Research Article

Determination of the Selected Heavy Metal Content and Its Associated Health Risks in Selected Vegetables Marketed in Bahir Dar Town, Northwest Ethiopia

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Introduction. Fresh vegetables are of great value and the most common foods in the human diet around the world. They contain minerals, vitamins, antioxidants, antimetabolites, protein, carbohydrates, and water. However, they are a major source of heavy metals, which contain both essential and toxic heavy metals over a wide range of concentrations. The study sites serve as a regional commercial center, where vegetables such as cabbages, onions, carrots, potatoes, beetroots, lettuce, and tomatoes were irrigated year round and sold to consumers. The aim of the study was to determine the level of cadmium, chromium, copper, and lead and to estimate the health risks associated with their daily intake of vegetables marketed in Bahir Dar town, Northwest Ethiopia. Methods. The concentrations of copper (Cu), chromium (Cr), cadmium (Cd), and lead (Pb) were determined, and their health risks were estimated using estimated daily intake (EDI), target hazard quotient (THQ), hazard index (HI), and target cancer risk (TCR) for selected heavy metals by using flame atomic absorption spectrometry. A total of 5 kg composite samples for each type of vegetable were collected by simple random sampling from an open market in Bahir Dar town, Northwest Ethiopia, and sub-samples (1.25 kg) were digested via the wet digestion method. Results. The average concentrations of Cr and Cu in all selected vegetables were lower than the maximum limit of expected values. However, the concentration (mg·kg⁻¹) of Pb in carrots, potatoes, and beetroots exceeded the safe limit of 0.3 mg·kg⁻¹ set by the FAO/WHO and the concentration of Cd (mg·kg⁻¹) in carrots, which is higher than the FAO/WHO limit, 0.2 mg·kg⁻¹, in dry weight. The health index (HI) values (mg·kg⁻¹ day⁻¹) of all vegetables except carrots were lower than one. The TCR values for Pb, Cd, and Cr in all vegetables exceeded the US-EPA recommended threshold risk limit, but the TCR value of carrot was above the moderate risk limit (>1 × 10⁻³) set by the US-EPA. Conclusion. This study indicated that the concentration level of lead and cadmium in potatoes, onions, carrots, and beetroots marketed in Bahir Dar town is not safe for use by the local community. The consumption of carrots in the study area may cause both noncancerous and cancerous health risks. Therefore, regular monitoring of these toxic metals in vegetables should be carried out to prevent heavy metal toxicity associated with the consumption of those vegetables marketed in Bahir Dar town, Ethiopia.

1. Introduction

Fresh vegetables are a source of minerals, vitamins, antimetabolites, antioxidants, protein, carbohydrates, and water, which are essential for health maintenance, prevention, and treatment of various diseases [1].

However, they are also major sources of heavy metals, which contain both essential and toxic heavy metals over a wide range of concentrations in the human diet because metals and other elements can be present naturally in food or can enter food as a result of human activities such as industrial and agricultural processes, which cause chronic and acute health problems such as depression, cancer, osteoporosis, brain and nervous system damage, metabolic abnormalities, respiratory disorders, vascular diseases, kidney or bone damage, low intelligent quotients in children,
and irregular functioning of the human and animal reproductive systems. The intake of heavy metal-contaminated vegetables regularly may pose a risk to human health [2, 3].

The World Health Organization (WHO) estimated that about a quarter of the diseases facing mankind today occurs due to prolonged exposure to environmental pollution and is increasing worldwide. The most commonly found heavy metal pollutants include Cd, Cr, Cu, and Pb, all of which cause risks to human health and the environment [1, 3].

In recent years, because of industrial and agricultural development, concern over the adverse effects of inorganic fertilizers, pesticides, animal manure, mining activities, and atmospheric deposition to agricultural soils have prompted numerous surveys due to the extensive use of those agrochemicals, which hurt the soil and water supply and these agrochemicals leave residues such as heavy metals and organic compounds, which pose health risks to humans and hazardous ecological risks to plants, animals, and microorganisms [1, 4]. Especially in developing countries like Ethiopia, environmental pollution is becoming a major concern because of rapid economic activities, poor waste management systems, and the absence of a monitoring system. Therefore, vegetable quality and safety have become a major public concern worldwide, mainly in developing countries like Ethiopia [1–5].

