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APPRAISAL OF HEAVY METAL CONTENTS IN DIFFERENT VEGETABLES GROWN IN THE VICINITY OF AN INDUSTRIAL AREA

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Abstract

The contents of lead (Pb), copper (Cu), chromium (Cr), zinc (Zn) and cadmium (Cd) in various leafy vegetables viz., spinach, coriander, lettuce, radish, cabbage and cauliflower grown in an effluent irrigated fields in the vicinity of an industrial area of Faisalabad, Pakistan were assessed using atomic absorption spectrophotometer. The concentrations of Pb, Cu, Cr, Zn and Cd in the leaves, stems and roots of spinach, coriander, lettuce, radish, cabbage and cauliflower were found to be 1.1331–2.652, 1.313-2.161, 1.121-2.254; 0.252-0.923, 0.161-0.855, 0.221-0.931; 0.217-0.546, 0.376-0.495, 0.338-0.511; 0.461-1.893, 0.361-0.874, 0.442-1.637; 0.033-0.073, 0.017-0.061, 0.011-0.052 mg kg^{-1} on dry matter basis, respectively. The contents of Cu, Zn, Cr, Pb and Cd were below the recommended maximum acceptable levels proposed by the Joint FAO/WHO Expert Committee on Food Additives. The leaves of spinach, cabbage, cauliflower, radish and coriander contained higher concentrations of Cu (0.923 mg kg^{-1}), Cd (0.073 mg kg^{-1}), Cr (0.546 mg kg^{-1}), Zn (1.893 mg kg^{-1}) and Pb (2.652 mg kg^{-1}) as compared to other parts of each vegetable. High concentrations of heavy metals as analyzed in the present analysis of different parts of the vegetables might be related to their concentration in the soils irrigated with industrial waste water.

Introduction

Wastewater irrigation is known to contribute significantly to the heavy metal contents of soils (Mapanda *et al*., 2005). Although problems occur in waterways when pollutants are leached out of the soil. If the plants die and decay, heavy metals taken into the plants are redistributed, so the soil is enriched with the pollutants. Uptake and accumulation of elements by plants may follow two different paths i.e., through the roots and foliar surface (Sawidis *et al*., 2001). The uptake of metals from the soil depends on different factors such as their soluble content in it, soil pH, plant growth stages types of species, fertilizers and soil (Sharma *et al*., 2006; Ismail, *et al*., 2005). Plant species have a variety of capacities in removing and accumulating heavy metals, so there are reports indicating that some species may accumulate specific heavy metals, causing a serious health risk to human health when plants based food stuff are consumed (Wenzel & Jackwer, 1999).

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. 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 (Singh *et al*., 2004). As a result, it leads to contamination of the food chain, because vegetables absorb heavy metals from the soil polluted air and water. One important dietary uptake pathway could be through crops irrigated with contaminated wastewater. Heavy metals are not easily biodegradable and consequently can be accumulated in human vital organs. This situation causes varying degrees of illness based on acute and chronic exposures (Demirezen & Ahmet, 2006).

Vegetables are an important part of human's diet. In addition to a potential source of important nutrients, vegetables constitute important functional food components by contributing protein, vitamins, iron and calcium which have marked health effects (Arai, 2002). Vegetables, especially those of leafy vegetables grown in heavy metals contaminated soils, accumulate higher amounts of metals than those grown in uncontaminated soils because of the fact that they absorb these metals through their leaves (Al Jassir *et al*., 2005). Demirezen & Ahmet (2006) investigated the concentrations of heavy metals such as Cd, lead (Pb), Zinc (Zn), Cu and Ni in different vegetables, grown in various parts of Turkey. The levels of heavy metals (lead, cadmium, copper and zinc) were examined in selected fruits and vegetables sold in the local markets of Egypt (Radwan & Salama, 2006). Fytianos *et al*., (2001) studied the contents of heavy metals in vegetables grown in an industrial area of North Greece.

The present study was carried out around industrial areas of Faisalabad, Pakistan, where irrigation of vegetable crops with wastewater is a very common practice. Knowledge on the contamination of vegetables with heavy metals from industrial areas of Faisalabad is not yet established. Therefore the present study was undertaken with an aim to compare and investigate the concentration of heavy metals (cadmium, lead, zinc, copper and chromium) accumulation potential of the commonly grown leafy vegetables from sites having long-term use of industrial wastewater for irrigation of agricultural land.

