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Physico chemical analysis of spring water used in Anger: Gutie Town, East Wollega, Ethiopia

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Abstract
Water quality is essential parameter to be study when the overall focus is sustainable development keeping humanity at focal point, since it has directly linked with human welfare. The present study conducted to assess the spring water quality in Anger Gutie Town East Wollega, Oromia, Ethiopia. The samples were analyzed for six physico–chemical parameters (Temperature, pH, Total dissolved solids, Total Suspended Solid, Electrical conductivity, Turbidity), for eleven major chemical parameters (Al^{3+},Cr^{+6},Cu, Mn, Fe,K^{+},SO_4^{2-}, PO_4^{3-}, NO_2^{-}–N, F^{-}, Cl^{-}), and four other physico–chemical parameters (SiO_2, NH_3–N, Total hardness, and Dissolved oxygen) using standard methods. The analyzed parameters in waters were below the currently recommended guidelines for drinking and irrigation water quality.

Keywords: Spectro-photometric methods, Physico–chemical parameters, spring water, Ethiopia

1. Introduction

Water is an essential component of the resources required by all life forms; it is a universal solvent of organic or inorganic compounds [1, 2]. Water for human consumption must be free from contaminants and/or pollutants, which include toxic elements, chemical compounds and microorganisms. Natural water from rivers, springs and underground resource are polluted by the addition of a various kinds of contaminants through residential sewage, industrial effluents, agricultural runoff and the like; this brings about a series of changes in the physico-chemical characteristics of the water [3]

Spring water is believed to be comparatively much clean and free from pollution than surface water [3]. However, spring water is usually exposed to pollution either by natural or anthropogenic causes or by both [4]. Natural causes of spring water pollution are generally the result of leaching from geologic formations [5]. The major sources of anthropogenic pollution include waste dumps by landfills, accidental spills, agricultural runoff, septic tanks, and the like. These waste materials introduce harmful pathogens, inorganic and toxic organic chemical pollutants [5, 8]. In developing countries like Ethiopia, spring water is the major source of drinking water. The suitability of spring water for drinking purpose is determines by its quality [9].

Water quality analysis essential requirement for sustainable development since it is directly linked with human welfare [10]. The World Health Organization (WHO) sets guidelines for drinking-water quality from which national standards of countries could be derived as required [11]. According to WHO, about 80% of all the diseases in human beings are caused by water. The study of physico-chemical parameters like pH, total hardness (TH), electrical conductivity (EC), temperature, turbidity, total dissolved solid (TDS), total suspended solid (TSS) as well as major cations and anions is used to set the quality of water.

The Anger Gutie town is located in East Wollega Zone, in Oromia region of Ethiopia. Spring water is the major source of drinking tap water in the town. The physico-chemical properties of this drinking water have not studied so far for quality check; hence, there is no baseline data for this water resource. Therefore, the objective of this study was to analyze selected physico–chemical parameters of the spring water used for drinking and domestic purpose in the town.

2. Materials and Methods

2.1 Description of the Study Area

The study area is Anger Gutie spring water used for drinking purpose. It is located in East Wollega zone, Western Ethiopia of Oromia Regional State. It is included in Gida Ayana “wereda” and is 70 km far from Nekemte Town (Figure 1). The satellite navigation system locates Anger Gutie, within 9°33'39.32" N 36°37'47.08" E and altitude of 1390 m. The laboratory analyses were carried out in the chemistry department of Wollega University and Nekemte Town Water Supply and Sewerage Enterprise.

