

Physiological Analysis and Contamination of Heavy Metal Contents in Vegetables and Fruits Irrigated with Wastewater

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Abstract

The following research work has been undertaken to examine the presence of heavy metals i.e., lead (Pb), Cadmium (Cd), Copper (Cu), Iron (Fe), Cobalt (Co) in some selected vegetables and fruits supplied in the local market. The process used to determine heavy metals is Atomic Absorption Spectrometer. Iron concentration in spinach, tomato, cauliflower and lady finger showed higher ranges which were exceeding the permissible limits. Cauliflower and spinach were within the limits specified. The pH value, ascorbic concentration and moisture content significantly decreased after oven drying of vegetables and fruits. However, the Total Soluble Solids (TSS) and ash content significantly increased after oven drying as compared with fresh vegetables and fruits. The present research data revealed that the fresh and oven dried vegetables such as Spinach, Cauliflower, Lady finger and Tomato contains 0.13-1.50%, 0.25-2.32%, 0.26-2.52% and 0.19-3.13% Titratable acidity respectively. Similarly, fresh and oven dried Guava Titratable acidity was highest 0.27 and 1.92 as compared with Water melon and Mango. The reduction in acidity may be due to catabolic activities in fruit cells and increased in pH. The pH value of vegetables and fruits dropped after oven drying. Similarly, ascorbic concentration and moisture content significantly decreased after oven drying as compared to fresh vegetables and fruits. However, the Total Soluble solids (TSS) and ash content significantly increased after oven drying as compared with fresh vegetables and fruits. Overall, from the following study we can conclude that vegetables and fruits were found to be contaminated by heavy toxic metals. Regular monitoring is required because these toxic metals will damage human body as well disturb our food chain. The main objective to conduct this study is to monitor the heavy metal toxicity and provide some recommendation, which in future will assure food safety and human health.

Keywords: Vegetables • Heavy metals • Fruits • Human health • Soil • Dietary intake

Introduction

Vegetables and fruits are of great value and widely used for dietary purposes globally. Fruits are an important constituent because of vitamins, mineral salts, water, nutrients such as calcium (Ca), iron (Fe), Sulphur (S) and potassium (K) [1]. They protect our body from foreign infections. Presence of heavy metals in food supplies will not only cause harm to our body but will also damage our food chain. Due to easy availability of wastewater and scarcity of freshwater, it is mostly used for irrigation of vegetables and fruits. Waste irrigation is thought to make a considerable contribution to presence of heavy metals in wastewater [2]. The metals content of the soil are dangerous because they do not get degrade easily and they can easily get assemble in our body. In-addition these metals are dangerous because they can easily dissolve in our water bodies [3]. A small amount of these metals is harmful because there is no proper method to remove these metals from our body. Heavy metals find their use in many industrial applications and so there are widely spread [4]. Due to this reason the available wastewater have large unit of these heavy metals in them as which when indirectly used for irrigation severely effects human body. Excess amount of accumulation in agricultural land irrigated by wastewater affects the food quality. The metal requirement in our body is obtained from the food and water that we consume and this in turn directly exposes us from the entry of toxic heavy metals [5]. Vegetables

play an important role in our daily diet because it has vitamins, minerals dietary fiber and antioxidants. Leaves from different plant species such as perennial and annuals are consumed especially in rural areas and there has been an increased trend of the consumption among the persons living in metro cities. Vegetables which have leaves as edible part are an economic source to ensure the micronutrient intake. Examples include Spinach, Cauliflower, Ladyfinger, Tomato, Watermelon, Mango and Guava.