Materials and Methods

Collection of samples: The samples of vegetables (spinach, coriander, lettuce, radish, cabbage and cauliflower) were randomly collected from effluent irrigated fields during 2006 in the vicinity of Sheikh Irfan Dying Industries Private Limited, Rehman Pura and ABC Road, Faisalabad, Pakistan. Leafy vegetables were preferred for sampling because previous researches indicate that they accumulate heavy metals at a greater capacity than other vegetables. The varieties of the vegetables collected were made sure. For this purpose, the samples of vegetables were further authenticated from the Department of Botany, University of Agriculture, Faisalabad, Pakistan.

Pretreatment

Washing of samples: The collected vegetable samples were washed with distilled water to remove dust particles. The samples were then cut to separate the roots, stems and leaves using a knife.

Drying of samples: Different parts (roots, stems and leaves) of vegetables were air-dried and then placed in a dehydrator at 80 °C for 2-3 days and then dried in an oven at 100 °C.

Grinding of samples: Dried samples of different parts of vegetables were ground into a fine powder (80 mesh) using a commercial blender (TSK- Westpoint, France) and stored in polyethylene bags, until used for acid digestion.

Heavy metal composition

Preparation of samples / Wet digestion: Duplicate samples (0.5g) of each part (leaves, stems and roots) of each vegetable were weighed in digestion flasks and treated with 5 mL of concentrated HNO_3. A blank sample was prepared applying 5 mL of HNO_3 into empty digestion flask (Sahito *et al*., 2002). The flasks were heated for 2 hours on an electric hot plate (HP 220, UTEC Products Inc., Albany N.Y., USA) at 80-90^oC and then the temperature was raised to 150^oC at which the samples were made to boil. Concentrated HNO_3 and 30% H_2O_2 were further added to the sample (3-5 mL of each was added occasionally) and digestion continued until a clean solution was obtained. After cooling, the solution was filtered with Whatman No. 42 filter paper and <0.45 µm Millipore filter paper. It was then transferred quantitatively to a 25 mL volumetric flask by adding distilled water.

Preparation of standards and analysis of samples: Working standard solutions of lead (Pb), copper (Cu), chromium (Cr), zinc (Zn), cadmium (Cd) were prepared from the stock standard solutions containing 1000 ppm of element in 2N nitric acid. Calibration and measurement of elements were done on atomic absorption spectrophotometer (A Analyst 300, Perkins Elmer, Norwalk, Conn., USA). The calibration curves were prepared for each element individually applying linear correlation by least square method. A blank reading was also taken and necessary correction was made during the calculation of concentration of various elements.

Statistical analysis: Three samples (leaves, stems and roots) of each vegetable were assayed and analyzed individually in triplicate. Data were reported as mean ± SD. One way analysis of variance (ANOVA) was used to determine significant difference between groups, considering a level of significance of less than 5% (p<0.05) by using Minitab 2000 Version 13.2 statistical software (Minitab Inc, Pennsylvania, USA).

Results and Discussion

The mean concentrations of Pb, Cu, Cr, Zn and Cd in different parts (leaves, stem and roots) of vegetables studied are given in Tables 1-3. The concentrations of heavy metals in these samples are quite variable such as Cd (0.011–0.073 mg kg^{-1}), Pb (1.121–2.652 mg kg^{-1}), Cu (0.161–0.923 mg kg^{-1}), Zn (0.361–1.893 mg kg^{-1}) and Ni (0.288–0.546 mg kg^{-1}). The magnitude of heavy metals detected in different kinds of vegetables was Cd < Cu < Cr < Zn <Pb. The cabbage (0.073 mg kg^{-1}) exhibited higher levels of Cd than the other vegetables. In contrast, radish (2.652 mg kg^{-1}) contained the highest levels of Pb, while spinach (0.923 mg kg^{-1}) contained the highest Cu concentration. Furthermore, the concentration of Cr was higher in cauliflower, whereas lettuce revealed greater amount of Zn than the other vegetables.

