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Effect of Seasonal Variation on the Levels of Heavy Metals and Physicochemical Parameters of Borehole Water in Woreillu Town, Amhara

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Abstract

People on the globe are under tremendous threat due to undesired changes in the physical, chemical and biological characteristics of air, water and soil. Due to increased human population, industrialization, excess use of fertilizers and other man made activities; water is highly polluted with different harmful contaminants. During the investigation of heavy metals and physicochemical parameters of borehole water in Woreilu town was analyzed to determine the water quality seasonally. Some physicochemical parameters such as temperature, pH, Conductivity, Turbidity, TDS, Alkalinity, Hardness, nitrate, sulphate, phosphate and heavy metal such as Zinc, Lead, cadmium, chromium, manganese, copper and Iron were evaluated using standard methods and ICP-OES respectively. Most of the parameters analysed were within the WHO and ES guideline limits for potable water. From the results, temperature varied between 11.17-15.67°C, total dissolved solids 2190-135 mg/L, turbidity 1.3-7 NTU, Electrical conductivity 0.28-0.37 μS/cm, pH 7.6-8.21, total hardness 142-264 mg/L, alkalinity 120-180 mg/L, nitrate 0.176-0.231 mg/L, phosphate 0.06-0.73 mg/L, Sulphate 2.7-22.87 mg/L and Heavy metals such as Fe varied between 0.123-0.642 mg/L, Cu 0.03-0.212 mg/L, Pb 0.009-0.098 mg/L, Mn 0.022-0.161 mg/L, Zn 0.144-1.227 mg/L but Cd and Cr were below detection limit in all the sampling sites. All the parameters analysed were influenced by seasonal variations. There was a general increase in all the parameters during the wet season but temperature, TDS and zinc were higher during the dry season. However, all the sampled boreholes showed high concentration of Pb which were above WHO and ES drinking water standards during the dry and wet seasons and turbidity showed high concentration above the permissible limits at Jegola site in both seasons.

The results suggest that groundwater from Woreillu town boreholes need to be treated so that the water could meet WHO (2012) and ES (2011) drinking water standards. Plain sedimentation or use of cloth/membrane filters may remove turbidity while nanofiltration could be used to remove heavy metals such as lead.

Keywords: Borehole water • Physico-chemical parameters • Heavy metals • ICP-OES

Introduction

The quality of water over the decade had been described by the colorless, odorless, tasteless and its transparent character. It is a basic resource necessary for sustaining all human activities, so its provision in desired quantity and quality is of utmost importance [1]. The two major sources of freshwater are the surface water and groundwater. The groundwater provides a valued fresh water resource to human population and constitutes about two-third of the fresh water reserves presently occupying various spaces across the world [2]. The deterioration of water quality has led to the destruction of ecosystem balance, contamination of soil and surface water sources [3].

The physical, chemical, and biological parameters were often used to determine the safety of water required for consumption [4]. Most developing and underdeveloped economy is faced with the challenge of lack of adequate, clean and safe water supply infrastructures. Ethiopia, as a developing country is also striving hard to supply potable drinking water especially in rural areas where most people depend on ground and surface water for sustenance. Over the years the Ethiopian government had put in place policies that could encourage the priority for the provision of safe, clean and adequate water especially in the rural areas; however the implementation of such policies was overwhelmed by the inadequacies of implementation of such policies. Groundwater is often the first alternative choice of many consumers due to its perceived cleanness and safeness. However, many studies have shown that groundwater can appear clean but contains a wide variety of contaminants [5,6]. According to world health organization, an estimated 80% of all diseases and over one-third of deaths in developing countries are caused by the consumption of contaminated water and on average as much as one-tenth of each person's productive time is sacrificed to water related diseases. Groundwater contamination occurs when pollutants are released and make their way down into the ground [2]. Main sources of groundwater contamination are from mine dumps, agricultural products, leach residue, landfills, leaking septic tanks, oil spillage, acid rain and host rock in which it is dug. Hence, the location of a borehole yet to be drilled should be well assessed in other to avoid water pollution that can pose as a threat to human lives. Contaminants such as heavy metals, lead, arsenic, chromium, cadmium and mercury are dangerous for human health when consumed at high concentration because they are toxic and can be carcinogenic [7,8]. Owing to changes in environmental factors, a continuous water quality assessment should be carried out for provision of necessary information on the water quality and its suitability for domestic use. The objective of this paper is to assess the quality of water obtained for domestic consumption in Woreillu town Amhara Region, North West Ethiopia by evaluating the physicochemical properties and heavy metal contents and examines the influence of seasonal variation on the physicochemical and heavy metal qualities of water from boreholes in this area.

Materials and Methods

Description of the Study Area

Woreilu is one of the 24 administrative districts in South Wollo Zone of Amhara Region, Ethiopia. It is located at 36° 26′ 0″–39° 43′ 0″ E longitude and 10° 34′ 0″–10° 60′ 0 ″ N latitude and 492 km far from Addis Ababa, Ethiopia, 571 km from Bahir Dar, capital city of Amhara Region, as well as 91 km from Dessie, West of Zonal Town. As of 2007 Ethiopia census, Woreilu town had a Population of 14,817 and 71013 hectare total area. According to the Agricultural and Rural Development office of the Woreda, agro-ecologically, the Woreda is classified as "Dega" which accounts 82% while the remaining 18% is "Woina Dega". From the total number of 23 kebeles administrations 20 are rural [9]. In the Woreda, most Kebeles produce crops in "Meher" season, six kebeles in both seasons and only one kebele in "Belg" seasons. The agro-climatic conditions of the Woreda ranged from moderate to high, with an average altitude of 2730 m above sea level. Annual rainfall ranges from 766.2 to 1250 mm which is usually inadequate (short in duration), poorly distributed and highly variable in inter and intra seasons [9].

Water Point Sources

Woreillu town drinking water supply comes from ten water point sources but only five water point sources were purposely selected for this study. The two borehole water sources are located in the northwest; one borehole water sources are located in the southwest, one in the East and one in the West directions of the town (Table 1).The coordinates of all sampling points were taken using Handheld Global Positioning System

(GPS) (Model N20230 etrex Garmin).

Research Design

Field survey design was employed and accompanied by laboratory tests which were used in determining the levels of physico-chemical parameters, heavy metals of borehole water and in assessing the effects of seasonal variation on the levels of the physico-chemical parameters and heavy metals of borehole water in the study area. Purposive sampling method was employed to sample the sites under study.

Sample Size and Sampling Procedure

In the study area, there exist ten functional hand-pumped operated boreholes and five functional boreholes were purposely selected. Sampling was done in two seasons; during the dry and wet seasons in order to determine the effects of seasonal variation on the levels of physico-chemical parameters and heavy metals of borehole water. The dry season sample collection was done in the month of March, 2019 when the daily average precipitation for the month was 4mm while the wet season sample collection was done in the month of July, 2019 when the daily average precipitation for the month was 50 mm. Sampling was carried out in the morning hours between 6.30 am to 9.00 am when the residents were fetching water. Borehole water was collected in two litre plastic sample bottles which had been soaked in dilute hydrochloric acid and rinsed twice with distilled water. On the site, the bottles were rinsed three times using the respective well water before collecting the samples. Water samples were collected from the shallow wells through a borehole nozzle.

Each two litre water sample collected from each sampling site was then divided into two equal portions; a portion for the physico-chemical analysis and the other for the analysis of dissolved heavy metals. One portion was first filtered using Whatman No 1 filter paper in to a 1000 mL pre-cleaned polyethylene bottle, and acidified by adding two mL of concentrated HNO_3 to minimize precipitation and adsorption on the container walls and was then stored in a refrigerator until analysis [10]. The other portion of the water sample was used for the determination of physico-chemical parameters without any pre-treatment (Figure 1).