Therefore, this study is intended to insight the selected heavy metal concentration in cabbage, onion, carrot, potato, beetroot, lettuce, and tomato samples marketed in Bahir Dar town, Northwest Ethiopia. In addition, their harmful effects on living organisms related to the consumption of these vegetables have been appraised through the determination of the estimated daily intake (EDI), target hazard quotient (THQ), hazard index (HI), and target cancer risk (TCR) for selected heavy metals. The findings of this study also may have a significant value for policymakers and development partners who lend a hand in the growth of good quality vegetables and apply environmental protection policies, food quality policies, and regulations that can be implemented to boost and stimulate the factors (1–5).

2. Materials and Methods

2.1. Equipment and Apparatus. A flame atomic absorption spectrophotometer (FAAS) (Buck Scientific Model 210VGP AAS, USA), a ceramic mortar with a pestle (Halden Wanger, Germany), polyethylene bags, a digital analytical balance (Model E11140, Switzerland), beakers, measuring cylinders, conical flasks, pipettes, volumetric flasks, a biological safety cabinet, a conical flask, a hot plate (Stuart Scientific, UK), Whatman No. 42 filter papers (Whatman Limited, England), a hot air oven, a funnel, porcelain crucibles, and a plastic knife were used for the determination of Pb, Cd, Cr, and Cu in samples.

2.2. Chemicals, Regents, and Solvents. Analytical graded chemicals, reagents, and solvents were used. Deionized water, HClO4 (70%, Sisco Pvt Ltd., India), HNO3 (69%, Oxford Lab. Chem., India), H2O2 (30%, Scharlab S. L., Spain), and standard stock solutions such as Cd (NO3)2, Pb (NO3)2, Cu (NO3)2, and Cr (NO3)2 (99.99%, Merck, Germany) were used.

2.3. Study Area and Period. The study was conducted in Bahir Dar town, Northwest Ethiopia, from January 2021 to June 2021. Bahir Dar, the capital city of Amhara National Regional State, is 552 kilometers away from Addis Ababa, the capital city of Ethiopia and located at 11°36′ N, 37°23′ E on the southern shore of Lake Tana, where the Blue Nile river starts (Figure 1). It is a rapidly expanding town with commercial centers, small industries, and residences in all sectors of the town. Based on the 2014/15 census conducted by the Central Statistical Agency of Ethiopia, the town has 108,456 men and 113,535 women from a total population of 221,991 [6].

2.4. Study Design and Sample Collection Methods. An experimental-based study design was used. The possible representative samples of highly consumable vegetables (cabbages, onions, carrots, potatoes, beetroots, lettuce, and tomatoes) in the study area were selected (6) and collected based on the European Commission Regulation 333/2007 by using simple random sampling in Bahir Dar town from the open market starting from May 15 to 30, 2021 (Table 1). About 0.25 kg of each type of a vegetable sample was purchased from randomly selected twenty farmers in the open market of Bahir Dar town and thoroughly mixed together to form 5 kg of the composite sample. A quarter of the composite sample should be used as subsamples (1.25 kg each), which is considered to be a quite representative sample for analysis for each type of the vegetable. The subsamples were stored in a refrigerator via polyethylene bags and transported to the laboratory, where sample pretreatments were made [7].

2.5. Sample Pretreatment. The collected samples were treated according to Association of Analytical Communities (AOAC) methods: The vegetable samples (cabbages, onions, carrots, potatoes, beetroots, lettuce, and tomatoes) were washed with tap water and rinsed three times with deionized water to remove the dust particles and other pollutants from the outer surface. The edible parts were separated from the nonedible parts because the edible portions were only included in the analysis. The edible portions were sliced and dried in the oven at 105°C for 24 h. After getting completely dried, they were grounded into powder form and stored in plastic-sealed bags with proper labels [8, 9].

