Pure Appl. Biol., 9(1): 847-858, March, 2020
http://dx.doi.org/10.19045/bspab.2020.90090

Research Article

Health risk assessment of metals in wheat grown in municipal solid waste amended soil

Kafeel Ahmad[1], Zafar Iqbal Khan[1*], Radiqa Arshad[1], Naunain Mehmood[2], Kinza Wajid[1], Shahzadi Mahpara[3], Muhammad Nadeem[4], Humayun Bashir[1], Mudasra Munir[1], Ifra Saleem Malik[1], Asma Ashfaq[1], Maria Ghazzal[1], Mubeen Akhtar[1] and Pervaiz Akhter[1]
1. Department of Botany, University of Sargodha, Sargodha-Pakistan
2. Department of Zoology, University of Sargodha, Sargodha-Pakistan
3. Department of Plant Breeding and Genetics, Ghazi University, D.G. Khan-Pakistan
4. Institute of Food Science and Nutrition, University of Sargodha, Sargodha-Pakistan
**Corresponding author's email:* zafar.khan@uos.edu.pk

Citation
Kafeel Ahmad, Zafar Iqbal Khan, Radiqa Arshad, Naunain Mehmood, Kinza Wajid, Shahzadi Mahpara, Muhammad Nadeem, Humayun Bashir, Mudasra Munir, Ifra Saleem Malik, Asma Ashfaq, Maria Ghazzal, Mubeen Akhtar and Pervaiz Akhter. Health risk assessment of metals in wheat grown in municipal solid waste amended soil. Pure and Applied Biology. Vol. 9, Issue 1, pp847-858. http://dx.doi.org/10.19045/bspab.2020.90090

Received: 12/09/2019 Revised: 01/12/2019 Accepted: 13/12/2019 Online First: 01/01/2020

Abstract

The current research was performed during (November 2016-April 2017) to determine the contents of heavy metal in wheat (*Triticum aestivum*) variety (Ujala) that was grown on soil irrigated with municipal solid waste and to estimate the health risk in human-caused by the consumption of contaminated wheat crop. The result shows that mean concentration of (mg kg^{-1}) of heavy metals Fe, Zn, Cd and Co in the soil of all four treatments were ranged from 42.11 to 22.32, 14.21 to 31.78, 2.67 to 8.18 and 2.13 to 2.94 mg/kg respectively. According to current findings, the concentration of Fe metal was higher among all treatments while Co was lower among all treatments. In the root of wheat, the heavy metal concentrations (mg kg^{-1}) varied between 2.12 to 2.87 for Co, 2.29 to 3.39 for Zn, 2.23 to 3.48 for Cd and 20.71 to 31.01 for Fe respectively. In shoot of wheat the specific order of heavy metals was found in T-1, i.e. Fe>Co>Cd>Zn while in T-2, T-3 and T-4 it was: Fe>Zn>Cd>Co. According to our findings, Fe concentrations were higher, while Zn and Co showed lower concentrations among all treatment. In grains, heavy metals mean concentrations (mg kg^{-1}) varied for Co from 1.82 to 2.29, for Zn 1.57 to 1.97, for Cd 1.52 to 2.81 and 2.06 to 3.42 for Fe respectively. In our current study, the mean concentration of Fe was higher while Cd, Co and Zn were lower in all treatments. Health risk index of each metal among all treatments trends was similar as Cd>Co>Zn>Fe. Cadmium showed highest health risk index among all treatments.

Keywords: Heavy metals; Municipal solid waste; *Triticum aestivum*, Health risk

Introduction

The yield gap in wheat is about 60%, representing the incredible chance to enhance wheat productivity. At the government level, the decline in any crop production increase has been observed; this is due to the wheat crop importance for Pakistan's food security [1]. Due to the unfortunate resources operations for the better yield and to proceed it becomes tough for the most of the farmers [2].

The entire study on wheat was done in Pakistan's Province Punjab explored that wheat yield a crucial element. The chief wheat yielding province that has been appraised is Punjab province in the country it imparts about 77% in wheat yield and credits for 76% of the wheat area. Each year this province is granted with the total harvested area of about 39% [3].

For wheat production and growth, this province is full of resources or well granted with resources like land productivity, hardworking farming community and better varieties. Instead of accomplishing the optimum level of the crop entirely the farmers are incapable [4]. In the irrigated areas of Pakistan, the elements of higher wheat productivity have been studied [5].

This all study has been based on the sample and on the primary data, which involves the chief as well as lesser or slight zones of flooded areas of the country in variety of wheat. In the country they found the factors which contributes significantly to wheat crop are the number of furrowing for grounding of land and the sprinkling of fertiliser nutrients, and the number of seed use, number of streaming. After that some of the researches have directed various studies in the country on yield of wheat crop, but analysis and the extent of these studies are diverse [6].

Numerous scholars have examined the practical wheat growers proficiency. Due to the general rise in input prices, a decline is carried out in input resources use the capacity of the farmers, this is also one of the major reason to conduct this study. In Pakistan, the local prices of wheat were still underneath to benefit the net consumers of this exchange, which recital for about 80% of the population of country then the worldwide exchange level [7].

