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Heavy Metals Assessment in Vegetables Irrigated with Wastewater: A Case Study in District Sargodha, Pakistan

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Authors' contributions

This work was carried out in collaboration between all authors. Author AK designed the research, authors SJ, MN FS and IM performed the statistical analysis, authors IA and HN wrote the research paper. All authors have read and approved the final manuscript.

Original Research Article

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ABSTRACT

An experiment was conducted to evaluate the heavy metals toxicity in vegetables irrigated with wastewater. Different experimental sites were selected from district Sargodha, Pakistan. Samples of wastewater, contaminated soil and vegetables irrigated with wastewater were collected and analyzed. Concentration of heavy metals such as Cadmium (Cd), Copper, (Cu), Chromium (Cr), Zinc, (Zn) and Iron (Fe) were determined from soil, water and vegetables samples irrigated with wastewater and fresh water. Cadmium concentration was present from 0.1 to 0.3 μgg^{-1}, chromium concentration from 0.03 to 0.11 μgg^{-1}, Copper concentration from 0.2 to 0.7 μgg^{-1}, iron concentration was present from 2.6 to 4 μgg^{-1} and Zinc concentration was present from 0.1 to 0.3 μgg^{-1} in vegetables irrigated with waste water. Heavy metals concentrations recorded in vegetables were within the safe limit except cadmium as recommended by WHO.

Keywords: Experimental sites; radish; spinach; contaminated soil; heavy metals; wastewater.

1. INTRODUCTION

In Pakistan, shortage of surface water supply is a serious issue. This shortage of water is being compensated by wastewater (sewage and industrial effluents) to grow vegetables

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especially in areas around the big cities [1]. Disposal of sewage water and industrial wastes is a great problem. Often it is drained to the agricultural lands where it is used for growing crops including vegetables. Industrial or municipal wastewater is mostly used for the irrigation of crops due to it's easily availability, disposal problems. This concern is of great important, where un-treated sewage is applied for longer periods to grow vegetables in urban lands. Some metals are essential micronutrients at low concentration and at high concentration they cause growth inhibition of plants [2]. Irrigation of agriculture soils through wastewater may not only result in soil contamination, but also affect food quality and safety [3]. Irrigation with wastewater becomes the source of heavy metals in crops and vegetables. Some of the heavy metals are essential but the others are not essential for proper plant growth. These sewage effluents are considered not only a rich source of organic matter and other nutrients but also they elevate the level of heavy metals like Fe, Mn, Cu, Zn, Pb, Cr, Ni, Cd and Co in receiving soils [4]. Therefore, as the concentration of heavy metals increased in the soil they could be transferred in body through food and water and accumulate in the body of animals and may lead to the disruption of numerous biological and biochemical processes in the human body [5]. Food and water are the main sources of our essential metals; these are also the media through which we are exposed to various toxic metals. Heavy metals are easily accumulated in the edible parts of plants. The main objective of this study was to determine the concentrations of Cu, Zn, Cd, Cr, and Fe vegetables irrigated with wastewater.

Permissible limits [6] of the metals (µgg-1) recommended by WHO

Metals	Cd	Cu	Cr	Zn	Fe
Permissible Limits(µgg-1)	0.1	73.3	2.3	100	425

2. MATERIALS AND METHODS

2.1 Study Area and Sampling

Experimental sites were selected in Sargodha region to evaluate the level of heavy metals toxicity from soil, vegetables irrigated with wastewater. The samples of wastewater, contaminated soil and different vegetables (spinach and radish) were collected from the experimental sites (Silanwali, Kot Frid and Isataqlalabad) to determine the level of heavy metals from vegetables irrigated with wastewater.

2.2 Collection of Samples

Three samples of contaminated soil, wastewater and vegetables irrigated with wastewater were collected during growing seasons from three different sites of District Sargodha. The sample of each vegetable was same size and age group.

2.3 Sample Preparation

All the collected samples of vegetables (spinach and radish) were washed with double distilled water to remove pollutants. The edible parts of each sample of vegetable were weighed and air-driedto reduce the water content. All the samples were then oven-dried in a hot air oven at 60–70ºC for 24 h, to remove all moisture. Dried samples were powdered using a pestle and mortar and sieved through muslin cloth.

