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Effect of Sewage Water Irrigation on Accumulation of Metals in Soil and Wheat in Punjab, Pakistan

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Abstract

The aim of this study was to determine the levels of potential toxic metals; cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), nickel (Ni), zinc (Zn), and lead (Pb) in the wheat variety (Fsd-2008) irrigated by sewage water. Various indices were examined such as bioconcentration factor, enrichment factor and health risk index in order to better understand the transport and accumulation of metals through the food chain. Seeds of wheat variety were sown toward the end of October 2014 and flooded with different combinations of local sewage water and groundwater. Determination of metal concentration in soil and wheat samples was carried out by atomic absorption spectrophotometer. Analysis of mean metal concentration in soil that was irrigated by five different water treatments revealed that the mean concentration of Cd was less in the soil of treatment III, IV and V. Results also indicated that the mean concentrations of Cd, Cu and Cr increased and that of Ni and Pb decreased by sewage water irrigation.

Keywords: *Triticum aestivum*, Heavy metal, Soil, Sewage water, Contamination level, Health risk.

Introduction

Substantial metal accumulation in plant and soil from normal and fake source is associated with the vital natural contamination issues. The vast majority of the overwhelming metals aggregate in the organic environment in various ways through the food chain [1, 2]. Expanding substantial metal collection at discriminating levels in living beings from the tainted environment may have mortality impacts [3, 4]. Probably the most poisonous follow components for living beings is fitting with the substantial metal groups [5, 6].

Despite the fact that sewage water contains a parcel of conceivably destructive substances that may bring about different maladies in living beings, yet it is being utilized for the watering system of numerous parts of the world. The fixings present in wastewater influence the way of soil and development of different plants [7]. Wastewater, particularly from an industrial source, contains overwhelming metals that can stay in biological communities for a long time because of their long half-life.

There are numerous sicknesses which are brought about by low or high levels of metals found in sustenance developed in sewage water [7, 8]. The sufficiency of minerals and thorough data about different components in sustenance water is vital [9, 10].

In some plants, a mechanism is present to overcome the hazardous effects of metals accumulated in plants tissues [11, 12]. Diverse varieties of plants have an unusual capability to gain a large number of heavy metals by absorption from soil [13]. Meanwhile, besides the accumulation and absorption, plants have dangerous and unfavourable possessions, resistance, stress, harmful effects, and underdeveloped development and effects on photosynthesis by heavy metal accumulation [14, 15].

Metals have a high tendency to build up in plants as compared to the soil from polluted water, the tendency of uptake may be high or low. The metal build-up in plants may also be due to some protective mechanisms like opposition to pathogens and herbivores [16]. Consumption of such metal-rich plant may contaminate the human body. The most important way of accumulation of hazardous metals in the human body is all the way through nutritional ingestion [17, 18].

In this direction, the aim of this study was to determine the level of potential toxic metals such as cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), nickel (Ni), zinc (Zn), and lead (Pb) in the wheat irrigated by sewage water and to examine various indices such as bioconcentration factor, enrichment factor and health risk index in order to better understand how metals are transported and accumulate through the food chain.

Materials and Methods

The experiment was carried out in Sargodha city. The temperature of Sargodha is very high in the summer season (≥38 ^{o}C) and low in the dry season (12 ^{o}C). The population of Sargodha is 1.5 million. It is an agricultural district with main crops of wheat, sugarcane and rice.

Plant cultivation

Wheat variety Fsd-2008 was sown in October 2014 in 45 pots. Three replications of 15 pots were arranged, in each replication, about 2.5 kg of soil was added. Ten seeds were sown per pots. The pots were supplied with different treatments as T-I (100% groundwater), T-II (75% groundwater (GW)+25% sewage water (SW)), T-III (50% GW+50% SW), T-IV (25% GW+75% SW) and T-V (100% SW). Sewage water was taken from sewage water ponds. In April 2015, the crop was harvested. The samples of grain taken from each pot were ground to get a wheat grain powder. This grain powder was kept in a convection oven for three days at 104^{o}C to get rid of moisture.

Sample preparation

Samples of soil and grain (each 2 g) were digested by adding H_2O_2 and HNO_3 (2:4). The digestion method sustained until each sample became clear. The sample mixture was filtered and diluted up to 50 mL by adding deionized water.

