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Potential of sewage irrigation for heavy metal contamination in soil–wheat grain system: Ecological risk and environmental fate

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ABSTRACT

Anthropogenic activities are major cause of environmental pollution with significant risks for human health that can lead to excessive pollutant entry into the terrestrial ecosystem. The present study was conducted to evaluate the impact of bioaccumulation of carcinogenic metals (Cd, Ni, Co, Cr), and mineral elements (Zn, Fe, Mn and Cu) in the wheat irrigated with sewage water and different environmental traits (bio-concentration factor, pollution load index, daily intake of metals, health risk index) were compared to understand the ultimate sink of these toxic metals. The Cd was in range of 2.89–3.04 mg/kg in soil. The Fe and Mn were in range of 2.87–4.16 and 1.54–1.66 mg/kg, while Zn varies from 0.18 to 1.21 mg/kg, respectively. Grain exhibit higher concentration (3.31 mg/kg) of Zn while lowest (1.02 mg/kg) of Ni. Bio-concentration factor (BCF) values of Cd, Ni, Fe and Mn being less than 1.0 indicates lower Ni, Cd, Fe and Mn concentration in grains. BCF varies from 0.46 to 0.80 mg/kg for Cd, 0.31 to 0.41 mg/kg for Ni, 0.29 to 0.44 mg/kg for Fe and 0.15 to 0.73 mg/kg for Mn. Pollution load index (PLI) of Zn and Cd was lowest and highest among the evaluated trace metals, respectively. Health risk index was highest for Zn and Cd while it was < 1 for all other metals that showed no danger to human health. Enrichment factor (EF) of Zn was highest followed by Cd while found lowest in Mn. To minimize the health risks in humans, regular monitoring of wheat crop irrigated with wastewater is highly recommended.

1. Introduction

Agriculture sector heavily depends on fresh water resources that are globally scarce for irrigation. This situation will adversely affect many countries especially tropical, sub-tropical, and arid regions of Asia, Arabian Peninsula and North Africa including several regions of Sahel (Ibekwe et al., 2018; Hussain and Al-Dakheel, 2015; Hussain et al., 2016, 2020a, 2020b). Smallholder farmers in West Asia and North Africa are using different non-conventional water resources (brackish water, municipal water, and grey water) to grow crops, vegetables and forages at their farms (Ofori et al., 2020; Hussain et al., 2020a, 2020b). In West Asia and North African countries, about 80 % vegetables grown via treated or un-treated water irrigation (Woldetsadik et al., 2017).

Various water sources such as salty water, wastewater and grey water have been used in agricultural sector (vegetables, oilseeds, landscaping, aquaculture, forages, food and fiber crops, forestry, fruit trees and perennial grasses) (Hussain and Al-Dakheel, 2015, 2018; Hussain et al., 2018, 2019, 2020a, 2020b). The rehabilitated marginalized and degraded areas could be used to meet the growing demand for food through sustainable use of non-conventional water for the growing global population but has been poorly studied in the past (Hussain et al., 2020a, 2020b). According to an estimate, non-conventional water has been used for agriculture production on about 20 million hectares (Ibekwe et al. 2018; Hussain and Qureshi, 2020). However, in order to determine the prospects for the use of wastewater, it is necessary to improve soil as a means of treating wastewater, as well as to share knowledge about the impact of various wastewaters on physical, biochemical and fertility profile of soil with the farming community (Ibekwe et al., 2018). The untreated wastewater and sludge exhibit varying degree of trace metals and pollutants while these water resources can be used after sustainable treatment at a certain level for agriculture, oil seed and fiber crops to meet demand from cooking oil

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and textile industry, landscaping and afforestation schemes. However, it will open the doors for heavy metals to enter into soil-plant ecosystem (Mateo-Sagasta et al., 2013; Farhadkhani et al., 2018). The reuse of treated wastewater from the water sources like surface water, groundwater, and seawater/salt water desalination should be well examined biological and biochemically, before using it as a source of irrigation for field crops (Diaz-Sosa et al., 2020; Deh-Haghi et al., 2020; Reznik et al., 2017).

Sewage wastewater irrigation may provide essential nutrients because it possesses these elements in its composition (Hussain and Al-Dakheel, 2015; Hussain and Al-Dakheel, 2018; Qadir and Scott, 2010). However, persistent pollutants may accumulate in the water-soil-plant environment after wastewater irrigation and can enter in the food web (Cherfi et al., 2015). However, long-term wastewater supply to agriculture is very harmful to the environment, climate and human wellbeing (Kim et al., 2015). Trace metals can influence the target plant digestion, photosynthesis and stomatal opening, and other ecophysiological attributes (Parveen et al., 2015), and can likewise influence microbial networks or cause harmfulness (Becerra-Castro et al., 2015). The accessibility and portability of trace metals relying upon different components, including their structure, cation exchange capacity (Rezapour et al., 2019), temperature, moistness, natural matter, pH, supplements soil conditions, and plant type (Kim et al., 2015). Study of Hussain and Qureshi (2020) show that ingestion of substantial metals was very unique in various vegetables and were higher in leafy vegetables (lettuce, spinach) than root and fruit vegetables such as tomatoes, radish.