Determination of Physico-chemical Properties

Temperature, pH, electrical conductivity, turbidity and total dissolved solids were determined immediately using Jelway multi - purpose portable meter model 430, while other physico-chemical parameters such as total hardness, alkalinity, nitrate, phosphate and sulphate were also analyzed using standard method of water examinations [11].

Determination of Heavy Metals

The heavy metals Pb, Cd, Cr, Zn, Mn, Fe, and Cu were determined by inductively coupled plasma optical emission spectrometry (ICP-OES) as described by APHA [12]. The water sample was thoroughly mixed by shaking and one hundred milliliters of it were introduced into a 250 mL beaker. The sample was digested with concentrated nitric acid and thereafter filtered into a sample bottle. The water sample was aspirated into the oxidizing air-Argon flame. When the aqueous sample was aspirated, the absorbance was read using the PerkinElmer Avio® 500 ICP-OES and the value was recorded.

Statistical analysis

Statistical analysis was performed by SPSS version 16.0 to calculate average mean, standard deviation, and Pearson's correlation (r) value to show the degree of physicochemical and metal association in borehole water. The ANOVA test (level of significance $\alpha = 0.05$) was employed to understand the spatial and seasonal variation in the physico-chemical and heavy metal concentrations.

Results

Determination of Physico-chemical Parameters

It is known that the physicochemical contents of the water determine the quality of water. Therefore, water quality guidelines like World Health Organization (WHO), European Union (EU), United States Environmental Protection Agency (USEPA) and Ethiopian standard (ES) provides basic information about water quality parameters and ecological relevant toxicology threshold values to protect specific water uses. The mean values of the physico-chemical properties of groundwater during the dry and wet season are shown in Tables 2 and 3 respectively.

In the present study, the water temperature ranged from 11.33°C to 15.67°C in dry season and 11.17°C to 14.10°C in wet season. The temperatures were comparatively higher during the dry and lower in the wet season (Tables 2 and 3). The result of one way ANOVA revealed that the mean values of temperature show significant differences ($p<0.05$) among Mume, Abazinab, Konteb and Agamti but there was no significant differences ($p>0.05$) between Mume and Jegola in the dry season. Moreover, Mume, Abazinab and Jegola did not show significant differences in the wet season. This change was due to seasonal variation which could be attributed to warming or cooling at the earth's surface or introduction of cold water from the surface during high recharge time periods as it rains [13] . The temperature of the borehole water samples collected varied depending on the time of collection and seasonal variation as the lowest values in the morning hours [14]. This was in line with who argues that the variation in the water temperature influenced by time of sample collection and season, hence timing also could have contributed to the variation in the water temperature. High temperature increases chemical

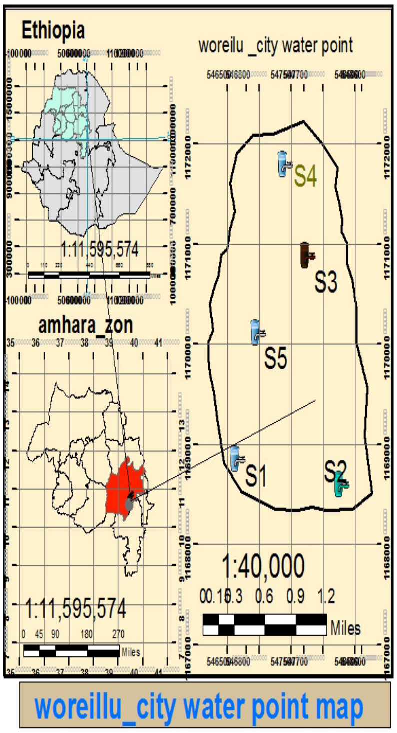

Figure 1. Map showing the distributions of the various sampling locations
Source: Adopted and modified from administrative map of Woreillu woreda

Table 1: Sampling locations and their respective point co-ordinates

Sample number	Point coordinates						Sample locations	Designation
	Latitude			Longitude				
	Degree	Minute	Second	Degree	Minute	Second		
1	10	34	21.6	39	25	35.2	Mume	S1
2	10	34	13.4	39	26	28.4	Abazinab	S2
3	10	35	27.9	39	26	10.9	Konteb	S3
4	10	36	56.9	39	25	47.2	Jegola	S4
5	10	35	2.7	39	25	45.9	Agamti	S5

reactions in the aquifer such as weathering of rocks which leads to the release of the chemical contaminants in water and reduces the level of dissolved gases in water [15].

The mean pH for the entire dry season ranged from 7.6-8.0 with the highest of 8.0 recorded at Agamti and the lowest of 7.6 at Jegola (Table 2). In the wet season, mean pH also ranged from 7.07 -8.21 (Table 3). The highest pH of 8.21 was also recorded at Agamti and the lowest of 7.07 at Jegola. pH for all the samples in both the dry and wet seasons were mildly alkaline.

One way ANOVA analysis performed at $p < 0.05$ showed significant difference between Mume and Abazinab,Mume and Konteb, Mume and Agamti, Abazinab and Jegola, Konteb and Jegola, Agamti and Jegola but there were no significance differences between Mume and Jegola, and among Abazinab, Konteb and Agamti in the dry season. Besides, there were no significant differences between Abazinab and Agamti in the wet season. However, all the sites were within the ES (2011) and WHO (2012) standards both in the dry and wet seasons.

Higher pH values during wet season could be due to discharges of waste into the water and also due to microbial decomposition of organic matter. The observed variation in pH of groundwater samples may be attributed to the differences in the geological materials and chemistry of the groundwater. Similar results were obtained by [16], in Oromia region, Ethiopia, which is basic in nature pH generally, plays an important role in metal bioavailability, toxicity and leaching capability. Therefore, such pH values in the groundwater could leach metal ions such as iron, manganese, copper, lead, and zinc from the aquifer into the water [17].

The Electrical Conductivity of groundwater of Woreillu town varied from 0.28 to 0.34 in the dry season (Table 2) and 0.31 to 0.37 in the wet season (Table 3). The highest value of 0.34 and 0.37µS/cm in Konnteb and Agamti and the lowest value 0.28 and 0.31 µS/cm were recorded at Mume and Jegola respectively. The one way ANOVA analysis at $p < 0.05$ showed significant differences in the mean electrical conductivity concentration levels among the different sampling sites but no significant differences were observed betweeen Abazinab and Agamti in the dry season. In addition, there were no significant differences in the mean electrical conductivity concentration levels between Mume and Jegola and among Abazinab, Konteb and Agamti in the wet season.

The levels EC in the wet season were higher than the levels for the dry season, which could have resulted from the infiltration of ions from the soil, carried by floods as per the results revealed by Dufor et. al. [18]. It signifies the cations and anions level in the water and is a useful tool to evaluate the purity of water. Conductivity is a factor of the total dissolved solids in the water [19]. The values of electrical conductivity depend upon temperature, concentration and types of ions present [13]. Generally, conductivity of clean water is lower but as it moves down the earth, it leaches and dissolves ions from the soil and also picks up organic from biota and detritus [20]. The conductivity values recorded for borehole waters sampled from the town does not pose any potential health risk for consumers. They were all within the acceptable limit prescribed by WHO limits.

Turbidity of the borehole water samples during the dry season varied from 1.3 to 6.1NTU with the lowest recorded at Agamti and the highest at Jegola. Contrastingly, turbidity of the boreholes water samples were higher during the wet season and varied from 2.57 to 7.00 NTU (Table 2 and 3). However, these values fall within the ES and WHO recommended acceptable limits 0.00-5.0 NTU except Jegola, it above the acceptable limits. The high turbidity values above the WHO standard for drinking water may be due to suspended matter such as clay, salt, finely divided organic and inorganic matters, planktons, and microscopic organisms. Detergents and emulsifying agents produce stable colloids that could result in turbidity [21]. The use of turbid water for domestic properties may constitute a health risk because this could stimulate the growth of bacteria and pathogenic microorganisms [22].The results of the mean values of turbidity revealed that there were significant differences ($p<0.05$) among Mume, Jegola and Agamti, Abazinab, Jegola and Agamti, Konteb, Jegola and Agamti, whereas, among Mume, Abazinab and Konteb were found to be not significantly different ($p<0.05$) in both seasons.

