



Selected toxic heavy metals in spring and river waters and their health implications: The case of Nonno Benja District, Ethiopia

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Abstract	Article Information
<i>Water resources are facing an increasing environmental and public health problem due to heavy metal poisoning. This paper presents the investigation of selected hazardous heavy metals in spring and river waters and their health effects in Nonno Benja District, Ethiopia. For this purpose, three water samples were collected from three sources, namely Laga Hillo, Laga Bakare, and Laga Burkitu springs. The mean values of temperature, pH, total suspended solids, total dissolved solids, electrical conductivity, nitrate (NO_3^-), and phosphate (PO_4^{3-}) ranged from 20.93-21.77 °C, 6.4-6.86, 52.97-105.5 $\mu\text{S}/\text{cm}$, 34.47-68.9 mg/L, 0.21-0.41 mg/L, 0.046-4.4 mg/L and 0.058-1.37 mg/L, respectively for the three samples. The concentration ranges of the heavy metals detected by flame atomic absorption spectrophotometer (FAAS) follows Pb (21.76 ± 2.65 to 17.94 ± 4.67 mg/L), Zn (8.61 ± 0.03 to 1.73 ± 0.02 mg/L), and Cd (10.41 ± 0.03 to 1.15 ± 0.03 mg/L) which are by far greater than the value recommended by World Health Organization (WHO) (0.003 mg/L; 0.01 mg/L; 3.0 mg/L). The increase in metal levels may account for the fact that both natural and anthropogenic sources play a great role. Improved water safety, illness prevention, and sustainable environmental management could all benefit from the study's conclusions.</i>	Article History: Received: 16-05-2026 Revised: 13-08-2026 Accepted: 28-09-2026 Keywords: <i>Heavy metals, drinking water, Nonno Benja, water pollution, non-essential elements, some physico-paramete</i>
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INTRODUCTION

Water is a crucial natural resource supporting life on Earth because it is mainly used for drinking and other related purposes (Banica et al., 2026; Çelik et al., 2026). Heavy metals in water systems lack natural elimination processes and occur naturally in the ground layer at different levels in all ecologies. Human activity has significantly disrupted the heavy metal balance and biogeochemical cycle in many ecosystems, such as water. The occurrence of heavy metals in water systems is mainly due to manmade and natural processes (Jagaba et al., 2024). Because of their solubility in water and their

capacity to form bonds with sediment particles, heavy metals are frequently found in water sources (Bao et al., 2024). The toxic nature and long-term stability lead heavy metals to bioconcentrate in many living systems via the food chain.

Toxic heavy metals can move via the food chain, and they accumulate in water and residues, ultimately affecting humans and other living things over the aquatic bionetwork and human body (Singh et al., 2026). Some toxic heavy metals like cobalt (Co), zinc (Zn), manganese (Mn), and chromium(III) (Cr (III)) are essential metals

because they play a great role in physiological functions and regulate various biological processes (Banica et al., 2026). Some metals, including Cd, Hg, Pb, Ti, As, Bi, and Sb, are non-essential for many living organisms (Maremane et al., 2026). Ten heavy metals, Co, Pb, Hg, As, Ti, Ni, Mn, Zn, Cd, and Cr, are poisonous at higher concentrations and are associated with enduring ailments like renal failure, liver cirrhosis, and mental disorder, as well as being significant in ecotoxicology (Samanth, 2024; Maremane et al., 2026).

Statement of the problem

The World Health Organization (WHO) recommends the permissible values of 0.01 mg/L (Pb), 3.0 mg/L (Zn), and 0.003 mg/L (Cd) in consumable water (Almaliki et al., 2022). Nonno Benja district in Jimma zone experiences different geologic conditions and mineral weathering, as well as intensive farming involving the application of various agrochemicals, which in turn increase the concentration of metals in soil, water, and air and subsequently in plants. Most of the community residing in this district relies on the ground, river, and spring waters as the main sources for drinking water. All factors call for the urgent need to evaluate the levels of toxic heavy metals in the drinking water sources to maintain the consumers' health. Therefore, this study aimed at the determination of the levels of Cd, Pb, and Zn in spring drinking water in Nonno Benja District, Jimma Zone, Oromia Region, Ethiopia.

Research questions

1. What are the concentration levels of selected toxic heavy metals in spring and river waters of Nonno Benja District used for drinking purposes?
2. Do the detected heavy metal concentrations exceed WHO permissible limits for drinking water?

3. Are there possible health risks related to exposure to polluted water in the study area?
4. What are the likely causes contributing to heavy metal pollution in the district?

