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Research Article

Heavy Metals Assessment in Different Fresh and Processed Tuber Crops Grown with Fresh and Sewage Water

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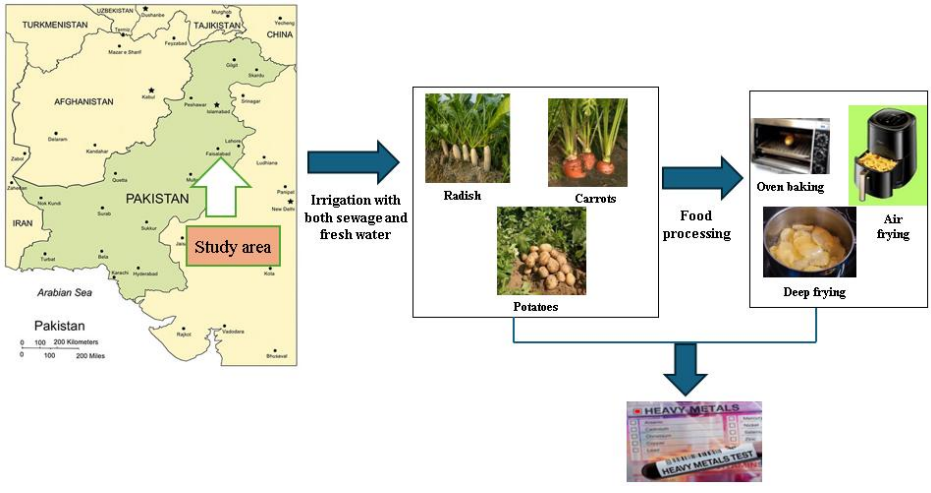
Abstract

The problems from heavy metals content increasing day by day over the world. Heavy metal contamination in vegetables has become a serious food safety concern in developing Asian countries, including Pakistan. Due to lack of clean water resources in many Asian countries, sewage water is frequently utilized to irrigate the crops, particularly in Pakistan. Irrigation of sewage water may increase the levels of heavy metals in such soil, which eventually transfer to crops. In humans, these metals induce a variety of illnesses, i.e. cancer. In this study, the concentrations of heavy metals (As, Pb, Cd, Hg, Co and Cr) in raw and processed tuber vegetables irrigated with ground water and sewage water were compared utilizing a wet digesting method. Different levels of heavy metals in raw, oven baked, air fried and deep-fried vegetables have been evaluated. Results showed higher levels of heavy metals in vegetables grown with sewage water and were above the permissible limits. It also shows that different processing methods had a significant effect on the level of heavy metals but was unable to reduce it to the safe limit designated by FAO and WHO. Maximum level of percentage decrease of lead (Pb) and cadmium (Cd) was found in deep fried vegetables.

Keywords: Heavy metals; food processing techniques; tuber crops; water contamination

