



Assessment of Physio-Chemical Parameters and Selected Heavy Metals in Hand Pump Water Samples of Yebejeyche, Ageta, and Yewache Keble Muher Aklil Woreda, Gurage Zone, Snnpr, Ethiopia

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Abstract

In the world, among the most vital natural resource water is the one, and water contamination is a major environmental issue globally. In this regard, the quality of drinking water should be observing frequently. Thus, this study was intended to investigate hand-pump water quality of Yebejeyche (Ye), Ageta (Ag) and Yewache (Yw) in MuherAklilworeda, Gurage Zone, Southern Ethiopia. The physicochemical parameters; viz, Electrical conductivity (EC), Total Hardness (TH), Temperature (T), Total Dissolved Solids (TDS) and Potential hydrogen (pH), of water samples collected from different areas were determined. In addition to these, the concentration of elements like Na, Ca, Cr, Fe, Zn, Cd, and Pb were quantified in three samples. The Temp, pH, and EC were measured at the sampling sites. TH was analyzed by EDTA titration using ammonium buffer at pH 10 and E-Blank T indicator. The concentration of Na and Ca was analyzed using a Flame photometer. A wet acidic digestion method was employed to extract selected metals from water samples followed by the concentration of target analytes was quantified using flame atomic absorption spectroscopy (FAAS). The average values of T, pH, EC, and TH in the studied area were in the range of 22.89 °C to 22.90 °C, 6.77 to 7.01, 394 µS/cm to 410 µS/cm, 131 mg/L to 146 mg/L, 4.36 mg/L to 6.3 mg/L were obtained, respectively. The analyzed mean values of Na, Ca, Cr, Fe, Zn, Cd, and Pb were obtained in the interval of 30 mg/L to 33.8 mg/L, 24.9 mg/L to 28.2 mg/L, 0.0019 mg/L to 0.0035 mg/L, 0.04 mg/L to 0.05 mg/L, 0.115 mg/L to 0.223 mg/L, 0.003 mg/L to 0.005 mg/L, and 0.018 mg/L to 0.0306 mg/L, respectively. All the tested parameters coincide with the drinking water quality standards set by the World Health Organization (WHO), indicating that the three hand-pumped water sources are safe for consumption.

Keywords: Hand pump water, physicochemical parameter, heavy metals, wet digestion and FAAS

1. Introduction

Water is the most vital compound on Earth, as all living organisms including humans, animals, and plants depend on it for survival and growth. [1]. Groundwater is an indispensable water supply that is used for different kinds of purposes. Currently, the population is booming globally and nationally and their improper consumption has led to the deterioration of surface and groundwater [2]. Generally, groundwater is increasingly at risk due to human activities, prompt industrial development, unintended expansion of cities, and when fertilizers and pesticides are added in inappropriate amount on farmland [3]. Industrial and household wastes may be released into the environment, either deliberately or inadvertently, and can potentially pollute groundwater.

Metals are introduced into water bodies through various pathways, such as physical, chemical, or biological weathering, soil leaching, atmospheric deposition of aerosol particles, and several anthropogenic actions, like processing, mining, and the use of metal-based materials [4]. The physicochemical properties of groundwater such as total hardness (TH), temperature (Temp), electrical conductivity (EC), potential hydrogen (pH), and total dissolved solids (TDS) along with the concentrations of elements including Na, Ca, Cr, Fe, Zn, Cd, and Pb, are critical for public health studies. Therefore, monitoring the level of contaminated substances in groundwater is crucial. The probability of getting adequate safe water is questionable in many developing countries [5]. Specifically, in the Ethiopian context, the major sources of water pollution include industrial discharges, sewage, urban and rural wastewater,

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agricultural practices, garages, and various institutions. The availability of high concentration of toxic heavy metals in drinking water is the cause for serious risks to human being. Moreover, small fraction only about 2.5% of the Earth's total water resources is fresh and safe for drinking purpose [6]. Heavy metals are the key toxic contaminants that have negative impact on the quality of drinking water [7]. Their accumulation has made drinking water pollution a main worry in many countries.

