation

Goosefoot (*Chenopodium album* L.) samples were grown at the end of October 2016 in 60 small plastic pots. Approximately 2.5 kg of soil was filled in each plastic pot and a different treatment was applied to every 20 plastic pots. Ten seeds were sown in each plastic pot, and each pot was irrigated twice a week with a litre of groundwater (TI: GWI), canal water (TII: CWI), and sugar mill water (TIII: MWI). After the plant samples in the pots matured, only four plants were left in each pot and 210 kg ha^{-1} urea fertilizer was applied to each pot.

The samples of water used in the irrigation of the pots were also taken as examples in the metal analysis. Soil samples were taken from the pots at a depth of 5 cm with the help of an auger. At the end of April 2017, goosefoot leaves were collected for analysis, dried outdoors, and ground by pounding in a mortar. Ground powdered plant samples were dried in an oven for 3 days at 75 ^{o}C. After it was completely dry, the samples were prepared for metal analysis using the Wet Digestion Method [17].

Sample Preparation and Metal Analysis

During the preparation of soil and goosefoot samples for analysis by wet digestion method, 1 g of soil and goosefoot sample was digested. Soil samples were digested with HNO_3 using a standard protocol. Plant samples were digested with a mixture of HNO_3, H_2SO_4, and $HClO_4$ (5:1:1) at 80°C until a transparent solution was obtained. After the solution had cooled, it was filtered through Whatman filter paper #42 and the final volume of the solution was made up to 50 mL. The final solution was stored in plastic bottles for metal analysis. The Cd, Cu, Cr, Fe, Zn, Ni, and Mn concentrations were determined with the analysis performed using Atomic Absorption Spectrophotometer-AAS (Shimadzu model AA-6300). The operating conditions for the respective potentially toxic metals are given in Table 1.

Table 1. **Operating conditions for the analysis of metals using atomic absorption spectrometry.**

Element	Cd	Cr	Cu	Fe	Ni	Zn	Pb
Wavelength (nm)	228.8	422.7	324.8	248.3	232.0	213.9	283.3
Slit width (nm)	0.7	0.7	0.7	0.2	0.2	0.7	0.7
Lamp current (mA)	8	10	6	12	12	8	10
Air flow rate (L/min)	15	15	15	15	15	15	15
Acetylene flow rate (L/min)	1.8	2.8	1.8	2.2	1.6	2	2.0
Burner height (mm)	7	9	7	9	7	7	7

Statistical Analysis

The variance of the metal values for water, soil, and vegetables was analysed by one-way ANOVA by SPSS 23 at 0.001, 0.01, and 0.05 significance levels. Correlations between vegetables and soil were calculated with Pearson's correlation coefficient.

Bioconcentration factor (BCF)

The following formula was used to calculate the BCF, which shows the metal accumulation in the plant as a result of heavy metal transfer from the soil to the plant:

$$BCF = C_{veg} / C_{soil}$$

C_{veg}: metal value in plant (mg/kg), C_{soil}: metal value in soil (mg/kg) [12].

Daily intake of metals (DIM)

DIM, one of the methods used to assess whether the consumed products pose a health risk, was measured using the following formula:

$$DIM = C_{metal} \times C_{food\ intake} / B_{average\ weight}$$

C_{metal}: metal value in plant, $C_{food\ intake}$: daily food intake, $B_{average\ weight}$: average body weight. The daily food intake of a person was taken as 0.345 mg/kg and an average body weight of 60 kg as a standard [9].

Health risk index (HRI)

In this study, the HRI used to evaluate the health risk status that may occur in the case of consumption of *C. album* samples by humans was calculated using the following formula [9].

$$HRI = DIM / \text{Oral reference dose}$$

Pollution load index (PLI)

The PLI for each irrigation application was calculated using the formula below [9]:

PLI = Metal value of soil / Reference metal value of soil

The reference soil values (mg/kg) of Cd (1.49), Cr (9.07), Cu (8.39), Fe (56.90), Ni (9.06), Zn (44.19), and Mn (46.75) were taken according to Ugulu et al. [3].

