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ABSTRACT: This study aimed to determine the physicochemical quality of groundwater and its potential health risk for drinking in Oromia, Ethiopia. The groundwater samples were collected from 17 sampling stations in the dry and wet season in the Sebeta zone, Oromia, from March to August 2020. Metals and physicochemical parameters, and selected heavy metals, such as iron (Fe), copper (Cu), manganese (Mn), chromium (Cr), zinc (Zn), and lead (Pb) were monitored. The data were analyzed using multivariate statistical methods (Pearson's Correlation and T-test). The means seasonal variations were higher in the dry season than in the wet season except for pH and Turbidity. The variation was significant for most parameters except Pb, Zn, chlorine, Total Alkaline, Magnesium Hardness, Calcium Hardness), and Turbidity. There was a strong and positive correlation between Total dissolved solids (TDS) and Conductivity), (pH and Cr), (T.H. and Magnesium (Mg)), (bicarbonate and Calcium (Ca), (Zn and Turbidity) in the dry season; and (T.H. with Potassium (K), (Pb and Fe); (bicarbonate and T.H.); (Ca and Mg); (Na and T.A.,) in the wet season. The hazard index (H.I.) values in the dry season ($HI = 1.331$) were higher than in the wet season ($HI_{adults} = 0.075$). Likewise, the H.I. (dry season) was higher ($HI_{children} = 1.861$) than in the wet season ($HI_{children} = 0.105$). Chronic groundwater exposure at drinking sources in the dry season is a potential health risk to humans in general and is relatively high for children. Urgent management and close monitoring are required for drinking groundwater sources and other nearby residents' safety areas.

KEYWORDS: Hazard quotient, drinking water, physicochemical analysis, Sebeta zone

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Introduction

The most vital component of the ecosystem is water. Its quality is determined by the appropriate monitoring of its various physical, biological, and chemical parameters as defined by the World Health Organization (WHO).[1] Unsafe water, inadequate sanitation, and poor hygiene are linked to about 88% of diarrhea cases worldwide.[2] Besides microbial contaminants, heavy metal water resource contaminations have received much attention because of their substantial toxicity, even at lower concentrations.[3] About 1 billion people live in regions with unsafe drinking water, including Sub-Saharan Africa, East Asian, and South Asian countries, which results in the loss of many lives yearly.[4]

Groundwater is one of the primary freshwater sources for drinking, irrigation, and industrial uses in most communities worldwide.[5,6] Groundwater is typically less polluted than surface water because of its self-cleaning ability and ease of treatment.[7] In developing countries, a lack of access to clean drinking water adversely affects the population's general health and life expectancy.[8,9] Clean surface water is radically subordinate, and people are devoted to groundwater sources.[3] Due to rapid population growth, urbanization, agricultural fertilizers, and planting industrial waste, drinking water quality in many cities and rural areas is affected.[10,11] The health-hazardous nature of these primarily depends on the concentration of the toxicants present in the drinking water, which has gained the attention of national regulatory agencies and the WHO.[12] The human health risk from unsafe drinking water is due to prolonged exposure to chemicals present in the drinking water.[5,6] The complications and deterioration of health depend on the concentration of the chemicals and the time of exposure.[13] Some chemicals might produce immediate impacts on human health because of the nature of the hazardous chemicals.[14,15] Severe human health implications, such as cardiovascular and skeletal diseases, infertility, neurotoxicity, etc., are associated with heavy metal exposure.[4] Moreover, exposure to metals results in numerous liver and kidney problems, where some groups of toxicants are considered genotoxic carcinogens.[8]

For many years, Ethiopians used drinking water from groundwater sources (Borehole sources), shallow wells, and springs, especially people living in rural areas.[16] Such groundwater sources delivered a deprived supply of clean water and poor sanitation.[17] The water quality problem has extended for the lowest coverage in Sub-Saharan countries, with 57% and 28% improved drinking water supply and improved sanitation, respectively.[18] The study areas mainly cover population growth,