Metals analysis

Metals analyzed in this study were Cd, Cr, Cu, Fe, Ni, Zn and (Pb). For that reason, an atomic absorption spectrophotometer (AA-6300 Shimadzu) was used to determine the metal concentration in samples. Precision and accuracy of analyses were ensured through repeated samples against National Institute of Standard Technology, Standard Reference Material (SRM 1570) for all the metals. The operating conditions for the respective metals are given in (Table 1).

Table 1. **Operating conditions for the analysis of metals using fame atomic absorption spectrometry.**

Element	Cd	Cr	Cu	Fe	Ni	Zn	Pb
Wavelength (nm)	228.8	422.7	324.8	248.3	232.0	213.9	283.3
Slit width (nm)	0.7	0.7	0.7	0.2	0.2	0.7	0.7
Lamp current low (mA)	8	10	6	12	12	8	10
Air flow rate (L/min)	15	15	15	15	15	15	15
Acetylene flow rate (L/min)	1.8	2.8	1.8	2.2	1.6	2	2.0
Burner height (mm)	7	9	7	9	7	7	7

Statistical analysis

One-way ANOVA was applied on data of soil and grain by using SPSS 20. Correlation between metals of grains and soil was determined with the Pearson Correlation.

Bioconcentration factor

Bioconcentration factor (BCF) was determined by following Cui et al. [19].

BCF= level of metal in the wheat/level of metal in soil.

Pollution load index

The pollution load index (PLI) for each treatment was estimated by following Liu et al. [20].

PLI= [level of metal/reference level of metal] in soil.

Daily intake of metal

Daily intake of metal (DIM) was calculated by following Khan et al. [21].

DIM= metal × food intake ×conversion factor ⁄ average weight.

Daily intake of metal by consumption of wheat grain is 0.242 (kg/person) as reported by Wang et al. [22] and average body weight of 55.9 kg was used [23].

Health risk index

Health risk index **(**HRI) values depend on the daily intake of metals and oral reference dose (R_fD).

The health risk index was calculated by using following equation described by Cui et al. [19].

HRI= daily metal intake / reference oral value

Results and Discussion

The present study had generated data on heavy metals in soil and grains of wheat Fsd-2008 treated with different concentrations of wastewater. ANOVA yielded interesting results; only Pb concentration in grains differed significantly in different treatments however, the soil had considerably different mean concentrations of Cd, Cr, Fe, Ni and Zn (Table-2).

Table 2. **Analysis of variance of data for metal contents in soil and wheat.**

Metal	Soil	Grains
Cd	0 .036*	0.007^{ns}
Cr	0 .041***	0.001^{ns}
Cu	0.519^{ns}	0.001^{ns}
Fe	22.928**	3.580^{ns}
Ni	0.063*	0.022^{ns}
Zn	67.135***	21.832^{ns}
Pb	0.016^{ns}	0.031*

*, **, ***: Significant at 0.05, 0.01, and 0.001 levels; ns: non-significant

Metals in soil

Mean concentrations of Zn and Fe were found higher in the soil of all five treatments (Table-3), although all metal concentrations were below the specified permissible limits [24]. Results indicated that the mean concentrations of Ni and Cr increased by sewage water irrigation of wheat (Fsd-2008). Metal values were estimated to be high in treatments containing higher percentages of sewage water [25]. In the present study, mean Fe, Ni and Zn values also increased by sewage water irrigation. In current results, all-metal values were lower than the values reported by Alghobar et al. [26]. In another study, Khan et al. [27] reported higher values for these metals.

Metals in grains

Mean concentrations of Cd, Cu and Cr were increased by sewage water for irrigation. Mean concentrations of Zn and Cu were higher in grains of all five treatments (Table-3). All metal concentrations were found below the permissible limits [24]. Analysis of metals in wheat grains that were irrigated by five different treatments of water indicated that the mean concentrations of Cd, Cu and Cr were increased by sewage water irrigation. Mean concentrations of Zn and Cu were higher in grains of all five treatments. Ozyazici [28] found a high Cu level (55 to 36 mgkg^{-1}) than the present study. In another study, Kansal et al. [29] examined the plant grown in metal contaminated soils and observed a high amount of Zn, Fe, Cu and Cd in plants than plants from non-contaminated soils. In the current study, Zn and Cu were also high that similar to findings of Kansal et al. [29].