The mean levels of turbidity for the wet season were higher than that of the dry season. This could be attributed to a high rate of impurities infiltrating into the shallow groundwater as it rains. Turbidity can provide shelter for opportunistic microorganisms and pathogens in water [13]. Similar study was conducted in Bona district, Simada Zone, southern Ethiopia, out of 6 improved well, one well was reported 11NTU and others resulted <5NT [16]. However, most of the borehole water in the study area is safe for drinking and domestic purposes.

Table 2. The mean value of physico-chemical properties of borehole water (mean± SD; N=3) in the dry season

Physicochemical Parameters	Sampling Sites					ES standards	WHO Standards
	Mume	Abazinab	Konteb	Jegola	Agamti		
Temperature (°C)	$13.93^{a}\pm0.21$	$12.97^{b}\pm0.15$	$11.33^{c}\pm0.29$	$14.03^{a}\pm0.35$	$15.67^{d}\pm0.29$	-	-
P^{H}	$7.7^{a}\pm0.70$	$7.9^{b}\pm0.40$	$7.9^{b}\pm0.10$	$7.6^{a}\pm0.40$	$8.0^{b}\pm0.10$	6.5-8.5	6.5-8.5
EC (µS/cm)	$0.28^{a}\pm0.00$	$0.31^{b}\pm0.01$	$0.34^{c}\pm0.01$	$0.29^{a,b}\pm0.01$	$0.31^{b}\pm0.01$	-	1000
Turbidity(NTU)	$3.6^{a}\pm0.03$	$2.8^{a}\pm0.04$	$3.7^{a}\pm0.11$	$6.1^{b}\pm0.05$	$1.3^{c}\pm0.23$	5	5
TDS (mg/L)	$190^{a}\pm0.00$	$210^{b}\pm0.00$	$235^{c}\pm5.00$	$193^{a,d}\pm5.77$	$205^{b,d}\pm5.00$	1000	1000
TH (mg/L)	$175^{a}\pm0.00$	$260^{b}\pm0.00$	$215^{c}\pm0.00$	$190^{d}\pm0.00$	$142^{e}\pm2.89$	300	500
Alkalinity (mg/L)	$163^{a}\pm2.52$	$120^{b}\pm0.00$	$165^{a}\pm5.00$	$178^{c}\pm2.89$	$132^{d}\pm2.89$	200	200
Nitrate (mg/L)	$0.177^{a}\pm0.00$	$0.182^{b}\pm0.00$	$0.217^{c}\pm0.00$	$0.176^{a}\pm0.002$	$0.168^{d}\pm0.00$	50	50
Phosphate (mg/L)	$0.57^{a}\pm0.01$	$0.216^{b}\pm0.01$	$0.06^{b}\pm0.01$	$0.54^{a}\pm0.01$	$0.20^{b}\pm0.00$	-	5
Sulphate (mg/L)	$20.7^{a}\pm0.58$	$13.7^{b}\pm0.58$	$21.0^{a}\pm0.00$	$5.0^{c}\pm0.00$	$2.7^{d}\pm0.58$	250	250

**Means values followed by the same small letter within the same row are not significantly different at 95% confidence level and ES is Ethiopian standard*

Table 3. The mean value of physicochemical properties of borehole water (mean ± SD; N=3) in the wet season

Physicochemical Parameters	Sampling Sites					ES standards	WHO Standards
	Mume	Abazinab	Konteb	Jegola	Agamti		
Temperature ()	$13.17^{a}\pm0.29$	$12.67^{a}\pm0.29$	$11.17^{b}\pm0.29$	$13.00^{a}\pm0.20$	$14.10^{c}\pm0.26$	-	-
P^{H}	$7.91^{a}\pm0.21$	$8.20^{b}\pm0.01$	$7.98^{a,b}\pm0.03$	$7.07^{c}\pm0.06$	$8.21^{b}\pm0.01$	6.5-8.5	6.5-8.5
EC (µS/Cm)	$0.32^{a}\pm0.01$	$0.35^{b}\pm0.00$	$0.36^{b}\pm0.01$	$0.31^{a}\pm0.01$	$0.37^{b}\pm0.01$	-	1000
Turbidity(NTU)	$4.17^{a}\pm0.12$	$4.67^{a}\pm0.29$	$4.27^{a}\pm0.15$	$7.00^{b}\pm0.17$	$2.57^{c}\pm0.05$	5	5
TDS (mg/L)	$189^{a}\pm0.71$	$209^{b}\pm0.04$	$232^{c}\pm0.00$	$191^{a}\pm1.73$	$203^{d}\pm0.00$	1000	1000
TH (mg/L)	$182^{a}\pm1.73$	$264^{b}\pm1.04$	$217^{c}\pm0.05$	$193^{d}\pm1.15$	$146^{e}\pm3.06$	300	500
Alkalinity (mg/L)	$166^{a}\pm1.15$	$121^{b}\pm1.15$	$173^{c}\pm1.73$	$180^{d}\pm0.00$	$136^{e}\pm1.73$	200	200
Nitrate (mg/L)	$0.185^{a}\pm0.00$	$0.189^{b}\pm0.01$	$0.231^{c}\pm0.01$	$0.193^{d}\pm0.01$	$0.179^{e}\pm0.01$	50	50
Phosphate (mg/L)	$0.73^{a}\pm0.05$	$0.28^{b}\pm0.00$	$0.13^{c}\pm0.01$	$0.57^{d}\pm0.02$	$0.29^{b}\pm0.00$	-	5
Sulphate (mg/L)	$21.87^{a}\pm0.12$	$15.03^{b}\pm0.35$	$22.87^{c}\pm0.23$	$5.90^{d}\pm0.17$	$3.67^{e}\pm0.29$	250	250

**Means values followed by the same small letter within the same row are not significantly different at 95% confidence level*

The mean total dissolved solids concentrations ranged from 190 to 235 mg/L in the dry season and 189 to 232 mg/L in the wet season with the highest values recorded at Konteb and the lowest at Mume (Tables 2 and 3). The total dissolved solids were within the ES and WHO acceptable limits of 1000 mg/L. There were statistically significant differences ($p<0.05$) in the mean concentration of TDS among the sampling sites in the dry season but no statistically significant differences ($p>0.05$) in the mean concentration of TDS between Mume and Jegola in the wet season. The levels were higher during the dry season than the wet season. According to Trivedi et al., the high values during the dry season could be due to concentration of ions in water as a result of evaporation which lead to decrease in the volume of water [23]. The low overall TDS concentrations suggested that the waters had short contact times with host rock materials, rock dissolution had been relatively small, and the borehole waters have undergone the smallest amounts of reaction. This showed that all the borehole waters were fresh water and suitable for domestic purposes since their total dissolved solids (TDS) did not exceed 1000 mg/L recommended for domestic water. Desissa et. al. and Senthuran et. al. classified water as excellent (if it is <300 mg/L), good (if it is between 300- 600 mg/L), fair (if it is between 600-900 mg/L), poor (if it is between 900-1200 mg/L) and unacceptable (if it is >1200 mg/L). As per this classification, all of the samples come under excellent category [24,25].

The observed overall total hardness value for the borehole water samples ranged from 142 to 260 mg/L in the dry season and 146 to 264 mg/L in the wet season (Tables 2 and 3). The highest values were recorded at Abazinab and the lowest at Mume. The statistical analysis ($P < 0.05$) also showed significant differences across all sampling sites in both the dry and wet seasons. All borehole water samples showed higher mean values of total hardness in the wet season as compared to the dry season. This could be attributed to the recharge of water containing the ions from the ground during the rainy season [9]. Groundwater tends to be harder than the surface water because it's highly solubilising property, particularly for the rocks containing gypsum, calcite and dolomite which are responsible for water hardness. Pollution of groundwater from sewage and run-off from soils particularly limestone origin could also cause hardness [26].