Results and Discussions

The use of wastewater in agricultural irrigation saves water in areas with clean water shortages, but it can positively or negatively affect the development of plants grown with organic and inorganic substances in their content [11]. In addition, harmful chemicals such as heavy metals in the composition of wastewater can seriously threaten human health by participating in the food chain as well as affecting the development of agricultural products [13]. In the present study, it was aimed to determine the influence of using wastewater in agricultural irrigation on the metal contamination in vegetables in the *C. album* sample in Pakistan, an agricultural country where there is a significant deficiency of fresh water, and to evaluate the risks posed by this accumulation for human health.

First of all, in this experimental study, when the metal values in the samples used in irrigation for the cultivation of *C. album* samples were examined, it was determined that the Fe and Zn values in all irrigation water samples were higher than the other metal values (Fig. 2). However, it was determined that heavy metal values in canal water (TII: CWI) and sugar mill water (TIII: MWI) samples were higher than groundwater (TI: GWI) values. The ANOVA results indicated that there are no significant differences (p>0.05) between the metal concentrations for the Cr, Cd, Cu, Ni, and Mn while the significant differences for Fe and Zn in the water samples (Table 2).

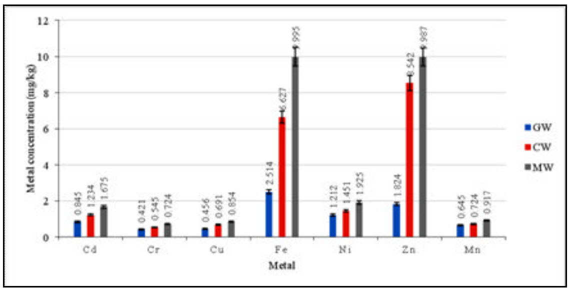

Figure 2. **Fluctuation of heavy metals in irrigation water**

The limits for the heavy metal content of water suitable for use in agricultural irrigation have been determined by institutions such as WHO, FAO, USEPA, and European Standard Guidelines [27]. Many countries and agricultural organizations try to prevent the risks that may arise in terms of environmental health by carrying out their inspections within these limits [8]. Accordingly, the maximum metal limits allowed for the water to be used in agricultural irrigation are determined by the European Standard Guidelines as 0.01, 0.5, 0.2, 5, 0.2, 2, and 0.2 mg/L for Cd, Cr, Cu, Fe, Ni, Zn, and Mn, respectively [30]. When these limits are compared with the data obtained in this study, it is seen that the metal values in the irrigation waters are higher than the limit values, except for Mn. As stated in the introduction of the study, many countries use wastewater in agricultural irrigation, but they do not or cannot do enough filtration in this process [22]. This situation can be shown as one of the main reasons why the heavy metal values determined in the irrigation water samples are above the reported limit values.

In the study conducted in Khushab, Khan et al. [9] noticed the metal values in groundwater (GWI), canal water (CWI), and industrial water (IW) samples from the region as 0.01-0.02-0.03 mg/L for Cu, 1.69-1.76-1.88 mg/L for Cd, 0.64-0.72-0.83 mg/L for Fe, 0.54-0.57-0.65 mg/L for Cr, 0.08-0.10-0.14 mg/L for Ni, 0.07-0.08-0.12 mg/L for Mn and 0.57-0.61-0.66 mg/L for Zn, respectively. Ugulu et al. [31] researched the effect of the use of various water sources in agricultural irrigation on metal contamination in vegetables in the ginger plant sample, and found that the Cd, Co, Cr, Cu, Fe, Ni, Pb, Zn, and Mn values in the wastewater samples were between 0.84-1.67, 0.08–0.22, 0.42-0.72, 0.45-0.85, 2.51-9.99, 1.21-1.92, 0.02–0.15, 1.82-9.98, and 0.64-0.91 mg/kg, respectively. As a result of the study, Ugulu et al. [31] determined that Fe and Zn values in wastewater samples were higher than other metals, similar to the findings of this study. Likewise, the metal values in the studies mentioned are above the maximum allowable limit values reported by the USEPA [32].

