Research Article

Mohammad Kazem Souri*, Neda Alipanahi, Mansoure Hatamian, Mohammad Ahmadi, Tsehaye Tesfamariam

Elemental Profile of Heavy Metals in Garden cress, Coriander, Lettuce and Spinach, Commonly Cultivated in Kahrizak, South of Tehran- Iran

Abstract: Heavy metal accumulation in vegetable tissues often poses a great risk for human health. In the present study, accumulation of heavy metal in green leafy vegetable crops of coriander, garden cress, lettuce and spinach were evaluated under waste water irrigation in fields located in Kahrizak, on the southern edge of the metropolitan city of Tehran, Iran. Atomic absorption spectrophotometry was used for determination of heavy metal concentrations in leaf tissue. The results showed that heavy metal concentrations in soil and irrigation water were significantly high than allowable levels. Analysis of plant leaf tissue showed that spinach and garden cress accumulated higher concentrations of heavy metals compared to coriander and lettuce plants. Central leaves of lettuce showed the lowest heavy metal concentration compared to outer leaves or leaves of other vegetable crops, and can be the safer product for fresh consumption. The results indicate that the vegetables produced in the region are not suitable for fresh consumption and the agricultural activities should change towards ornamental or industrial crops production.

Keywords: contamination, food quality, pollution, toxic elements, vegetable crops

1 Introduction

Vegetable crops are the major source of minerals, vitamins, antioxidants and many other beneficial food nutrients in human nutrition. On the other hand, leafy vegetables are more susceptible to contamination with higher dosage of heavy metals or other toxins (Naiji and Souri, 2014). Contaminated leafy vegetables can pose a serious risk to human health; greater than their beneficial effects. So, healthy production of leafy vegetable crops is very important, a quality that organic farming tries to improve.

Heavy metals are among the most dangerous toxins in the environment, especially in agricultural soils. Industrial activities and various factories have contributed to boosting heavy metal contamination of environmental resources. Reports indicate that their environmental abundance and bioavailability were found to increase to a hazardous threshold (Gyekye 2013; Sharma et al. 2008; Girisha and Ragavendra 2006). Agricultural lands were also affected particularly in arid and semi-arid regions, mainly due to application of wastewater as an irrigation source (Souri 2016; Gupta et al. 2010; Li et al. 2010).

Industrial activities generally generate huge amounts of wastewater that contain a range of heavy metals and other toxic substances (Tiwari et al. 2011). Due to marketing issues, production of vegetable crops is a common practice in suburb of cities in Iran (Naiji and Souri 2014) and other parts of the world (Smith 2009; Girisha and Ragavendra 2006), in which waste water is used as the main irrigation source. Application of wastewater is the main factor responsible for accumulation of heavy metals in soil, water and edible parts of many vegetable crops (Smith 2009). There is no known biological role for most heavy metals such as Cd in plant and human physiology, however, increasing their concentration to a critical level in living tissues becomes extremely toxic for various biological functions (Clemens 2006).
Tehran is a metropolitan city located south of the Alborz Mountains in Iran. The main vegetable production areas are located nearby to this industrial zone that plays an important role in supply of fresh vegetables for the capital and nearby cities. Adjacent to these vegetable production areas, a big oil refinery plant and the country’s main international airport are located. Several thousands of tons of wastes and byproducts are generated annually from domestic and industrial sources in the metropolitan city of Tehran and nearby areas. As a result, highly contaminated wastewater stream are present in this metropolitan city and due to geographical features, the stream flows to the southern region and are generally used as sources of irrigation water for production of various vegetable crops during the 8-9 months production season of the year. The present study aimed to evaluate the potential risk of heavy metal accumulation in leafy vegetable crops commonly cultivated in this region.

2 Materials and Methods

A major production area of vegetable crops located in southern suburb of Tehran-Iran was chosen for collection of leaf samples of various vegetable crops. Leaf samples of garden cress (Lipidium sativum L.), coriander (Corianderum sativum), lettuce (Lactuca sativa subvar “Romain”), and spinach (Spinacea olarcea) were randomly collected from farmers’ cultivated fields. In this region and many other parts of Iran, generally the local varieties of leafy vegetable crops are cultivated. The fields were located in Kahrizak, on the southern edge of Tehran. There are many small and big fields of vegetable production in the region, which are generally dependent on streams of domestic and industrial wastewater for irrigation.

