sustainability

MDPI

Article

Risk Assessment of Heavy Metals in Basmati Rice: Implications for Public Health

Farah Tariq [1], Xiukang Wang [2,*], Muhammad Hamzah Saleem [3], Zafar Iqbal Khan [1,*], Kafeel Ahmad [1], Ifra Saleem Malik [1], Mudasra Munir [1], Shehzadi Mahpara [4], Naunain Mehmood [5], Tasneem Ahmad [6], Hafsa Memona [7], Ilker Ugulu [8], Sajid Fiaz [9] and Shafaqat Ali [10,11,*]

1 Department of Botany, University of Sargodha, Sargodha 40100, Pakistan; farahtariq@gmail.com (F.T.); kafeeluaf@yahoo.com (K.A.); ifrasaleemmalik26@gmail.com (I.S.M.); Munirmudasra01@gmail.com (M.M.)
2 College of Life Sciences, Yan'an University, Yan'an 716000, China
3 MOA Key Laboratory of Crop Ecophysiology and Farming System in the Middle Reaches of the Yangtze River, College of Plant Science and Technology, Huazhong Agricultural University, Wuhan 430070, China; saleemhamza312@webmail.hzau.edu.cn
4 Department of Plant Breeding and Genetics, Ghazi University, Dera Ghazi Khan 32200, Pakistan; Shehzadimahpara@gmail.com
5 Department of Zoology, University of Sargodha, Sargodha 40100, Pakistan; Naunainmehmood@gmail.com
6 Thathi Pak Farm House, Toba Tek Sigh 36070, Pakistan; tasneem91@gmail.com
7 Department of Zoology, Lahore College for Women University, Lahore 40050, Pakistan; Hafsamemona@gmail.com
8 Faculty of Education, Usak University, Usak 64100, Turkey; ilkerugulu@gmail.com
9 Department of Plant Breeding and Genetics, The University of Haripur, Haripur 22620, Pakistan; sfiaz@uoh.edu.pk
10 Department of Environmental Sciences and Engineering, Government College University Allama Iqbal Road, Faisalabad 38000, Pakistan
11 Department of Biological Sciences and Technology, China Medical University, Taichung City 40402, Taiwan
* Correspondence: wangxiukang@yau.edu.cn (X.W.); zafar.khan@uos.edu.pk (Z.I.K.); shafaqataligill@yahoo.com (S.A.)

Abstract: Basmati rice is increasingly recognized and consumed in different parts of the world due to its different tastes and nutritional properties. This research focused on determining the cadmium (Cd), cobalt (Co), Copper (Cu), iron (Fe), manganese (Mn), nickel (Ni) and zinc (Zn) content in locally grown basmati rice in Pakistan and assessing the risks of these values to human health. Root, shoot and grain samples of basmati rice were taken, along with soil samples from the five regions studied. Metal mean concentrations (mg/kg) in grains fluctuated from 2.70 to 9.80 for Cd, 4.80 to 9.85 for Zn, 1.16 to 1.46 for Cu, 1.84 to 10.86 for Co, 2.05 to 13.07 for Fe, 5.03 to 11.11 for Mn and 3.24 to 13.28 for Ni, respectively. All metal values were within permissible limits except for Cd. The enrichment factor for Cd was highest among all sites. Cobalt and zinc had the highest bioaccumulation factor and translocation factor. The highest enrichment factor was noticed for Cd and the lowest for Cu. The health risk index at all examined sites was less than one. Consistent examination is recommended to limit health hazards instigated by the use of rice polluted with a greater concentration of Cd.

Keywords: Basmati; daily intake of metals; contamination factor; *Oryza sativa*; trace element

check for updates

Citation: Tariq, F.; Wang, X.; Saleem, M.H.; Khan, Z.I.; Ahmad, K.; Saleem Malik, I.; Munir, M.; Mahpara, S.; Mehmood, N.; Ahmad, T.; et al. Risk Assessment of Heavy Metals in Basmati Rice: Implications for Public Health. *Sustainability* **2021**, *13*, 8513. https://doi.org/10.3390/su13158513

Academic Editor: Park Jin Hee

Received: 11 June 2021
Accepted: 26 July 2021
Published: 30 July 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

In Pakistan, rice is the staple food crop that provides a significant amount of nutrition and vitamins [1]. Rice contains 3% nutritive fat and 20% proteins and provides 27% nutritive energy [2]. Rice is characterized by its nature to grow on acidic and alkaline soil. It can also grow in arid areas [3]. Punjab and Sindh are renowned for rice production in Pakistan [4]. Approximately 60–70% of individuals in these provinces use rice as food; 6.0 million tons of rice are produced by Pakistan annually and it exports almost 4.0 million tons, with the remaining 2.0 million tons being the approximate annual consumption of

rice. Prices are comparable to those of local competitors, especially India, and therefore Pakistani exporters can maintain their share of the world market [3]

Those elements having a density higher than 4 g/cm^3 are considered heavy metals [5]. Elements such as cadmium (Cd), nickel (Ni) and copper (Cu) accumulate in edible and non-edible parts of plants [6,7]. In small amounts, these elements function as micronutrients, while in large amounts they are considered toxic [8]. Growing crops on polluted soil can present a severe danger to human life [9–11]. Industrial effluents and mining are significant causes of toxicity [12,13]. The burning of waste material, the exhaust of vehicles, the application of chemical fertilizers and the treatment of sewage sludge as fertilizer on agronomic land are the primary causes of contamination [14].

Application of pesticides, improper disposal of waste material and distinctive deposition can also cause metals pollution [15]. Growing food crops on polluted soil causes metal toxicity in food crops [16,17]. Elements in the soil diffuse into food chains through bioaccumulation [18]. As a result, these metals affect human beings and plants [19,20].

High metal concentrations can increase the soil's potential to accumulate these elements [21]. Heavy metals have a mobile structure that can be transported from soil to plants [22]. These elements show mobility between root and shoots, and between shoots and grains. Contaminated crops may expose people to various serious diseases [23–25]. Heavy metals are supported by many studies to be carcinogenic, and also cause blood, bone, heart and kidney diseases [26–29]. Small concentrations of heavy metals can be quite harmful to living things. For example, alveolitis, bronchitis, and emphysema result from ingesting small concentrations of Cd. Kidney problems are also caused by inhalation of Cd [30]. Cd toxicity also causes nerve and bone diseases in humans [31]. While low concentrations of Zn are responsible for many physiological functions in the body, higher concentrations pose a serious threat to life [32]. Excessive Cu concentration causes diarrhoea, nausea and Wilson's disease [33,34].

As human beings consume contaminated rice, metals accumulate in body parts. Therefore, the aim of this research was to evaluate Ni, Co, Fe, Cd, Zn and Mn content in regionally cultivated rice and assess the nutritive hazards related to the consumption of *Oryza sativa* among native inhabitants. The objective of the study was to calculate the hazard posed by heavy metals in primarily rice-cultured areas of Jhang. Accumulations of dangerous elements were measured in soil and parts of rice plants to evaluate the bioaccumulation factor and translocation factor.

2. Materials and Methods

2.1. Study Area

Agronomic fields in Jhang district were chosen as a study area (Figure 1). Jhang is located in Punjab province, Pakistan. Most of the land, almost 8809 km^2, is agronomic, excluding the area near the Chenab River. The district receives an average of 150 mm (https://jhang.punjab.gov.pk/climate, accessed on 29 July 2021) annual rainfall, with irregular rainfall taking place in winter. Five agricultural sites were carefully selected near the side of Moza Satiana Chiniot road to investigate metal contents in randomly collected basmati rice (grain, root and shoot) and soil samples. All sites were selected to determine the level of contamination in rice crops due to canal water irrigation.