Pakistan is a country with increasing population with food security issues and that's why soils are intensively cropped. Nevertheless, there is a problem in food production because thousands of hectares of soil in Pakistan are infertile (Jamal et al., 2002). Wheat satisfies nutritional and food needs of the Pakistani people. A number of studies reported the contamination of soil and vegetables following irrigation of soil with wastewater (treated or untreated) (Hussain et al., 2019). However, soil contamination and toxicity of heavy metals in food grain crops especially wheat are very scarce (Xue et al., 2019; Zhu et al., 2011). Wheat has been cultivated on several thousand hectares of irrigated and rainfed land but scarcity of fresh water resources is a major hurdle in its cultivation on a wide geographical area of Pakistan (Khan et al., 2021; Mahmood et al., 2020). Several authors have recommended using treated wastewater (TWW) as a vital source of irrigation for vegetables but information regarding the use of wastewater for cultivation of wheat are scarce (Xue et al., 2019; Huang et al., 2008). Meanwhile, risks associated with the wastewater use in agriculture should be minimized via different means such as wastewater quality improvement, controlling human exposure, farm-level wastewater management through appropriate crop selection and irrigation management. These strategies can significantly help to minimize the risk and hazards of entry of heavy metals entry into terrestrial ecosystem system in Pakistan.

Understanding the significance of wastewater, field study conducted to evaluate the advantages of utilizing metropolitan wastewater for wheat production, crop development and yield traits. Potential trace elements and their associated bioaccumulation in soil and crop system was explored. Increasing fresh water demand for human consumption in Pakistan, has accelerated the use of non-conventional water for agriculture and forestry. The contamination caused by heavy metals not only damages the growth and yield of food crops, water, and soil ecology, nevertheless hazardous to the human and animals health. To improve wastewater quality and to avoid human exposure, farm-level wastewater management through appropriate product selection and irrigation management strategies can significantly help to minimize the risk of wastewater use in agriculture.

2. Materials and methods

2.1. Experimental site

Sahiwal is a suburban agricultural town of Sargodha district and is now a major hot spot of environmental concern due to pollution caused by sewage discharge (Fig. 1). It is situated in the southwest of the Punjab province, 37 km from the main Sargodha municipality, belongs to Jhelum River Delta and is most fertile agriculture sub-tropic area. The Jhelum River is a close proximity on the left side almost 5 km away. The geographical demarcation of this region is between 31° 58' 23" North, 72° 19' 32" East. The experiment was conducted during 2015–16 cropping season at the experimental site of the University of Sargodha, College of Agriculture, Punjab, Pakistan. The different industries nearby include citrus processing, packing and export zones, flour mills, brick kilns, paddy and rice Sheller's, and other industries and these are discharging their wastes into the Jhelum river and other open fields which are the major cause of pollution to plant-soil-environment ecosystem.

2.2. Field experiment and soil preparation

The wheat variety (Lasani-2008) seeds were acquired from Ayub Agriculture Institute (AARI), Faisalabad, Pakistan. The wheat was sown manually in plastic pots during the last week of November 2015. The seeds were grown in 5 groups consist of control and 4 were applied with another percentages of ground water and wastewater. There were five treatments named as T–I, T–II, T–III, T–IV, and T–V with four replicates of each treatment. T–I: completely ground water, T–2: 25 % wastewater and 75 % ground water, T–3: 50 % wastewater and 50 % ground water, T–IV: 75 % wastewater and 25 % water from soil surface, T–V: 100 % wastewater. Wastewater was taken from sewage pond that was situated in Sahiwal, Sargodha, Pakistan. For each treatment, 3 pots were used. In April 2016, plants were harvested and grains were collected. The samples were air dried and ground. The grains were put in oven at 105 °C for 24 h. All the environmental indices (bio-concentration factor, pollution load index, daily intake of metals, health risk index) were calculated from the basic data according to the procedure as described previously (Qureshi et al., 2016; Hussain and Qureshi, 2020).

2.3. Samples preparation and analysis

Samples of soil, and wheat were processed by wet digestion. By using electric balance, 1 g of dried sample (each of soil and wheat) was weighed. The concentrated HNO_3 (10 ml) was used in samples for digestion in flask. The samples in flask were kept overnight at room temperature. The H_2O_2 (2 ml) was used and digestion procedure was carried on hot plate and volume of the test solution was made upto 50 ml in a volumetric flask. Atomic absorption spectrophotometer (AAS; GBC 932) was used to analyze the samples.