2.6. Sample Digestion and Analysis. The samples were digested following the optimized procedure of the wet acid digestion method according to standard methods reported by AOAC [8]. Therefore, from each vegetable sample, 1 g of homogenized sample was digested via a mixture of 10 mL HNO3 (70%), 4.0 mL HClO4 (70%), and 4.0 mL H2O2 (30%) established at 240°C for 2 h until all samples were dissolved completely and to obtain a clear and colorless solution. The diluted digestive solutions were filtered with the help of a Whatman filter paper No. 42 to remove any suspended and
turbid matter using a 50 mL volumetric flask and funnel. The volume of the clear solution was made up to 50 mL with deionized water [7–9]. A blank solution containing the only mixture of 10 mL HNO₃ (69%), 4.0 mL HClO₄ (70%), and 4.0 mL H₂O₂ (30%) was prepared using the same digestion procedures used for the sample preparations and diluted to 50 mL with deionized water. All the digested samples and the blank solutions were stored in a refrigerator at 4°C until the analysis is completed. The analysis is carried out using FAAS at the Analytical Chemistry Laboratory, Department of Chemistry, University of Gondar. Triplicate digestion and analysis were carried out for each sample and the blank [7–9].

2.7. Calibration Curve Procedure. Analytical graded reference standard solutions (1000 mg/L) containing Pb, Cd, Cr, and Cu in their corresponding salts were used. After calibrating the FAAS instrument (Table 2), five series of working standard solutions were prepared by serial dilution with deionized water from the respective intermediate standard solution (50 mL of 10 mg/L). Finally, a five-point calibration curve was constructed using standard concentrations of the metals and the absorbance value of each metal (Table 3) [10–12].

<table>
<thead>
<tr>
<th>S. no</th>
<th>Common names</th>
<th>Scientific names</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cabbage</td>
<td>Brassica oleracea L.</td>
</tr>
<tr>
<td>2</td>
<td>Onion</td>
<td>Allium cepa</td>
</tr>
<tr>
<td>3</td>
<td>Carrot</td>
<td>Daucus corota L.</td>
</tr>
<tr>
<td>4</td>
<td>Potato</td>
<td>Solanum tuberosum L.</td>
</tr>
<tr>
<td>5</td>
<td>Beet root</td>
<td>Beta vulgaris L.</td>
</tr>
<tr>
<td>6</td>
<td>Lettuce</td>
<td>Lactuca sativa L.</td>
</tr>
<tr>
<td>7</td>
<td>Tomato</td>
<td>Lycopersicum escentum L.</td>
</tr>
</tbody>
</table>

Source: CSA, 2015.

2.8. Method Validation. To validate the analytical method and the efficiency of the FAAS instrument, the method validation parameters such as instrumental detection limit, method detection limit, quantification limit, precision, and accuracy studies were carried out.

2.9. Determinations of Heavy Metals. The average concentration value of each metal was expressed in mg kg⁻¹ of the dry weight of a 1 g sample using the ASEAN manual of food analysis as follows [13]:
2.10. EDI of Heavy Metals in the Selected Vegetables. The value of EDI was calculated using the following equation [15]:

\[
\text{EDI} = \frac{C_{\text{metal}} \times IR}{BW},
\]

where EDI is the estimated daily intake of heavy metals (mg kg\(^{-1}\) day\(^{-1}\)) in vegetables; \(C_{\text{metal}}\) is the average concentration of heavy metals in the edible portion of vegetables (mg kg\(^{-1}\) dry weight) which is determined by using equation (1); IR (the ingestion rate) is the average daily vegetable consumption rate for the Ethiopians (adult) which is 115 g person\(^{-1}\) day\(^{-1}\) [16], and BW is the reference body weight for an adult, which is 70 kg [17, 18].

2.11. Health Risk Assessment of Heavy Metals in the Selected Vegetables. This was computed based on the average contents of carcinogenic and noncarcinogenic metals determined in the vegetable samples using the probabilistic risk assessment model of the United States Environmental Protection Agency [15, 19].

