

Research Article

Assessment of Health Risks in Wheat Crop Irrigated by Manka Canal, Dera Ghazi Khan, Pakistan

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Background. Manka canal's metal concentration rises from human activities' garbage. Untreated water from the canal is used by farmers for local crop irrigation. Immediate action is crucial to assess heavy metal levels and ensure soil suitability for agriculture as metal pollution persists. Purpose. The current study was conducted to assess the health risks associated with metal pollution at Manka Canal, Dera Ghazi Khan. Methods. A total of eighty-four wastewater, soil, and wheat samples were collected from study areas. The collected samples were analyzed for heavy metals (Cd, Cu, Fe, Mn, Ni, Pb, and Zn) using a flame atomic absorption spectrometer (FAAS). Results. The significant findings of the study revealed that the concentration of heavy metals in most of the collected samples of soil, water, and wheat was above the World Health Organization (WHO) permissible limits. The mean concentrations of Cd, Cu, Mn, Ni, Pb, and Zn were at relatively higher concentrations, i.e., 4.88, 22.03, 38.2, 89.2, 19.62, and 67.9 mg/kg, respectively, in collected wheat samples. The soil and irrigation water quality metrics had values that exceeded the acceptable thresholds, rendering them unfit for agricultural use. The local community faces an elevated health risk index for both children and adults due to the consumption of wheat crop as HRI is greater than 1 for nonessential elements like Cd and Pb. Conclusion. The study suggested that wastewater irrigation leads to the accumulation of heavy metals in foodstuffs, causing potential health risks to consumers. The gradual accumulation of these contaminants in biological systems finally gives rise to severe health-related issues. Therefore, it is crucial to implement robust wastewater treatment processes and stringent quality control measures to minimize health risks associated with the consumption of crops grown using reclaimed water. Prior to irrigating crops like wheat and vegetables, it is strongly advised to treat municipal wastewater to prevent soil and dietary toxicity from heavy metals.

1. Introduction

Accumulation of heavy metals is one of the most serious environmental concerns of the present day, not only because many of these metals are toxic to the crops themselves but also potentially harmful to animals and humans who

consume them. Metals are nonbiodegradable and considered as major environmental pollutants, resulting in cytotoxic, mutagenic, and carcinogenic effects in animals [1-3]. Heavy metals have great ecological significance due to their toxicity and tendency to accumulate in both sediment and biota [4].

Metals such as copper, zinc, and, nickel are essential metals since they play important roles in biological systems, while some others such as arsenic, cadmium, lead, and mercury are nonessential metals as they have no known role in biological systems [5]. They are even toxic at lower levels of exposure. Once absorbed by the body, heavy metals continue to accumulate in vital organs such as the brain, liver, bones, and kidneys for years or decades, causing serious health consequences [6]. Plant species have the capacity to remove and accumulate heavy metals [7]. Numerous reports indicate that certain species may accumulate specific heavy metals [8] causing serious risks to human health when plant-based foodstuff is consumed [9, 10]. However, zinc is an essential element for plants, but its elevated concentration is phytotoxic, directly affecting crop yield, and soil fertility. In soil, Zn concentrations greater than 200 mg/kg are classified as critical, above which toxicity is considered likely [11]. Intake of heavy metals through the food chain by the human population has been widely reported throughout the world [12, 13]. Human exposure to metal pollutants may cause diseases of the nervous, renal, cardiovascular and reproductive systems [14].

The most important sources of heavy metals in the environment are anthropogenic activities such as mining, smelting, steel and iron industry, chemical industry, traffic, agriculture, as well as domestic activities [15]. The volume of sewage water generated by domestic, industrial, and commercial sources has increased along with the increasing population, urbanization, improved living conditions, and economic development [16]. The quality of irrigation water available to farmers and others has a considerable impact on the type of plants grown, the productivity of the plants, water infiltration and other soil physical conditions. The first step in understanding how an irrigation water source can affect a soil-plant system is by analyzing soil and plant samples in a laboratory. Irrigation with wastewater contributes significantly to the heavy metals content in soil [17].