MATERIALS AND METHODS

Description of the study Area

This study was conducted in Nonno Benja district, one of the districts found in Jimma administrative zone, Oromia Regional State, Ethiopia (Figure 1). The district is located about 506 km from Addis Ababa and 156 km from Jimma city, Jimma Zone. Nonno Benja District is surrounded by East Wollega, Chora Botor District, Seka District, and West Shoa Zone in the North, South, West, and East, respectively. The district consists of 21 kebeles, of which 19 are rural, and the remaining are urban. According to the population and housing census, the total population of Nonno Benja District was 88204 (78103 rural dwellers and 10101 urban dwellers). The elevation of the district ranged from 1600 m to 2600 m above sea level. The yearly average temperature of the district varies from 17.5 °C to 22 °C whereas the annual average precipitation ranges from 1300 to 1600 mm. The study area has three climatic precincts: high land 18%, middle land 58%, and low land 24%;

Chemicals and reagents

The reagents used in this study were all of analytical grade; nitric acid (70%) and hydrochloric acid (37%) were used for digestion of the water sample. The standard solution of 100 mg/L in 70% HNO₃ of the nitrate salt metals (Cd, Pb and Zn) was prepared by dissolving the salts in distilled water in order to obtain a working standard solution through dilution. Potassium nitrate, ammonium molybdate tetrahydrate, 99.3%, hydrazine sulphate 99%, and potassium dihydrogen orthophosphate anhydrous, 99.5% were used for determination of phosphate ion and nitrate ion.

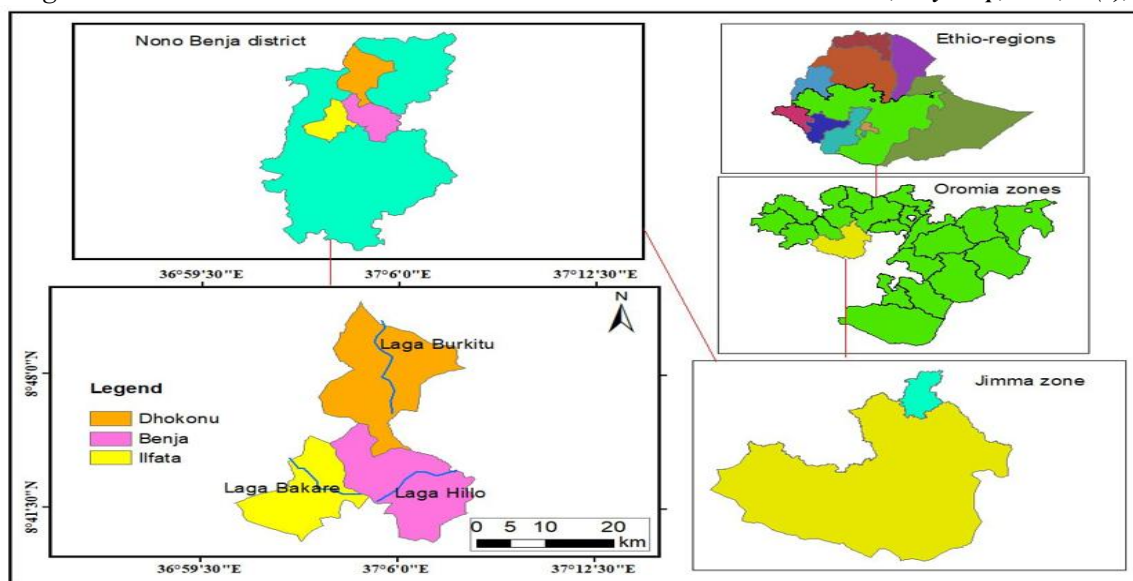


Figure 1. Map of the Study area

Apparatus and instruments

pH meter (3100 Janeway, England) and Flame Atomic Absorption Spectroscopy (FAAS, Savant AA 8350, Australia) were used to measure acidity and electrical conductivity and heavy metals in drinking water samples, respectively.

Water sample collection

In this study, Laga Hillo, Laga Burkitu, and Laga Bakare water sources found in Nonno Benja district were considered for water sample collection (Figure 2). Two springs and one river, a total of three drinking water samples were collected from

three Kebeles based on the number of people who use the water. Each plastic bottle was cleaned 3 times with water from the sampling sites before the collection of samples. Water samples were collected during the morning (7 am), noon (12: 00 pm), and evening (6:00 pm). Then the water samples were mixed well, and 1 L of each was taken into polyethylene pre-cleaned bottles to obtain representative samples. The collected water samples were categorized with a unique code and transported in an insulated box to the chemistry laboratory at Wollega University and kept in a refrigerator at 4°C before analysis.