The primary origin of drinking water, in Yebejeche, Ageta and Yewache Kebeles, is underground water. In addition, the people also employ the groundwater for various purposes such as irrigation, sanitation and washing. In these areas, the physicochemical parameters and the concentration levels of selected elements was not yet studied. Accordingly, this study focused on assessing the status of groundwater at different sampling sites by analyzing selected physicochemical parameters and the concentrations of target analytes.

2. Materials and Methods

2.1. Portrayal of the Study Area

Muher Aklil Woreda is situated in the Gurage Zone of the Southern Nations, Nationalities, and Peoples' Region (SNNPR), Ethiopia. It lies about 200 km from Addis Ababa, the capital city, and 52 km from Wolkite town. Three sites were designated for the gathering of hand-pumped drinking water samples, namely Yebejeche, Ageta, and Yewache, and transported to the Chemistry Laboratory at Wolkite University for the analysis of EC, temperature, TDS, TH, and pH. The concentrations of metals were quantified by employing FAAS at the Amhara Design and Supervision Works Enterprise Laboratory Service in Bahir Dar (ADSWE).

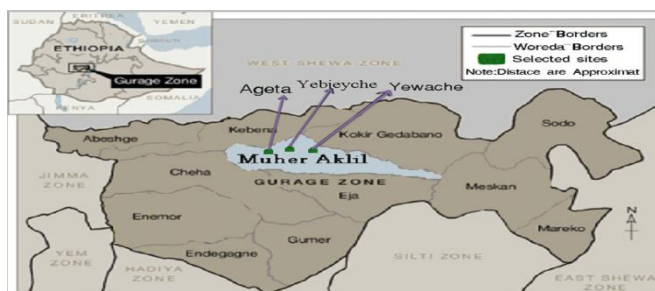


Figure 1. Map of the study areas

2.2. Cleaning apparatus, Sample gathering, and Conservation

The apparatus was cleaned with tap water and detergent, rinsed with distilled water, and then soaked in a 1:1 nitric acid solution for 48 hours, rinsed again with deionized water, dried in an oven, and stored in a dustless environment up to the point of analysis. The water samples were gathered from three selected hand

pump water sites namely Yebejeche(Yb), Ageta(Ag) and Yewach(Yw). Three samples of water were taken from every sampling site. The three collected samples were transported to the Bahir Dar Laboratory Service of the Amhara Design and Supervision Works Enterprise for further analysis.

2.3. Instruments

For the analysis of underground water samples, various instruments were employed. A pH meter and a conductivity meter were used to determine the hydrogen ion concentration and the presence of cations and anions, respectively. A flame atomic absorption spectrophotometer was employed for the determination of the concentration of target metals in the water samples.

2.4. Laboratory Chemicals and Reagents

Analytical grade chemicals were used during the course of this study. Stock solutions, 1000 mg/L of Pb, Cr, Cd, Na, Zn, Ca, and Fe were used as standards. For the determination of total hardness, disodium salt of EDTA, buffer solution (pH 10.0) ammonium chloride–ammonium hydroxide, anhydrous Na_2CO_3 , and CaCO_3 were applied. Argentometric titration for chloride determination was carried out using AgNO_3 and $\text{K}_2\text{Cr}_2\text{O}_7$. Distilled water was used to prepare both stock and working standard solutions.

2.5. Procedure

2.5.1. Physicochemical study

Electrical conductivity, Temperature, and pH were assessed on-site during sampling, whereas total dissolved solids (TDS), and total hardness (TH) were investigated in the Chemistry Laboratory at Wolkite University [8].

2.5.1.1. Temperature, pH and Electrical conductivity

The water temperature was measured at each of the three sampling sites by immersing a digital thermometer into the samples. The pH value of the water sample was conducted by placing the pH meter into it. After each measurement, the electrode was washed with distilled water before proceeding to the next sample. During every stage of analysis, all probes were thoroughly rinsed with deionized water both before and after use [9]. For further measurements, 100 mL of each water sample was poured into 500 mL beakers, and readings were taken by immersing the electrode in the samples.