2.11.1. Target Hazard Quotient (THQ). Used to assess the noncarcinogenic risk to humans from long-term exposure to heavy metals from vegetables. The THQ was calculated as a fraction of the chronic daily dose to the reference oral dose (\(R_fD_o\)) using the following equation [15]:

\[
\text{THQ} = \frac{\text{EDI}}{R_fD_o},
\]

where EDI is the estimated daily intake of heavy metals via vegetables in mg kg\(^{-1}\) day\(^{-1}\) determined by equation (2) and \(R_fD_o\) is the reference oral dose of the metal (mg kg\(^{-1}\) day\(^{-1}\)) which is an estimated exposure of metal to the human population per day that has no hazardous effect during a lifetime, which used in EPA’s noncancer health risk assessments. The values of oral reference dose (\(R_fD_o\)) (mg kg\(^{-1}\) day\(^{-1}\)) for Pb, Cd, Cr, and Cu are 0.0035, 0.001, 0.003, and 0.04, respectively [15].

2.11.2. Health Risk Index (HRI). It helps to evaluate the overall noncarcinogenic risk to human health through more than one heavy metal in the same vegetable, which means exposure to more than one pollutant results in additive effects and it is determined using the following equation [15]:

\[
\text{HRI} = \sum \text{THQ}_{\text{metal}} = \text{THQ}_{\text{Pb}} + \text{THQ}_{\text{Cu}} + \text{THQ}_{\text{Cr}} + \text{THQ}_{\text{Cd}},
\]

where Pb, Cu, Cr, and Cd are the individual heavy metals found in one vegetable species.

2.11.3. Target Cancer Risk (TCR). The intake of carcinogenic heavy metals was estimated using equation (5) as described by Liu et al. [20]. The TCR value of Pb, Cd, and Cr was estimated using equation (6) as described by Liu et al. [20, 21].

\[
\text{ILCR} = \text{EDI} \times \text{CSF}_o,
\]

\[
\text{TCR} = \sum \text{ILCR} = \text{ILCR}_{\text{Pb}} + \text{ILCR}_{\text{Cr}} + \text{ILCR}_{\text{Cd}},
\]

where ILCR represents the incremental lifetime cancer risk by individual heavy metal ingestion via vegetables; EDI is the estimated daily carcinogenic metals intake of the population in mg kg\(^{-1}\) day\(^{-1}\) body weight; and CSF\(_o\) is the oral cancer slope factor in mg kg\(^{-1}\) day\(^{-1}\), which is the risk produced by
the average dose of 1 mg kg\(^{-1}\) day\(^{-1}\), that has values (mg kg\(^{-1}\) day\(^{-1}\)) 0.0085, 0.38, and 0.5 for Pb, Cd, and Cr, respectively [15].

2.12. Data Analysis. The data were analyzed using SPSS version 23. The results were expressed as mean ± SD (mg kg\(^{-1}\), dry weight) of triplicate analysis.

3. Results and Discussion

3.1. Regression Equation. The calibration curves for the selected metals showed good linearity, with coefficients of determination (\(R^2\)) values greater than 0.999 within the acceptable limit of greater than 0.998 (Table 3). This indicates a good correlation or linearity between the concentration and the absorbance value of each heavy metal in each sample and good calibration of the instrument, which provides accurate and precise results [10].

3.2. Method Detection and Quantification Limit. In this study, the IDL for all metals was below the MDL of vegetable samples (Table 4), which indicates that the measuring instrument has good sensitivity for the analysis of interested metals at trace levels; hence, the results of the analysis could be reliable.

3.3. Accuracy and Precision. All recovery values were within the acceptable range of 80%–120% for metal analysis and the percentage relative standard deviation (%RSD) values for all metals in a spiked sample was below 7.7%, which was under the required control limits ≤10% [22] (Table 5). This indicates that the proposed analytical method is precise and accurate for the analysis of heavy metals. Therefore, the results obtained by this method are precise and accurate.

3.4. Concentration of Heavy Metals. The average concentrations of Pb, Cd, Cr, and Cu in the examined vegetables in the dry weight along with the relevant standard deviation values were determined using equation (1) and are presented in Table 6.