The results of the present analysis showed that the concentration of Pb in the leaves of spinach, coriander, lettuce, radish, cabbage and cauliflower from the vicinity of industrial areas of Faisalabad, Pakistan were 2.251, 2.652, 2.411, 2.035, 1.921 and 1.331 mg kg^{-1}, respectively (Table 1). Pb contents in the leaves of coriander were significantly (p<0.05) higher as compared to those in the other vegetables, whereas, the leaf samples of cauliflower were found to be significantly (p<0.05) lower in Pb contents. However,

Table 1. Heavy metal concentrations (mg kg^{-1}) in leaves of different vegetables.

Vegetables	Pb	Cu	Cr	Zn	Cd
Spinach	2.251±0.09^{b}	0.923±0.03^{a}	0.217±0.01^{d}	0.461±0.02^{c}	0.035±0.001^{d}
Coriander	2.652±0.04^{a}	0.653±0.06^{b}	0.369±0.04^{c}	0.705±0.04^{b}	0.062±0.004^{b}
Lettuce	2.411±0.08^{b}	0.851±0.03^{a}	0.434±0.01^{b}	0.743±0.02^{a}	0.049±0.002^{d}
Radish	2.035±0.10^{c}	0.273±0.02^{c}	0.288±0.02^{cd}	1.893±0.05^{b}	0.033±0.001^{a}
Cabbage	1.921±0.04^{c}	0.252±0.02^{c}	0.336±0.03^{c}	0.777±0.02^{b}	0.073±0.005^{b}
Cauliflower	1.331±0.04^{d}	0.323±0.01^{c}	0.546±0.06^{a}	0.678±0.05^{b}	0.064±0.003^{c}
Safe Limit [a]	5	40	-	60	0.3

Values are mean ± SD of three samples of leaves of each vegetable, analyzed individually in triplicate.
Mean values in the same column followed by the same superscript letters are not significantly different (p>0.05)
Pb = Lead; Cu = Copper; Cr = Chromium; Zn = Zinc; Cd = Cadmium.
[a] FAO/WHO standard (Codex Alimentarius Commission, 1984).

Table 2. Heavy metal concentrations (mg kg^{-1}) in stems of different vegetables.

Vegetables	Pb	Cu	Cr	Zn	Cd
Spinach	1.193±0.04^{e}	0.529±0.06^{c}	0.492±0.02^{a}	0.361±0.04^{c}	0.061±0.004^{a}
Coriander	1.642±0.02^{c}	0.855±0.03^{a}	0.376±0.03^{c}	0.874±0.03^{a}	0.026±0.002^{b}
Lettuce	1.883±0.02^{b}	0.751±0.02^{b}	0.495±0.02^{a}	0.498±0.02^{b}	0.015±0.001^{c}
Radish	2.161±0.03^{a}	0.346±0.04^{d}	0.386±0.02^{bc}	0.813±0.03^{a}	0.017±0.001^{c}
Cabbage	1.624±0.02^{c}	0.161±0.01^{e}	0.426±0.01^{b}	0.539±0.05^{b}	0.023±0.002^{b}
Cauliflower	1.313±0.01^{d}	0.207±0.02^{e}	0.386±0.02^{bc}	0.456±0.02^{b}	0.025±0.002^{b}
Safe Limit [a]	5	40	-	60	0.3

Values are mean ± SD of three samples of stems of each vegetable, analyzed individually in triplicate.
Mean values in the same column followed by the same superscript letters are not significantly different (p>0.05)
Pb = Lead; Cu = Copper; Cr = Chromium; Zn = Zinc; Cd = Cadmium.
[a] FAO/WHO standard (Codex Alimentarius Commission, 1984).

Table 3. Heavy metal concentrations (mg kg^{-1}) in roots of different vegetables.

Vegetables	Pb	Cu	Cr	Zn	Cd
Spinach	1.121±0.02^{d}	0.391±0.04^{b}	0.511±0.04^{a}	0.781±0.02^{b}	0.052±0.003^{a}
Coriander	1.531±0.05^{c}	0.931±0.05^{a}	0.502±0.04^{a}	0.745±0.02^{b}	0.026±0.002^{b}
Lettuce	1.854±0.06^{b}	0.352±0.04^{b}	0.511±0.04^{a}	1.637±0.03^{a}	0.015±0.001^{c}
Radish	2.254±0.09^{a}	0.462±0.03^{b}	0.489±0.02^{a}	0.813±0.04^{b}	0.051±0.003^{a}
Cabbage	1.152±0.04^{d}	0.361±0.02^{b}	0.543±0.04^{a}	0.442±0.02^{d}	0.013±0.001^{c}
Cauliflower	1.222±0.03^{d}	0.221±0.01^{c}	0.338±0.01^{b}	0.564±0.05^{c}	0.011±0.001^{c}
Safe Limit [a]	5	40	-	60	0.3