In the experimental study, after the metal values in the wastewater samples (GWI, CWI, and MWI) used for irrigation were determined, the heavy metal values of the soil samples taken from the pots where the goosefoot samples were grown were measured. The mean metal values in soil samples ranged from 0.83-1.033, 0.18-0.26, 0.071-0.124, 2.27-6.19, 0.38-0.40, 2.32-7.11, and 0.39-0.61 mg/kg for Cd, Cr, Cu, Fe, Ni, Zn, and Mn, respectively. The Fe and Zn concentrations for all soil samples were higher than other metal values (Fig. 3). These values also clearly showed that heavy metal accumulation values in soil samples irrigated with sugar mill water (MWI) were higher than the metal accumulation values of soil samples irrigated with other waters (GWI and CWI). The analysis of the variance of the data showed that the three treatments had a non-significant effect (p>0.05) on Cr and Ni while significant effects on Cd, Cu, Fe, Zn, and Mn concentrations were observed in the soil used to grow Chenopodium album (Table 2).

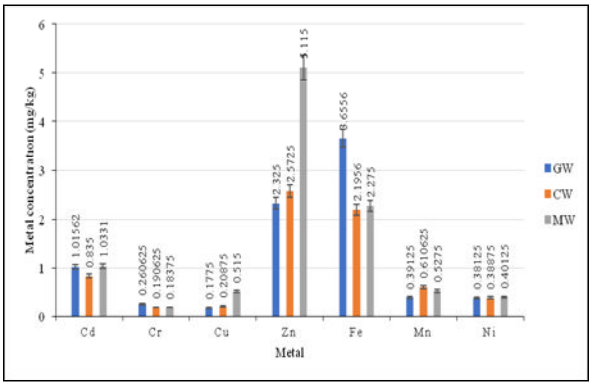

Figure 3. **Fluctuation of heavy metals in soil of *C. album***

Maximum permissible limits (MPL) can be defined as the highest tolerable values for heavy metals or other contaminants [24]. USEPA (1997) reported the MPLs of Cd, Cr, Cu, Fe, Ni, Zn, and Mn for soil as 3, 100, 50, 21000, 50, 200, and 2000 mg/kg, respectively. The metal values determined for soil samples in this study did not exceed these limits. A similar study was performed by Jamali et al. [33] who reported that the Zn value (208.6 mg/kg) was the highest and the Cd value (4.2 mg/kg) was the lowest in the studied soil samples. The results reported by Jamali et al. [33] were much higher than the present study. On the other hand, heavy metal concentrations in the soil of the present study were much lower than those reported by Chao et al. [34]. According to Chao et al. [34], Zn, Pb, Cu, and Ni concentrations in soils were 21.17-79.50, 24.36-40.69, 21.67-46.85, and 13.72-24.00 mg/kg (in dry matter), respectively. Concentrations of Cr and Fe noted by Balkhair and Ashraf [35] were 0.87-1.00 and 0.36-0.75 mg/kg, respectively, and the Cr value (0.87-1.00) was higher and the Fe value (0.36-0.75) was lesser than the present study. Many studies performed in Pakistan reported on the high concentration of heavy metals in vegetables irrigated with industrial water or sewage sludge. Ahmad et al. [36] examined the heavy metal accumulation in the soil samples irrigated with wastewater and tap water in their study in Khushab, Pakistan, and found that the cobalt accumulation in the soil irrigated with sewage water (20.2 mg/kg) was more than irrigated with tap water (13.5 mg/kg). As mentioned in this study, it was concluded that heavy metal accumulation was higher as a result of irrigation with the sewage water.

Metal concentrations in goosefoot samples ranged from 0.84 to 1.08, 0.55 to 0.78, 0.23 to 0.70, 2.09 to 5.56, 2.84 to 13.53, 0.53 to 1.13 and 0.32 to 0.39 mg/kg for Cd, Cr, Cu, Fe, Ni, Zn, and Mn, respectively. The Fe and Zn concentrations for all soil samples were higher than other metal values (Fig. 4). These values showed that heavy metal accumulation values in goosefoot samples irrigated with sugar mill water were higher than the metal accumulation values of goosefoot samples irrigated with other waters except Cu, Mn, and Ni. The analysis of the variance of the data showed that the three treatments had a non-significant effect ($p>0.05$) on Cr, Cu, and Zn but significant effects were observed on Cd, Fe, Mn, and Ni concentrations in collected C. album samples (Table 2).