3.4.1. Lead (Pb). The level of the Pb concentration in the edible portions of vegetable samples ranged between ND and 0.576 mg kg\(^{-1}\). The highest concentration of Pb was observed in potatoes (0.507) and carrots (0.507) and also its concentration in onions (0.301) and beetroots (0.301) exceeded the safe limits, which indicates that 50% of the samples exceeded the safe limit, 0.3 mg kg\(^{-1}\), set by the FAO/WHO, hence the products might be unsafe for human being consumption [19]. Similar findings have been reported in Ethiopia by Brhane and Shiferaw in Bahir Dar town and Adet [23], Girmaye in Adama town [24], Gebeyehu and Bayissa in Mojo area [9], and Berihun, et al. in Gondar city [25]. However, low levels of Pb below the WHO permissible limit have been reported in Ethiopia by Tegegne from Awassa and Addis Ababa [5]. The mean total Pb concentration values (mg kg\(^{-1}\)) in the edible portion of vegetables were in the following order: carrots (0.507) > potatoes (0.507) > beetroots (0.301) > onions (0.301) > lettuce (0.297) > cabbages (0.296) (Table 6). Due to industrial development (lead-containing paints are used in industries such as shipbuilding, construction, demolition industries, fabrication of lead glass and crystal, mining, smelting, and informal processing and recycling of electric and electronic waste), extensive use of agrochemicals, and the use of untreated water for irrigation purposes leads to the level of Pb higher than the FAO/WHO permissible limit. The progressive exposure may cause poor muscle coordination, gastrointestinal symptoms, brain and kidney damage, hearing and vision impairments, and reproductive defects [26].

3.4.2. Cadmium (Cd). It is nonessential, has no advantageous role in plants, animals, or people, and has no nutritional capacity as it is toxic. The level of the Cd concentration in the edible portions of vegetable samples was found in the range of ND to 1.771 mg kg\(^{-1}\). But its concentration in carrots (1.767) varied significantly, which is higher than the WHO recommended permissible limit, 0.2 mg kg\(^{-1}\) [19]. Hence, consumers of carrots in Bahir Dar town are likely to encounter a health risk due to high Cd levels. The Cd concentration values (mg kg\(^{-1}\)) in the edible portion of vegetable samples were in the following order: carrots (1.767) > tomatoes (0.178) > onions (0.146) > beetroots (0.138) > potatoes (0.134) (Table 6). Similar results of high levels of Cd have been reported in previous studies conducted in Ethiopia by Berhane and Shiferaw [23], Girmaye [24], Gebeyehu and Bayissa [9], and Berihun et al. [25]. Due to the development of iron and steel production, cement nonferrous metals production, fossil fuels, waste incineration, smoking and fertilizers, and untreated water used for irrigation leads the level of Cd higher than the FAO/WHO limit. A high intake of Cd is known to be very toxic and carcinogenic and can lead to disturbances in calcium metabolism, the formation of kidney stones, softening of the bones, and osteoporosis [26].
3.4.3. Chromium (Cr). In this study, Cr was detected in 100% of the selected vegetable samples. The level of the Cr concentration in the edible portions of vegetable samples ranged between 0.728 mg·kg\(^{-1}\) and 0.809 mg·kg\(^{-1}\). The maximum and the minimum concentration (mg·kg\(^{-1}\)) of Cr was found in tomatoes (0.809) and beetroot (0.752), respectively, but the concentration in all types of vegetable samples was below the safe limit, 2.3 mg·kg\(^{-1}\), set by the FAO/WHO [19]. The Cr concentration values (mg·kg\(^{-1}\)) in the edible portion of vegetable samples were in the following order: tomatoes (0.809) > lettuce (0.779) > carrots (0.777) > potatoes (0.764) > onions (0.763) > cabbages (0.758) > beetroot (0.752) (Table 6). Similar results of low levels of Cr have been reported in a study conducted in Ethiopia by Girmaye [24], Tegegne [5], and Berihun et al. [25]. However, contrary to this finding, the concentration of Cr above the WHO maximum permissible limit was reported in previous studies in Ethiopia: Gebeyehu and Bayissa [9] and Ejigu et al. [27].