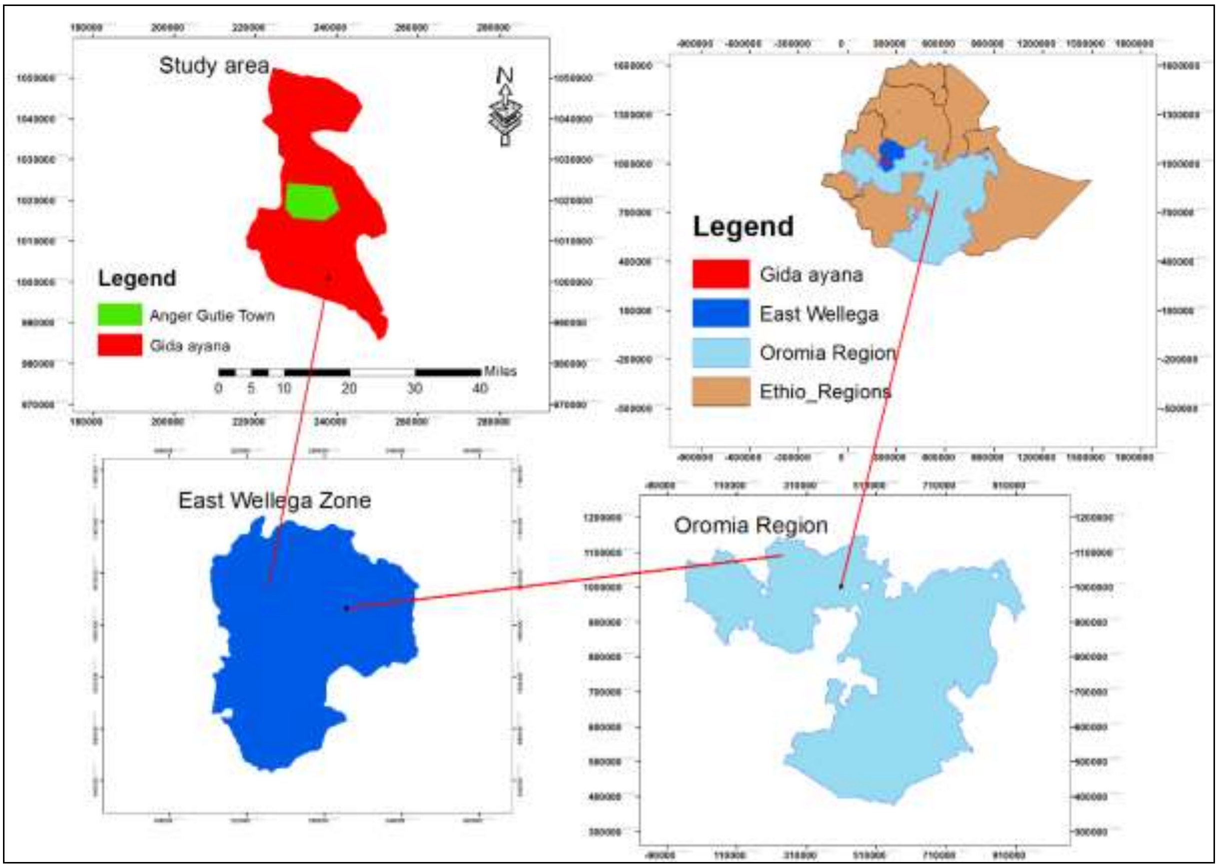

Fig 1: Map of Sampling Site

2.2 Instruments and Equipment

For the analysis of physico–chemical properties of water different instruments such as portable spectrophotometer (Model Dr/2400), portable microprocessor turbidity meter, microprocessor based conductivity/TDS meter (Model1601), DO meter, pen type pH meter (Model 009), Thermometer, Refrigerator, Whatmann filter paper, beakers (different size), volumetric flask (different size), and digital analytical balance were used.

2.3 Chemicals and Reagents

Methyl orange indicator, $CaCO_3$, sodium hydroxide, anhydrous sodium carbonate, 50% silver sulfate, buffer solution, distilled water, H_2SO_4, Na_2SO_4, silver nitrate, potassium chromate, KCl, EDTA Solution, Ascorbic acid, sulfuric acid reagent calcium and magnesium indicator solution and phosphate reagent. All chemicals used were of high purity and analytical grade. At all times, fresh reagents are used and great care has taken to avoid chemical contamination.