Values are mean ± SD of three samples of roots of each vegetable, analyzed individually in triplicate.
Mean values in the same column followed by the same superscript letters are not significantly different (p>0.05)
Pb = Lead; Cu = Copper; Cr = Chromium; Zn = Zinc; Cd = Cadmium.
[a] FAO/WHO standard (Codex Alimentarius Commission, 1984).

there was no significant (p>0.05) variation in the level of Pb in the leaves of spinach and lettuce. Stems of spinach, coriander, lettuce, radish, cabbage and cauliflower contained 1.193, 1.642, 1.883, 2.161, 1.624 and 1.313 mg kg^{-1}, respectively (Table 2). Higher level of Pb was determined in radish stems, whereas considerably (p<0.05) lower amount of Pb was found in spinach stems, but no considerable difference of Pb although concentration was observed in the leaves of coriander and cabbage (p>0.05). The roots of spinach, coriander, lettuce, radish, cabbage and cauliflower contained 1.121, 1.531, 1.854, 2.254, 1.152 and 1.222 mg kg^{-1} of Pb contents respectively (Table 3). Significantly (p<0.05) higher contents of Pb were found in radish roots, but lower were found in the spinach roots. However, there was no significant (p>0.05) difference in the roots of cabbage and cauliflower with regard to Pb contents. The amount of Pb in the leaves of different vegetables was higher as compared to those in the other investigated parts. One possible explanation of this situation is that the Pb uptake can be promoted by the pH of soil and the levels of organic matter. Demirezen & Ahmet (2006) analyzed different samples of vegetables and reported a high concentration (3.0-10.7 mg kg^{-1}) of Pb which poses health risks to human life. In another study, Sharma *et al*., (2006) investigated that concentration of Pb (17.54-25.00 mg kg^{-1}) in vegetables grown in wastewater industrial areas were above the safe limit (2.5 mg kg^{-1}). Muchuweti *et al*., (2006) reported the level of Pb (6.77 mg kg^{-1}) in vegetables irrigated with mixtures of wastewater and sewage from Zimbabwe to be higher than WHO safe limit (2 mg kg^{-1}). Fytianos *et al*., (2001) examined a high concentration of Pb in spinach grown in industrial and rural areas of Greece. Al Jassir, *et al*., (2005) studied 6 washed and unwashed green leafy vegetables from Saudi Arabia and noted the highest concentrations of Pb in the coriander (0.171 mg kg^{-1}) and purslane (0.226 mg kg^{-1}).

The amounts of Cu in the samples of spinach, coriander, lettuce, radish, cabbage and cauliflower leaves was accounted for 0.923, 0.653, 0.851, 0.273, 0.252, 0.323 mg kg^{-1}, respectively (Table 1). Significantly (p<0.05) higher level of Cu was noted in the spinach leaves and the lowest in the cabbage leaves. However, concentration of Cu in the leaves of radish, cabbage and cauliflower did not vary significantly (p>0.05). Samples of vegetable viz., spinach, coriander, lettuce, radish, cabbage and cauliflower stems contained Cu 0.529, 0.855, 0.751, 0.341, 0.161 and 0.207 mg kg^{-1}, respectively (Table 2). Stem samples of coriander were significantly (p<0.05) higher in Cu contents, while those samples of cabbage were found to be significantly (p<0.05) lower. The roots of spinach, coriander, lettuce, radish, cabbage and cauliflower contained 0.391, 0.931, 0.352, 0.462, 0.361 and 0.221 mg kg^{-1} of Cu concentration respectively (Table 3). A significantly (p<0.05) higher content of Cu was analyzed in coriander roots, but lower (p<0.05) amount of Cu was found in cauliflower roots. However, there were no significant (p>0.05) differences in the amount of Cu of the roots of spinach, lettuce, radish and cabbage. It was found that heavy metals accumulated more in roots and leaves than those in other parts because both are the entry points of heavy metals from soils and air, respectively. Demirezen & Ahmet (2006) reported that levels of Cu (22.19-76.50 mg kg^{-1}) were higher in the leafy species than the non-leafy vegetable species from Turkey. This may be related to the richness in chlorophyll. Sharma *et al*., (2006) reported the concentration of Cu (2.25-5.42 mg kg^{-1}) in vegetables grown in wastewater areas of Varanasi, India to be within the safe limit. Singh *et al*., (2001) analyzed 6 leafy vegetables from India and reported that copper contents were higher in spinach. Tandi *et al*., (2005) also reported a higher uptake of Cu in lettuce and mustard rape and pointed out that leafy vegetables produced around industrial sites pose a health risk to poor communities, especially to children. Furthermore, Radwan & Salama (2006) carried out a survey of various fruits and vegetables in Egypt and noted that the highest levels of Pb, Cd, Cu and zinc were present in strawberries, cucumber, dates and spinach, respectively. Fytianos *et al*., (2001) analyzed different vegetables from industrial and rural areas of Greece and reported no significant differences in the concentration of metals in most of the vegetables analyzed. Our study revealed that although all the vegetable parts accumulated Cu below the critical level (10.00 mg kg^{-1}, WHO), the concentration was very high in spinach leaves (0.923 mg kg^{-1}).

