IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 7, Issue 6 Ser. I (Nov. – Dec. 2019), PP 15-21
www.iosrjournals.org

Suitability of Water for Drinking and Irrigation Purpose in A Part Of Kulfo River Basin, Arba Minch, Ethiopia

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Abstract : *Surface water is one of the most important sources for drinking and agricultural purpose in many parts of the world. The unsuitability of surface water is often caused due to the contamination by inherent toxicity of rocks. Surface water contains many necessary ions like sodium, potassium, calcium, magnesium, chloride, sulphate, bicarbonate and fluoride the concentration of which has considerable effect on surface water quality if exceeding the permissible limits. However, the consumption of water with desirable concentration of ions is good for human health. An assessment of river water quality with special reference to drinking and irrigation purpose was carried out in a part of Kulfo River basin, Arba Minch, Southern Ethiopia. Surface water in the study area is mostly alkaline. The concentration of cation in river water is in the order of* $Na^{+} > Mg^{2+} > Ca^{2+} > K^{+}$*, while that of anions is* $Cl^{-} > HCO_3^{-} > CO_3^{-}$*. The types of water in the area found to be mixed Ca-Mg-Cl-*SO_4 *and Na-*HCO_3^{-} *type. Based on TDS values, most of the river water samples fall under fresh showing most of the study area is characterized by suitable surface water for drinking purposes. The concentration of all cations and anions were within the recommended limits of drinking water quality set by both Ethiopian Standard and WHO guide lines. The water samples are classified as good (50%) and permissible (50%) according to sodium percentage. Therefore, the river water is good for irrigation purpose. The SAR of water of this region varies from 0.79 to 1.54. With respect to RSC, 100% of water samples of this area are safe for irrigation, and none of the sample is falling under doubtful category*
Keywords *– Kulfo river, spring, water quality index, permissible limit, irrigation quality*

Date of Submission: 26-10-2019 Date of Acceptance: 11-11-2019

I. Introduction

Surface water is being widely used to meet varies needs of the human kind around the world. Around one third of the world's population consumes surface water for various purposes like domestic, agriculture and industry [8]. Potable water is the water which is suitable for drinking and cooking, and for agricultural purposes. Portability considers both the safety of water in terms of health, and its acceptability to the consumer, usually in terms of taste, odor, color, and other sensible qualities [2]. The quality of water is highly important component to understand the healthiness of a water body and is a critical factor affecting human health and welfare of the society. Physicochemical and biological water quality indicators will be affected by various ways. The main causes for the water quality deteriorations are anthropogenic and natural agents. Some of the natural and human induced factors, which affect the quality of water, are water-rock interaction natural hazards, sedimentation/erosion, agricultural and industrial activities, mining, fishing, sewage discharging/disposal, deforestation, and other commercial activities. These activities aggravate the contamination and pollution of water bodies and greatly influence the quality of water [17]. The main objective of this paper is to investigate suitability of water for drinking and irrigation purpose in a part of Kulfo River basin, Arba Minch, Ethiopia.

II. Study Area

The study area is located in Gamo Gofa zone, Southern Nation Nationalities and Peoples' Regional (SNNPR), Arba Minch, Ethiopia (Fig.1). The climate of the study area varies from hot to very hot with average weather condition. The inter-tropical convergence zone (ITCZ) is responsible for the bimodal rainfall system bringing humid wind from the Indian Ocean. Apart from the ITCZ, the effects of altitude affect the rainfall distribution in the area. Most parts of the area are experienced with short rains in spring and long rains in summer [12]. The drainage pattern assumes different shapes and behaviors depending on the soil types, rock formations and structures. The study area is characterized by dendritic drainage pattern. The land use is broadly classified as "Intensive annual crop production" describes areas where annual crops (cereals, pulses, oilseeds and vegetables) are cultivated. "Intensive perennial and annual crop production" describes areas of mixed agriculture where both perennial (coffee, chat, fruit trees like mango, bananas, etc.) and annual crops are the main sources of income. The Kulfo river basin is comprised of volcanic rocks and alluvial sediments. Volcanic rocks constitute the greater portion of the area whereas areas having elevation less than about 1200 m above sea level are restricted to alluvium. Two quite different types of volcanic rocks are identified in the study area [16].