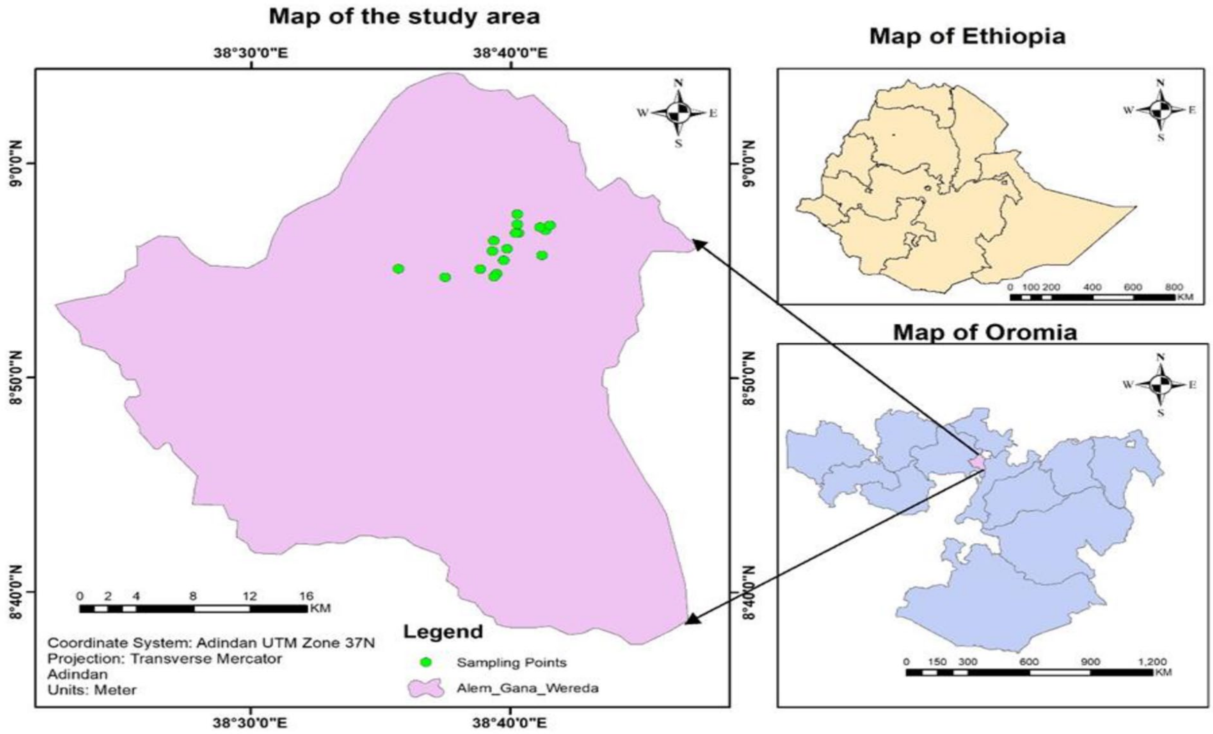

Figure 1 Map showing the sampling locations (GPS Location, 2020). .

the expansion of settlements, the shortage of potable drinking water access and supply coverage, environmental mismanagement, and uncontrolled liquid and solid waste disposal.[19] We hypothesized that long-term exposure to metals and physicochemical parameters with higher than the standard limit causes human health risks. Seasonal variation affects the value of groundwater on selected parameters. The elevation level of these parameters was existed within highly populated industries, unplanned and uncontrolled disposal wastes, and urbanization. No previous study was conducted in this study area regarding the physicochemical quality of drinking water and the potential health risk of groundwater. This study aims to assess the quality of drinking groundwater and its potential health risk.

Material and Methods

Study area and period

The Sebeta Hawas special Zone is one of the 15 zones of the Oromia regional states located in Addis Ababa surrounding. The area is situated 35 km southwest of the capital, Addis Ababa. In this district, there are 328 water source points, including 189 hand-dug wells (HDW), 124 developed springs (SPD), and 15 shallow wells (SHW), of which 23 HDW and 10 SPD can be repaired with minimal care, while 12 HDW, 11 SPD, and 3 SHW need extensive renovation.

Sampling and analysis of Borehole Point sources

The Borehole site selection is based on the population size served by the entire Borehole site for drinking and related purposes. Out of the 553 groundwater point sources in the study area, 17 Borehole water sources were selected purposively due to the establishment and expansion of industries that are currently upsurging in this study area (Figure 1).[20] The water samples were collected in the Dry Seasons (July-August) and Wet seasons (January-February) of 2020. This study majorly focused on the borehole site was due to the highly consumable water source in the study area.

The sample collection bottles were washed thoroughly with the detergent, acid (1:1 Nitric Acid (HNO_3) and Water (H_2O) by 10% v/v), tap water, and distilled water. The chemical parameters were determined by using the American Public Health Association (APHA, 1998)[21] standard methods immediately after taking them into the laboratory. The samples were collected from different 17 groundwater sources (borehole) in pre-cleaned sterilized bottles and stored in an icebox. A total of 51 (17×3) water samples were collected from 17 borehole drinking water sources in each season (dry and wet) separately. In general, a total of 102 (51×2) samples were collected from both dry and wet seasons. The groundwater sources selected for the dry season are also used again in the wet season simultaneously. The sample collected for each Borehole water source, 3 samples (triplicate) at the same time were taken for laboratory analyses to minimize the analytical error for each season. The mean of triplicate measurements was taken to the final analysis. The APHA 1998 standard water and wastewater analysis method was implemented to analyze the Borehole samples.

Determination of physicochemical parameters: The Hydrogen ion concentration (pH) is measured by the Electrometric Method. Turbidity, fluoride, chloride, iron,

Table 1. Input assumption parameters to derive the intake value and RFDS (mg/kg/day) for the risk assessment due to groundwater exposure.

