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Research Article

Effect of different concentrations of municipal solid waste on metal uptake of wheat (*Triticum aestivum*)

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Citation

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Abstract

Heavy metal accumulation in edible parts of plants is major international concern now a day. This research was aimed to observe the influence of different level of municipal solid waste on metal accumulation by wheat variety (Inqalab-91). The metal concentration in soil and wheat grains was quantified using atomic absorption spectrophotometer (AA-6300 Shimadzu Japan). Results demonstrated that municipal solid waste treatment increased the heavy metals in various parts (root, shoot, grains) of wheat plant. The metals in wheat grains varied from 1.5-2.46, 10-18.16, 0.8-0.95 and 0.53-0.95 mg/kg for Cd, Fe, Zn and Co, respectively. The amount of all heavy metals were determined within the permissible range except for Cd. The cadmium had the highest bio concentration and enrichment factor. The pollution load index values for Cd and Co were the highest. The health risk index values for Cd, Fe and Co were > 1 indicating that wheat grains were not suitable for human consumption. So, it is concluded that proper treatment of municipal solid waste is necessary before its application on land.

Keywords: Heavy metal; Municipal solid waste; *Triticum aestivum*

Introduction

The competition for development among different nation of the world purported very effects to human life. Every country is dependent on agricultural and industrial progress for its development to attain the goals of progress every country has to make use of all its available resources **[1]**.

Cereal are the most important portion of the food for human as well as for animals now a days they are playing very important role as energy production such as biogas and bioethanol which are produced from the fermentation are chiefly produced by cereals crops. Different varieties of wheat exist worldwide, the most important type which is being cultivated (*Triticum aestivum*) and hard wheat (*Triticum durum*). *Triticum aestivum* as compared to the hard wheat is rich in phosphorus, starch, iron, vitamin B and fats and can be easily grown in temperate and hot areas [2].

The element of high density (usually $< 5 g/cm^3$) are termed as the heavy metals and even the little amount can be very toxic. These elements exist naturally in soil high pH induces their mobility [3] amongst the dangerous element which can cause very serious effects to livings are arsenic, chromium, lead, nickel, cadmium, mercury, beryllium, selenium and manganese [4].

Heavy metals bring along them very negative effects to the environment because of their half-life and non-biodegradable nature [5]. Owing to the exorbitant concentration of copper in cereal causes liver damage and failure of hair pigmentation [6]. High level of Zn takes part in weakness of muscles, nausea and pain. Higher doses of such metals in the wheat can lead to serious health problems [7].

Industrial wastes are the chief source of the heavy metals, as they pour their all waste material in running water, lakes and stream and accelerate their amount in the water. This untreated water in many countries, used for agriculture purposes [8, 9], it brings very harmful effects on crops and soil. This high concentration of the heavy metals which are present in crops causes very lethal effects to the heath of human and animals through the food chain [10].

The current work was performed with objectives: (1) to examine the metal concentration in different parts of wheat plant, (2) to determine bioconcentration factor and transfer factor, (3) to estimate pollution load index, (4) to appraise 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 treatment, a pot experiment was conducted at Department of Botany, University of Sargodha during 2016-2017.

Plant cultivation

Twelve pots were filled with 3 kg soil. After that, wheat variety (Inqalab-91) was grown in four groups, one control group (ground soil) and the remaining three treatments with various amount of municipal solid waste. Eight seeds were sown in each pot. T1 consisted of 100% ground soil. T2 consisted of 25% municipal solid waste and 75% ground soil. T3 consisted of 50% municipal solid waste and 50% ground soil. T4 consisted of 75% municipal solid waste 25% ground soil. Three replicates of the selected crop were made for each treatment. Plants were irrigated twice a weak. Maturation period was 5 months. Different morphological parameters of different varieties of wheat were also observed. Plants were harvested in April, 2017.

Sample preparation

After harvesting plants were oven dried. After removing from the oven, grains were separated from the spikes and ground in electrical grinder into fine powder, for heavy metal detection 1g of each sample was taken and digested as wet digestion method.