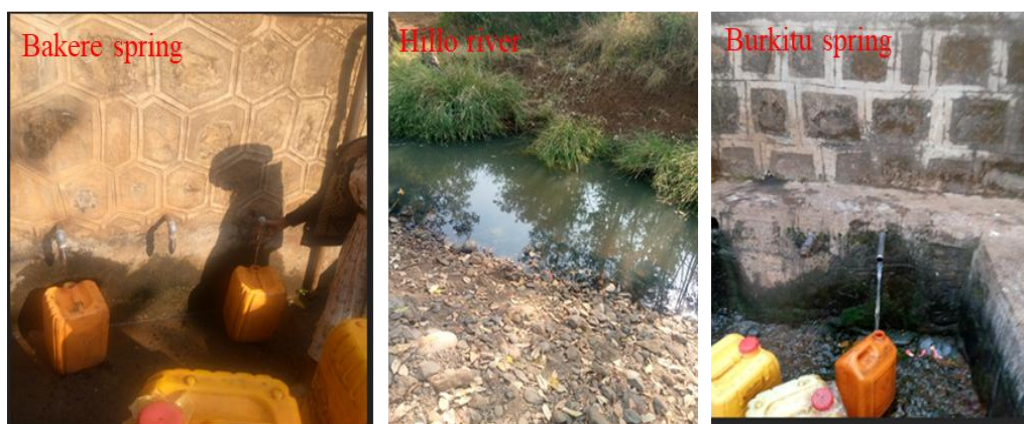


Figure 2. Drinking Water sources under study captured in Nonno Benja District
Analysis of selected physicochemical properties

The electrical conductivity (EC) (Manimaran et al., 2024), pH (Rajab et al., 2025), temperature (Khaliq et al., 2024), total dissolved solids (TDS), total suspended solids (TSS) (Gong et al., 2025), nitrate ion (NO_3^-) (Kapp et al., 2025), and phosphate ion (PO_4^{3-}) (Pratiwi et al., 2024) were determined following standard methods reported before. For the determination of heavy metals, 100 mL of homogeneous sample was transferred to the beaker; 3 mL of HNO_3 and 1 mL of HCl were added and then heated on a steam bath till the volume was concentrated to 25 mL. Then, the cooled sample was transferred to a measuring cylinder and adjusted to 100 mL. Similarly, a blank sample was digested to allow a blank correction to be made. Finally, the heavy metals under investigation were measured using FAAS.

Method validation

The practice of confirming that an analytical method is suitable for its proposed usage is identified as method validation. For every target analyte, a limit of quantification, accuracy, linear dynamic range, and interference adjustments were determined. To ensure accuracy, the certified reference material was utilized. A valid and accurate FAAS method was developed to estimate the heavy metals in drinking water samples. The authenticity of the digestion process was guaranteed through the addition of a known quantity (spiking) of the standards into the samples because the laboratory did not have approved reference material for the samples. The identical digestion process that was previously devised for water samples was used to digest the spiked samples in triplicate (Yohannes et al., 2024) to determine the percentage (%) recovery by using the following equation.

$$\% \text{ Recovery} = \frac{\text{amount of analyte recovered}}{\text{amount of analyte added}} \times 100 \quad (1)$$

The percentage standard deviation of the three replicate samples' results and nine measurements for a particular blank sample were used in this study

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to assess the accuracy of the findings (Pigliasco et al., 2024).

$$\% \text{ RSD} = \frac{SD}{\bar{x}} \times 100 \quad (2)$$

Analysis of human health risk

Heavy metal-related possible health risk assessment can be grouped depending on the approximation of the hazard into carcinogenic or non-carcinogenic classes (Eslamizad et al., 2025). The health risks were determined using hazard quotients (HQ), hazard index (HI), and the incremental lifetime cancer risk (ILCR) by considering only adults.

$$CDI_{\text{ingestion}} = \frac{C \cdot W \cdot DI \cdot ABS \cdot EF \cdot EP}{WB \cdot AT} \quad (3)$$

$$CDI_{\text{dermal}} = \frac{C \cdot W \cdot SA \cdot Kp \cdot ABS \cdot ET \cdot EF \cdot EP \cdot CF}{WB \cdot AT} \quad (4)$$

Where, C_w (in mg/L) is the concentration of heavy metals in water, SA (in cm^2) is the skin area available for contact, Kp (in cm/hour) is the permeability coefficient, ABS (unitless) is the dermal absorption factor, DI (in L/day) is the daily average intake of water in the area, ET (in h/event) is the exposure time, EF (in days/year) represents the annual exposure frequency, EP (in years) is exposure period, CF (in L/cm^3) is the unit conversion factor, BW (in kg/person) is body weight, and AT (in days) is the average time.