Various studies applied different tools in order to monitor and for the management of irrigation water quality (IWQ). In a study of Nigeria, multiple linear regression (MLR), radial basis function neural network (RBF-NN), and multilayer perceptron neural network (MLP-NN) models were developed for this purpose. This study first integrates and then simultaneously implements these predictive methods for the modeling of IWQ indices [18].

Wheat (*Triticum aestivum* L.) is one of Pakistan's main crops and an integral constituent of the national diet. It plays a vital role in human growth by providing carbohydrates, proteins, and certain inorganic micronutrients [19]. The most important crop worldwide in terms of basic food commodities is wheat, followed by coarse grains and rice, with a global production estimated to 779.6 million metric tonnes in 2022-23 [20].

In Dera Ghazi Khan (D. G. Khan), the effluents from various small industries like fertilizers, pesticides, workshops, cement production, dye, detergents, and chemicals are discharged into the Manka Canal without any treatment. The utilization of polluted water for wheat production presents both opportunities and potential health risks. It can contribute to sustainable agriculture and resource conservation, and the

presence of contaminants in wastewater can pose significant health hazards when not properly treated and monitored. The continuous use of this water may disrupt soil health by altering its pH, nutrient balance, and metals accumulation. This results in reduced crop yields and overall soil degradation over time. In addition, the people of the study area and its surrounding locality use this wheat as their income source and for their basic food needs. By integrating comprehensive analyses of irrigation water quality, soil contamination levels, and subsequent uptake in wheat, this research offers novel insights into the multifaceted dynamics of heavy metal risks, providing a comprehensive understanding crucial for informed agricultural practices and safeguarding public health. Considering the above scenario, the current study hypothesized that the use of canal wastewater for wheat cultivation results in metal accumulation, potentially posing health risks for the local community consuming the wheat. The present study was aimed to: (1) measure the concentration levels of various essential Cu, Fe, Mn, Ni, Zn, and nonessential elements Cd and Pb in Manka Canal used as irrigation water, agricultural soils and wheat crops are grown under the influence of that contaminated water and (2) assess the potential health risks by these elements through the intake of locally grown wheat crop on this wastewater, focusing on contaminants and exposure pathways.

The findings of this study hold significant importance for addressing global challenges related to water scarcity, agriculture sustainability, public health, and environmental protection. The Sustainable development goal (Goal 2) aims to end poverty in all its forms everywhere is especially targeted at over 836 million people. With a majority of the poor engaged in the agricultural sector, its growth and development are central to achieving this goal. The role of agriculture development in poverty reduction is well established in economics literature. There is overwhelming evidence that, with very few exceptions, sustained reduction in poverty cannot be achieved without productivity increases in the agricultural sector [21].

At the studied site, there could be many heavy metals, but the current work covers only a few heavy metals in soils, water, and wheat crop in the study area. Also, because of inaccessibility, less time frame, and resource availability, the current study covers only D. G. Khan division.

2. Materials and Methods

2.1. Study Area. This study was conducted at D. G. Khan, located in $(30^{\circ}03'34.86''N, 70^{\circ}38'18.62''E)$, southern Punjab, Pakistan (Figure 1). Pakistan is the 7th largest wheat producing country with 3.38% share in global wheat production during growing year 2021-22 producing 26.08 million tons of wheat in 2022-23. Punjab is a major producer of wheat [20]. It supplies wheat at a large scale to the national market. The study area has an arid climate with 236.3 mm of average rainfall annually. Winter is cold with an annual temperature of at least 40 F (4°C) and summer is very hot with usually high temperatures of about 115 F (46°C). The various weather parameters of wheat growing season in Pakistan are shown in Table 1. The geology of study area is characterized by diverse formations that contribute to its geological richness. The area is notably



FIGURE 1: Study area map.

TABLE 1: Weather parameters of wheat growing season in Pakistan in 2022.