Kumar et. al. classify water as soft (if it is between 0- 60 mg $CaCO_3$/l), moderate (if it is between 61-120 mg $CaCO_3$/l), hard (if it is between 121-180 mg $CaCO_3$/l) and very hard (if it is > 181 mg $CaCO_3$/l) [27]. As per this classification, all the sampling sites, namely, Mume, Abazinab, Konteb, Jegola and Agamti were under hard category. On the basis of this classification, it has been observed that no water samples are soft but all the measured values were within the acceptable limit values of ES (300 mg/L) and WHO (500 mg/L). The results of a number of studies have suggested that water hardness may protect against disease [28]. There exist, an inverse relationship between the hardness of drinking water and cardiovascular disease at elevated hardness [29]. Some data suggested that very soft water, with a hardness of less than 75mg/dm3 may have an adverse effect on mineral balance in the body [30]. Depending on the interaction of other factors, such as pH and alkalinity, water with hardness above approximately 200 mg/L may cause scale deposition in the distribution system, as well as increased soap consumption [29]. Therefore, the inhabitants of the study area are not at risk of water hardness related cardiovascular disease but scale deposition in distribution system and increased soap consumption are likely to occur in the study area due to the concentration range of hardness obtained.

Total alkalinity is a measure of the ability of water to neutralize acids. The alkalinity of groundwater is mainly due to carbonates and bicarbonates [31]. Mean total Alkalinity ranged from 120 to 178 mg/L in the dry season and 121 to 180 mg/L in the wet season with the high est recorded values at Jegola and the lowest at Abzinab in both the dry and wet seasons (Tables 2 and 3). Besides, the statistical analysis performed using one-way ANOVA revealed significant differences at $p < 0.05$ among all the sampling sites but no statistical significant differences were observed between Mume and Konteb in the dry season.

The mean level of total alkalinity in the wet season was higher than that of the dry season. Alkalinity in natural water is due to the presence of salts of weak acids [32]. Natural waters contain appreciable amounts of carbonate and hydroxyl alkalinities. These results indicate that, the levels of alkalinity are high in wet season than in dry season. This could be attributed to alkaline substances which are able to reach water body during this period [13]. The result of the analysis showed that the value of total alkalinity content of borehole water of Woreillu town in all sampling sites were within the ES and WHO limit of 200 mg/L and fit for drinking purposes.

Nitrate concentrations of the borehole waters of Woreillu town varied from 0.179 to 0.231 mg/L for the wet season and 0.168 to 0.217 mg/L for the dry season (Tables 2 and 3). Samples from Konteb had the highest level of nitrate recording 0.217 and 0.231mg/L in the dry and wet seasons respectively and samples from Agamti had the lowest level of nitrate recording 0.168 and 0.17 mg/L in the dry and wet season respectively. The nitrate levels in both seasons were within the ES and WHO standards levels of 50 mg/L and the statistical analysis performed using one-way ANOVA revealed significant differences at $p < 0.05$ among all the sampling sites but no statistical significant differences were observed between Mume and Jegola in the dry season.

The wet season recorded comparatively high mean values of nitrate concentration as compared to the dry season. An increase in levels of nitrate during the wet season could have resulted from the infiltration of the water into the aquifer from the runoff [33]. The study area is noted for its grazing land and large scale of farming where inorganic fertilizer is used extensively. The elevated nutrient levels could be attributed to the use of chemical fertilizers by the farming communities. Poor drainage and the spreading of animal manure, sewage sludge, and effluent could also contribute to nitrate leaching common in the study area. The low levels of nitrate in the borehole waters is that, agricultural activities were not carried out near the sampling sites and this is confirmed by [34] in his studies, where he associated high levels of nitrates in groundwater in places with intensive agriculture and heavy use of nitrogen fertilizer. Similar study was reported in Adaa woreda Oromia region, Ethiopia, where nitrate levels in the area range from 0.6 to 1.3 mg/L [16]. The results of the present investigation showed that the Nitrate ranges of the study area were from 0.179 to 0.231 mg/which Indicates pollution free, good water quality wise and fit for drinking purpose.

The mean phosphate concentration in the samples varied between 0.06 to 0.57 mg/L in dry season and 0.13 to 0.73 mg/L in the wet season (Tables 2 and 3). The highest value was recorded at Mume in the wet season and the lowest at Konteb in dry season. The mean concentrations of phosphate were within the acceptable limits prescribed by ES and WHO of 5 mg/L in both seasons. Moreover, One-way ANOVA analysis at $p < 0.05$ also revealed that there were stastical significant differences between Mume and Abazinab, Mume and Konteb, Mume and Agamti, Jegola and Abazinab, Jegola and Koneb, Jegoland Agamti but no stastical significant differences between Mume and Jegola in dry season. Contrastingly, there were no statistical significant difference between Abazinab and Agamti in wet season. The wet season samples however showed slight increases in the level of phosphates. This may due to phosphates held in soil can be dissolved in water and carried off by leaching, tile drainage or surface runoff. Similar study conducted in Tonk district, India, reported that borehole water phosphate concentration was ranged from 0.16 to 1.09 mg/L [35].

The concentration of phosphate encountered in the natural water environment is normally not enough to causes any detrimental health effect on humans or animals. Phosphate like any other nutrient is harmless in lower concentrations but become harmful only in higher doses. Higher doses of Phosphate are known to interfere with digestion in both humans and animals. The phosphate concentrations of the samples analyzed were all within the acceptable limit and therefore do not pose any health risk to the consumers. The presence of phosphate in all the borehole waters analyzed could be an indication that the source of phosphate in water samples may be of the same origin.

The presence of sulphate in drinking water can also results in a noticeable taste [36]. In the study area, the mean level of sulphate in the sampling sites analysed in the entire period ranged from 5.0 to 22.87 mg/L (Tables 2 and 3). The highest value of 22.87 mg/L was recorded at Konteb in the wet season and Jegola recorded the lowest value of 5.0 mg/L in the dry season. Sulphate concentration was more enriched in the borehole water at Konteb than the other borehole waters. This occurs due to agricultural activities especially crop farming was intensive with the use of more agrochemicals. Thus, the influence of agricultural and other anthropogenic activities could be the probable source of sulphate in the groundwater at the specified area. The values were however within the ES and WHO permissible limit of 250 mg/L. The statistical analysis using one-way ANOVA indicated that there were significant differences among the sampling sites in both the dry and wet seasons (except Mume and

Jegola in the dry season). The variation could be attributed due to the dufferences in the watershed of the sampling points.

The levels of mean sulphate concentrations were higher in wet season than in dry season. This could be attributed to dissolution as water moves through the soil and rock formations that contain sulphate minerals during rain; as a result, some of the sulphate dissolves in the water into the groundwater [37]. Sulphate can only adversely affect the health of human consumers in high concentration above 500 mg/L and causes laxative effect when combine with calcium and magnesium, the two most common components of hard water. The guideline values of 250 mg/L (WHO and ES) as above were established for sulphates based on taste consideration not on health reason. Therefore, sulphates do not pose adverse health risk to the consumers of the sampled waters since all sample recorded value were below 500 mg/L which is limit that has health implication.