The ratio of the computed average day-to-day consumption (ADI, mg/kg/day) of a metal used up with polluted water to the reference oral dose (RfD) by oral ingestion and cutaneous absorption for the inhabitants was used to estimate the HQ for each heavy metal. The total possible health risks, or HI, were estimated using the sum of all HQs (Yazman et al., 2024). The calculation of the HQ caused by water was presented as (Eq. 6):

$$HQ = \frac{CM \times IR \times EF \times ED}{AW \times AT} \quad (5)$$

Where CM = heavy metal levels in water mg/Kg weight, IR = ingestion rate of water considered to be

65 g/person/day; EF= exposure frequency (365 days/year), ED= exposure duration (70 years), AW= adult body weight considered as 70 Kg, AT = average exposure time for non-carcinogenic health risk calculated as $ED \times 365 = 25,550$ days.

The overall likely non-carcinogenic health effects of exposure to a mixture of heavy metals in water are estimated using HI. The EPA's references for health risk assessment were followed while calculating the HI for a number of heavy metals (Enkhjargal et al., 2025) using the following equation (Eq. 6).

$$HI = \sum_{k=1}^n HQ = HQ_{Pb} + HQ_{Cd} + HQ_{Zn} \quad (6)$$

So, the HI value of heavy metals in the spring drinking water was $HI < 1$ and not harmful for drinking and other purposes. $HI > 1$ implies that there were potential health risks, while $HI < 1$ was regarded as safe.

Statistical analysis

The data collected for the laboratory were subjected to statistical analysis (SAS) which was done using SPSS software. All analyses were carried out in triplicate and data were presented as mean $\pm$ standard deviation (mean $\pm$ SD) and variance.

RESULTS AND DISCUSSION

Results

Analysis of selected physicochemical properties

The proximate analysis of water samples is essential to obtain essential hand-full information about the nature of the samples, selection of parameters for testing and further studies. The drinking water samples were subjected to the measurement of parameters like pH, temperature, TDS, TSS, EC, NO_3^- and PO_4^{3-} are shown in Table 1.

Table 1

Certain physicochemical properties of water samples (Mean $\pm$ SD values and variance) (n=3).

Parameter	Unit	Sample sites		
		Laga Burkitu Mean $\pm$ SD	Laga Bakare Mean $\pm$ SD	Laga Hillo Mean $\pm$ SD
Temperature	° C	20.93 $\pm$ 0.12	20.97 $\pm$ 0.06	21.77 $\pm$ 0.25
pH	-	6.42 $\pm$ 0.02	6.40 $\pm$ 0.02	6.86 $\pm$ 0.02
TDS	mg/L	54.33 $\pm$ 0.15	34.47 $\pm$ 0.06	68.90 $\pm$ 0.17
TSS	mg/L	0.210 $\pm$ 0.01	0.317 $\pm$ 0.01	0.405 $\pm$ 0.01
EC	μ s/cm	84.17 $\pm$ 0.06	52.97 $\pm$ 0.06	105.50 $\pm$ 0.35
NO_3^-	mg/L	4.48 $\pm$ 0.004	1.286 $\pm$ 0.001	0.423 $\pm$ 0.21
PO_4^{3-}	mg/L	0.177 $\pm$ 0.41	0.058 $\pm$ 0.02	1.37 $\pm$ 0.24

From Table 1, the temperature ranges were from 20.93 °C - 21.77 °C in Burkitu, Bakare, and Hillo. The minimum mean pH value is 6.4033 for Bakare, and the maximum mean value is 6.8633 for the Hillo source. Briefly, Laga Hillo (6.85-6.88), Laga Burkitu (6.40-6.43), and Laga Bakare (6.39-6.42) have pH values less than seven, implying that the water samples are slightly acidic in nature. The average pH of Laga Hillo 6.863, Laga Burkitu 6.42

and Laga Bakare water samples was 6.403. The pH of the spring water samples, in increasing order, follows Laga Hillo 6.863 greater than Laga Burkitu (6.42), Laga Burkitu (6.42), and Laga Bakare (6.403).

