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Research article

# Analysis of the concentration of heavy metals in soil, vegetables and water around the bole Lemi industry park, Ethiopia

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ABSTRACT

Irrigation water contaminated with industrial waste could pollute the soil and vegetables with heavy metals. The objective of this study was to analyze the concentration of heavy metals in soil and vegetables after irrigation practices with wastewater emanating from industrial parks. 24 samples were collected from 8 sampling stations for vegetable, soil and water samples separately, following APHA procedures. Samples were collected using a composite sampling method in May and June 2021. Water samples were collected using clean polyethylene plastic bottles while soil and vegetables were sampled using clean plastic bags. Analysis was done for heavy metal concentrations such as Pb, Cr, Cd, and Zn for each sample using descriptive statistics of changes in concentrations, one-way analysis of variance (ANOVA), Principal Component Analysis and Pearson Correlation Coefficient. The mean concentration of heavy metals in soil, vegetables, and water samples was analyzed. Unlike the rest of the heavy metal concentrations, the result showed the highest levels for Zn, i.e., 7.82 mg/kg and 5.12 mg/kg for vegetables and soil samples, respectively. The maximum value of the bioconcentration factor (BCF), the highest value of Estimated Daily Intake (EDI), and the maximum Target Cancer Risk (TCR) value recorded were 19.39, 0.001, and $8.09 \times 10^{-5}$ for Cd, Zn, and Cr, respectively. But, Hazard Index (HI) indicated no potential health effects. On the other hand, the concentration of heavy metals in the soil sample showed that Cr and Cd were strongly positively correlated with the concentration of Pb in vegetables during May. Cd concentration in the water sample was also strongly positively correlated with the concentration of Pb during May. The application of proper management for the reduction of contaminants, and suitable irrigation methods with treated wastewater is essential. The study can provide a basis for the City Administration of Addis Ababa to properly protect the water quality of rivers and provide a reference for river management around the industry parks across the country.

## 1. Introduction

Rapid industrialization and urbanization have polluted the environment with heavy metals, and the rate of migration and transport of these metals in the environment has increased dramatically since the 1940s (Khan et al., 2004). Pollution due to heavy metals poses an environmental threat and is currently a major concern (Ali et al., 2013; Hashem et al., 2017). Rapid industrial development has resulted in a serious concern for natural resources such as soil and water in many countries (Abbasnia et al., 2018). Industries are one of the anthropogenic activities that have contributed to increased concentrations of many heavy metals in the environment (Mohammadi et al., 2019a).

Heavy metals are among the most important contaminants threatening human well-being (Dehghani et al., 2016; Qasemi et al., 2018). They are not biodegradable and remain in the environment. They contaminate the food chain and cause various health problems in animals and humans due to their toxicity (Davydova, 2005; Wieczorek Dabrowska et al., 2013; Javed and Usmani, 2015). About one-fourth of human diseases are due to exposure to environmental pollutants (Basma and Alhogbi, 2017). Heavy metals such as cadmium (Cd), lead (Pb), arsenic (As) and mercury (Hg) constitute one of the main environmental pollutants that can cause a critical problem for all organisms, such as soil microbial populations, plants as well as humans (Lenart and Wolny-Kołładka, 2013; Mohammadi et al., 2018) and harm human health (Jafar-

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zadeh et al., 2021). For example, exposure to high Pb concentrations brings about health problems such as the skeletal, circulatory, nervous, enzymatic, endocrine, and immune systems in the human body (Zhou and Guo, 2015; Esmaeilzadeh et al., 2019; Vasseghian et al., 2020), exposure to Cd can cause cancer (Vasseghian et al., 2020).

Industrialization in many countries has led to serious environmental pollution (Sadeghi et al., 2020). The rapid growth of industries and increased disposal of hazardous waste has deteriorated the quality of water resources (Shams et al., 2020; Fiore et al., 2019). Industrial discharges are one of the major sources of heavy metals responsible for ecological pollution (Rajaram and Das, 2008). Human activities undoubtedly create many environmental issues, which considerably affect the surrounding soil and water resources (Miri et al., 2017). According to Karimi et al. (2020), using treated and untreated wastewater for irrigation may result in the accumulation of heavy metals in soils and consequently in plants and foodstuffs. Soil pollution occurs due to various human activities such as industrial activities and chemical applications (Esmaeilzadeh et al., 2019). Soil is generally regarded as the ultimate sink for heavy metals released into the environment (Qingjie et al., 2008). Soil pollution by industries is one of the greatest environmental issues, posing major issues to the environment, organisms, and humans (Mohammadi et al., 2019a). Therefore, human health risks as a result of exposing the soil to heavy metals should not be ignored (Mohammadi et al., 2019a). Untreated industrial waste discharge has a severe effect on the environment and human health (Fekede et al., 2020).

The behaviors of heavy metals such as Cd, Cr, Pb, Co, etc. have become a growing concern in ecological research because of their capability of ecotoxicity, persistence, bioaccumulation and biomagnification properties, making them a threat to the water and soil resources' health (Kamani et al., 2018; Jafarzadeh et al., 2021). Heavy metals due to their non-biodegradability and long resistance properties are among the critical contaminants in the environment (Mohammadi et al., 2019a). They vary in their chemical properties and biological functions and have deleterious impacts on human health and ecosystems (Karimi et al., 2020). They have thus become a major concern due to their toxic, bio-accumulative and persistent nature (Yang et al., 2018). Their elevated concentrations in soil can damage the fertility and productivity of the farmlands (Sadeghi et al., 2020), and are potentially toxic to most living organisms at a high level of exposure (Rezaei et al., 2019).

Several studies have been conducted on heavy metals. For example, the assessment of the human health risk of heavy metals in agricultural soils irrigated by effluents of stabilization ponds by Karimi et al. (2020), the levels of heavy metal contamination of surface water, groundwater and soils by Sadeghi et al. (2020), the concentrations of heavy metals in surface sediment samples and pollution status by Seifi et al. (2019), the pollution status of heavy metals in soils by Mohammadi et al. (2019a) and the human health risk indices of arsenic (As), chromium (Cr), lead (Pb) and zinc (Zn) due to drinking water consumption using chronic daily intake, hazard quotient, hazard index and cancer risk by Sajjadi et al. (2022). Consuming polluted water with heavy metals can increase the risk to human health (Jafarzadeh et al., 2021).

Heavy metals exist in water, air, soil and consequently also in foods, eventually can cause adverse health effects such as carcinogenic and non-carcinogenic human health risks (Shams et al., 2020), and the health risk due to exposure to underground water resources (Jafarzadeh et al., 2021), Many recent studies have shown the association between heavy metals and some forms of human health. For example, association between heavy metals in soil and human health risks (Adimalla, 2020), between food contamination of heavy metals and the incidence and spatial distribution of stomach cancer (Fei et al., 2018), and the involvement of heavy metals in the development of colorectal cancer (Sohrabi et al., 2018). Long-term exposure to even low concentrations of As, for example, can increase the risk of skin and lung cancer (Shams et al., 2020). Cd is a 'lethal' metal due to its severe health effects, causing bone fracture, cancer, kidney dysfunction and hypertension, human respiratory cancers, also causing infertility in humans, and developmental disorders in children at higher concentrations (Shams et al., 2020). Moghaddam et al. (2022) also studied the concentrations of heavy metals such as Pb, Cu, Fe, Ni, and Zn in water, soil, and vegetables in Iran and assessed the investigation of the extent of contamination health risks in consumers.

In developing countries, agricultural land is contaminated by heavy metals, which is a serious environmental problem due to heavy metal toxicity (Agca and Ozdel, 2014). Irrigation water contaminated by industrial effluents has led to severe heavy metal contamination in soil and plants. Due to the use of wastewater for soil irrigation, the concentration of heavy metals in the edible parts of growing plants is increasing (Arora et al., 2008).