Chromium concentration in the leaves of spinach, coriander, lettuce, radish, cabbage and cauliflower leaves was 0.217, 0.369, 0.434, 0.288, 0.336 and 0.546 mg kg^{-1}, respectively (Table 1). Leaves of cauliflower were found to be significantly (p<0.05) higher in Cr content, whereas those of spinach contained less amount of Cr. However, there was no significant (p>0.05) variation in the content of Cr between the leaves of cabbage and coriander. Samples of spinach, coriander, lettuce, radish, cabbage and cauliflower stems from the vicinity of industrial areas of Faisalabad, Pakistan accounted 0.492, 0.376, 0.495, 0.386, 0.426 and 0.386 mg $kg^{-1}$of Cr contents respectively (Table 2). Cr content of the lettuce stems was significantly (p<0.05) higher as compared to that in other vegetables. However, the samples of the coriander stems were found to be significantly (p<0.05) lower in their Cr contents, whereas no significant (p>0.05) difference was observed in the stems of spinach and lettuce. Roots of different vegetables i.e. spinach, coriander, lettuce, radish, cabbage and cauliflower contained 0.511, 0.502, 0.511, 0.489, 0.543 and 0.338 mg kg^{-1} of Cr, respectively (Table 3). Maximum concentration was determined in the cabbage roots, whereas significantly (p<0.05) lower amount of Cr was found in the cauliflower roots. However, there was no significant (p>0.05) difference among the roots of spinach, coriander, lettuce, radish and cabbage with respect to Cr content. Sharma *et al*., (2006) studied the heavy metal contents in different vegetables grown in the lands irrigated by wastewater and noted the concentration of Cr to be with in the safe limits. During the investigations of trace metals in leafy vegetables grown in Addis Ababa, Itanna (2002) examined that cabbage was the least accumulator of Cr. Our present study showed the radish leaves and cauliflower leaves to be the least and highest accumulator of Cr, respectively. However, it was noted that chromium concentrations in all the cases were under permissible limits (1.30 mg kg^{-1}, WHO).