2.4. Statistical data analysis

Data was statistically analyzed using SPSS and employing one way ANOVA and multiple comparison test at $p \leq 0.05$ level.

3. Results and discussion

Accumulation of trace metals in the food chain via plants-soils-environment transfer and through irrigation of food and vegetables with wastewater (treated or untreated) and consequently is a major issue due to health risk to the local inhabitants (Hussain and Qureshi, 2020). Mineral nutrients such as Cu and Zn are required as essential plant nutrition for certain physiological functions while higher quantity of these elements might be toxic and harmful to plant, soil and environment (Heidari et al., 2019). Several cereal and food grain crops (wheat, maize and rice) exhibit the principal human diet because they

Fig. 1. Location map of the study area at Sargodha (Punjab), Pakistan.

exhibit vital nutrient elements for health (Khanam et al., 2020). During field crop irrigation, the farmers should use the tertiary level treated municipal water and should avoid industrial wastewater for ecological and human health protection.

3.1. Biochemical composition and trace metals concentration in water

The Cd content in present study ranged from 1.73 to 1.95 mg/kg (Table 2). The value of Cd was lower than the results reported by Feizi (2001) that was 0.009 mg/kg. Although, the value of Cd was similar (1.53 mg/kg) to present study, as reported by Rattan et al. (2005). The concentration of Cd in water was lower to present value that was 0.067 mg/kg given by Mojiri and Aziz (2011) Table 1.

The Ni level range from 1.07 to 1.41 mg/kg (Table 2). However, the study of Rattan et al. (2005) demonstrates a higher (49 mg/kg) level of Ni than the present study. The Ni level in water was lower to present value that was 0.026 mg/kg given by Mojiri and Aziz (2011). The Fe ranges from 1.25 to 9.79 mg/kg (Table 2). The value of Fe was lower to present value to present value given by Feizi (2001) that was 0.19 mg/kg. The value of Fe was much higher that was 1464 mg/kg, as given by Rattan et al. (2005) to present study. The Fe concentration in water was lower to present value that was 0.359 mg/kg, as given by Mojiri and Aziz (2011).

Our study showed Mn level was in the range from 0.43 to 0.75 mg/kg (Table 2). The value of Mn was lower to present value given by Feizi (2001) that was 0.08 mg/kg. The value of Mn was higher (64 mg/kg) given by Rattan et al. (2005) as compared to present study. The Mn content in water was found in higher amount as compared to present value when compared with values (0.076 mg/kg) given by Mojiri and

Table 2
Mean values for heavy metals (Cd, Ni, Co, Cr), and mineral elements (Zn, Fe, Mn and Cu) (mg/kg) in water.

Metals	T-I	T-II	T-III	T-IV	T-V	PML
Cd	1.738 ± 0.19	1.831 ± 0.12	1.885 ± 0.15	1.906 ± 0.14	1.950 ± 0.17	0.01*
Ni	1.070 ± 0.14	1.095 ± 0.11	1.125 ± 0.12	1.188 ± 0.09	1.415 ± 0.08	0.20*
Fe	1.257 ± 0.17	3.644 ± 0.15	7.530 ± 0.14	8.677 ± 0.15	9.794 ± 0.16	5.0*
Mn	0.438 ± 0.12	0.493 ± 0.09	0.593 ± 0.10	0.660 ± 0.08	0.759 ± 0.11	0.2**
Cu	0.580 ± 0.18	0.655 ± 0.17	0.708 ± 0.15	0.730 ± 0.13	0.817 ± 0.11	0.2*
Cr	0.665 ± 0.15	0.630 ± 0.13	0.642 ± 0.09	0.682 ± 0.11	0.745 ± 0.12	0.1**
Zn	1.196 ± 0.16	4.827 ± 0.14	8.153 ± 0.12	9.313 ± 0.15	9.867 ± 0.13	2**
Co	0.330 ± 0.14	0.439 ± 0.11	0.497 ± 0.13	0.559 ± 0.12	0.605 ± 0.09	0.05*

Source *WWF (2007); source** FAO (1985).

Table 1
Analysis of variance for heavy metals (Cd, Ni, Co, Cr), and mineral elements (Zn, Fe, Mn and Cu) in water.