The physicochemical properties of wastewater samples used in the region are presented in Table 1. Four samples of surface soil (0-30 cm depth) were also collected from the fields, which after air drying, were passed through a 2 mm sieve and homogenized, from which a sample was used for soil analysis. The physicochemical characteristics of soil under cultivation fields are presented in Table 2. Plant samples were collected during October and November 2012. Five samples (as replications) were randomly collected from two or three fields. Each sample consisted of 3 plants which were grown in a 2 m radius.

The edible parts of the four leafy vegetable crops were used for heavy metal determination. The leaf samples consisted of petiole and blade, as well as fresh vegetative shoots for all four vegetable crops. The inner leaves of lettuce including leaves with 3-5 cm length of apical shoot were also sampled separately. After collection, samples were packed in paper bags and immediately transferred to a laboratory. The old or discolored leaves were removed, and the remaining leaves were gently washed using distilled water to remove any possible dust on the leaves. The samples then were dried by carefully pressing between tissue papers, cut into small pieces, and oven-dried at 60°C for 48 h. A mix of whole leaves including blades and petioles for 3 plants (as replication) was used for analysis. The samples were ground into powder using a grinding machine, transferred into small plastic bags and stored under dry conditions. At the time of analysis, 1 g of each sample was transferred to a crucible and placed in a furnace at 550°C for 6 hours for dry ashing. The full digestion of ash was performed using drops of HCl (5 N) and HNO₃ (3 N) solutions. The mixture was heated at 70°C for 20 min until a light-colored solution was achieved.

The residue was washed and filtered into 50 ml flask using distilled water and Whatman 4 filter paper. Atomic absorption spectrophotometer was used to measure the levels of the heavy metals in the vegetables foliage. Each sample solution was run in duplicate following the same procedure to give higher creditability of the results obtained. Standard solutions of lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), arsenic (As), cobalt (Co), zinc

<table>
<thead>
<tr>
<th>Texture</th>
<th>pH</th>
<th>EC (dS m⁻¹)</th>
<th>Cd (mg kg⁻¹)</th>
<th>Pb (mg kg⁻¹)</th>
<th>As (mg kg⁻¹)</th>
<th>Cr (mg kg⁻¹)</th>
<th>Ni (mg kg⁻¹)</th>
<th>Zn (mg kg⁻¹)</th>
<th>Cu (mg kg⁻¹)</th>
<th>Co (mg kg⁻¹)</th>
<th>SAR (meq L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loamy</td>
<td>7.23</td>
<td>13.4</td>
<td>14.3</td>
<td>281</td>
<td>6.4</td>
<td>26.3</td>
<td>22.1</td>
<td>75.2</td>
<td>28.4</td>
<td>11.3</td>
<td>12.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>pH</th>
<th>EC (mg L⁻¹)</th>
<th>TDS (mg L⁻¹)</th>
<th>Cd (mg L⁻¹)</th>
<th>Pb (mg L⁻¹)</th>
<th>As (mg L⁻¹)</th>
<th>Cr (mg L⁻¹)</th>
<th>Ni (mg L⁻¹)</th>
<th>Zn (mg L⁻¹)</th>
<th>Cu (mg L⁻¹)</th>
<th>SAR (meq L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.56</td>
<td>4.37</td>
<td>3737</td>
<td>8.6</td>
<td>14.8</td>
<td>0.26</td>
<td>6.7</td>
<td>4.8</td>
<td>13.1</td>
<td>4.6</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Table 1: The physicochemical properties of wastewater samples used for irrigation of crops production in fields in Kahrizak, located in the southern suburb of Tehran.

Table 2: The physicochemical properties of top soil from the cultivated field.
(Zn) and copper (Cu) were prepared from a stock solution of 1000 mg L\(^{-1}\) in 2N HNO\(_3\) from MERCK grade of chemicals. A blank sample was also included for better correction and calculation of concentrations for all the heavy metals under analysis. Accordingly, the calibration curves were prepared for each element, and concentrations of heavy metals were expressed as mg kg\(^{-1}\) leaf fresh weight (FW).