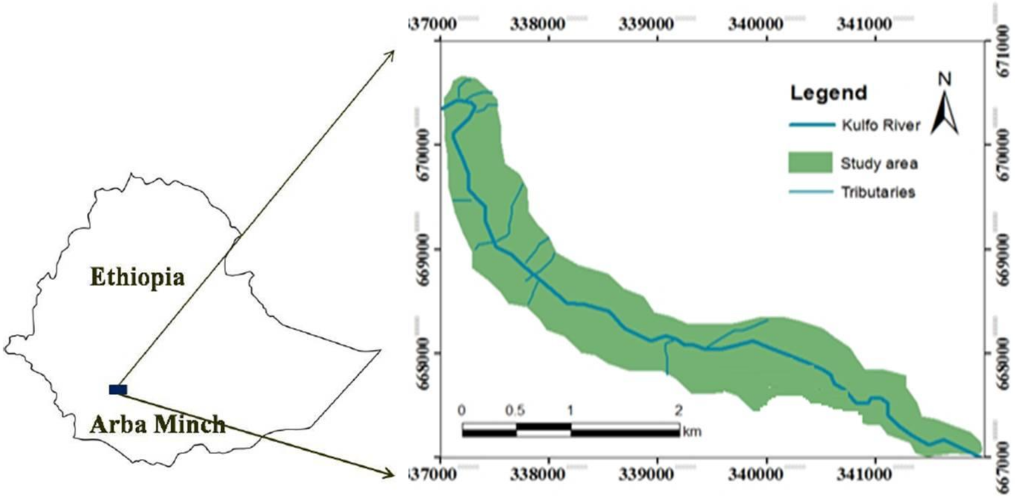

Fig. 1 Location of the study area

III. Methodology

Surface water samples were collected from 6 rivers and 2 spring water during the month of may 2018. The temperature of water was measured by using a digital hand held thermometer, and result was expressed in ˚C. The TDS of water samples was measured using water quality TDS meter. Electrical Conductance (EC) was calculated from the relationship EC = TDS /0.64 [3]. The pH of water was measured with help of digital 'hydrogen ion electrode'. Water samples was analysed for major ion concentration by using standard procedures. Alkalinity of the water samples was analysed by titrating with standard solution of HCl. sodium and potassium analysed by Atomic Absorption Spectrophotometer (AAS), Model 210. Concentration of calcium and magnesium of water samples was analysed by Titrimetry (using complexometric titration with EDTA). Concentration of Chloride of water samples was analysed by Titrimetry (using $AgNO_3$).

IV. Result and Discussion

Study of water chemistry is essential because it will help to know the different geochemical processes that take place in an aquifer system. 6 rivers and 2 springs' water samples were collected and they were analysed for the concentration of major ions. The overall order of the dominance of cations is Na^+> Mg^{2+}>Ca^{2+} > K^+ and of anions is $Cl^−$ > $HCO_3^{−−}$> CO_3^-. Thus, Na^+ is the dominant cation and $Cl^−$ is the dominant anion in water of this river. Piper trilinear diagram [9] was prepared to assess the hydrochemistry of surface and spring water of study area (Fig. 2). The spring water falls in the Na-HCO_3 type and similarly majority of river water samples fall in the Ca-Mg-Cl-SO_4 and a few samples are fall in Na-HCO_3 type. The pH of the water samples of this area ranges from 6.7 to 7.9 with an average value of 7.5 indicating the alkaline nature of the water. Only a one spring samples had pH less than 7. EC of the groundwater ranges from 100 to 439 µS/cm. The minimum, maximum and mean values of EC, pH and concentration of ions are given in Table 1.