The measured TDS values were found between the minimum mean value of 34.47 mg/L for Bakare and the maximum mean value of 68.90 mg/L for Hillo site, as shown in Table 1. TSS determines the

amount of organic matter that is suspended in water sample. The range of TSS for Laga Hillo is 0.4024 0.4105 mg/L, for Laga Bakare is 0.311 0.321 mg/L, and Laga Burkitu is 0.2009 0.2199 mg/L.

EC is a measure of the electron transfer through water and highly depends on the ionic species present in it. These anions and cations in water are the main factors affecting the conductivity because of their specific mobility at a particular temperature. In this study, EC values ranging from 52.97 - 105.5 $\mu\text{S}/\text{cm}$ were measured for Laga Hillo, Laga Burkitu, and Laga Bakare (Table 1). The minimum value of EC was recorded at the Bakare site (52.97) $\mu\text{S}/\text{cm}$ and the maximum value was documented at the Hillo site (105.5 $\mu\text{S}/\text{cm}$), which are less than the permissible limit recommended by WHO (400 $\mu\text{S}/\text{cm}$) (WHO, 2024).

The occurrence of NO_3^- in the analyzed waters could be ascribed to agricultural activities. Excreta

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from humans and animals may contribute to NO_3^- levels in the waterways under study. The presence of NO_3^- in these waterways was likely due to its natural availability in the water. A higher rate of NO_3^- in water was an instrumental factor in cancers (Sanjupriya et al., 2025). The average amount of NO_3^- assort from 0.423 mg/L to 4.48 mg/L for all water samples investigated.

In the current study, the minimum PO_4^{3-} concentration was documented at 0.0583 mg/L in Laga Bakare and the maximum recorded at 1.37 mg/L in Burkitu spring water.

Analysis of heavy metals

The mean values of triplicate measurements plus/minus the variance (R^2) and standard deviation were used to report the presence of heavy metals in various drinking water samples (Table 2).

Table 2

Heavy metals' concentration in the different water samples (Mean $\pm$ SD values and Variance ($n=3$) (mg/L)).

Parameter	Laga Burkitu		Laga Bakare		Laga Hillo	
	Mean $\pm$ SD	R^2	Mean $\pm$ SD	R^2	Mean $\pm$ SD	R^2
Pb	21.76 $\pm$ 2.65	7.009	23.83 $\pm$ 2.19	4.833	17.94 $\pm$ 4.67	21.741
Zn	8.61 $\pm$ 0.03	0.001	8.18 $\pm$ 0.04	0.001	1.73 $\pm$ 0.02	0.001
Cd	10.41 $\pm$ 0.03	0.001	1.05 $\pm$ 0.03	0.001	1.15 $\pm$ 0.03	0.001

The level of Pb in all the samples was detected. The level of Pb ranged from 17.94 $\pm$ 4.67 mg/L (Laga Hillo), 21.76 $\pm$ 2.65 mg/L for Laga Burkitu, and 23.83 $\pm$ 2.19 mg/L for Laga Bakare.

The mean value of Zn concentrations ranged from 1.7270 mg/L (Hillo), which was the lowest, to 8.61 mg/L (Burkitu), which was the highest. In Laga Hillo, the Zn concentrations in the spring under study were less than the USEPA's limit of 5.0 mg/L (Table 2). Therefore, based on the findings of this investigation, there were no negative consequences associated with the Zn concentration in the drinking water sample from Laga Hillo. Cd concentrations between 1.012 mg/L and 10.44

mg/L were recorded for the water samples studied in this work.

Pearson correlation analysis

The connection between different heavy metal concentrations and a few physicochemical properties was investigated using Pearson's correlation coefficient. At the 0.05% significance level, a high correlation coefficient (near +1 or -1) indicates a strong association between two variables, while a value around zero indicates no relationship at all. The relationship between the physical and chemical properties and heavy metals in spring drinking water was assessed to determine possible similarity in the sources (Table 3). The physical and chemical properties and heavy metals

with positive relationships were reflected to have similar sources.