2.5.1.2. Total dissolved solids (TDS)

The TDS in the water were determined using the gravimetric method. Firstly, 100 mL of the water sample was filtered using a standard glass-fiber filter with a 2-micron ($2\ \mu\text{m}$) pore size. This step confirms that the quantity reflects dissolved solids rather than

suspended particles in the water. The filtrate portion was evaporated to dryness at 180 °C, and the amount of total dissolved solids was determined using equation 2.1. The reason for the higher temperature was to remove all mechanically blocked water [10].

$$\text{TDS in (mg/l)} = \frac{X_b - X_a}{\text{Volume(ml) of sample}}$$

Equation 2.1

Where:

X_b = weight of porcelain dish + weight of the residue (filtrate) after cooling X_a = weight of clean and dried porcelain dish.

2.5.1.3. Total Hardness (TH)

Total hardness was determined by EDTA method. 100 mL of water sample were measured and poured into a beaker containing a stirrer bar and then three drops of Eriochrome Black T indicator was added. Next, the water sample was titrated with a 0.01 M EDTA solution until a blue color performed. Total hardness is expressed as equivalent of calcium carbonate concentration [10] and calculated by equation 2.2.

$$\text{Total hardness as CaCO}_3(\text{mg/l}) = \frac{\text{Volume of EDTA} \times M \text{ of EDTA} \times MW \text{ of CaCO}_3 \times 1000}{\text{ml of sample}}$$

Equation 2.2

2.5.1.4. Analysis of selected heavy metals

Flame atomic absorption spectroscopy was used for the analysis of metals in a water sample using a calibration curve method. Appropriate amounts of each target analyte were weighed and put into a 1000 mL volumetric flask to prepare the stock standard solution. To determine metals in the hand pump water sample, standard solutions of seven points, including calibration blanks, were prepared for each metal. Standard curves were arranged for every metals using serial dilution from stock solutions. The calibration standard solution was used to calibrate the instrument's response with respect to analyte concentration. A standard mixture solution consisting of the metals at the same concentrations was prepared by taking the same volume of each metal stock standard solution. In wet digestion of water samples, 20 mL con HNO_3 , 5 mL of HClO_4 , and 10 mL of H_2O_2 peroxide were added to 100 mL of water samples, respectively. The samples were put on a hot plate and heated at 100°C for 3 hours. The samples were taken off from the hot plate as soon as a clear solution was observed. The digested solution was cooled at room temperature and filtered into 50 mL volumetric flasks using Whitman filter paper No.541 (125 mm). Then, it was rinsed thoroughly 654 with warm distilled water and topped up to the mark. For each quantification, the average values of the three replicates were calculated to attain reliable results. Distilled water was used as a blank

sample, and it was analyzed in a similar procedure to the preceding one.

3. Results and Discussions

3.1. Physicochemical Analysis

Some physicochemical parameters which determine the underground hand pump water quality were measured at each sampling sites and the data is presented in Table 1.

Table 1. The results of the physicochemical parameters of hand pump water samples (n=3).

Sample sites				
Parameters	Yebejeyche(Yb) Mean ±SD	Ageta(Ag) Mean ±SD	Yewache(Yw) Mean ±SD	WHO Standard
Temp.°C	22.63 ±0.200	22.93±0.513	22.83±0.321	
pH(0-14)	6.77±0.030	7.01±0.030	6.86±0.085	6.5-8.5
EC(μS/cm)	394.66±5.033	410.33±1.527	405.66±2.516	≤1500
TDS(mg/l)	254.73±1.497	263.90±1.552	259.30±1.053	<1000
TH(mg/l)	146.33±1.527	131.66±1.527	135.66±2.082	500
Ca(mg/l)	28.1± 0.458	25.33±0.145	26.25± 0.11	≤100
Na(mg/l)	33.8± 1.058	30±0.700	31.8± 0.5	≤20

3.1.1. Temperature

Temperature reveals the degree of coldness or hotness of water and influences the rate of chemical reactions. In general, cold water is considered more potable than warm water. Temperature promotes the growth of microorganisms and influences the taste, odor, and color of water [11]. In this study, the recorded temperature ranged between 22.63°C and 22.93°C (Table 1). Since these values fall below the WHO guideline limits [12], the water samples were deemed appropriate for drinking purpose. The relatively higher temperature observed in this study was attributed to the environmental conditions of the Kola region [13].