2.2. Soil

From five cultivation sites treated with water from the canal, four samples (each sample with five replicates) of soil and Basmati rice were collected. Soil was taken from a depth of 15 cm from the examined area by using a sterilized augur, applying the method of Sanchez [35]. Samples were first sun-dried then shifted to an oven at a temperature of 105 °C.

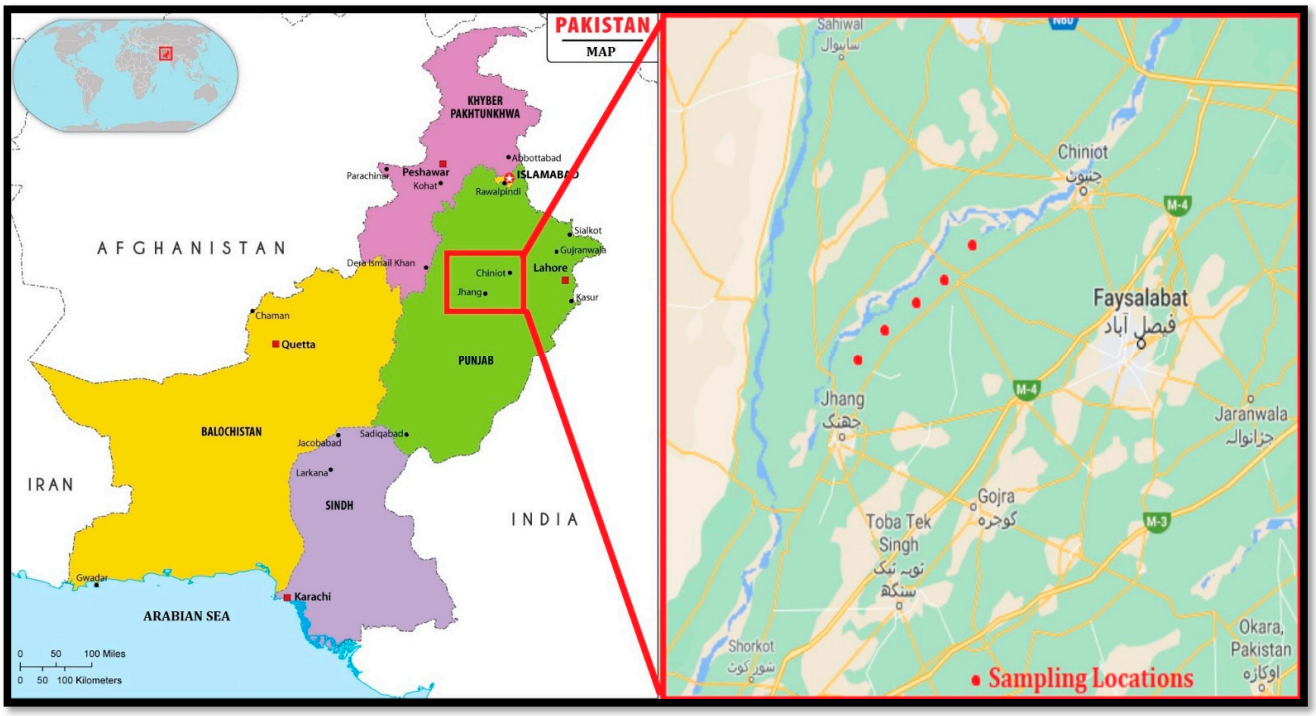


Figure 1. Study area and sampling locations.

2.3. Roots, Shoots, Grains

By using a sterilized apparatus, four samples of Basmati (rice variety) roots, shoots and grains from five different sites were collected (each sample with five replicates). Distilled water was applied to the samples to eradicate soil particles and then HCl was added for dilution purposes. Sun-dried samples were shifted to an oven for five days' drying at a temperature of 105 °C.

2.4. Digestion of Soil, Grains, Roots and Shoots Samples

After drying in the oven continuously for five days, the samples were pulverised into powder form via pestle and mortar. By following Vukadinović and Bertić [36]'s "Wet Digestion Method", 2 g of each powdered sample was digested. After this process, samples were transferred to digestion booths. An amount of 10 mL of 1:3 aqua regia HNO_3: HCl solution was poured into each beaker containing root, shoot, soil and grain samples. Digested samples were left overnight. Subsequently, hot plates containing each sample solution were heated at 70 °C for 4 h. H_2O_2 (2 mL) was continuously added and the solution was then further heated at 70 °C for 4 h until becoming colourless. The solution was filtered through 42 µm filter paper after cooling. Distilled water was added to increase each sample to a volume of 50 mL.

2.5. Metal Analyses

Filtered samples after digestion were run through an atomic absorption spectrophotometer (AAS) (Model: AA-6300, Shimadzu, Kyoto, Japan) to analyze element concentration. For accurate results, the following technique was applied: optical emission immersion was used to find the concentration of the metals under study, for which the instrument operating conditions are given in Table 1.

Table 1. Atomic absorption spectrophotometer operating parameters for determination of heavy metal levels.

Metal	Cd	Co	Zn	Fe	Cu	Mn	Ni
Wave length (nm)	228.8	250.0	213.9	248.3	324.8	279.5	232.0
Lamp current low (mA)	8	9.5	8	12	6	12	12
Slit width (nm)	0.7	0.2	0.7	0.2	0.7	0.2	0.2
Air flow rate (L/min)	15	15	15	15	15	15	15
Burner height (mm)	7	10	7	9	7	9	7

2.6. Quality Control

All necessary procedures and precautions were followed during analyses. To obtain precise outcomes from the AAS, chemicals and salts required for digestion were obtained from E. Merck (Germany) with a certified purity of 99%. Standard preparation precautions were sustained during the experiment. Metal absorption in rice and soil was determined on a dry weight basis. Each sample was analysed three times.

2.7. Statistical Analysis

SPSS 20 was employed to find correlation and variance. A one-way ANOVA was used to check variance and correlation (association between rice and soil). The variance between metals for each soil and rice sample was determined to be 0.001, 0.01 and 0.05, according to Steel and Torrie [37].

2.8. Bioaccumulation Factor

Bioaccumulation factor (BAF) was calculated via the equation determined by Cui et al. [38].

BAF = Element conc. (mg/kg) at edible part of *Oryza sativa*/Element conc. (mg/kg) in soil.

2.9. Translocation Factor (TF)

Translocation factor (TF) was calculated according to Liu et al. [39].

TF = Element conc. (mg/kg) in shoot/Element conc. (mg/kg) in root.

2.10. Pollution Load Index (PLI)

The pollution load index (PLI) determines the level of metal pollution in soil by applying the following formula [39]:

PLI = Element conc. (mg/kg) in soil/Element conc. in referenced soil.

2.11. Enrichment Factor

Enrichment factor (EF) determines metals availability in soil and variance in growth rate [40].

EF = Element conc. (mg/kg) at edible part of *Oryza sativa*/Element conc. (mg/kg) in examined soil/Standard Element conc. (mg/kg) in edible part of *Oryza sativa*/Standard Element conc. (mg/kg) of metal in soil.

2.12. Daily Intake of Metals

The daily intake of metal (DIM) in the human body was evaluated using the following equation [41].

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

C_{metal} designates the concentration of elements,

$C_{dailyfood\ intake}$ designates the daily intake of food crops mg/kg/person/day, and

$B_{average\ weight}$ designates the average body weight of a person. The daily intake of rice and average body weight of a person were assumed as 0.345 mg and 60 kg respectively [42,43].