The amount of Zn in the samples of leaves of different vegetables i.e., spinach, coriander, lettuce, radish, cabbage and cauliflower was found to be 0.461, 0.705, 0.743, 1.893, 0.777 and 0.678 mg kg^{-1}, respectively (Table 1). Leaves of radish were found to be significantly (p<0.05) higher in zinc content, while low amount of Zn was present in the leaves of spinach. However, there was no significant (p>0.05) difference in the concentration among the leaves of coriander, radish and cabbage. Samples of spinach, coriander, lettuce, radish, cabbage and cauliflower stems from the vicinity of industrial areas of Faisalabad accounted for 0.361, 0.874, 0.498, 0.813, 0.539 and 0.456 mg kg^{-1} of Zn, respectively (Table 2). Samples of coriander stems were appreciably (p<0.05) higher in their Zn contents, whereas spinach stems contained appreciably (p<0.05) low amount of Zn. There were no significant (p>0.05) differences observed among stems of lettuce, cabbage and cauliflower with regards to the Zn levels. The roots of spinach, coriander, lettuce, radish, cabbage and cauliflower contained 0.78, 0.74, 1.637, 0.813, 0.442 and 0.546 mg $kg^{-1}$of Zn, respectively (Table 3). The highest concentration of Zn was in the samples of lettuce roots, whereas the lowest amount of zinc was observed in the cabbage roots. However, there was no significant (p>0.05) difference in the level of Zn among samples of roots of spinach, radish and coriander. Singh *et al*., (2001) analyzed six and Itanna (2002) three green leafy vegetables respectively and both reported higher concentration of Zn in spinach. Demirezen & Ahmet (2006) analyzed various vegetables (cucumber, tomato, green pepper, lettuce, parsley, onion, bean, eggplant, pepper mint, pumpkin and okra) and reported that the Zn concentration (3.56–4.592 mg kg^{-1}) was within the recommended international standards. Fytianos *et al*., (2001) also reported a significant uptake of Zn in spinach and endive produced around industrial areas of Greece. Furthermore, Radwan & Salama (2006) carried out a survey of various fruits and vegetables in Egypt and were able to conclude that the highest mean levels of Pb, Cd, Cu and Zn were present in strawberries, cucumber, dates and spinach, respectively. Al Jassir *et al*., (2005) reported the levels of Zn to be higher in the purslane vegetable species for both washed and unwashed samples. Analysis of the vegetables from an industrial area in our present study demonstrated the concentration of Zn to be within the set limits of international standards (5.00 mg kg^{-1}, WHO, 1996). Overall, the radish leaves were higher accumulator and spinach stems the least accumulator of Zn.

Small amounts of cadmium were also estimated in the leaves, stems and roots of different vegetables. The contents of cadmium in the leaves of spinach, coriander, lettuce, radish, cabbage and cauliflower were found to be 0.035, 0.062, 0.049, 0.033, 0.073 and 0.064 mg kg^{-1}, respectively (Table 1). A significantly ($p<0.05$) higher amount of cadmium was found in the samples of cabbage leaves, while lower ($p<0.05$) in the radish leaves. However, there was no significant ($p>0.05$) difference between the leaves of spinach and lettuce with regard to Cd content. Samples of stems of spinach, coriander, lettuce, radish, cabbage and cauliflower contained 0.061, 0.026, 0.015, 0.017, 0.023 and 0.025 mg kg^{-1} of Cd, respectively (Table 2). Amount of Cd in the spinach stems was significantly ($p<0.05$) high, while in cabbage stem it was considerably low. However, there was no significant ($p>0.05$) difference observed within the stems of coriander, cabbage and cauliflower. The roots samples of spinach, coriander, lettuce, radish, cabbage and cauliflower contained 0.052, 0.026, 0.015, 0.051, 0.013 and 0.011 of mg $kg^{-1}$of Cd, respectively (Table 3). Samples of spinach roots were found to be significantly ($p<0.05$) higher in Cd while, the samples of cauliflower roots contained considerably ($p<0.05$) lower amount of Cd. However, Cd concentration in the roots of lettuce, coriander and cauliflower did not vary significantly ($p<0.05$). Demirezen & Ahmet (2006) analyzed various vegetables (cucumber, tomato, green pepper, lettuce, parsley, onion, bean, eggplant, pepper mint, pumpkin and okra) from Turkey and reported that the Cd content (0.24–0.97 mg kg^{-1}) was in higher concentration and not suitable for human consumption. Its highest concentration (0.073 mg kg^{-1}) was determined in cabbage leaves. Fytianos *et al.*, (2001) reported that spinach and lettuce grown in the soil of industrial area of Greece are enriched in Cd. Al Jassir *et al*., (2005) reported that levels of Cd were higher in the garden rocket vegetable species for both washed and unwashed samples. In our study, concentration of Cd was noted to be above the critical level of 0.01 mg kg^{-1} as reported by WHO and thus might be a threat for the consumers.

Conclusion

The results from this study suggested that significant differences existed in the elemental concentrations among the vegetables analyzed that might be in due part to the geological status of the area under investigation and the ability of plants and their specific parts to accumulate metals as well. The present study revealed that Pb and Cd were above the toxicity level in leafy vegetables grown in the vicinity of an industrial area of Faisalabad, whereas other heavy metals (Zn, Cu and Cr) were within the permissible limits. From the results of present investigations, it could be concluded that in the vicinity of industrial areas, the uptake of certain toxic and heavy metals by the vegetables may increase and thus a risk factor for consumption of such vegetables.

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