Table 2. **Analysis of variance for heavy metals and metalloids in soil and *C. album*.**

Sample	Source of Variation SOV	Degree of freedom df	Mean Squares						
			Cd	***Cr***	***Cu***	***Fe***	***Ni***	***Zn***	***Mn***
Water	**Treatments**	4	$.215^{ns}$	$.002^{ns}$	$.364^{ns}$	6.189^{*}	$.750^{ns}$	$.006^{***}$	$.186^{ns}$
	Error	10	.052	.001	.074	.813	.307	.001	.039
Soil	**Treatments**	4	$.048^{*}$	.007	$.139^{***}$	15.819^{*}	.001	29.093^{*}	$.049^{**}$
	Error	10	.010	.005	.009	2.036	.001	6.721	.005
Goosefoot	**Treatments**	4	.057**	.006	.468	440.392**	.005**	54.826	.412**
	Error	10	.009	.008	.301	39.272	.001	31.330	.053

, **, ** significant at 0.05, 0.01, and 0.001 levels; ns, non-significant

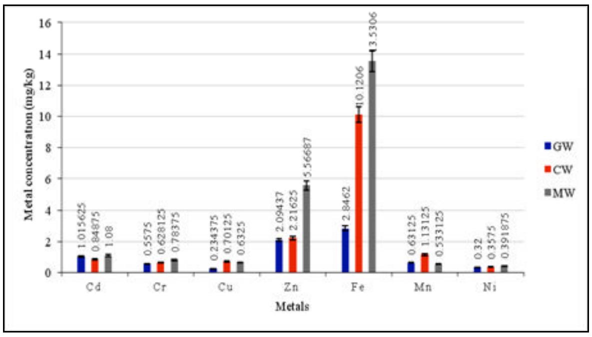

Figure 4. **Fluctuation of heavy metals in *C. album***

USEPA [31] reported the maximum permissible limits in plants as 0.1, 5, 73, 425, 67, 100, and 500 mg/kg for the Cd, Cr, Cu, Fe, Ni, Zn, and Mn, respectively. The determined metal values in *C. album* specimens did not exceed these MPLs except the Cd (0.84 to 1.08 mg/kg). Ugulu et al. [31] investigated the effect of the use of various water sources in agricultural irrigation on heavy metal accumulation in vegetables in the ginger plant sample and found that cadmium accumulation (1.710 to 1.810 mg/kg) was high in the sample plants, especially as a result of the use of industrial wastewater. Ahmad et al. [36] observed a higher range of cobalt in the root samples (1.07–1.26 mg/kg) of the plants irrigated with the sewage water. As mentioned in this study, it was concluded that heavy metal accumulation was higher as a result of irrigation with the sewage water. This result may be due to the cultivation of vegetables grown in soil irrigated by sewage water. Sharma et al. [37] reported that the highest value of Zn (0.23 mg/kg) was present as compared to other heavy metals studied in the vegetable palak, radish, tomato, cabbage, and carrot of Varanasi city, India. This variation of metals' amounts in vegetables may be due to the different metals' absorption capacities in food [17, 22].

Many studies were conducted in different cities of Pakistan, using different plants, investigating the effect of wastewater use in agricultural irrigation on heavy metal pollution. Khan et al. [1] and Khan et al. [16] investigated the effect of wastewater irrigation on trace metal/metalloid accumulation in vegetables in Jhang and Bhakkar cities of Pakistan's Punjab province and used okra (Abelmoschus esculentus) samples as study material. Khan et al. [1] determined As, Se, Cd, Fe, Zn, Cu, and Co values between 9.150-11.200, 0.540-0.550, 0.270-0.480, 39.390-42.940, 55.710-60.270, 20.550-23.510 and 0.480-0.490 mg/kg, respectively, in okra in Jhang sample. Khan et al. [16] defined Mo, As, Se, Fe, Cu, Zn, Ni, Pb, Cd, and Co values between 7.01-9.29, 2.80-3.58, 0.37-0.48, 39.71-44.04, 11.79-19.84, 28.20-37.05, 6.08-9.33, 4.88-7.06, 3.37-4.19, and 0.12-0.32 mg/kg, respectively, in okra in the Bhakkar sample. Khan et al. [22] used luffa (Luffa cylindrica) samples in a study on the effects of using untreated wastewater in agricultural irrigation on metal pollution and associated health risks. Accordingly, metal/metalloid values in luffa samples watered with municipal wastewater, groundwater, and canal water were defined as follows: 7.9-9.0, 3.7-4.2, 0.5-0.6, 39.1-43.2, 15.7-20.8, 29.0-42.4, 6.9-8.2, 5.8-7.7, 4.0-4.3 and 0.1-0.4 mg/kg for Mo, As, Se, Fe, Cu, Zn, Ni, Pb, Cd and Co, respectively. The metal values identified by these researchers in the okra and luffa samples in both Jhang and Bhakkar cities were higher than the values recorded in Khushab city for goosefoot in this study. This situation also reveals the diversity of factors affecting heavy metal accumulation. The differences between the studies whose findings are presented may be due to the study areas, the geological characteristics of the regions, and the accumulation characteristics of the plants used in the studies [15].