3.1.2. pH

pH shows the concentration of hydrogen ions in a water sample and is used to determine whether the water is acidic or alkaline. pH values ranged from 6.77 to 7.01, which falls within the WHO recommended limits. The average pH values for Yb and Yw were slightly acidic but still complied with drinking water standards (Table 1). The relatively lower pH of hand pump water may be attributed to the long-term dissolution of sulphate, phosphate, and carbonate rocks.

3.1.3. Electrical conductivity ($\mu\text{S}/\text{cm}$)

Conductivity states to the ability of a aqueous sample to passes an electrical current, which depends on the concentration of ions present in the solution. The recommended limit of electrical conductivity (EC) in drinking water is $1500 \mu\text{S}/\text{cm}$ [14]. In this study, EC values ranged from 394.66 to $405.66 \mu\text{S}/\text{cm}$, which are well below the WHO guideline (Table 1). The relatively high conductivity observed in the groundwater may be attributed to its prolonged interaction with surrounding rocks.

3.1.4 Total Hardness

Hardness refers to the characteristic of water that hinders soap lather formation and elevates its boiling point. According to WHO, the allowable limit for total hardness in water is 500 mg/L of CaCO_3 . In the current study, the mean total hardness ranged from 131.66 mg/L to 146.33 mg/L , which fall within the recommended limit.

3.1.5. Total Dissolved Solids (TDS)

The TDS consist of calcium, chlorides, nitrate, phosphate, iron, sulfur, and other ions [15]. The average TDS values of water samples were obtained as 254.73 mg/l (Yb), 263.90 mg/l (Ag), and 259.3 mg/l (Yw). According to WHO guiding principle, a TDS level of up to 500 mg/L is considered highly desirable, while levels up to $1,500 \text{ mg/L}$ are the higher permitted. TDS values ranged from 254.73 mg/L to 263.90 mg/L , showing that most groundwater fall well within the maximum permissible limit (Table 1). All measured values complied with WHO standards.

3.1.6. Calcium, Sodium

Calcium is an indispensable element in the human body for cell construction and bone building. The mean values of calcium concentration were found 25.33 mg/L (Yb), 28.10 mg/L (Ag) and 26.43 mg/L (Yw) (Fig 2). According to quality water standards highest permissible concentration of calcium in drinking water is 100 mg/L . In all samples the mean values of Ca^{2+} were observed within the guidelines,

indicating the water is appropriate for drinking purpose.

Sodium is an essential element commonly found in natural waters. The amount of sodium in drinking water is usually below 20 mg/L . In this study, the amount of sodium in water samples ranged from 30 mg/L to 33.8 mg/L , beyond the 20 mg/L benchmark. This elevated level may be attributed to dissolved salts originating from natural underground rocks.

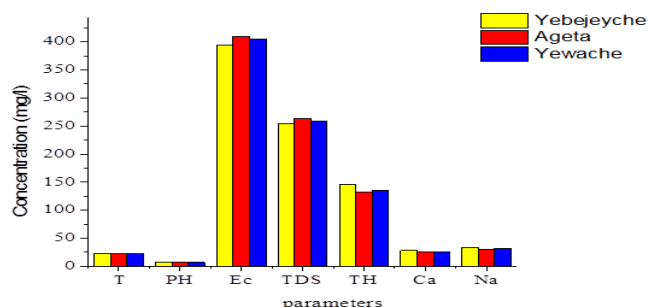


Figure 2. Concentration of parameters in various water samples

3.2. Determination of heavy metals

The amount of selected heavy metals was analyzed by validated analytical method. The mean with standard deviation values of all metals determined in the samples taken from the three sampling sites were shown in Table 2.