2.4 Sample collection and preservation

The water sample from Anger Gutie drinking spring water have been collected following standard procedure as described by APHA. Using pre-cleaned plastic bottle of one-liter capacity. Prior to sampling, plastic bottles have washed with detergents; HNO_3 acid, tap water, then distilled water, and later rinsed with sampled water several times. Sample containers have labeled on the field using appropriate codes. The protected spring water samples have collected from four sites of tap water based on the recommended specific guidelines. Samples had also been collected from (S_1 = spring water, S_2 = collection chamber, S_3 = reservoir, S_4 = tanker, residences and hotels). The water samples were temporarily stored in ice packed cooler and transported to the laboratory and stored in a refrigerator at about 4ºC prior to analysis [12].

2.5 Sample analysis

The present study has conducted through experimental method. The physical parameters such as pH, Electrical conductivity (EC), Turbidity, Dissolved oxygen (DO), and Total dissolved solids (TDS) by instruments listed in Table 1 was been determined. Total suspended solids (TSS) have determined by filtration method. The other chemical parameters including Chromium (Cr^{+6}), Chloride (Cl^-), Sulphate (SO_4^{-2}), NH_3–N, K^+, Al^{+3}, Fe, SiO_2, Cu, F^-, Mn, NO_2^-–N and phosphate (PO_4^{3-}) were analyzed using spectrophotometers with their respective reagents as indicated on Table 1. The water Temperature, pH, TDS and Electrical conductivity have analyzed immediately on the spot during the sample collection, whereas the analysis of remaining parameters has done in the laboratory [5, 8, 13, 14].

Table 1: Methods used for the determination of physico–chemical parameter

S/N	Parameters	Methods
1	Turbidity	Nephelometric method
2	Temperature	Temperature meter
3	pH	pH Method
4	Electrical conductivity (EC)	Conductivity Method
5	Dissolved Oxygen (DO)	HRDO Method
6	Total dissolved solids (TDS)	Conductivity/TDS Method
7	Total suspended solids (TSS)	Filtration method
8	Aluminum (Al^{3+})	Aluminon Method
9	Chromium (Cr^{6+})	1,5-Diphenylcarbohydrazide Method
10	Copper (Cu)	Bicinchoninate Method
11	Manganese (Mn)	Periodate Oxidation Method
12	Iron (Fe)	FerroVer® Method
13	Potassium (K)	Tetraphenyl borate Method
14	Silica (SiO_2)	Silicomolybdate Method
15	Nitrite-Nitrogen (NO_2^-–N)	Diazotization Method
16	Phosphate (PO_4^{3-})	PhosVer® 3 (Ascorbic Acid) Method
17	Sulfate (SO_4^{2-})	SulfaVer® 4 Method
18	Fluoride (F^-)	SPADNS Method
19	Hardness	Complexometric titration method
20	Chlorine, (Cl^-)	Argentiometric titration Method
21	Ammonia-Nitrogen (NH_3-N)	Salicylate Method

3. Results and Discussion

The water samples collected from the four sites (S_1 = spring water, S_2 = collection chamber S_3 = reservoir and S_4 = distribution sites in residence, certain centers or hotels) in Anger Gutie Town spring water were analyzed for different measurement parameters. A summary of values (Mean± SD) of different selected physical and chemical parameters (n=3) of the protecting spring water samples have been presented in the following sections.

2.5 Common Physical Parameters

The results of the studied common physical parameters including Electrical conductivity, Total dissolved solid, Total suspended solid, Turbidity, Temperature, and pH are displayed in Table 2.