Graphical Abstract



1. Introduction

Food safety is a major socioeconomic issue worldwide. There has been an alarming increase in the inappropriate use of chemicals in agriculture over the last centuries. This has resulted in several food-safety, which have been widely publicized. As a result, consumers are becoming more concerned about their health and food safety [1]. Nowadays vegetables are irrigated by sewage water, containing high amounts of organic and inorganic nutrients, consumed by humans by direct or indirect sources, Shortage of fresh water is a major reason to utilize wastewater for irrigation although it contains many toxic metals [2]. Rapid urbanization and industrialization have caused heavy metals (HMs) pollutants to spread over the world, threatening human health and the environment [3]. Heavy metals are difficult to decompose and as a result, can accumulate in human major organs. Based on acute and long - term exposures, this situation causes various levels of illness [4]. Farmers are using untreated water in underdeveloped countries for irrigation purposes [5]. The demand for natural fresh food crops is increasing day by day, farmers are focusing on producing wholesome food crops [6]. The safety, quality, and preferences of organic and traditional fruits, vegetables, and grains are becoming a concern for producers and consumers, according to the literature. Consumers expect fresh produce to be of high quality and safe to eat [7]. The quality of fresh produce is dogged by its taste, colour, nutritional value, and microbial safety [8]. The increase in urbanization and industrialization over the last centuries has been accompanied by unexpected environmental changes. Pollution from heavy metals in soil is a mounting problem in Pakistan, which are due to flow of water from industries to streams without any treatment, traffic residues, and from different polluted source [9]. As the primary factor of the environment, agricultural and urban soil act as a major reservoir or sink for pollution, including heavy metals, in the food supply chain [10]. In treated sewage water contains chemicals like lead (Pb), cadmium (Cd), zinc (Zn) and iron. Plants take up minerals from soil to roots and transfer them to their edible portion and thus cause toxicity in living organisms [11]. The permission able limit of these heavy metals for potatoes is (0.1 mgkg-1) [12]. The presence of heavy metals in plants depends mainly upon the functional and structural properties of plants and water. The accrual of heavy metals in plants fluctuates over time with no apparent relationship to climatic circumstances, making it difficult to predict the accumulation of metals in plants [13]. To regulate the quality of the plant and water it is mandatory to prevent the ingress of heavy metals into the food from farm to folk, to avoid health risks [14]. Heavy metals are not decomposable, and higher concentrations of these can be dangerous to human health, animals, and plants. Serious health problems may be caused by the accrual of these toxic metals in living individuals [15]. Heavy metals are harmful due to their non- biodegradability, and ability to collect in many body parts [16]. Because of their aqueous solubility, most heavy metals are hazardous and there is no effective solution for removing them from the body. Heavy metals have become ubiquitous because of their widespread use in industries [17]. High amount of heavy metal deposit in agricultural soil because of wastewater irrigation is causing soil contamination in addition to safety and food quality concerns [18]. Three majorly used tuber crops (carrots, radish and potatoes) that were grown with sewage water and ground water have been studied in this article. Most used food processing methods (air frying, deep frying and oven baking) were selected for this study to assess the impact of food processing techniques on the levels of heavy metals in the samples under investigation. An atomic-absorption spectrometer was used to compare the effect of processing both for sewage irrigated crops and ground water crops on the concentration of heavy metals.

2. Materials and methods

2.1 Sample preparation

Vegetables samples were collected from both fresh and sewage irrigated sites. The vegetables samples were collected and washed. These samples were processed in three different processing ways that are air frying, deep frying and oven baking. All the samples were oven baked, deep fried and Air fried at a temperature of 150°C for 25 minutes, 180°C for 3-4 minutes and 160°C for 12 minutes respectively [19]. After the sample was

cut into pieces and dried in oven for 24hrs at 60±5 °C in laboratory of food chemistry, agriculture university, Faisalabad. Then vegetables samples were mashed with the help of pestle and mortar into fine powder. During every stage of the sample preparation process, only teflon, glass, and ceramic tools were used to prevent food contamination from metallic dishes and other instruments.

2.2 Determination of heavy metals

To find the concentration of heavy metals in the fresh and sewage irrigated vegetables, wet digestion method was used for samples preparation according to [20].

2.3 Wet digestion

A sample of 0.5 g each was weighed in a beaker. 3mL of per chloric acid (HCLO4) and 7mL of nitric acid (HNO3) were added in it and placed on hot plate till sample become crystal clear. Digested sample was allowed to cool down. Then distilled water was added to make volume up to 100mL followed by filtering with Whatman No. 42-filter paper. After that samples were stored in transparent bottles and then labeled them.

All the heavy metals (As, Pb, Cd, Hg, Cr, Co) were measured in fresh tuber vegetables and processed tuber vegetables samples by atomic absorption spectrophotometry [20].

2.4 Standards preparation

From the stock standard solutions containing 1000 ppm of element in 2N nitric acid, working standard solutions of Lead (Pb), Cadmium (Cd), and Arsenic (As) were prepared.