EXPOSURE PARAMETER	INDIVIDUAL	VALUE	METALS	R_FD	REFERENCES
Bodyweight, as B.W. (kg)	Children	15	Manganese	0.1	Chabukdhara et al[8], Usepa[25]
	Adults	60			
Exposure frequency, as E.F. (days year 1)	Children	360	Copper	0.037	Chabukdhara et al[8], Chai et al[24]
	Adults	360			
Exposure duration, as E.D. (years)	Children	10	lead	0.014	Chabukdhara et al[8]
	Adults	58			
Average time as AT (day)	Children	10 × 365	Zinc	0.3	Chabukdhara et al[8]
	Adults	58 × 365			
			Iron	0.3	
Daily water intake as IngR (L/Day)	Children	1.8	Chromium	1.5	Chabukdhara et al[8], Usepa[25]
	Adult	2.0			

copper, and sodium were determined following the APHA method (1998). The Turbidity was determined by the nephelometric method using a turbid meter. Fluoride content was determined by a colorimetric method using SPADNS. The Argentometric method was followed to determine the chloride (Cl^-) content. Atomic Absorption Spectrometry (AAS) was used to determine the iron (Fe) and copper (Cu) content following the acid digestion method. The sodium (Na^+) content was determined using the flame photometric method. The Ethylene diamine tetraacetic acid (EDTA) titrimetric method was used to measure the concentration of the total water hardness. The magnesium ($Mg^{2}+$) concentration was determined by the difference after assessing the Total Hardness and the Calcium ($Ca^{2}+$).

Phosphate was analyzed by the Stannous chloride method using an Ultra Violet-Visible (U.V.–vis) spectrometer. The nitrate, nitrite, and chromium levels of the drinking water samples were determined using the rapid digital pack test apparatus (Kyoritsu Chemical-Check Lab., Corp. Japan).

Statistical analysis

The data were analyzed using SPSS version 20 and Microsoft Excel. Descriptive statistics like Percentage, Median, Mean, and Range of the quantified drinking water physicochemical data were computed from the samples. A Pearson Correlation Matrix was used to analyze the relation of each Physicochemical parameter within and in-between each sample to identify the effect of each parameter on the groundwater. Since there are no extreme outliers in the data, and shows normally distributed, the study used Paired sample[22] *T*-test for the dry and wet seasons to identify the seasonal variation of the analyzed parameter. At 95 % CI, 5% of margin error with degree of freedom (n−1) = 16. The $P < .05$ value indicates statistically significant variation observed in the dry and wet seasons for selected parameters. The sample size for this analysis is very small, but this can not thwart to analyze the data with t-test.[22]

Exposure to metals and health risk assessment

Hazard Quotient (H.Q.) is determined for each parameter separately, however, Hazard Index (H.I.) is the sum of Hazard Quotient to calculate for the potential human health risk due to exposure of metals. The potential ingestion risks were calculated for 2 population subgroups, that is, adults and children. The equations used for estimating the daily intake of water and H.Q. are as follows:

$$\text{DailyIntake} = \frac{c\left(\textit{mean metal concentration}\right)\times IR\left(\textit{Daily water intake}\right) \times EF\left(\textit{Exposure frequency}\right)\times ED\left(\textit{Exposure duration}\right)^{8,23}}{BW\left(\textit{Bodyweight}\right)\times AT\left(\textit{Average time}\right)}$$

$$\text{HAZARD QUOTIENT}\ \left(HQ\right) = \frac{\textit{Daily Intake}^{8,23}}{RfD\left(\text{reference dose}\right)}$$

The average adult and children's body weights were 55.9 and 32.7 kg, respectively.[23]

To assess the overall potential health risk for the HHRs posed by more than one metal, the H.Q. calculated for each metal was summed and expressed as a hazard index (H.I.): $H.I. = HQ1 + HQ2 \cdots + HQ_n$. [24]: The individual metal toxicity responses (dose-response) are 5.0×10^{-4} for Cd, 3.0×10^{-3} for Cr, 3.5×10^{-3} for Pb, 1.4×0^{-2} for Mn, 7.0×10^{-1} for Fe, 3.0×10^{-1} for Zn, and 4.2×10^{-2} for Cu all in mg/kg/day as the Oral Reference Dose (R_fD)[25,26] (Table 1).

The health risk assessment is differentiated between the cariogenic and noncarcinogenic hazards of health and is based on the analysis of the risk level of each contaminant.[26] The health risk is calculated with the help of a hazard quotient (H.Q.), which requires the Chronic Daily intake (CDI) and U.S. EPA reference dose (RfD).[25] According to the U.S. EPA guideline of carcinogenic risk assessment, 2005, it is calculated as:

The hazard quotient (HQ) is used to calculate the risk of non-carcinogenic effects by assuming that the total sum of exposures is equal to the number of negative impacts caused by the metals.[27] The high HI value indicates the long-term non-carcinogenic effects.[28]

Where THQ is the total hazard quotient, and H.Q. is the hazard quotient of the single parameters. There is no negative impact expected from the element if the value of HQ is less than 1. Here, we calculated the risk assessment for 2 seasons, wet and dry, in the adult and the child.