The major sources of heavy metal contamination in the environment are human activities such as industrial waste generation, eventually resulting in the serious contamination of the surrounding water resources on local, regional, and global scales and causing significant health problems in humans and animals (Radfard et al., 2019; Kamani et al., 2018). One of the greatest water quality issues is heavy metal contamination (Shams et al., 2020). Fresh water is under pressure due to industrial activities (Almasi et al., 2014; Yousefi et al., 2018). Thus, determining the chemical contents of water resources before any human use is necessary (Mgbenu and Egbueri, 2019). The effluent generated by industries, as outlined in essence, often consists of an over-awareness of heavy metals such as cadmium (Cd), arsenic (As), mercury (Hg), copper (Cu), and lead (Pb) which are environmental issues (Bigdeli and Seilsepour, 2008; Odai et al., 2008; Yusuf and Oluwole, 2009; Ahmad and Goni, 2010; Alghobar and Suresha, 2017).

Likewise, Ethiopia nowadays is among the very fast urbanized and industrialized nations having shared dilemmas with industrial wastewater and toxic effluent planning and management. The country, as far as recently practicing a multi-dimensional development alternative to attract investments, has given preceding attention to industrial sector development in general and Industry Park Development (IPD) as a strategic preference in particular. With this fundamental need and prolonged strategy, the country has been involved in implementing almost about fourteen Industry Parks at different localities of the country. Primarily, Bole Lemi Industry Park which is found in Addis Ababa is the first and the model for this new development sector while practicing and promoting the eco-industrial park's development at the national level.

Furthermore, the Government of Ethiopia has set and launched the IPD as the excellence center for comparative and competitive economic advantages and strategic development program to prompt Foreign Capital investment, new technology transfer, and excellence for vast job opportunity creation for the youth as well as the center for sustainable eco-industry development practice (Arkebe, 2017). This has been aimed to interface the socio-economic factors with environmental attributes to excite environmental friendly.

Fekede et al. (2020) have supposed the impacts of wastes from non-clustered and scattered industries on community welfare and the environment. And few studies had conducted on the assessment of some aspects of Industrial Parks development (IPs) in Ethiopia, and the environmental sustainability issues regarding clustered industrial park development have not yet been addressed. An assessment of socioeconomic performance particularity, the foreign direct investments and job opportunities (Fesseha et al., 2019); eliciting comments and stimulating debates on Ethiopian IPD policy (Zhang et al., 2018) and why business groups, specifically foreign investors' preference to Ethiopia's IPD (Mihretu and Liobet, 2017) had been reviewed.

To our knowledge, this is the first study in Bole Lemi Industrial Park in Ethiopia. There is no published literature on heavy metal pollution around Bole Lemi Industrial Park. Therefore, this study aimed to determine the concentrations of heavy metals around Bole Lemi Industrial Park to evaluate their status and their impacts on water, soil, and vegetables produced using industrial wastewater effluents from the clustered, Bole Lemi Industrial Park in Addis Ababa, Ethiopia.

## 2. Materials and methods

### 2.1. Description of study area

Addis Ababa, the capital of the Federal Democratic Republic of Ethiopia, is known also as *Finfinne* which was the inherent name that means "*natural spring*". Addis Ababa is located in the horn of Africa at geographic coordinates 9°2′0″N and 38°42′0″E covering a total area of 540 km$^2$. And it is also a chartered city and the capital of Oromia National Regional state. Addis Ababa is the largest city in Ethiopia with melodramatic urban growth (urbanization and industrialization) (AACSPO, 2017). The Population size has also increased uncontrollably. This growth shows a hundred percent incremental in two decades. According to the 2007 census, the population was estimated as 2,739,551 inhabitants, whereas the city structure Plan office had declared that the size has booming and estimated about 4,408, 656 inhabitants. It occupies a total area of 540km$^2$ land surrounded by a mountainous landscape (AACSPO, 2017).

The city is located in the central highland with an Afro-Alpine temperate and warm climate with an average elevation of 2,400m above sea level whereas the highest altitude of 3200m has been registered at the peak of the Entoto mountain, and coordinates: 9°2′48″ N latitude and 38°45′E longitude (Wubneh, 2013). The temperature ranges from 10° to 23° and the annual rainfall is 1165mm in the study areas (Census, 2007). Accordingly, Bole Lemi Industrial Park which is found at Addis Ababa City, specifically in the Bole sub-city has been situated with GPS coordinates at 8°58′17.2200″N and 38°51′24.5088″E on a 156 ha area of land (Figure 1). The Park has 20 sheds, and hosts companies that engaged in export business in the areas of garments, Apparel, and Textiles, and Leather and leather products (Gebremariam and Feyisa, 2019).).

Hence, the city as a whole and the study site as a prime model industry park have to be predictable clean, evergreen, beautiful, and attractive environments, free of industrial waste refuges and environmentally friendly.

### 2.2. Description of sampling sites

To understand the impact of industrial wastewater from various industries on pollution by heavy metals such as water, soil, and vegetables, as part of the cooperative development of Bole Lemi Industrial Park, six sampling stations (Table 1) were selected from a random sample of all sampling study stations by taking into account the stressors from sampling station of the upper stream to the downstream the river. Similarly, three sampling stations were considered where irrigation of vegetables with wastewater exists (Table 2).

### 2.3. Source of data

Primary and secondary data used in this study; primary data comes from field observations, samples for heavy metals analysis are taken from the water, soil, and vegetation at various sampling stations, and secondary data comes from literature.

### 2.4. Sampling design

As defined by the American Public Health Association (APHA, 1999), Jones et al. (1991) and Kim and Tan (1995), applied methods and

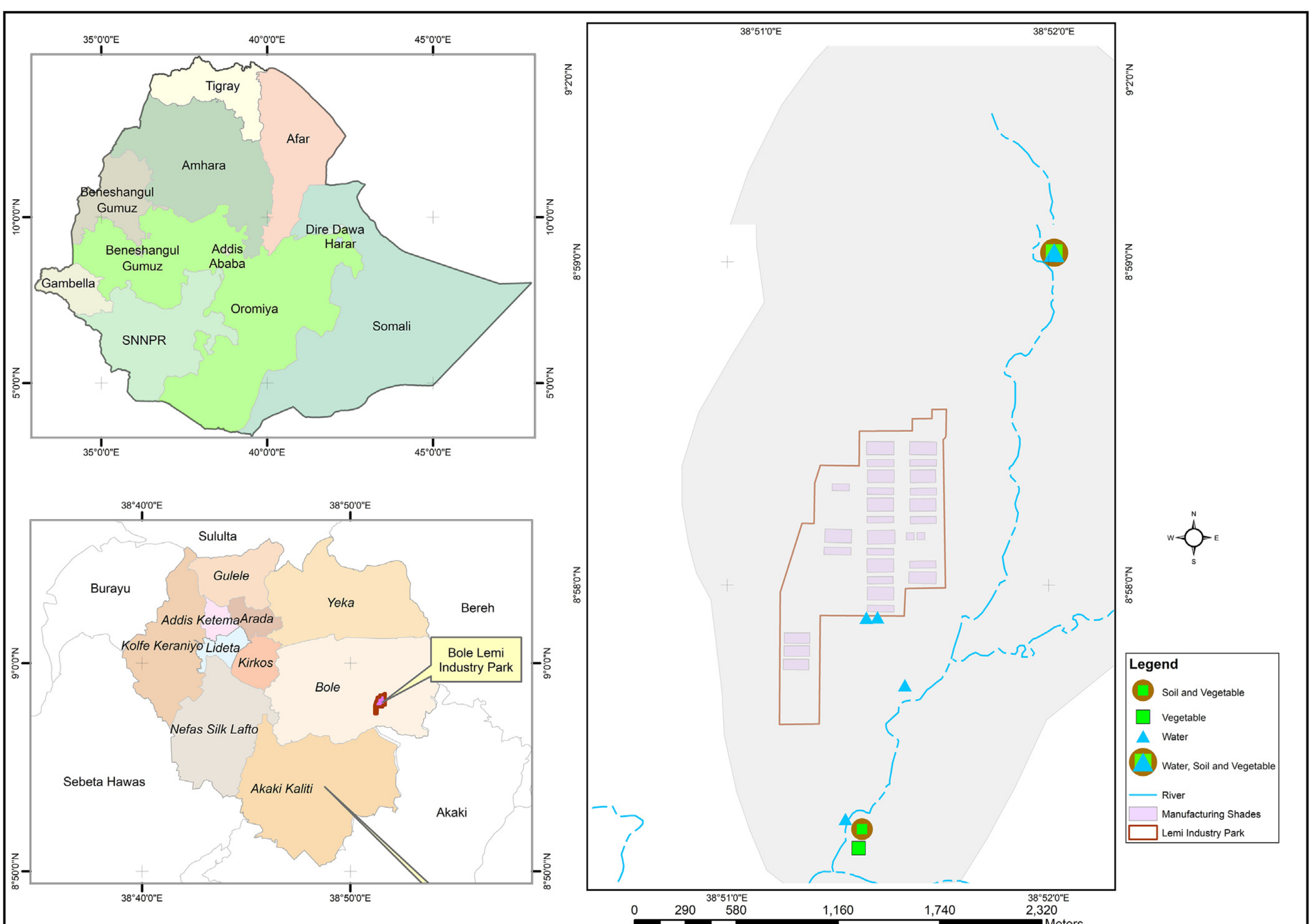


Figure 1. Map of the study area.