2.5 Analysis of samples

Atomic absorption spectrometer (AA240) was used for standardization and measurement of elements. For each element the gradation curves were prepared. A blank reading was also taken, and correction that is required was made during the calculation of concentration of various elements.

2.10 Statistical analysis

To check the level of significance, the obtained data was statistically analyzed by using

Statistics 8.1. $P \leq 0.05$ was considered as statistical significance. All the means were compared and pairwise comparison was made using Tuckey comparison test [21].

3. Results and discussion

3.1 Heavy metals concentration in fresh and processed carrots

The concentration of heavy metals Lead (Pb), Cadmium (Cd), Cobalt (Co), Mercury (Hg) and Arsenic (As) was investigated both in fresh and processed carrots. According to figures 1 and 2 processing methods in carrots that are grown with fresh water represent that there is a significant effect of all processing for all five heavy metals. There was a highest concentration of lead 0.09mg/kg and cadmium0.08mg/kg in raw carrots was detected. Figure 1 showed the clear effect of processing in decreasing the heavy metal concentration. The maximum content of lead decreased in deep frying. The release of these metals as free salts with loss of water during cooking might explain the decrease in metal content. According to FAO/WHO, Pb content should be less than 0.3 mg kg-1 in leafy vegetables, 0.3 mg kg-1 in root and tuber vegetables (Radish) and 0.1 mg kg-1 in bulb vegetables (Garlic). Although, the content of Pb found in all vegetables grown with fresh water was below the permissible limits whereas content of Pb found in sewage water irrigated vegetables was above the permissible limits.

In deep fried carrot samples that are grown with sewage water showed that cadmium concentration got higher after processing, because of the oil used for frying and concentration loss of water. Our outcomes are in line with [22] in which they assessed the content of cadmium in the vegetables and stated that vegetables grown with untreated industrial wastes have the maximum content of cadmium. Also, the use of these effluents for irrigation may help in the accrual of heavy metals in soil.

3.2 Heavy metals concentration in fresh and processed radish:

The concentration of investigating HM in radish mg/kg grown with fresh and sewage water was analyzed. These HM was determined in the NIFSAT laboratories by following method of AOAC [20]. Concentration of heavy metals in both fresh and sewage irrigated radish are reduced after cooking. Fresh irrigated water radish shows the maximum effect of deep-frying method, but for arsenic it increases the concentration that is due to the contamination of oil.

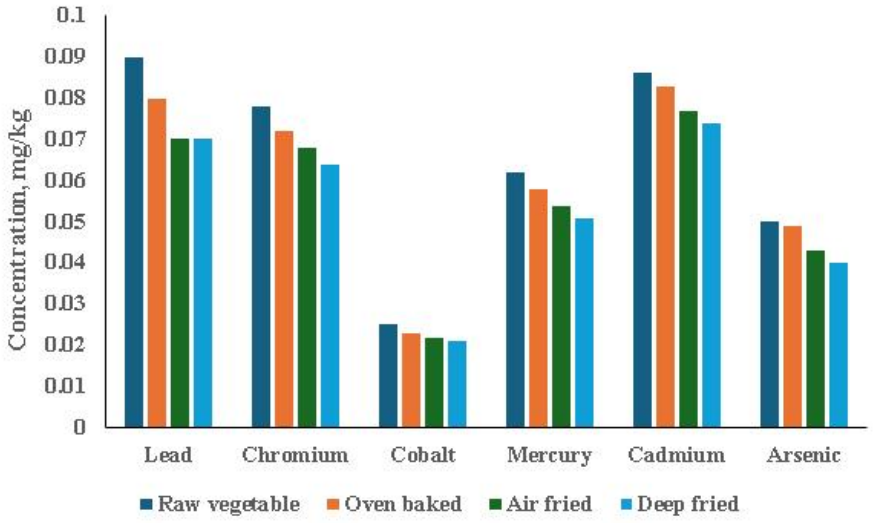


Figure 1. Concentration of HM in fresh water irrigated carrots.