Wet digestion of grains and soil

The dried samples were placed in a small conical flask and digested with conc. 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 transparent solution and again placed on the hot plate. Digestion continued until colourless solution appeared. After cooling, samples were diluted with distilled water up to 50 mL and filtered through Whatman filter paper No. 42.

The soil samples were collected from the upper 3-5 cm layer of the soil from each pot. After drying in the oven, the samples were digested in the same manner. The ground and sewage water also digested.

Metals concentration

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

The results were subjected to analysis of variance (ANOVA) and the correlation using SPSS (Statistical Package for Social Sciences) software, Version 16.0 **[11]**.

Bioconcentration factor and health risk index was determined by following Cui *et al*. **[12]**. Pollution load index was calculated by method described by Liu *et al*. **[13]**. Daily intake of metal was according to Sajjad *et al*. **[14]**. Al-Hwaiti and Al-Khashman **[15]** was followed for calculation of enrichment factor.

Results

Morphological parameters

Results showed that municipal solid waste significantly affected the morphological parameters of wheat (Table 1). The following order for effect of different treatments on morphological parameters was observed: T4>T3>T2>T1. The maximum values of morphological parameters were seen at T4 (Table 2).

Cadmium contents in soil and grain

The results from ANOVA depicted that treatments have non-significant effect ($p>0.05$) on concentration of Cd in soil (Table 3). Cd content in all treatments was found in following sequence: T1>T2>T4>T3 (Table 4). Non-significant effect ($p>0.05$) of treatments was observed in Cd content in grains (Table 3). The Cd content in grain of wheat variety (Inqalab-91) was in found in following order T2>T4>T1>T3. The comparison between four different treatments indicated that Cd was the highest in T2 while the least concentration of Cd was found in T1 (Table 4).

Iron contents in soil and grain

The results from ANOVA depicted that treatments have non-significant impact ($p>0.05$) on level of Fe in soil (Table 3). Order that found in the soil of Fe was T4>T2>T3>T1 in wheat variety Inqalab-91. Fe was the highest in T4 while the least concentration of Fe was found in T1. In the soil, Fe content ranges from 31.7 to 41.3 mg/kg (Table 4).

The treatments show non-significant effect ($p>0.05$) on Fe content in soil (Table 3). Fe content in grain of wheat variety (Inqalab-91) was in found in following order T2>T3>T4>T1. Fe was the highest in T2 while the least concentration of Fe was found in T1. The Fe content in grains of wheat in present study ranges from 10 to 18.16 mg/kg (Table 4).

Zinc contents in soil and grain

The ANOVA depicted treatments show non-significant effect ($p>0.05$) on Zn content in soil (Table 3). The level of Zn in soil was found in following sequence: T2>T3>T4>T1. Zn content was the highest in T2 while the least concentration of was found in T1. In soil, the concentration of Zn ranges from 2.16 to 2.28 mg/kg (Table 4). The treatments result non-significant effect ($p>0.05$) on Zn content in the grains (Table 3). The mean concentration of Zn in grains was found in following order T4>T3>T1>T2. Zn content was highest in T4 while the least concentration of Zn was found in T2. Zn in grains of wheat ranges 0.80 - 0.95 mg/kg (Table 4).

Cobalt contents in soil and grain

The treatments demonstrated non-significant impact ($p>0.05$) on Co content in soil and grains (Table 3). The Co content in the soil was in following order T4>T3>T2>T1. Co content was highest in T4 while the least concentration of Co was found in T1. In soil, values of Co ranged from 1.15 to 1.73 mg/kg (Table 4). The mean concentration of Co in the grains of wheat variety (Inqalab-91) was in following order T2>T4>T3>T1. In T2, Co mean concentration was highest while the least concentration of Co was found in T1. The Co content in grains of wheat variety ranged from 0.5 to 0.95 mg/kg (Table 4).

Bioconcentration factor of wheat

Transfer factor at T1, T2, T3 and T4 was in following trend respectively: Fe>Co>Cd>Zn, Cd>Fe>Co>Zn, Fe>Cd>Co>Zn and Cd>Fe>Zn>Co (Table 5).