Therefore, in the country, the food prices were controlled by increasing the wheat support prices which may encourage food production. In 2008-2009, the prices of wheat produced have been raised by the government firstly and then again in 2011-2012. Thus, the prices of wheat have been enhanced from 2007-08 to 2011-12 was only 67.4%. While at the same time the average prices of diesel have been increases speedily, rise in the prices of DAP and urea also the for agricultural tube-wells rise in prices of electricity correspondingly which is documented as 109.65%, 195.9 %, 440.3%, and 151.3% [8].

In the arid and semiarid areas of the world, there is the fast population growth in various cities which continues to enhance the demands or requirements on the supplies of the limited freshwater. Different districts and cities are struggling to create the equilibrium in the use of water among the agricultural, industrial, municipal and recreational users [9, 10]. Intensification in the urge for the freshwater and created wastewater volume increases with the increase in the population. As the other sources have been declined (are declining) then the treated or recycled wastewater is the only water which appears as the water resource [11, 12]. Recycled wastewater use for the irrigating landscapes is frequently appeared as one of the methods to maximise the water resources that are existing and also the current urban water supplies stretch [13].

The aim of the current research was to determine the contents of heavy metal in different varieties of wheat (*Triticum aestivum*) that was grown on irrigated soil and to estimate the health risk in human-caused by the consumption of contaminated wheat crop. To analyse the heavy metal contents in wheat parts and in soil. To check the effect of heavy metals on humans. To estimate the different indices like correlation, pollution load index, enrichment factor, daily intake of metals and health risk index

Materials and methods

Study area

In order to analyse heavy metal content in the wheat (*Triticum aestivum* L.) using municipal solid waste, a pot experiment was conducted. The present research work was performed at Department of Botany, University of Sargodha, Sargodha, during the year 2016-2017. The climate of Sargodha is very burning and reasonable, cold in winter. In summer, maximum temperature goes up to 50°C and minimum up to 12°C in winter. Sargodha is very well-known for citrus production.

Cultivation of plant

For the duration of 2016 vigorous seeds of wheat were accumulated. In the current study, one variety of wheat, Ujala was used. The conducted experiment consists of four treatments, with three replicates of the selected crop. Took 12 pots and filled with soil. After that, seeds were cultivated in four cultivation groups, consisting of one control group (ground soil) and the remaining three with different percentages of municipal solid waste (municipal solid waste treatment). Twelve seeds in the form of pairs were sowed in each pot. The experiment consists of four treatments: T-1 was consisted of 100% ground soil, T-2 was consisted of 25% municipal solid waste and 75% ground soil, T-3 was consisted of 50% municipal solid waste and 50% ground soil, T-4 was consisted of 75% municipal solid waste and 25% ground soil.

For six months, pot treatments were accompanied in a usual atmosphere system (November 2016 to April 2017). Municipal solid waste was found from municipal solid waste pools or areas that were present near Sargodha University. Seeds of altered selections of wheat were developed in mud pots (15 cm in height and 20 cm in diameter) for research purpose, at the end of November 2016. In each pot 3 kg of soil was added. The trial pots were watered with groundwater. For each treatment (25%, 50%, and 75% municipal solid waste) 3 pots were used. In a week pots were watered with two times. In the form of pairs twelve seeds were seeded in separately pot. The information about germination of seed was documented. For proper growth, five plants remained in each pot after germination. Maturation period was five months. Different morphological parameters of different varieties of wheat were also observed. At ripeness plant height was measured. The quantity of leaf for each plant was also calculated, associating with plants which were grown-up in perfect conditions. Harvesting was done during April 2017.

Sample collection and preparation

After harvesting, the whole plant samples were collected from each pot. The samples after drying in the air were then oven-dried at 72°C for a few days. After removing from the oven, grains were separated from the spikes and ground in an electrical grinder into fine powder, for heavy metal detection. 1 g of each sample was taken. For the digestion of samples, wet digestion method was used.

Method of wet digestion

The dried samples were placed in a small conical flask and digested with concentrated HNO_3 and H_2O_2 1:2 on a hot plate. When fumes disappear, samples were removed from the heat and H_2O_2 was further added to attain a transparent solution and again placed on the hot plate. Digestion continued until a colourless solution appear and allow to cool. After cooling, dilute all the samples in a measuring flask up to 50 ml as final volume. The samples were then filtered through Whatman filter paper No. 42.

Soil digestion

The soil samples were collected from the upper 3-5 cm layer of the soil from each pot. After drying in the air, soil samples were placed in the oven for two days at 65°C. The samples were digested in the same manner.

Metals analysis

All the digested samples were then subjected to Atomic Absorption Spectrophotometer (AA-6300 Shimadzu Japan) to detect heavy metals in them. The metals to be analysed were: cobalt (Co), zinc (Zn), iron (Fe), and cadmium (Cd). For detection, the standard solution of different metals was also prepared from the stock solution, to obtain a calibration curve.