S.O.V.	df	Mean squares							
		Cd	Ni	Fe	Mn	Cu	Cr	Zn	Co
Treatments	4	0.020***	0.058***	38.838***	0.050***	0.023***	0.006*	39.575***	0.035***
Error	10	0.001	0.001	0.328	0.001	0.001	0.003	0.104	0.002

Aziz (2011). Manganese was a vital nutrient and its daily requirement for adults was 2.5–5.0 mg/kg. Manganese can cause change in erythro poiesis, disturbed secretion of 17-ketosteroids, effects formation of granulocyte and decrease in systolic blood pressure (Athar and Vohora, 1995). The concentration of Cu in our present study ranges from 0.58 to 0.81 mg/kg (Table 2). The value of Cu 0.029 was lower to present study given by Feizi (2001). Rattan et al. (2005) documented value for Cu was higher than the present research (29(29 mg/kg). Wilson's disease was caused an inborn due to inaccuracy of metabolic rate. The excretion of Cu into the bile reduced liver size that led to build up of Cu in brain, tissues of liver, cornea and kidney resultant in damaging of organ.

In the present study, the Cr level ranges from 0.66 to 0.74 mg/kg (Table 2). Chromium concentration 2.6 mg/kg given by Jakubus and Czekala (2001) was higher than present study. The value of Cr was lower to present study from the value 0.10 mg/kg as given by Akhtar et al. (2012). In water, Cr compounds were very persistent in residues as they bound to soil and were not transfer to ground water. Chromium (III) was an essential nutrient while compounds of chromium (VI) were toxins. These are cancer-causing agents in human beings. Allergic reactions such as swelling of the skin and severe redness have also been reported. The effects such as kidney circulatory, damage to liver, nerve tarsus, skin irritation can caused by long term exposure to chromium (IV) (Martin and Griswold, 2009). The Zn level in present study ranged from 1.19 to 9.86 mg/kg (Table 2). The present value of Zn was higher to the value of Zn that was 0.093 mg/kg given by Feizi (2001). The value of zinc was higher that was 61 mg/kg given by Rattan et al. (2005) to present study. The concentration of Co ranged from 0.33 to 0.60 mg/kg (Table 2) in present study. The value of cobalt in water was lower in present study to value given by Gulfraz et al. (2003).

3.2. Metals contents in soils

In the soil samples, Co and Zn contents were significantly lower as compared to Fe content that was the highest. In current study, the increased in application of wastewater, metals content in soil increased. The metal contents were higher in soil samples irrigated with wastewater comparative to ground water. In the soil, metal contents irrigated with different water treatments was below than the maximum level as given by WHO/FAO (2001) and Chiroma et al. (2014). The Cd content in soil ranges from 2.89 to 3.04 mg/kg in present study. The value of Cd is higher as compared to value 0.46 mg/kg given by Yu et al. (2016). In present study, the Ni content in soil ranges from 2.25 to 2.44 mg/kg (Table 3). Ni investigated by Hassan et al. (2013) was higher that is 7.5 mg/kg. Fe content in present study ranges from 2.87 to 4.16 in soil (Table 3). Fe content is higher to present value given by Feizi (2001) that is 32 mg/kg. The Mn content in soil ranges from 1.54 to 1.66 mg/kg. The value 2.5 mg/kg of Mn given by Balkhair and Ashraf (2016) is higher to present value. The Cu content in present study ranged from 1.25 to 2.07 mg/kg (Table 3). The copper content (15 mg/kg) given by Ekmekyapar et al. (2012) is significantly higher as compared to current values. The Cr ranges from 1.14 to 1.37 mg/kg in soil (Table 3). Cr content is low than 18.239 mg/kg given by Asdeo (2014). The Zn content ranges in soil from 0.18 to 1.21 mg/kg in present work. As compared to present values, higher value of Zn is given by Feizi (2001) i.e. 130 mg/kg. Co content varied from 0.70 to 0.92 mg/kg in soil (Table 3). The cobalt contents were found lower in present study as compared to 18.9 mg/kg observed by Page et al. (2006).

Table 3
Mean values of heavy metals (Cd, Ni, Co, Cr), and mineral elements (Zn, Fe, Mn and Cu) (mg/kg) in soil.

Metal	T–I	T–II	T–III	T–IV	T–V	Permissible limit
Soil (mg/kg)						
Cd	2.896 ± 0.1	2.928 ± 0.09	2.958 ± 0.08	2.986 ± 0.11	3.046 ± 0.07	3[a]
Ni	2.256 ± 0.11	2.318 ± 0.07	2.758 ± 0.09	2.553 ± 0.06	2.441 ± 0.08	50[b]
Fe	2.876 ± 0.12	3.455 ± 0.09	3.972 ± 0.07	4.050 ± 0.08	4.163 ± 0.10	50,000[b]
Mn	1.548 ± 0.09	1.593 ± 0.06	1.458 ± 0.08	1.630 ± 0.07	1.665 ± 0.05	46.75[b]
Cu	1.253 ± 0.13	1.550 ± 0.07	1.735 ± 0.09	2.001 ± 0.11	2.078 ± 0.12	100[a]
Cr	1.141 ± 0.08	1.246 ± 0.06	1.285 ± 0.07	1.523 ± 0.09	1.373 ± 0.05	50[a]
Zn	0.180 ± 0.12	0.415 ± 0.09	0.495 ± 0.06	0.935 ± 0.08	1.216 ± 0.07	300[b]
Co	0.706 ± 0.08	0.760 ± 0.06	0.806 ± 0.08	0.848 ± 0.07	0.923 ± 0.05	100[a]