2.4 Digestion

Dry material was digested according to the methods [7]. For each vegetable, three powdered samples from each source of irrigation (0.1 g each) were accurately weighed and placed in digestion tube and 3ml of concentrated H_2SO_4 was added in the digestion tubes. Samples were incubated overnight and then placed in the digestion chamber and heated at 300^oC for 30 minutes. Fumes from the samples were emitted. The Digestion tubes were removed from the digestion chamber and cooled and put 0.1 ml of H_2O_2 along the sides of digestion tubes and placed digestion tube again in the digestion chamber and fumes were emitted from digested material and again removed digestion tubes from digestion chambers and put H_2O_2 into the digestion tubes and place in digestion chamber. Repeated the process until samples become transparent. Distilled water was added into the extract material up to volume 50ml and filtered for determination of heavy metals.

2.5 Standards

Standard solutions of heavy metals (1000 mg/l) were procured from Merck. Solutions of varying concentrations were prepared for different heavy metals by diluting the standards.

2.6 Heavy metal Determination

From the digested material heavy metals Cadmium (Cd), Copper, (Cu), Chromium (Cr), Zinc, (Zn) and Iron (Fe) were analyzed from atomic absorption spectrophotometer model number AA-6300.

2.7 Statistical Analysis

The data were analyzed by analysis of variance technique. Difference for variance character was compared by using least significance difference at 0.05 levels [8].

3. RESULTS

Analysis of variance of the data of cadmium, chromium, copper, iron and zinc concentration in normal and wastewater, contaminated and non- contaminated soil and vegetables irrigated with wastewater is presented in (Tables 1 and 2). According to the analysis of variance, the concentrations of heavy metals were recorded significantly high in waste water and contaminated soil as compared to normal water and non-contaminated soil (Tables 1 and 2). The concentration of different heavy metals observed from normal and wastewater are presented in (Table 3). Cadmium, copper and zinc concentration was observed high in waste water collected from Kot Farid (Table 3). Chromium was observed from the wastewater collected from Istaqlalaabad (Table 3). The data of heavy metals observed from contaminated and non- contaminated soil is presented in (Table 4). Cadmium concentration was observed high from the soil samples collected from Silanwali (Table 4). Chromium was observed high from the soil samples collected from Kot Farid (Table 4). Copper was observed high from the soil samples collected from Silanwali and KotFarid (Table 4). Zinc concentration was observed high from the samples collected from Istaqlalabad and Silanwali (Table 4). Data of different heavy metals collected from vegetables is presented in (Table 5). Cadmium and chromium was observed high in spinach collected from Istaqlalabad and KotFarid (Table 5). Copper concentration was observed high in spinach collected from Silanwali, KotFarid and Istaqlalabad (Table 5). Iron was observed high from the samples of spinach collected from Sialanwali. Zinc concentration was observed high from spinach samples collected from Silanwali (Table 5). Overall, heavy metals were observed high from the spinach samples irrigated with waste water.

Table 1. Mean square from the analysis of variance of the data of cadmium, chromium and copper concentration for radish *(Raphanus sativus)* and spinach *(Spinacia oleracea)* irrigated with normal and wastewater from District Sargodha

SOV	D.F	Cadmium			Chromium			Copper		
		Water	Soil	Vegetable	Water	Soil	Vegetable	Water	Soil	Vegetable
Sites	2	3.57*	13.7*	0.685*	1.48*	36.90*	0.10*	1.05*	24.98*	1.95*
Vegetable	1	8.20*	49.94*	5.39*	1.13*	111.69*	1.21*	0.12*	108.59*	7.22*
Interaction	2	2.93*	2.51*	0.56*	0.78*	16.70*	0.29*	3.30*	0.46*	0.45*
Error	12									
Total	17									

Table 2. Mean square from the analysis of variance of the data of Iron and Zn concentration for radish *(Raphanus sativus)* and spinach *(Spinacia oleracea)* irrigated with normal and waste water from District Sargodha

SOV	D.F	Iron			Zn		
		Water	Soil	Vegetable	Water	Soil	Vegetable
Sites	2	6.11*	91.79*	0.10*	1.96*	0.72*	9.09*
Vegetable	1	1.20*	563.63*	1.21*	8.45*	2.10*	19.00*
Interaction	2	2.76*	23.0*	0.29*	4.99*	1.02*	5.78*
Error	12						
Total	17						

Table 3. Heavy metals concentration ($\mu g g^{-1}$) in waste and normal water collected from different experimental sites of District Sargodha

Sites	Water					
	Silanwali		Kot Farid		Istaqlal Abad	
	Waste water	Normal water	Waste water	Normal water	Waste water	Normal water
Cadmium	0.065±0.001	0.019±0.002	0.07±0.004	0.05±0.002	0.056±0.002	0.034±0.005
Chromium	0.05±0.002	0.03±0.001	0.04±0.002	0.02±0.001	0.08±0.003	0.06±0.002
Copper	0.06±0.001	0.04±0.001	0.07±0.004	0.03±0.001	0.05±0.001	0.04±0.001
Iron	1.6±0.005	1.2±0.02	2.1±0.04	1.5±0.06	1.6±0.3	0.5±0.04
Zinc	8.2±0.2	6.7±0.03	10.2±1.2	8.3±2.1	9.7±1.3	7.5±1.7