Correlation analysis showed strong correlation between phosphate and nitrate, Zn and phosphate, Cd and Zn, and a moderate correlation between EC and TDS and phosphate with pH. The pH has a strong correlation with temperature owing to the generation of either hydrogen ions or hydroxyl ions

in water, thereby altering the values of temperature accordingly. The EC showed strong correlation with NO_3^- and Cd, indicating the availability of soluble salts of $\text{Cd}(\text{NO}_3)_2$ in the rocks or other sources. Similarly, strong correlation was observed between NO_3^- and PO_4^{3-} , Zn and PO_4^{3-} as well as between Cd and NO_3^-

Table 3

Correlation coefficient of some physical and chemical parameters and heavy metals in water sample

	Temp	pH	TDS	TSS	EC	NO_3^-	PO_4^{3-}	Pb	Zn	Cd
Temp	1									
pH	-.99*	1								
TDS	.80	-.75	1							
TSS	-.91	.98	-.86	1						
EC	.91	0.945	.50	-.87	1					
NO_3^-	-.91	.94	-.50	.87	-.1.00**	1				
PO_4^{3-}	-.74	.69	-.42	-.99	-.59	.99	1			
Pb	.29	-.22	.80	-.39	-.10	.10	-.85	1		
Zn	-.72	.66	-.99	.78	-.38	.38	.99*	.23	1	
Cd	-.89	.92	-.46	.84	-.99*	.99*	.38	-.82	.93	1

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Assessment of human health risk

Risk assessment was defined as the process of defining the possibility that a specific amount of harmful health effects will happen over a specific

period of time (Farahmandkia et al., 2025). The HI for several heavy metals was computed as shown in Table 4.

Table 4

HQ and HI in different water samples

Heavy metal	HQ Burkitu	HQ Bakare	HQ Hillo	Hazard index (HI)	
				Adult	Child
Pb	0.1700	1.8800	0.1400	2.1900	1.5800
Zn	0.0009	0.0009	0.0002	0.0020	0.0041
Cd	0.3300	0.0033	0.0036	0.3666	0.8400
$\Sigma(\text{HI})$	0.5009	1.8838	0.1438		

For all samples, the HI is less than 1, except Laga Bakare where its HI is greater than 1, implying that the water from this source may not be safe for drinking for an extended time. HI for children is greater than that of adults due to the small body

weight of children. For all samples studied, the levels of Pb, Cd, and Zn are above the acceptable limits set by WHO and other organizations. The levels of the studied heavy metals (Pb, Cd and Zn) in water samples from Nonno Benja district were

compared with both Ethiopian and WHO standards as presented in Table 5.

Table 5

Some physicochemical parameters compared with national and international standards.

Parameter	Level	Ethiopia (2024)	WHO (2024)
Temp	20.80-22.00	-	-
pH	6.39-6.88	6.5-8.5	6.5-8.5
TDS (mg/L)	34.40-69.10	1000	1000
TSS (mg/L)	0.20-0.41	-	-
EC (μS/cm)	52.90-105.70	1500	400
NO ₃ ⁻ (mg/L)	0.27-4.48	50	50
PO ₄ ³⁻ (mg/L)	0.04-1.64	0.03	0.01
Pb (mg/L)	0.02-25.77	0.007	0.01
Zn (mg/L)	1.71-8.63	5.0	3.0
Cd (mg/L)	1.01-10.44	0.006	0.003

The pH and PO₄³⁻ values of the three water samples are slightly lower or greater than the limits set by Ethiopia and WHO, while the TDS, EC and NO₃⁻ are far lower than the standard values. The amounts of heavy metals (Pb, Cd and Zn) studied in this work are greater than the recommended limits set by WHO and Ethiopia, showing that there is a concern related to the health implications for consumers. However, the HI values for the three drinking water samples show that the water is safe for adults consuming it.

Distribution patterns of heavy metals in different water sources

The results of the investigation showed that the three water samples had different quantities of the heavy metals found in them (Figure 3). Pb (21.1797 mg/L) was found to have the greatest concentration

of all the heavy metals, followed by Zn (6.1743 mg/L) and Cd (4.33607 mg/L). Pb, Zn, and Cd concentrations were found in all of the spring samples that were examined. In summary, the heavy metal concentration profile found in the liquid spring water sample is listed in decreasing order as follows: Pb > Zn > Cd (since the concentrations of Pb, Zn, and Cd were beyond the instrument's detection limit). The results of the heavy metal analysis generally indicated that Laga Hillo spring water had the lowest content of Zn and Cd, while Laga Bakare spring water had the highest concentration of Pb, followed by Laga Burkitu spring water. Therefore, peoples consuming Laga bakare and laga burkitu spring waters were exposed to the toxic effect of lead and Zn than those peoples who drinks Laga Hillo.

