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Research Article

Appraisal of chromium and cobalt contents of vegetables grown in soil irrigated with sewage water: A risk for consumers' health

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Abstract

The aim of the present research was to determine the concentrations of chromium (Cr) and cobalt (Co) in soil, vegetables grown at the areas which are usually irrigated with canal water (CW) and sewage water (SW). The samples were analysed through Atomic Absorption Spectrophotometer.

The mean concentrations of Cr and Co in soil samples varied from 0.9 to 1.80 mg/kg and 0.575 to 1.10 mg/kg, respectively. The highest value of Cr was observed in *Solanum lycopersicum* irrigated with SWI and the lowest in *Brassica rapa* irrigated with CW. While in case of cobalt, the highest value was found in *Solanum lycopersicum* irrigated with SW and the lowest was noticed in *Capsicum baccatum* irrigated with CW. In all vegetables, the daily intake of metal values for Cr and Co were higher in SWI as compared to the CWI. Bio-concentration factor values of heavy metals were less than 1 in all vegetables for Cr and Co, and these results specified that metal bioavailability was low at CWI and SWI. Health Risk Index values of Cr and Co were less than one. The findings suggested that the locals were safe while consuming these vegetables but consistent use of waste water may increase the risk of contaminants as they may reach the toxic levels.

Keywords: Chromium; Cobalt; Wastewater; Vegetables

Introduction

Trace metals are potentially toxic and even lesser quantities of these metals in organisms are harmful as they are utilized in industrial processes [1]. Trace metals could be collected in the food stuff consumed by humans and other living beings [2]. Wastewaters have higher concentration of potentially toxic metals [3, 4]. The infectivity of vegetables by these metals could be because of excessive use of sewage water in irrigation [5, 6]. Extended ingestion of these heavy metals by consuming contaminated vegetables could be lethal to humans and organisms resulting in many biological disorders [7, 8].

The levels of trace metals are increasing day by day in ecosystems and cause uneasiness among people because of occurrence of trace metal remains [9, 10]. The community has become fearful and worried regarding the safety of vegetables because the food items having heavy metals are not considered appropriate for consumption. Hazards related to utilization of contaminated food items have increased manifolds [11, 12]. Pollution by trace metals is owed to usage of industrial wastewater, automobiles, organic substances used for enhancing plant growth, pesticides and harvesting processes [13, 14]. The food components absorb trace metals from land polluted with wastewater [15, 16]. By observing the possible hazards of trace metals, their constant life and the regular use of contaminated vegetables, the matter of concern is to examine the toxic levels in food items to protect humans from health hazards [17, 18].

The main objective of the present research, therefore, was to determine the concentration of chromium and cobalt in vegetables grown at the areas which were usually irrigated with canal water and wastewater. The soil was also observed for its metal content at two sites i.e. site I, where canal water was used for irrigation and site II, where industrial wastewater was used. Moreover, fitness of these vegetables for human consumption was evaluated.

Materials and methods

Study area

The present research was performed in an urban area of Sargodha, Punjab, Pakistan. This city has tolerable winter season and warm temperature in months from May to July. The temperature differs from 25 to 50 °C in the summer. The main production of this city is citrus fruit. Areas irrigated with sewage and canal water in Sargodha were selected for this study. The land used in agriculture is saline in nature. Mostly the areas surrounding Sargodha are irrigated with the industrial wastewater. Two sites were selected for study i.e. site I, where canal water was used for irrigation and site II, where industrial sewage water was used.

Sample preparation

In this study, *Raphanus sativus* L. (roots), *Brassica rapa* L. (roots), *Zingiber officinale* Roscoe (roots), *Capsicum baccatum* L. (fruit), *Capsicum frutescens* L. (fruit), *Capsicum annuum* L. (fruit), *Solanum lycopersicum* L. (fruit) and *Curcuma longa* L. (rhizome) were chosen as vegetable samples. All these samples were collected at maturity.