Rapid industrialization and the use of natural resources have increased the accumulation of toxic substances like heavy metals in the soil. The required protein and vitamin which are supplied by vegetables are best to act against rough digestion and prevents constipation are supplied by vegetables [6]. The spreading of urban waste and sewage sludge in agricultural fields has been a common practice since decades. Sewage sludge, livestock manure, waste water irrigation are feasible alternatives for reutilization of residual resource of high nutrient and organic matter contents representing a good fertilizer or soil conditioner for plants and soil [7]. Besides agricultural fields, recreational parks, golf courses, home gardens are also irrigated using waste waters from sewage plants [8]. The solids from the sewage plants are processed and sold as soil amendments and low grade fertilizers Reclaimed lands are known to contain significant amount of metals and are being used for growing food crops and vegetables. The current research work was conducted with a view to calculate the amount of heavy metals that enter in our body through the agricultural practices that involves the use of wastewater irrigation [9]. The various disadvantage of using wastewater was noticed and daily intakes of heavy metals were calculated with regard to different section of society.

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Materials and Methods

Study area

The following study was conducted in Prayagraj (Figure 1) formerly known as (Allahabad) market which is located at 25.45°N 81.84°E in the southern part of the Uttar Pradesh, at an elevation of 98 meters, shown in Figure 1. It



Figure 1. Site selected for sample collection.

stands at the confluence of two rivers Ganges and Yamuna. It is one of the famous holy cities of India, well known for Magh Mela.

Samples collection site

The selected fruits and vegetables for the following study (Table 1) were collected from transporter who were bringing these products from the farmers and were shifting them to local markets. We have taken the edible portions of the vegetables selected for the study.

Determination of pH

pH of each fig sample was measured with the help of digital pH meter (AD 1020) by standard method described by AOAC (2006).

Total Soluble Solids (TSS): Total soluble solids were measured according to procedure of AOAC (2006) using digital refractometer at room temperature.

Moisture Content: Moisture content was measured by using the method prescribed by AOAC (2006).

$$\text{Moisture\%} = \frac{\text{Weight of sample} - \text{weight of sample after drying}}{\text{Weight of sample}} \times 100$$

Determination of titratable acidity: Total titratable acidity was measured by standard literature method given by AOAC (2006) by using 100 ml volumetric flasks separately.

Determination of ascorbic acid

Ascorbic acid was determined with the help of standard method described in AOAC (2006).

Total ash content

Ash content was determined by using AOAC method (2000). Ash content was determined by applying following formula: $\text{Percent Ash} = \frac{W_2 - W_1}{W_2} \times 100$

Preparation of sample

To remove harmful chemicals from the different vegetable samples double distilled water was used. Water content from the edible parts of the plant was removed by weighing the plant sample and then air-drying it. Vegetable samples were dried in oven at 70 - 80°C for 24 hrs to remove moisture from it. Dry vegetable samples were crushed with mortar and pestle and filtered through cotton fabric. All the samples were run in triplicates.

Table 1. Selected fruits and vegetables for the study.

Common name	Botanical names
Selected vegetables	
Spinach	<i>Spinacia oleracea. L.</i>
Tomato	<i>Solanum lycopersicum. L.</i>
Cauliflower	<i>Brassica oleracea. L.</i>
Selected fruits	
Mango	<i>Mangifera indica. L.</i>
Watermelon	<i>Citrullus Lanatus thumb</i>
Guava	<i>Psidium guajava. L</i>

Digestion of the samples

From different irrigation method three powder samples weighing 0.5 g was prepared for each leafy vegetable and three replicates were made. Crushing of ash was done with the help of perchloric acid and HNO₃ which was in the ratio 1:4. The sample was left to cool down and it was then filtered using Whatman filtrater paper No 42. A final volume of solution was made with 25 ml of distilled water and was sent for Atomic absorption spectrophotometry.