2.13. Health Risk Index

The health risk index (HRI) indicates the hazard to individuals who consume contaminated food crops. It was determined by applying the equation from [44]:

$$HRI = DIM/R_FD.$$

If HRI is greater than 1 it designates harmfulness whereas if less than 1 it designates harmless conditions for human health.

R_FD refers to an oral reference dose.

3. Results

ANOVA found that site location significantly ($p < 0.05$) influenced element concentration in the soil of Basmati rice fields (Table 2). At all soil sites, the value of Cd was higher, while the values of Fe and Mn were lower (Figure 2). Significant concentrations of Ni, Co, Fe, Cd, Zn, Cu and Mn content were found at different sites (Table 2). In rice plant roots, the levels of Cu and Co were highest, while Ni was low at all sites (Figure 3).

Table 2. ANOVA for heavy metals in soil and roots, shoots and grains of Basmati rice.

Source of Variation	Degree of Freedom	Mean Square						
		Cd	Zn	Cu	Co	Fe	Mn	Ni
Paddy Soil								
Sites	4	0.206	0.004	0.004	0.002	0.002	0.003	0.002
Error	10	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Root								
Sites	4	0.158 ***	0.073 ***	0.001 ***	0.001 ***	0.124 ***	0.002 ***	0.001 ***
Error	10	0.002	0.001	0.001	0.001	0.002	0.001	0.001
Shoot								
Sites	4	0.003 ***	0.002 ***	0.003 ***	0.002 ***	0.002 ***	0.002 ***	0.001 ***
Error	10	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Grain								
Sites	4	0.004 ***	0.002 ***	0.001 ***	0.002 ***	0.002 ***	0.003 ***	0.002 ***
Error	10	0.001	0.001	0.001	0.001	0.001	0.001	0.001

***: Significant at 0.001 level.

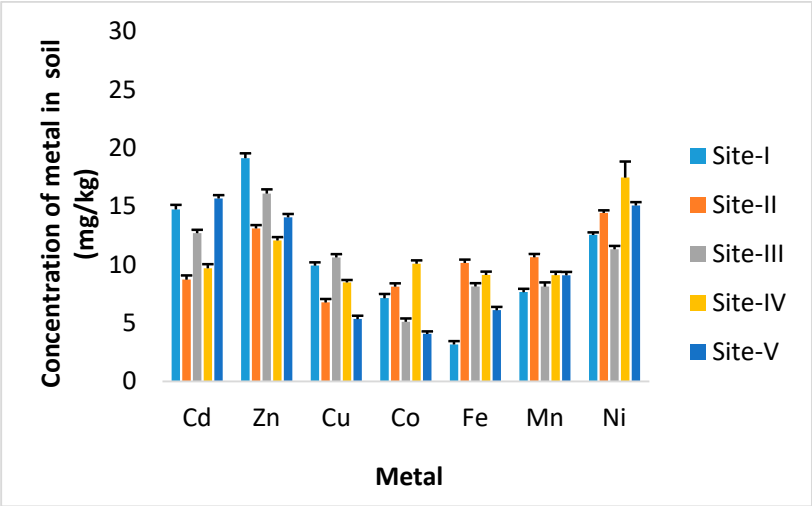


Figure 2. Dispersal of heavy metals in paddy soil at the five sites.

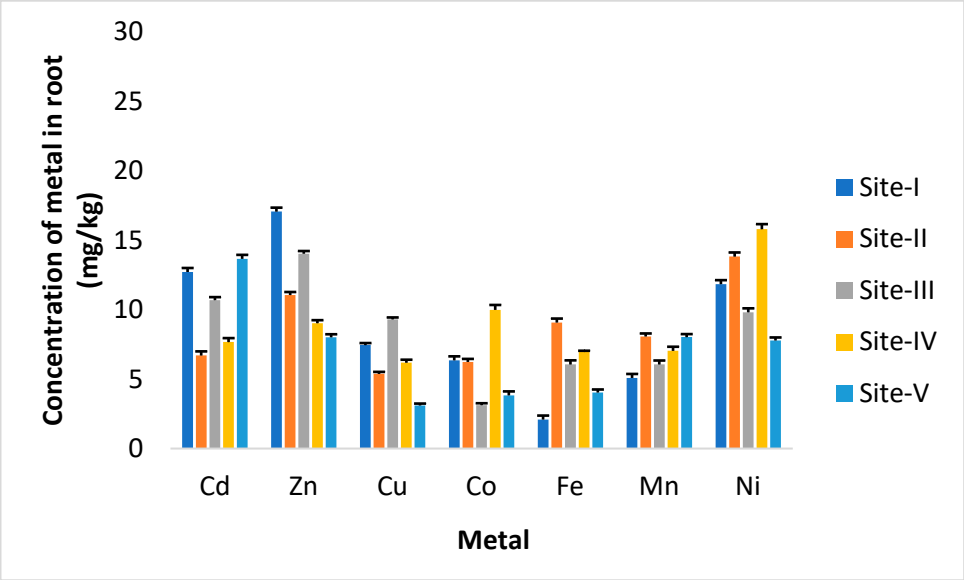


Figure 3. Variation in concentration of heavy metals in plant roots at the five sites.

The outcomes from the ANOVA revealed a significant effect of sites on Ni, Co, Cd, Zn, Cu, Mn and Fe content in rice shoots (Table 2). In these shoots, the values of Cu and Co were highest, while Ni was low at all sites (Figure 4).

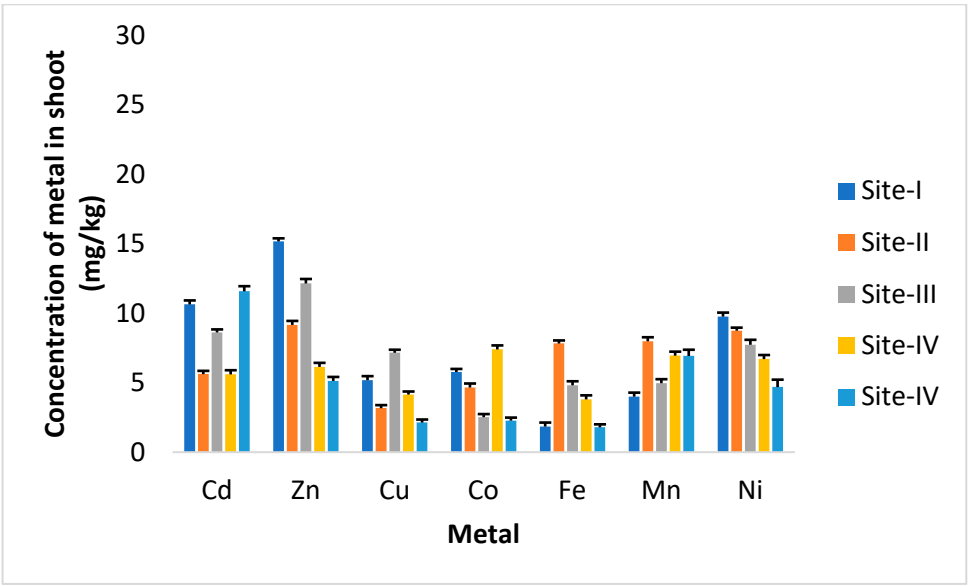


Figure 4. Variation in concentration of heavy metals in rice shoots from the five sites.

