Food Safety Assessment: Trace Metal Concentrations in Onion (Allium cepa L.) from Kewot District, North Shoa, Ethiopia

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Article

Keywords: Onion bulb, Allium cepa, L., ICP- MS, Trace Metal

Posted Date: February 24th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-7940511/v1

Additional Declarations: No competing interests reported.

Food Safety Assessment: Trace Metal Concentrations in Onion (Allium cepa L.) from Kewot District, North Shoa, Ethiopia"

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Acknowledgments

The authors sincerely thank the Chemistry Department of Debre Berhan University for supplying the necessary chemicals reagents and instruments that enabled the successful execution of this project

Abstract

The present investigation focused on assessing the concentrations of heavy metals in onion bulb samples collected from two kebeles (townships) within North Shewa, Ethiopia, a region known for extensive cultivation of onions (Allium cepa L). Onion bulbs (Allium cepa, L.) were randomly collected from the farms in Yelen Kebele and Kewot District Terre. Following appropriate pre-treatment, ICP-MS was used to determine the concentration levels of selected metals. The optimum parameters of 240°C digestion temperature, (3mL of 69% HNO3, 2mL of 37% HClO4, and 0.5ml of 30% H_2O2) volume of reagents and 3 hours' digestion time were employed. The results obtained showed that the average concentrations of Zn, Cu, Pb and Cd in onion bulb samples were in the range of 2.15-3.05 mg/kg, 0.10-0.125 mg/kg, 0.03-0.04 mg/kg, 0.0001 mg/kg respectively. The percentage relative standard deviations were 17.0 to 19.9%, 3.4 – 3.5%, 7.0 t0 9.5% and 10.0% for Zn, Cu, Pb and Cd, respectively. The accuracy of the method, expressed as percentage recovery, was in the range of 95.3 -113.5%, with corresponding %RSD (n = 3) values ranging from 1.7–6.5% being obtained. Results of comparison of the level of metals with WHO/FAO standard limits revealed that the level of all analyzed heavy metals were below the corresponding metals permitted values for vegetables. Health risk assessment of onions from Terre and Yelen revealed very low estimated daily intakes and target hazard quotients for Zn, Cu, Pb, and Cd, with cumulative hazard indices well below the safety threshold of 1. This indicates negligible non-carcinogenic health risks from consuming these onions. Therefore, onions from both kebele are considered safe regarding heavy metal contamination.

Key words: Onion bulb, Allium cepa, L., ICP- MS, Trace Metal

1. Introduction

Onion (Allium cepa L.) is recognized globally as one of the most significant horticultural crops [1]. It is extensively utilized in a variety of dishes and serves as a common household remedy, valued for its abilities to aid digestion, treat minor burns and asthma, among other health benefits [2-3]. Besides its rich nutritional contribution, onion cultivation provides a vital source of income for many vegetable farmers [4]. Essential trace elements such as copper (Cu) and zinc (Zn) naturally occur in vegetables and are crucial for maintaining health; however, their toxicity arises when their concentrations exceed safe exposure limits [5,6]. Deficiencies or excesses of Cu and Zn have been linked to numerous health issues including anemia, impaired growth, dermatitis, dwarfism, electrolyte imbalance, gastrointestinal problems, neurological disorders, lethargy, and nausea [7-12]. Research shows that various metals ions including cobalt (Co), cadmium (Cd), lead (Pb), iron (Fe), copper (Cu), chromium (Cr), manganese (Mn), zinc (Zn), arsenic (As), , mercury (Hg) and nickel (Ni) are found in fruits and vegetables. For example, a study by Scutarașu and Trincă identified spinach, lettuce, cabbage, and tomato as common subjects in heavy metal contamination studies because of their high accumulation potential [13]. Similarly, fruits such as apples, bananas, grapes, and berries have been tested in different countries, with some displaying arsenic and zinc concentrations above the Codex Alimentarius safety limits. Additionally, Ezez and Belew reported that cabbage and tomato samples from central Ethiopia contained arsenic, lead, cadmium, chromium, and mercury exceeding permissible levels, with mean dry weight concentrations between 0.33 and 7.26 mg/kg. In the same investigation, mango fruits from southern Ethiopia contained measurable amounts of iron, copper, manganese, zinc, lead, and cadmium, where iron concentrations were highest (1.166–1.486 mg/kg) and lead concentrations lowest (0.035–0.097 mg/kg) [14].