Results

Physicochemical parameters seasonal variation of groundwater sources

In this study, seasonal differences were observed in almost all of the selected parameters, but some parameters did not indicate significant variation. Some of them were pH, electrical conductivity, turbidity, chloride, total hardness, calcium hardness, magnesium, and copper, while most of the analyzed physicochemical and metal parameters were observed to have significant seasonal discrepancies (*t*-test, $P < .05$). The recorded value indicated in the dry and wet seasons for the Potassium (53%, 41%), Iron (88.5%, 23.5%), fluoride (47.1%, 5%), and Phosphate (100%, 100%) of sampled groundwater sources respectively.

In the dry and wet seasons, the mean Electrical Conductivity (EC µmho/cm) was recorded to be 462.294 ± 165.392 and 337.412 ± 203.876, respectively. The mean of the total dissolved solids (TDS) was recorded to be 233.129 ± 84.166 and 168.941 ± 101.986 in the dry and wet seasons, respectively (Table 2).

The physico-chemical parameters results of the dry and wet season metal correlation analyses are presented in Tables 3 and 4. A strong significant positive relationship for Na, K, and Ca was observed with total alkalinity, plus Ca and Mg with total hardness during the dry and wet season.

The results presented in Tables 5 and 6 indicate the hazard quotients of metal ingestion with groundwater. The Total Hazard Quotient (THQ) for adults ranged between 7.2677 × 10-4and 0.1693 and 0 to 0.0256 in the wet and dry season, respectively.

Discussion

Seasonal variation in physicochemical parameters

The result revealed in (Table 2) indicates that the mean PH was found to be 6.906 ± 0.745 and 7.224 ± 0.460 during the dry and wet seasons, respectively. The values fall within the normal range of the national and WHO standards[29] showing almost neutral during the dry season and above the standard during the wet season.[4,29] If $_{P}$H is higher than the standard limit of WHO, it might endanger human health, mostly caused in the mouth, nose, eye, anus, and abdomen.[30,31] These findings were un-like with the finding in Tigray, Addis Ababa, Amhara, Afar, and Oromoia regions which showed a PH value of 9.7 and 11.80, 10.35, 9.0, and 9.1, respectively.[14] The result variations in the country might be observed due to the source of water and geographic differences of samples. A result from different studies in the region like Jimma[32] and Arsi zones[16] have shown the electrical conductivity of water sources was in the range of 621 to 627.33 and 46.42 to 366.93 respectively in various water sources like tap water, protected wells, unprotected wells, protected spring, and unprotected springs in the region.

As indicated in Table 2, the mean TDS (mg/L) value for the dry season was higher than the wet season, but it is tranquil in the normal standard limit of WHO. This shows that any source of drinking water containing a TDS value of more than 500 mg/L may induce an unfavorable physiological reaction in the transient consumer and lead to irritation, fluorosis, and gastrointestinal infections in the long run.[8] Likewise, Total Alkalinity, Total Chlorine, Total Hardness, Ammonium, Sodium, Calcium, Magnesium, Iron, Manganese, Fluoride, Nitrite, Nitrate, and Sulfate showed significant seasonal variations (*t*-test, $P < .05$). The calculated means of these selected parameters were under the permissible limit of the WHO and the Ethiopian standard.[29] The cause of the seasonal variation was due to the intensive use of agricultural products like nitrogen (N), phosphate (P), and potassium (K) in ***rural areas.***[31] Lower Mg causes structural and functional changes in human beings.[33] This could lead to a higher non-carcinogenic health risk for a child than Adults.[34] However, the recorded value indicated for the Potassium (53%, 41%), Iron (88.5%, 23.5%), fluoride (47.1%, 5%), and Phosphate (100%, 100%) of sampled groundwater sources were over the permissible limit of the WHO and Ethiopian standard in both the dry and wet seasons respectively. These values were recorded to be lower than a study done in the southwest of the country for groundwater sources in both the dry and wet seasons.[10] In addition, the highest amount of fluoride (5 mg/L) recorded in the area may expose the community to mild dental fluorosis or even crippling skeletal fluorosis as the level and period of exposure increases according to the WHO standards.[29,35] Potassium (K^+) helps to balance the fluids ***in the human body***[31]. The higher value of potassium content in the drinking water causes nervous and digestive disorders.[36]

A 4.01 mg/L of iron was recorded at point sources in both dry and wet seasons showing higher than the WHO recommended limits.[29] This result was found to be similar to a study done on groundwater from the Metu area.[37] The possible reason for high iron content in the area might be the infiltration of the adjacent groundwater sources with iron content released from industries and small factories. A high concentration of iron can change the taste and color of the water, causes

Table 2. Statistical summary of Physicochemical and metals water quality parameters with the comparison to (WHO, 2011) and Ethiopian Standard (2001) value at the dry and wet seasons of Sebeta groundwater sources.