Examination of variance indicated significant influence of sites on element concentration (Cu, Ni, Co, Fe, Cd, Zn and Mn content) in Basmati grains (Table 2). In grains, the levels of Cu and Co were the highest, while Ni was low at all sites (Figure 5).

Variance in the degree of contamination between sites was determined using the PLI [45]. Pollution load index values greater than one are considered polluted, while PLI values less than one are considered unpolluted [46]. The value of PLI for all metals at all sites was less than one, indicating that the soil of all sites was safe (Table 3).

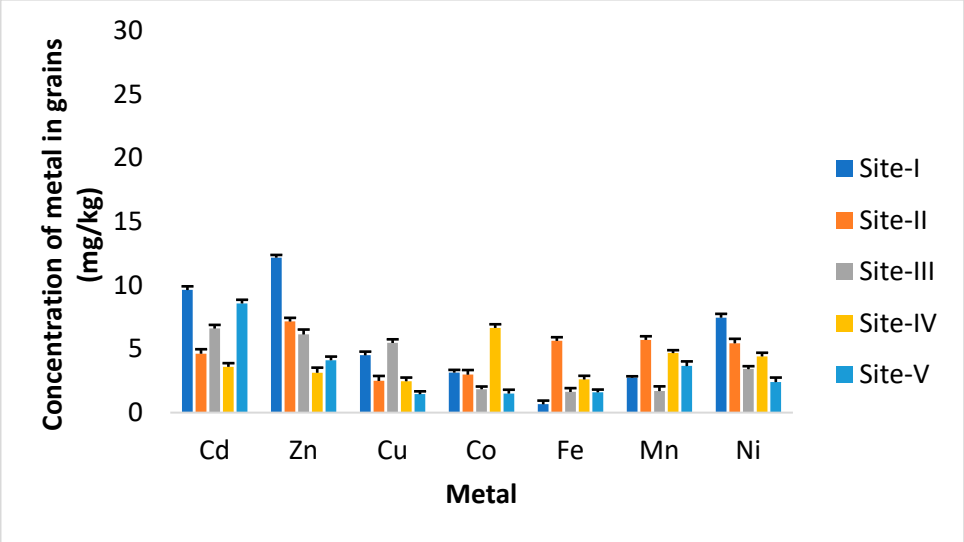


Figure 5. Variation in concentration of heavy metals in rice grains from the five sites.

Table 3. Pollution load index, Bioaccumulation, enrichment and translocation factors for Basmati rice.

Site	Metal						
	Cd	Zn	Cu	Co	Fe	Mn	Ni
Pollution load index							
Site-I	0.0928	0.3235	0.4217	0.4767	0.3222	0.3285	0.7139
Site-II	0.9732	0.2779	0.5389	0.3441	0.1287	0.2631	0.0433
Site-III	0.1924	0.3681	0.2989	0.4845	0.2338	0.3491	0.2624
Site-IV	0.7707	0.2318	0.2938	0.6279	0.3390	0.3059	0.9296
Site-V	0.6510	0.2763	0.4114	0.5504	0.1103	0.2414	0.3761
Bioaccumulation factor							
Site-I	0.8129	0.6891	0.4147	0.4682	0.6611	0.7237	0.6001
Site-II	0.9873	0.4753	0.3212	0.6309	0.4245	0.6559	0.6105
Site-III	0.4453	0.7264	0.4952	0.5292	0.6834	0.6170	0.6482
Site-IV	0.2574	0.4688	0.5172	1.1664	0.6779	0.4231	0.3587
Site-V	0.2376	0.5559	0.3380	0.2930	0.3279	0.4462	0.2603
Enrichment factor							
Site-I	6.0563	0.3045	0.1731	2.0131	0.0884	0.0677	0.5437
Site-II	7.355	0.2100	0.1348	2.7130	0.0568	0.0613	0.5531
Site-III	3.3177	0.3210	0.2077	2.2754	0.0914	0.0577	0.5873
Site-IV	1.9173	0.2072	0.2161	5.0155	0.0907	0.0396	0.3250
Site-V	1.7705	0.2457	0.1418	1.2601	0.0439	0.0417	0.2358
Translocation factor							
Site-I	0.9019	0.8824	0.9423	0.8721	0.9392	0.9157	0.8964
Site-II	0.9255	0.9616	0.6756	0.9068	0.7082	0.8914	0.9222
Site-III	0.8790	0.9781	0.5891	0.8909	0.8615	0.8528	0.8752
Site-IV	0.5572	0.8514	0.8640	0.8173	0.8491	0.7281	0.8753
Site-V	0.6312	0.7864	0.5625	0.8361	0.5740	0.7486	0.5931

At Site-I, BAF of Cd, Mn, Zn and Fe was higher than that of Cu, Co and Ni. At Site-II, BAF of Cu, Fe and Zn was lower than that of Co, Mn, Cd and Ni. At Site-III, BAF of Fe, Ni, Mn and Zn was higher than that of Co, Cu and Cd. At Site-IV, BAF of Ni, Cd and Mn was lower than that of Cu, Zn, Fe and Co. At Site-V, BAF of Mn, Fe, Cu and Zn was higher than that of Co, Ni and Cd. Across the five various sites, Co and Mn displayed the highest BAF while Cd and Cu displayed the lowest BAF (Table 3).

Levels of diffusion of metals from soil to rice grains diverged among sites, as the EF of the tested elements at the five various sites was as follows: Cd (1.7705–7.355), Zn (0.2072–0.3045), Cu (0.1418–0.2161), Co (1.2605–5.0155), Fe (0.0439–0.0914), Mn (0.0396–0.0677) and Ni (0.2358–0.0.5873) mg/kg individually (Table 4). At all sites, Cd and Zn had the highest translocation factor value, while Cu had the lowest TF value (Table 3).

Table 4. Daily intake of metal and health risk index of rice.

Site	Metal						
	Cd	**Zn**	**Cu**	**Co**	**Fe**	**Mn**	**Ni**
Daily intake of metal							
Site-I	0.0564	0.0566	0.0084	0.0225	0.0697	0.0639	0.0536
Site-II	0.0505	0.0336	0.0083	0.0339	0.0179	0.0465	0.0641
Site-III	0.0274	0.0671	0.0071	0.0223	0.0523	0.0579	0.0764
Site-IV	0.0215	0.0276	0.0073	0.0625	0.0752	0.0348	0.0361
Site-V	0.0156	0.0390	0.0067	0.0106	0.0118	0.0289	0.0187
Health risk index							
Site-I	0.0378	0.0013	0.0010	0.5235	0.0012	0.0014	0.0059
Site-II	0.0339	0.0008	0.0009	0.7885	0.0003	0.0001	0.0072
Site-III	0.0184	0.0015	0.0008	0.5187	0.0009	0.0012	0.0084
Site-IV	0.0145	0.0006	0.0007	0.4529	0.0013	0.0007	0.0040
Site-V	0.0105	0.0009	0.0007	0.2469	0.0002	0.0006	0.0021
R_FD * mg/kg/day)	1×10^{-3}	3×10^{-1}	4×10^{-2}	43×10^{-2}	1×10^{-1}	14×10^{-1}	2×10^{-2}

Source: * USEPA (2010).

At Site-I, DIM of Zn, Fe, Cd and Mn was higher than that of Cu, Co and Ni. At Site-II, DIM of Cu, Fe and Co was lower than that of Cd, Zn, Ni and Mn. At Site-III, DIM of Ni, Fe, Zn and Mn was greater than that of Cu, Cd and Co. At Site-IV, DIM of Zn, Cd and Cu was lower than that of Fe, Co, Ni and Mn. At Site-V, DIM of Fe, Co and Cu was lower than that of Cd, Zn, Mn and Ni. Among all five different sites, DIM of Fe and Ni was highest and of Co was lowest (Table 4).