Table 1: The minimum, maximum and mean values of EC, pH and concentration of ions

Parameters	Unit	Minimum	Maximum	Mean	Standard Deviation
EC	µS/cm	100	439	194	147.63
pH	-	6.7	7.9	7.5	0.36
Ca^{2+}	mg/l	0	20	6.357142857	7.00
Mg^{2+}	mg/l	5	50	18.625	19.81
Na^+	mg/l	10.44	56.487	22.89625	16.95
K^+	mg/l	0.369	1.96	18.625	0.54
CO_3^{2-}	mg/l	-	-	0	0
HCO_3^-	mg/l	9	43.5	18.9375	12.92
Cl^-	mg/l	39	130	62.75	36.35

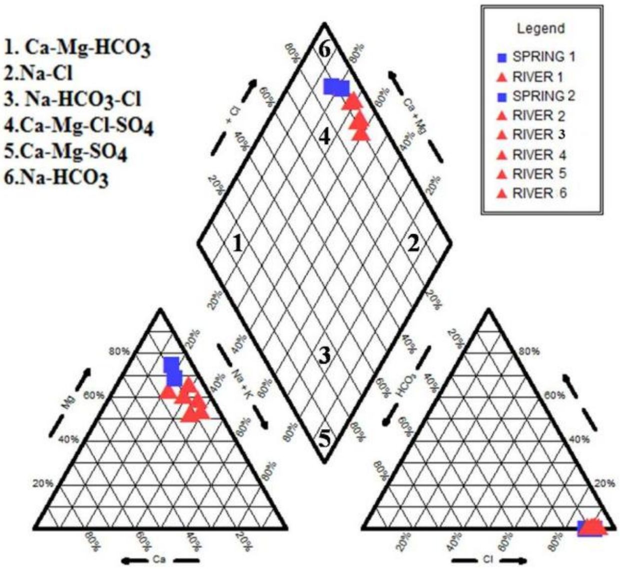

Fig. 2 Piper diagram showing different type of water

Drinking Water Quality

The suitability of river water of this area for drinking purpose was assessed by comparing the measured concentration of ions and other parameters with the recommended ranges given by World Health Organization (2004) and Ethiopian standard (2001) given in Table 2.

Table 2: The number of samples exceeding the WHO (2004) and Ethiopian standard (2001) recommended limits of drinking quality

Parameters	Unit	WHO (2004)		Number of samples exceeding allowable limits	ES(2001)		Number of samples exceeding allowable limits
		Most desirable limits	Maximum allowable limits		Most desirable limits	Maximum allowable limits	
pH	-	6.5	8.5	Nil	6.5	8.5	Nil
EC	µS/cm	-	1500	Nil	-	-	-
TDS	mg/l	500	1500	Nil	-	1000	Nil
TH	mg/l	500	1000	Nil	-	300	Nil
Ca^{2+}	mg/l	75	200	Nil	-	75	Nil
Mg^{2+}	mg/l	30	150	Nil	-	50	Nil
Na^{+}	mg/l	50	200	Nil	-	200	Nil
K^{+}	mg/l	10	12	Nil	-	10	Nil
HCO_3^-	mg/l	300	600	Nil	-	600	Nil
Cl^-	mg/l	200	600	Nil		250	Nil

Out of eight water samples collected and analyzed, the concentration of all cations and anions were always within the recommended limits of drinking water quality set by both ES and WHO guide lines. The spatial variations in pH, EC, TDS and all major ions are explained in the following sections. pH plays an important role in maintaining the carbonate and bicarbonate concentration in water. The pH of water of this river is within permissible limits (6.5–8.5) of [15]. The spatial variation in pH of river water is shown in Fig. 3a. The pH of the water was increase towards lower course that is along the river water flow direction. EC is a measure of the capability of water to conduct an electric current and this depends on concentration of all dissolved ions. The EC of water of this region varies from 100 to 439 µS/cm. The maximum permissible limit of EC according to WHO (2004) for use of water for drinking purpose is 1500 µS/cm. thus, 100% of the samples had EC below the maximum permissible limit of drinking water quality (Fig 3b). To determine the suitability of river water for all purpose, it is essential to classify the water based on the TDS [4]. [7] classified the water as fresh, brackish, saline and brine based on the TDS. The TDS of water of the study region were varies from 64 to 266 mg/l. The classification of water of the study region based the range of TDS as recommended by [7] is given in Table 3.