PARAMETER	DRY SEASON			WET SEASON			*T*-VALUE	*P*-VALUE	ES (2001) MAXIMUM PERMISSIBLE LEVEL	WHO PERMISSIBLE LIMITS MG/L
	RANGE		MEAN ± SD	RANGE		MEAN SD				
	L	H		L	H					
PH	5.500	8.000	6.906 ± 0.745	6.40	7.90	7.224 ± 0.460	−2.149	.047	6.5-8.5	6.5-8.5
Temperature	20.300	35.200	24.500 ± 4.267	21.10	26.20	22.982 ± 1.404	13.087	*P* < .001*	30°C	30°C
EC, µS/cm	223.000	894.000	462.294 ± 165.392	108.00	787.00	337.412 ± 203.876	3.217	.005*	-	400 µS/cm
TDS	111.500	451.500	233.129 ± 84.166	54.00	394.00	168.941 ± 101.986	3.327	.004*	1000	1000
Turbidity	4.000	25.000	13.294 ± 6.372	6.00	28.00	15 ± 7.089	−.675	.509	-	0.2 NTU
Total chlorine	0.010	0.100	0.047 ± 0.025	0.00	0.06	0.031 ± 0.019	2.297	.035*	0.5 mg/L	0.5mg/L
Total Hardness	15.000	200.000	79.765 ± 62.084	20.00	160.00	68.271 ± 42.314	1.874	.079	300 mg/L	200 mg/L
Calcium Hardness	5.000	150.000	49.412 ± 39.494	10.00	115.00	45.765 ± 31.740	1.129	.276	60-120	200 mg/L
Magnesium Hardness	10.000	60.000	23.765 ± 12.823	5.60	50.00	22.506 ± 11.957	0.755	.461	50 mg/L	<30 mg/L
Total Alkalinity	29.000	450.000	209.647 ± 113.519	15.00	305.00	160.882 ± 82.201	3.824	.001*	200 mg/L	600 mg/L
Bicarbonate alkalinity	25.000	325.000	185.177 ± 87.907	15.00	305.00	160.882 ± 82.201	3.203	.006*		
NH3	0.190	0.650	0.359 ± 0.109	0.09	0.57	0.285 ± 0.103	3.068	.007*		
Ammonium	0.210	0.940	0.579 ± 0.21	0.11	0.74	0.367 ± 0.134	5.143	*P* < .001*		0.2
Sodium	22.000	150.000	54.718 ± 30.510	0.00	126.40	41.735 ± 32.710	5.672	*P* < .001*	200	200
Potassium	4.000	29.000	14.706 ± 7.556	3.40	15.00	9.094 ± 3.199	4.144	.001*	1.5	1.2
Calcium	10.000	59.000	29.353 ± 14.718	4.00	46.00	18.306 ± 12.696	4.406	*P* < .001*	75	75

(Continued)

Table 2. (Continued)

PARAMETER	DRY SEASON			WET SEASON			*T*-VALUE	*P*-VALUE	ES (2001) MAXIMUM PERMISSIBLE LEVEL	WHO PERMISSIBLE LIMITS MG/L
	RANGE		MEAN ± SD	RANGE		MEAN SD				
	L	H		L	H					
Magnesium	3.000	15.700	7.747 ± 3.638	0.00	12.20	5.029 ± 3.319	−6.951	*P* < .001*	50	50
Iron	0.070	4.010	1.291 ± 1.096	0.00	0.61	0.195 ± 0.183	4.151	.001*	0.3	0.3
Copper	0.010	0.770	0.137 ± 0.215	0.00	0.07	0.032 ± 0.022	1.905	.075	0.05	0.05
Manganese	0.000	0.098	0.041 ± 0.034	0.00	0.00	0.000 ± 0.000	5.011	*P* < .001*	0.5	0.1
Chromium	0.011	0.055	0.028 ± 0.013	0.01	0.03	0.016 ± 0.006	3.263	.005*	0.05	0.05
Chloride	1.400	6.000	3.565 ± 1.028	1.00	25.00	3.753 ± 5.575	−.141	.890	250	250
Fluoride	0.400	5.000	1.554 ± 1.118	0.12	2.13	0.807 ± 0.475	2.939	.010*	1.5	1
Nitrite	0.010	3.400	1.494 ± 1.083	0.00	2.68	0.270 ± 0.736	4.005	.001*	3	3
Nitrate	3.400	17.500	9.765 ± 3.838	4.00	15.80	8.177 ± 3.382	2.295	.036*	50	45
Sulfate	2.000	19.000	7.647 ± 5.338	0.00	16.00	2.412 ± 3.906	3.394	.004*	250	200
Phosphate	0.889	1.980	1.378 ± 0.366621	0.100	1.850	0.710 ± 0.372	6.335	*P* < .001*	0.1	0.1
Bicarbonate	116.000	372.000	218 ± 82.808	0.00	372.00	178.588 ± 119.341	2.050	.057	-	-
Zinc	0.010	0.700	0.222 ± 0.241	0.00	0.44	0.106 ± 0.116	1.959	.068	-	5.0
Lead	0.000	0.005	0.002 ± 0.002	0.00	0.01	0.001 ± 0.002	0.457	.653	-	0.01