Wet digestion process

The procedure for sample arrangement and preparation involved the wet digestion process. This process involved following steps: Firstly, complete digestion of samples was done by using acid and hydrogen per oxide. After digestion, the samples were diluted with distilled water and filtered through Whatman filter paper. Wet digestion breaks down organic components found in plant tissue into CO_2 by strong reducing agents. After the wet digestion process, a colourless transparent and clear solution is obtained.

Firstly, soil was weighed, and 1 g sample was added in flask with 20 ml of nitric acid and 10ml of hydrogen per oxide to be eventually placed on hot plate for heating till boiling. After removing the sample from hot plate, the sample was allowed to cool down. Samples were then filtered and put in clean plastic bottles till futher use after making volume upto 50 ml by adding distilled water.

For plants, the parts were first converted into powdered form and then dried completely in oven for 24 h. The samples were then added to the digestion flask with hydrochloric acid and nitric acid in 1:3 ratio. Hotplate boiling was done till achieving transparent solution which was allowed to cool. The volume of the solution was made 50 mL ater filtration through Whatman filter paper. The bottles were labelled and stored till further use**.**

Chromium and cobalt analysis

The analysis of heavy metals requires the formulation of specific standard solution for the heavy metals that are under research. Before starting the analysis of Cr and Co, the formulation of the standard solution was done. After formulation of specific standard solution, the heavy metal analysis done with atomic absorption spectrophotometer (AAS-6300 Shimadzu Japan).

Preparation of the standard solution

Statistical analysis

Among different plants (crops) and soil samples, the degree of variation was measured by using SPSS 22 (Statistical Package for Social Sciences). To measure the mean concentration values for soil and food crop samples, one-way ANOVA was conducted.

Daily intake of metals (DIM)

The normal value of DIM is 0.242 kg with standard human mean weight of 55.9 kg. It is defined as the amount calculated to the intake of trace metals orally which was obtained by formula given by Sajjad et al. [19].

DIM = (Concentrations of metal) x Daily consumption of vegetable (kg per person)/Average body weight of a person

Pollution load index (PLI)

The presence of heavy metals in soil was assessed by this factor. By relating the amount of trace element in the polluted soil under consideration with reference to the amount of the same trace element as mentioned by the reference value of that element in soil, PLI is measured [20]. It is calculated by following formula:

PLI= metal concentrations in soils/metal concentration taken as reference

Health risk index (HRI)

Health risk index is calculated relative to DIM value and relative dose (RfD). The formula described by Cui *et al.* [20] is used to measure the relative measurement of HRI.

HRI= DIM/ food oral reference dose for the metal

Bio-concentration factor (BCF)

The concentration of a substance in the tissue of organism is called bio-concentration factor

(BCF). It is also known as enrichment factor or biomagnification factor. It is measured by the following formula:

BCF = Vegetable metals/Soil metals

Results and discussion

Chromium and cobalt concentrations in soil samples

The mean Cr concentration in soil varied from 0.9 to 1.80 mg/kg. Higher Cr values in soil were observed during sewage water irrigation and lower values were found in canal water irrigation. The ANOVA results showed that the irrigation water had significant effect ($p \le 0.05$) on the Cr concentration in soil (Table 1). The mean Co concentration in soil ranged from 0.575 to 1.10 mg/kg. Higher Co values in soil were observed during sewage water irrigation. The ANOVA results showed that the irrigation water had significant effect ($p \le 0.05$) on the Co concentration in soil (Table 1).

Soil serves as the most central component in agricultural environment and contents of heavy metals and various other minerals in soil determine the accretion of heavy metal in plant body. In the present study, the mean Cr concentration in soil ranged between 0.9-1.80 mg/kg. The Cr levels in the soil samples investigated in the present research were lower than the maximum permissible limit of Cr (100 mg/kg) reported by WHO [21]. The present Cr concentrations in soils were also lower than the values obtained by Haiyan and Stuanes [22] who found Cr concentration to be approximately 108 (µg/g DW). According to Gupta et al. [23], level of Cr in soil elevate through application of wastewater. The concentration of Co in soil fell within the permissible limit of 100 mg/kg given by FAO/WHO [24]. Cobalt content in the current research was higher than the findings of Ahmad et al. [12].