Onions have been reported to contain various heavy metal ions including iron (Fe), manganese (Mn), zinc (Zn), lead (Pb), copper (Cu), cadmium (Cd), mercury (Hg), nickel (Ni), chromium (Cr), cobalt (Co), arsenic (As), tin (Sn), and boron (B) [14,16]. Research conducted in Ethiopia and other regions reports that iron concentrations in onions vary between 9.8 and 40 mg/kg dry weight, while zinc levels range from 12.33 to 13.85 mg/kg. Notably, lead and cadmium have also been detected at concentrations of approximately 2.09 mg/kg and 0.34 mg/kg, respectively [13–15]. Although certain samples surpass local safety limits for Pb and Cd, the majority comply with international standards established by WHO-FAO [14]. Among the metal ions, iron, zinc, and manganese generally exhibit the highest concentrations in both onion bulbs and leaves; however, anthropogenic activities significantly contribute to the presence of toxic metals such as lead and cadmium [16]. Health risk assessment suggests that current heavy metal levels in onions typically do not pose substantial carcinogenic or non-carcinogenic risks, though continuous surveillance is advised to mitigate potential future contamination [14,16]. Conversely, some vegetables have been found to exceed safety thresholds, raising concerns over possible adverse health effects from habitual consumption. The buildup and concentration of heavy metals in edible fruits and vegetables is influenced by factors including soil quality, farming practices, proximity to industrial zones, and overall environmental pollution [13–16]. In areas close to industrial or urban centers, crops may absorb contaminants through irrigation with polluted water or the use of contaminated soils, facilitating heavy metal transfer from the environment to food crops.

The ingestion of vegetables and fruits contaminated with heavy metals including arsenic (As), lead (Pb), mercury (Hg) and cadmium (Cd), has been linked to chronic health complications, including cancer, renal impairment, and neurological disorders [13,14]. Therefore, consistent monitoring and stringent regulatory measures are essential to minimize dietary exposure to these toxic elements both in Ethiopia and globally. A range of advanced instrumental techniques is currently used for the quantification of heavy metal ions in diverse sample matrices [17]. Analytical methods include atomic absorption and emission spectrometry, inductively coupled plasma optical emission spectrometry (ICP-OES), inductively coupled plasma mass spectrometry (ICP-MS), as well as X-ray fluorescence spectrometry [17 – 23]. Among these, ICP-MS stands out for its superior sensitivity, wide dynamic range, low detection limits, and rapid analysis, making it the preferred technique for this study [24]. The present research aims to quantify the concentrations of selected heavy metals in onion (Allium cepa L.) samples collected from two strategically chosen sites in the Kewot District, North Shoa, Amhara Regional State, Ethiopia. Given the paucity of existing data on heavy metal content in this region, the study seeks to enhance local awareness, particularly in areas where onion cultivation is a predominant agricultural activity.

2. Materials and Methods

2.1. Detailed Description of the Study Location and Surroundings

This study was conducted out in Kewot District, located within the Amhara Regional State of Ethiopia, specifically in the Terre and Yelen kebeles. Kewot is one of the districts in the North Shewa Zone, bordered to the southwest by Termaber, to the northwest by Menz Mama Midir, to the north by Efratana Gidim District, and to the east by the Afar Region. Kewot is located geographically at approximately 11°05' North latitude and 37°20' East longitude, with an altitude of 1380 meters above sea level. The area experiences an average annual rainfall of 1007 mm, characterized by short rains from March to April and longer rain from June to September. The soil types are predominantly sandy clay and sandy loam, possessing moderate fertility [25]. Covering an area of 785.85 km^2, the district's economy is primarily agriculture-based, including dryland farming, irrigation, and livestock rearing. Kewot is situated about 237 kilometers north of Addis Ababa, the capital of Ethiopia. According to the 2007 national census by the Central Statistical Agency of Ethiopia, the district has a population of 118,381 [26]. For the purpose of this research, Terre and Yelen kebeles (sub cities) recognized as major onion cultivation areas within the district were selected as sampling sites.