Data were analyzed using SPSS 16 and differences among treatments were determined at 5% level by Duncan's test. Graphs were prepared using Microsoft EXCEL.

Ethical approval: The conducted research is not related to either human or animals use.

3 Results

The results showed that samples of spinach had significantly higher concentrations of cadmium compared to other vegetable crops (Figure 1). Garden cress was the crop that accumulated the next highest Cd in leaf samples. While lettuce showed higher concentration of Cd, however it had no significant difference with coriander plants. The lowest Cd concentration was in inner leaves of lettuce (Figure 1). The trend of Cd concentration for these vegetable crops was in the following order: spinach > garden cress > lettuce ≥ coriander > inner leaves of lettuce. The range of cadmium in plant foliage was from 0.02 to 0.52 mg kg\(^{-1}\) FW. Regarding lead concentration, spinach showed the highest Pb concentration followed by garden cress (Figure 2). Coriander and lettuce plants had significantly lower concentrations of Pb compared to garden cress and spinach. Similar to Cd, the lowest Pb concentrations were observed in the inner leaves of lettuce plants (Figure 2). The order of Pb concentrations seen among the four vegetable crops was as following: spinach > garden cress > coriander ≥ lettuce > inner leaves of lettuce. The range of lead concentration in plant foliage was from 0.23 to 4.7 mg kg\(^{-1}\) FW.

Analysis of arsenic concentration of plant foliages (Figure 3) showed that the highest concentration was in foliage of spinach plants that was significantly higher compared to other vegetable crops. Garden cress plants had the next significant highest arsenic concentration; followed by lettuce and coriander plants (Figure 3). Inner leaves of lettuce showed the significantly lowest arsenic concentration (Figure 3). The range of measured arsenic in plant foliage was 0.018 - 0.126 mg kg\(^{-1}\) FW. Determination of chromium (Table 3) in leaf samples showed that Spinach and garden cress had the highest Cr concentration and there was no significant difference between these two crops. The Cr concentration in coriander and lettuce plants was significantly lower compared to spinach and
not garden cress. There was no significant difference in Cr concentration between coriander and lettuce plants. The lowest concentration of Cr was observed in inner leaves of lettuce (Table 3). The range of chromium concentrations in plant foliage was 0.1 - 1.87 mg kg\(^{-1}\) FW.

In this study, nickel and cobalt showed a similar trend, in which the significantly highest Ni and Co concentrations (Table 3) were observed in spinach. The next highest Ni and Co concentrations were recorded for garden cress, despite it had no significant difference with lettuce plants. Coriander plants accumulated significantly lower concentration of Ni and Co compared to the other three vegetable crops. However, the lowest Ni and Co concentrations were in inner leaves of lettuce. The range of nickel concentrations in plant foliage was 0.04 – 0.81 mg kg\(^{-1}\) FW, and the range of nickel concentrations in plant foliage was 0.005 – 0.21 mg kg\(^{-1}\) FW (Table 3). Determination of zinc concentration of vegetable samples (Table 3) showed a similar trend to other heavy metals. The highest Zn concentration of leaf samples was observed in spinach followed by lettuce, garden cress and coriander plants; however, there was no significant difference between lettuce and garden cress. The significantly lowest Zn concentration was in inner leaves of lettuce (Table 3).

Zinc concentrations in vegetable samples ranged from 1.7 to 6.7 mg kg\(^{-1}\) FW. Determination of copper concentrations (Table 3) in edible foliage of these vegetable crops revealed that spinach and garden cress had the highest Cu levels followed by coriander and lettuce plants. However, regarding Cu concentration there was no significant difference between spinach and garden cress, and also between coriander and lettuce plants. The lowest Cu levels were recorded in inner leaves of lettuce plants (Table 3). Overall, spinach plants accumulated the consistently highest levels of the heavy metals analyzed, while inner leaves of lettuce shared the lowest heavy metal concentrations (Figures 1-3 and Table 3).