Chromium concentration in vegetable samples

In the present study, the mean Cr concentrations (mg/kg) ranged from 0.303-0.600 (*R. sativus*), 0.110-0.216 (*B. rapa*), 0.241-0.470 (*Z. officinale*), 0.196-0.393 (*C. baccatum*), 0.144-0.288 (*C. frutescens*), 0.190-0.378 (*C. annuum*), 0.221-10.428 (*S. lycopersicum*) and 0.250-0.525 (*C. longa*) (Table 1). Higher Cr values were observed in *S. lycopersicum* irrigated with sewage water and lower Cr contents were noticed in *B. rapa* irrigated with canal water. According to the ANOVA results the irrigation water had significant effect ($p \le 0.05$) on the Cr concentrations in *R. sativus*, *B. rapa*, *Z. officinale*, *C. frutescens*, *C. annuum* and *C. longa* whereas non-significant effect ($p>0.05$) was noticed in *C. baccatum* and *S. lycopersicum* (Table 1).

The Cr levels in the vegetable samples investigated in the present research were lower than the maximum permissible limit of 50 mg/kg reported by Chiroma *et al.* [25]. The investigated values of Cr were also lower than the study conducted by Nagajyoti *et al.* [26] who found Cr concentration in five leafy vegetables ranging from 0.89 to 1.08 (µg/g) except for *S. lycopersicum*. Haiyan and Stuanes [22] reported that the Cr content in the vegetables grown in controlled area ranged from 0.4 to 2.7 (µg/g of dw). The total Cr levels in edible portions of vegetables were similar to the values found in presumably less contaminated areas, such as Jiangsu, China (0.67 mg/kg) [27] and Brazil (0.01-0.6 mg/kg) [28]. Higher concentrations of total Cr in China region may be expected due to the mass production of refractory materials in Changxing county, especially in where there are many refractory factories [27].

Anwanghe *et al.* [29] reported Cr values (0.06-0.14 mg/kg; 0.02-0.44 mg/kg) in vegetables that were in accordance with the present research. Difference could be attributed to change in climate or season or other environmental factors. The EU Standards for the metal in soils and vegetables are 150 and 0.3 mg/kg, respectively. Chromium does not apparently pose a health threat in the farm soils and vegetables.

In different vegetables the mean Co concentrations (mg/kg) ranged between 0.106-0.211 (*R. sativus*), 0.096-0.195 (*B. rapa*), 0.078-0.155 (*Z. officinale*), 0.060-0.120 (*C. baccatum*), 0.060-0.120 (*C. frutescens*), 0.094-0.186 (*C. annuum*), 0.119-0.236 (*S. lycopersicum*) and 0.158-0.311 (*C. longa*) (Table 1). Higher Co values were observed in *S. lycopersicum* irrigated with sewage water and lower Co contents were noticed in *C. baccatum* irrigated with canal water. According to the ANOVA results, the irrigation water had significant effect ($p \leq 0.05$) on the Co contents in *R. sativus, Z. officinale, C. frutescens, C. annuum, S. lycopersicum* and *C. longa* while non-significant effect ($p>0.05$) was observed in *B. rapa* and *C. baccatum* (Table 1).

Cobalt is a basic component of vitamin-B12. It is essential in synthesis of red blood cells and prevents anemia. Too much intake of cobalt may cause overproduction of red blood cells [30]. The Co content in vegetables samples was found within the allowable limit of 50 mg/kg suggested by FAO/WHO [24]. Cobalt content in all vegetables was similar to the range of 0.02-0.22 mg/kg given by Ahmad *et al.* [12].