Table 4. Heavy metal concentration (μgg^{-1}) in contaminated and non- contaminated soil collected from different experimental sites of District Sargodha

Sites	Soil					
	Silanwali		Kot Farid		Istaqlal Abad	
	Contaminated soil	Non-contaminated Soil	Contaminated soil	Non-contaminated soil	Contaminated soil	Non-Contaminated soil
Cadmium	0.13±0.004	0.08±0.03	0.06±0.004	0.04±0.007	0.05±0.009	0.04±0.01
Chromium	0.07±0.02	0.08±0.03	0.14±0.07	0.06±0.004	0.16±0.02	0.06±0.012
Copper	0.08±0.02	0.05±0.008	0.08±0.02	0.06±0.003	0.1±0.008	0.07±0.02
Iron	1.6±0.5	1.0±0.04	1.7±0.5	1.0±0.06	1.8±0.01	1.2±0.7
Zinc	0.07±0.02	0.03±0.02	0.075±0.02	0.04±0.007	0.07±0.02	0.03±0.002

Table 5. Heavy metal concentration (μgg^{-1}) in radish *(Raphanus sativus)* and spinach *(Spinacia oleracea)* irrigated with wastewater collected from different experimental sites of District Sargodha

Sites	Silanwali		Kot Farid		Istaqlalabad	
	Radish	Spinach	Radish	Spinach	Radish	Spinach
Cadmium	0.3±0.002	0.48±0.001	0.1±0.005	0.29±0.0007	0.1±0.003	0.65±0.004
Chromium	0.03±0.002	0.11±0.005	0.02±0.001	0.08±0.003	0.06±0.001	0.089±0.006
Copper	0.23±0.005	0.7±0.01	0.2±0.004	0.7±0.0004	0.5±0.002	0.7±0.005
Iron	3.5±0.2	4.0±0.02	3.4±0.005	2.6±0.02	3.5±0.4	3.0±0.08
Zinc	0.17±0.06	0.8±0.03	0.2±0.04	0.3±0.01	0.1±0.004	0.25±0.01

4. DISCUSSION

As the population is increasing day by day and demand of food also has been increased. To meet the demand of food, vegetables are being grown around the big cities by using a wastewater as irrigation source. Wastewater contains different heavy metals, which disturb the food quality and safety. It has been observed from the current scenario that majority of the population is suffering from malnutrition and therefore, different disease have been diagnosed due to nutrients deffiency. The heavy metals accumulation and translocation potential varied from metal to metal and from plant to plant. Heavy metals are included in the main category of environmental pollutants as they can remain in the environment for long periods; their accumulation is potentially hazardous to humans, animals and plants [9]. Cadmium is well known as a highly environmental element due to its great toxicity and highly mobility from soil to plants and food chain [10]. Elevated levels of heavy metals in sewage water have been reported by many other scientists in Pakistan and they noted excessive concentration of Cu, Mn, Pb and Cd in sewage water samples [11]. In Pakistan, it was also reported higher contents of Zn, Cu, Pb, Ni, Cd and Cr in wastewater samples from Rawalpindi Area and from Peshawar [12]. Genotypic effect, environmental effect and their interaction effects highly affect heavy metals uptake in crop genotypes [13]. The uptake of heavy metal by vegetables is not only affected the plant species but also affect the physicochemical characteristics of soil. [14] Collected spinach, bitter gourd, okra, pumpkin and egg plant samples and observed that they were contaminated with heavy metals. Similarly, [15] collected spinach and turnip samples from market and found that these vegetables were unsafe for eating due to higher heavy metal concentration. It has been investigated by many scientists that heavy metals are accumulated in edible portion of vegetables and found that Zn, Cu, Pb, Ni, Cd and Cr contents were higher than the safe limits [16]. It has been noted that irrigation with waste water contaminated the leaf and fruit parts of the vegetables and increased the levels of heavy metals than the recommended levels of WHO [17]. Due to copper toxicity plant appears stunted are usually bluish in colour and eventually turn yellow or brown. Chromium toxicity in plants observed at multiple levels from reduced yield through effects on leaf and root growth and inhibition of enzymatic activities and mutagenesis.

5. CONCLUSION

From the experimental study it is observed that wastewater was the main source of pollution to soil and irrigation with waste water containing high amount of cadmium leads to increase the concentration of cadmium in vegetables.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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