	Temperature (°C)	Precipitation (%)	Wind speed (mph)	Humidity (%)	Rainfall (mm)
January	13	5	5.1	0	5
February	16	8	5.5	0	12
March	22	9	5.8	7.5	15
April	32	7	6.1	8	10
May	36	5	6.8	10	7
June	38	8	8.5	18	35

influenced by the Indus River system, resulting in alluvial deposits and fertile plains. In addition, the region showcases formations from various geological periods, including the Jurassic, Cretaceous, and Pleistocene epochs, which contribute to its geological diversity and potential mineral wealth. Overall, study area geology reflects a mosaic of sedimentary formations, riverine influences, and a geological history that offers insights into the area's natural resources and landscape evolution. The population of the city also uses drinking water available free of cost from the water filtration plants. In rural areas, people use groundwater to fulfill their drinking water requirements, which is also unsuitable in many areas. Around 17% of crops are irrigated by Manka Canal while for the remaining groundwater is used [22].

Canal irrigation for wheat cultivation involves a structured process of water management. Water is sourced from the main canal, and subdivided into distributaries. These distributaries then lead to smaller field channels, which supply water to wheat fields through controlled structures. Successful wheat cultivation depends on farmers scheduling irrigation based on the crop's growth stages and water needs. Wheat cultivation in the study involves sowing seeds in well-prepared soil, providing regular irrigation throughout the growth stages, and harvesting the mature grains.

2.2. Collection of Samples. A total of 84 samples (water, soil, and wheat) were randomly collected from the area from Pull Datt to Kot Chutta at a distance of (500–1000) meters. Altogether, the three kinds of samples, i.e., irrigated water, soil, and wheat grains were collected from every sampling location. All samples were collected from 4th May to 17th May 2022.

The samples are representative of about 32 kilometers (Pull Datt to Kot Chutta) of the study area. However, water, soil, and wheat samples were obtained where fields were irrigated by Manka Canal wastewater via installations of pumps, streams, or drainage to wheat fields. Rain events were avoided, and samples were collected three days after a rain event. While collecting the samples, all measures were taken to avoid any sample contamination or loss. From either site, three appropriate samples ($n = 6 \times 84 = 450$) of either water, soil (top to 10 cm deep soil), and wheat grain were collected, aggregated, and preserved in identifiable sealed packs. These samples were prepared for the subsequent metal analysis.

2.2.1. Soil Sample Collection. For soil sampling, 28 wheat fields were selected randomly. The soil samples were taken from the agricultural land that was irrigated by Manka Canal's wastewater. Approximately 0.5–0.9 kg of a soil sample was collected at every sampling point. The soil sample was collected from a depth of about 0–10 cm using a stainless-steel auger.

Soil samples from wheat fields were collected at a distance of 5–10 meters away from the roads within an area of 2 square meters. One sample was collected at a distance of 3–5 meters from each point, with the final sample consisting of six composite homogenously mixed samples from randomly selected sites. Such samples were obtained from 28 wheat fields. Each soil sample was dried, sieved, crushed, and stored for further analysis. After collection, the sample was stored in clean polythene bags which were sterilized before analysis. Soil samples were labeled according to the region from the site where these were acquired from. The homogenized composite samples were first air-dried, crushed, and then sieved with a mesh size of 2 mm.

2.2.2. Water Sample Collection. Water samples from Manka Canal, which is used for irrigation of wheat fields, were collected from 28 randomly selected sites in the study area. Three grab water samples were taken from each sampling point at a mutual distance of about 5–10 meters, at the same time as when soil samples were taken. A total of 28 water samples were collected from sites where wheat and soil were also collected. The samples were collected at about 6 p.m. in May 2022.

Water samples were collected in precleaned plastic bottles and stored for laboratory analysis. The water samples were labeled according to their collection site and the time when they were obtained. These were stored at 15°C temperature, until they were transported to the research laboratory for analysis.

2.2.3. Wheat Grain Sample Collection. Like water and soil samples, wheat samples were also 28 in number. About 250 g of wheat grains were collected at the time of harvesting from each field of the study area. Distilled water was used for washing wheat grains to eliminate any adhered soil and other contamination. All samples were labeled according to their site location. After labeling, these samples were stored in a sterilized container for transportation to the laboratory for analysis. Details of all samples collected are given in Table 2.