Bioconcentration factor

The BCF values of Cr and Co in various vegetables are presented in (Table 2). In different vegetables, the BCF values of Cr differed from 0.333 to 0.336 (*R. sativus*), 0.120-0.122 (*B. rapa*), 0.261-0.268 (*Z. officinale*), 0.218-0.218 (*C. baccatum*), 0.160-0.160 (*C. frutescens*), 0.210-0.211 (*C. annuum*), 0.238-0.246 (*S. lycopersicum*) and 0.278-0.292 (*C. longa*). High BCF values were recorded for *R. sativus* in canal water irrigation. On the other hand, the BCF values of Co differed from 0.185 to 0.192 (*R. sativus*), 0.167 to 0.177 (*B. rapa*), 0.135 to 0.141 (*Z. officinale*), 0.104 to 0.109 (*C. baccatum*), 0.104 to 0.109 (*C. frutescens*), 0.163 to 0.169 (*C. annuum*), 0.207 to 0.215 (*S. lycopersicum*) and 0.274 to 0.283 (*C. longa*). Higher BCF values were recorded for *C. baccatum* in canal water irrigation and lower Co values were found in *C. longa* by sewage water irrigation.

When the BCF is ≤1, this presents that the plant only absorbs but does not build up heavy metals; when BCF>1, this shows that plant gathers metals in it [31]. BCF values of heavy metals were less than 1 in all vegetables for Cr and Co, and these results specify that metal bioavailability was low at CWI and SWI sites.

Daily intake of metal and health risk index

The DIM values for Cr and Co are presented in (Table 3). Among two irrigations, the DIM values for Cr were 0.0017-0.0023 (*R. sativus L.*), 0.0006-0.0008 (*B. rapa*), 0.0014-0.0018 (*Z. officinale*), 0.0011-0.0015 (*C. baccatum*), 0.0008-0.0011 (*C. frutescens*), 0.0011-0.0014 (*C. annuum*), 0.0013-0.0016 (*S. lycopersicum*) and 0.0014-0.0020 (*C. longa*). In all vegetables, the DIM values for Cr were higher during sewage water irrigation compared to canal water irrigation. On the other hand, the DIM values for Co were 0.0006-0.0012 (*R. sativus*), 0.0006-0.0011 (*B. rapa*), 0.0004-0.0011 (*Z. officinale*), 0.0003-0.0007 (*C. baccatum*), 0.0003-0.0007 (*C. frutescens*), 0.0005-0.0011 (*C. annuum*), 0.0007-0.0013 (*S. lycopersicum*) and 0.0009-0.0018 (*C. longa*). In all vegetables, the DIM values for Co were higher in sewage water irrigation compared to canal water irrigation. Daily intake of metal for Cr and Co in present findings was found within the similar range given by Ahmad *et al*. [12].

The results revealed that HRI of Cr and Co was less than 1 in each vegetable which was below the permissible limit. To determine the health risk associated with heavy metal contamination of plants grown locally, estimated exposure and risk index were calculated. In all vegetables, the HRI values for Cr and Co were higher in sewage water irrigation compared to canal water irrigation (Table 3). In the present study, the HRI values of Cr and Co fell under the safe limit of HRI and were considered fit for human consumption. The present study results were relatively identical to the observations of Zhuang *et al.* [32].

Pollution load index

Values of PLI for Cr and Co of two study sites are given in Table 4. The PLI values of Cr in soil samples were 0.0140 and 0.0280 for CWI and SWI treatments, respectively. On the other hand, the PLI values of Co for soil samples were 0.1099 and 0.2103 for CWI and SWI treatments, respectively. Contamination level in soil can be explored using PLI. This index provides a simple and comparative means for assessing the quality of different combinations of water irrigation. As described by Tomlinson *et al.* [33], a value of zero indicates no risk, whereas a value of one and values above one would indicate progressive deterioration of the site irrigated with this water quality.

Table 1. Analysis of variance and mean values of chromium and cobalt (mg/kg) in soil and vegetables treated with canal and sewage water

	Chromium			Cobalt		
	Mean ± S.E.		Mean Square	Mean ± S.E.		Mean Square
	CWI	SWI		CWI	SWI	
Soil	0.900±0.198	1.800±0.063	9.720*	0.575±0.066	1.100±0.132	12.600**
R. sativus	0.303±0.075	0.600±0.227	0.177*	0.106±0.002	0.211±0.005	341.419***
B. rapa	0.110±0.184	0.216±0.198	7.375*	0.096±0.031	0.195±0.060	2.127^{ns}
Z. officinale	0.241±0.113	0.470±0.227	42.074**	0.078±0.017	0.155±0.018	15.584**
C. baccatum	0.196±0.063	0.393±0.075	2.928^{ns}	0.060±0.014	0.120±0.027	3.840^{ns}
C. frutescens	0.144±0.126	0.288±0.126	39.089**	0.060±0.005	0.120±0.011	24.686*
C. annuum	0.190±0.075	0.378±0.184	16.892*	0.094±0.013	0.186±0.025	10.654*
S. lycopersicum	0.221±0.198	0.428±0.113	17.947^{ns}	0.119±0.013	0.236±0.025	17.191*
C. longa	0.250±0.184	0.525±0.063	7.118*	0.158±0.003	0.311±0.005	639.254***