Analysis of various metals in three irrigations, Mn and Fe showed the highest BCF values in sugar mill water treatment (treatment-III). In treatment-I, the bioconcentration factor for Mn and Cu was higher than Fe and Ni. In treatment II, the bioconcentration factor for Mn was higher than Cu and in treatment III, the BCF value of Fe was higher than Ni (Table 3). Bioconcentration factor values for Cd, Cu, and Mn for goosefoot samples irrigated with groundwater, Cd, Cr, and Mn values for canal water irrigated samples, and Cd, Cu, Fe, Zn, and Mn values for sugar mill water irrigated samples were found to be higher than 1. The order of BCF values for treatment I: Mn>Cu>Cd>Cr>Zn>Ni>Fe, treatment II: Mn>Cr>Cd>Ni>Zn>Fe>Cu, and treatment III: Fe>Mn>Cu>Zn>Cd>Cr>Ni.

The BCF is one of the best methods used in the evaluation of metals transferred from soil to plants in the agricultural production process or other chemicals to be determined [22]. Okereke et al. [38] observed higher BCF values for Cr (0.14), Cu (1.07), and Ni (0.38) in seven green leafy vegetables than the BCF values in the present study for Cr (1.10), Cu (0.4-1.3) and Ni (0.9). The mean values for BCF reported by Ahmad et al. [36] were 0.036 and 0.038 for Co in *Brassica rapa* grown at tap water and sewage water irrigated sites, respectively. Although it was close to each other, it was observed that the BCF value in the wastewater irrigation area is higher than in the present study. Ugulu et al. [24] determined the highest BCF value for Fe (8.009) in *Trigonella foenicum* samples irrigated with municipal wastewater as a result of their study investigating the effect of wastewater irrigation on heavy metal accumulation in vegetables in Khushab, another city in Pakistan. Regional differences may be the reason for the differences between the findings of the studies mentioned, or it may be due to the accumulation characteristics of the plants [7].

The Daily Intake of Metal **(**DIM) analysis values showed that the daily intake of Fe was the highest but those of Cu and Cr were the lowest with all treatments (Table 3). According to WHO/FAO (1996), DIM values for Cd, Cr, Cu, Ni and Zn were 0.06, 0.05–0.2, 3, 1.4, and 60 mg/day, respectively. The DIM values for all metals presented in this study are below the standard values. Mahmood and Malik [39] pointed out that, the daily intake of metal was higher for Zn and less for Cr and Cd in foodstuff grown in wastewater. In the present study, the consequences of the DIM value of vegetables irrigated with sugar mill wastewater showed a resemblance to that given by Mahmood and Malik [39].

***Table 3*. Bioconcentration Factor, Daily Intake of Metal, Pollution Load Index and Health Risk Index values for *C. album*.**

Irrigation treatment		Heavy Metals						
		Cd	***Cr***	***Cu***	***Fe***	***Ni***	***Zn***	***Mn***
BCF	**I**	1.000	0.98	1.320	0.778	0.839	0.900	1.613
	II	1.016	1.196	0.485	0.63	0.919	0.86	1.85
	III	1.045	1	1.228	10.34	0.976	1.204	1.310
DIM	**I**	0.00583	0.00148	0.00134	0.01636	0.00184	0.01204	0.00362
	II	0.00488	0.00131	0.00058	0.03419	0.00205	0.01274	0.00650
	III	0.00621	0.00105	0.00363	0.13530	0.00225	0.04925	0.00306
PLI	**I**	0.681	0.0287	0.0211	0.0642	0.0420	0.0526	0.0083
	II	0.5604	0.0210	0.0248	0.108	0.0429	0.058	0.0130
	III	0.693	0.020	0.061	0.039	0.044	0.161	0.011
HRI	**I**	5.8398	0.00098	0.03369	0.0233	0.092	0.0401	0.08852
	II	4.8803	0.00087	0.01455	0.08313	0.10278	0.0424	0.1586
	III	6.21	0.00070	0.0909	0.1932	0.11266	0.16419	0.0747