**Table 1.** Description of Sampling Sites for Water Sampling points.

| Study Station | Stations Code | X-Coordinate | Y-Coordinate | Altitude | Brief description |
|---|---|---|---|---|---|
| BOLIP | $UPWS_1$ | 0481164 | 1001030 | 2660 | Station 1 – upper stream (Wendraide station) |
| | $GS_2$ | 0485375 | 0992975 | 2261 | Station 2 – at Garbiel Church where the river is polluted with domestic wastes (Ayat condo. Runoff) |
| | $IPS_3$ | 0484305 | 0990893 | 2244 | Station 3 – the station at which effluents are deposited to be released from Bole Lemi industry park inside the Compound of the Treatment Plant |
| | IPS4 | 0484369 | 0990895 | 2242 | Station 4 – the station at which effluents are released from the Bole Lemi industry park outside of the Treatment Plant |
| | WWJS5 | 0484525 | 0990508 | 2218 | Station 5 – the station at which effluent from Bole Lemi IP and Lemi river mixed |
| | DSS6 | 0484187 | 0989757 | 2202 | Station 6 – downstream station, where the local communities have used the Bole Lemi's river wastewater for irrigation purposes |

**Table 2.** Description of sampling stations for soil and vegetable samples.

| Study Station | Station Code | X-Coordinate | Y-Coordinate | Altitude | Brief description |
|---|---|---|---|---|---|
| BOLIP | $GS_2$ | 0485377 | 0993006 | 2260 | Station 2 – at Garbiel Church where vegetables cultivated with river water polluted with domestic wastes, runoff, etc. |
| | Dir.S7 | 0484281 | 0989689 | 2211 | Station 7 – downstream of the Bole Lemi river where local communities used the wastewater for irrigation |
| | DGar.S8 | 0484188 | 0989641 | 2202 | Garden Station 8 – the station at which vegetables cultivated with tap water/ groundwater |

procedures for sampling water, soil, and plants from different stations in the study area. Sampling stations were assembled using Global Positioning System (GPS) from the research sampling station points (Figure 1).

Through May and June 2021, water, soil, and vegetation samples were taken, and the heavy metal content in each sample was analyzed for Pb, Cr, Cd, and Zn by collecting samples in plastic bottles for water and a plastic bag for soil and vegetables and were traced less than 8 h to Oromiya Environmental Laboratory Center of Oromia Environmental Protection, Forestry and Climate Change Authority at Burayu town with properly labeled with complete information on the container sample (sample code, date, time, source, sample type, and collector name).

### 2.5. Sampling method

Vegetable samples collected from different stations in the study area for cabbage, swiss chard, lettuce, and tomato were packed in plastic bags and rinsed with nitric acid and distilled water before sampling. Soil samples were plowed with a shovel to collect soil samples. Take the topsoil 20 cm deep in the irrigated area and take 1 kg of topsoil. Sampling is done once a day from 7:00 am to 11:00 am in order to analyze the content of heavy metals (Pb, Cr, Zn, and Cd) for both samples separately.

By using clean polyethylene plastic bottles and rinsing them three times with distilled water before sampling, water samples were collected from the study area of sampling stations and analyzed at the Oromiya Environmental Laboratory Center of Environmental Protection, Forestry, and Climate Change Authority at Burayu town using Atomic Absorption Spectrometer (NovAA 400P AAS) for the analysis of heavy metals in water and wastewater.

### 2.6. Digestion procedures for soil samples

Soil samples taken at each sampling point were crushed, sieved, and dried in an oven at 105 °C for 24 h, then 1000 g of dry soil was transferred to a 100 ml Erlenmeyer flask and 23 ml of water was added to the humidifiers in which 7.5 ml of concentrated hydrochloric acid and 2.5 ml of concentrated nitric acid were placed in a fume hood, then covered with a watch glass and placed under a fume hood at room temperature overnight. Then, the lower flask is carefully boiled on an electric stove at 100 °C for 2 h, then cooled to room temperature, washed with 30ml of water, and the extract is filtered through acid-resistant filter paper in a 100 ml volumetric flask. For clarification, continue rinsing the digester and filter paper residues. Use $2MHNO_3$ (±50 °C) hot several times and after cooling, mark the volume with 2 M nitric acids including blank. Bath (100 °C) for 2 h. Finally, an atomic absorption spectrometer (AAS) was used to analyze the concentration of heavy metals in the prepared soil solution.

### 2.7. Digestion procedures for vegetable samples

The collected vegetable samples were treated with nitric acid ($HNO_3$) to separate heavy metals (Pb, Zn, Cr, and Cd). Approximately 1000 g of dried vegetables were placed at 105 °C in a porcelain crucible and Muffle furnace at 200 °C. The samples are heated at 450 °C for at least 2 h until complete mineralization, remove the crucible, add 5 ml of $6MHNO_3$ and decompose by gentle boiling until about 1 ml remains, the remaining 5 ml $3MHNO_3$ was added and the extract was heated for 30 min, then the warm solution was filtered into a 100 ml volumetric flask and the transfer was fixed with a glass rod, the beaker and glass rod were washed several times with 1% $HNO_3$ and the residue and collected on the filter. The filtrate is cooled and diluted with water to 100 ml and close the jar with a stopper. Then, using an atomic absorption spectrometer (Analytical Jena, Germany, NOVAA 400), the concentration of heavy metals in the solution was determined.

The effectiveness of this method has been determined in accordance with the certification guidelines of the Soil and Plant Analytical Laboratory Network of the Ethiopian (SPALNE) and the National Soil Research Laboratory (NSRL). Quality control includes analysis of blank samples without analyte or zero concentration units which means no calibration and no national standard solutions of heavy metals. Soil and vegetation samples were measured using the flame or graphite method with a detection limit of 1 unit per billion (ppb). The limit of Quantification (LOQ) and Limit of Detection is determined according to the version of the standard operating procedure for an atomic absorption spectrometer for the determination of heavy metals in the laboratory, as well as the instructions for use of the instrument developed by Oromia

Environmental Protection, Forest and Climate Change Central Laboratory.

### 2.8. Data calculations

#### 2.8.1. Bioconcetration factor

The bioconcentration factor is the relationship between the concentration of heavy metals in some plant samples and the concentration of heavy metals in soil samples (Rattan et al., 2005; Sharma et al., 2018). And Kachenko and Singh (2004), use the following formula to calculate the transfer of heavy metals from soil to plants:

$$\mathbf{BCF} = \frac{\mathbf{C}_{\mathbf{plant}}}{\mathbf{C}_{\mathbf{soil}}} \quad (1)$$

Among them, $C_{plant}$ is the concentration of heavy metals in plant parts, and $C_{soil}$ is the concentration of heavy metals in the soil. Values greater than 1 BCF indicate that the plant is a potential heavy metal reservoir under consideration for analysis.