2.3. Preparation of Samples. All the collected samples were stored in polyethylene bags and labeled. The water samples were collected in precleaned plastic bottles previously cleaned by washing in nonionic detergent. The detergent was rinsed with the tap water and afterward soaked in 10% HNO_3 for 24 hours and further before utilization it was rinsed with deionized water [22].

2.3.1. Preparation of Water Samples. One hundred ml of well-mixed acid-protected water sample was transferred into a measuring beaker and 5 ml of concentrated nitric acid was

TABLE 2: Detail of collected samples.

Sr no.	Sample type	No. of samples	Reference sample
01	Waste water	25	03
02	Soil	25	03
03	Wheat grain	25	03

added. The measuring beaker was placed on a hot plate and evaporated to around 5 ml without boiling. This procedure took around 35 min. The sample was then diluted to 100 ml in a volumetric flask and was used for analysis. This strategy was used for all water samples [23].

2.3.2. Digestion of Soil Samples. For the measurement of trace metals in soil samples, the following digestion procedure was used. One gram of a soil sample was homogenized and weighed precisely and digested in 10 ml of 1:1 concentrated HNO₃. The mixture was heated on a hot plate and evaporated to dryness. Then, 15 ml of 1:1 HCl was added. Whatman-filter paper No. 40 was used to filter the sample which was then made up to 100 ml with 2% HNO₃ [24]. All soil samples were prepared as outlined above.

2.3.3. Digestion of Wheat Samples. Wheat (Triticum aestivum L.) grains were dried for about 10 hours in an oven at 60°C. The grains were then crushed and powdered with a grout. The crushed sample (1 g) was digested using a mixture of concentrated nitric and perchloric acids. An identical procedure was repeated for all the collected wheat grain samples.

2.4. Sample Analysis. pH of water and soil was measured using a pH meter. Concentrations of essential (Cu, Fe, Mn, Ni, and Zn) and toxic metals (Cd and Pb) were measured using a flame atomic absorption spectrophotometer (Model, Al 1200) in all the collected samples. The limit of detection (LOD) and limit of quantification (LOQ) for the studied elements were 0.01, 0.005, 0.004, 0.04, 0.005, 0.04, and 0.005 mg/L and 0.04, 0.119, 0.112, 0.12, 0.276, and 0.04 mg/L for Cd, Cu, Fe, Mn, Ni, Pb, and Zn, respectively.

2.5. Hazard Assessment

2.5.1. Enrichment Factor (EF). To measure the contamination levels of the environment, the enrichment factor (EF) is considered a suitable tool [25]. The enrichment factor for every element was calculated to estimate the anthropogenic impacts of heavy metals in soil using the formula in equation [26]:

$$EF = \frac{(C_n/C_{\text{ref}})_{\text{sample}}}{(B_n/B_{\text{ref}})_{\text{background}}},$$
(1)

where C_n (sample) is the concentration of the required element in the examined environment, C_{ref} (sample) is the concentration of the reference element in the examined environment, B_n (background) is the concentration of the examined element in the reference environment, and B_{ref} (background) is the concentration of the reference element in the reference environment. Commonly, an enrichment value of about 1 suggests that the given metal may originate completely from crustal materials and natural weathering processes [27]. Samples having enrichment factor greater than 1.5 are indicative of human interference, and (arbitrarily) EFs of about 1.5–3, 3–5, 5–10, and >10 imply minor, moderate, severe, and very severe pollution levels [28].

2.5.2. Pollution Load Index (PLI). The concentration factor (CF) is the quotient obtained by dividing the concentration of each metal by its concentration in the reference sample. The PLI of the site is determined by taking the nth root of the product of n CFs. The formulae employed are given in the following equations [29]:

$$CF = \frac{C_{\text{Soli}}}{C_{\text{reference}}},\tag{2}$$

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \times \dots \times CF_n},$$
 (3)

where CF is the contamination factor for the nth metal, C_{Soli} is the metal concentration in polluted soil, and $C_{\text{reference}}$ is the background value of that metal. PLI value of >1 implies a polluted site whereas PLI <1 indicates zero pollution.