Determination of Heavy Metals

Heavy metals are often referred to as common pollutants, which are widely distributed in the environment with sources mainly from the weathering of minerals and soils [38]. However, the level of these metals in the environment has increased as a result of increase in human activities [39]. Heavy metals concentrations in borehole water is influenced by impute from source, character of sediment, organic materials, temperature and sometimes the mineral composition of underlying rock in the area where the borehole water situated. Thus, spatial and temporal variation in heavy metals concentration in borehole water should be naturally expected. In the present study, from the selected heavy metals, With the exception of Cd and Cr, all the other (Fe,Cu, Pb, Mn, Zn) were detected in all the sampling sites. Hence, the results of heavy metal parameters analyzed were described (Table 4).

The mean level of iron in the water samples analysed in the entire period ranged from 0.123 to 0.642 mg/L. The highest value of 0.642 mg/L was recorded at Agamti in the wet season and the lowest value was recorded at Konteb of 0.123 mg/L also in the dry season (Table 4). The values were above the acceptable limit of 0.3 mg/L prescribed by ES at Agamti in the dry season and Jegola at the wet season and the values were also above the acceptable limit of 0.3 mg/L prescribed by ES and 0.5mg/L by WHO in Agamti in the wet season. The analyses have shown that 35% and 8% of the borehole water had iron concentrations above these and WHO prescribed limit for drinking water both for the dry and wet seasons respectively. High iron concentrations in groundwater are widespread and sometimes underrated constraints in water supply. This may be due to the appreciable quantity of iron detected in all the samples may be as result of common source of contamination which is probably from the iron bearing minerals in the rocks as they interact with the under borehole water. The pipes used in the construction of the boreholes could also be a possible source of contamination. Gautam et. al. reported a range of 0.05 mg/L to 0.85 mg/L iron in drinking water, which they linked to probable interaction of the groundwater with rock layers or soil minerals. Iron is essential for good health and helps in transporting of oxygen in the blood but at high concentrations above the recommended levels affect the taste and the odour of the water [40]. However, excessive iron concentration can cause damage to the cells of gastrointestinal tract and may also damage the cells in the heart and liver [41].

From the mean values of iron concentrations in the borehole waters, the concentration is higher in wet season than in the dry season. This may be due to the contact of rainwater with soil and rocks which releases ferrous iron into groundwater sources. This seasonal trend is consistent with the findings of Marian et. al. and Akoto et. al. [42, 43].

The mean concentration of iron in Agamti was statistically different ($p<0.05$) as compared to the means in the other four sites namely, Mume, Abazinab, Koteb and Jegola. However, there was no statistically significant difference in mean concentration of Fe in the four sites of Mume, Abazinab, Koteb and Jegola in the dry season and Mume and Konteb in the wet season.

Copper concentration in water samples varied from 0.03 to 0.186mg/L (Table 4). Copper levels were highest at Jegola and the lowest recorded at Mume in the wet and dry season respectively. The values were within the acceptable limit of 2.0 mg/L prescribed by ES and WHO. Besides, Cu mean concentration in site Mume was statistically significant difference ($p<0.05$) as compared to the means in the other four sites namely, Abazinab, Koteb, Jegola and Agamti. However, there was no statistically significant difference in mean concentration of Cu among Abazinab, Koteb and Agamti in the dry season and Mume and Konteb in the wet season. Copper may be found in water through the natural process of dissolution of minerals, industrial discharge, through its use as copper sulphate for controlling biological growth in some reservoirs and distribution system or through copper corrosion of copper alloy water pipes but most copper contamination in drinking water happens in the water delivery system as a result of corrosion of copper pipes or fittings [44]. The result of the present investigation showed that Copper concentrations were noted to be higher in the wet season than the dry season. This may be an indication of the dissolution of minerals and the rocks underlying the study area have detectable copper influencing on the groundwater.

Copper deficiency causes anaemia, loss of hair pigment, growth inhibition and loss of arterial elasticity. Higher doses of copper can however be very dangerous and toxic to people especially infants resulting in metabolic disorders. High levels of vitamin C however inhibit good copper absorption. Zinc, silver, cadmium and sulphates in the diet can also affect the uptake of copper. Copper deficiency causes complications in the blood circulatory system.

The mean level of lead in the water samples analysed in the entire period ranged from 0.009 to 0.098 mg/L (Table 4). The highest value of 0.098 mg/L was recorded at Agamti in the wet season and the lowest value of 0.009mg/L was recorded at Abazinab in the dry season. Lead value was found in all the sampling sites except Abazinab in the dry season, to be higher than 0.01 mg/L, recommended limit of Pb in drinking water. This makes the water unsuitable for human consumption, as Pb is known to be toxic even at low levels with resultant ill-health effects, as chronic

Table 4: Multiple Comparisons of means of the concentration (mean SD) of heavy metals among the sites in the dry and wet seasons

Seasons	Heavy metals	Sampling Sites					ES standard	WHO Standard
		Mume	Abazinab	Konteb	Jegola	Agamti		
Dry Season	Fe(mg/L)	$0.198^{a}\pm0.001$	$0.144^{a}\pm0.004$	$0.123^{a}\pm0.001$	$0.209^{a}\pm0.024$	$0.403^{b}\pm0.003$	0.3	0.5
	Cu(mg/L)	$0.030^{a}\pm0.001$	$0.034^{b}\pm0.001$	$0.034^{b}\pm0.000$	$0.050^{c}\pm0.000$	$0.035^{b}\pm0.000$	2	2
	Pb(mg/L)	$0.069^{a}\pm0.002$	$0.009^{b}\pm0.001$	$0.013^{b}\pm0.001$	$0.070^{a}\pm0.002$	$0.078^{c}\pm0.003$	0.01	0.01
	Mn(mg/L)	$0.051^{a}\pm0.000$	$0.028^{a}\pm0.000$	$0.022^{a}\pm0.000$	$0.035^{a}\pm0.000$	$0.023^{a}\pm0.000$	0.5	0.4
	Cd(mg/L)	ND	ND	ND	ND	ND	0.003	0.005
	Zn(mg/L)	$0.703^{a}\pm0.002$	$0.853^{b}\pm0.005$	$0.401^{c}\pm0.003$	$0.521^{d}\pm0.001$	$1.227^{e}\pm0.005$	5	4
	Cr(mg/L)	ND	ND	ND	ND	ND	0.05	0.05
Wet Season	Fe(mg/L)	$0.217^{a}\pm0.012$	$0.156^{b}\pm0.002$	$0.209^{a}\pm0.002$	$0.345^{c}\pm0.006$	$0.642^{d}\pm0.004$	0.3	0.5
	Cu(mg/L)	$0.151^{a,c}\pm0.002$	$0.143^{a}\pm0.003$	$0.166^{a,c}\pm0.029$	$0.212^{b}\pm0.001$	$0.186^{b,c}\pm0.001$	2	2
	Pb(mg/L)	$0.089^{a}\pm0.001$	$0.024^{b}\pm0.001$	$0.018^{c}\pm0.001$	$0.084^{d}\pm0.001$	$0.098^{e}\pm0.001$	0.01	0.01
	Mn(mg/L)	$0.161^{a}\pm0.001$	$0.071^{b}\pm0.002$	$0.052^{c}\pm0.001$	$0.042^{c}\pm0.001$	$0.117^{d}\pm0.007$	0.5	0.4
	Cd(mg/L)	ND	ND	ND	ND	ND	0.003	0.005
	Zn(mg/L)	$0.305^{a}\pm0.006$	$0.522^{b}\pm0.002$	$0.144^{c}\pm0.002$	$0.229^{d}\pm0.002$	$0.858^{e}\pm0.002$	5	4
	Cr(mg/L)	ND	ND	ND	ND	ND	0.05	0.05

**Means values followed by the same small letter within the same row are not significantly different at 95% confidence level*
**ND: not detected*

exposure has been linked to growth retardation in children [45, 46]. The statistical analysis performed using one-way ANOVA at $p< 0.05$ showed that there were no any significant differences among the sampling sites in the wet season but no statistical significant differences between Mume and Jegola, Abazinab and Konteb in the dry season.