Table 6: Mean concentration of heavy metals in selected vegetables in Bahir Dar town, Northwest Ethiopia (mean ± SD, \(n=9\)).

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Pb</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD %RSD</td>
<td>0.507 ± 0.008</td>
<td>0.134 ± 0.001</td>
<td>0.764 ± 0.007</td>
<td>2.233 ± 0.008</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.274 ± 0.014</td>
<td>0.178 ± 0.001</td>
<td>0.809 ± 0.009</td>
<td>2.522 ± 0.01</td>
</tr>
<tr>
<td>Onions</td>
<td>0.301 ± 0.004</td>
<td>0.146 ± 0.012</td>
<td>0.763 ± 0.006</td>
<td>0.178 ± 0.008</td>
</tr>
<tr>
<td>Cabbages</td>
<td>0.296 ± 0.014</td>
<td>ND</td>
<td>0.758 ± 0.015</td>
<td>2.806 ± 0.008</td>
</tr>
<tr>
<td>Carrots</td>
<td>0.507 ± 0.009</td>
<td>1.767 ± 0.008</td>
<td>0.777 ± 0.014</td>
<td>2.325 ± 0.015</td>
</tr>
<tr>
<td>Beetroot</td>
<td>0.301 ± 0.015</td>
<td>0.138 ± 0.001</td>
<td>0.752 ± 0.012</td>
<td>0.206 ± 0.001</td>
</tr>
<tr>
<td>Lettuce</td>
<td>0.297 ± 0.012</td>
<td>ND</td>
<td>0.779 ± 0.025</td>
<td>0.152 ± 0.015</td>
</tr>
<tr>
<td>FAO/WHO limit (mg·kg(^{-1}))^a</td>
<td>0.3</td>
<td>0.2</td>
<td>2.3</td>
<td>40</td>
</tr>
</tbody>
</table>

ND = not detected; SD = standard deviation; source: a = FAO/WHO, 2012.

3.4.4. Copper (Cu). It was detected in 100% of the selected vegetable samples in the range between 0.138 mg·kg\(^{-1}\) and 2.806 mg·kg\(^{-1}\). The minimum concentration value was recorded in lettuce (0.152 mg·kg\(^{-1}\)) and the maximum was in cabbage (2.806 mg·kg\(^{-1}\)) but did not exceed the safe limit, 40 mg·kg\(^{-1}\), set by the FAO/WHO [19]. The Cu concentration values (mg·kg\(^{-1}\)) in the edible portions of vegetables were in the following order: cabbages (2.806) > tomatoes (2.522) > carrots (2.235) > potatoes (2.233) > beetroot (0.206) > onions (0.178) > lettuce (0.152) (Table 6). Similar results of low levels of Cu have been reported in previous studies conducted in Ethiopia [5, 9, 23–25, 27].

3.5. EDI of Heavy Metals in the Selected Vegetables. The EDI of the metals was estimated based on the mean concentration of each metal in each vegetable with the respective consumption rate of the vegetables in Ethiopia using equation (2). The EDI of heavy metals for the population of the study area is presented in Table 7.

In this study, the EDI for Pb, Cr, and Cu was below the \(R_D\) value in all vegetable samples, which is nearly free of risks, but Cd was above the \(R_D\) value in carrots (Table 7). The total EDI of Pb, Cd, and Cr obtained due to the consumption of all types of vegetables were observed to be more than \(R_D\), but less than the maximum tolerable daily intake of each metal while the total EDI of Cu is less than both the \(R_D\) and the maximum tolerable daily intake set by the FAO/WHO [19].

3.6. Health Risk Assessment of Heavy Metals in the Selected Vegetables. The calculated estimated daily intakes were used to determine both noncancer and cancer health risks of heavy metals through vegetables.