2.2. Chemicals and reagents

All the reagents and chemicals used for the analysis were an analytical grade. HNO_3 (69% to 72%), $HClO_4$(37%) and extra pure H_2O_2 (30%) were used for the digestion of onion samples. A stock standard solution of 1000 mg L^{-1}, in 2 % HNO_3 of each metal Pb, Cu, Cd and Zn, were prepared. From this, intermediate solutions were prepared by dilution with distilled water and five different range working standard solutions were prepared from the intermediate standard solution for each metal.

2.3. Apparatus and instrument

Onion bulbs were cut into pieces using a PTFE chopping board and Teflon knife. Pounding of the onion bulbs was performed with a porcelain mortar, pestle, and crucibles (Haldenwanger, Germany). The samples were weighed using an analytical balance (Model BA-E1204, SCItek, China) with a precision of ± 0.0001 g. For digestion, round-bottom flasks (250 mL) with ground glass joints were fitted with reflux condensers and used on a Kjeldahl heating apparatus (Gallenkamp, England). Dried onion bulb samples were ground and homogenized using a ceramic mortar and pestle. The analysis of essential and non-essential metals in the samples was conducted using inductively coupled plasma mass spectrometry (ICP-MS).

2.4. Sample collection

For this study, Terre and Yelen kebeles (sub cities) recognized as principal onion producing areas within the district were selected as sampling sites (Figure 1). Fresh onion samples totaling 2 kilograms were randomly collected using clean polyethylene bags from these two sites, with one kilogram sourced from Terre irrigation fields and another kilogram collected approximately 3 km from the Yelen onion garden, a village near Kewot (the specified quantity of onions was purchased directly from the farmers). The samples were subsequently transported to the Chemistry Department laboratory at Debre Berhan University for further analysis. Kewot experiences a moderate climate with mean annual temperatures ranging roughly from 15°C to 20°C, supporting diverse agricultural activities. The region's bimodal rainfall pattern and soil characteristics are suitable for crop cultivation, although challenges related to variable rainfall and soil fertility persist, influencing farm productivity. The selection of Terre and Yelen kebeles for sampling reflects their agricultural prominence and relevance to the scope of this study.