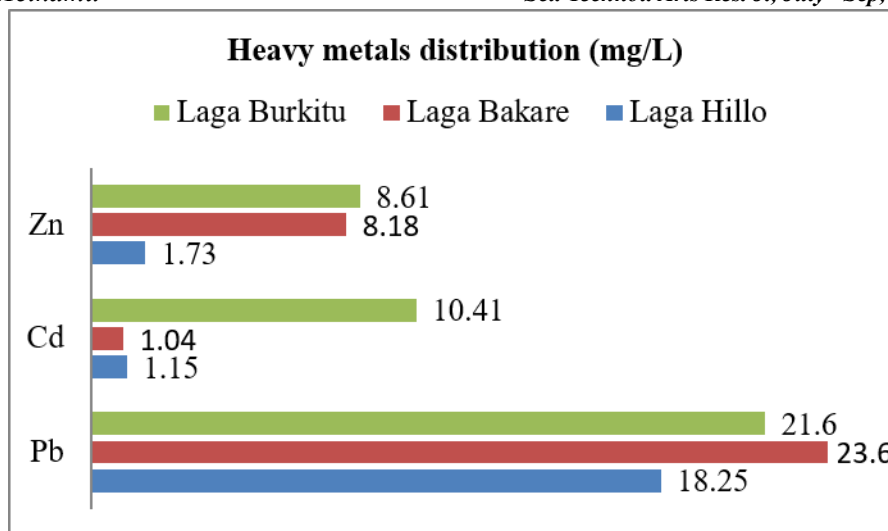


Figure 3. Distribution of Pb, Cd and Zn in the three water samples

Discussion

Selected physicochemical properties

The Ethiopian guideline values (2013) and the recommended range of 25°C (WHO, 2024) for drinking water quality were both below the values reported in this analysis. In terms of the temperature of the water samples under study, the water sources were suitable for drinking, and the observed temperature fluctuation at each site was not significant.

pH is the measure of the hydrogen potential of water and is used to express the intensity of the acidity or alkalinity, and it was determined by a pH meter (Lewenstam et al., 2025). The pH values for all samples are below the WHO (6.5-8.5) recommended limits and the Ethiopian standard guideline. For this reason, this water is not suitable for drinking and other purposes.

The results showed that there was no issue with the TDS of the examined waters because they were below the WHO norm (500 mg/L) and Ethiopian guidelines for drinking water quality. As a result, these ranges were acceptable, and the TDS value had no negative effects on drinking or other uses.

The TSS minimum mean value of 0.2103 mg/L for Laga Burkitu and the maximum mean value of 0.4051 mg/L for Hillo were found (Table 1), both of which are much lower than the WHO and

Ethiopian standard guideline's acceptable limit of 30 mg/L.

In terms of EC and associated mineral levels, all sampling sites' EC values fall within the standard range, indicating that the water sources are suitable for consumption.

The great differences in the concentrations of NO_3^- in Hillo and Burkitu might be due to nitrogen-containing compounds in the soil in organic forms. These nitrogenous compounds obtained from decaying plant and animal residues were converted into NO_3^- by bacteria and leached into the spring water. The results obtained from this study are below the recommended values for drinking water (50 mg/L) presented by both the international organization and Ethiopian guidelines for drinking water quality. Thus, it is less probable that health problems and environmental issues associated with NO_3^- levels in the three water sources would happen.

PO_4^{3-} is a crucial chemical indicator of water quality that affects drinking water's flavor and smell (Palaka et al., 2025). Phosphates are forms of phosphorus, a critical nutrient in ground and freshwater ecosystems. While small amounts of phosphate were essential for aquatic life, excessive levels can lead to environmental problems such as eutrophication. Mostly, orthophosphate was the bioavailable form for algae and aquatic plants.

The water samples had PO_4^{3-} -values greater than the recommended level by WHO and the Ethiopian standard guideline, which is 0.03 mg/L. Though there are variations in the concentration of PO_4^{3-} among the water samples studied, none of them are suitable for drinking and other domestic purposes. The presence of high quantities of PO_4^{3-} in water bodies remains the main threat for both human health and the aquatic environment (Nadagouda et al., 2024).

Heavy metals analysis

Heavy metals tend to build up in canal sediments along with organic and inorganic waste since they are not biodegradable (Kutluer et al., 2026). Therefore, one important metric was the monitoring of heavy metals in drinking water. The current study's findings were contrasted with Ethiopian drinking water quality requirements and WHO-established tolerable levels for heavy metals such as Cd, Zn, and Pb. According to Ethiopian guidelines for drinking water quality standards and WHO (2024), the maximum permissible quantities of the heavy metals Cd, Zn, and Pb were 0.003 mg/L, 5.0 mg/L, and 0.01 mg/L, respectively.