Quality control

To assess the reliability and assurance of the data, such measures were taken. By comparing with the international standards, the precision of the results can be done. The repeated analyses of the examined samples can also verify the accuracy of the analyses.

Statistical analysis

Variance

Statistical Program for Social Sciences (SPSS 16) was used for statistical analysis. ANOVA (One-way analysis of variance) was useful in the maintenance of soil, root, shoot and grains of wheat.

Correlation

Using the software package SPSS (version 16.0), the correlation results obtained. To assess soil-plant interaction, "Pearson's correlation coefficient" was calculated. It is a bivariant process. The significant correlation was at 0.001, 0.01 and 0.5 probability stages [14].

Pollution load index

The pollution load index (PLI) for each cure was controlled out [15].

PLI= Concentration of metals in investigated soil/Reference values of metals in soil

Enrichment factor

To calculate the extent of soil pollution, an index enrichment factor (EF) was calculated following Al-Hwaiti and Al-Khashman [16].

EF= Concentration of examined metal in amended soil/ Concentration of metal in control soil

Daily intake of metal

By different ways, toxic heavy metal enters into the human body sometimes it may be by oral intake, by inhalation or by dermal contact [17]. Daily intake of metal (DIM) was computed according to Sajjad *et al*. [18].

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

Where: C_{metal} described as the heavy metal concentrations in food crop (mg kg^{-1}), $D_{food\ intake}$ is the daily intake of food crop (kg/day) and $B_{average\ weight}$ average body weight (kg), respectively.

The average body weight was taken as 55.9 kg [19] and daily intake of metal in wheat as 0.242 kg/person/day, respectively [20].

Health risk index

Health risk index (HRI) was defined as "the relation of expected contact to metal through food crop" and verbal reference prescription, according to Cui et al. [21].

$HRI= DIM/ R_fD$

Oral reference dose (R_fD) is the maximum acceptable oral dose of heavy metals. An index >1 is measured risky for human [22].

Results and discussion

Morphological parameters

The effect of municipal solid waste on morphological attributes such as root length, shoot length, leaf length, leaf width and leaf area of wheat variety (Ujala) (Table 1).

Notably outcome of (p<0.05) of different treatments on shoot length, root length and leaf width expressed by variance analysis, contrary non-notably outcome (p>0.05) of treatments on leaf area and leaf length expressed by variance analysis. According to our recent findings, T-1 showed the highest values of different parameters, while T-4 showed the lowest values of all parameters. The results showed the effect of solid waste on different parts of plants due to this heavy metal content of soil increases, which increases the effect of toxicity on plants. Andaleeb *et al.* [23] discussed similar results. In our recent investigation, the values of root length were quite similar as suggested by Konate *et al.* [24].

Table 1. Mean values of morphological parameters of wheat

Parameter	T-1	T-2	T-3	T-4	Mean square
Root length (cm)	9.6±1.3	9±1.01	10.2±1.22	15.43±1.67	26.241**
Shoot length (cm)	54.86±2.59	47.83±2.67	49.43±2.6	35.43±2.01	202.241**
Leaf length (cm)	22.73±1.2	21.66±1.01	19.56±1.04	19.3±1.05	8.259^{ns}
Leaf width (cm)	0.73±0.99	0.46±1.01	0.56±0.97	0.43±0.98	0.054*
Leaf area (cm^2)	12.57±1.04	7.52±0.99	8.96±0.98	6.41±1.02	21.652^{ns}

*, ** = significant at 0.05 and 0.001 levels, ns = non-significant

Soil

The non-notably outcome (*p*>0.05) of treatmentsnoticed on the deliberation of metals Cd, Zn, Fe, and Co determined by variance analysis in soil used to grown wheat variety (Ujala) (Table 2 & 3).In samples of soil, the trends of heavy metals at T-1 was: Zn>Fe>Cd>Co, at T-2, T-3 and T-4 was: Fe>Zn>Cd>Co. The concentration (mg kg^{-1}) of heavy metals in soil samples was ranged from 14.21 to 31.78 for Zn, 2.13 to 2.94 for Co, 2.67 to 8.18 for Cd and 42.11 to 22.32 for Fe respectively. According to current findings, the concentration of Fe metal was higher among all treatments while Co was lower among all treatments. The concentrations of all heavy metals was fall within the permissible limit of Fe (5000 mg kg^{-1}), Zn (300 mg kg^{-1}), Co (100 mg kg^{-1}) and Cd (3 mg kg^{-1})as reported by the FAO/WHO **[25]**.

Sihag and Lohchab **[26]** was conducted the experiment by using sludge-amended soil and reported higher concentration of Fe as compared to present concentration of Fe. The mean concentration of Fe was lower than the findings of Sihag and Lohchab **[26]**. This difference was arisen because they used the soil, sludge and sludge amended soil collected from different places. Both type of sludge having pH that was slightly alkaline in nature and it contains higher contents of organic matter and major nutrients. Both type of sludge was very useful for many agricultural purposes because it increases the fertility and the quality of soil and tolerates the productivity of soil. According to our current study, mean concentration of Fe was higher as those recorded by Khan *et al.* **[27]** because municipal solid waste contains much higher contents of heavy metals rather than the canal water and wastewater. The high concentration of Fe causes various diseases like intestines, skin, lung and soft tissue diseases. In our investigation, the value of mean concentration was lower as those reported by Szabo et al. **[28]**. The samples that was collected by the Szabo contain higher fraction rate of clay. Therefore, those soil samples having high contents of clay were considered with lowest *pH* value this was due to the difference of precipitations.