Pollution load index of wheat

The sequence of PLI at T1, T2, T3 and T4 was: Cd>Fe>Co>Zn. The PLI of Cd was highest while Co and Zn was lowest at four treatments. In current study, PLI for Cd was greater than 1 and Fe, Co and Zn remained lower than 1. High pollution load index was observed for Cd due to high percentage of sewage sludge (Table 5).

Enrichment factor for wheat

The order of enrichment factor was Cd>Zn>Co>Fe in T1, T2 and T3 and differ for T4 that was Cd>Zn>Fe>Co. When enrichment value is high (>1) it indicates higher availability and distribution of metals (Table 5).

Transfer factor (root-shoot) of wheat

In all treatments, Co showed the highest values for TF and it was lowest for Cd. The orders of TF for T1, T2, T3 and T4 were Co>Cd>Zn>Fe, Co>Fe>Cd>Zn, Cd>Co>Zn>Fe and Co>Fe>Zn>Cd, respectively (Table 6).

Transfer factor (shoot-grain) of wheat

In four treatments, Cd exhibited the highest values for TF and it was the lowest for Co. The trend of TF for T1, T2, T3 and T4 were Cd>Co>Zn>Fe, Co>Cd>Fe>Zn, Co>Fe>Cd>Zn and Cd>Zn>Co>Fe, correspondingly (Table 6).

Daily intake of metal in wheat

Among four treatments, daily intake of metals for Co was higher in T2, T3 and T4 while lower for Cd and Zn. The order of daily intake of metals for T3 and T4 were same as Co>Fe>Cd>Zn but differed for T1: Co>Fe>Zn>Cd and T2: Co>Cd>Fe>Zn (Table 7).

Health risk index of wheat

The trend of HRI Cd>Co>Fe>Zn was same for T1, T2, T3 and T4 respectively. If HRI for food crop is <1, only then it is considered safe for consumers' health, however if HRI >1 it exerts hazardous effects on human health (Table 7).

Correlation of wheat

In present findings, Fe and Cd exhibited positive and non-significant ($p>0.05$) correlation among root and soil of wheat variety (Inqalab-91). Co showed positive and highly significant correlation. Cd and Fe showed slightly strong relationship between soil and root and Zn had a positive and significant correlation, whereas, Fe and Co showed positive and significant correlation from root to shoot while positive and non-significant correlation was estimated for Zn and Co.

In the present investigation, the Cd, Fe and Zn showed positive and non-significant correlation and the Co showed negative and non-significant correlation (Table 8).

Discussion

The mean level of Cd in soil ranged from 2.80 to 2.98 mg/kg. The value of Cd was similar to present value that is 2.80 mg/kg given by Hassan *et al.* **[16]**. The value of Cd was lower that was 0.20 mg/kg given by Rattan *et al*. **[17]** as compared to the value found in present study. Geochemically Cd is relatively movable element in soil and it is easily taken up by plants. Due to high toxicity Cd has a bad repute and unapproachable to growth of plants **[18]**.

Table 1. Analysis of variance for morphological parameters of wheat

SOV	DF	Mean squares				
		Leaf length	Leaf width	Leaf area	Root length	Shoot length
Treatments	3	35.460^{ns}	.103^{ns}	52.881^{ns}	20.460^{ns}	19.548^{ns}
Error	8	18.258	.019	13.165	13.516	41.051

ns: non-significant

Table 2. Morphological parameters of wheat

Treatment	Leaf length (cm)	Leaf width (cm)	Leaf Area (cm^2)	Root length (cm)	Shoot length (cm)
T1	27.167±3.5	0.5±0.005	10.415±1.9	13.333±2.9	55.633±5.6
T2	25.967±3.6	0.767±0.44	15.075±2.5	08.933±2.8	59.633±5.9
T3	19.667±2.9	0.433±0.03	6.74±1.9	14.633±3.1	58.467±5.8
T4	26.267±2.6	0.8±0.05	15.695±2.5	10.433±2.8	54.067±5.5