4 Discussion

In the present study, foliage samples of four common vegetable crops were collected from fields, where vegetables are grown on farms irrigated using domestic and industrial wastewater. Heavy metal levels of waste water presented in Table 1 showed high levels of heavy metal contaminations. As a result, significant amounts of those heavy metals were measured in the soil samples (Table 2). Furthermore, analysis of plants foliage showed that the concentrations of Cd, Pb and Cr were significantly higher than allowable levels (Table 4) as recommended by international organizations such as FAO/WHO (FAO 2014). In Iran standards also follow international WHO and FAO standards.

Hence, using such highly contaminated stream of wastewater generated by domestic and industrial activities of Tehran for irrigation of suburb vegetable production has resulted in accumulation of significantly high amount of some heavy metals in edible foliage tissues of all four vegetable crops examined. Elevated levels of heavy metal concentrations in tissues of various vegetable crops due to irrigation using wastewater have been widely reported (Delbari and Kulkarni 2014; Gyekye

<table>
<thead>
<tr>
<th>Table 3: Concentrations of chromium, nickel, cobalt, zinc and copper in foliages of different vegetable crops irrigated using waste water</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chromium Con.</strong> (mg kg(^{-1}) FW)</td>
</tr>
<tr>
<td>Garden cress</td>
</tr>
<tr>
<td>Coriander</td>
</tr>
<tr>
<td>Lettuce</td>
</tr>
<tr>
<td>Lettuce inner leaves</td>
</tr>
<tr>
<td>Spinach</td>
</tr>
</tbody>
</table>

Each value is the average of five replicates ±SD.

Data with same letter in each column are not significantly different at 5% level of Duncan test.

<table>
<thead>
<tr>
<th>Table 4: Maximum allowable concentrations of measured heavy metals in fresh vegetable tissues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cd</strong></td>
</tr>
<tr>
<td>Max. Allowable levels (mg/kg FW)</td>
</tr>
</tbody>
</table>
2013; Maleki and Zarasvand 2008; Fite and Leta 2015; Sharma et al. 2008; Singh et al. 2010; Khan et al. 2008; Smith 2009). Different green leafy vegetables collected from markets in Colombo, Sri Lanka were reported to have high levels of heavy metals mainly due to industrial pollutions (Kananke et al. 2014).

Earlier reports document high levels of chromium and lead in various plant and vegetable crops cultivated near the metropolitan city of Tehran (Delbari and Kulkarni 2014). Similarly, high levels of Cd, Pb, Cu and Cr concentrations were reported in vegetable crops of leek, sweet basil, parsley, garden cress, and tarragon grown in the western city of Sanandaj, Iran (Maleki and Zarasvand 2008; Maleki et al. 2014). Now it has become a common phenomenon that plants grown in polluted environments can accumulate metals at high concentrations causing a serious risk to human health when these foods are consumed (Wenzel and Jackwer 1999). The need for the production of high quantity leafy vegetable crops around urban areas requires more irrigations and high applications of various fertilizers. These conditions can lead to increased soil biological activity which in turn intensifies the absorption and buildup of heavy metals in plant tissues (Naiji and Souri 2014). Hence, the high levels of heavy metals in the irrigation water, soil samples and vegetable tissues documented in this study (Tables 1, 2 and 3; Figures 1-3) are in line with earlier reports.

Generally elevated levels of heavy metals in soils may lead to higher uptake by plants; however, there is no generally consensus on high relationship between concentrations in soils and in plants, because of many factors including soil metal bioavailability, plant growth and metal distribution to plant parts (Wenzel and Jackwer 1999). However, in the present study despite accumulation of heavy metals in plant foliages, only Cd, Pb and Cr were higher than maximum allowable levels (Tables 1, 2 and 3; Figures 13).

Vegetables absorb heavy metals primarily from the soil by their root system, as well as from the air by foliage (Voutsa et al. 1996). Air deposition and absorption through the foliages can also be significant for some heavy metals such as cadmium and lead, which are pollutants from certain industrial and traffic activities (Khan et al. 2008; Voutsa et al. 1996). Frequently dusty air is a common phenomenon in many cities in Iran including the region under study, which generally contains relatively high concentrations of heavy metals, such as Cd, Cr, Cu, Pb and Zn (Tang et al. 2013). Traffic and vehicles were suggested to be the main contributors with industrial factories as the second source arising from dusty air in the metropolitan city of Tehran (Delbari and Kulkarni 2014). In vegetables the significance of dusty air deposition on plant tissues contaminations with heavy metals is more than other crops (Tang et al. 2013; Voutsa et al. 1996). In the present research, the fields under study were located along side several major Iran’s main roads. Heavy metal content of plants often increased with closeness to highways in many populated areas (Delbari and Kulkarni 2014; Sharma et al. 2008).