Root

The non-notably outcome (*p*>0.05) of treatments determined on the concentrations of metals such as Fe, Zn, Cd, and Co documented by variance analysis in root of wheat variety (Ujala). In the root of wheat, heavy metals deliberation (mg kg^{-1}) varied from 2.12 to 2.87 for Co, 2.29 to 3.39 for Zn, 2.23 to 3.48 for Cd and 20.71 to 31.01 for Fe respectively (Table 2 & 3). At T-1 the order of heavy metals was: Fe>Cd>Co>Zn, at T-2 and T-3 was: Fe>Zn>Cd>Co and it was at T-4: Fe>Cd>Zn>Co. in the present investigation, the deliberations of Co and Zn was inferior in all treatments while mean deliberations of Fe was superior. In accord to WHO/FAO **[25]** within the tolerable limit excluding Cd, all heavy metals deliberations in root decrease.

In the present study, deliberations of Zn in wheat root was higher than those concentrations suggested by Al-Othman *et al.* **[29]**, samples collected from Swabi and quite similar to the Shergarh samples concentrations. The source of irrigation in

Swabi was a tube well water that was rich in dissolved metal salts, that indicates the high levels of Zn in plants. While in the case of Shergarh, the source of irrigation was surface water (canal and river water), so it was assumed that flowing water contains Zn salts in it from the geological strata of that specific area.

Zinc was an essential element for the plant growth, it occurs naturally in the soil (about 70 mg kg^{-1} in crustal rocks) [30], but by the anthropogenic additions, the concentrations of Zn increasing unnaturally. The addition of Zn was mostly occurred during the industrial activities like as in coal, mining, and steel processing.

Table 2. Analysis of variance for heavy metals in soil, root, shoot and grains of wheat

	Mean square			
Metal	**Cd**	**Fe**	**Zn**	**Co**
Soil	0.857^{ns}	299.244^{ns}	473.541^{ns}	0.302^{ns}
Root	20.347^{ns}	179.739^{ns}	1.534^{ns}	0.681^{ns}
Shoot	0.395^{ns}	125.492^{ns}	0.047^{ns}	0.246^{ns}
Grain	1.275^{ns}	0.944^{ns}	95.582^{ns}	0.372^{ns}

Ns= non-significant

Table 3. Mean concentration (mg kg^{-1}) of cadmium, iron, zinc and cobalt in soil root shoot grain of wheat

Treatment	T-1	T-2	T-3	T-4
		Cadmium		
Soil	8.18±0.97	2.67±1.01	2.86±1.12	3.56±1.13
Root	3.17±1.04	2.23±1.09	2.83±1.05	3.48±1.01
Shoot	1.97±1.18	2.15±1.12	2.58±1.14	3.01±1.05
Grain	1.52±0.14	2.01±0.14	2.41±0.13	2.81±1.12
		Iron		
Soil	22.32±1.35	22.78±1.41	37.5±1.56	42.11±1.66
Root	20.71±1.06	21.01±1.08	29.26±1.16	31.01±1.26
Shoot	12.12±1.41	19.81±1.45	16.74±1.55	27.33±1.56
Grain	2.06±0.18	2.6±0.15	2.71±0.13	3.42±0.15
		Zinc		
Soil	24.46±1.26	14.21±1.01	23.86±1.08	31.78±1.49
Root	2.29±0.99	3.02±1.01	3.21±1.04	3.39±1.05
Shoot	1.71±1.2	2.63±1.22	2.84±1.04	3.08±1.05
Grain	1.57±0.12	1.97±0.13	1.71±0.13	1.74±0.15
		Cobalt		
Soil	2.75±1.06	2.13±1.01	2.54±1.03	2.94±1.11
Root	2.44±1.01	2.12±1.01	2.45±1.09	2.87±1.11
Shoot	2.16±1.12	2.09±1.11	2.42±1.12	2.11±1.12
Grain	1.82±0.12	1.92±0.14	2.29±0.13	1.95±0.16

Shoot

Non-notably outcome (p>0.05) of treatments noticed on the deliberations of metals such as Co, Zn, Fe, and Cd documented by variance analysis in the shoot of wheat variety (Ujala). In shoot of wheat the concentrations (mg kg^{-1}) of heavy metals, one to one varied from 2.09 to 2.42 for Co, 1.71 to 3.08 for Zn, 12.12 to 27.33 for Fe and 1.97 to 3.01 for Cd (Table 2 & 3).