Table 3. Analysis of variance for metals in soil and various parts of wheat

Source	Metal			
	Cd	Fe	Zn	Co
Soil	.008^{ns}	109.06^{ns}	.007^{ns}	.234^{ns}
Root	42.29^{ns}	54.75***	.006^{ns}	.101^{ns}
Shoot	.076^{ns}	54.71***	.011^{ns}	.197^{ns}
Grain	117.97^{ns}	44.654^{ns}	.012^{ns}	.092^{ns}

***: Significant at 0.001 level, ns: non-significant

Table 4. Mean concentration (mg/kg) of cadmium, iron, zinc and cobalt in soil root shoot grain of wheat

Treatment	Soil	Root	Shoot	Grain
		Cadmium		
T1	2.925±0.2	2.37±0.2	2.113±0.2	2.15±0.3
T2	2.815±0.2	2.915±0.2	2.483±0.3	2.463±0.2
T3	2.91±0.3	2.46±0.2	2.455±0.2	1.5±0.3
T4	2.98±0.2	2.89±0.2	2.267±0.3	2.167±0.2
		Iron		
T1	31.723±3.5	28.767±3.1	24.217±2.7	10±2
T2	38.17±3.8	35.173±3.5	30.667±3.1	18.167±2.1
T3	37.085±2.8	32.587±3.6	28.037±3.2	17.667±2.1
T4	41.315±3.2	38.323±3	33.813±3.3	13.25±2.3
		Zinc		
T1	2.2083±0.07	1.76±0.02	1.485±0.07	0.9±0.04
T2	2.1683±0.06	1.73±0.04	1.46±0.06	0.805±0.05
T3	2.2317±0.07	1.773±0.06	1.567±0.06	0.893±0.06
T4	2.285±0.06	1.84±0.06	1.593±0.09	0.957±0.07
		Cobalt		
T1	1.1533±0.04	0.9517±0.09	0.863±0.08	0.535±0.03
T2	1.1683±0.06	0.965±0.08	0.883±0.09	0.95±0.04
T3	1.2083±0.09	0.985±0.07	0.933±0.09	0.665±0.04
T4	1.7333±0.1	1.333±0.1	1.4±0.08	0.67±0.08

Table 5. Bioconcentration factor, pollution load index and enrichment factor of wheat

Treatment	Cd	Fe	Zn	Co
Bioconcentration factor				
T1	0.8102	0.9068	0.7969	0.8251
T2	10.355	0.9214	0.7978	0.8259
T3	0.8453	0.8787	0.7944	0.8151
T4	0.9697	0.9275	0.8052	0.7690
Pollution load index				
T1	273.364	0.5575	0.0491	0.2205
T2	263.084	0.6708	0.0482	0.2233
T3	271.962	0.6517	0.0497	0.2310
T4	278.504	0.7260	0.0508	0.3314
Enrichment factor				
T1	54.760	0.0421	0.1811	0.0844
T2	65.184	0.0636	0.1650	0.1479
T3	38.402	0.0637	0.1778	0.1001
T4	54.175	0.0428	0.1861	0.0703

Table 6. Transfer factor for all heavy metals of wheat

Treatment	Cd	Fe	Zn	Co
Root-Shoot				
T1	0.8915	0.8418	0.8437	0.9067
T2	0.8518	0.8718	0.8439	0.9150
T3	0.9979	0.8603	0.8838	0.9472
T4	0.7844	0.8823	0.8657	10.502
Shoot-Grain				
T1	10.175	0.4129	0.6060	0.61993
T2	0.9919	0.5923	0.5513	10.758
T3	0.6109	0.6301	0.5698	0.7127
T4	0.9558	0.3918	0.6007	0.4785

Table 7. Daily intake of metal and health risk index via intake of wheat

Treatment	Cd	Fe	Zn	Co
Daily intake of metals				
T1	0.0123	0.0575	0.0051	0.4458
T2	0.0141	0.1044	0.0046	0.7916
T3	0.0086	0.1015	0.0051	0.5541
T4	0.0124	0.0761	0.0055	0.5583
Health risk index				
T1	847.838	57.412	0.0139	103.682
T2	575.863	10.446	0.0125	184.108
T3	503.125	101.585	0.0138	128.876
T4	503.7	76.188	0.0148	129.844