In the present study, spinach and garden cress have accumulated significantly more heavy metals compared to lettuce and coriander. Spinach and garden cress are well known plants with regard to phytoremediation due to their ability to accumulate high levels of heavy metals. The use of garden cress has been suggested as an indicator for biomonitoring of urban soil, due to its simplicity, sensitivity, and cost-effectiveness (Gyekye 2013). In all sampling sites, inner leaves of lettuce plants have shown lower levels of heavy metal concentrations. This is probably due to less deposition of dusty air and less internal translocation of heavy metals (Marschner 2011). Generally plants may have different potential for heavy metal uptake and sensitivity to various heavy metals (Alexander et al. 2006), nevertheless, vegetable crops are capable of mobilizing the heavy metals in the soil, more potently than any other crop. Despite the root characteristics were not measured in the present study, root growth and root length are adversely affected by heavy metals (Lux et al. 2010), indicating tissues specific responses to heavy metal contaminations.

Continuous and steady uptake of heavy metals can lead to accumulation of toxic heavy metals in edible plant parts. However, the uptake, translocation from the roots and accumulation of heavy metals in vegetarian shoots are influenced by many factors including; climate, plant species, water and soil pollution and atmospheric deposition (Voutsa et al. 1996). Several clinical disorders and physiological problems could arise over their buildup in plant, animal and human tissues (Khan et al. 2008). Heavy metals are not degradable substances and continuously accumulate inside the soil over their entrance from effluent wastewater and atmospheric deposition (Sharma et al. 2008). In India, plant samples of leafy vegetables in sewage-irrigated area around populated cities were found with high levels of heavy metal contamination including Cd, Zn, Cu, Mn and Pb (Sharma et al. 2008; Singh et al. 2010; Tiwari et al. 2011). A deadly amount of heavy metals in vegetable samples collected from Delhi and its surrounding areas in India was also reported (Delbari and Kulkarni 2014).
5 Conclusion

Vegetables are essential components of human nutrition. Hence, a continuous control and evaluation is required on their safety to human health. In the present study, analysis of the wastewater used for irrigation and the topsoil of the field under investigation has shown high levels of heavy metal contamination. As a result, plant samples of vegetable crops collected from these fields under waste water irrigation demonstrated considerably high levels of some heavy metal accumulations in their shoot tissues. Therefore, if there should be any program to use waste waters for irrigation, there should be multi-layer well tested wastewater treatment strategy to reduce the toxic levels, and use this refined and treated wastewater for production of landscape plants or industrial crops, but not for fresh green vegetables.

Acknowledgment: This study was conducted with financial support from Iran National Science Foundation (INSF, Grant No 88002063), and we express our thanks to this foundation and those people who helped conducting this research.

Conflict of interest: Authors state no conflict of interest.

References

Clemens S., Toxic metal accumulation, responses to exposure and mechanisms of tolerance in plants. Biochim., 2006, 88, 1707–1719
Guyksee K.A., An assessment of toxic in urban soils using garden cress (Lepidium sativum) in Vaseileostrovsky Ostrov and Elagin Ostrov, Saint Petersburg, Russia. Geography and Geology, 2013, 5, 63-70
Nalij M., Souri M.K., The potential for organic production of savory (Satureja hortensis) in Iran. In “Bridging the gap between increasing knowledge and decreasing resources” Tropentag, Prague, Czech Republic, September 17-19, 2014
Smith S.R., A critical review of the bioavailability and impacts of heavy metals in municipal solid waste composts compared to sewage sludge. Environ. Inter., 2009, 35, 142–156
Souri M.K., Aminoche late fertilizers: the new approach to the old problem; a review, Open Agri. 2016, 1, 118-123
Wenzel W., Jackwer F., Accumulation of heavy metals in plants grown on mineralized solids of the Austrian Alps. Environ. Pollut., 1999, 104, 145-155