At T-1 the direction of heavy metals was: Fe>Co>Cd>Zn and at T 2, T-3 and T-4 was:

Fe>Zn>Cd>Co. According to our findings, Fe concentrations were higher, while Zn and Co showed lower concentrations among all treatment. The mean concentration values of Cd were lower than the Singh *et al.* **[31]** documented, they irrigated plants with wastewater rather than municipal solid waste. Usually, the mean concentrations of heavy metals were lower in the cereals crop such as rice and wheat as related to the vegetable crops as Singh et al. **[31]** stated. In the crops ofcereal, Sinha et al. **[32]** also concluded the lower concentrations of the heavy metals than the leafy and non-leafy vegetables as grown in wastewater-irrigated areas. In animals, Cd was not well known for any necessary biological functions, and it was the most poisonous heavy metal **[33]**. In our body, it was known to affect various enzyme. The renal damage that causes proteinuria was due to the adverse effects of Cd on enzymes that were responsible for the reabsorption of proteins in kidney tubules **[34]**.

Grains

The analysis of variance determined the non-significant effect (p>0.05) of treatments on the concentrations of metals such as Zn, Co, Cd and Fe in grains of wheat variety (Ujala). At T-1 the general patterns of heavy metals was: Fe>Co>Zn>Cd, and it was at T-2: Fe>Cd>Zn>Co, and at T-3 and 4 T it was: Fe>Cd>Co>Zn (Table 2 & 3).

One to one heavy metals Mean deliberations (mg kg^{-1}) varied from for Co 1.82 to 2.29, 1.57 to 1.97 for Zn, 2.06 to 3.42 for Fe and Cd 1.52 to 2.81. In the current study, the mean concentration of Fe was higher while Cd, Co and Zn were lower in all treatments. The higher concentrations of Zn and Cd in wheat grains was reported by Khan *et al.* **[35]** as compared to our readings. They used different treatments for their experiment, in control lowest contents of Zn was found, this might be due to the no use of sewage sludge and the urea that was applied in control, which causes the precipitation of Zn such as its hydro-oxides and oxides. Therefore, it was unreachable to plants because nitrogen was present in it that increases the pH of soil, the negative affect of higher pH on Zn that into wheat grains was also studied by Hooda and Alloway **[36]**. In the sewage sludge, the existence of various elements in substantial amounts were well known, Cd was one them. Its contents increase non-significantly, by enhancing the amount of sewage sludge especially in the sludge amended soil. The contents of Cd showed significant change among all treatments. Due to the high pH of soil, transfer of Cd contents in grains was lower; the Oliver *et al.* **[37]**, also corroborated that the high pH reduces the availability of Cd for plant uptake.

Correlation

Correlation between soil and root was positive and significant for Fe while positive and non-significant for Zn, Cd and Co. Correlation between root and shoot was positive and significant for Zn, negative for Co while positive and non-significant for Fe (Table 4). Correlation between shoot and grains was positive and significant for Cd and Fe while positive and non-significant for Zn, and Co. Lago-Vila **[38]** reported a positive and highly significant correlation between root and shoot by using different extractants for Co. In rice, the concentrations of Cd showed positively and significantly correlated within their concentrations in soil as recorded by Singh et al. **[39]**. Sinha *et al.* **[32]** also found the negative and positive correlations between the concentrations of heavy metals in plants and soil that was due to the various interactions between the uptakes of heavy metals in the plants **[40]**.

Pollution load index

In all heavy metals the values of PLI varied one to one from 0.234066 to 0.323077mg kg^{-1} for Co, for Zn 0.321566 to 0.719167mg kg^{-1}, 0.392267 to 0.74007mg kg^{-1} for Fe and for Cd 1.791946 to 5.489933mg kg^{-1}. Pollution load index at T-1 was in following trends:

Cd>Zn>Fe>Co and at T-2, T-3 and T-4 was: Cd>Fe>Zn>Co (Table 5).

In the current study, the pollution load index of Cd was greater than 1;it means that Cd caused high environmental risk and showed the high-contaminated soil [41]. Rahman et al. [42] also worked on heavy metals and concluded their pollution load index such as in case of Zn was 2.72-2.95 and in Fe was 0.36-0.65, the PLI of Zn was higher, and Fe was quite similar as compared to our findings.

Enrichment factor

The enrichment factor for each metal ranged from 0.024341 to 0.061633mg kg^{-1} for Zn, 0.120451 to 0.164087mg kg^{-1} for Co, 1.384353 to 6.277803mg kg^{-1} for Cd and 0.009664 to 0.015263mg kg^{-1} for Fe and sequence for each metal at T-1, T-2, T-3 and T-4 was: Cd>Co>Zn>Fe (Table 5). It means that sequence of EF for all metals was similar among all treatments.

Huu et al. [43] reported that EF was an approach that was used to calculate the effect on soil for metal concentrations by naturally and anthropogenically with heavy metals. The enrichment factor higher than one means that it was much more anthropogenic source of heavy metals that were usually obtained from industrialisation, wastewater irrigation, urbanisation, fertilisers and pesticides used in agricultural activities, and others [44].