Table 8. Metal correlation between different levels of wheat

Metal	Soil-Root	Root-Shoot	Shoot-Grain
Cd	0.255	0.598	0.554
Fe	0.356	1.000**	0.636
Zn	0.985*	0.884	0.817
Co	1.000**	0.999**	-0.125

*, **: Correlation is significant at the 0.05 and 0.01 level

The mean value of Cd was higher compared to value (0.46 mg/kg) given by Yu *et al*. [19]. Cadmium content (0.34 mg/kg) given by Ekmekyapar *et al*. [20] was lower than current value. In the body, excess Cd interrupts bone metabolism, kidneys, deforms endocrine system and reproductive tract. It is an accumulative carcinogen and toxicant. Due to long-term exposure to Cd in the kidneys, numerous morpho-physiological changes occur. Renal toxicity decreases by intake of Zn that is caused by intake of Cd. In soil the concentration of Fe ranged from 31.7 to 41.3 mg/kg. In the present study, Fe content was lower compared to value (270 mg/kg) given by Hassan *et al*. [16]. The Fe content was lower in another study carried out by Mojiri and Aziz [21]. The Fe concentration of 6205 mg/kg given by Ekmekyapar et al. [20] was higher than the current value. The value of Fe (21 mg/kg) observed by Balkhair and Ashraf [22] was approximately similar to present value. The Fe content was similar to present value given by Feizi [23] that was 32 mg/kg. Zn content varied from 2.160 to 2.280 mg/kg. The value of Zn in current study was higher than estimation of 7.31 mg/kg given by Rattan *et al*. [17]. The lower value of Zn was observed in the present investigation as compared to value 129.08 mg/kg given by Yu *et al*. [19]. Lower Zn content in current work was detected as compared to 59.1 mg/kg given by Aydin *et al*. [24]. The zinc concentration (35 mg/kg) given by Ekmekyapar *et al*. [20] was higher than current value. The value of Zn in a study carried out by Salakinkop and Hushnal [25] was nearly similar to present value. The Co concentration in soil ranged from 1.150 to 1.730 mg/kg. The result of present research showed lower Cd content as compared to the values of Shad *et al*. [26] that was 5.33 mg/kg. The value of Co (1.73 mg/kg) given by Ahmad *et al*. [27] was similar to current value. The values of Co given by Bibi *et al*. [28] (17.63 mg/kg) and Chiroma *et al*. [29] (14.4 mg/kg) were higher than current study. The cobalt concentration was lower in present study than estimated value of 18.9 mg/kg given by Page *et al*. [30].

The Cd content ranged from 1.50 to 2.46 mg/kg in grains of wheat. In current study, the value of Cd was higher as compared to value 0.062 mg/kg given by Yu *et al*. [19]. Concentration of Cd was higher in current to value 0.10 mg/kg estimated by Stefanovic *et al*. [31]. Cadmium affect negatively if accumulates in the body of human and effects several organs: lung, liver, bones, kidney, central nervous system, placenta and brain [32]. The other damages that have been detected include development toxicity, hematological effects hepatic and reproductive disorders [33].

The value of Cd (0.29 mg/kg) given by Singh *et al*. [34] was lower compared to present value. The value of Cd in present study was higher than 0.06 mg/kg given by Zeng *et al*. [35]. The permissible value of Cd is 0.20 mg/kg [36]. Cd is not useful for human and plant health. Cd is willingly taken up by plants due to its natural presence in soils. Use of commercial sludge as fertilizer maybe the possible source of Cd toxicity in plants.

The concentration of Fe in grains of wheat in present study ranged from 10 to 18.16 mg/kg. Iron concentration given by Ekmekyapar *et al*. [20] (151 mg/kg) was higher in comparison to present value. The value of Fe (404mg/kg) was higher in another study carried out by Rattan *et al*. [17] in contrast to present study. The Fe content was lower in current study to value of 35.63 mg/kg given by Stefanovic *et al*. [31].