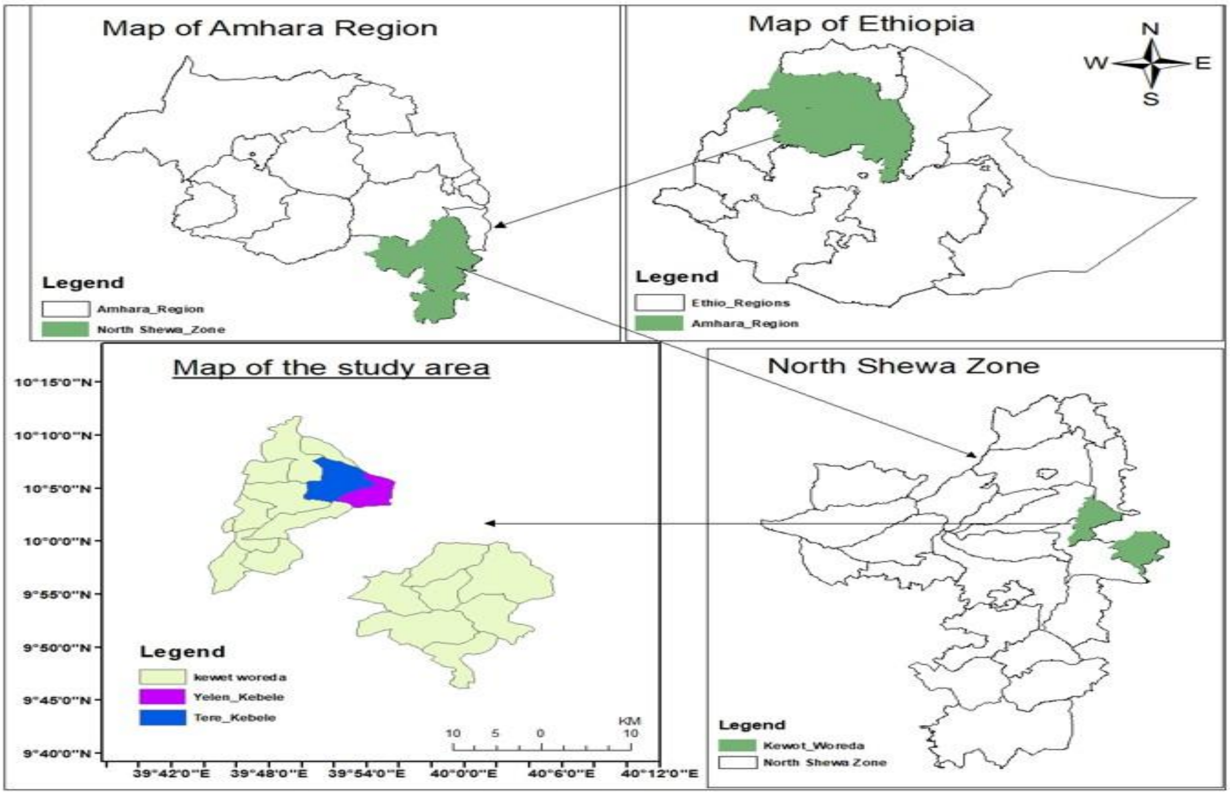

Figure 1: Map Illustrating the Study Site and Surrounding Kebeles

2.5. Sample pretreatment Procedures

The onion samples were rinsed first with tap water and then with deionized water to eliminate any soil residues, dust, spray residues and any other impurities, then chopped to facilitate drying by placing them in an aluminum foil. The chopped and cleaned onions were then allowed to dry in a warm air circulating oven at 70 ^{0}C for 24 hrs. The samples were finely ground and homogenized using a grinding device, then stored in clean, dry polyethylene bags until the digestion process.

2.6. Digestion of onion bulbs

The digestion of onion bulb samples and blank controls was performed by using the procedure outlined by Abdullahi et al., [27] with specific modifications involving varying proportions of nitric acid and perchloric acid, temperature, and digestion time. A 0.5 g portion of the ground sample was transferred into a 250 mL round-bottom flask, to which 3 mL of 69% nitric acid (HNO3), 0.5 mL of 30% hydrogen peroxide (H_2O_2 mL of 37%) and perchloric acid (HClO4) were added. The flask, attached to a reflux condenser, was heated on a Kjeldahl digester hot plate at 240°C for three hours until the solution became light in color, signaling complete digestion. After allowing the digestion vessels to cool at room temperature for 30 minutes, 5 mL of distilled water was added to the mixture, which was then filtered through a 0.35 μm Whatman filter paper into a 50 mL volumetric flask. The round-bottom flask was rinsed an additional time with 5 mL of distilled water, and this rinse was combined with the initial filtrate. The volume was then adjusted to the mark with distilled water. Each onion bulb sample was digested in triplicate to ensure reproducibility. The resulting diluted solutions were transferred into labeled, tightly sealed polyethylene bottles and stored refrigerated until analysis by ICP-MS.

2.7. Optimization of Sample Digestion Methodology

To select the best procedure suitable for analysis using ICP-MS, the sample digestion procedure was optimized using HNO_3, $HClO_4$ and H_2O_2 acid mixtures by varying parameters like, reagent volume, digestion temperature and time. The best procedure was chosen based on minimal reagent volume consumption, minimal digestion time, minimal digestion temperature and clarity of digests.

2.8. Statistical data analysis and Data processing

All statistical analyses were performed on an hp computer using Microsoft EXCEL (version 2010). All analysis was performed in triplicate; the results were expressed as mean with corresponding %RSD.