Table 4. Correlation between soil to root, root to shoot and shoot to grains of wheat

	Correlation		
Heavy Metal	**Soil-Root**	**Root-Shoot**	**Shoot-Grains**
Zn	0.234^{ns}	1.000^{**}	0.510^{ns}
Co	0.927^{ns}	-.005	0.898^{ns}
Cd	0.433^{ns}	0.521^{ns}	0.975^{*}
Fe	0.999^{**}	0.644^{ns}	0.961^{*}

*, ** = significant at 0.05 and 0.01 levels, ns = non-significant

Table 5. Pollution load index and enrichment factor of wheat

Treatment	Zn	Co	Cd	Fe
		Pollution load index		
T-1	0.093622	0.887273	0.387531	0.927867
T-2	0.212526	0.995305	0.835206	0.9223
T-3	0.134535	0.964567	0.98951	0.780267
T-4	0.106671	0.97619	0.977528	0.736405
		Enrichment factor		
T-1	0.028535	0.120451	1.384353	0.012342
T-2	0.061633	0.164056	5.608435	0.015263
T-3	0.031861	0.164087	6.277803	0.009664
T-4	0.024341	0.120714	5.880487	0.010861

Daily intake of metals

At T-1, the pattern for daily intake of metals was:Fe>Co>Zn>Cd, at T-2 was: Fe>Cd>Zn>Co and at T-3 and T-4 was: Fe>Cd>Co>Zn. Daily intake of metal contains values ranged from 0.006797 to 0.008528 for Zn, 0.007879 to 0.009914 for Co, 0.00658 to 0.012165 for Cd and 0.008918 to 0.014806 for Fe. Daily intake of metal values of Fe was higher among all treatments in our present study (Table 6).

Balkhair and Ashraf [45] reported lower DIM values of Cd (0.0017), Zn (0.0004) and Fe (0.0019) as compared to our readings, they used sewage water irrigation in their experiment that contains high contaminants.

Daily intake of metal values for adults was calculated for the average consumption of vegetables and cereals as related to the recommended daily intake [46, 47].

Table 6. Daily intake of metal and health risk index via intake of *Triticum aestivum*

Treatment	Zn	Co	Cd	Fe
Daily intake of metal				
T-1	0.006797	0.007879	0.00658	0.008918
T-2	0.008528	0.008312	0.008702	0.011256
T-3	0.007403	0.009914	0.010433	0.011732
T-4	0.007533	0.008442	0.012165	0.014806
Health risk index				
T-1	0.022657	0.183233	6.58	0.01274
T-2	0.028427	0.193302	8.702	0.01608
T-3	0.024677	0.230558	10.433	0.01676
T-4	0.02511	0.196326	12.165	0.021151

Health risk index

Health risk index of each metal among all treatments (1, 2, 3 and 4) trends was similar as Cd>Co>Zn>Fe and their values ranged from 0.022657 to 0.028427 for Zn, 0.183233 to 0.230558 for Co, 0.183233 to 0.23055 for Cd and 0.01274 to 0.021151 for Fe (Table 6). Cadmium showed the highest health risk index among all treatments. Oral reference dose defined as the daily exposure of individuals to pollutants and toxins that can pose no substantial risks over their lifetime. Oral reference dose values for the heavy metals Zn (0.3), Co (0.043), Cd (0.001), and Fe (0.70) respectively [48]. In all wastewater-irrigated crops, Cd (1.67) exhibited HRI>1 except wheat (*Triticum aestivum)* observed by Balkhair and Ashraf [45] that was greater than over calculations. Therefore, Cd was considered as non-essential metals, which contributed to health risks even at deficient concentrations. Zhuang et al. [49] also observed the HRI values for Cd that was above than the permissible limits in vegetables as well as in cereals. Therefore, wheat grown in contaminated soil was not beneficial for humans.

Conclusion

It was concluded that the application of municipal solid waste on agricultural land enhance the growth parameters of wheat but it also cause accumulation of heavy metals in root, shoot and grains of wheat. The values of all metals in wheat plant parts (root, shoot and grains) were present within the acceptable limit except for the Cd. The values of PLI for all metals were less than 1. The values of health risk index for the Cd were greater than 1 showed that municipal solid water treated wheat grains are not safe for human consumption.

Authors' contributions

Conceived and designed the experiments: ZI Khan, K Ahmad & N Mehmood, Performed the experiments: R Arshad, P Akhter & H Bashir, Analyzed the data: M Akhtar & K Wajid, Contributed reagents/ materials/ analysis tools: M Nadeem, M Ghazzal & M Akhtar, Wrote the paper: IS Malik, S Mahpara, A Ashfaq & M Munir.

References

1. GOP (Government of Pakistan) (2013). Pakistan Economic Survey 2011-12. Ministry of Finance, Government of Pakistan, Islamabad. 19-21.
2. Ahmad K, Nawaz K, Khan ZI, Nadeem M, Wajid K, Ashfaq A, et al (2018a). Effect of diverse regimes of irrigation on metals accumulation in wheat crop: An assessment - dire need of the day. *Fresen Environ Bull* 27(2): 846-855.