HRI determines the extent of hazard arising from ingestion of food polluted with toxic elements [38,44]. Health risk index lower than one is suggested to be safe whereas if higher than one is considered dangerous for humans [44]. The HRI values for intake of rice from the various sites varied from 0.0001–0.785. This suggests that health risk index was minor, as no value exceeded one at any of the five various sites. (Table 4).

Cadmium exhibited a positive but non-significant correlation between soil and root levels and root and shoot levels; however, a significant positive correlation was determined between shoot and grain levels. Zn and Fe indicated a significant positive correlation between soil and root levels, root and shoot levels and shoot and grain levels. In another recent study, a definite significant association was found between root and shoot levels of metals and shoot and grain levels; however, the positive association was not significant between shoot and grain levels. The positive correlations found here reveal that elements from the specific conjoint origin as carbon-based substances were fundamental substances with adaptable availability of elements in soil (Table 5).

Table 5. Metal levels correlation between soil and root, root and shoot and shoot and grain of Basmati rice.

Metal	Soil-Root	Root-Shoot	Shoot-Grain
Cd	0.169	0.664	0.893 *
Zn	0.983 **	0.953 **	0.899 *
Cu	0.548	0.480	0.820
Co	0.815	0.986 **	0.919 *
Fe	0.988 **	0.991 **	1.00 **
Mn	0.981	0.949	0.978
Ni	0.879	0.982	0.988

*, **: Significant at the 0.05 and 0.01 levels.

4. Discussion

In this study of metal elements in soil flooded via water from a canal, levels of Co and Ni were higher while levels of Mn, Fe, Cu and Zn were lower as compared to the findings of Jaishree et al. [47]. Levels of the investigated elements in soil samples obtained from all the examined cultivation sites were below the PML guidelines determined by European Union [48] except for Cd. The current study also found lower levels of Fe than the USEPA [49] suggested values.

In the present study, the mean concentration of metals in samples from five different sites, except for Cu, was higher than the results reported by Othman [50]. Greater absorption of metals indicated that rice plants hyper-accumulate these metals from soil to plant [38,40,51]. Cu level investigated in the current shoot samples was lower than while Zn, Mn, Fe and Cd levels were higher than the outcomes of Othman et al. [50]. Juen et al. [52] found values of Co (0.11 mg/kg) higher to those found in the present inquiry. Mean grain values of all studied elements were less than the maximum values given by FAO/WHO [53], excluding Cd. Yap et al. [13] recorded higher levels of Cd (0.14) and Cu (0.048) and lower levels of Zn (0.05), Co (0.07), Fe (0.34) and Ni (0.34) as compared to the current investigation. Eticha and Hymete [54] recorded higher levels of Mn (15.4 mg/kg) as compared to the present findings.

In these studies Cu, Cd, Ni and Zn pollution in soil was smaller than the standards advanced by Singh et al. [55] which were designated as Zn (44.19), Cd (1.49), Cu (8.39) and Ni (9.06 mg/kg). Cobalt (9.1 mg/kg) contamination in soil in the Dutch Standards [56] also exceeds levels found in the current study. Dosumu et al. [57]'s standard proposed an amount of Fe (56.9 mg/kg) PLI in soil significantly greater than that found in this investigation. Mn contamination in soil was less than the standard determined by Singh et al. [58], which was 46.75 mg/kg. The contamination load index at the five studied sites was highest for Co and lowest for Fe. In the current analysis, PLI for Ni was highest and for Cd was lowest, however, for all metals, PLI values were lower than one. The reasons for the lower pollution load index in the studied region may be due to the low industrial density and reduced application of canal water. This study indicated a lower pollution load index for Ni, Zn, Co, Cu, Mn and Fe than found by Wajid et al. [59].

Bioaccumulation factor for Co, Zn, Fe, Ni, Mn, and Cu in the current analysis was higher than the levels determined by Badawy et al. [60]. BAF for all elements was lower than one, apart from Co. This may be because BAF depends on specific food crop types [38]. Greater BAF for Mn and Ni indicated greater accumulation ability of these metals from soil to rice grains [39].

Singh et al. [61]'s conclusions found a lower TF for Cd (0.82) and Zn (0.85) and a higher TF for Mn (1.38), Fe (1.27) and Ni (0.940 mg/kg) as compared to the current analysis. The mobility factor for Co (0.09 mg/kg) was less than as determined by Juen et al. [52]. The high mobility factors found for Cd and Zn suggests that *Oryza sativa* has the capacity to hyperaccumulate Zn and Cd from roots to shoots [61].

Brunetti et al. [62]'s outcomes indicated a higher EF for Zn (3.6 mg/kg), Ni (1.5 mg/kg), and Cu (1.4) and lower EF for Cd (1.8 mg/kg) as compared to the current analysis. The enrichment factor of Fe (3.40 mg/kg) and Mn (3.40 mg/kg) were higher in the findings of Singh et al. [61] as compared to this study. Absorption and accumulation of metals from soil to root and root to grains diverged from site to site [63].

In this study, the total amounts of Mn, Ni, Co and Zn were higher than the results found by Mahmood and Malik [64]. Daily intake of metals in the present study for all metals was lower than one. Ogunkunle et al. [65]'s results found a daily ingestion of Zn (0.083 mg/kg/d) that was lower than in this study. Balkhair and Ashraf [66] recorded higher DIM values for Mn (1.6) and Ni (5.2) mg/kg/person/day as compared to the present study. Daily consumption of Fe was less than the result found by Khan et al. [67], which was (0.195 mg/kg).

Satpathy et al. [68] recorded higher levels of Cd and Zn and lower levels of Cu compared to current findings. The HRI for Ni and Fe was lower than that found by Khan et al. [67]. The value of HRI for Co was higher than that found by Bibi et al. [69]. The HRI for Mn was lower than that found of Fan et al. [70]. Possible HRI via ingestion of rice for all metal was <1, indicating no health risk due to consumption of rice.

The study results indicated that the translocation of Zn and Fe from soil to root, from root to shoot and from shoot to grain showed significant association. The study of Khan et al. [67] also showed the same results for Zn and Fe. These findings indicate that these elements may pose an accumulation threat for basmati rice.

5. Conclusions

The results of the study showed that metal deposition occurred mostly in rice grains. Cd concentration in soil samples taken from the study area was above the standards set by FAO/WHO. In addition, a high pollution load index value was determined in the canal water used for irrigation of rice. These may be among the reasons for the high heavy metal accumulation values in the basmati rice samples used in the research. In addition to these, various other factors such as production waste, fertilizer application, herbicide sprays and various agricultural chemicals polluting the canal water are likely among the reasons for the high metal values in basmati rice. As such, the metal values in all commonly consumed grains such as basmati rice and the soil they grow in should be regularly tested, and the risks to human health should be monitored.

Author Contributions: Formal analysis, M.M., H.M. and S.F.; Funding acquisition, K.A., N.M., T.A. and I.U.; Investigation, F.T., X.W., I.S.M. and S.A.; Methodology, F.T., X.W., M.H.S., Z.I.K., T.A., S.F. and S.A.; Project administration, Z.I.K., S.M. and N.M.; Resources, X.W., Z.I.K., I.S.M., H.M., I.U., S.F. and S.A.; Software, M.H.S., M.M. and I.U.; Supervision, N.M.; Validation, K.A.; Visualization, K.A.; Writing—original draft, M.H.S. and S.M. All authors have read and agreed to the published version of the manuscript.