Table 3. Correlation matrix of the physicochemical parameters and metals during the dry season.

	P^{H}	T^{O}	CDT	TDS	TURB	THARD	TALK	NH_4	NA	K	CA	MG	FE	CU	MN	CR	CL	F	NO_3	HNO_3	SO_4	PO_4	HCO_3	ZN	PB
P.H.	1																								
T^{O}	.222	1																							
CDT	.032	–.294	1																						
TDS	.014	–.293	.999**	1																					
TURB	–.187	–.152	.011	.032	1																				
HARD	.179	.386	–.093	–.087	–.096	1																			
TALK	.063	.545*	–.054	–.046	.314	.382	1																		
NH4	–.280	.043	–.119	–.120	.165	.197	.103	1																	
Na	–.295	.227	–.003	.010	.182	.093	.745**	–.050	1																
K	.257	.509*	–.040	–.054	.008	.062	.695**	.249	.560	1															
Ca	–.067	.448	–.091	–.075	.085	.741**	.641*	.182	.548	.339	1														
Mg	.127	.244	–.289	–.290	–.122	.846**	.083	.193	–.103	–.093	.468	1													
Fe	–.017	.607**	–.025	–.034	.047	.159	.366	.499	–.061	.421	.170	.059	1												
Cu	.332	–.087	.102	.093	.220	.135	.197	–.296	.109	.085	–.187	.320	–.214	1											
Mn	–.321	.244	.059	.060	.222	–.244	.496	.036	.452	.384	.010	–.450	.440	.020	1										
Cr	.704**	–.033	.163	.154	.064	–.120	–.098	–.627	–.116	.010	–.244	–.075	–.331	.451	–.275	1									
Cl	.093	–.110	–.181	–.180	.351	–.351	.057	–.059	.171	.211	.090	–.317	–.091	–.171	.104	.282	1								
F	.211	–.134	.000	–.011	–.322	–.019	–.152	.297	–.151	.241	–.126	–.055	–.212	–.051	–.130	–.177	–.048	1							
NO_2^-	–.070	.532*	–.214	–.225	–.199	.240	.417	.140	.290	.333	.194	.297	.518**	.248	.393	–.146	–.055	–.212	1						
NO_3^-	–.563*	–.167	.134	.144	.006	.267	.230	.209	.479	.041	.553*	.264	–.013	–.097	.033	–.554	–.022	–.165	.151	1					
SO_4^-	–.286	.278	.158	.160	.183	.100	.423	.710**	.278	.408	.259	–.020	.699*	–.120	.481	–.562	–.090	–.044	.412	.357	1				
PO_4	–.190	.505*	–.187	–.182	.131	–.002	.492	–.003	.255	.253	.076	–.033	.520*	.170	.658	–.317	–.077	–.148	.515*	.068	.403	1			
HCO_3^-	–.021	.261	.003	.013	.036	.706**	.729**	.144	.715**	.451	.808**	.452	–.044	.175	.066	–.139	–.121	.058	.231	.469	.188	.050	1		
Zn	.242	–.229	–.172	–.159	.574*	.145	.124	.076	.089	–.103	.208	.194	–.302	.240	–.295	.371	.552*	–.169	–.137	–.038	–.066	–.281	.184	1	
Pb	–.549*	.150	–.030	–.019	.319	–.356	.214	.089	.489	.234	.086	–.212	.077	–.018	.250	–.303	.170	–.244	.181	.420	.342	.272	–.017	–.065	1

**Correlation is significant at the .01 level (2 tailed).
*Correlation is significant at the .05 level (2 tailed).

Table 4. Correlation matrix of the physicochemical parameters and metals during the wet season.