2.9. Validation of experimental protocol

The efficiency of the digestion procedure was checked by spiking 5 mg L^{-1} mixture of metals to the obtained samples from the two kebele (Terre and Yelen) and percentage recovery was calculated using equation 1.

$$\%\text{ Recovery} = \frac{\text{Concentration in spiked sample} - \text{Concentration in unspiked sample}}{\text{Amount spiked}} * 100 \qquad (1)$$

In the current study a total of four metals (Zn, Cu, Cd, and Pb) for each of the samples were analyzed by using the ICP-MS. The external calibration curve was used to calculate the concentrations of the metals.

2.10. Health risk assessment

Multiple assessment tools were employed to evaluate the health risks posed by trace elements in onions. The target hazard quotient (THQ) was determined to evaluate the potential non-cancer health risks posed by each heavy metal individually, whereas the hazard index (HI) was used to quantify the overall risk arising from the combined exposure to multiple heavy metals.Additionally, projected dietary exposure assessments estimated the daily intake of these trace elements through onion consumption, enabling a comparison with established safety limits. Collectively, these approaches provide a thorough evaluation of the potential health risks related to consuming onions contaminated with trace metals.

Estimated dietary exposure (EDI): The estimated daily metal intake determined in this study was estimated by combining the average metal concentrations found in onions with the typical daily amount of onions consumed, expressed in grams. The equation (2) used to calculate EDI:

$$EDI = \frac{C * D\ food\ intake}{BW_{average}} \qquad (2)$$

Here, C represents the concentration (mg/kg) of trace metals found in the onion vegetables, D denotes the daily food intake per person (0.100 kg), and BW signifies the average body weight of an adult consumer, set at 70 kg.

Target hazard quotient (THQ): The THQ was computed using the specified equation (2). A THQ value below 1 is considered to indicate no significant non-carcinogenic health risk, whereas a THQ exceeding 1 suggests the potential for adverse health effects.

$$THQ = \frac{Ef * ED * FIR * CM * Cf * 0.001}{BW * TA} \qquad (3)$$

In this context, BW denotes the average body weight of an adult, assumed to be 70 kg; CM signifies the concentration of metals (mg/kg) measured in the onions; Ef represents the frequency of exposure, set at 365 days per year; and ED refers to the duration of exposure, specified as 65 years, FIR is the average daily vegetable intake (240 g per person), TA denotes the total exposure period (65 years × 365 days), 0.001 serves as the unit conversion factor, and Cf is the conversion factor used to convert fresh vegetable weight to dry weight (0.085).

The hazard index (HI): The HI is calculated as the sum of the individual target hazard quotients (THQs) for all the elements assessed in a particular food type. It accounts for the possibility of simultaneous exposure to multiple potentially toxic elements through the consumption of that food. Even if each individual THQ is below one, their combined effect may still pose health risks. A hazard index exceeding 1 suggests a potential risk of adverse non-carcinogenic health effects. The hazard index was calculated using equation (3).

$$HRI = \Sigma THQ \qquad (4)$$

3. Results and Discussion

3.1. Instrument Calibration

Under optimized conditions, the digestion procedure utilized 3 g of the sample with reagent volumes of 3 mL HNO_3, 2 mL $HClO_4$, and 0.5 mL H_2O_2, operated at a temperature of 240 °C for 180 minutes. The calibration curve showed linearity over a wide concentration range from 0.5 mg/L to 50 mg/L, as detailed in Table 1. The selected metal ion concentrations demonstrated excellent linearity with correlation coefficients (R^2) greater than 0.995, confirming a robust and consistent relationship between analyte concentration and signal response (Table 2). The method detection limit (MDL) was established as three times the standard deviation calculated from the mean signal of the blank reagent, while the method quantification limit (MQL) was established as ten times that standard deviation [28]. The values of MDL and MQL were in the range of 0.01–0.1 mg/kg and 0.03–0.3 mg/kg, respectively (Table 2). These values ranged from 0.01 to 0.1 mg/kg for the MDL and from 0.03 to 0.3 mg/kg for the MQL, as summarized in Table 2. Additionally, the instrumental detection limit (IDL) which is the lowest concentration that was determined statistically by injecting the lowest concentration seven times. The calculated values of were in the range of 0.002 mg/kg – 0.049 mg/kg.