2.5.3. Geo-Accumulation Index (I_{geo}). The geo-accumulation index is calculated to determine local man-made sources of heavy metal pollution. The equation (4) by [30] was used.

$$I_{\text{geo}} = \frac{\log_2 C_n}{1.5B_n},\tag{4}$$

where C_n is the amount of the nth element in the fraction. While B_n is the background value for this element. The factor 1.5 is used for the possible variations of the background data due to lithological variations. I_{geo} is divided into classes as given in Table 3.

2.5.4. Estimated Daily Intake. To evaluate the health risks of any chemical toxin, it is essential to assess the degree of exposure by measuring the routes of introduction of a contaminant to the targeted living organisms. The main path of exposure to heavy metals and other contaminants is the food chain. As indicated in many research studies, the consumption of food crops that are contaminated with heavy metals may cause many health hazards to humans. For the evaluation of health risks from analyzed metals in the study, the DIM (daily intake of metals) was calculated by using equation (5) [31].

$$DIM = \frac{C_{metal} \times C_{factor} \times D_{food-intake}}{B_{average-weight}},$$
 (5)

where C_{metal} , C_{factor} , $D_{\text{food-intake}}$ and $B_{\text{average-weight}}$ correspond to the heavy. Metal concentrations in plants (mg kg⁻¹), conversion factor, average body weight, and daily intake of vegetables, respectively. For the conversion of fresh green vegetable weights to dry weights, the conversion factor of 0.085 was used

TABLE 3: Contamination categories based on geo-accumulation index (I_{geo}) .

Class	$I_{\rm geo}$ value	Classification
0	<0	Uncontaminated
1	0-1	Uncontaminated to moderately contaminated
2	1-2	Moderately contaminated
3	2-3	Moderately to strongly contaminated
4	3-4	Strongly contaminated
5	4-5	Strongly to extremely strongly contaminated
6	>5	Extremely contaminated

Source: Muller, 1998.

as described by Rattan et al. [32] in a study. The weights of 55.9 and 32.7 kg were taken as an average adult and child body weights, respectively, as used in most studies [33]. For adults and children, the average daily. Intake rates for wheat are taken as 0.411 and 0.301 kg/day per person, respectively [34].

2.5.5. *Health Risk Index (HRI).* The HRI for the public consumption of a crop is based on daily intake and the Reference Oral Dose (RfD) for every metal individually. The HRI was calculated by using equation (6), where DIM is daily intake of each metal and RfD is the reference oral dose of the subsequent metal [35].

$$HRI = \frac{DIM}{RfD}.$$
 (6)

2.6. Statistical Analysis. Data obtained were analyzed using Microsoft Excel, and the results were expressed as the mean \pm standard deviation.

3. Results

3.1. Water Analysis. The measured concentrations of essential elements in the irrigation water at Manka Canal sites ranged between (3.6-9.99) mg/L for Cu, (33.3-50.8) mg/L for Fe, (19.9-39.0) mg/L for Mn, and (5.5-39.5) mg/L for Zn with mean values shown in Figure 2. While the concentrations in the reference samples for comparison ranged between (6.7-8.5) mg/L for Cu, (0.50-45.5) mg/L for Fe, (21.2-28.0) mg/L for Mn, and (7.30-11.7) mg/L for Zn as shown in Table 4. The concentration of nonessential/toxic elements in irrigation water at Manka Canal sites ranged between (0.00-0.099) mg/L for Cd and (0.00-0.91) mg/L for Ni with mean values shown in Figure 3, while for reference samples, the concentrations ranged from (0.01-0.04) mg/L for Pb and (0.00-0.04) mg/L for Ni (Table 4). While Cd was not detected in all samples.

3.2. Soil Analysis. The concentrations of essential elements in soil at Manka Canal sites ranged between (1.77–4.93) mg/kg for Cu, (7.30–12.10) mg/kg for Fe, (8.29–16.25) mg/kg for Mn, and (2.75–19.75) mg/kg for Zn with mean values shown in Figure 4, while reference samples the values ranged between (4.26–3.34) mg/kg for Cu, (9.45 to 11.33) mg/kg for Fe, (8.81–11.67) mg/kg for Mn, and (3.63–5.85) mg/kg for Zn



FIGURE 2: Concentration (mg/l) of essential elements in irrigation water.