3.6.1. Noncancer Risks. The noncancer risks of the intake of a single metal through the consumption of each vegetable were determined by HI values. The HI values of all the studied metals were lower than one in each vegetable sample except carrots (Table 8). This suggests that those populations do not face a significant potential noncancer health risk caused by the intake of all heavy metals being studied via the consumption of a single type of vegetables. The relative contributions of Pb, Cd, Cr, and Cu to the HI from all vegetable consumption were also calculated. Cd is a major risk contributor for the residents in Bahir Dar town, which accounts 54.0% of the total HI followed by Cr (31.2%), while the risk contributions from Pb and Cu were 10.7% and 4.1%, respectively (Figure 2). The studied vegetables, as well as the intake of all studied heavy metals via consumption of a single type of vegetable from long-term exposure for adult consumers of the study area were determined by the hazard quotient (THQ) using equation (3) (Table 8).
### Table 7: The estimated daily intake (EDI) and total intake values of heavy metals through the consumption of vegetables.

<table>
<thead>
<tr>
<th>Types of samples</th>
<th>Pb</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Total intake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potatoes</td>
<td>8.33E-04</td>
<td>2.20E-04</td>
<td>1.26E-03</td>
<td>3.67E-03</td>
<td>5.98E-03</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>4.50E-04</td>
<td>2.92E-04</td>
<td>1.33E-03</td>
<td>4.14E-03</td>
<td>6.22E-03</td>
</tr>
<tr>
<td>Onions</td>
<td>4.95E-04</td>
<td>2.40E-04</td>
<td>1.25E-03</td>
<td>2.93E-04</td>
<td>2.28E-03</td>
</tr>
<tr>
<td>Cabbages</td>
<td>4.86E-04</td>
<td>BDL</td>
<td>1.25E-03</td>
<td>4.61E-03</td>
<td>6.34E-03</td>
</tr>
<tr>
<td>Carrots</td>
<td>8.33E-04</td>
<td>2.90E-03</td>
<td>1.28E-03</td>
<td>3.67E-03</td>
<td>8.68E-03</td>
</tr>
<tr>
<td>Beetroot</td>
<td>4.95E-04</td>
<td>2.27E-04</td>
<td>1.24E-03</td>
<td>3.38E-04</td>
<td>2.29E-03</td>
</tr>
<tr>
<td>Lettuce</td>
<td>4.88E-04</td>
<td>BDL</td>
<td>1.28E-03</td>
<td>2.49E-04</td>
<td>2.02E-03</td>
</tr>
<tr>
<td>Total intake</td>
<td>4.08E-03</td>
<td>3.88E-03</td>
<td>8.89E-03</td>
<td>1.70E-02</td>
<td>3.38E-02</td>
</tr>
</tbody>
</table>

RfDo (mg kg⁻¹)a  
FAO/WHO limits (mg kg⁻¹day⁻¹)b  
0.214 0.06 0.2 3.0


### Table 8: THQ values of individual heavy metals through the consumption of different vegetables in the study area.

<table>
<thead>
<tr>
<th>Type of samples</th>
<th>Pb</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>HI = ∑THQ</th>
<th>Upper limita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potatoes</td>
<td>2.38E-01</td>
<td>2.20E-01</td>
<td>4.18E-01</td>
<td>9.17E-02</td>
<td>9.68E-01</td>
<td></td>
</tr>
<tr>
<td>Tomatoes</td>
<td>1.29E-01</td>
<td>2.92E-01</td>
<td>4.43E-01</td>
<td>1.04E-01</td>
<td>9.68E-01</td>
<td></td>
</tr>
<tr>
<td>Onions</td>
<td>1.41E-01</td>
<td>2.40E-01</td>
<td>4.18E-01</td>
<td>7.33E-03</td>
<td>8.06E-01</td>
<td></td>
</tr>
<tr>
<td>Cabbages</td>
<td>1.39E-01</td>
<td>BDL</td>
<td>4.15E-01</td>
<td>1.15E-01</td>
<td>6.69E-01</td>
<td></td>
</tr>
<tr>
<td>Carrots</td>
<td>2.38E-01</td>
<td>2.90E+00b</td>
<td>4.26E-01</td>
<td>9.18E-02</td>
<td>3.66E+00b</td>
<td>HI &lt; 1</td>
</tr>
<tr>
<td>Beetroot</td>
<td>1.41E-01</td>
<td>2.27E-01</td>
<td>4.12E-01</td>
<td>8.45E-03</td>
<td>7.88E-01</td>
<td></td>
</tr>
<tr>
<td>Lettuce</td>
<td>1.39E-01</td>
<td>BDL</td>
<td>4.27E-01</td>
<td>6.23E-03</td>
<td>5.72E-01</td>
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</tr>
<tr>
<td>∑THQ</td>
<td>1.17E+00</td>
<td>9.79E-01</td>
<td>2.96E+00</td>
<td>4.25E-01</td>
<td>4.77E+00</td>
<td></td>
</tr>
<tr>
<td>RfDo (mg kg⁻¹)a</td>
<td>3.50E-03</td>
<td>1.00E-03</td>
<td>3.00E-03</td>
<td>4.00E-02</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: a = US EPA, 2015; b = THQ values > 1; BDL = below detection limit.