Table 1. Optimization of the volume of reagent, temperature and time for digestion of 0.5g of onion bulb samples

No	Amount of samples (g)	Reagent Volume (mL)				Digestion Temp. (° C)	Digestion time (min)
		HNO_3	$HCLO_4$	H_2O_2	Total		
1	0.5	2	2	1	5	200	120
2	0.5	5	-	1	6	200	120
3	0.5	5	2	-	7	240	120
4	0.5	3	2	0.5	5.5	240	180
5	0.5	2	2	-	4	210	150
6	0.5	2	2	-	4	210	150
7	0.5	2.5	2.5	-	5	210	190
8	0.5	6	-	-	6	-	-

Table 2: Correlation coefficient of the calibration curves for the determination of heavy metals in onion

bulbs using ICP-MS

Metals	Concentration (mg/L)	Correlation coefficient(R^2)	IDL (mg/kg)	MDLs (mg/kg)	MQLs (mg/kg)
Zn	0.50 – 5	0.9993	0.0031	0.01	0.03
Cu	0.50 – 7	0.9999	0.0027	0.01	0.03
Pb	2.62 – 50	1	0.0495	0.1	0.30
Cd	0.16 – 50	0.9950	0.0073	0.0	0.30

3.2. Recovery Test

Method validation tests whether an analytical method is suitable for its intended purpose. Accuracy was assessed by analyzing recoveries from spiked onion samples collected from Terre and Yelen kebeles (Table 3 and Table 4, respectively), with results ranging from 102.0–106.0% (RSD 1.7–5.7%) and 95.4–108.0% (RSD 1.7–6.5%), respectively (Table 3). These findings confirm the method's reliability for determining metals (Zn, Cu, Pb, and Cd).

Table 3: Percentage Recovery of spiked sample from Terre kebele

Heavy metals	Unspiked Amount(mg/kg	Amount Added (spiked) in(mg/kg)	Amount after spiked(mg/kg)	%Recovery	%RSD
Zinc (Zn)	6.304	5	11.405	102.02	5.3
Copper (Cu)	2.054	5	7.509	109.10	5.7
Lead (Pb)	1.305	5	6.547	104.84	3.2
Cadmium (Cd)	0.365	5	5.708	106.86	1.8

Table 4: Percentage recovery of spiked sample from Yelen kebele

Heavy metals	Unspiked Amount (mg/kg	Amount Added(spiked) in(mg/kg)	Amount after spiked(mg/kg)	%Recovery	%RSD
Zinc (Zn)	4.903	5	10.306	108.06	3.5
Copper (Cu)	0.908	5	6.437	110.58	5.4
Lead (Pb)	0.907	5	5.674	95.34	6.5
Cadmium (Cd)	0.364	5	6.042	113.56	1.7

3.3. Determination of Metal Concentrations in the Onion Bulb Samples

In the current study the concentrations of two non-essential metals cadmium (Cd) and lead (Pb) and two essential metals zinc (Zn) and copper (Cu) in onion samples collected randomly from two locations near the Kewot district in the North Shoa zone of the Amhara region, were analyzed. Each reported value represents the mean of three replicates (n = 3) analyzed by ICP-MS. The results, summarized in Table 5, indicate that the average concentrations ranged from 2.15 – 3.05 mg/kg for Zn, with relative standard deviation (% RSD) of 17.0 –19.9%; 0.10 to 0.125 mg/kg for Cu, with % RSD of 3.4 and 3.5%; 0.03 to 0.04 mg/kg for Pb, with % RSD ranging from 7.0 to 9.5%; and 0.0001 mg/kg for Cd, with a % RSD of 10.0%. Statistical analysis comparing heavy metal ions concentrations in onion bulbs from the two sampling locations demonstrated a significant difference ($p = 0.05$) in the average levels of copper and lead. Copper concentrations were significantly higher in samples from Terre compared to Yelen, whereas lead levels were elevated in Yelen relative to Terre. Conversely, no significant differences ($p = 0.05$) were detected in the mean concentrations of zinc and cadmium between the two locations.