#### 2.8.2. Estimated daily intake of heavy metals

Calculation of the estimated daily intake (EDI) (mg/day) of heavy metals based on the weight of vegetables consumed per unit body weight and their respective average concentrations in vegetable samples. As stated by Chen et al. (2011), use the following formula to calculate the value of EDI of each heavy metal in each cabbage, lettuce, Swiss chard and tomato:

$$EDI = \frac{Ef \times ED \times FIR \times CM \times Cf}{BW \times TA} * 0.001 \quad (2)$$

Ef is the exposure frequency (365 days/year), ED is the duration of exposure (65 years) based on the average lifespan (Woldetsadik et al., 2017), and FIR is the consumption of vegetables (cabbage, lettuce, Swiss chard and tomato per person 240 g/person/day), according to the World Health Report of the World Health Organization (2002), low-consumption fruits and vegetables CM is the concentration of heavy metals (mg/kg dry weight), and Cf is the concentration conversion factor (0.085) (Rattan et al., 2005; Arora et al., 2008; Harmanescu et al., 2011), after Woldeshadik et al. (2017), BW is the reference weight of an adult, 70 kg; TA is the average exposure time (65 years × 365 days) and 0.001 is the unit conversion factor.

#### 2.8.3. Target hazard quotient (THQ)

*2.8.3.1. Non-carcinogenic and carcinogenic risk assessment.* The non-carcinogenic risk for an individual's heavy metals via veggies intake had been assessed through the target hazard quotient (THQ). Accordingly, the target hazard quotient values of the populace because of the intake of infected vegetables had been calculated as the following formula (Zheng et al., 2007; Khan et al., 2008; Chen et al., 2011; Ezemonye et al., 2019):

$$THQ = \frac{\mathrm{EDI}}{\mathrm{RfD}} \quad (3)$$

EDI is the estimated daily intake of heavy metals in the population, in mg/day/kg body weight, and RfD is the oral reference dose (mg/kg/day) of each heavy metal. If the value of THQ is $< 1$, which indicates that safe for risk of non-carcinogenic effects and if it is $> 1$ it is imaginary that there is a chance of non – carcinogenic effects with an increasing probability as the value increases (Chen et al., 2011; Antoine et al., 2017).

#### 2.8.4. Hazard index (HI)

The human health risks from the analysis of heavy metals in selected vegetables are cumulative and expressed as a hazard index (Rattan et al., 2005; Zheng et al., 2007; Chen et al., 2011; Mahmood and Malik, 2014; Shaheen et al., 2016; Antoine et al., 2017; Lie et al., 2018; Ezemonye et al., 2019). Then, as suggested by Antoine et al. (2017), the HI of the heavy metals selected in this study was calculated using the following Eq. (4):

$$HI = \sum_{n=1}^{i} \mathrm{THQn};\ \mathrm{i} = 1, 2, 3, \ldots, \mathrm{n} \quad (4)$$

HI is the sum of various hazards associated with heavy metals. When the HI value becomes $<1$ the impact of heavy metals on health has not been carefully considered and if the HI value is $>1$ this indicates possible health effects. For HI value $>10$, it indicates that there are serious chronic health effects (Antoine et al., 2017; Lie et al., 2018).

#### 2.8.5. Target cancer risk (TCR)

According to Sharma et al. (2018), human health represents the risk of cancer caused by the intake of certain potentially carcinogenic heavy metals, calculated according to the following formula. Then as Kamunda et al. (2016), stated the target cancer risk (TCR) for the carcinogenic effects of heavy metals (Pb, Zn, Cr, and Cd) intake is calculated using Eqs. (5) and (6):

$$\mathrm{CR} = \mathrm{EDI} \times \mathrm{CPSo} \quad (5)$$

$$\sum_{n=1}^{i} \mathrm{CR};\ \mathrm{i} = 1, 2, 3, \ldots, \mathrm{n} \quad (6)$$

CR is the lifetime cancer risk of body weight heavy metal intake, EDI is the estimated daily intake of heavy metals in the population, in mg/day/kg body weight, CPSo is the slope coefficient of oral cancer, in units of $(\mathrm{mg/kg/day})^{-1}$ and n is the deliberate amount of heavy metals used to calculate cancer risk. The CPSo values of Pb, Cr, and Cd (0.0085, 0.5, and 0.38, respectively) (Gebeyehu and Bayissa, 2020).

### 2.9. Statistical data analysis

The data of heavy metal content in water, soil, and plants in the sample plots of the study area used one-way analysis of variance (ANOVA) and descriptive statistics of changes in heavy metal in the study area, Principal Component Analysis, and Pearson Correlation Coefficient used the 24th edition of IBM SPSS statistical data.

## 3. Results

### 3.1. Method validation

For the heavy metals considered in this study, the Limit of Quantification (LOQ) and Limit of Detection Method (LDM) were calculated using standard formulas: LOQ = 3 × SD and MDL = 10 × SD. The LOQ and MDL values were specifically confirmed by sample and blank atomic absorption spectrometers. The precision and reliability of the heavy metals considered in this study are as follows (Table 3). The relative standard deviation (% RSD) of vegetables and the potential health risks of the collected samples were analyzed.

### 3.2. The concentration of heavy metal in soil and vegetable

Spatially different mean concentrations of heavy metals were observed in vegetables at different study stations available in Table 4. Zn concentration in Garden Swiss chard vegetable (8.72 mg/kg) at the station of GS2 site followed by Zn concentration in Garden cabbage vegetable (8.56 mg/kg) was statistically significant (P = 0.0014). Temporarily also Zn concentration in Garden Swiss chard vegetable (8.72 mg/kg) during May month was recorded which was statistically not significant (P = 0.88).

**Table 3.** Data Specification for AAS, MDL, LOQ and % RSD for the heavy metals considered in this study.

| Parameter | Test method | Wavelength (nm) | MDL (mg/L) | LOQ (mg/L) | %RSD | Av. recovery | $R^2$ |
|---|---|---|---|---|---|---|---|
| Cr | FAAS | 357.90 | 0.0162 | 0.162 | 0.2–9.3 | 96.5–110 | 0.99719 |
| Zn | FAAS | 213.90 | 0.0063 | 0.063 | 0.2–10.2 | 89–120 | 0.99821 |
| Cd | FAAS | 228.00 | 0.0069 | 0.069 | 1.7–9.4 | 93.2–103 | 0.99501 |
| Pb | FAAS | 283.30 | 0.0036 | 0.036 | 0.6–8.7 | 89.1–112 | 0.99953 |

**Table 4.** Mean Value of heavy metals in vegetable samples.

| Study Site | Vegetable | Sample Code | In May Month, 2021 | | | |
|---|---|---|---|---|---|---|
| | | | Parameter | | | |
| | | | Pb (mg/kg) | Cr (mg/kg) | Cd (mg/kg) | Zn (mg/kg) |
| BOLIP | Cabbage | CGS2 | 0.169 ± 0.0004 | 0.2382 ± 0.0021 | 0.477 ± 0.0016 | 4.96 ± 0.0001 |
| | Swiss Chard | SGS2 | 0.087 ± 0.0003 | 0.31 ± 0.00003 | 0.0399 ± 0.0003 | 8.72 ± 0.0005 |
| | Lettuce | LGS2 | 0.200 ± 0.003 | 0.2429 ± 0.0004 | 0.0415 ± 0.0006 | 4.60 ± 0.0002 |
| | Tomato | TGS2 | 0.061 ± 0.0002 | 0.324 ± 0.00012 | 0.0422 ± 0.001 | 4.12 ± 0.0002 |
| | Garden Cabbage | CDGar.S8 | 0.079 ± 0.0004 | 0.4045 ± 0.0002 | 0.0366 ± 0.001 | 8.56 ± 0.0005 |
| | Garden Swiss Chard | SDGar.S8 | 0.741 ± 0.0008 | 1.141 ± 0.00027 | 0.0472 ± 0.001 | 3.74 ± 0.0001 |
| | Cabbage | CDIr.S7 | 0.228 ± 0.0004 | 0.398 ± 0.0001 | 0.045 ± 0.001 | 4.12 ± 0.0008 |
| | Lettuce | LDIr.S7 | 0.741 ± 0.0008 | 1.14 ± 0.00027 | 0.047 ± 0.0016 | ND |
| | Tomato | TDIr.S7 | ND* | 0.327 ± 0.00013 | 0.028 ± 0.0017 | ND |
| BOLIP | Cabbage | CGS2 | 0.309 ± 0.003 | 0.263 ± 0.0002 | 0.066 ± 0.002 | 4.51 ± 0.015 |
| | Swiss Chard | SGS2 | ND | 0.555 ± 0.0008 | 0.037 ± 0.0006 | 0.012 ± 0.003 |
| | Lettuce | LGS2 | ND | 0.138 ± 0.0002 | 0.044 ± 0.0009 | 0.032 ± 0.007 |
| | Tomato | TGS2 | ND | 0.136 ± 0.0002 | 0.03 ± 0.001 | 3.82 ± 0.021 |
| | Garden Cabbage | CDGar.S8 | ND | 0.178 ± 0.0001 | 0.037 ± 0.0003 | 3.24 ± 0.0288 |
| | Garden Swiss Chard | SDGar.S8 | ND | 0.378 ± 0.0001 | 0.034 ± 0.001 | 8.35 ± 0.005 |
| | Cabbage | CDIr.S7 | ND | 0.154 ± 0.00008 | 0.046 ± 0.001 | 4.77 ± 0.0135 |
| | Lettuce | LDIr.S7 | ND | 0.211 ± 0.0006 | 0.03 ± 0.002 | ND |
| | Tomato | TDIr.S7 | ND | 0.226 ± 0.0005 | 0.05 ± 0.0001 | ND |

* is to mean not detected.