High lead concentration in drinking water may result in metallic poisoning that manifest symptoms such as tiredness, lassitude, slight abdominal discomfort, irritation, anaemia and, in the case of children, behavioural changes. It is cumulative poison and a possible human carcinogen [47]. The mean values of lead concentrations in groundwater are higher in the wet season when compared to that of the dry season. This is consistent with the findings of Bakare-Odunola et. al. and Okereke et. al. [48, 49]. The study also revealed 100% and 80% of the borehole water had lead concentrations above the WHO prescribed limit for drinking both in the wet and dry seasons respectively. The possible causes of high lead concentration in these boreholes water are rather very surprising being a rural environment. Nonetheless, increased use of chemical fertilizer due to rapidly declining soil fertility in the study may have accounted for high lead contamination of the groundwater. Moreover, the recorded high level of lead in the sampled water signified a possible rock mineral and groundwater interaction. The underlying rocks may contain minerals of lead composition capable of impacting lead on the groundwater. Adenkule et. al. reported high level of lead in groundwater above WHO recommended limit and suggested the possible source of contamination from the nature of the rock underlying the study area. Thus, too much lead concentration detected above a threshold value needs immediate intervention to improve the quality of water around sampling area [50].

The mean level of manganese in the water samples in the entire period ranged from 0.022 to 0.161 mg/L (Table 4). The highest value of 0.161 mg/L was recorded at Mume in the wet and the lowest value of 0.022 mg/L was recorded at Konteb in the dry season with no statistically significant differences ($p>0.05$) in all the sampling sites in the dry season. However, there were statistically significant differences among the sampling sites except between Konteb and Jegola in the wet season. These values were within the acceptable limit of 0.5 and 0.4 mg/L prescribed by ES and WHO respectively.

Manganese is also a naturally occurring element in rocks and is released into the soil through weathering of the rocks. It can therefore be deduced that the high levels of manganese contamination is as a result of the underlying geological formation (rocks). Manganese like other trace metals is essential to the sustenance of life. Manganese, molybdenum, selenium and zinc are needed at low levels as catalyst for enzyme activities. However, drinking water containing high levels of these essential metals or elements may be hazardous to human health. Its contact to groundwater is however through leaching. Excess manganese in a person's diet may inhibit the use of iron in the regeneration of blood haemoglobin. A high dose of manganese causes apathy, headaches, insomnia and weakness of legs. Symptoms of excessive manganese include impulsive acts, absent-mindedness, hallucinations, aggressive- ness and unaccountable laughter. Under extreme case, nervous system disorders such as Parkinson's disease may develop [51].

From the mean concentrations, manganese level is higher in the wet season when compared to that of the dry season. This is probably due to the dissolution of minerals of manganese in the under borehole water and occurs as a result of weathered and solubilised manganese from soil and bedrock [52]. Tiimub et. al. reported high level of manganese in groundwater analysis with range 0.038 mg/L to 0.638 mg/L and attributed it to the probable interaction of groundwater with rock layers or soil minerals [53]. The result of the analysis revealed that the concentration of manganese in the borehole water samples obtained from the study area is acceptable since it is below the maximum permissible limit.

The mean level of zinc in the water samples analysed in the entire period ranged from 0.144 to 1.227 mg/L (Table 4). The highest value of 1.227 mg/L was recorded at Agamti in the dry season and the lowest value of 0.144 mg/L was recorded in the wet season. There were also significant differences ($p<0.05$) in the levels of Zn concentration among the sampling stations both in the dry and wet seasons. From the analyses zinc concentrations in the borehole waters were lower in the wet season when compared to that of dry season. This variation was similar with the findings of them [42]. The study by Bakare-Odunola et. al. showed consistency in concentrations in water for both in the wet and dry seasons. These discrepancies in research results may be due to variation in the geology of the different study areas as well as dissimilar anthropogenic activities occurring in the areas [48]. However, zinc concentrations in all the borehole waters were all within the WHO acceptable limit for drinking water for the wet and dry seasons. Zinc is considered an essential trace metal which functions as a catalyst for enzymatic activity in human bodies. Drinking water contains this trace metal in very small quantities which may reduce the possibility of its deficiency in the diet. However, its accumulation in the human body causes harmful effects such as stomach cramps, nausea, vomiting, decrease good cholesterol and acceleration of anaemic conditions [54, 55]. In addition, Zinc is essential to plant and animal physiology, however concentration above 4 mg/L can cause problem of bitter, astringent taste, opalescent appearance and render the water unpalatable [56]. Therefore, the water quality in study area in reference with zinc concentration is acceptable.

Seasonal Variations of Physico- chemical Parameters

The seasonal variations (wet and dry seasons) of all the physico-chemical parameters studied in borehole waters were calculated and the results of the analysis are shown (Table 5).

Temperature in the borehole water significantly ($P<0.05$) varied

Table 5: Seasonal variations of physico-chemical parameters in borehole water (N=10)

Physico-chemical parameters	Dry season Mean ± SD	Wet season Mean ± SD	P-value
Temperature (°C)	13.6±1.5	12.8±1.2	0.008
PH	7.8±0.16	7.9±0.13	0.036
EC (µS/cm)	0.31±0.02	0.34±0.06	0.067
Turbidity(NTU)	3.5±0.17	4.53±0.14	0.773
TDS (mg/L)	207±16.9	205±14.3	0.000
TH (mg/L)	196±34.1	200±33.7	0.000
Alkalinity (mg/L)	152±22.8	155±20.5	0.000
Nitrate (mg/L)	0.18±0.01	0.20±0.01	0.084
Phosphate (mg/L)	0.32±0.02	0.40±0.03	0.000
Sulphate (mg/L)	12.6±0.79	13.9±0.82	0.000

Table 6: Seasonal variations of heavy metals in borehole water (N=10)

Heavy metals	Dry season Mean±SD	Wet season Mean±SD	P-value
Fe (mg/L)	0.215600.001	.31360±0.001	0.099
Cu (mg/L)	0.03673±0.007	.17180±0.002	0.000
Pb (mg/L)	0.04773±0.003	.06253±0.004	0.236
Mn (mg/L)	0.03180±0.001	.08987±0.004	0.000
Zn (mg/L)	0.74107±0.002	.41153±0.003	0.003

seasonally and was high during the dry season which could be attributed to the high level of solar (sun) radiation in the dry season. In Ethiopia, especially in the study area, the temperature begins to rise from the middle of January and reached its maximum by the end of May and starts to decline at the middle of June to the December. Moreover, TDS in the borehole waters was a significantly different between the dry and wet season at ($p \leq 0.05$) which was high during the dry season. The high values during the dry season could be due to concentration of ions in water as a result of evaporation which lead to decrease in the volume of water. However, the results of physicochemical analysis revealed that the parameters such as total hardness, total alkalinity, phosphate and sulphate in the borehole water were significantly ($p<0.05$) varied seasonally and were higher during the wet season. The high value of these parameters can be attributed by anthropogenic activities, effective ion leaching and discharge of effluents from agricultural and domestic wastes in wet season.

Seasonal Variations of Heavy Metals

The seasonal variations (wet and dry seasons) of all the heavy metals studied in borehole water were calculated and the results of the analysis are shown (Table 6).