The concentration of Pb in this study is by far greater than the permissible values in drinking water by WHO (0.01 mg/L) (WHO, 2024) and the Ethiopian standard guideline (0.007 mg/L). Pb does not readily dissolve in the environment, but after rain and surface water runoff, it can combine with dust or soil particles and find its way into drinking water or subsurface water. Pregnancy and lactation expose fetuses and breastfed newborns to lead, a hazardous heavy metal that accumulates in the skeleton and mobilizes from bones, affecting numerous organs in the human body (Jomova et al., 2025). All water samples studied contain Pb above the recommended values by WHO and the Ethiopian guideline for drinking water quality, and there would be a potential health hazard to consumers and the environment. This metal is known to be toxic, with known associations with various health effects, which makes the water samples unsuitable for human consumption.

The drinking water from the Laga Bakare and Laga Burkitu springs has higher values than the USEPA and WHO limits (3.0 mg/L), which has a harmful effect on the community residing there. Zn concentrations in the three water samples varied from 1.73 ± 0.02 mg/L to 8.61 ± 0.03 mg/L, indicating a substantial difference between the water sources. Zn contents in two of the samples were higher than the WHO maximum allowable level. Natural and anthropogenic factors may be the cause of the increased concentration of Zn in the spring water of Burkitu (8.61 ± 0.03 mg/L) and Bakare (8.18 ± 0.04 mg/L), which exceeded the WHO's permissible limit of 3.0 mg/L (WHO, 2024) and the Ethiopian standard guideline for drinking water. This indicates that the two spring waters are more polluted with Zn and therefore not acceptable for drinking purposes. This might be due to possible Zn poisoning from the continuous consumption of the water from the three sources studied (Singh et al., 2026).

The permissible value of Cd concentration in drinking water is 0.003 mg/L (WHO, 2024), and 0.006 mg/L (Ethiopian standard guideline). Therefore, the concentration of Cd in the three study sites was above the recommended levels. This implies that geological activities and rock weathering processes in the study areas, along with the intensive use of various agrochemicals, contributed to the increased levels of Cd. The existence of Cd at higher levels is a potential threat to the community using these water sources frequently. Thus, alternative water sources or water treatment plants are very important to avoid exposure to this toxic metal (Kamagate et al., 2025). Of course, it is important to note that river water has self-cleaning capacity, while spring water does not and thus needs due attention to treat the waters before use for drinking purposes (Mussakulkyzy et al., 2025).

There are no appreciable non-cancer health hazards, as indicated by the HQ and HI values for water samples from Laga Burkitu and Laga Hillo being less than unity. The water sample from Laga Bakara, however, had an HI value of more than 1

(1.8838), suggesting a substantial non-cancer risk. The HI value for Pb in several samples is larger than 1 for both adults and children, indicating that long-term exposure to it carries a substantial non-cancer health risk.

CONCLUSIONS

This study presents the levels of some physical and chemical parameters as well as three heavy metals of water samples from Burkitu, Bakare and Hillo spring water sources. In this study, physical and chemical parameters such as (pH, temperature, EC, TDS, TSS, PO_4^{3-} , NO_3^- and heavy metals (Zn, Cd, and Pb) of the spring waters were measured. The results showed that the concentrations of most physicochemical parameters of the water samples, such as pH, temperature, EC, TDS, TSS, PO_4^{3-} , NO_3^- ions were below the permissible limits of the WHO (2024) and Ethiopian guideline (2024) values for drinking water quality standards. Concentrations of Cd, Pb, and Zn in the water samples obtained from the three water sources exceeded the recommended limits. The higher concentration of Pb in the Laga Bakare spring water may be due to emissions from land application of fertilizers, natural mineral decomposition over a long period of time, or Pb metals that are naturally occurring in the Earth's crust. The overall concentration range of all heavy metals obtained from the three springs was above the WHO recommended limit and Ethiopian standard guideline; therefore, it may pose some health effects. The HI values for both adults and children are above 1 for Pb and that of Laga Bakare; corrective measures are needed to remove Pb from the water sources before consumption to avoid the risk of non-cancer health issues.

Recommendation

It is recommended that further study on other toxic heavy metals in the study area is very important, in addition to enhancing treatment technology, community awareness, and strengthening their capacity in order to safeguard spring water supplies from potential sources of pollution.

CRedit authors statement

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Declaration of competing interests

The authors declare that they have no conflict of interest in publishing this version of the manuscript.

Ethical approval

Not applicable

Data availability statement

Data will be available from the corresponding author upon formal request.

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