### 3.3. The concentration of heavy metal in soil

As shown in Table 5, the results for heavy metal concentrations in soil samples from various irrigated land use systems showed spatially and temporary, the highest Zn levels (5.12 mg/kg) at GS2 which was significantly different (P = 4.9E-07) during May month which was no significant difference (P = 0.94) followed by concentration of Zn (4.31 mg/kg) at irrigation land of DSS6 station study site during June month.

### 3.4. The concentration of heavy metal in water

The mean concentrations of heavy metals analyzed in water samples at different sampling stations during the May and June months are shown in Table 6. Spatially and temporary concentration of Cr (0.82 mg/L) was observed at the sampling station of UPWS1 during June month which was statistically significant (P = 0.45), followed by Zn (0.62 mg/L) at the sampling station of WWJS5 during June month which was statistically significant (P = 0.024). And the lowest concentration recorded were concentrations of Cr and Zn at the sampling station of UPWS1 during May and also for the concentration of Zn during June month.

### 3.5. Pearson Correlation Coefficient for soil, vegetable, and water

Pearson's correlation is necessary to determine the spatial and temporary relationship between the concentrations of heavy metals in the soil during different months and at different sampling stations. Thus, the concentrations of heavy metals were differentially correlated with the concentrations of individual heavy metals (Table 7). During May month most heavy metals are strongly positively correlated with each other's while a few metals had seen strongly negatively correlated. On the other hand, the concentrations of heavy metals such as Cr and Cd with the concentration of Pb were strongly positively correlated in vegetables

**Table 5.** Mean Value of heavy metals in soil and vegetable samples.

| | Soil | Sample Code | In May 2021 | | | |
|---|---|---|---|---|---|---|
| | | | Parameter | | | |
| | | | Pb (mg/kg) | Cr (mg/kg) | Cd (mg/kg) | Zn (mg/kg) |
| BOLIP | Irrigated land | GS2 | ND* | 0.6755 ± 0.0007 | 0.0246 ± 0.0001 | 5.12 ± 0.0015 |
| | | DIr.S7 | 1.10 ± 0.0006 | 1.981 ± 0.00143 | 0.0783 ± 0.00112 | 4.36 ± 0.0023 |
| | Irrigated land | GS2 | 0.09 ± 0.00013 | 0.52 ± 0.0004 | 0.028 ± 0.0002 | 3.489 ± 0.0012 |
| | | DIr.S7 | 0.15 ± 0.0006 | 0.33 ± 0.0005 | 0.035 ± 0.0002 | 4.31 ± 0.0013 |

* is to mean not detected.

**Table 6.** The concentration of heavy metals in water samples collected from different study sites (Mean ± SD).

| Study Area | Sample Code | In May 2021 | | | |
|---|---|---|---|---|---|
| | | Heavy Metal | | | |
| | | Cr (mg/L) | Zn (mg/L) | Cd (mg/L) | Pb (mg/L) |
| **BOLIP** | UPWS1 | ND | ND | 0.05 ± 0.0002 | ND |
| | GS2 | 0.40 ± 0.0004 | 0.057 ± 0.0003 | 0.053 ± 0.006 | 0.028 ± 0.003 |
| | IPS3 | 0.38 ± 0.0009 | 0.078 ± 0.0004 | 0.06 ± 0.006 | 0.62 ± 0.0015 |
| | IPS4 | 0.41 ± 0.0005 | 0.26 ± 0.0001 | 0.12 ± 0.0009 | 0.04 ± 0.001 |
| | WWJS5 | 0.16 ± 0.0001 | 0.061 ± 0.0007 | 0.058 ± 0.0004 | 0.56 ± 0.004 |
| | DSS6 | 0.53 ± 0.0001 | 0.201 ± 0.0002 | 0.04 ± 0.0007 | 0.21 ± 0.0001 |
| | | **In June 2021** | | | |
| | UPWS1 | 0.82 ± 0.0005 | 0.513 ± 0.0005 | 0.016 ± 0.0006 | ND |
| | GS2 | 0.39 ± 0.0002 | 0.026 ± 0.0001 | 0.017 ± 0.0007 | 0.048 ± 0.0003 |
| | IPS3 | 0.31 ± 0.001 | 0.071 ± 0.0002 | 0.029 ± 0.001 | 0.25 ± 0.0013 |
| | IPS4 | 0.29 ± 0.0006 | 0.62 ± 0.0005 | 0.019 ± 0.0005 | 0.72 ± 0.0002 |
| | WWJS5 | 0.31 ± 0.0003 | 0.097 ± 0.0005 | 0.024 ± 0.001 | 0.061 ± 0.0001 |
| | DSS6 | 0.30 ± 0.0001 | 0.252 ± 0.0006 | 0.027 ± 0.0005 | 0.048 ± 0.0009 |

during May month. The rest concentrations of heavy metals were weakly positive and negatively correlated with each other's (Table 7).

Pearson's correlation is necessary to determine the relationship between the concentrations of heavy metals in water spatially at different sampling stations and during different months. Consequently, the concentrations of heavy metals, as shown in Table 5, Cd concentration have a strong positive correlation with Pb concentration during May month and Zn concentration also has a strong positive correlation with Cr during May month. The concentration of Cr has a weak positive correlation with Pb concentration during May month but has a weak negative correlation during June month.

### 3.6. Bioconcetration factor

The results of the analysis of the factor of bioconcentration for various heavy metals in different sampling stations of the study are shown in Table 9, determined according to Eq. (1). The maximum value of the bioconcentration factor recorded was 19.39 for Cd during May month at the sampling station of GS2 irrigation land in cabbage. And the lowest values recorded were 0.00 for Pb during May at all sampling stations of GS2 in all vegetables considered in this study and tomato vegetables during May month at the sampling station of DIr.S7, similarly during June month in all vegetables measured and at all sampling stations except cabbage vegetable at sampling station of GS2 (Table 8).

### 3.7. Estimated daily intake (EDI) of heavy metals

The analyzed result of EDI of heavy metals at different sampling stations within the different periods, Table 9, has been calculated via means of the use of Eq. (2). The highest value of EDI recorded has been