Zn in the borehole water samples was significantly ($P<0.05$) varied seasonally and was high during the dry season. The higher level observed in the dry season could be due to low volume of water which leads to elemental concentration while the lower level observed could be attributed to the influx of water from surface runoffs which is capable of washing away some of the heavy metals, thereby reducing their levels [57,58]. Besides, Mn, and Cu in the borehole waters was significantly varied

Table 7: Correlation matrix of the physicochemical parameters obtained from the borehole water samples

Site Mume		Temperature ( )	pH	EC (µs/cm)	Turbidity(NTU)	TDS (mg/L)	TH (mg/L)	Alkalinity (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)	Sulphate (mg/L)
Temperature (ºC)	Pearson Correlation	1	-524	-0.786	-.881*	0.588	-.953**	-0.463	-.881*	-.888*	-.822*
	P-value		0.286	0.064	0.02	0.219	0.003	0.355	0.02	0.018	0.045
pH	Pearson Correlation		1	0.45	0.809	-.961**	0.642	0.474	0.662	0.655	0.49
	P-value			0.371	0.051	0.002	0.169	0.342	0.152	0.158	0.324
EC (µS/cm)	Pearson Correlation			1	.853*	-0.367	.879*	0.699	.956**	.955**	.846*
	P-value				0.031	0.474	0.021	0.122	0.003	0.003	0.034
Turbidity(NTU)	Pearson Correlation				1	-0.772	.964**	0.627	.968**	.965**	0.809
	P-value					0.072	0.002	0.183	0.002	0.002	0.051
TDS (mg/L)	Pearson Correlation					1	-0.623	-0.379	-0.612	-0.611	-0.52
	P-value						0.186	0.458	0.197	0.197	0.291
TH (mg/L)	Pearson Correlation						1	0.574	.962**	.961**	0.81
	P-value							0.233	0.002	0.002	0.051
Alkalinity (mg/L)	Pearson Correlation							1	0.684	0.662	0.367
	P-value								0.134	0.152	0.474
Nitrate (mg/L)	Pearson Correlation								1	.999**	.870*
	P-value									0	0.024
Phosphate (mg/L)	P.Correlation									1	.889*
	P-value										0.018
Site Abazinab		Temperature ()	PH	EC (µs/cm)	Turbidity(NTU)	TDS (mg/L)	TH (mg/L)	Alkalinity (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)	Sulphate (mg/L)
Temperature (ºC)	Pearson Correlation	1	-0.639	-0.532	-0.421	0.488	-0.738	0.34	-0.651	-0.641	-0.585
	P-value		0.172	0.278	0.406	0.326	0.094	0.509	0.161	0.17	0.223
pH	Pearson Correlation		1	.908*	0.734	-.934**	.948**	0.432	.985**	.955**	.929**
	P-value			0.012	0.097	0.006	0.004	0.392	0	0.003	0.007
EC (µS/cm)	Pearson Correlation			1	.903*	-.916*	.917*	0.43	.957**	.962**	0.733
	P-value				0.014	0.01	0.01	0.395	0.003	0.002	0.098
Turbidity (NTU)	Pearson Correlation				1	-0.811	0.758	0.504	.817*	0.809	0.492
	P-value					0.05	0.081	0.308	0.047	0.051	0.322
TDS (mg/L)	Pearson Correlation					1	-.821*	-0.562	-.922**	-.960**	-0.757
	P-value						0.045	0.246	0.009	0.002	0.081
TH (mg/L)	Pearson Correlation						1	0.241	.977**	.918**	.888*
	P-value							0.645	0.001	0.01	0.018
Alkalinity (mg/L)	Pearson Correlation							1	0.405	0.354	0.369
	P-value								0.426	0.491	0.471
Nitrate (mg/L)	Pearson Correlation								1	.966**	.886*
	P-value									0.002	0.019

Phosphate (mg/L)	Pearson Correlation									1	0.79
	P-value										0.061
Site Konteb		Temperature (°c)	PH	EC (μs/cm)	Turbidity(NTU)	TDS (mg/L)	TH (mg/L)	Alkalinity (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)	Sulphate (mg/L)
Temperature ()	Pearson Correlation	1	-0.218	-0.535	-0.406	-0.359	-0.104	0.199	-0.365	-0.469	-0.424
	P-value		0.678	0.275	0.424	0.485	0.845	0.706	0.476	0.349	0.402
pH	Pearson Correlation		1	0.7	.944**	-0.486	0.747	0.705	.869*	.852*	.856*
	P-value			0.122	0.005	0.328	0.088	0.118	0.025	0.031	0.029
EC (μS/cm)	Pearson Correlation			1	0.711	-0.575	0.582	0.531	.827*	.835*	.869*
	P-value				0.113	0.232	0.226	0.278	0.042	0.039	0.025
Turbidity(NTU)	Pearson Correlation				1	-0.303	.850*	0.66	.941**	.948**	.928**
	P-value					0.56	0.032	0.154	0.005	0.004	0.008
TDS (mg/L)	Pearson Correlation					1	-0.43	-0.621	-0.461	-0.376	-0.456
	P-value						0.394	0.188	0.358	0.463	0.363
TH (mg/L)	Pearson Correlation						1	0.803	.917*	.891*	.880*
	P-value							0.054	0.01	0.017	0.021
Alkalinity (mg/L)	Pearson Correlation							1	0.784	0.714	0.759
	P-value								0.065	0.111	0.08
Nitrate (mg/L)	Pearson Correlation								1	.993**	.996**
	P-value									0	0
Phosphate (mg/L)	Pearson Correlation									1	.994**
	P-value										0
Site Jegola		Temperature (°c)	pH	EC (μs/cm)	Turbidity(NTU)	TDS (mg/L)	TH (mg/L)	Alkalinity (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)	Sulphate (mg/L)
Temperature (°C)	Pearson Correlation	1	.854*	-0.727	-.860*	0.215	-.846*	-0.697	-.949**	-0.396	-.928**
	P-value		0.031	0.102	0.028	0.683	0.034	0.124	0.004	0.437	0.008
pH	Pearson Correlation		1	-.886*	-.968**	0.297	-.940**	-0.409	-.968**	-0.036	-.951**
	P-value			0.019	0.002	0.567	0.005	0.421	0.001	0.947	0.004
EC (μS/cm)	Pearson Correlation			1	.908*	-0.383	0.728	0.135	.860*	-0.034	.850*
	P-value				0.012	0.453	0.101	0.799	0.028	0.949	0.032
Turbidity(NTU)	Pearson Correlation				1	-0.384	.860*	0.448	.967**	0.189	.899*
	P-value					0.452	0.028	0.373	0.002	0.719	0.015
TDS (mg/L)	Pearson Correlation					1	-0.346	0.264	-0.241	-0.517	-0.281
	P-value						0.502	0.613	0.645	0.294	0.59
TH (mg/L)	Pearson Correlation						1	0.415	.904*	0.122	.947**
	P-value							0.413	0.013	0.818	0.004
Alkalinity(mg/L)	Pearson Correlation							1	0.575	0.481	0.437
	P-value								0.232	0.334	0.387
Nitrate (mg/L)	Pearson Correlation								1	0.194	.961**
	P-value									0.712	0.002
Phosphate (mg/L)	Pearson Correlation										0.12
	P-value										0.821
Site Aganti		Temperature (°C)	PH	EC (μS/cm)	Turbidity(NTU)	TDS (mg/L)	TH (mg/L)	Alkalinity (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)	Sulphate (mg/L)
Temperature (°C)	Pearson Correlation	1	-.965**	-.931**	-.979**	0.314	-0.594	-0.64	-.966**	-.949**	-0.748
	P-value		0.002	0.007	0.001	0.544	0.214	0.171	0.002	0.004	0.087
PH	Pearson Correlation		1	.984**	.981**	-0.352	0.594	0.706	.995**	.998**	0.792
	P-value			0	0.001	0.494	0.214	0.117	0	0	0.06

EC (µS/cm)	Pearson Correlation			1	.950**	-0.413	0.669	0.786	.989**	.981**	.865*
	P-value				0.004	0.415	0.146	0.064	0	0.001	0.026
Turbidity(NTU)	Pearson Correlation				1	-0.207	0.565	0.656	.981**	.974**	0.7
	P-value					0.694	0.243	0.157	0.001	0.001	0.121
TDS (mg/L)	Pearson Correlation					1	-0.208	-0.244	-0.327	-0.326	-0.7
	P-value						0.692	0.642	0.527	0.528	0.122
TH (mg/L)	Pearson Correlation						1	.959**	0.666	0.593	0.793
	P-value							0.002	0.149	0.214	0.06
Alkalinity (mg/L)	Pearson Correlation							1	0.763	0.716	.842*
	P-value								0.077	0.11	0.036
Nitrate (mg/L)	Pearson Correlation								1	.991**	.816*
	P-value									0	0.048
Phosphate (mg/L)	Pearson Correlation									1	0.779
	P-value										0.068