	P^H	T^O	CDT	TDS	TURB	THARD	TALK	NH_4	NA	K	CA	MG	FE	CU	MN	CR	CL	F	NO_3	HNO_3	SO_4	PO_4	HCO_3	ZN	PB
P.H.	1																								
T^O	–.171	1																							
CDT	.343	–.273	1																						
TDS	.343	–.274	1.000	1																					
TURB	.306	–.067	–.005	–.004	1																				
tHARD	.037	–.214	.175	.173	.237	1																			
TALK	–.006	.368	–.052	–.054	.097	.430	1																		
NH4	–.577	–.050	–.003	–.003	–.343	–.015	–.348	1																	
Na	–.258	.520*	–.060	–.060	.030	.105	.833**	–.113	1																
K	.043	.537*	–.296	–.297	.124	.298	.791**	–.153	.692**	1															
Ca	.077	–.194	.230	.229	.181	.988**	.461	–.026	.129	.289	1														
Mg	–.189	–.141	.099	.098	.311	.856**	.342	.096	.204	.268	.805**	1													
Fe	–.670	.473	–.346	–.348	–.392	.177	.292	.322	.390	.338	.168	.306	1												
Cu	.157	–.166	–.181	–.180	.137	–.311	–.589*	.206	–.522*	–.248	–.332	–.404	–.430	1											
Mn															1										
Cr	.500*	.038	–.010	–.010	.424	–.057	–.194	–.185	–.420	.003	–.047	–.325	–.480	.648**	.	1									
Cl	–.264	.326	–.320	–.319	–.066	–.314	.385	.051	.646	.503	–.310	–.250	.132	–.096	.	–.249	1								
F	.140	.054	.086	.087	–.308	–.373	.062	.131	.012	.185	–.322	–.489	–.297	.158	.	.173	.371	1							
NO_2^-	–.237	–.308	–.019	–.018	.256	.164	–.456	.669**	–.318	–.222	.106	.309	–.079	.283	.	.051	–.115	–.082	1						
NO_3-	–.469	.223	–.393	–.393	.116	.250	.492*	.340	.629**	.563*	.250	.344	.490*	–.171	.	–.214	.587*	–.105	–.469	1					
SO4	–.113	–.099	.270	.269	–.282	.503*	.569*	.150	.465	.275	.553*	.329	.147	–.360	.	–.234	.100	–.057	–.135	.388	1				
PO4	–.475	.154	–.249	–.249	.060	.262	.353	.153	.200	.221	.244	.163	.337	–.231	.	–.038	.118	.054	–.082	.300	.146	1			
HCO3	–.171	.378	.041	.040	.147	.472	.911**	–.237	.900**	.665**	.494	.525	.403	–.650**	.	–.404	.343	–.194	–.332	.566*	.557*	.272	1		
Zn	.090	–.043	–.155	–.154	.508*	.202	–.119	.279	–.083	.198	.155	.300	.014	.428	.	.331	–.179	–.291	.436	.361	–.140	.024	–.035	1	
Pb	–.658**	.256	–.301	–.302	–.250	.021	.142	.470	.318	.175	–.009	.208	.804**	–.180	.	–.386	.112	–.302	.048	.488	.149	.232	.256	.219	1

**Correlation is significant at the .01 level (2 tailed).
*Correlation is significant at the .05 level (2 tailed).

Table 5. Non-carcinogenic health risk assessment by Hazard Quotient analysis for metals in groundwater in the dry season.

METALS	MEAN OF METAL CONCENTRATION	REFERENCE	CHRONIC DAILY INTAKE	HQ ADULT	HQ CHILD
Mn	0.0411	0.1	0.0016	0.0162	0.0226
Cu	1.129	0.04	0.0444	1.1108	1.5537
Lead	0.0016	0.014	6.2969E-05	0.0045	0.0063
Zinc	0.222	0.3	0.0087	0.0291	0.0407
Chromium	0.0277	1.5	0.0011	0.0007	0.0010
Iron	1.290588	0.3	0.0508	0.1693	0.2368
HI (THQ)				1.3307	1.8611

Table 6. Non-carcinogenic health risk assessment by Hazard Quotient analysis for metals in groundwater in the wet season.

METALS	METAL CONCENTRATION	REFERENCE	CHRONIC DAILY INTAKE	HQ ADULT	HQ CHILD
Mn	0	0.1	0	0	0
Cu	0.0317	0.04	0.0013	0.0312	0.0436
Lead	0.0014	0.014	5.5098E-05	0.0039	0.0055
Zinc	0.1055	0.3	0.0046	0.0138	0.0194
Chromium	0.0163	1.5	0.0006	0.0004	0.0006
Iron	0.1950	0.3	0.0077	0.0256	0.0358
HI (THQ)				**0.0750**	**0.1049**

corrosion of the plumbing systems, and ultimately lead to liver disease. However, if the concentration also becomes low, the people might be highly susceptible to anemia.[38,39]

The mean value for Phosphate was recorded as 1.378 ± 0.367 mg/L and 0.710 ± 0.372 mg/L in the dry and wet seasons respectively showing higher than the WHO standard limit.[4,29] These values were also higher than a study done in another part of Ethiopia, showing 0.05, 0.04, and 0.06 mg/L in spring, tap, and well water.[14] The highest elevation in the concentration of phosphate might be due to the contact with natural minerals or pollution from the uncontrolled application of fertilizer as the area is highly prone to farming in large or untreated sewage and direct industrial waste disposal in the area.