3.3. Metal contents in grains of wheat

In comparison among five treatments, Zn content was the highest while Mn and Ni contents were the lowest in all the treatments. The increased amount of wastewater leads to increase in heavy metals contents. Trace metals in wheat grains was below the maximum limits except Cd FAO/WHO (2001). The cadmium in present work ranges from 1.34 to 1.86 mg/kg. The value of Cd content (0.12 mg/kg) given by Singh et al. (2010) is lower as compared to present value. The kidney is the first organ to show signs of Cd poisoning. Chronic ingestion of exceptionally high dosage Cd causes severe kidney and bone damage (Tribowo et al., 2014). The patients with higher urine Cd had a higher risk of diabetes. Headaches, chest pains, muscle weakness, pulmonary edema, and mortality may occur as a result of acute toxicity to cadmium

Table 4
Mean values for heavy metals (Cd, Ni, Co, Cr), and mineral elements (Zn, Fe, Mn and Cu) (mg/kg) in grains of wheat.

Metal	T–I	T–II	T–III	T–IV	T–V	Permissible limit
Grain (mg/kg)						
Cd	1.346 ± 0.08	2.353 ± 0.09	1.490 ± 0.07	1.556 ± 0.05	1.860 ± 0.06	0.2[a]
Ni	0.765 ± 0.06	0.830 ± 0.05	0.871 ± 0.03	0.948 ± 0.04	1.021 ± 0.02	67[a]
Fe	0.850 ± 0.07	1.323 ± 0.04	1.415 ± 0.03	1.441 ± 0.05	1.856 ± 0.04	425.5[a]
Mn	0.505 ± 0.08	0.791 ± 0.07	1.043 ± 0.06	0.926 ± 0.04	1.218 ± 0.05	500[a]
Cu	1.685 ± 0.06	1.840 ± 0.07	2.050 ± 0.04	1.970 ± 0.05	2.281 ± 0.03	73.3[a]
Cr	1.376 ± 0.07	1.435 ± 0.05	1.448 ± 0.03	1.495 ± 0.02	1.510 ± 0.04	2.3[a]
Zn	2.610 ± 0.09	2.635 ± 0.08	2.675 ± 0.05	2.856 ± 0.07	3.313 ± 0.06	99.4[a]
Co	1.025 ± 0.07	1.090 ± 0.05	1.126 ± 0.06	1.198 ± 0.07	1.221 ± 0.05	50[a]

Note: Data sources are[a] FAO/WHO (2001), [b]Chiroma et al. (2014).

(Hanson et al. 2010). In present study, the concentration of Ni ranges from 0.76 to 1.02 mg/kg (Table 4). The value of Ni in present study was higher to 0.28 mg/kg given by Li et al. (2015). In occupationally unprotected populations, nickel may cause allergies in skin, cancer of respiratory tract, lung fibrosis and have potential to cause cancer in lungs. Fe in present study ranges from 0.85 mg/kg to 1.85 mg/kg. The Fe content is lower in current study as compared to the value 49.36 mg/kg given by Stefanović et al. (2016). The Mn level varied from 0.50 to 1.21 mg/kg (Table 2), and were below the. than permissible value, so there is no harm to eat the bread prepared from this wheat flour. The Cu in present study varied from 1.68 mg/kg to 2.28 mg/kg. The value of Cu is higher as compared to value given by Feizi (2001) that is 10 mg/kg. The zinc content found in present work ranges from 2.61 to 3.31 mg/kg. The value of Zn (22.21) is higher to present study given by Hassan et al. (2013). In this study, the Co ranges from 1.02 to 1.22 mg/kg. The Co content in the wheat grains was significantly lower than the permissible limit.

3.4. Correlation of wheat

In several South Asian countries, including Pakistan, urban wastewater is used as nonconventional water resources for crop production in order to protect freshwater supplies (Khan et al., 2021; Chen et al., 2022). In the soil-grain, Fe, Cu, Cr, Zn, and Co showed positive and significant correlation (Table 5). Cd gave positive and non-significant correlation. Meanwhile, non–significant and positive correlation showed by Ni, and Mn between wheat grains and soil. In current research work, significant correlation was observed between Cr contents in grains and soil, while Ashfaq et al. (2015) reported the contrary results. A positive and significant correlation of heavy metals (Cu, Cr, Co, Zn and Fe) was observed between soil and wheat grains.