Table 3: Freeze and Cherry classification of groundwater based on TDS values

TDS (mg/l)	Nature of water	Number of samples	Percentage of samples
<1000	Fresh water	8	100
1000 -10000	Brackish water	Nil	Nil
10000-100000	Saline water	Nil	Nil
>100000	Brine water	Nil	Nil

About 100 % river water samples in the study region falling under fresh and none of water samples are brackish, saline and brine. Magnesium and calcium in water plays a major role on the water quality. The concentration of magnesium in water in this study region varies from 5 to 50 mg/l. The maximum permissible limit of magnesium in drinking water is 150 mg/l [15]. The spatial variation of concentration of magnesium ions in water in the study area is shown in Fig.3c. For humans, calcium is a crucial element for growth of bones and teeth. Calcium ions are common in water, due to the abundance and solubility of calcium rich minerals in all types of rocks and soils. The maximum permissible limit of calcium in drinking water is 200 mg/l [15]. The concentration of calcium in water in the study region is varies from 2 to 20 mg/l. Concentration of calcium in water of this region is lesser than the maximum permissible limits of drinking water standards (Fig. 3d)

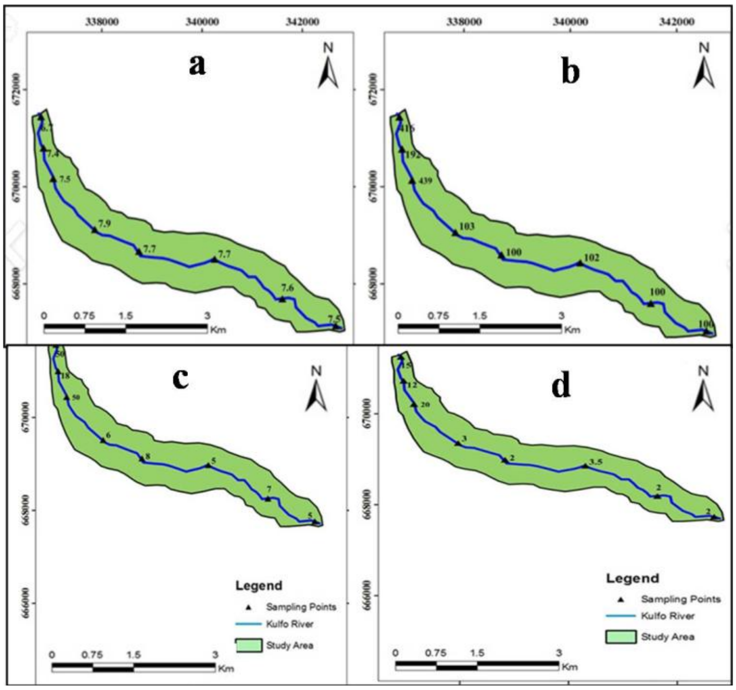

Fig. 3 Spatial distribution of pH(a), EC (b), magnesium (c) and calcium (d) (mg/l)

Sodium is a dominant ion present in majority of the natural waters and contributes around 40 to 75 % of the total cations. This is because of the dissolution of sodium rich salts in the soils, silicate weathering, evaporation from surface water, anthropogenic activities, agricultural activities and poor drainage conditions. The concentration of sodium in water of the study region varies from 10 to 56 mg/l (Fig. 4a). According to the [15], the permissible limit for sodium in drinking water is 200 mg/l. All the water samples were within permissible limit. Potassium is a common ion in water; however, its concentration is normally much lower compared to sodium, calcium and magnesium ions. The minimum concentration of potassium ions in water of this region is 0.36 mg/l and the maximum concentration is 1.96 mg/l whereas the [15] maximum permissible limit for drinking water is 12 mg/l. All of the water samples within the maximum permissible limits for drinking water standard (Fig. 4b)

Generally, chloride is the dominant anion in the water as it is commonly occurring in all nature of rocks. The concentration of chloride in water in the study region varies from 40 to 11 mg/l (Fig. 4c). The chloride concentration is within the maximum allowable limit of 600mg/l [15]. All of the water samples within the maximum permissible limits. Carbonate equilibrium controls the concentration of bicarbonate in water. The concentration of bicarbonate in water of the study area varies from 9 to 43.5 mg/l. All of the water samples analysed within the maximum permissible limit recommended by [15]. The spatial variation in bicarbonate in water of the study area is shown in Fig. 4d.

