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Estimation of Heavy Metals in Locally Available Vegetables Collected from Road Side Market Sites (1-4) of Different Areas of Ranchi City

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ABSTRACT

Heavy metals are among the major contaminants of food supply and may considered the most important problem to our environment. The hypothesis behind the present study is that the irrigation with waste water, transportation and marketing site of vegetables in contaminated environment may elevate the levels of heavy metals in vegetables through surface deposition. Eight Road side Markets and two organised Markets were demarcated for vegetable purchasing. The present study was focused on Site-1 to Site-4 only. Six vegetables out of thirteen showed higher Metal Pollution Index in Site-3 and Site-4. All sites showed several fold higher concentrations of Lead (Pb), than the permissible PFA limit. Site-4 contains significantly higher concentration of Pb (P<0.001) than all other sites. The present study has generated data on heavy metal pollution in and around Ranchi City, Capital of Jharkhand and associated risk assessment for consumer’s exposure to the heavy metals.

Key words: Heavy metals, vegetables, PFA, MPI, ICP-OES

INTRODUCTION

Food safety is a major public concern worldwide and food consumption has been identified as the major pathway for human exposure to certain environmental contaminants, accounting for >90% of intake compared to inhalation or dermal routes of exposure. About 30% of human cancers are caused by low exposure to initiating carcinogenic contaminants in the diet1. During the last decades, the increasing demand of food safety has stimulated research regarding the risk associated with consumption of foods contaminated by pesticides, heavy metals and/or toxins2.

Heavy metals (Lead, Arsenic, Cadmium, Copper, Chromium and Nickel) contamination of vegetables cannot be underestimated as these foodstuffs are important components of human diet. Vegetables are rich sources of vitamins, minerals, and fibers, and also have beneficial antioxidative effects. However, intake of heavy metal-contaminated vegetables may pose a risk to the human health. Heavy metal contamination of the food items is one of the most important aspects of food quality assurance3-6. International and national regulations on food quality have lowered the maximum permissible levels of toxic metals in food items due to an increased awareness of the risk these metals pose to food chain contamination4.

Heavy metals are among the major contaminants of food supply and may considered the most important problem to our environment7. Heavy metals, in general, are not biodegradable, have long biological half-lives and have the potential for accumulation in the different body organs leading to unwanted side effects8-9. Lead and cadmium are among the most abundant heavy metals and are particularly toxic. The excessive content of these metals in food is associated with etiology of a number of diseases, especially with cardiovascular, kidney, nervous as well as bone diseases8,10-12. In addition, they are also implicated in causing carcinogenesis, mutagenesis and teratogenesis13-14.
Heavy metal contamination may occur due to irrigation with contaminated water, addition of fertilizers and metal-based pesticides, industrial emissions, transportation, harvesting process, storage and/or sale. Emissions of heavy metals from the industries and vehicles may be deposited on the vegetable surfaces during their production, transport and marketing.

It is well known that plants take up metals by absorbing them from contaminated soils as well as from deposits on parts of the plants exposed to the air from polluted environments\textsuperscript{15-16}.

Heavy metals are non-biodegradable and persistent environmental contaminants, which may be deposited on the surfaces and then absorbed into the tissues of vegetables. Plants take up heavy metals by absorbing them from deposits on the parts of the plants exposed to the air from polluted environments as well as from contaminated soils. A number of studies have shown heavy metals as important contaminants of the vegetables. Heavy metal contamination of vegetables may also occur due to irrigation with contaminated water. The potential toxicity, persistent nature and cumulative behavior as well as the consumption of vegetables and fruits, there is necessary to test and analyze these food items to ensure that the levels of these contaminants meet the agreed international requirements.

Regular survey and monitoring programmes of heavy metal contents in foodstuffs have been carried out for decades in most developed countries. But, in developing countries limited data are available on heavy metals. Therefore this study will present data on the level of heavy metals in selected vegetables and this study will be also dealing with the daily intake of these metals through consumption of vegetables.

MATERIALS AND METHODS

Study Areas

The study was conducted around Ranchi city (23°21’ N latitude 85°20’ E longitude and 729 m (2,392 ft) above the sea level) in Jharkhand eastern plains of India during July 2010 to February 2012. Various small scale industries situated in this city. A large area around industries have no access to clean water resources, so farmers use treated and untreated wastewater for irrigation. The hypothesis behind the present study is that the irrigation with waste water, transportation and marketing site of vegetables in contaminated environment may elevate the levels of heavy metals in vegetables through surface deposition. Eight Road side Markets viz. Site-1 (Lalpur Market), Market Site-2 (BIT More Market), Site-3 (Daily Market), Site-4 (Kanke Road Market), Site-5 (Boothi More Market), Site-6 (RIMS Market), Site-7 (Morabadi Stadium Market), Site-8 (Bahu Bazar Market) and two organised Markets i.e. Site-9 (Reliance Fresh) & Site-10 (Big Bazar) were demarcated for vegetable purchasing. The present study was focused on Site-1 to Site-4 only.