4. Assessment of wheat grain contamination and associated health risk

4.1. Bio-concentration factor

The Bio-concentration factor (BCF) < 1.0 show no accumulation of HM from the soil to the different parts of the plant organs. If the value of BCF > 1 then it shows accumulation of heavy metals (Singh et al., 2011). BCF values ranged from 0.46 to 0.80 for Cd, 0.31 to 0.41 for Ni, 0.29 to 0.44 for Fe and 0.15 to 0.73 for Mn, respectively (Fig. 2). The values of BCF for Zn, Co, Cu and Cr were highest while the values of BCF for Mn were lowest in all treatments (Fig. 2). The Bio-concentration factor values of Cd, Ni, Fe and Mn being less than 1.0 indicates lower Ni, Cd, Fe and Mn concentration in grains which was in line with those found by Li et al. (2015). Hussain and Qureshi (2020), documented a significant difference in BCF among the target vegetables, and Fe exhibit higher BCF in lettuce while Cr was lowest in eggplant. Similar results were documented by Qureshi et al. (2016) and Khan et al. (2017). Several factors are responsible for heavy metals presence in the plant-soil-water environment such as atmospheric deposition, manure from farm animals, use of un-treated wastewater or municipal water for irrigation, herbicides/pesticides, and excessive use of phosphate-based fertilizers (Woldetsadik et al., 2017; El-Kady and Abdel-Wahhab, 2018; Hussain et al., 2020a, 2020b). The long term use of above practices can lead to the severe soil and environment contamination which can cause groundwater contamination and human health impact (Yang et al., 2017; Rai et al., 2010, 2018; Hussain and Qureshi, 2020).

Table 5
Metal correlations between grains and soil of wheat.

Correlation	
Metals	Soil–Grain
Cd	0.066^{ns}
Ni	0.283^{ns}
Fe	0.868^{**}
Mn	0.160ns
Cu	0.716^{**}
Cr	0.708^{**}
Zn	0.863^{**}
Co	0.900^{**}

Note: Marker ** means significant (0.01) level, whereas ns is non–significant.

4.2. Pollution load index

The soil contamination was evaluated through pollution load index (PLI). Tomlinson et al. (1980) documented that a value of zero indicates no hazard, while a value of one or more than one indicates a gradual increase in pollution due to un-treated wastewater irrigation. PLI value for irrigated soils with different treatments has shown in Table 6. All values were less than one and ranged from a minimum of 0.004 for Zn in T-I to a maximum of 2.04 for Cd in T-V. PLI Zn and Cd rated as the lowest and highest among the trace metals. As for the average number of treatments, Cd and Ni had the highest distribution in soil samples. Contamination sequence T-I Cd < Ni < Cu < Cr < Zn < Fe < Co < Zn. In T-II, the order was Cd < Ni < Cu < Cr < Zn < Fe < Co < Zn, while in T-III, T-IV, and TV the order was Cd < Ni <Cu < Cr <Zn < Fe < Co. < On Cd < Ni < Cu < Cr < Zn < Fe < Co < Zn and Cd < Ni <Cu < Cr < Zn < Fe < Co < Zn, respectively (Table 6).

4.3. Daily intake of metal (DIM)

To assess the health risk of a contaminant, we assessed the human exposure of each element through the pathways of the food chain. Here, we assumed that the path of absorption of the studied metals is associated with the consumption of wheat grain. Meanwhile, DIM values were calculated based on the average consumption of wheat grains by the adults. For adults, the mean DIM values for Cd, Ni, Fe, Mn, Cu, Cr, Zn and Co were 0.0071, 0.0040, 0.0045, 0.0026, 0.0089, 0.0072, 0.0138 and 0.0054 mg/kg/day, respectively (Table 7). DIM values in this study were less than the acceptable daily value. The DIM value was < 1, indicating no risk to the human beings, when consuming wheat flour or wheat products. Thus, we can assume that the crops of wheat irrigated with sewage do not pose a danger to residents and consumers.

4.4. Health risk index

Assessing the human health risk by eating contaminated foods evaluated through proper procedures and protocol (USEPA (United States Environmental Protection Agency), 2002). The HRI is equally important for all countries, particularly in those areas where wastewater operation left unattended. If the HRI of a particular nutrient was < 1, it was believed to be safe for human consumption. However, if it > 1, may pose a serious threat to human health (USEPA (United States Environmental Protection Agency), 2002).