**Table 7.** Pearson correlation coefficient (r) for soil, vegetables.

| | Pb (May) | Pb (June) | Cr (May) | Cr (June) | Cd (May) | Cd (June) | Zn (May) | Zn (June) |
|---|---|---|---|---|---|---|---|---|
| **Soil** | | | | | | | | |
| Pb (May) | 1 | | | | | | | |
| Pb (June) | 1.000** | 1 | | | | | | |
| Cr (May) | 1.000** | 1.000** | 1 | | | | | |
| Cr (June) | −1.000** | −1.000** | −1.000** | 1 | | | | |
| Cd (May) | 1.000** | 1.000** | 1.000** | −1.000** | 1 | | | |
| Cd (June) | 1.000** | 1.000** | 1.000** | −1.000** | 1.000** | 1 | | |
| Zn (May) | −1.000** | −1.000** | −1.000** | 1.000** | −1.000** | −1.000** | 1 | |
| Zn (June) | 1.000** | 1.000** | 1.000** | −1.000** | 1.000** | 1.000** | −1.000** | 1 |
| **Vegetable** | | | | | | | | |
| Pb (May) | 1 | | | | | | | |
| Pb (June) | −.115 | 1 | | | | | | |
| Cr (May) | .949** | −.271 | 1 | | | | | |
| Cr (June) | .130 | .039 | .162 | 1 | | | | |
| Cd (May) | −.085 | .999** | −.248 | .040 | 1 | | | |
| Cd (June) | −.382 | .796* | −.529 | −.067 | .781* | 1 | | |
| Zn (May) | −.400 | .079 | −.424 | .370 | .079 | −.013 | 1 | |
| Zn (June) | .327 | .223 | .303 | .010 | .241 | .035 | .142 | 1 |
| **Water** | | | | | | | | |
| Pb (May) | 1 | | | | | | | |
| Pb (June) | −.116 | 1 | | | | | | |
| Cr (May) | .027 | .342 | 1 | | | | | |
| Cr (June) | −.472 | −.408 | −.777 | 1 | | | | |
| Cd (May) | −.206 | .964** | .154 | −.291 | 1 | | | |
| Cd (June) | .822* | −.039 | .453 | −.612 | −.243 | 1 | | |
| Zn (May) | −.166 | .730 | .719 | −.623 | .619 | .226 | 1 | |
| Zn (June) | −.594 | .546 | −.223 | .393 | .593 | −.460 | .420 | 1 |

**Table 8.** Bioconcentration Factor (ND is to mean not detected) In May Period, 2021.

| Site | Vegetable | Bioconcentration of heavy Metals | | | | |
|---|---|---|---|---|---|---|
| | | Sample code | Pb | Cr | Cd | Zn |
| **In May Period, 2021** | | | | | | |
| BOLIP | Cabbage | CGS2 | ND* | 1.3382 | 19.3902 | 0.9688 |
| | Swiss Chard | SGS2 | ND | 0.4589 | 1.0784 | 1.7031 |
| | Lettuce | LGS2 | ND | 0.3596 | 1.6870 | 0.8984 |
| | Tomato | TGS2 | ND | 0.4796 | 1.7154 | 0.8047 |
| | Garden Cabbage | CDGar.S8 | 0.0718 | 0.2042 | 0.4674 | 1.9633 |
| | Garden Swiss Chard | SDGar.S8 | 0.6736 | 0.5760 | 0.6028 | 0.8578 |
| | Cabbage | CDIr.S7 | 0.2073 | 0.2009 | 0.5747 | 0.9450 |
| | Lettuce | LDIr.S7 | 0.6736 | 0.5755 | 0.6003 | 0.0000 |
| | Tomato | TDIr.S7 | 0.0000 | 0.1651 | 0.3576 | 0.0000 |
| **In June Period, 2021** | | | | | | |
| | Cabbage | CGS2 | 3.4333 | 0.5058 | 2.3571 | 1.2926 |
| | Swiss Chard | SGS2 | 0.0000 | 1.0673 | 1.3214 | 0.0034 |
| | Lettuce | LGS2 | 0.0000 | 0.2654 | 1.5714 | 0.0092 |
| | Tomato | TGS2 | 0.0000 | 0.2615 | 1.0714 | 1.0949 |
| | Garden Cabbage | CDGar.S8 | 0.0000 | 0.5394 | 1.0571 | 0.7517 |
| | Garden Swiss Chard | SDGar.S8 | 0.0000 | 1.1455 | 0.9714 | 1.9374 |
| | Cabbage | CDIr.S7 | 0.0000 | 0.4667 | 1.3143 | 1.1067 |
| | Lettuce | LDIr.S7 | 0.0000 | 0.6394 | 0.8571 | 0.0000 |
| | Tomato | TDIr.S7 | 0.0000 | 0.6848 | 1.4286 | 0.0000 |

0.001 for Zn in tomatoes at the sampling station of GS2 during June month. While the lowest value of EDI was 0.00 during June month for Pb in all vegetables designed in this study except in cabbage at the sampling station of GS2 during June month.

### 3.8. Target hazard quotient (THQ)

The target hazard quotient was calculated based on Eq. (3). Thereafter, the results of the target non-cancer hazard quotient (THQ) analysis showed that person who ate lettuce had a high health risk with a Pb accumulation of 0.062 at the sampling station of DSS6 during May which was followed by THQ of Cr in Swiss chard at sampling station of GS2 during June month (Table 10). Additionally, the highest value of HI recorded was at the sampling station of GS2 in cabbage (0.056) during June month followed by HI in Swiss chard (0.054) at the sampling station of GS2 during June month.

### 3.9. Target cancer risk (TCR)

The TCR was calculated based on Eq. (5). The TCR analysis results are then shown in (Table 11), for Pb, Cr, and Cd in cabbage, Swiss chard, lettuce, and tomato through different study station sites, accordingly the maximum TCR value determined was $8.09 \times 10^{-5}$ for Cr in the garden Swiss chard at sampling station of SGS2 during June month followed by $5.51 \times 10^{-5}$ for Cr in Swiss chard at sampling station, SDGar.S8 during June month.

### 3.10. Principal Component Analysis of soil, vegetables and water samples

Soil analysis results for principal components showed through May and June strongly positive correlation at the sampling stations of the study (Table 12). The results of the analysis of the principal components of vegetables considered in this study at sampling stations CGS2, SGS2, LGS2, TGS2, CDGar.S8, SDGar.S8, and CDIr.S7 indicated a strongly positive correlation by the first component through May and June and also strongly positive correlation at the sampling stations of SGS2, LGS2, LDIr.S7 and TDIr.S7 during June, while having slightly negative correlation at sampling stations of LDIr.S7 and TDIr.S7 by the first component (Table 12).

The analysis of principal components analyzed in water samples collected from different study stations through May and June showed in (Table 11). Accordingly, by component 1 at sampling stations of UPWS1, GS2, IPS4, WWJS5, and DSS6 they indicated a strongly positive correlation during May and June. Similarly, at sampling stations of the study of IPS3 and WWJS5 indicated that strongly positive correlation through May by component 2, while components 1 and 2 at the sampling station of UPWS1 during May slightly showed a slightly negative correlation (Table 12).

## 4. Discussion

The rapid development of industries and the use of industrial wastewater in agriculture have resulted in increased concerns about the accumulation of heavy metals in agricultural soils (Esmaeilzadeh et al., 2019). According to Seifi et al. (2019), the spatial distribution of heavy metals is much higher in industrial areas as a comparison to urban areas. Contamination of water and soils with a variety of heavy metals is one of the increasing environmental issues all over the world (Kanu and Achi, 2011). The issue has been aggravating in developing countries due to the rapid and unplanned growth of the population, poor management, and excessive consumption of agricultural and industrial activities (Saleh et al., 2018). In this study, the analysis of soil, vegetables and water was carried out to assess the content of heavy metals Pb, Cr, Cd, and Zn. The results were compared with the WHO/FAO and USEPA standards and guidelines.

**Table 9.** Estimated daily intake of heavy metals.

| Site | Vegetable | In May Period, 2021 | | | | | In June Period, 2021 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sample code | EDI of Heavy Metal | | | | Sample code | EDI of Heavy Metal | | | |
| | | | Pb | Cr | Cd | Zn | | Pb | Cr | Cd | Zn |
| BOLIP | Cabbage | CGS2 | 0.000049 | 0.000069 | 0.000139 | 0.001445 | CGS2 | 0.00009 | 0.000077 | 0.000019 | 0.001314 |
| | Swiss Chard | SGS2 | 0.000025 | 0.00009 | 0.000012 | 0.002541 | SGS2 | ND* | 0.000162 | 0.000011 | 0.000003 |
| | Lettuce | LGS2 | 0.000058 | 0.000001 | 0 | 0.00002 | LGS2 | ND | 0.00004 | 0.000013 | 0.000009 |
| | Tomato | TGS2 | 0.000018 | 0.000001 | 0 | 0.000018 | TGS2 | ND | 0.00004 | 0.000009 | 0.001113 |
| | Garden Cabbage | CDGar.S8 | 0.000021 | 0 | 0 | 0.000009 | CDGar.S8 | ND | 0.000052 | 0.000011 | 0.000944 |
| | Garden Swiss Chard | SDGar.S8 | 0.000216 | 0.000001 | 0 | 0.000004 | SDGar.S8 | ND | 0.00011 | 0.00001 | 0.002433 |
| | Cabbage | CDIr.S7 | 0.000066 | 0 | 0 | 0 | CDIr.S7 | ND | 0.000045 | 0.000013 | 0.00139 |
| | Lettuce | LDIr.S7 | 0.000216 | 0 | 0 | 0 | LDIr.S7 | ND | 0.000061 | 0.000009 | 0 |
| | Tomato | TDIr.S7 | 0 | 0 | 0 | 0 | TDIr.S7 | ND | 0.000066 | 0.000015 | 0 |

* is to mean Not Detected.