Table 3. **Mean concentration of heavy metals in soil and wheat irrigated with five different treatments.**

Metal	T-I	T-II	T-III	T-IV	T-V	Permissible limit
Soil ($mgkg^{-1}$)						
Cd	0.95±0.07	1.025±0.08	0.54±0.07	0.36±0.06	0.41±0.08	3[a]
Cr	0.90±0.09	0.58±0.08	0.99±0.07	0.93±0.05	1.41±0.08	100[a]
Cu	0.75±0.06	1.43±0.07	1.16±0.27	0.54±0.06	0.45±0.07	100[a]
Fe	4.51±0.29	5.03±0.43	6.15±0.38	4.08±0.16	3.59±0.59	50000[b]
Ni	0.46±0.05	0.67±0.08	0.68±0.13	0.86±0.06	0.74±0.09	50[a]
Zn	6.5±0.33	7.85±0.29	5.79±0.43	3.76±0.58	2.4±0.56	300[a]
Pb	0.91±0.12	0.87±0.05	0.56±0.05	0.44±0.05	0.63±0.06	100[a]
Wheat ($mgkg^{-1}$)						
Cd	0.19±0.02	0.143±0.017	0.24±0.027	0.18±0.02	0.118±.060	0.10[a]
Cr	0.065±0.02	0.07±0.025	0.06±0.08	0.06±0.007	0.04±0.019	50[b]
Cu	0.062±0.02	0.06±0.024	0.078±0.05	0.076±0.008	0.037±0.02	73[a]
Fe	1.94±0.21	1.76±0.15	4.48±0.49	2.8691±19	2.357±1.74	425[a]
Ni	0.45±0.13	0.48±0.04	0.53±0.01	0.56±0.014	0.34±0.18	67[a]
Zn	7.63±1.96	10.3±1.94	12.8±1.13	12.91±2.87	7.35±4.64	100[a]
Pb	0.13±0.02	0.09±0.03	0.31±0.07	0.11±0.01	0.05±0.04	0.3[a]

Sources: [a]Chiroma et al. (2014), [b]USEPA (1997)

Bioconcentration factor

Results of BCF of wheat grains showed that the BCF value for Zn was maximum, and for Pb and Cu was minimum in all five treatments (Table-4). A plant's capacity to accumulate metals from soils can be assessed using the BCF values >1 [30, 31]. In the present study, the BCF value of Zn was greater than 1 which showed that its level was dangerous for health. Cui et al. [32] found BCF values >1 for Zn in food crops. In the present study transfer factor value for Zn was also more than 1 for T-III, T-IV and T-V that was parallel to the values indicated by Cui et al. [32]. Present BCF values for all metals were higher as compared to BCF values for different metals like Mn, Ni, Pb, and Zn reported by Jaishree and Khan [33].

Daily intake of metal and Health risk index

Daily intake of metal value for Fe and Zn were maximum, while Cr, Cu and Pb had minimum values in all five treatments (Table-4). In the present study, DIM for Cu was 0.0002-0.0006 that was much lower than that mentioned by Dang [34]. Risk index >1 has damaging consequences on human health [35]. Current results showed that Zn and Cd HRIs were observed more than 1 in some treatments which were above the permissible limit (Table 4). In comparison to the present study, Singh et al. [36] reported higher values of HRI ($mgkg^{-1}$ day^{-1}) for Cu (0.003) and Ni (0.001). On the other hand, a lower value of HRI for Zn (0.39) was reported than the present study [36].