The results of HRI of the metals showed that the HRI level for zinc is the highest and it was in the range of 4.611–50.45, in T-I and T-IV, respectively (Table 8). It means, it may pose a potential risk to human health via Food consumption. This was in line with findings of Bansal and Singh (2015) whom demonstrated that HRI of zinc was higher in the tested food products. The HRI of Cd in all treatments from T-I to T-V was found elevated than 1 and exceeds than allowable limits that might pose a threat to human health. However, HRIs of other metals was below than 1 (Ni, Fe, Mn, Cu, Cr, and Co) and showed no danger to human health. All of the examined vegetables had target hazard quotients (THQ) for Cu, Zn, and Fe that are less than one, suggesting that they are relatively safe. Heavy metals had risk index (RI) values < 1.0, indicating a lesser risk to humans (Hussain and Qureshi, 2020).

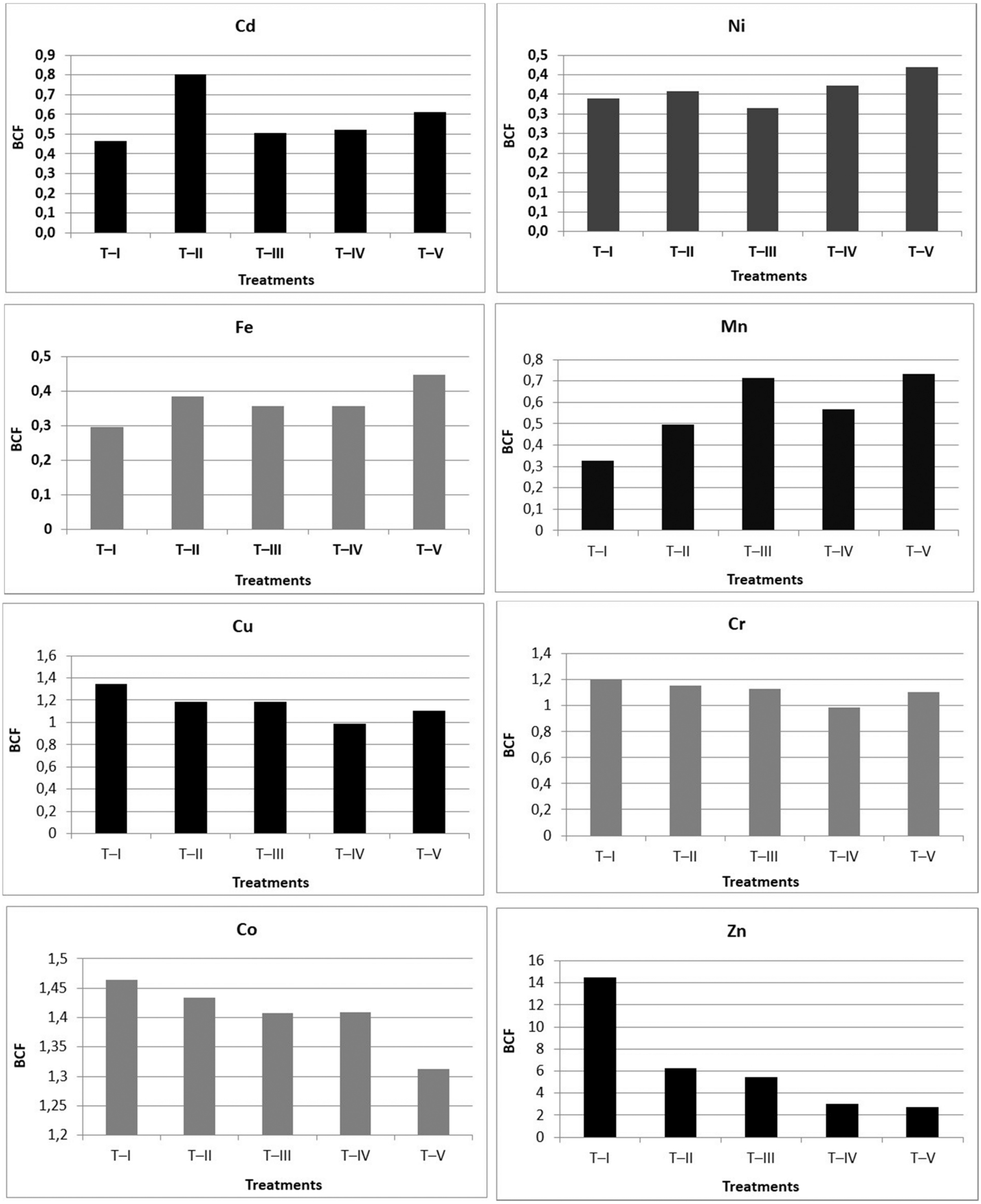

Fig. 2. Bio-accumulation factor (BAF), a ratio of heavy metals concentrations in the edible parts of wheat (grains) to that in the corresponding soil.