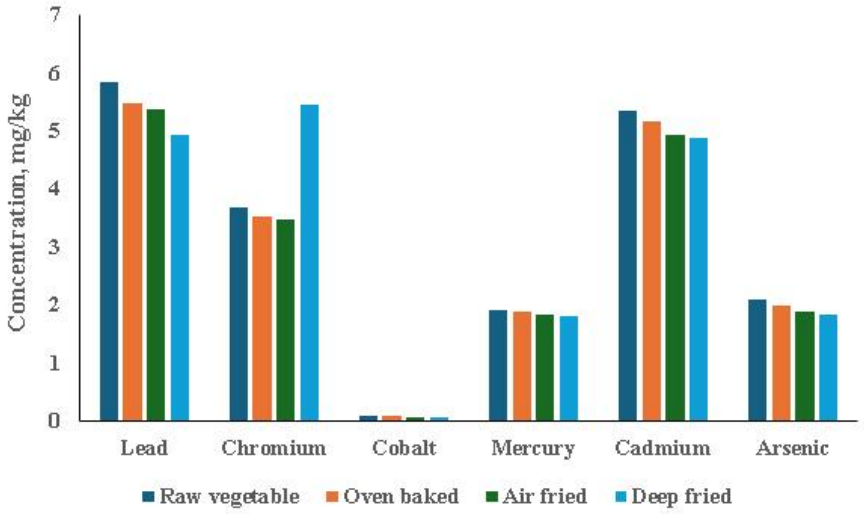


Figure 2. Concentration of HM in sewage water irrigated carrots.

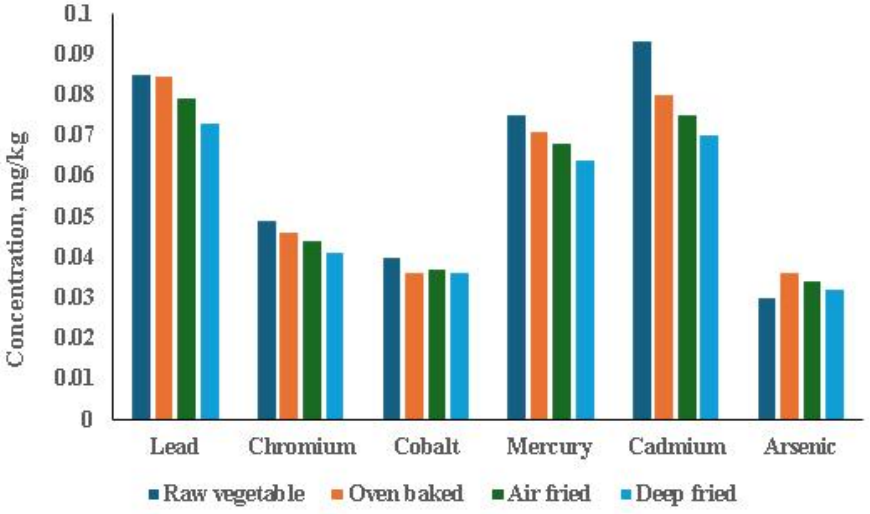


Figure 3. Concentration of HM in fresh water irrigated radish.

Our results are in line with [23] in which they assessed the influence of various cooking methods in content of lead, cadmium, mercury and arsenic. The content of lead in raw tuber vegetable was 0.023 mg/kg after cooking (frying and boiling) the content of lead was not found in tuber vegetables. The amount of reduction is determined by the cooking conditions (time, temperature, and medium of cooking). According to FAO/WHO, As content should be less than 0.1 mg/kg in leafy vegetables (Spinach), 0.05 mg/kg in root and tuber vegetables (Radish) and 0.2 mg/kg in bulb vegetables (Garlic). Though, the content of As found in all vegetables irrigated with fresh water was below the permissible limits whereas content of As found in sewage water irrigated vegetables was above the permissible limits. In sewage grown vegetables the concentration of lead is high while with fresh water it shows the high concentration of cadmium. [24] studied that cadmium is well known as a highly environmental pollutant due to its great toxicity and high mobility from soil to plant. [25] examined the impact of metal accumulation and its consequences on the biochemical plant responses irrigated with metal-contaminated water and wastewater.