Standards and statistical analysis of data

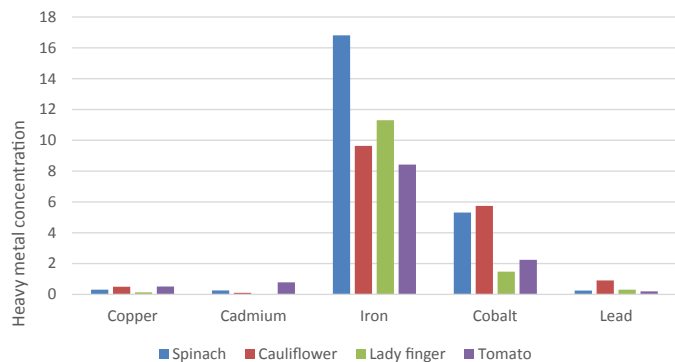
Standard solution used (1000 mg/l) (Merck, Germany). Different concentration solution for various metals were also prepared. Data was compiled in Excel sheet and analyzed statistically by using Statistics 8.1 (Statistics software). The analysis of the data was achieved by using one-way analysis of variance (ANOVA) and LSD value of P < 0.05.

Results and Discussion

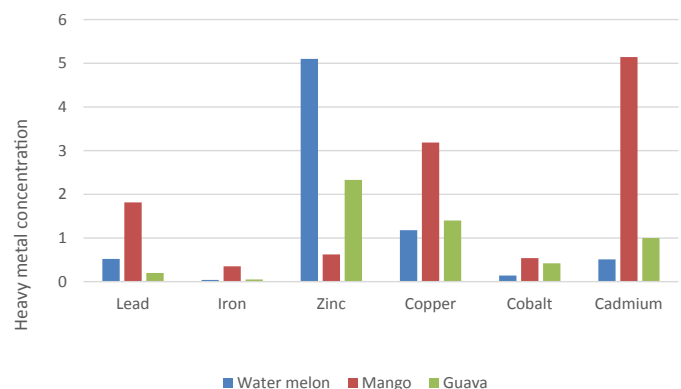
Iron concentration was higher in all the vegetables and even crossed the permissible limits (Table 2 and Figure 2). From the following study we can conclude that average concentration ranges from 0.2 to 5.75 mg/kg for the selected fruits (Table 3 and Figure 3) and vegetables. Copper concentrations were below the safe limits in a water melon and mango. Heavy metals showed their presence could be due to following reasons i.e., agricultural practices, geographic position and ability of the plant to absorb heavy metals [10]. Suggested measure may include regular examination of heavy metals in all the food commodities grown in and out. Daily consumption of food results in

Table 2. Heavy metal concentration (mg/kg or ppm) in selected vegetables.

Vegetable samples	Copper	Cadmium	Iron	Cobalt	Lead
Spinach	0.31	0.26	16.81	5.31	0.25
Cauliflower	0.5	0.1	9.64	5.74	0.91
Lady finger	0.13	0.01	11.3	1.48	0.31
Tomato	0.511	0.78	8.426	2.243	0.2

**Figure 2.** Heavy metals concentration in the selected vegetables.**Table 3.** Heavy metal concentration (mg/kg or ppm) in fruits.

Fruit sample	Lead	Iron	Zinc	Copper	Cobalt	Cadmium
Water melon	0.52	0.04	5.10	1.18	0.142	0.511
Mango	1.814	0.352	0.625	3.185	0.54	5.142
Guava	0.2	0.05	2.33	1.4	0.42	1

**Figure 3.** Heavy metal concentration in the selected fruits.

long term low level body accumulation of heavy metals, with negative impacts only after certain time interval of metal exposure [11]. As a consequence, regular inspection of these heavy metals from different water sources, leafy vegetables and other daily intake is necessary to their entry in our food chain.

The results of physicochemical properties of vegetables and fruits such as pH, Total Soluble Solids (TSS 0Brix), Titratable Acidity, Moisture content, Ascorbic Acid was presented in Tables 4 and 5. The results shown in Table 4 showed the pH values of fresh, and oven dried vegetables Spinach as 5.00, 2.30, Cauliflower 5.30, 3.10, Lady finger 4.22, 3.44 and Tomato 4.83 and 2.96 units. Similarly, Table 5 showed the pH of fresh and oven dried fruits such as Water melon as 6.00, 3.30, Mango 5.00, 2.00 and Guava 5.32 and 3.24 respectively.