Table 2: The Mean values of common physical parameters in the studied water samples

No	Parameters	Sampling sites					
		S_1	S_2	S_3	S_4	ESA	WHO
1	EC (μs/cm)	28.16	31.23	34.83	810	-	1,500
2	TDS (mg/L)	217	270	322	524.66	1000	1000
3	TSS (mg/L)	0.33	1.46	1.13	1.06	-	-
4	pH	5.1	5.5	6.2	6.1	6.5-8.5	6.5 - 8.5
5	T (°C)	25	25	24	24	-	25
6	Turbidity (NTU)	0.5	1.8	4.7	4.9	-	5

2.5.1 Electrical conductivity (EC)

The value of the electrical conductivity of sample from distribution sites (S_4, 810μS/cm) differ significantly from the values of those of spring water (S_1, 28.16μS/cm), reservoir (S_3, 34.83μS/cm) and collection chamber (S_2, 31.23μS/cm) (Table 2). Thus, the minimum and maximum EC values of 28.16 and 810μS/cm has observed respectively. Large differences have observed between the conductivity values of spring water (S_1) and those of distribution sites (S_4). High conductivity indicates high water mineralization. The geomorphological context, depth of the levels captured and geological nature of soil formations are all factors that influence variations in conductivity [16]. This should attribute to the quality/sanitary status of the tanker (reservoir) at S_3 and/or the lines from the tanker to the distribution site (S_4). Generally, the value of all water sample of the electrical conductivity is comparable with in ESA and WHO guideline.

2.5.2 Total Dissolve Solid (TDS)

The electrical conductivity of water samples correlates with the concentration of dissolved minerals or with what commonly known as the total dissolved solid of water samples. The acceptable range of total dissolved solid is less than 1000 mg/L as recommended by ESA and WHO. The range of total dissolved solid of analyzed water samples varied between 217 to 525 mg/L as shown in Table 2. The highest total dissolved solid value has observed on the distribution site. This unusual increase of total dissolved solid in the line between the reservoir and distribution sites may indicate that the pipeline with in the locations has some scratch or broken parts allowing leakage of soluble solids in to the water [12]. Therefore, we can conclude that the total dissolved solid of Anger Gutie spring water is within ESA and WHO permissible limit.

2.5.3Total Suspended Solids (TSS)

The total suspended solid values of the water samples ranged from 0.33 to 1.46 mg/L. Total suspended solid value usually taken as an index of contamination potential of drinking water [15]. This may introduce different diseases, which affect all living things especial human beings.

2.5.4 Hydrogen Ion Concentration (pH)

The minimum and maximum pH values of 5.1 and 6.2 (Table 2) have observed respectively in the spring water and reservoir water sample ($S_1$and S_3). All the value of spring water sample is below the ESA and WHO range (6.5 to 8.5). This result shows that the pH of these waters has an acidic tendency (pH below 7). The spring water sources with pH below 6.5 may attributed to the discharge of acidic products into this source by the agricultural and domestic activities. The bedrock of the area may not have basic rocks such as carbonate minerals. This may supported by the fact that studies have shown that 98% of all spring water worldwide related to the geological nature of the aquifer formations and the lands traversed [17].

2.5.5 Temperature
In the present study temperature varied from 24^0C–25^0C. All the water samples of temperature have found within the permissible limit set by WHO guidelines. The temperature of the spring water in this study area is quite high; this should attribute to the altitude of the region. Temperature is an important factor to influence the physico–chemical parameters and the biological reaction in water. Higher values of temperature accelerate the chemical reaction, to reduce the solubility of gases and dissolved oxygen [17].

2.5.6 Turbidity
The minimum and maximum turbidity values of the water samples was found to be of 0.5 and 4.9 NTU (Table 2) respectively in in spring water sample and distribution site water sample (S_1 and S_4). All the water samples of turbidity were found below the permissible limit set by WHO. Turbidity of water is actually the expression of optical property in which the light is scattered by the particles present in the water. Clay, silt, organic matter, Phytoplankton and other microscopic organisms cause turbidity in spring water [6].

2.6 Common Chemical Parameters
The results of the studied common metals including Al^{3+}, Cr^{+6}, K^+, Cu, Mn, and Fe are displayed in Table 3.