The results in Table 2 indicate that during the dry season, the mean concentrations of Manganese, Lead, Zinc, and Chromium were within the permissible limits set by the WHO. However, the range of chromium and iron was higher than the WHO permissible limits. In this study, about 5% of the sampled groundwater source have exceeded the permissible limit of WHO. Long-term exposure to total chromium leads to carcinogenic effects in the gastrointestinal tract and lungs depending on the route site of the human body.[29,40] This finding was similar to a study done in Sabata showed that the Pb and Mn in the upstream part of the Sabata river were within the standard limit of the WHO, however, the downstream region showed elevated Cu, Pb, Mn, and Zn in the dry season.[41]

Similarly, studies in Ghana,[42] India,[36] Bangladesh[43] showed elevated concentrations of Cu, Mn, Zn, and Pb, in drinking water around an industry region. Rivers and ponds are affected by the emancipation of untreated toxic waste products from industries; likewise, groundwater might be contaminated through similar circumstances. This result is supported by a study in Ethiopia (Mojo), demonstrating higher Pb, Zn, and Cu concentrations above the reference level for agricultural soil.[44] The elevated concentration of Cu causes several genetic disorders associated with Menkes syndrome (a deficiency disorder) and Wilson disease (a toxicity disorder).[29]

Non-carcinogenic health risk analysis with the consumption of Metals (H.Q. ingestions)

The highest HQ was recorded to be 1.1108 and 1.5537 for copper respectively, for adult and children groups in the dry season exclusively. The current study values were found to be higher than a study conducted on a water sample from a Hand-dug well in Nigeria.[45] Another study in India indicates, the unacceptable non-carcinogenic risk for children caused by copper.[40] The results revealed the HQ value of indicated parameters was lower than the global standard, which means lower risk for human health individually. But with the aggregation of other metals, the hazard index (HI) shows that greater than one.

Based on the HQ values, the order of the metals in the dry season was Fe>Cu>Zn>Mn>Pb>Cr. On the other hand, the wet season was Cu>Fe>Zn>Pb>Cr>Mn. However, the HI in the wet season was <1, which did not exceed the recommended limit. This finding was similar to an Indian study, during the post-monsoon period, and no risk was observed for both adults and children for all the selected metals except for Pb and Cd.[8]

In the child category, the range of HQ was found to be between 0.2368 and 1.5537 for the dry season, 0 and $4.3623 \times 10\text{-}2$ in the wet seasons. The findings indicated that the HQ value was higher for children, and subsequently, children were more vulnerable to health risks according to standard recommendations of WHO. The non-cancer HI values in Tables 5 and 6 indicated that higher HI values were observed in the dry season than the wet season for both categories, and these were beyond the recommended level. This study finding was similar to drinking water in India. The non-cancer risk (HQ) of Pb and Cd exposure to the adults via a dietary intake of groundwater is 6.44E-01 during the pre-monsoon period.[8] Children are more vulnerable to metal exposure via drinking groundwater than adults, leading to several pediatric effects, including neurodevelopmental disorders,[46] rapid bone growth, and differences in physiology, even at low levels of exposure.[47]

Correlation analysis of the physico-chemical parameters and metals in groundwater

pH showed a significant negative relationship with lead and nitrite, while a strong positive relationship was observed with chromium during the wet and dry seasons. Various studies indicate that the strong relationship of Cr might be due to the presence of the leading industries in the study area, including textiles, electroplating/galvanizing, dyes, pesticide formulations, induction/foundries, etc. Disposal from these industries may contribute to Cr in the groundwater.[8,48]

Limitations and Further Directions

The water sources mainly focus on groundwater, it is better to include other water sources like wells, tap water, rivers. The seasonal variation will be better off with a large sample size (source of groundwater) to indicate in the *t*-test analysis. This limits the power of the seasonal variation indications.

Conclusion

The physicochemical quality of Borehole drinking water sources is well in compliance with the WHO standard. It is safe for drinking purposes. However, Potassium, Iron, fluoride, and Phosphate of most sampled groundwater sources were above the permissible limit of the WHO. Based on the Borehole drinking water samples from the Sebeta Special Zone, the water sources have slightly salty. The risk indices calculated for metals in the dry season were not harmful to adults and children if the HQ_{cu} was more than 1. However, in the wet season, the H.Q. was lower than 1, indicating no potential carcinogenic risk. The HQ was higher than the permissible limit during the dry season, indicating a negative impact, whereas the HQ had no negative impact in the wet season. In conclusion, the water needs some treatment before consumption during the dry seasons.

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Institutional Review Board Statement

Ethical clearance was obtained from the Institutional Review Committee of the Addis Abebe medical and Business College and University, Ethiopia. Permission letter obtained from the Sebeta Zone water and Minerals Authority.

Data Availability Statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Supplemental Material

Supplemental material for this article is available online.

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