3. GOP (Government of Pakistan) (2012). Wheat Area, Production and Yield. Agricultural Statistics of Pakistan, 2011-12. Statistics Division, Federal Bureau of Statistics, *Government of Pakistan*, Islamabad. 3.
4. Tahir M & Javeed MR (2010). Constraints on Wheat Production. Econ. Bus. Rev. Daily The Dawn, December 20, pp 1.
5. Ahmad K, Kokab R, Khan ZI, Ashfaq A, Bashir H, Mudasra M et al (2018b). Assessment of heavy metals in wheat variety ‘‘Chagi-2’’ under short-term wastewater irrigation. *Biologia (Lahore, Pakistan)* 64(1): 15-25.
6. Ahmad M, Mustafa CG & Iqbal M (2002). Wheat Productivity, Efficiency, and Sustainability. *Pak Dev Rev* 40(4): 643- 663.
7. Dorosh A & Salam A (2007). Distortions in Agricultural Incentives. Agricultural Distortions Research Project Working Paper 33, World Bank, Washington DC, pp 1.
8. GOP (Government of Pakistan) (2008). Pakistan Economic Survey 2007-08. Ministry of Finance, *Government of Pakistan*, Islamabad, Pakistan. 22-23.
9. Khan ZI, Safdar H, Ahmad K, Wajid K, Bashir H, Ugulu I & Dogan Y (2019a). Health risk assessment through determining bioaccumulation of iron in forages grown in soil irrigated with city effluent. *Environ Sci Pollut Res* 26(14): 14277-14286.
10. Khan ZI, Nisar A, Ugulu I, Ahmad K, Wajid K, Bashir H & Dogan Y (2019b). Determination of cadmium concentrations of vegetables grown in soil irrigated with wastewater: evaluation of health risk to the public. *Egypt J Bot* in Press https://doi.org/10.21608/EJBO.2019.99 69.1296.
11. Khan ZI, Ahmad K, Nawaz K, Nadeem M, Ashfaq A, Munir B, et al (2018a). Sugar industry effluents as a source of foil fertility and potential toxicological risk of heavy metals in food crop. *Biologia (Pakistan)* 64(II): 257-264.
12. Khan ZI, Ahmad K, Safdar H, Ugulu I, Wajid K, Bashir H & Dogan Y. 2018b. 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* 9(5): 759-770.
13. USEPA (United States Environmental Protection Agency) (1992). Manual: Guidelines for Water Reuse. USEPA Rep. 625/R-92/004. USEPA, Washington, DC, pp 1.
14. Steel RGD & Torrie JH (1996). Principles and Procedures of Statistics*: A Biometrical Approach*, Mc Graw-Hill New York. 195-233.
15. Liu WH, Zhao JZ, Ouyang ZY, Soderlund L & Liu GH (2005). Impacts of sewage irrigation on heavy metals distribution and contamination in Beijing, China. *Environ Int* 31: 805-812.
16. Al-Hwaiti M & Al-Khashman O (2014). Health risk assessment of heavy metals contamination in tomato and green pepper plants grown in soils amended with phosphogypsum waste materials. *Environ Geochem Health* 37(2): 287-304.
17. Khan ZI, Safdar H, Ahmad K, Wajid K, Bashir H, Ugulu I & Dogan Y (2020). Copper bioaccumulation and translocation in forages grown in soil irrigated with sewage water. *Pak J Bot* in Press http://doi.org/10.30848/PJB2020-1(12).
18. Sajjad K, Farooq R, Shahbaz S, Khan MA & Sadique S (2009). Health Risk Assessment of Heavy Metals for Population via Consumption of