Sampling

The edible portions of Vegetables were collected from different markets during July 2010 to June 2011. Samples were brought back to the laboratory and washed with clean tap water to remove the soil particles and dusts of the vegetables. After removing the extra water from the surface of vegetables with blotting paper, samples were cut into pieces, packed into separate bags, and kept in an oven until a constant weight was achieved. The dried samples were grinded and passed through a sieve of 2 mm size and then kept at room temperature for further analysis.

Digestion of Plant Samples

0.5 gm of the dried powdered sample was digested in Microwave Digester 3000 SOLV at 1400
watt for 3 hours in the solvent system of HNO₃ : H₂O₂, in 7:0.5 ratio until a transparent solution was obtained. After cooling, the digested sample was filtered using Whatman Grade No. 44 (Quantitative Filter Paper, Ashless) and the filtrate was finally maintained to 100 ml with distilled water.

**Analysis of Heavy Metals**
Concentrations of As, Cd, Co, Cr, Cu, Mn, Ni and Pb in the filtrate of digested plant samples were estimated by using an Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) (Model Optical 2100DV ICP-OES, Perkin Elmer, USA) with argon laser. The Spectral range was of 160 nm to 900 nm and resolution of 0.009 nm at 200 nm. The instrument was fitted with UV sensitive dual backside – illuminated CCD array detector.

**DATA ANALYSIS**

**Metal Pollution Index (MPI)**
To examine the overall heavy metal concentrations in all vegetables, metal pollution index (MPI) was computed. This index was obtained by calculating the geometrical mean of concentrations of all the metals in the vegetables¹⁷.

\[
MPI (\mu g/g) = (Cf_1 \times Cf_2 \times \ldots \times Cf_n)^{1/n}
\]

Where, \(Cf_n\) = concentration of metal \(n\) in the sample.

**Statistical Analysis**
The data of heavy metal concentrations in the vegetables of different sites (Site-1 to Site-4) were subjected to two way analysis of variance (ANOVA) test for assessing the significance of differences in heavy metal concentrations due to different irrigation practices, environmental pollutants, etc followed by Bonferroni’s multiple comparison test. All the statistical tests were performed using GraphPad Prism.

**RESULTS**

**Metal Pollution Index**
Metal Pollution Index (MPI) is suggested to be a reliable and precise method for metal pollution monitoring of wastewater irrigated areas¹⁷. Among different vegetables in Site-1, pea showed highest value of MPI followed by spinach. In Site-2 pea, spinach and beans showed higher MPI. Six vegetables out of thirteen showed higher MPI i.e. more than 2, in Site-3 and Site-4. These were pea, spinach, tomato, cucumber, lady finger and beans. Higher MPI suggests that these vegetables may cause more human health risk due to higher accumulation of heavy metals in the edible portion.

**Concentration of Heavy Metals**
Heavy metal concentrations showed variations among different vegetables collected from different market sites (Figure 1 to Figure 6). All sites showed several fold higher concentrations of Lead (Pb), than the permissible PFA limit, in cucumber (range, 7.10 ± 1.52 ppm to 12.67 ± 1.52 ppm), pea (range, 6.17 ± 1.51 ppm to 20.67 ± 3.29 ppm) and tomato (range, 5.00 ± 1.97 ppm to 9.67 ± 0.33 ppm). Site-1 and Site-4 also showed higher concentration of Pb in lady finger (6.40 ± 2.89 ppm and 7.83 ± 1.51 ppm, respectively). Site-2 and Site-4 showed higher concentration of Pb in beet, beans and spinach. Apart from these Site-3 showed higher concentration of Pb in cabbage and coriander. Nickel (Ni) was found to be higher in pea (4.33 ± 0.56 ppm to 4.83 ± 0.60 ppm) and beans (3.83 ± 0.48 ppm to 4.67 ± 0.42 ppm) than PFA permissible limit in all sites. Cucumber (2.93 ± 0.31 ppm) of Site-3 and tomato
(4.33 ± 0.67 ppm) of Site-4 were found to contain high amount of Ni than the permissible PFA limit. Site-4 contains significantly higher concentration of Pb (P<0.001) than all other sites. Concentration of Nickel in cucumber of Site-3 and tomato of Site-4 were significantly higher (P<0.001) in comparison to all other sites. Cadmium was found to be significantly higher Cucumber (P<0.01) and Coriander (P<0.05) of Site-4 in comparison of Site-1. Rest all heavy metals were found to be below the PFA permissible limit in all vegetables collected from different sites. Results of two way ANOVA test showed that variations in the heavy metal concentrations were significant for some heavy metals due to site, vegetable and site plant interaction (Table 1). The variations in heavy metal concentrations in vegetables of the same site may be ascribed to the differences in their morphology and physiology for heavy metal uptake, exclusion,
accumulation and retention\textsuperscript{18-19}. The use of contaminated irrigation water may also increase the uptake and accumulation of the heavy metals in the vegetables.