The highest Pollution Load Index (PLI) value was observed for Cd and the lowest PLI value was defined for Mn in all three irrigations (Table 3). It was observed that the PLI values of the sugar mill water and canal water irrigated samples were higher than the groundwater irrigated samples. However, the measured values were lower than the values found by Khan et al. [16]. A higher PLI value (1.493) was noticed by Ahmad et al. [38] when the sewage source was used to irrigate the soil instead of tap water. In the study conducted in the region, Ahmad et al. [1] found the highest PLI value for Cd. In this direction, the results of the present study were parallel to the values reported by Ahmad et al. [1]. Ashfaq et al. [40] investigated the accumulation of Cr, Mn, Fe, Mo, Pb, and Cd in pumpkin (Cucurbita maxima) samples grown by wastewater irrigation in the urban area of Sargodha city, and the PLI values for these metals were 0.4, 0.01-0.03, 0.01-0.009, and 0.01-0.02 for Cd, Fe, Mn, and Cr, respectively. All of the PLI values found as a result of this study are below one. One (1) is considered the critical value for the pollution load index (PLI). Accordingly, a PLI value higher than this value is interpreted as the food is contaminated with metal, and if it is less than this value, it is interpreted as not contaminated [15]. All of the PLI values determined for heavy metal values in *C.album* samples in this study were below the value of 1. Therefore, it can be concluded that these plants are not contaminated with heavy metals. In addition, it can be said that irrigation with wastewater does not cause heavy metal contamination to a certain extent for the *C.album* plant.

In the present study, the metal with the lowest health risk index (HRI) for goosefoot samples in all irrigation environments was Cr, and the metal with the highest risk was Cd (Table 3). The fact that the calculated HRI value is higher than 1 indicates that the consumption of this food carries health risks and that less than 1 indicates that consumption is not a problem in terms of health [41]. Among the HRI values calculated in this study, a value greater than 1 was determined only for Cd. Due to the high HRI value determined for cadmium, it can be said that C. album plants consumed in the region pose a risk to human health [15]. On the other hand, although HRI values less than 1 were determined for C. album samples irrigated with canal water and sugar mill water, the heavy metal values detected in these samples were generally higher than those irrigated with groundwater. Ahmet et al. [36] found higher HRI values for vegetables irrigated with wastewater as a result of their study in Khushab, Pakistan, where they examined heavy metal accumulation in soil samples irrigated with wastewater and tap water. Ugulu et al. [31] investigated the effect of agricultural irrigation with wastewater on heavy metal accumulation in ginger plants in Sheikhupura (Pakistan), a region where industrial settlements are located, and determined a high HRI value for the lead as a result of irrigation with wastewater.

Correlation analysis is one of the most effective methods used to find the relationships between various variables in environmental sciences and environmental pollution studies, as it is in many fields related to science [42-44]. In this study, correlation analysis was used to determine whether the determined heavy metal values were related to each other. According to the results of the analysis, an insignificant positive correlation was found between Cd, Cu, Cr, Mn, and Ni, and an insignificant negative correlation was found for Fe (Table 4). The reasons for the positive correlation between heavy metals can be cited as having common sources, the interdependence of their chemical properties, or having similar behaviours during transportation [45-46].

Table 4. **Metal correlation between soil-vegetable.**

	Correlation
Metals	***Soil-vegetable***
Cd	.981
Cr	.847
Cu	.947
Fe	-.500
Ni	.986
Zn	1.000*
Mn	.685

* Pearson Correlation Coefficient is significant at the 0.05 level (2-tailed).

Conclusion

The research findings showed that the metal contents in the irrigation water samples used in the study were in the order of sugar mill water>canal water>ground water. When the values in the plant samples were evaluated, it was observed that the Cd accumulation exceeded the maximum permissible limits. The results also showed that the health risk index value of cadmium was higher than 1.0. The fact that the calculated HRI value is greater than 1.0 indicates that the consumption of this food carries a risk in terms of health. According to these results, it can be said that if C. album samples grown in the study area are consumed continuously, Cd may accumulate in the human body through food and this may cause diseases in many tissues and organs.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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