3.3 Heavy metals concentration in fresh and processed potatoes

The concentration of heavy metals in raw potatoes grown with fresh water 0.076mg/kg, while in sewage water the concentration is above the permissible limit, however we can see the significant effect of cooking method for both sewage and fresh irrigated potatoes. After different processing techniques, mercury content reduced in vegetables irrigated with fresh and sewage water. The maximum content of decreases in air frying and deep frying. The reduction in the metal content during cooking as shown in figure 4A, 4B and 4C may be related to the release of these metals with the loss of water as free salts.

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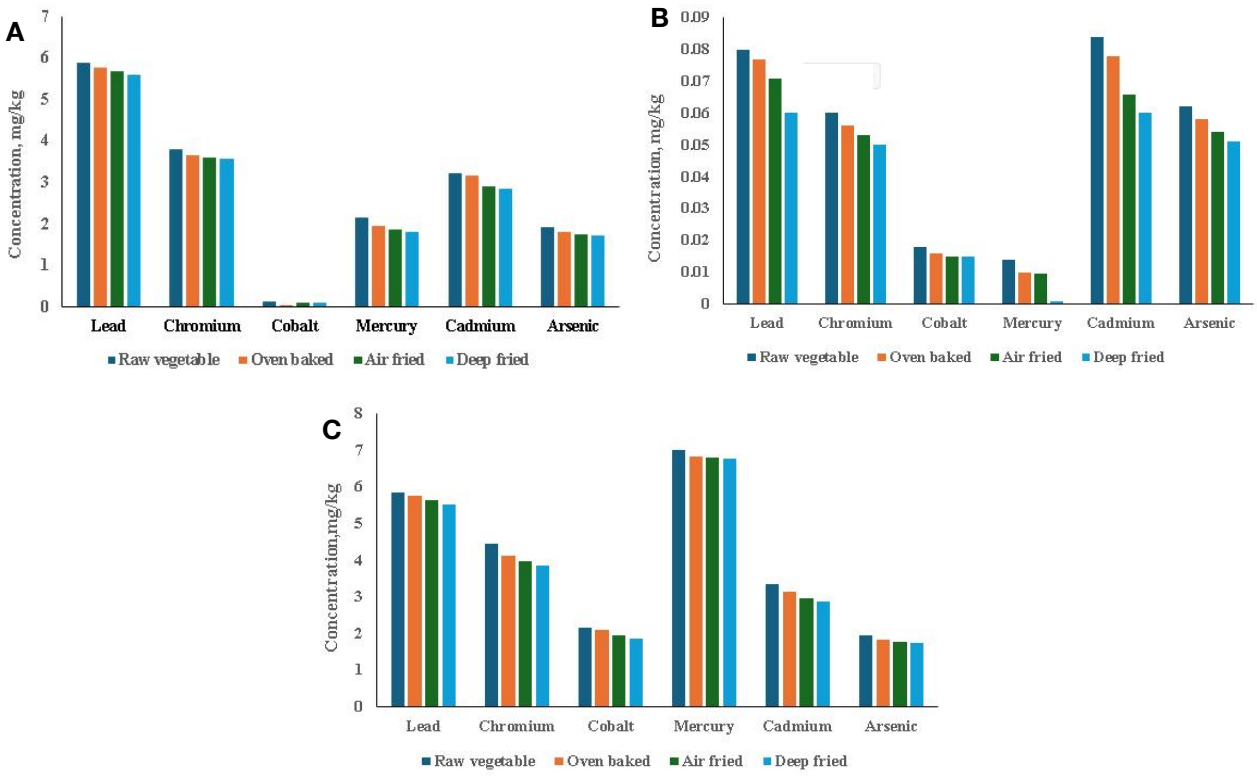