These findings illustrate that drying process lowering the hydrogen ion concentration in vegetable and fruits. Our findings are in agreement with Jany MNH et al. [12] that vegetables and fruits contains pH range from 5.0-5.1 units and the drying process influenced more in lowering pH content thus decreased. Our findings are further authenticated that vegetables and fruits contain natural pH which is near to normal pH. Having normal pH indicates more suitability of the edible vegetables and fruits when intake does not affect

the body pH. Similarly, the total soluble solids (TSS) of fresh and oven dried vegetables and fruits significantly increased in oven dried vegetables and fruits. The highest increase in TSS was observed in oven dried Tomato (74.02) and Guava (68.54) (Tables 4 and 5). The increment in TSS concentration of dried vegetables and fruits are due to evaporation of moisture during drying. Our results are closely correlated with the findings of Khapre AP et al. [13] that fresh fig contains 22 (°Brix) total soluble solids. However, wild figs are sweeter than other figs because other reported less than 22 (brix).

The present research data revealed that the fresh and oven dried vegetables such as Spinach, Cauliflower, Lady finger and Tomato contains 0.13-1.50%, 0.25-2.32%, 0.26-2.52% and 0.19-3.13% Titratable acidity respectively (Table 4). Similarly, fresh and oven dried Guava Titratable acidity was highest 0.27 and 1.92 as compared with Water melon and Mango (Table 5). The reduction in acidity may be due to catabolic activities in fruit cells and increased in pH.

Ascorbic acid contents in fresh and oven dried vegetables are presented in Table 4. Results showed that fresh and oven dried Tomato contains highest ascorbic acid (11.32 and 4.41 (mg/kg) as compared with other vegetables. Similarly, Table 4 showed highest Ascorbic acid content in Guava (14.32-6.21 mg/kg) as compared with Water melon and Mango [14]. The results showed massive reductions after oven drying techniques. These results are correspondingly authenticate with other former researchers reported that on drying of vegetables and ascorbic acid concentration degraded because it is highly heat sensitive and may easily degrade vitamin C content in drying products [15].

The moisture content was also determined as shown in Table 4 and 5. The moisture content in fresh vegetables such as Spinach, Cauliflower, Lady Finger and Tomato was 44.02%, 53.11%, 63.31 and 76.52% which decreased

Table 4. Measurement of pH, total soluble solids (TSS), Titratable acidity and Ascorbic acid (mg/kg), moisture and ash contents in fresh and oven dried vegetables.

Treatments	pH	TSS	Titrateable acidity	Ascorbic acid	Moisture content	Ash content
Fresh Spinach	5.00 ^a	19.01 ^b	0.13 ^c	10.21 ^a	44.02 ^a	4.32 ^b
Oven dried Spinach	2.30 ^b	48.32 ^a	1.50 ^a	4.00 ^b	22.31 ^b	7.53 ^a
Fresh Cauliflower	5.30 ^a	15.00 ^a	0.25 ^c	9.31 ^a	53.11 ^a	5.01 ^a
Oven dried Cauliflower	3.10 ^b	36.01 ^b	2.32 ^a	3.12 ^b	6.23 ^b	12.12 ^b
Fresh Lady finger	4.22 ^a	19.32 ^a	0.26 ^a	13.32 ^a	63.31 ^a	6.54 ^a
Oven dried Lady finger	3.44 ^b	58.54 ^c	2.52 ^b	7.41 ^b	25.12 ^b	15.15 ^b
Fresh Tomato	4.83 ^a	22.45 ^a	0.19 ^a	11.32 ^a	76.52 ^a	3.51 ^a
Oven dried Tomato	2.96 ^b	74.02 ^b	3.13 ^b	4.41 ^a	33.37 ^b	17.52 ^b

Mean values are the results of the triplicate (n=3). Means with dissimilar alphabets indicate significant difference ($P \leq 0.05$), while similar letters indicate non-significant difference between treatments.