Table 3: Themean values of common metals in the studied water samples in mg/L

No	Parameters	Sampling sites					
		S_1	S_2	S_3	S_4	ESA	WHO
1	Al^{3+}	0.038	*BDL	BDL	0.002	0.20	0.20
2	Cr^{+6}	0.07	0.04	0.11	0.1	-	0.05
3	Cu	0.04	0.05	0.06	0.08	2	1.00
4	Mn	1.4	2.5	1	0.3	0.5	0.40
5	Fe	0.07	0.07	0.43	0.2	0.3	2.00
6	K^+	0.6	0.5	0.1	0.9	1.5	-

*BDL= below detection limit

2.6.1 Aluminum ion (Al^{+3})
The maximum value (Table 3) of Aluminum concentration recorded in the spring water sample (0.038 mg/L) and the other collection chamber and reservoir water samples recorded below detection limit. Ethiopian Standard Agency and World health organization recommended that the concentration should not exceed 0.2 mg/L. As a result, the observed concentration level of aluminum was within the acceptable limit of a given ESA and WHO guidelines [16].

2.6.2 Chromium ion (Cr^{+6})
The acceptable range of Cr^{+6} is 0.05 mg/L. The range of $Cr^{+6}$of analyzed water samples varied between 0.04 to 0.11 mg/L as shown in Table 3. The highest Cr^{+6} value was observed at location of the reservoir. Therefore, it can be concluded that the Cr^{+6} of Anger Gutie spring water above WHO maximum permissible limit [14].

2.6.3 Copper (Cu)
The minimum and maximum value of this study area was recorded in the spring water (0.04) and distribution site (0.08) in Table 3. All water samples in this study have Copper quantities below the permissible limit in ESA and WHO guidelines. Copper is an essential nutrient, but at high doses it causes stomach and intestinal distress, liver and kidney damage, and anemia [12].

2.6.4 Manganese (Mn)
Manganese is generally present in natural spring water at concentrations below 0.40 mg/L. However, the level of Mn in “Anger Gutie” spring water was about 2.5 mg/L in collection chamber, 1.4 in spring water sample and 1in reservoir water sample, which is above the recommended value of ESA and WHO. Manganese occurs in over 100 common salts and mineral complexes that are widely distributed in rocks and soils. Manganese is an essential element in humans and animals. It has regarded as one of the least toxic elements; toxicity in humans is usually the result of chronic inhalation of high concentrations of manganese in dust from industrial sources. At levels exceeding 0.15 mg/L, manganese stains plumbing fixtures and laundry and causes undesirable tastes in beverages. It may lead to the accumulation of microbial growths in the distribution system that could give rise to taste, odor, and turbidity problems in the distributed water [18].

2.6.5 Iron (Fe)
The amount of iron in the water samples range from 0.07 to 0.43 as given in Table 3; this data found within WHO guidelines. However, in the reservoir water sample recorded 0.43 above ESA. Food rich in iron is very important, particularly for children and women in fertile age. The recommended daily intake is 10mg. Possible increase in iron (up to 200 mg/L) are not to be considered harmful, even if they make the water not nice to drink and give an unpleasant reddish color. It found that more significant concentration in drinking water because of its abundance in the earth’s crust [19].

2.6.6 Potassium ion (K^+)
The Potassium ion concentration of analyzed water samples varied from 0.1 to 0.9 mg/L in reservoir and distribution site as shown in Table 3. All the water sample value recorded with in ESA. Potassium occurs naturally in water after passing through certain mineral deposits and rock strata. Potassium is an important cation and plays a vital role in intermediately metabolism. Potassium is an essential nutrient for both plant and human life. However, ingestion of excessive amounts may prove detrimental to human beings Common anion composition of the water samples studied includes PO_4^{3-}, SO_4^{2-}, F^-, NO_2^- and Cl^-. The resulting data displayed in Table 4.