Figure 4. (A) Concentration of HM in sewage water irrigated radish, (B) Concentration of HM in freshwater grown potatoes, and (C) Concentration of HM in sewage water grown potatoes

According to FAO/WHO, Cd content should be less than 0.2 mg/kg in leafy vegetables (Spinach), 0.2 mg/kg in root and tuber vegetables (Radish) and 0.05 mg/kg in bulb vegetables (Garlic). Though, the content of Cd found in vegetables irrigated with fresh water was below the permissible limits although content of Cd found in sewage water irrigated vegetables was beyond the permissible limits. This apparent Cd decreasing with cooking may be related with the solubilization of heavy metals in the leaching water because heavy metals usually bind with proteins, and thermal processing could accelerate protein degradation and release of cadmium with water as free salts, soluble amino acids, and uncoagulated protein. In addition, after microwave cooking, the texture of potato was quite soft, and consequently, this textural characteristic may make the cadmium leaching into the water quite easy [26]. Our results are parallel to the (Hussain et al.,2013) they found that green vegetable which irrigated with sewage water have higher contents of Cu, Zn, and Pb and also reported that nutritional quality of vegetables significantly affected by heavy metals. [27] studied that cadmium can easily accumulate in vegetables because of their solubility with respect to other heavy metals [24].

4. Conclusion

The extraction of metals as free salts with the loss of water may be related to the reduction in metal content of the vegetables during cooking. Sewage water is employed as the main source for irrigation of vegetables and fodder consumed directly or indirectly by humans as a potential source of irrigation. For plant growth, untreated wastewater is an enriched source of nutrients (organic and inorganic), since in all urban areas farming with sewage water is quite common. In agriculture, the practice of reusing wastewater has become the most common in areas where deficiency of clean water is more distinct. In some cities, wastewater, where industrial sewage is discharged, can contain large quantities of toxic metals. As a result, with respect to the type of industrial waste discharge, the composition of domestic wastewater may vary.

People who eat, drink, or ingest crops and/or vegetables grown in unclean areas, the agricultural soils which are irrigated by sewage water threaten their lives because of excessive accrual of heavy metals. Sewage water contains considerable amounts of toxic contaminants and useful nutrients, which create problems and opportunities for production of agriculture, respectively.

According to the results of this study, there were higher levels of heavy metals in wastewater irrigated vegetables than in freshwater cultivated vegetables. The levels of lead, cadmium, arsenic, chromium, cobalt, and mercury in wastewater-grown vegetables reached the toxic effects threshold. In vegetables irrigated with fresh water, the same heavy metal levels were within allowable limit. Because of their different assimilation capacities and structures, heavy metal accumulation varied between vegetables like carrots, radish, and potatoes. In comparison, radish, potatoes and carrots had enough highest lead levels, while the percentage decrease of heavy metals was also highest for lead.

Heavy metals content of sewage and fresh irrigation can be reduced by cooking, but it is not possible to reduce heavy metals in sewage irrigated tubers to safe levels, according to FAO/WHO. The release of these metals as free salts with the loss of water during cooking could explain the decrease in metal content. Heavy metals from vegetables can also be leached into water via osmotic leaching.

Authors Contribution

Khadija Ramza: Conceptualization, Investigation, Visualization, Writing—Original Draft.

Dr. Muhammad Atif: Supervision, Funding Acquisition, Methodology, Validation, Formal Analysis, Reviewing & Editing.

Hijab Zehra: Writing—Introduction, Editing.

Maria Seher: References, Editing & Formatting.

Conflicts of Interest

There are no conflicts of interest reported by the writers.

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Data Availability statement

The data presented in this study are available on request from the corresponding author.

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