**CONCLUSION**

The variations in the concentrations of the heavy metals in vegetables observed during the present study may be ascribed to the physical and chemical nature of the soil of the production sites, absorption capacities of heavy metals by vegetables, atmospheric deposition of heavy metals, which may be influenced by innumerable environmental factors such as temperature, moisture and wind velocity, and the nature of the vegetables, i.e. leafy, root, fruit, exposed surface area, hairy or smoothness of the exposed parts\textsuperscript{20}. The variations in the concentrations of heavy metals in the vegetables tested may also be ascribed to the variations in the anthropogenic activities such as heavy traffic, addition of phosphate fertilizers or use of metal-based pesticides around production sites and urban industrial activities at market sites.

The present study has generated data on heavy metal pollution in and around Ranchi City, Capital of Jharkhand and associated risk assessment for consumer’s exposure to the heavy metals. The proposed hypothesis that the transportation and marketing of vegetables in contaminated environment may elevate the levels of heavy metals in vegetables through surface deposition has been proved through this study. Appropriate precautions should also be taken at the time of transportation and marketing of vegetables.

Heavy metals have a toxic impact, but detrimental impacts become apparent only when long-term consumption of contaminated vegetables occurs. It is therefore suggested that regular monitoring of heavy metals in vegetables and other food items should be performed in order to prevent excessive build-up of these heavy metals in the human food chain.

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**Table 1. Variation in heavy metal concentration of vegetables of different sites**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Vegetable</th>
<th>Heavy metal</th>
<th>Site</th>
<th>Concentration (ppm)</th>
<th>Level of Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pea</td>
<td>Lead</td>
<td>Site-1</td>
<td>13.733 ± 2.733*</td>
<td>Site-4 vs All</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Site-2</td>
<td>12.000 ± 1.932*</td>
<td>**P&lt;0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Site-3</td>
<td>06.167 ± 1.515*</td>
<td>***P&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Site-4</td>
<td>20.667 ± 3.293</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Tomato</td>
<td>Nickel</td>
<td>Site-1</td>
<td>0.333 ± 0.076*</td>
<td>Site-4 vs All</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Site-2</td>
<td>0.317 ± 0.054*</td>
<td>***P&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Site-3</td>
<td>0.433 ± 0.076*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Site-4</td>
<td>4.333 ± 0.667</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Cucumber</td>
<td>Nickel</td>
<td>Site-1</td>
<td>1.167 ± 0.167*</td>
<td>Site-3 vs All</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Site-2</td>
<td>1.333 ± 0.211*</td>
<td>**P&lt;0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Site-3</td>
<td>2.933 ± 0.981</td>
<td>***P&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Site-4</td>
<td>1.167 ± 0.211*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cadmium</td>
<td>Site-1</td>
<td>0.100 ± 0.068*</td>
<td>Site-4 vs All</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Site-2</td>
<td>0.200 ± 0.045*</td>
<td>**P&lt;0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Site-3</td>
<td>0.383 ± 0.083*</td>
<td>*P&lt;0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Site-4</td>
<td>0.800 ± 0.073</td>
<td>ns: Non significant</td>
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<tr>
<td>4</td>
<td>Coriander</td>
<td>Cadmium</td>
<td>Site-1</td>
<td>0.267 ± 0.123*</td>
<td>Site-4 vs All</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Site-2</td>
<td>0.333 ± 0.120*</td>
<td>*P&lt;0.05</td>
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<tr>
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<td></td>
<td>Site-3</td>
<td>0.517 ± 0.122*</td>
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<td>Site-4</td>
<td>0.867 ± 0.152</td>
<td>significant</td>
</tr>
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Results represented as Mean ± SEM (n=6). Two way analysis of variance (ANOVA) followed by Bonferroni’s multiple comparison test.
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