Funding: The publication of the present work is supported by the National Key Research and Development Program of China (grant no. 2017YFC0504704) and the National Natural Science Foundation of China (51669034, 41761068, 51809224).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors greatly acknowledge the Department of Botany, University of Sargodha, Sargodha, Pakistan for their support.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Fresco, L. Rice is life. *J. Food Compos. Anal.* **2005**, *18*, 249–253. [CrossRef]
2. Kennedy, G.; Burlingame, B.; Nguyen, V.N. Nutrition contribution of rice and impact of biotechnology and biodiversity in rice consuming countries. In Proceedings of the 20th Session of the International Rice Commission, Bangkok, Thailand, 23–26 July 2002.
3. Kennedy, G.; Burlingame, B. Analysis of food composition data on rice from a plant genetic resources perspective. *Food Chem.* **2003**, *80*, 589–596. [CrossRef]
4. *Agriculture Statistics of Pakistan 2010–2011*; Government of Pakistan, Pakistan Bureau of Statistics: Islamabad, Pakistan, 2011.
5. Saleem, M.H.; Ali, S.; Rehman, M.; Hasanuzzaman, M.; Rizwan, M.; Irshad, S.; Shafiq, F.; Iqbal, M.; Alharbi, B.M.; Alnusaire, T.S.; et al. Jute: A Potential Candidate for Phytoremediation of Metals—A Review. *Plants* **2020**, *9*, 258. [CrossRef]
6. Saleem, M.H.; Ali, S.; Hussain, S.; Kamran, M.; Chattha, M.S.; Ahmad, S.; Aqeel, M.; Rizwan, M.; Aljarba, N.H.; Alkahtani, S.; et al. Flax (*Linum usitatissimum* L.): A Potential Candidate for Phytoremediation? Biological and Economical Points of View. *Plants* **2020**, *9*, 496. [CrossRef]
7. Saleem, M.H.; Ali, S.; Rehman, M.; Rana, M.S.; Rizwan, M.; Kamran, M.; Imran, M.; Riaz, M.; Soliman, M.H.; Elkelish, A.; et al. Influence of phosphorus on copper phytoextraction via modulating cellular organelles in two jute (*Corchorus capsularis* L.) varieties grown in a copper mining soil of Hubei Province, China. *Chemosphere* **2020**, *248*, 126032. [CrossRef]
8. Zaheer, I.E.; Ali, S.; Saleem, M.H.; Arslan Ashraf, M.; Ali, Q.; Abbas, Z.; Rizwan, M.; El-Sheikh, M.A.; Alyemeni, M.N.; Wijaya, L. Zinc-lysine Supplementation Mitigates Oxidative Stress in Rapeseed (*Brassica napus* L.) by Preventing Phytotoxicity of Chromium, When Irrigated with Tannery Wastewater. *Plants* **2020**, *9*, 1145. [CrossRef] [PubMed]
9. Saleem, M.H.; Kamran, M.; Zhou, Y.; Parveen, A.; Rehman, M.; Ahmar, S.; Malik, Z.; Mustafa, A.; Anjum, R.M.A.; Wang, B.; et al. Appraising growth, oxidative stress and copper phytoextraction potential of flax (*Linum usitatissimum* L.) grown in soil differentially spiked with copper. *J. Environ. Manag.* **2020**, *257*, 109994. [CrossRef]
10. Saleem, M.H.; Fahad, S.; Khan, S.U.; Din, M.; Ullah, A.; EL Sabagh, A.; Hossain, A.; Llanes, A.; Liu, L. Copper-induced oxidative stress, initiation of antioxidants and phytoremediation potential of flax (*Linum usitatissimum* L.) seedlings grown under the mixing of two different soils of China. *Environ. Sci. Pollut. Res.* **2019**, *27*, 5211–5221. [CrossRef]
11. Zaheer, I.E.; Ali, S.; Saleem, M.H.; Imran, M.; Alnusairi, G.S.H.; Alharbi, B.M.; Riaz, M.; Abbas, Z.; Rizwan, M.; Soliman, M.H. Role of iron–lysine on morpho-physiological traits and combating chromium toxicity in rapeseed (*Brassica napus* L.) plants irrigated with different levels of tannery wastewater. *Plant Physiol. Biochem.* **2020**, *155*, 70–84. [CrossRef]
12. Javed, M.T.; Saleem, M.H.; Aslam, S.; Rehman, M.; Iqbal, N.; Begum, R.; Ali, S.; Alsahli, A.A.; Alyemeni, M.N.; Wijaya, L. Elucidating silicon-mediated distinct morpho-physio-biochemical attributes and organic acid exudation patterns of cadmium stressed Ajwain (*Trachyspermum ammi* L.). *Plant Physiol. Biochem.* **2020**, *157*, 23–37. [CrossRef]
13. Afzal, J.; Saleem, M.H.; Batool, F.; Elyamine, A.M.; Rana, M.S.; Shaheen, A.; El-Esawi, M.A.; Tariq Javed, M.; Ali, Q.; Arslan Ashraf, M.; et al. Role of Ferrous Sulfate ($FeSO_4$) in Resistance to Cadmium Stress in Two Rice (*Oryza sativa* L.) Genotypes. *Biomolecules* **2020**, *10*, 1693. [CrossRef] [PubMed]
14. Zaheer, I.E.; Ali, S.; Saleem, M.H.; Ali, M.; Riaz, M.; Javed, S.; Sehar, A.; Abbas, Z.; Rizwan, M.; El-Sheikh, M.A.; et al. Interactive role of zinc and iron lysine on *Spinacia oleracea* L. growth, photosynthesis and antioxidant capacity irrigated with tannery wastewater. *Physiol. Mol. Biol. Plants* **2020**, *26*, 2435–2452. [CrossRef]
15. Rehman, M.; Liu, L.; Wang, Q.; Saleem, M.H.; Bashir, S.; Ullah, S.; Peng, D. Copper environmental toxicology, recent advances, and future outlook: A review. *Environ. Sci. Pollut. Res.* **2019**, *26*, 18003–18016. [CrossRef]
16. Saleem, M.H.; Ali, S.; Seleiman, M.F.; Rizwan, M.; Rehman, M.; Akram, N.A.; Liu, L.; Alotaibi, M.; Al-Ashkar, I.; Mubushar, M. Assessing the Correlations between Different Traits in Copper-Sensitive and Copper-Resistant Varieties of Jute (*Corchorus capsularis* L.). *Plants* **2019**, *8*, 545. [CrossRef]
17. Saleem, M.H.; Fahad, S.; Rehman, M.; Saud, S.; Jamal, Y.; Khan, S.; Liu, L. Morpho-physiological traits, biochemical response and phytoextraction potential of short-term copper stress on kenaf (*Hibiscus cannabinus* L.) seedlings. *PeerJ* **2020**, *8*, e8321. [CrossRef] [PubMed]
18. Kamran, M.; Danish, M.; Saleem, M.H.; Malik, Z.; Parveen, A.; Abbasi, G.H.; Jamil, M.; Ali, S.; Afzal, S.; Riaz, M.; et al. Application of abscisic acid and 6-benzylaminopurine modulated morpho-physiological and antioxidative defense responses of tomato (*Solanum lycopersicum* L.) by minimizing cobalt uptake. *Chemosphere* **2021**, *263*, 128169. [CrossRef]
19. Saleem, M.H.; Ali, S.; Kamran, M.; Iqbal, N.; Azeem, M.; Javed, M.T.; Ali, Q.; Haider, M.Z.; Irshad, S.; Rizwan, M.; et al. Ethylenediaminetetraacetic Acid (EDTA) Mitigates the Toxic Effect of Excessive Copper Concentrations on Growth, Gaseous Exchange and Chloroplast Ultrastructure of Corchorus capsularis L. and Improves Copper Accumulation Capabilities. *Plants* **2020**, *9*, 756. [CrossRef] [PubMed]
20. Hashem, I.A.; Abbas, A.Y.; El-Hamed, A.E.-N.H.A.; Salem, H.M.; El-Hosseiny, O.E.; Abdel-Salam, M.A.; Saleem, M.H.; Zhou, W.; Hu, R. Potential of rice straw biochar, sulfur and ryegrass (Lolium perenne L.) in remediating soil contaminated with nickel through irrigation with untreated wastewater. *PeerJ* **2020**, *8*, e9267. [CrossRef] [PubMed]
21. Khan, Z.I.; Safdar, H.; Ahmad, K.; Wajid, K.; Bashir, H.; Ugulu, I.; Dogan, Y. Copper bioaccumulation and translocation in forages grown in soil irrigated with sewage water. *Pak. J. Bot.* **2020**, *52*, 111–119. [CrossRef]
22. Dogan, Y.; Ugulu, I.; Durkan, N.; Unver, M.C.; Mert, H.H. Determination of some ecological characteristics and economical importance of Vitex agnus-castus. *Eurasia. J. Biosci.* **2011**, *5*, 10–18. [CrossRef]