Table 4: The mean values of common anions in the studied water samples in mg/L

No	Parameters	Sampling sites					
		S_1	S_2	S_3	S_4	ESA	WHO
1	PO_4^{-3}	0.46	1.15	1.23	4.68	-	-
2	SO_4^{-2}	3	4	1	1	250	500
3	F^-	BDL	BDL	BDL	0.34	1.5	1.5
4	NO_2^-–N	6.3	5.7	6.4	22.4	3	3
5	Cl^-	22.72	21.6	42.6	24.85	250	250

2.6.7. Phosphateion (PO_4^{-3})
In the present study the phosphate concentration varied from 0.46 to 4.68 mg/L (Table 4). The maximum concentration of phosphate is 4.68 mg/L detected at the distribution site (S_4) while minimum concentration of phosphate observed 0.46

mg/L at the spring water sample (S_1). The maximum permissible limit for PO_4^{-3} has not indicated in the ESA and WHO guideline [11, 14].

2.6.8. Sulphateion (SO_4^{2-})
The sulphate content in analyzed water samples varied from 1 to 4 mg/L shown in Table 4. All the samples found to be well within permissible limit of ESA and WHO guidelines. Sulphate occurs naturally in many source waters after contact with particular mineral deposits and rock strata. The concentrations normally found in drinking water do not represent a risk to health. Sulphur in spring water is normally present in sulphate form. Sulphate may enter into spring water through weathering of sulphide bearing deposits [15]. The acceptable limit of sulphate is 250 mg/L.

2.6.9. Fluoride ion (F^-)
The concentration of fluoride in spring water samples is below detection limit for most of the sites in spring water sample, collection chamber and reservoir (S_1, S_2, and S_3). The sample from distribution site (S_4) is to found to contain about 0.34 mg/L as shown in Table 4. Fluoride concentrations in all these samples have found to be well within permissible limit of ESA and WHO. The sources of fluorides are mainly, industries of iron, steel production and petroleum refining and phosphate fertilizer. Higher concentration of fluoride causes bone and dental fluorosis. The ESA and WHO permissible limit for fluoride in spring water is 1.5 mg/L as given in Table 5. However, in temperate region this limit is 1.5 mg/L, where, water intake is low. Fluoride (F^-) varied from permissible limit for F^- concentration is 1−1.5 mg/L according to WHO (2003). Fluoride concentration less than 0.8 mg/L leads to dental caries. Hence, it is essential to maintain fluoride concentration between 0.8 to 1.0 mg/L in drinking water [15, 18].

2.6.9. Nitriteion (NO_2^-)
The mean value for the spring water sample has recorded as 5.7−22.4 (Table 4). It was recorded above ESA and WHO guideline value. Therefore, these sources may not be safe for domestic and livestock use. Nitrites are most of the time absent from surface waters, but their presence is possible in groundwater, mainly because nitrogen will tend to exist in smaller (ammonia) or more oxidized (nitrate) forms[16].

2.6.10. Chlorideion (Cl^-)
In the analyzed water samples, the concentration of chloride varied from 21.6 to 42.6 mg/L. The chloride content of the water sample has found that all samples showed concentration within the permissible limit. The maximum Chloride concentration has observed at S_3 (reservoir), as shown in Table 4.

This could be because of the addition of Chloride on the reservoir. Chloride is an anion found in variable amount in spring water. Chloride may also be present naturally in spring water and may also originate from diverse sources such as weathering, leaching of sedimentary rocks and infiltration of seawater etc. The maximum permissible limit of ESA and WHO chloride in potable water is 250 mg/L. It produces salty taste at 250−500g mg/L.

2.7 Other Physico−Chemical Parameters
The other physico−chemical parameters of the water samples studied include total hardness, ammonia, Silica and dissolved oxygen. The resulting data are displayed in Table 5.