*, **, ***= significant at 0.05, 0.01 and 0.001 levels, ns = non-significant

Table 2. Bio-concentration factor for vegetable/soil system for chromium and cobalt

Vegetables	Chromium		Cobalt	
	CWI	SWI	CWI	SWI
R. sativus	0.336	0.333	0.185	0.192
B. rapa	0.122	0.120	0.167	0.177
Z. officinale	0.268	0.261	0.135	0.141
C. baccatum	0.218	0.218	0.104	0.109
C. frutescens	0.160	0.160	0.104	0.109
C. annuum	0.211	0.210	0.163	0.169
S. lycopersicum	0.246	0.238	0.207	0.215
C. longa	0.278	0.292	0.274	0.283

Table 3. Daily intake of metals and health risk index of chromium and cobalt contents via intake of different vegetables from canal and sewage wastewater irrigated sites

Vegetables	Chromium		Cobalt		Chromium		Cobalt	
	Daily intake of metal				Health risk index			
	CWI	SWI	CWI	SWI	CWI	SWI	CWI	SWI
R. sativus	0.0017	0.0023	0.0011	0.0023	0.0006	0.0012	0.0140	0.0280
B. rapa	0.0006	0.0008	0.0004	0.0008	0.0006	0.0011	0.0127	0.0258
Z. officinale	0.0014	0.0018	0.0009	0.0018	0.0004	0.0009	0.0103	0.0205
C. baccatum	0.0011	0.0015	0.0007	0.0015	0.0003	0.0007	0.0079	0.0159
C. frutescens	0.0008	0.0011	0.0005	0.0011	0.0003	0.0007	0.0079	0.0159
C. annuum	0.0011	0.0014	0.0007	0.0014	0.0005	0.0011	0.0124	0.0247
S. lycopersicum	0.0013	0.0016	0.0008	0.0016	0.0007	0.0013	0.0157	0.0313
C. longa	0.0014	0.0020	0.0009	0.0020	0.0009	0.0018	0.0208	0.0412

Table 4. Pollution load index for chromium and cobalt in soil

Sites	Chromium		Cobalt	
	Reference soil value	PLI	Reference soil value	PLI
CWI	9.07	0.0140	9.1	0.1099
SWI	9.07	0.0280	9.1	0.2103

Source[a] = Singh et al. [31], Source[b] = Dutch standards [34]

Conclusion
Scarcity of fresh water resources has diverted the attention of famers towards the use of sewage water to get optimum yield of crops. Sewage water contains surplus amount of toxic metals and essential plant nutrients. The results of current work revealed that the levels of Cr and Co in all vegetables were within the acceptable limits given by FAO/WHO. The bio-concentration factor and HRI for Cr and Co was less than 1 indicating safe consumption of vegetables. Supporting the findings of this study with new data will be useful for the health of the people living in the region.

Authors' contributions
Conceived and designed the experiments: ZI Khan, I Ugulu, K Ahmad & IR Noorka, Performed the experiments: A Nisar, H Bashir, M Munir, F Shaheen, A Ashfaq, R Abdullah, S Iqbal & F Batool, Analyzed the data: K Wajid, M Nadeem, TM Qureshi & IS Malik, Contributed reagents/ materials/ analysis tools: K Nawaz, MJZ Rasheed, A Hussain, H Memona, M Shehzadi & M Sana, Wrote the paper: N Mehmood, F Arshad, S Akhtar, T Abbas, S Ullah, H Muqadas & S Siddique.

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