23. Yorek, N.; Ugulu, I.; Sahin, M.; Dogan, Y. A qualitative investigation of students' understanding about ecosystem and its components. *Nat. Montenegrina* **2010**, *9*, 931–981.
24. Khan, Z.I.; Ahmad, K.; Safdar, H.; Ugulu, I.; Wajid, K.; Bashir, H.; Dogan, Y. Manganese bioaccumulation and translocation of in forages grown in soil irrigated with city effluent: An evaluation on health risk. *Res. J. Pharmaceut. Biol. Chem. Sci.* **2018**, *9*, 759–770.
25. Khan, Z.I.; Ahmad, K.; Rehman, S.; Ashfaq, A.; Mehmood, N; Ugulu, I.; Dogan, Y. Effect of sewage water irrigation on accumulation of metals in soil and wheat in Punjab, Pakistan. *Pak. J. Anal. Environ. Chem.* **2019**, *20*, 60–66.
26. Ugulu, I. Development and validation of an instrument for assessing attitudes of high school students about recycling. *Environ. Educ. Res.* **2015**, *21*, 916–942.
27. Ugulu, I.; Khan, Z.I.; Sheik, Z.; Ahmad, K.; Bashir, H.; Ashfaq, A. Effect of wastewater irrigation as an alternative irrigation resource on heavy metal accumulation in ginger (Zingiber officinale Rosc.) and human health risk from consumption. *Arab. J. Geosci.* **2021**, *14*, 702. [CrossRef]
28. Ugulu, I.; Unver, M.C.; Dogan, Y. Potentially toxic metal accumulation and human health risk from consuming wild Urtica urens sold on the open markets of Izmir. *Euro-Mediterr. J. Environ. Integr.* **2019**, *4*, 36. [CrossRef]
29. Ugulu, I.; Khan, Z.I.; Rehman, S.; Ahmad, K.; Munir, M.; Bashir, H.; Nawaz, K. Trace Metal Accumulation in Trigonella foenum-graecum Irrigated with Wastewater and Human Health Risk of Metal Access Through the Consumption. *Bull. Environ. Contam. Toxicol.* **2019**, *103*, 468–475. [CrossRef] [PubMed]
30. Nadeem, M.; Qureshi, T.M.; Ugulu, I.; Riaz, M.N.; An, Q.U.; Khan, Z.I.; Ahmad, K.; Ashfaq, A.; Bashir, H.; Dogan, Y. Mineral, vitamin and phenolic contents and sugar profiles of some prominent date palm (*Phoenix dactylifera*) varieties of Pakistan. *Pak. J. Bot.* **2019**, *51*, 171–178.
31. Ugulu, I.; Akhter, P.; Khan, Z.I.; Akhtar, M.; Ahmad, K. Trace metal accumulation in pepper (*Capsicum annuum* L.) grown using organic fertilizers and health risk assessment from consumption. *Food Res. Int.* **2021**, *140*, 109992.
32. Khan, Z.I.; Ugulu, I.; Zafar, A.; Mehmood, N.; Bashir, H.; Ahmad, K.; Sana, M. Biomonitoring of heavy metals accumulation in wild plants growing at soon valley, Khushab, Pakistan. *Pak. J. Bot.* **2021**, *53*, 247–252.
33. Wang, M.-J. Land application of sewage sludge in China. *Sci. Total Environ.* **1997**, *197*, 149–160. [CrossRef]
34. Ugulu, I.; Khan, Z.I.; Aslam, Z.; Ahmad, K.; Bashir, H.; Munir, M. Potentially toxic metal accumulation in grains of wheat variety Galaxy-2013 irrigated with sugar industry wastewater and human health risk assessment. *Euro-Mediterr. J. Environ. Integr.* **2021**, *6*, 38. [CrossRef]
35. Khan, Z.I.; Ugulu, I.; Sahira, S.; Mehmood, N.; Ahmad, K.; Bashir, H.; Dogan, Y. Human health risk assessment through the comparative analysis of diverse irrigation regimes for Luffa (Luffa cylindrica (L.) Roem.). *J. Water Sanit. Hyg. Dev.* **2020**, *10*, 249–261. [CrossRef]
36. Vukadinović, V.; Bertić, B. Agrochemistry and Plant Nutrition Practicum. Ph.D. Thesis, University J.J. Osijek, Osijek, Croatia, 1988.
37. Steel, R.; Torrie, J.H. *Principle and Procedures of Statistics, A Biometrical Approach*, 2nd ed.; McGraw Hill: New York, NY, USA, 1980.
38. Cui, Y.-J.; Zhu, Y.-G.; Zhai, R.-H.; Chen, D.-Y.; Huang, Y.-Z.; Qiu, Y.; Liang, J.-Z. Transfer of metals from soil to vegetables in an area near a smelter in Nanning, China. *Environ. Int.* **2004**, *30*, 785–791. [CrossRef]
39. Liu, W.; Zhao, J.Z.; Ouyang, Z.Y.; Soderlund, L.; Liu, G.H. Impacts of sewage irrigation on heavy metals distribution and contamination. *Environ. Int.* **2005**, *31*, 805–812. [CrossRef] [PubMed]
40. Tinker, P.B.; MacPherson, A.; West, T.S. Levels, distribution and chemical forms of trace elements in food plants. *Philos. Trans. R. Soc. B Biol. Sci.* **1981**, *294*, 41–55.
41. Chary, N.S.; Kamala, C.; Raj, D.S.S. Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. *Ecotoxicol. Environ. Saf.* **2008**, *69*, 513–524. [CrossRef]
42. Ge, K.Y. *The Status of Nutrient and Meal of Chinese in the 1990s*; People's Health & Hygiene Press: Beijing, China, 1992; pp. 415–434.
43. Wang, X.; Sato, T.; Xing, B.; Tao, S. Health risks of heavy metals to the general public in Tianjin, China via consumption of vegetables and fish. *Sci. Total Environ.* **2005**, *350*, 28–37. [CrossRef] [PubMed]
44. *Preliminary Remediation Goals, Region 9*; USEPA. United States Environmental Protection Agency: Washington, DC, USA, 2002.
45. Angula, E. The Tomlinson pollution index applied to heavy metal, mussel-watch data: A useful index to assess coastal pollution. *Sci. Total Environ.* **1996**, *187*, 19–56. [CrossRef]
46. Harikumar, P.S.; Nasir, U.P.; Rahman, M.P.M. Distribution of heavy metals in the core sediments of a tropical wetland system. *Int. J. Environ. Sci. Technol.* **2009**, *6*, 225–232. [CrossRef]
47. Jaishree, A.; Khan, T.I. Assessment of heavy metals' risk on human health via dietary intake of cereals and vegetables from effluent irrigated land Jaipur district, Rajasthan. *Int. J. Innov. Res. Sci. Eng. Technol.* **2015**, *4*, 5142–5148.
48. European Union. Commission Regulation (EC) No. 1881/2006 of 19 December 2006 Setting Maximum Levels for Certain Contaminants in foodstuffs. *Off. J. Eur. Union* **2006**, *364*, 5–24.
49. *Exposure Factors Handbook*; VolumeII-Food Ingestion Factors. EPA/600//P-95/002Fa; USEPA. United States Environmental Protection Agency: Washington, DC, USA, 1997.
50. Othman, A.A.; Ali, R.; Othman, A.M.; Ali, J.; Habila, M.A. Assessment of toxic metals in wheat crops grown in selected soils, irrigated by different water sources. *Arab. J. Chem.* **2016**, *9*, 1555–1562. [CrossRef]
51. Lorestani, B.; Cheraghi, M.; Yousefi, N. Accumulation of Pb, Fe, Mn, Cu and Zn in plants and choice of hyper accumulator plants in the industrial town of Vian, Iran. *Arch. Biol. Sci.* **2011**, *63*, 739–745. [CrossRef]