**Table 10.** Target hazard quotient for heavy metals.

| Site | Vegetable | In May Period, 2021 | | | | | | In June Period, 2021 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sample code | THQ of Heavy Metals | | | | | Sample code | THQ of Heavy Metals | | | | |
| | | | Pb | Cr | Cd | Zn | HI | | Pb | Cr | Cd | Zn | HI |
| BOLIP | Cabbage | CGS2 | 0.014072 | 0.023139 | 0.000366 | 0.004818 | 0.042395 | CGS2 | 0.025729 | 0.025549 | 5.06E−05 | 0.004381 | 0.055709 |
| | Swiss Chard | SGS2 | 0.007244 | 0.030114 | 3.06E−05 | 0.008471 | 0.04586 | SGS2 | ND* | 0.053914 | 2.84E−05 | 1.17E−05 | 0.053954 |
| | Lettuce | LGS2 | 0.016653 | 0.000359 | 4.84E−07 | 6.80E−05 | 0.01708 | LGS2 | ND | 0.013406 | 3.37E−05 | 3.11E−05 | 0.013471 |
| | Tomato | TGS2 | 0.005079 | 0.000479 | 4.92E−07 | 6.09E−05 | 0.005619 | TGS2 | ND | 0.013211 | 2.30E−05 | 0.003711 | 0.016945 |
| | Garden Cabbage | CDGar.S8 | 0.00598 | 0.000144 | 1.03E−07 | 3.05E−05 | 0.006155 | CDGar.S8 | ND | 0.017291 | 2.84E−05 | 0.003147 | 0.020467 |
| | Garden Swiss Chard | SDGar.S8 | 0.0617 | 0.000406 | 1.33E−07 | 1.33E−05 | 0.062119 | SDGar.S8 | ND | 0.03672 | 2.61E−05 | 0.008111 | 0.044858 |
| | Cabbage | CDIr.S7 | 0.018984 | 1.57E−05 | 1.40E−08 | 1.63E−06 | 0.019002 | CDIr.S7 | ND | 0.01496 | 3.53E−05 | 0.004634 | 0.019629 |
| | Lettuce | LDIr.S7 | 0.0617 | 4.51E−05 | 1.47E−08 | 0 | 0 | LDIr.S7 | ND | 0.020497 | 2.30E−05 | 0 | 0.02052 |
| | Tomato | TDIr.S7 | 0 | 2.20E−06 | 1.49E−09 | 0 | 0 | TDIr.S7 | ND | 0.021954 | 3.83E−05 | 0 | 0.021993 |

* is to mean not detected.

Average concentrations of Pb in cabbage and lettuce at the study sampling stations of GS2 and garden Swiss chard, cabbage, and lettuce of sampling station of DIr.S7 irrigated with the wastewater in May. Similarly, the mean value of Pb in cabbage at the sampling station of GS2 during June was above the permissible limit following the WHO/FAO set for Pb (0.1 μg/g). The existence of metals in soil is natural, but values exceeding the standard permissible limit are considered environmental contaminant sources (Esmaeilzadeh et al., 2019). A comparison of metals with the standard values of the quality of agricultural soils in Iran indicated that lead had a larger value than standard levels and can cause problems due to entrance into crops and the food chain (Esmaeilzadeh et al., 2019), causing toxicity and carcinogenic effects for humans (Saleh et al., 2018). Likewise, the mean values of Cr and Cd concentrations in vegetables considered in this study at all sampling stations were above the permissible limit following the WHO/FAO set for Cr (0.1–0.2 μg/g) and Cd (0.02 μg/g) in both May and June. Cr, an element that is found in food resources and drinking water, is very harmful to human health, seriously damaging the lungs and kidneys (Saleh et al., 2018). And also the average values of Zn concentrations in vegetables considered at these study sites at most sampling stations are above the permissible limit under the WHO/FAO standards and guidelines except during both months at sampling station Dir.S7 Lettuce and Tomato are within the standard and guidelines.

The use of industrial wastewater for irrigation can be considered one of the reasons for the existence of metal contamination in vegetables and water in the study area. Such heavy metal contamination in agricultural soils may cause disorder in the soil structure, and interference with plant growth (Esmaeilzadeh et al., 2019). Besides, issues related to environmental pollution have increasingly negative impacts on human health by entering the food chain (Almasi et al., 2014). High concentrations of heavy metals, especially Pb, will lead to a risk of cancer if the daily intake exceeds the recommended values (Chang et al., 2014; Sa et al., 2016; Lin et al., 2016). Heavy metals in the environment may also affect aquatic life and alter plant diversity (Atafar et al., 2010; Islam et al., 2013). According to Woldetsadik et al. (2017), exceeding the permissible Pb concentration in leafy vegetables in Akaki, Addis Ababa, has been supposed. The accumulation of high heavy metals measured in this study in leafy vegetables in the present study may be related to the impact of sewage irrigation which was influenced by different industries. Eating vegetables contaminated with Pb has public health implications as lead and other heavy metals tend to bioaccumulate in the tissues of the human body, causing toxic effects (Antonio and Leret, 2000; Antonio et al., 2003; Assi and Hezmee, 2016). Pb causes detrimental problems in the blood, central nervous system, kidneys, and reproductive and immune systems in all animals and negatively affects children's intelligence (Jamal et al., 2018). Cd accumulates and produces serious problems in kidney and liver organs (Chen et al., 2014).

Average heavy metal concentrations for Pb, Cr and Cd in water samples taken from various sampling stations within May and June exceeded the acceptable limit in accordance with US Environmental Protection Agency guidelines (USEPA, 2004). However, the average heavy metal concentrations for the Cr at sampling station UPWS1, with May, Pb at some sampling stations, and Zn heavy metals in this study were below the limits set by the US EPA guidelines through May and June. This suggests that the continued use of wastewater and wastewater on agricultural land may increase the number of heavy metals in the soil (Seema, 2016).

Bioconcentration factors (BCFs), which represent the relationship between metal concentrations in plants and metal concentrations in soil, are used to represent the absorption of heavy metals by soil and plants and indicate the transfer of heavy metals from soil to vegetables. Accordingly, the Bioconcentration factor for Pb in cabbage at the sampling station of GS2 in June (3.43), similarly BCF for Cr in cabbage and Swiss chard during May and in garden Swiss chard at the sampling station of DIr.S7 during June, for Cd in cabbage, Swiss chard, lettuce and tomato at sampling stations of GS2 during May and June as well as for Zn in Swiss chard and garden cabbage at sampling stations of GS2 and DIr.S7

**Table 11.** Target cancer risk for heavy metals.

| Site | Vegetable | In May Period, 2021 | | | | In June Period, 2021 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Sample code | CR of Heavy Metals | | | Sample code | CR of Heavy Metals | | |
| | | | Pb | Cr | Cd | | Pb | Cr | Cd |
| BOLIP | Cabbage | CGS2 | 4.19E−07 | 3.47E−05 | 5.28E−05 | CGS2 | 7.65E−07 | 3.83E−05 | 7.31E−06 |
| | Swiss Chard | SGS2 | 2.16E−07 | 4.52E−05 | 4.42E−06 | SGS2 | ND* | 8.09E−05 | 4.10E−06 |
| | Lettuce | LGS2 | 4.95E−07 | 5.38E−07 | 6.99E−08 | LGS2 | ND | 2.01E−05 | 4.87E−06 |
| | Tomato | TGS2 | 1.51E−07 | 7.18E−07 | 7.11E−08 | TGS2 | ND | 1.98E−07 | 3.32E−06 |
| | Garden Cabbage | CDGar.S8 | 1.78E−07 | 2.16E−07 | 1.49E−08 | CDGar.S8 | ND | 2.59E−05 | 4.10E−06 |
| | Garden Swiss Chard | SDGar.S8 | 1.84E−06 | 6.10E−07 | 1.92E−08 | SDGar.S8 | ND | 5.508E−05 | 3.77E−06 |
| | Cabbage | CDIr.S7 | 5.65E−07 | 2.36E−08 | 2.03E−09 | CDIr.S7 | ND | 2.244E−05 | 5.09E−06 |
| | Lettuce | LDIr.S7 | 1.84E−06 | 6.76E−08 | 2.12E−09 | LDIr.S7 | ND | 3.07E−05 | 3.32E−06 |
| | Tomato | TDIr.S7 | 0 | 3.30E−09 | 2.15E−10 | TDIr.S7 | ND | 3.29E−05 | 5.54E−06 |