#### Figure 2: The total THQ values for Pb, Cd, Cr, and Cu in vegetables of the study area.

3.6.2. Target Cancer Risk (TCR). Pb, Cd, and Cr (IV) are classified by the IARC as carcinogenic agents [15]. Chronic exposure to low doses of Pb, Cd, and Cr (IV) could therefore result in many types of cancers [26]. The computed ILCR and cumulative incremental lifetime cancer risk (∑ILCR) for Pb, Cd, and Cr (IV) through the studied vegetables were determined using equations (5) and (6) (Table 9). The US EPA recommended the safe limit for the cancer risk is below about 1 chance in 1,000,000 lifetime exposures (ILCR < 1 × 10⁻⁶) and the threshold risk limit (ILCR > 1 × 10⁻⁴) for a chance of cancer is above 1 in 10,000 exposures where the remedial measures are considerable, and the moderate risk level (ILCR > 1 × 10⁻³) is above 1 in 1,000 where public health safety consideration is more
important [15]. ILCR for Pb, Cd, and Cr (IV) violated the threshold risk limit ($>1 \times 10^{-4}$) in all vegetables being studied (Table 9) [15, 26].

The cumulative cancer risk ($\Sigma$ILCR) of all the studied vegetables exceeded the recommended threshold risk limit ($>1 \times 10^{-4}$). Furthermore, among all the studied vegetables, the carrot has the highest chances of cancer risk ($1.75 \times 10^{-4}$). These risk values indicate that the consumption of carrots would result in an excess of 18 cancer cases per 10,000 people exposures [15]. Therefore, Cr is the most dominant carcinogen in the study area, and attention should be paid to controlling its exposure to the environment to save the population from the cancer risk. Furthermore, the cumulative cancer risk ($\Sigma$ILCR) for heavy metals in each vegetable exceeded the recommended threshold risk limit ($>1 \times 10^{-4}$) but the carrot level was above the moderate risk limit ($>1 \times 10^{-3}$). Therefore, the consumption of carrots in the study area is the most susceptible to cancer risk.

### 4. Conclusion

From the determination of toxic metals and their associated health risk, we can conclude that the analyzed vegetables: potatoes, onions, carrots, and beetroots contained unsafe levels of lead and cadmium that exceeded the FAO/WHO permissible limits. From the health perspective, the consumption of carrots in the study area may cause both noncancerous (THQ > 1) and cancerous health risks ($\Sigma$ILCR exceeded the moderate risk limit set by the US EPA). Therefore, regular monitoring of these toxic metals in vegetables should be carried out to prevent heavy metal toxicity associated with the consumption of those vegetables marketed in Bahir Dar town, Ethiopia.

### Data Availability

All data used to support the findings of this study are included within the article.

### Ethical Approval

A written official letter of cooperation was obtained from Wollo University’s Ethical Review Committee on the informed consent form issued to farmers ahead of providing vegetables, and an official letter of cooperation was also obtained from the Bahir Dar city urban agricultural office.

### Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

### Authors’ Contributions

Biset Asrade contributed to conceptualization, design of study writing, investigation, writing the original draft, and data analysis. Gebremariam Ketema contributed to supervision, reviewing, and editing. Both authors have agreed on the journal to which the article will be submitted, gave final approval of the version to be published, and agreed to be accountable for all aspects of the work.

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### References