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

Table 8: Correlation matrix of the physicochemical parameters obtained from the borehole water samples

Site Mume		Fe (mg/L)	Cu (mg/L)	Pb (mg/L)	Mn (mg/L)	Zn (mg/L)
Fe (mg/L)	Pearson Correlation	1	.808	.787	.801	-.814*
	P-value		.052	.063	.055	.049
Cu (mg/L)	Pearson Correlation		1	.995**	1.000**	-1.000**
	P-value			.000	.000	.000
Pb (mg/L)	Pearson Correlation			1	.996**	-.994**
	P-value				.000	.000
Mn (mg/L)	Pearson Correlation				1	-1.000**
	P-value					.000
Site Abazinab		Fe (mg/L)	Cu (mg/L)	Pb (mg/L)	Mn (mg/L)	Zn (mg/L)
Fe (mg/L)	Pearson Correlation	1	.727	.740	.724	-.729
	P-value		.102	.093	.104	.100
Cu (mg/L)	Pearson Correlation		1	.997**	.998**	-1.000**
	P-value			.000	.000	.000
Pb (mg/L)	Pearson Correlation			1	.999**	-.997**
	P-value				.000	.000
Mn (mg/L)	Pearson Correlation				1	-.999**
	P-value					.000
Site Konteb		Fe (mg/L)	Cu (mg/L)	Pb (mg/L)	Mn (mg/L)	Zn (mg/L)
Fe (mg/L)	Pearson Correlation	1	.974**	.968**	1.000**	-.999**
	P-value		.001	.001	.000	.000
Cu (mg/L)	Pearson Correlation		1	.924**	.971**	-.967**
	P-value			.008	.001	.002
Pb (mg/L)	Pearson Correlation			1	.967**	-.973**
	P-value				.002	.001
Mn (mg/L)	Pearson Correlation				1	-.999**
	P-value					.000
Site Jegola		Fe (mg/L)	Cu (mg/L)	Pb (mg/L)	Mn (mg/L)	Zn (mg/L)
Fe (mg/L)	Pearson Correlation	1	.688	.694	.686	-.690
	P-value		.131	.126	.132	.129
Cu (mg/L)	Pearson Correlation		1	.988**	.998**	-1.000**
	P-value			.000	.000	.000
Pb (mg/L)	Pearson Correlation			1	.990**	-.989**
	P-value				.000	.000
Mn (mg/L)	Pearson Correlation				1	-.998**
	P-value					.000
Site Agamti		Fe (mg/L)	Cu (mg/L)	Pb (mg/L)	Mn (mg/L)	Zn (mg/L)
Fe (mg/L)	Pearson Correlation	1	.999**	.989**	.996**	-1.000**
	P-value		.000	.000	.000	.000

Cu (mg/L)	Pearson Correlation		1	.987**	.996**	-1.000**
	P-value			.000	.000	.000
Pb (mg/L)	Pearson Correlation			1	.987**	-.987**
	P-value				.000	.000
Mn (mg/L)	Pearson Correlation				1	-.996**
	P-value					.000

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

seasonally (P<0.05) with Mn and Cu being high during the wet season. The slight rise in its level may be due to accounted by the influence of domestic waste, natural geological rocks and Percolation of minerals from soil [59].

Correlation Analysis of Physico- Chemical Parameters in Borehole Water Samples

Correlation analysis is principally calculated to understand the associations between two or more functionally independent parameters. The value of correlation coefficient ranges between -1 and +1. Rakesh et. al. reported that high correlation coefficient (near +1 or −1) means a good relation between two variables, and its concentration around zero means no relationship between them at a significant level of 0.05% level, it can be strongly correlated, if r > 0.7, whereas r values between 0.5 and 0.7 shows moderate correlation between two different parameters [60]. The result of the present study correlation coefficients between the physicochemical parameters and between various heavy metals in the borehole waters of Woreillu town were summarized in Table 7 and Table 8. The correlation analysis is a bivariant method, which is applied to describe the relation between two different parameters.

From the Pearson correlation matrix, the values of (r) can be classified into a positive correlation values for temperature and pH at Jegola, pH and turbidity at Mume and , pH and EC, turbidity, Nitrate, Phosphate, and Sulphate at Abazinab, pH and total hardness at Konteb, pH and EC, turbidity, alkalinity, nitrate, phosphate sulphate at Konteb and Agamti, EC and turbidity, total hardness, nitrate, phosphate, sulphate among the five sampling sites, EC and Alkalinity at Agamti, turbidity and total hardness, nitrate, phosphate, sulphate at Mume among the 5 sampling sites, total hardness and nitrate ,phosphate, sulphate at Mume, Abazinab and Konteb, total hardness and alkalinity at Konteb and Agamti, total hardness and nitrate , sulphate at Jegola, total hardness and sulphate at Agamti, nitrate and phosphate, sulphate at Mume, Abazinab, Konteb and Agamti, nitrate and sulphate at Jgola, alkalinity and nitrate phosphate, sulphate at Konteb, and Agamti, phosphate and sulphate at Mume, Abazinab, Konteb and Agamti, which indicates the strongest relation between these variables.

The second type of correlation values which is highly negative correlation observed for the parameters temperature and EC, turbidity, total hardness, nitrate, phosphate, sulphate at Mume, Jegola and Agamti, temperature and phosphate at Mumeand Agamti, temperature and total hardness at Abazinab, pH and total dissolved solid at Mume and Abazinab, pH and EC, turbidity, total hardness, nitrate, sulphate at Jegola, EC and total dissolved solid at Abazinaab, turbidity and total dissolved solid at Mume and Abazinab, total dissolved solid and total hardness, nitrate, phosphate, sulphate at Abazinab, total dissolved solid and sulphate at Agamti which indicates the strong negative relation between these variables.

Correlation Analysis of Heavy Metals in Borehole Water Samples

Pearson correlation analysis of metals in the borehole waters was performed to assess possible similar sources of metals. From the correlation table, a strong significant positive correlation was found between Fe and Cu, Pb, Mn, Cu and Pb, Mn, Pb and Mn at the five sampling sites namely, Mume, Abazinab, Konteb, Jegola and Agamti. Moreover, Fe, Cu, Pb, Mn and Zn showed strong negative correlation at the five sampling sites. The heavy metals with positive correlation were considered to have similar sources [61].

In general, a strong positive correlation in any two parameters indicated that parameters are derived from the same sources, when increase or decrease in the value of one parameter is associated with a corresponding increase or decrease in the value of other parameter, a common chemical behaviour and dependency of one parameter on the other and a strong negative correlation between any two parameters indicated that inverse relation between them meaning ,an increase or decrease in the value of one parameter is associated with the corresponding decrease or increase on the other parameters respectively and the two parameters have different sources of contamination or origin [62-65].

Conclusion

The findings reveal that most of the physicochemical parameters and heavy metals in the water samples from boreholes in Woreillu town were found to be within the safe limit according to the WHO and ES standard for drinking water quality except for turbidity and lead. It has been seen that there is a seasonal variation with respect to the physico-chemical parameters and concentration of heavy metals in the sampling sites. The levels of the physico-chemical parameters and heavy metals of the borehole water samples in the dry season were found to be significantly different (p≤ 0.05) from that of the wet season. Most of the water from these wells is suitable for domestic use and it is unlikely to pose a major health risk to consumers.

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Competing interests

Author has declared that no competing interests exist.

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