TABLE 4: Comparison of concentrations (mg/l) of essential and nonessential/toxic metals in reference and in studied water samples.

Coursel trans	Essential elements				Nonessential elements			
Sample type	Cu	Fe	Mn	Zn	Cd	Ni	Pb	
<i>R</i> 1	7.94	45.50	23.95	10.70	ND	0.04	0.01	
Present work (average)	6.40 ± 2.01	42.50 ± 5.41	19.89 ± 1.41	34.51 ± 4.01	0.04 ± 0.008	0.91 ± 0.05	0.99 ± 0.11	
WHO limit	1.5	5.0	0.9	2.0	0.01	0.2	0.10	

(Table 5). The concentrations in nonessential/toxic metals ranged between (0.11-4.22) mg/kg for Cd, (0.33-34.97) mg/kg for Ni, and (1.70-90.4) mg/kg for Pb with mean values shown in Figure 5, while the concentrations for reference samples ranged between (0.00-5.00) mg/kg for Cd, (5.19-10.01) mg/kg for Ni, and (4.91-10.62) mg/kg for Pb (Table 5).

3.3. Wheat Analysis. The concentrations of essential elements in wheat plants at Manka Canal sites ranged from (12.47– 34.5) mg/kg for Cu, (36.8–61.0) mg/kg for Fe, (39.8–78.0) mg/ kg for Mn, and (11.10–79.0) mg/kg for Zn with mean values shown in Figure 6, while the reference sample concentrations ranged between (23.4–29.8) mg/kg for Cu, (0.6–57.1) mg/kg for Fe, (42.3–56.0) mg/kg for Mn, and (14.5 to 23.4) mg/kg for Zn (Table 6). The nonessential/toxic elements in wheat plants have concentrations of Cd (0.10–4.98) mg/kg, Ni (0.38– 20.00) mg/kg, and Pb (0.38–20.00) mg/kg with mean values shown in Figure 7, while the concentrations in reference samples ranged between (1.00-2.90) mg/kg for Cd, (4.90-9.70) mg/kg for Ni, and (0.90-1.90) mg/kg for Pb (Table 6). The permissible limit for Pb in plants recommended by the WHO is 2 mg/kg.

3.4. Health Risk Assessment

3.4.1. Enrichment Factor. The enrichment factors (EF) that were calculated are presented in Figure 8. Higher values of enrichment factor (EF) suggest poor retention of metals in soil and/or more translocation in plants. In the wheat plant, nickel has the highest EF value of (3.25), while it is 2.25 for Pb and 1.5 for Zn.

3.4.2. Pollution Load Index. The pollution load index (PLI) was calculated are presented in Figure 9. In the current study, it was found that the majority of the essential metals



FIGURE 3: Concentration (mg/l) of nonessential/toxic elements in irrigation water.



FIGURE 4: Concentration (mg/kg) of essential elements in soil.

Samplas trms		Essential	Nonessential elements				
samples type	Cu	Fe	Mn	Zn	Cd	Ni	Pb
R2	4.26	10.83	9.98	5.85	4.07	32.97	7.39
Present work (average)	3.43 ± 1.0	10.12 ± 1.2	9.57 ± 1.5	6.99 ± 4.5	1.95 ± 1.0	11.27 ± 2.3	16.36 ± 3.4
WHO limit	36	20	30	50	0.8	19	85



and Equipment lower concentrations due to 244 Health Dick Inde

such as Mn, Cu, and Fe are at lower concentrations due to the influence of external sources such as agriculture runoff and industrial activities. Zn has a higher PLI value which indicates the contamination. The PLI for nonessential/toxic metals, i.e., Pb and Ni exceeds 2 (>2). The PLI for Cd does not exceed 1 (>1). Thus, the site ranges from unpolluted to moderately polluted for Zn, Ni, and Pb.