Concentration of Zn was lower in current study as given by Stefanovic *et al*. [31]. The Zn content was higher than the present value given by Feizi [23] that was 26 mg/kg. The permissible value of Zn given by Weigert [36] was 99.40 mg/kg. The range of Zn was useful for health of humans in current study.

In the present work, the Co concentration in grains of wheat variety ranges from 0.50 to 0.95 mg/kg. The value of Co was higher to present value 5.340 mg/kg given by Samera *et al*. [37]. The Co concentration was lower in current study to value 81.1 mg/kg demonstrated by Page *et al*. [30]. The value was similar to value reported by Shad *et al*. [26] that was 0.15 mg/kg in grains of wheat. Most relatively high Co content present in leafy plants, like cabbage, lettuce and spinach while lower in cereals and grasses. Co was also important for many legumes because it was an essential micronutrient for some nitrogen fixing bacteria, such as *Rhizobium.*

In current investigation BCF for all findings were higher than the findings of Puschenreiter et al. [38]. In recent study TF for Cd was higher as compared to those values as reported by Ullah *et al.* [39]. The value of Cd was high while value for Zn was lower than values reported by Balkhair and Ashraf [22]. Wang *et al*. [40] reported low values for Cd and Zn.

The pollution load index values of Zn and Cd were lower from the values 2.1 and 84 respectively as demonstrated by Khan *et al*. [41]. Pollution load index had lower values of Fe and Zn in current work as compared to values of 0.74 and 0.07 respectively given by Khan *et al*. [42]. The level of pollution or factor of contamination was lowest for Zn and highest for Cd in all treatments.

The load of pollution increases day by day due to agricultural runoff and human activities. For all metals, the load of pollution in current study was lower compared to the results of Bibi *et al*. [28]. If pollution load index value was higher than 1 the heavy metals were injurious to health. To minimize the extent of pollution severity proper monitoring of soil is necessary.

The population will be at greater risk if DIM was greater than 1 [14]. In current investigation value of DIM was less than1. The value of DIM was higher given by Khan *et al*. [42] than the values of present study. The estimated average DIM for children up to 6 years was 0.1315 and 0.0437 kg/person/day) correspondingly and average body weights were estimated to be 61.6 and 18.6 kg respectively [43].

Health risk index in present findings were greater than 1. Singh *et al*. [34] also recorded high value of HRI for Cd as compared to current findings. Health risk index for Fe was similar to those given by Cui *et al*. [12]. Consumption of food crop as safe if value OF HRI<1 (Khan *et al*. 2008)

When enrichment value is high (>1) it indicates higher availability and distribution of metals. The enrichment factor value given by Likuku *et al*. [44] was higher while Zn 1.25 was higher as compared to present value. The values of EF in our work were similar to the findings of Fytianos *et al*. [45].

In current findings, Zn, Cd and Fe exhibited positive and non-significant while Co showed negative and non-significant correlation. Positive and non-significant correlation were also observed by Khan *et al*. [46] for metal Zn.

Conclusion

It is concluded that the municipal soil waste contains surplus amount of heavy metals and when this was used in agricultural land it contaminates the soil and crop grown there and pose various clinical problems to consumers. In current investigation, values of Fe, Zn and Co in soil and grains were fall within the acceptable range given by FAO/WHO but the concentration of Cd exceeded the permissible limit. Cadmium could be considered potentially dangerous as it exceeded WHO limits and its HRI value was >1. This could be due to the application of municipal solid waste. So therefore, we must have to pass this solid waste through proper treatment to decrease its harmful effect.

Authors' contributions

Conceived and designed the experiments: ZI Khan & K Ahmad, Performed the experiments: IF Malik, M Ghazzal, H Bashir, M Munir & A Ashfaq, Analyzed the data: K wajid, M Sana & K Nawaz, Contributed reagents/materials/analysis tools: T Abbas, M Nadeem &N Mehmood, Wrote the paper: Z Fatima, H Muqaddas, M Shahzadi & S Ullah.

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