4.5. *Enrichment factor*

The enrichment factor was calculated to assess the metal contamination. Cadmium possessed the highest enrichment rate in the soil samples (Table 9). The T-2, results showed the greatest value for EF with Zn, followed by Cr and Cd (Table 9). If the value of FE is >1. it highlight availability and distribution of metals in the contaminated soil while the lowest EF was observed in Mn at T-1II. The trend of EF in the T-1, was Co < Cu < Ni < Fe < Mn. Mean value of EF >1 indicates an increase in the accumulation of metal in the terrestrial plant species (Gupta et al., 2018). In the present results, the EF level was higher than 1 for Zn, Cr and Cd. Therefore, it may cause risk of overcrowding of metals in the plants organs growing in the contaminated soil rhizosphere. However, lower BAF value indicates that this risk does not apply to wheat.

5. Conclusion

Wheat can accumulate a substantial number of poisonous trace and

Table 6
Pollution load index (mg/kg) of wheat.

Metals	Cd	Ni	Fe	Mn	Cu	Cr	Zn	Co
Pollution load index								
T–I	1.9436	0.2490	0.0505	0.0331	0.1493	0.1257	0.0040	0.0775
T–II	1.9651	0.2558	0.0607	0.0340	0.1847	0.1373	0.0093	0.0835
T–III	1.9852	0.3044	0.0698	0.1400	0.2067	0.1416	0.0112	0.0885
T–IV	2.0040	0.2817	0.0711	0.0348	0.2384	0.1679	0.0211	0.0931
T–V	2.0442	0.2694	0.0731	0.0356	0.2476	0.1513	0.0275	0.1014

Table 7
Daily intake of metals (mg/kg) in wheat.

Metals	Cd	Ni	Fe	Mn	Cu	Cr	Zn	Co
Daily intake of metal								
T–I	0.0071	0.0040	0.0045	0.0026	0.0089	0.0072	0.0138	0.0054
T–II	0.0124	0.0043	0.0070	0.0041	0.0097	0.0076	0.0139	0.0057
T–III	0.0078	0.0046	0.0074	0.0055	0.0108	0.0076	0.0141	0.0059
T–IV	0.0082	0.0050	0.0076	0.0049	0.0104	0.0079	0.0151	0.0063
T–V	0.0098	0.0054	0.0098	0.0064	0.0120	0.0080	0.0175	0.0064

Table 8
Health risk index (mg/kg) of wheat.

Metals	Cd	Ni	Fe	Mn	Cu	Cr	Zn	Co
Health risk index								
T–I	7.134	0.2027	0.0064	0.0652	0.6379	0.0048	4.611	0.1263
T–II	12.47	0.2199	0.0100	0.1022	0.6965	0.0050	46.553	0.1343
T–III	7.897	0.2308	0.0107	0.1348	0.7760	0.0051	4.726	0.1387
T–IV	8.247	0.2512	0.0109	0.1197	0.7457	0.0052	50.456	0.1476
T–V	9.858	0.2705	0.0140	0.1574	0.8635	0.0053	5.853	0.1504

Table 9
Enrichment factor (mg/kg) of wheat.

Metals	Cd	Ni	Fe	Mn	Cu	Cr	Zn	Co
Enrichment factor								
T–I	3.4626	0.0458	0.0395	0.0305	0.1539	4.7556	6.4462	0.2642
T–II	5.9869	0.0484	0.0512	0.0464	0.1358	4.5416	2.8227	0.2610
T–III	3.7527	0.0427	0.0476	0.0148	0.1352	4.4437	2.4024	0.2542
T–IV	3.8821	0.0502	0.0475	0.0531	0.1126	3.8709	1.3579	0.2571
T–V	4.5492	0.0565	0.0596	0.0683	0.1256	4.3369	1.2112	0.2407

hazardous elements in various plant tissues, particularly in grains, in addition to necessary nutrient elements. As a result, wheat is a vital cereal food grain crop that needs to be handled carefully to minimize any hazards associated with its consumption following irrigated with sewage water. Highest concentrations detected for Cd in the wheat grains that were greater than FAO limits that might be a risk for human through the consumption of contaminated foods. DIM was < 1 that indicates a low risk to local inhabitants. , We came to the conclusion that the primary cause of metal buildup in wheat grains is irrigation with sewage wastewater. which might led to serious health effects. The HRI values > 1 observed higher for Zn and Cd while PLI values were greater in Zn, Cr and Cd. It offer a succinct summary of the current situation for food contamination and potential future health risk to the local population. In order to prevent an excessive buildup of toxic metals in the plant-soil-water system and to safeguard the health of the local population, it is urgently necessary to monitor the wastewater irrigation system in the study area.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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