52. Juen, L.L.; Aris, A.Z.; Ying, L.W.; Haris, H. Bioconcentration and translocation efficiency of metals in paddy (*Oryza sativa*): A case study from Alor Setar, Kedah, Malaysia. *Sains Malays.* **2014**, *43*, 521–528.
53. FAO/WHO. Codex Alimentarius Commission, Food Additives and Contaminants. Joint FAO/WHO Food Standards Programme, ALINORM 01/12A: 1-289, Food and Agriculture. Available online: http://www.fao.org (accessed on 27 July 2001).
54. Eticha, T.; Hymete, A. Determination of some heavy metals in barley locally grown for brewing and its malt in Ethiopia. *J. Bioanal. Biomed.* **2015**, *7*, 171–173.
55. Singh, A.; Sharma, R.K.; Agarwal, M.; Marshal, F.M. Health risk assessment of heavy metals via dietary intake of foodstuffs from wastewater irrigated site of dry tropical area of India. *Food Chem. Toxicol.* **2010**, *48*, 611–619. [CrossRef]
56. *Dutch Standards. Circular on Target Values and Intervention Values for Soil Remediation*; Ministry of Housing, Spatial Planning and the Environment: Bilthoven, The Netherlands, 2000.
57. Dosumu, O.O.; Abdus-Salam, N.; Oguntoye, S.; Afdekale, F.A. Trace metals bioaccumulation by some Nigerian vegetables. *Centrepoint* **2005**, *13*, 23–32.
58. Singh, R.; Singh, D.P.; Kumar, N.; Bhargavai, S.K.; Barman, S.C. Accumulation of translocation of heavy metals in soil and plants from fly ash contaminated area. *J. Environ. Biol.* **2010**, *31*, 421–430.
59. Wajid, K.; Ahmad, K.; Khan, Z.I.; Nadeem, M.; Bashir, H.; Chen, F.; Ugulu, I. Effect of organic manure and mineral fertilizers on bioaccumulation and translocation of trace metals in maize. *Bull. Environ. Contam. Toxicol.* **2020**, *104*, 649–657.
60. Badawy, K.R.; Abd El-Gawad, A.M.; Osman, H.E. Health risks assessment of heavy metals and microbial contamination in water, soil and agricultural foodstuff from wastewater irrigation at Sahl El-Hessania area, Egyptian. *J. Appl. Sci. Res.* **2013**, *9*, 3091–3107.
61. Singh, J.; Upadhyay, S.K.; Pathak, R.K.; Gupta, V. Accumulation of heavy metals in soil and paddy crop (*Oryza sativa*), irrigated with water of Ramgarh Lake, Gorakhpur, UP, India. *Toxicol. Environ. Chem.* **2010**, *93*, 462–472. [CrossRef]
62. Brunetti, G.; Farrag, K.; Soler-Rovira, P.; Ferrara, M.; Nigro, F.; Senesi, N. Heavy metals accumulation and distribution in durum wheat and barley grown in contaminated soils under Mediterranean field conditions. *J. Plant Interact.* **2012**, *7*, 160–174. [CrossRef]
63. Khan, Z.I.; Arshad, N.; Ahmad, K.; Nadeem, M.; Ashfaq, A.; Wajid, K.; Bashir, H.; Munir, M.; Huma, B.; Memoona, H.; et al. Toxicological potential of cobalt in forage for ruminants grown in polluted soil: A health risk assessment from trace metal pollution for livestock. *Environ. Sci. Pollut. Res.* **2019**, *26*, 15381–15389. [CrossRef] [PubMed]
64. Mahmood, A.; Malik, R.N. Human health risk assessment of heavy metals via consumption of contaminated vegetables collected from different irrigation sources in Lahore, Pakistan. *Arab. J. Chem.* **2014**, *7*, 91–99. [CrossRef]
65. Ogunkunle, C.O.; Varun, M.; Jimoh, M.A.; Olorunmaiye, K.S.; Fatoba, P.O. Evaluating the trace metal pollution of an urban paddy soil and bioaccumulation in rice (*Oryza sativa* L.) with the associated dietary risks to local population: A case study of Ilorin, north-central Nigeria. *Environ. Earth Sci.* **2016**, *75*, 1383. [CrossRef]
66. Balkhair, K.; Ashraf, M.A. Field accumulation risks of heavy metals in soil and vegetable crop irrigated with sewage water in western region of Saudi Arabia. *Saudi J. Biol. Sci.* **2016**, *23*, S32–S44. [CrossRef] [PubMed]
67. Khan, Z.I.; Nisar, A.; Ugulu, I.; Ahmad, K.; Wajid, K.; Bashir, H.; Dogan, Y. Determination of cadmium concentrations of vegetables grown in soil irrigated with wastewater: Evaluation of health risk to the public. *Egypt. J. Bot.* **2019**, *59*, 753–762.
68. Satpathy, D.; Reddy, M.V.; Dhal, S.P. Risk assessment of heavy metals contamination in paddy soil, plants, and grains (*Oryza sativa* L.) at the East Coast of India. *Biomed. Res. Int.* **2014**, *2014*, 545473. [CrossRef]
69. Bibi, Z.; Khan, Z.I.; Ahmad, K.; Ashraf, M.; Hussain, A.; Akram, N.A. Vegetables as a potential source of metals and metalloids for human nutrition, A case study of (Momordica charantia) grown in soil irrigated with domestic sewage water in Sargodha, Pakistan. *Pak. J. Zool.* **2014**, *46*, 633–664.
70. Fan, Y.; Zhu, T.; Li, M.; He, J.; Huang, R. Heavy Metal Contamination in Soil and Brown Rice and Human Health Risk Assessment near Three Mining Areas in Central China. *J. Healthc. Eng.* **2017**, *2017*, 4124302. [CrossRef] [PubMed]