Table 4. **Metal bioconcentration factor, daily intake and health risk index for grains of wheat Fsd-2008.**

Treat ment	Metal						
	Cd	*Cr*	*Cu*	*Fe*	*Ni*	*Zn*	*Pb*
Bioconcentration factor							
T-I	0.37	0.31	0.08	0.29	0.97	0.73	0.29
T-II	0.61	0.25	0.05	0.25	0.71	0.88	0.19
T-III	0.77	0.87	0.07	0.73	0.77	1.09	0.62
T-IV	0.50	0.22	0.11	1.37	0.65	2.71	0.26
T-V	0.29	0.09	0.08	0.24	0.46	5.25	0.09
Daily intake of metal							
T-I	0.001	0.0003	0.0002	0.010	0.002	0.040	0.0007
T-II	0.0007	0.0004	0.0003	0.009	0.003	0.054	0.0005
T-III	0.0012	0.00041	0.0005	0.023	0.003	0.068	0.001
T-IV	0.0001	0.0003	0.0004	0.015	0.004	0.068	0.0006
T-V	0.0006	0.0002	0.0006	0.012	0.002	0.038	0.0003
Health risk index							
T-I	1.05	0.0002	0.008	0.014	0.12	0.94	0.21
T-II	0.76	0.0003	0.009	0.013	0.13	1.28	0.14
T-III	1.29	0.0004	0.010	0.033	0.14	1.58	0.48
T-IV	0.97	0.0002	0.007	0.021	0.15	1.59	0.18
T-V	0.63	0.0001	0.005	0.017	0.09	0.91	0.08

Pollution load index

The pollution level for Cr was minimum in all treatments and that of Cd and Zn was maximum (Table 5). In the present study, PLI value for all metals was less than 1. PLI >1 is considered as contaminated [37]. Pollution load index proposed to be a correct method for metal pollution checking of wastewater irrigated areas [38]. Singh et al. [36] found that wheat and rice showed lower metal pollution index. Higher PLI is considered as human health risk caused by the vegetables through high PLI of soil which is due to a higher build-up of metals in the edible portion. The intake value for Cu was reported in the range of 0.6-1.3 mg day/y for populations of Japan and Philippines [34].

Table 5. **Metals pollution load index of soil samples.**

Treatment	Metal						
	Cd	*Cr*	*Cu*	*Fe*	*Ni*	*Zn*	*Pb*
	Pollution load index						
T-I	0.36	0.02	0.09	0.11	0.051	0.24	0.058
T-II	0.16	0.03	0.17	0.12	0.075	0.27	0.060
T-III	0.21	0.009	0.14	0.11	0.076	0.27	0.062
T-IV	0.24	0.031	0.07	0.04	0.095	0.11	0.054
T-V	0.28	0.045	0.054	0.17	0.082	0.32	0.078

Correlation coefficients

Zn, Ni, Cd and Cu showed non-significant positive correlation; Pb and Fe showed non-significant negative correlation and Cr showed significant negative correlation between soil and grains (Table 6). Positive non-significant correlation of Cu was also observed by Szabo et al. [39]. Non-significant correlation of metals was also reported by Ekmekyapar et al. [40]. Sungur et al. [41] applied Pearson's correlation to determine the correlations between the selected physicochemical properties of soil samples and the amount of heavy metals in each fraction. It was also reported that the pH, $CaCO_3$ and organic matter contents of soil samples played a dominant role in correlations of heavy metals in various forms and shapes.

Table 6. **Metal correlation between soil and grains.**

Metal	Soil-Grains
Cd	0.087
Cr	-0.888*
Cu	0.755
Fe	-0.249
Ni	0.267
Zn	0.279
Pb	-0.294

***: Significant at the 0.05 level**

Conclusion

Heavy metal contamination of agricultural water sources and plants consequently is a major matter of concern to environmentalists. This study necessitates the emphasis on using clean water for irrigation purposes as different concentrations of sewage water enhanced the level of metals under study in both soil and wheat grains. Few metals (Cd, Cr, Fe, Ni, Zn) varied significantly in soil treated with differential water regimes. Wheat grains, however, accumulated relatively similar concentrations of heavy metals with only Pb as an exception which differed significantly in five treatments. Mean metal concentrations remained within prescribed limits which may surpass the critical level upon prolonged wastewater application. Zn transfer was favoured by the wheat plant as its BCF and HRI were above 1; HRI of Cd was also above 1 indicating dangerously higher levels of Zn and Cd in wheat grains. PLI values for all studied metals remained fairly below 1. This study concludes that wastewater application as an alternative means to irrigate plant crops is hazardous as it introduces contaminants to the soil which may also find their way into plants thereby affecting human health.

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Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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