* is to mean not detected.

during May, in cabbage and tomato at sampling station of GS2 likewise at sampling station of DIr.S7 in garden Swiss chard and cabbage during June is greater than 1. Comparing the results obtained from this research, it was observed that the total concentration obtained for zinc was larger than that obtained in the research conducted in the Eshghabad region in the northeast of Iran by Esmaeilzadeh et al. (2019). According to these authors, Zn at high concentrations can lead to toxicity and cause immunologic and digestive diseases.

According to Gupta et al. (2010), the transport factor of lead is very low compared to Cd and Cr. In general, the transfer of metals from soil to plants can depend on the nature of the soil, the composition of the starting metal material, the plant species, and the solubility of metals (Intawongse and Dean, 2006; Kabala et al., 2009).

People are encouraged to eat more vegetables because they are a source of vitamins, minerals, and fiber and are good for human health, but an increasingly important aspect of food quality is controlling the concentration of heavy metals in food to protect people from the harmful effects of heavy metals (FAO/WHO, 2003). The EDI values for Pb, Cr, Cd, and Zn at different sampling stations through May and June were within the FAO/WHO Maximum Permissible Daily Intake (PMTDI) range.

The non-carcinogenic risk to human health from eating vegetables contaminated with heavy metals is estimated by calculating the target hazard quotient (THQ) expressed in the methods section using the “3” equation, so the THQ value of heavy metals analyzed in this study in vegetables which were considered in this study through the study months at all sampling stations showed less than 1. So, except for heavy metals determined for THQ in this study, it is generally considered safe and cancer-free.

The hazard index (HI) was also calculated, reflecting the increasing effects of the consumption of various potentially hazardous heavy metals as a result of the consumption of various vegetables, as well as data of HI on cabbage, Swiss chard, lettuce, and tomato for heavy metals Pb, Cr, Cd and Zn at different sampling stations through May and June indicated that less than 1. As a result, this indicated that no potential health effects due to the consumption of these vegetables at these study stations.

As Sharma et al. (2018), state that the human health risk of cancer from the ingestion of carcinogenic heavy metals is calculated using Eq. (6). Then Target Cancer Risk (TCR) derived from the heavy metals in this study for Pb, Cr, and Cd, there may be beneficial carcinogenic effects depending on the dose of expression, hence the calculated TCR value for Pb and Cr in cabbage, Swiss chard, lettuce, and tomato vegetables via the

**Table 12.** Principal component analysis for soil, vegetable, and water samples.

Component Matrix

| Soil | Component | Vegetable | Component | | Water | Component | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | | 1 | 2 | | 1 | 2 | 3 |
| GS2 (May) | .997 | CGS2 (May) | .986 | .154 | UPWS1 (May) | −.627 | −.585 | .515 |
| GS2 (June) | .998 | CGS2 (June) | .983 | .180 | UPWS1 (June) | .920 | −.296 | −.256 |
| DIr.S7 (May) | .965 | SGS2 (May) | .981 | .193 | GS2 (May) | .928 | −.190 | .319 |
| DIr.S7 (June) | .992 | SGS2 (June) | −.495 | .869 | GS2 (June) | .938 | −.051 | .343 |
| | | LGS2 (May) | .981 | .190 | IPS3 (May) | .270 | .919 | .286 |
| | | LGS2 (June) | −.397 | .887 | IPS3 (June) | .734 | .611 | .295 |
| | | TGS2 (May) | .973 | .230 | IPS4 (May) | .882 | −.451 | −.135 |
| | | TGS2 (June) | .980 | .197 | IPS4 (June) | .066 | .762 | −.644 |
| | | CDGar.S8 (May) | .979 | .205 | WWJS5 (May) | −.088 | .979 | .182 |
| | | CDGar.S8 (June) | .977 | .214 | WWJS5 (June) | .990 | −.069 | .125 |
| | | SDGar.S8 (May) | .913 | .363 | DSS6(May) | .985 | .152 | .077 |
| | | SDGar.S8 (June) | .978 | .208 | DSS6 (June) | .865 | −.248 | −.435 |
| | | CDIr.S7 (May) | .973 | .226 | | | | |
| | | CDIr.S7 (June) | .981 | .193 | | | | |
| | | LDIr.S7 (May) | −.668 | .492 | | | | |
| | | LDIr.S7 (June) | −.544 | .838 | | | | |
| | | TDIr.S7 (May) | −.521 | .854 | | | | |
| | | TDIr.S7 (June) | −.573 | .810 | | | | |

sampling stations of the study during May and June were within the TCR value of Pb and Cr ($1 \times 10^{-4}$–$1 \times 10^{-6}$) as commented by the Ministry of Health (Health Canada, 2017) while the value of TCR for Cd in Swiss chard at sampling station of GS2 during May was not within ($1 \times 10^{-4}$–$1 \times 10^{-6}$) as stated by the Ministry of Health (Health Canada, 2017) as well as in all vegetables considered in this study for Cd heavy metal the TCR value at all sampling stations during June was not within ($1 \times 10^{-4}$–$1 \times 10^{-6}$) as noted by the Ministry of Health (Health Canada, 2017). So, there is currently a cancer risk for Cd due to the consumption of these heavy metal-contaminated vegetables covered in this study. Mohammadi et al. (2019b) evaluated the health risks of exposure to heavy metals along with the water distribution network of Khorramabad city in Iran and concluded that the degree of toxicity of heavy metals to human health is directly related to their daily intake, and long-term exposure to low amounts of toxic metals could result in many types of cancers. This calls for human health risk assessment to determine the nature and magnitude of adverse health effects in local communities around the study area that may be exposed to toxic substances in a contaminated environment. Agricultural soils influence public health directly and indirectly through food production, and therefore, protecting soil resources and ensuring their stability is important (Esmaeilzadeh et al., 2019).

## 5. Conclusion

Results for heavy metal concentrations in soil samples from various irrigated land use fields have shown no significant difference in irrigated soil at the Dir.S7 study site for a few heavy metals. Similarly, the Zn concentration which was recorded in the garden cabbage during May was not statistically significant. Heavy metals like Cr and Cd concentrations with Pb concentrations had shown a strong positive correlation in vegetables during May.

Vegetables irrigated with contaminated industrial wastewater were observed with heavy metal concentrations exceeding the permissible level on certain vegetables at some irrigated sampling stations in the study site. There was a high bio-concentration factor in vegetables in the sampling stations. Application of optimal management for the reduction of contaminants, and suitable irrigation methods with treated wastewater is therefore essential. Hence, industrial wastes or residues must be permanently checked and regulated. Heavy metals are not to remain in water sources and agricultural lands without significant treatment, tests and approval. Moreover, it is indispensable to monitor constantly the quality of water and soil to avoid the penetration of heavy metals into vegetables through water and soil effluence in order to prevent potential health hazards for human beings and other biotas. This study can provide a basis for the City Administration of Addis Ababa to properly protect the water quality of rivers and provide a reference for river management around the industry parks across the country.

## Declarations

### *Author contribution statement*

Fituma Lemessa: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Belay Simane; Assefa Seyoum: Conceived and designed the experiments; Analyzed and interpreted the data.

Girma Gebresenbet: Analyzed and interpreted the data, Contributed reagents, materials, analysis tools.

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### *Data availability statement*

Data will be made available upon request.

### *Declaration of interests statement*

The authors declare no competing interests.

### *Additional information*

No additional information is available for this paper.

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