Vegetables. *World Appl Sci J* 6: 1602-1606.
19. Wang X, Sato T, Xing B & Tao S (2005). Health risks of heavy metals to the general public in tianjin, china via consumption of vegetables and fish. *Sci Total Environ* 350: 28-37.
20. Wang X, Huan GW, Tian HG, Dong SR, Yin HG & Cao XH (2007). Investigation on Dietary of Urban Residents in Tiajin from 2000-2004, China. *J Public Health* 23: 12-45.
21. Cui YJ, Zhu YG, Zhai RH, Chen DY, Huang YZ, Qui Y & Liang JZ (2004). Transfer of metals from near a smelter in Nanning, China. *Environ Int* 30: 782-791.
22. USEPA (United States Environmental Protection Agency) (2002). Region 9, *Preliminary Remediation Goals*. Office of Research and Development, Washington, DC, USA, pp 1.
23. Andaleeb F, Anjum ZM, Ashraf M, Mahmood KZ (2008). Effect of chromium on growth attributes in sunflower (*Helianthus annuus* L.). *J Environ Sci* 20: 1475-1480.
24. Konate A, He X, Zhang Z, Ma Y, Zhang P, Alugongo GM & Rui Y (2017). Magnetic (Fe_3O_4) Nanoparticles Reduce Heavy Metals Uptake and Mitigate Their Toxicity in Wheat Seedling. *J Sustain* 9: 790.
25. FAO/WHO (Food and Agriculture Organization of the United Nations/World Health Organization) (2001). *Codex Alimentarius Commission*. Food Additive and Contaminants. Joint FAO/WHO Food Standards Programme, ALINORM 01/12a, 1-289.
26. Sihag, S & Lohchab RK (2017). Effects of Sewage Sludge Bio-Available Heavy Metals on Agricultural Soils and Wheat Crop. *J Environ Biol Sci* 31(1): 247-254.
27. Khan ZI, Ahmad K, Ashraf M, Yasmeen S, Ashfaq A & Sher M (2016). Metal accumulation in a potential winter vegetable mustard (*Brassica campestris* l.) irrigated with different types of waters in Punjab, Pakistan. *Pak J Bot* 48(2): 535-541.
28. Szabo G, Elek Z & Szabo S (2008). Study of Heavy Metals in the Soil-Plant System. *Cereal Res Commun* 36: 403-406.
29. Al-Othman ZA, Ali R, Al-Othman AM, Ali J & Habila MA (2016) Assessment of toxic metals in wheat crops grown on selected soils, irrigated by different water sources. *Arab J Chem* 9:1555-1563.
30. Davies BE & Jones LHP (1988). Micronutrients and Toxic Elements. In: Wild, A., Ed., Russell's Soil Conditions and Plant Growth, 11th Edition, John Wiley and Sons, New York. *Inter-Science* 781-814.
31. Singh A, Sharma RK & Agrawal M (2010a). Risk assessment of heavy metal toxicity through contaminated vegetables from wastewater irrigated area of Varanasi. *Tropic Ecol* 51: 375-87.
32. Sinha S, Gupta AK, Bhatt K, Pandey K, Rai UN & Singh KP (2006). Distribution of metals in the edible plants grown at jajmau, kanpur (india) receiving treated tannery wastewater, relation with physicochemical properties of the soil. *Environ Monit Assess* 115: 1-22.
33. Campbell PGC (2006). Cadmium-A Priority Pollutant. *Environ Chem* 3(6): 387-388.
34. Manahan, S.E. 2009. Toxicological Chemistry and Biochemistry. *CRC Press*.
35. Khan MA, Kazi TG, Ansari R, Mujtaba SM, Khanzada B, Khan MA, Shirazi MU & Mumtaz S (2007). Effects of un-treated sewage sludge on wheat yield,

metal uptake by grain and accumulation in the soil. *Pak J Bot* 39(7): 2511-2517.

36. Hooda PS & Alloway BJ (1996). The effect of liming on heavy metals concentration in wheat, carrots and spinach grown on previously sludge applied soils. *J Agric Sci* 127: 289-294.
37. Oliver DP, Penfold C, Derrick J, Cozens G & Tiller KG (1997). Cadmium concentration in grain grown under organic farming systems and using alternative fertilizer. *Technical Report Csiro* 13.
38. Lago-Vila M, Arenas-Lago D, Rodriguez-Seijo A, Andrade-Couce ML & Vega FA (2015). Cobalt, chromium and nickel contents in soils and plants from a serpentinite Quarry. *Solid Earth* 6: 323-335.
39. Singh A, Sharma RK, Agrawal M, Marshall FM (2010b). Health risk assessment of heavy metals via dietary intake of foodstuffs from the wastewater irrigated site of a dry tropical area of India. *Food Chem Toxicol* 48: 611-619.
40. An YJ, Kim YM & Jeong SW (2004). Combined effects of copper, cadmium and lead upon *cucumis sativus* growth and bioaccumulation. *Sci Total Environ* 326(1-3): 85-93.
41. Harikumar PS, Nasir UP & Rahman MPM (2009) Distribution of heavy metals in the core sediments of a tropical wetland system. *Int J Environ Sci Technol* 6(2): 225-232.
42. Rahman SH, Khanam D, Adyel TM, Islam MS, Ahsan MA & Akbor MA (2012). Assessment of heavy metal contamination of agricultural soil around dhaka export processing zone (DEPZ), Bangladesh: Implication of seasonal variation and indices. *Appl Sci* 2(3): 584-601.
43. Huu HH, Rudy S & Damme AV (2010). Distribution and contamination status of heavy metals in estuarine sediments near cua ong harbor, ha long bay, Vietnam. *Geologica Belgica* 13(1-2): 37-47.
44. Kwon YT, Lee CW & Ahn BY (2001) Sedimentation pattern and sediments bioavailability in a wastewater discharging area by sequential metal analysis. *Microchem J* 68(2-3): 135-141.
45. Balkhair KS & Ashraf MA (2016). 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* 23: 32-44.
46. WHO (World Health Organization) (1996). Guidelines for drinking-water quality, health criteria and other supporting information. World Health Organization, Geneva, 2, pp 1.
47. Trumbo P, Yates AA, Schlicker S & Poos M (2001). Dietary reference intakes: vitamin a, vitamin k, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. *J Am Diet Assoc* 101(3): 294-301.
48. USEPA (2010). Risk-based Concentration Table. United State Environmental Protection Agency, Washington, DC.
49. Zhuang P, McBride MB, Xia H, Li N & Li Z (2009). Health risk from heavy metals via consumption of food crops in the vicinity of dabaoshan mine, south China. *Sci Total Environ* 407(5): 1551-156.