Table 5: Summary of the detected mean level of each studied metal (mg/kg dry weight) and %RSD in the onion bulb samples from the two sites

Studyarea	Zn mg/kg	%RSD	Cu mg/kg	%RSD	Pb mg/kg	%RSD	Cd mg/kg	%RSD
Terre	3.05	19.9	0.125	3.4	0.03	7.0	0.0001	10.0
Yelen	2.10	17.0	0.10	3.5	0.04	9.2	0.0001	10.0

3.4. Determination of heavy metal content in onion bulbs from Terre and Yelen kebeles: A WHO/FAO standard-based assessment

The current study evaluated the concentration levels of four heavy metals Zn, Pb, Cu and Cd in onion bulbs to evaluate their safety for human consumption. The findings indicated that zinc concentrations were substantially below the WHO/FAO permissible limit of 99.4 mg/kg, suggesting that zinc exposure from onion intake poses no health risk. Likewise, copper levels were found to be significantly lower than the WHO threshold of 73.3 mg/kg, indicating a safe exposure level through onions. Lead concentrations were below the allowable limit of 0.3 mg/kg, confirming minimal contamination and a low likelihood of adverse health effects. Cadmium was detected at levels below the very stringent WHO/FAO limit of 0.0001 mg/kg, demonstrating very limited presence cadmium in the sampled onions. Collectively, these results affirm that the onion bulbs analyzed are safe for consumption with respect to the assessed heavy metals. The study emphasizes the necessity of continual monitoring of Zn, Cu, Pb, and Cd concentrations in food crops like onions to prevent health risks associated with heavy metal accumulation. By benchmarking measured values against internationally recognized WHO/FAO standards, accurate risk assessments can be made, ensuring consumer safety. This proactive approach not only safeguards public health but also promotes sustainable agricultural practices by enabling early detection and management of contamination sources. Ultimately, the data generated (Table 6) provide critical insights that support ongoing efforts to maintain the safety and quality of food products consumed by the population.

Table 6: Concentration of heavy metals compared with the recommended concentration by WHO/FAO in onion bulbs

Heavy metals	Concentration found in samples in mg/kg (Mean (n=3)		Allowed limits by FAO/WHO (2001 mg/kg)
	Teree	Yelen	
Zinc (Zn)	3.05	2.15	99.4
Copper (Cu)	0.125	0.10	73.3
Lead (Pb)	0.03	0.04	0.3
Cadmium (Cd)	0.0001	0.0001	0.2

3.5. Comparative analysis of selected metal concentrations (mg/kg) in onion bulb samples with literature values

The present study compared the concentrations of zinc, copper, lead, and cadmium in onion bulb samples with values reported in the literature, as summarized in Table 7. The average zinc levels observed in this study ranged from 2.15 to 3.05 mg/kg, while cadmium was detected at 0.0001 mg/kg. These zinc concentrations are lower than those reported in Nigeria (2.00–4.55 mg/kg), Korea (256.0 mg/kg), Chile (31.0 mg/kg), China (3.28 mg/kg), and Ethiopia (15.4 mg/kg). Similarly, copper concentrations in this study ranged between 0.10 and 0.125 mg/kg, and lead levels ranged from 0.03 to 0.04 mg/kg, both of which are lower than values reported in China (0.90 mg/kg Cu and 0.04 mg/kg Pb), Nigeria (0.34–1.00 mg/kg Cu and 2.00–9.5 mg/kg Pb), and Korea (26.4 ± 4.58 mg/kg Cu and 256 ± 79.5 mg/kg Pb). The cadmium concentration of 0.0001 mg/kg found in this study is also substantially lower than previously reported concentrations in Ethiopia (0.018 mg/kg), Korea (1.88 mg/kg), and Nigeria (0.22–0.89 mg/kg). These comparisons suggest that the heavy metal contamination in onion bulbs analyzed in the current study is comparatively low relative to these international and regional reports.