2.7.1 Silica (SiO_2)
The SiO_2 of the analyzed water samples in this study varied from 17.9−32.8 mg/L in Table 5.The crystalline form of silica, feldspars, amphiboles, pyroxene and mica the silicate minerals are the chief source of silica in spring water. In the freshwater, silica comes next in abundance to bicarbonate, but at higher concentrations the silica content is usually less than sodium bicarbonate, sulphate and chloride. Normal concentrations of silica were found in some highly alkaline waters and in some acidic waters[19]

Table 5: The mean values of other Physico–Chemical Parameters in the studied water samples in mg/L

No	Parameter	Sampling sites					
		S_1	S_2	S_3	S_4	ESA	WHO
1	SiO_2	18.4	32.8	19.7	17.9	-	-
2	NH_3–N	0.04	0.06	0.06	0.18	1.5	0.5
3	TH	116.79	206.87	236.9	286.95	300	400
4	DO	6.1	8.7	6.7	6.8	-	4.5–7.5

2.7.2. Ammonium (NH_3−N)
Ammonium (NH_3−N): The mean value of contamination of NH_3−N in the spring water sample varies from 0.04−0.06 mg/L shown in Table 5. However, the mean values of all the water samples are within the permissible level of Ethiopian Standard Agency and World Health Organization guideline[11] value for safety drinking water (1.5 and 0.5 mg/L). These high values could been explained by anthropogenic activities and fecal pollution originating from animal (spreading of wastewater, livestock breeding, and use of animal waste as fertilizer for agricultural land adjacent to water points) and the poor protection of these sources.

2.7.3. Total Hardness (TH)
The highest value of total hardness observed at distribution site, as shown in Table 5. In spring water, bicarbonates, carbonates, sulphates and chlorides of calcium and magnesium mainly contribute to water hardness. So, the principal hardness causing ions are calcium and magnesium. The acceptable limit of total hardness is in WHO 400 mg/L and ESA 300 mg/L. The hardness of the analyzed water samples in this study-varied from117 to 287 mg/L as $CaCO_3$. Water was classified as soft, moderate, hard and very hard;0−60 (soft water), 61−120 (moderate water), 121−180 (hard water),>181(very hard water)[14,19]. As per this classification, the collection camber comes under moderate and other three water samples are under very hard water category. Based on this classification, it has observed that no water samples are soft, 25% are moderately hard and 75% are very hard in nature.

2.7.4. Dissolved Oxygen (DO)
The dissolved Oxygen (DO) values for spring water samples ranged between 6.1−8.7 mg/L. There were not significant differences for dissolved oxygen values among the spring water. It was found that in collection chamber (S_2) contained the highest level 8.7 mg/L and in spring water sample (S_1) contained the lowest 6.1 mg/L as shown in Table 5. It is one of the most important parameters to

indicate the water purity. According to the environmental quality standard (EQS), the following requirements for DO are prescribed as 6.0 mg/L for drinking purpose, 4.0−6.0 mg/L for fish and livestock and 5.0 mg/L for industrial application[15].

3. Conclusion

In this study, four different site of spring water sample collected from Anger Gutie Town from East Wollega zone have assessed for the physical and chemical parameters. Such as pH, EC, TDS, TSS, T (^{0}C), Turbidity, Al^{3+}, Cr^{+6}, Cu, Mn, Fe, K^+, PO_4^{-3}, SO_4^{-2}, F^-, NO_2^-, Cl^-, SiO_2, NH_3−N, total hardness and dissolved oxygen of the spring water were measured. The experimental data values obtained in the current study are in line with World health organization (WHO) guidelines except for the dissolved oxygen in collection chamber. The ions NO_2^--N, Mn in (spring water, collection chamber and reservoir) and Cr^{+6} in (spring water, collection chamber and distribution site) were higher than the permissible levels for safe drinking water set by WHO and pH value was below WHO guidelines. Following this, the drinking spring water at the four locations were potable for drinking after moderate treatment of Mn, NO_2^-, pH, Cr^{+6} and dissolved oxygen. Generally, Anger Gutie protecting spring water was suitable for drinking purpose. The water quality varies depend on type of soil, climate and human activities. Compare to other studies in another part of the world this spring water has good physico-chemical property for drinking and domestic purpose according to the analysis of the current study. This study presents baseline data for future reference especially for drinking water assessment in Anger Gutie Town.

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