Table 5. Measurement of pH, total soluble solids (TSS), Titratable acidity and Ascorbic acid (mg/kg), moisture and ash contents in fresh and oven dried fruits.

Treatments	pH	TSS	Titrateable acidity	Ascorbic acid	Moisture content	Ash content
Fresh Water melon	6.00 ^a	22.01 ^b	0.23 ^c	12.31 ^a	92.02 ^a	3.32 ^b
Oven dried Water melon	3.30 ^b	58.32 ^a	1.20 ^a	5.00 ^b	30.91 ^b	6.53 ^a
Fresh Mango	5.00 ^a	18.00 ^a	0.21 ^a	10.31 ^a	62.01 ^a	4.01 ^a
Oven dried Mango	2.00 ^b	47.01 ^c	1.62 ^b	4.02 ^b	8.33 ^c	10.32 ^b
Fresh Guava	5.32 ^a	16.32 ^a	0.27 ^a	14.32 ^a	53.41 ^a	5.54 ^a
Oven dried Guava	3.24 ^b	68.54 ^b	1.92 ^b	6.21 ^c	22.32 ^b	13.45 ^b

Mean values are the results of the triplicate (n=3). Means with dissimilar alphabets indicate significant difference ($P \leq 0.05$), while similar letters indicate non-significant difference between treatments.

after oven drying as 22.31%, 6.23%, 25.12% and 33.37 respectively (Table 4). Similarly, Table 4 showed moisture content of fresh and oven dried fruits such as Water melon (92.02-30.91%), Mango (62.01-8.33%) and Guava (53.41-22.32%). These results indicated that moisture content dropped after oven drying. Previous research study also indicated the authenticity of our findings as reported [16] fresh fig contains 75.3% moisture while dried figs contains 10.43% respectively. Similar results were also reported by Naikwadi et al. [17] that lowering moisture content below 15% increases the shelf life of fruits and vegetables products hence drying methods are applied.

Ash content of fresh and oven dried vegetables Spinach, Cauliflower, Lady Finger and Tomato was by about 4.32-7.53%, 5.01-12.12%, 6.54-15.15% and 3.51-17.52 respectively (Table 3). Similarly, the ash content in fresh and oven dried fruits such as Water melon, Mango and Guava was 3.32-6.53%, 4.01-10.32% and 5.54-13.45% respectively (Table 4). Present results indicated that ash content increased after oven drying. Present results are correlated with the findings of Naikwadi et al. [17] that reported that fresh fruits contain lower ash content than dried fruits (Table 5).

Conclusion

When any form of wastewater is added to the soil it changes the physical and chemical properties of the soil. We all know that heavy metals intake by the vegetables and fruits are not only affecting the soil profile but also causing serious health issues. In the following study heavy metal accumulation in edible parts of the vegetable was studied showing the presence of heavy metals i.e., iron, copper, cadmium, cobalt, lead and zinc. Heavy metals showed their presence could be due to following reasons i.e., agricultural practices, geographic position and ability of the plant to absorb heavy metals. The pH value of vegetables and fruits dropped after oven drying. Similarly, ascorbic concentration and moisture content significantly decreased after oven drying as compared to fresh vegetables and fruits. However, the total soluble solids (TSS) and ash content significantly increased after oven drying as compared with fresh vegetables and fruits.

Suggested measure may include regular examination of heavy metals in all the food commodities grown in and out. Daily consumption of food results in long term low level body accumulation of heavy metals, with negative impacts only after certain time interval of metal exposure. As a consequence, regular inspection of these heavy metals from different water sources, vegetables and other daily intake is necessary to their entry in our food chain.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The results of the triplicate measurements data used to support the findings are available from the corresponding author upon request.

Author Contributions

Swati Singh Chandel and Amar Singh Rana performed the manuscript writing, collected the data and done the partial analysis work of the study. Muhammad Ibrahim carried out the analysis presented in the study and also edited and corrected the manuscript.

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Conflict of Interest

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission and redundancy have been completely witnessed by the authors.

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