3.4.3. Geo-Accumulation Index (I_{geo}). The geo-accumulation index (I_{geo}) for the site is plotted in Figure 10. This plot shows that all of the elements studied have positive values and all except Cd have I_{geo} values greater than one. Moreover, lead contamination is extremely high. I_{geo} for Cd suggests that the surface soil samples are uncontaminated to moderately contaminated by Cd. The soil is moderate to strongly contaminated by Ni and moderate to strongly polluted by Pb. For essential metals, the soil is extremely contaminated with Fe and Mn, while Cu showed moderate contamination and Zn showed moderate to strong contamination. 3.4.4. Health Risk Index. The health risk index (HRI) was also calculated and is plotted in Figure 11. If HI > 1, it means there is a maximum chance of noncarcinogenic effects, and the probability increases if the value of HRI increases [36]. For wheat grains, Pb and Cd have HRI values >1.9 which is unsafe for adults. Similarly, the HRI for children was also greater than one (>1) which is highly toxic to children. For Cu, Fe, Mn, and Zn the HRI index was within safer limits thus having no potential risk to human health. HI < 1 implies there is no risk of noncarcinogenic effects for a metal.

4. Discussion

In the world of agriculture and environmental science, it is often the smallest component that has the most significant influence. Trace elements, which are tiny but vital substances found in irrigated water, soil, and plants, are increasingly becoming the focal point of research and discussion. The same has been investigated in the current study.



FIGURE 6: Concentration (mg/kg) of essential elements in wheat.

TABLE 6: Comparison of concentrations (mg/kg) of essential and nonessential/toxic metals in reference and in studied wheat grain samples.

Commission from a		Essential	Nonessential elements				
Samples type	Cu	Fe	Mn	Zn	Cd	Ni	Pb
R3	27.8	54.6	47.3	25.5	2.90	7.40	1.90
Present work (average)	24.04 ± 7.2	51.0 ± 6.5	45.92 ± 5.6	27.98 ± 7.5	1.89 ± 1.2	14.69 ± 3.5	6.58 ± 1.3
WHO limit	10	200	30	0.60	0.2	10	0.10

4.1. Heavy Metals Analysis in Water, Soil, and Wheat. Results from the current work revealed that the Manka Canal samples showed high concentrations above WHO permissible limits for all essential and nonessential/toxic metals. The measured values showed lower concentrations in reference samples when compared with samples collected from Manka Canal. Hence, it indicates that the canal is contaminated by different heavy metals. Cadmium and Pb are toxic metals and can cause adverse health effects even at very low concentrations [8, 37]. All the measured values of essential metals in soil showed lower concentrations than their maximum permissible limits, while concentrations for nonessential/toxic metals were higher than permissible limits. Thus, it indicated soil pollution with nonessential metals. Ahmed et al. [8] also reported that nonessential elements such as Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn may accumulate in various plant parts (especially edible fruits) that may exceed the tolerable limits with time. For reference samples Cd and Ni were found above their permissible limits, so the study area has soil contamination with Cd and Ni concentration.

Singh et al. [38] have also reported 40.29% for Cu, 2.05% for Pb, 41.42% for Zn, and 15.7% for Cr higher concentrations in the soil of the Dinapur area irrigated by treated wastewater as compared to a site irrigated by clean water. Lead, as a soil contaminant, is a widespread issue. It accumulates with age in bones aorta, kidney, liver, and spleen. It can enter the human body through the uptake of food (65%), water (20%), and air (15%). Nickel is considered an essential trace element for human and animal health.

The present study also indicated that the concentrations of all of the heavy metals except iron in wastewater-irrigated food crops are higher than WHO permissible limits. Pb and nickel were at lower concentrations, but Cd concentrations were higher even in reference samples. A study conducted by the authors in [39] reported a 0.69 mg/kg cadmium concentration in wheat at Akaki, while the metal concentrations measured in this study are higher. The high levels of lead in the plants indicate the disposal of lead batteries, lead-based paints, plastics, and pipes at the site [40]. Zhuang et al. [41] have also found higher than maximum permissible levels of





FIGURE 8: Enrichment factor of heavy metals in collected wheat plant.

Cd and Pb concentrations in vegetables collected from six sampling sites around the Dabaoshan mine located in Shaoguan City, Guangdong, Southern China.