Table 2. Results of the mean concentration ($\bar{X} \pm \text{SD}$, $n=3$) of selected heavy metals in the water sample

Sampling sites			
Heavy metals	Yebejeiche Mean $\pm$ SD	Ageta Mean $\pm$ SD	Yewach Mean $\pm$ SD
Cr (mg/l)	0.0022 $\pm$ 0.0005	0.0035 $\pm$ 0.0005	0.0019 $\pm$ 0.0046
Fe (mg/l)	0.04 $\pm$ 0.010	0.05 $\pm$ 0.010	0.03 $\pm$ 0.020
Zn (mg/l)	0.115 $\pm$ 0.0002	0.223 $\pm$ 0.0001	0.149 $\pm$ 0.0046
Cd (mg/l)	0.005 $\pm$ 0.0008	0.004 $\pm$ 0.0001	0.003 $\pm$ 0.0002
Pb (mg/l)	0.0306 $\pm$ 0.0015	0.018 $\pm$ 0.0001	0.028 $\pm$ 0.0001

3.2.1. Zinc (Zn), Iron (Fe), Cadmium (Cd), Chromium (Cr), Lead (Pb)

In this study, the average iron concentrations in the water samples were 0.04 mg/L for Yb, 0.05 mg/L for Ag, and 0.03 mg/L for Yw. All values were within the limits recommended by WHO standards. The mean zinc concentrations in the water samples were Yb (0.115 mg/l), Ag (0.223 mg/l), and Yw (0.149 mg/l). At all three sampling sites, the Zn levels remained within the permissible limits set by WHO.

Cr exists in trivalent and hexavalent states. Hexavalent Cr enters water via industrial wastewater water, mainly discharged from paint and tanning factories. The chromium mean concentration values of the studied samples were found between 0.0019 mg/L to 0.0035 mg/L (Table 2). All three sample sites were within the permissible limit. Cadmium can be present in groundwater either naturally or as a contaminant originating from sewage sludge, fertilizers, or polluted water from mining and industrial discharges [13]. In the current study, the average values of cadmium concentration in the water samples were Yb (0.005 mg/L), Ag (0.004 mg/L), and Yw (0.003 mg/L). All three water samples were obtained within the permissible limit of the WHO standards.

Lead is fatal to humans even consumed in low concentrations and is present in various household products. Its levels in the environment can rise due to human activities, particularly from vehicle exhaust emissions. In this study, the average concentrations of lead in the three samples were Yb (0.0306 mg/L), Ag (0.018 mg/L), and Yw (0.028 mg/L). These values exceeded the maximum permissible limits set by USEPA and ESS but remained within the guideline value of WHO. The elevated levels of lead may be attributed to pipe corrosion, likely caused by the slightly acidic nature of the water at the welded sections.

3.3. Comparison of selected heavy metals in hand pump water samples

The concentration comparison of heavy metals in the three samples is shown in the following graph.

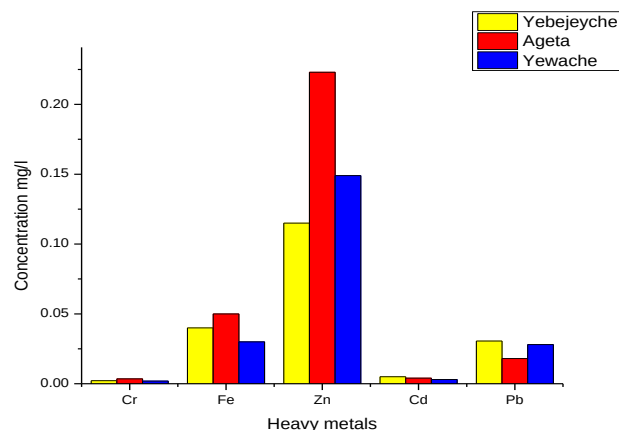


Figure 3. The graphs of heavy metals concentrations of hand pump water samples.