Table 7: Comparison of selected metal concentration (mg/kg) in onion bulb samples of this study with reported values from literature

Country	Vegetable	Zn	Cu	Pb	Cd	Reference
Nigeria	Onion	2.00−4.55	0.34−1.00	2.00−9.5	0.22−0.89	(29)
Korea	bulb Onion	256±79.5	26.4±4.58	4.23±1.16	1.88±0.35	(30)
Chile	Onion	31±8	7.7±1	NR	NR	(31)
China	Onion	3.280	0.900	0.040	NR	(32)
Ethiopia	Onion	15.4	5.24	NR	0.018	(33)
Ethiopia	Leaves Onion bulb	2.15-3.05	0.10-0.125	0.03-0.04	0.0001	This study

3.6. Health risk assessment

The health risk assessment of heavy metals in onion samples from Terre and Yelen kebele revealed consistently low exposure levels and negligible health risks (Table 8) [34]. For the Terre samples, the estimated daily intake (EDI) values for zinc (Zn), copper (Cu), lead (Pb), and cadmium (Cd) were 0.003, 0.00014, 0.000057, and 0.00000014 mg/kg body weight, respectively, with corresponding target hazard quotients (THQs) of 0.00061 for Zn, 0.000029 for Cu, 0.000012 for Pb, and 0.00000003 for Cd, resulting in a cumulative hazard index (HI) of 0.000934. Similarly, the Yelen samples showed slightly higher EDI values for Zn (0.00436) and Cu (0.00018), but lower Pb (0.000043) and equal Cd (0.00000014), with THQs of 0.00089, 0.000036, 0.000009, and 0.00000003, respectively, culminating in an even lower HI of 0.000653. In both locations, the HI values are far below the critical threshold of 1, indicating that the combined exposure to these metals through onion consumption poses no significant non-carcinogenic health risks. These findings confirm that onions from both Terre and Yelen are safe for consumption with respect to Zn, Cu, Pb, and Cd contamination.

Table 8: Evaluation of heavy metal exposure: EDI, THQ, and HRI assessment

Terre				Yelen		
Metal ions	EDI	THQ	HRI	EDI	THQ	HRI
Zn	0,004357143	0,000888857	0,000934	0,003	0,000612	0,000653
Cu	0,000178571	3,64286E-05		0,000142857	2,91429E-05	
Pb	4,28571E-05	8,74286E-06		5,71429E-05	1,16571E-05	
Cd	1,42857E-07	2,91429E-08		1,42857E-07	2,91429E-08	

4. Conclusion

This study investigates the levels of essential and non-essential heavy metals in onion bulb tests from two kebele in Ethiopia. The tests were conducted on onion bulbs from Terre and Yelen kebele, with optimized assimilation temperature, reagent volume, and assimilation time. The concentration of selected metal ions was analyzed using ICP-MS. The mean concentration of essential nutrients was Zn (2.15-3.05 mg/kg), Cu (0.10-0.125 mg/kg), and Pb (0.03-0.04 mg/kg). The recoveries test for the four analyzed metals ranged from 95 to 114%, indicating feasible and efficient digestion procedure for onion. All metals were found below the levels permitted for vegetables by WHO/FAO, and levels are in the safe base line levels for human use. The study highlights the quality and appropriateness of the method for extracting these metals from onion bulbs. The health risk assessment of onions from Terre and Yelen showed very low estimated daily intakes (EDI) and target hazard quotients (THQ) for zinc, copper, lead, and cadmium. The cumulative hazard index (HI) values for both locations were significantly below the critical threshold of 1. This suggests that the combined exposure to these heavy metals through onion consumption poses no significant non-carcinogenic health risks. Consequently, onions from Terre and Yelen are deemed safe for consumption with respect to heavy metal contamination.

Declaration statement

I declare that the authors have no competing interests as defined by Springer, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

Funding Statment

There is no funding for this project

Data availability

The authors declare that the data supporting the findings of this study are available within the paper. Should any raw data files be needed in another format they are available from the corresponding author upon reasonable request.

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