A study conducted by the authors in [42] also showed that the concentrations of heavy metals such as As, Cr, Ni, and Pb, with the exception of Cd, in soils of southern areas of the industrial zone in Iran were higher. Various industrial activities have resulted in elevated concentrations of these elements in the soil environments of these areas.



FIGURE 9: Pollution load index.

4.2. Health Risk Assessment. The higher uptake of heavy metals in leafy vegetables may be due to a higher transpiration rate to maintain the growth and moisture content of these plants. Soil pH also plays a significant role in trace element uptake. The availability of certain trace elements can be pH-dependent [8, 43]. These results show that Manka Canal is facing the problem of environmental pollution and





FIGURE 11: Health risk index for both children and adult.

the accumulation of heavy metals, especially Pb and Ni, in water, soil, and foodstuffs. This may originate from the increased rate of discharge of un-treatment industrial and household waste to the Manka Canal. Accumulation of heavy metals in water and soil can disrupt the balance of the local ecosystem through various interconnected mechanisms like bioaccumulation and biomagnification. The EF in the wheat plant shows greater value for Ni, Pb, and Zn. These values that are greater than (>1) suggest that the contamination sources are more likely to be anthropogenic [44]. The results of I_{geo} reveal that the sediments of Keratsini harbour, Greece, were heavily polluted in terms of Cd and Pb [45]. Another study [46] also reported that the sediments of the Wadi Al-Arab Dam were strongly to extremely contaminated with Cd. In our case, higher contamination is due to Pb, Zn, Ni, and Cu. A study conducted by the authors in [47] revealed that the metal transfer was highly effective from soil to the growing plants, i.e., brinjal, red corn, wheat, tomato, and spinach. Among the metals, Cr, Ni, Mn, and Pb in plant samples were exceeding the WHO/FAO safe limit. A study

conducted by [48] also depicts that from the total collected grape samples, the concentration of As in 11.76% and Zn in 5.88% of the samples were higher than the FAO/WHO permissible limits.

The presence of trace elements in irrigation water represents a critical environmental and agricultural challenge that demands immediate attention. The repercussions of such contamination are multifaceted, affecting not only crop quality and yield but also posing risks to the environment, public health, and long-term sustainability. Therefore, it is imperative that we prioritize responsible water management and agricultural practices. By doing so, we can hope to safeguard our ecosystems, protect our food supply, and ensure a healthier and more sustainable future for all.

5. Conclusion

Irrigating agricultural lands with sewage water can result in heavy metal accumulation in the soil, impacting crop safety. This study revealed elevated levels of heavy metals, particularly Pb and Cd, in soil samples, with Cd exceeding permissible limits in some cases. However, Ni, Fe, Zn, Cu, and Mn remained within permissible limits. Pollution load and health risk indices indicated contamination of Cd, Pb, and Ni in most plants tested, posing potential health risks for consumers. Wheat samples exhibited elevated concentrations of Cd, Cu, Mn, Ni, Pb, and Zn, i.e., 4.88, 22.03, 38.2, 89.2, 19.62, and 67.9 mg/kg, respectively, in collected wheat samples surpassing WHO and FAO limits. HRI is greater than 1 for nonessential element like Cd and Pb that depicts that prolonged consumption of such contaminated foods may lead to health issues as. Urgent action is required to regulate and monitor sewage effluents, provide guidance to farmers and industries on safe wastewater use, and mandate wastewater analysis before crop irrigation to prevent heavy metal toxicity in soil and diets. Also, regular monitoring of these toxic heavy metals from industrial and domestic effluents, irrigation water, and crops are necessary to prevent their sufficient accumulation in the food chain. It is further recommended that before irrigation of crops such as wheat and other vegetables the municipal wastewater must be treated to avoid soil and dietary toxicity of heavy metals.

Data Availability

Data supported the study will be available as supplementary file.

Conflicts of Interest

The authors declare that they have no conflicts of interest that could have appeared to influence the work reported in this paper.

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Supplementary Materials

All the data used to support the fndings of this study is included as supplementary file. (*Supplementary Materials*)

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