3.4. Method Validation and Quality Control Results

3.4.1. Calibration Curve and Linearity of Instrumental Responses

The calibration equation of each analyzed metal is revealed in Table 3. As observed from calibration curves, the correlation coefficient (regression, r^2) value of each metal varied in the range of 0.997- 0.999. These values were greater than the minimum linear correlation coefficients of accepted value of 0.995 set by [10]. Therefore, there was a linear relationship between instrumental response and standard concentration of each analytes. These indicated that, the present work was suitable for the quantification of unknown concentration in the individual water samples. Table 3 reveals the limit of detection (LOD), instrumental detection limit (IDL), and limit of quantification (LOQ) for the target analytes.

Table 3. The result of IDL, LOD, LOQ, r^2 values of metals in hand pump water samples (n=3)

Ana ly.	Calibration equation	IDL (mg/l)	LOD (mg/l)	LOQ (mg/l)	r^2
Na	$Y=0.9886x+0.1299$	0.050	0.120	0.360	0.999
Ca	$Y=0.1376+0.0015$	0.020	0.060	0.180	0.999
Fe	$Y=0.0299x+0.0067$	0.002	0.005	0.015	0.997
Cr	$Y=0.0411+0.0009$	0.003	0.050	0.200	0.999
Zn	$Y=0.1707+0.0025$	0.0025	0.046	0.138	0.999
Cd	$Y=0.1475+0.0017$	0.001	0.003	0.012	0.999
Pb	$Y=0.158x+0.0013$	0.001	0.0015	0.004	0.999

3.4.2. Method Accuracy and Precision

In this study, the accuracy and precision of the analytical methods were assessed using triplicate laboratory-fortified matrix samples (n=3) spiked at a mid-range calibration concentration. The percentage recovery of target analytes in the water samples showed values ranging between 86.56% to 104.77%. These results are confirming that the method achieved the required level of accuracy. Precision was determined by calculating the relative standard deviation (RSD) from repeated measurements, which ranged between 0.040% and 3.90%. These results show that the present study demonstrated good precision.

3.4.3. Comparison of the Current Results with Standards

The water quality parameters of the three representative hand pump water samples of in this study were assessed in contrast to WHO drinking water standards. Based on the output of the study, three hand pump water were recommended for drinking purposes because the level of water quality parameters (Temp, pH, EC, TH, TDS, Na, Ca, Fe, Cr, Cd, Zn, and Pb) were below the higher permissible limits of WHO, 2017 sets for drinking water.

Sampling Sites				
Anal. (mg/g)	Yebejeych Mean*±SD	Ageta Mean* ±SD	Yewach Mean*±SD	[12]
Cr	0.0022±0.0005	0.0035±0.0005	0.0019±0.0046	0.000-0.1
Fe	0.04± 0.01	0.05± 0.01	0.03± 0.02	0.300
Zn	0.115± 0.0002	0.223± 0.0001	0.149± 0.0046	5.000
Cd	0.005± 0.0008	0.004± 0.001	0.003±0.0002	0.005-0.010
Pb	0.0306± 0.0015	0.018± 0.001	0.0218± 0.001	0.100
Na	28.1±0.0020	25.3±0.0005	24.± 0.0005	1.0-200
Ca	0.671± 0.0005	1.192± 0.001	1.054± 0.0011	75-100

4. Conclusion

Groundwater is a common source of water for food preparation and for drinking purpose for many communities around the world, and its contamination can significantly reduce water quality. In this study, selected physicochemical parameters of three groundwater samples were analyzed, including electrical conductivity (EC), temperature, total hardness (TH), total dissolved solids (TDS) and pH. Additionally, one alkali metal (sodium), one alkali earth metal (calcium) and five heavy metals (chromium, iron, zinc, cadmium, and lead) were examined. The results were evaluated against established standards drinking water quality and were found to obey with the allowable limits established by the WHO

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