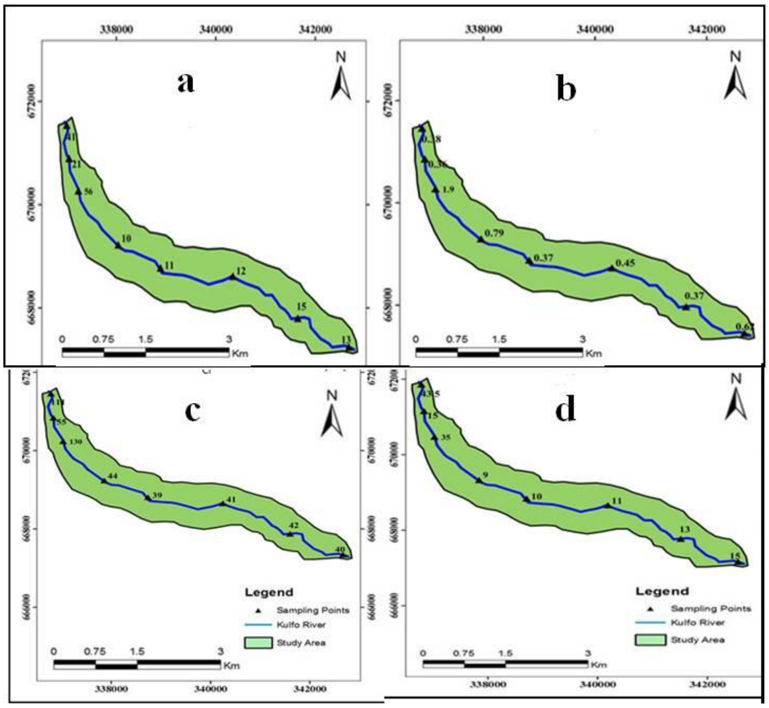

Fig. 4 Spatial distribution of Sodium (a), Potassium (b), chloride (c) and bicarbonate (d) (mg/l)

The major cations that contribute to the hardness are calcium and magnesium ions in water. The hardness in water samples varies from 25.6 to 243 mg/l. Classification of water based on total Hardness as suggested by [11] is given in Table 4. About 12.5 % of the water samples were moderately hard with TH varying between 75 to 150 and 25 % of the water samples were hard with hardness above 150 to 300 mg/l. About 62.5 % of samples were soft with TH below 75 mg/l (Table 4). The most desirable limit of TH in water use for drinking purpose is 500 mg/l and the maximum permissible limit is 1000 mg/l based on [15].

Table 4: Classification of water based on TH (mg/l)

Total hardness as $CaCO_3$ (mg/l)	Water class (Sawyer and McCarty, 1978)	Number of samples exceeding ES limits	Percentage of the Samples exceeding ES limits
<75	Soft	Nil	5
75 -150	Moderately hard	Nil	1
150-300	Hard	Nil	2
>300	Very hard	Nil	Nil

Irrigation water quality

High concentration of dissolved ions such as sodium, carbonate and bicarbonate in irrigation water may affect crops and agricultural soil physically and chemically, thereby decrease the productivity. Accumulation of these ions will decrease the osmotic pressure in the plant structural cells, thus blocking water from reaching the branches and leaves.

The effect of sodium concentration in irrigation water is commonly assessed by sodium percentage, which is calculated using the formula given in Equation (1) [14], where the concentrations are in meq/l.

$$Na\% = \frac{(Na^{+} + K^{+})}{(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})} \times 100 \quad (1)$$

The classification of water samples with respect to the sodium percentage is given in Table 5. The sodium percentage of water in the study region varies from 27 % to 54 %. The water samples are classified as good (50%), permissible (50%) according to sodium percentage. So, the all river water is good for irrigation purpose.

Classification of water based on % Na and EC as recommended by [14] was made and it is given in Fig.5. About 100 % of the water samples come under in the field of excellent to good. The agricultural yields are generally higher in areas irrigated with water belonging to excellent to good and good to permissible categories.

Table 5 Quality of water based on sodium percentage

Sodium percentage	Quality of water	Number of samples
< 20%	Excellent	Nil
20–40%	Good	4
40–60%	Permissible	4
60–80%	Doubtful	Nil
> 80%	Unsuitable	Nil

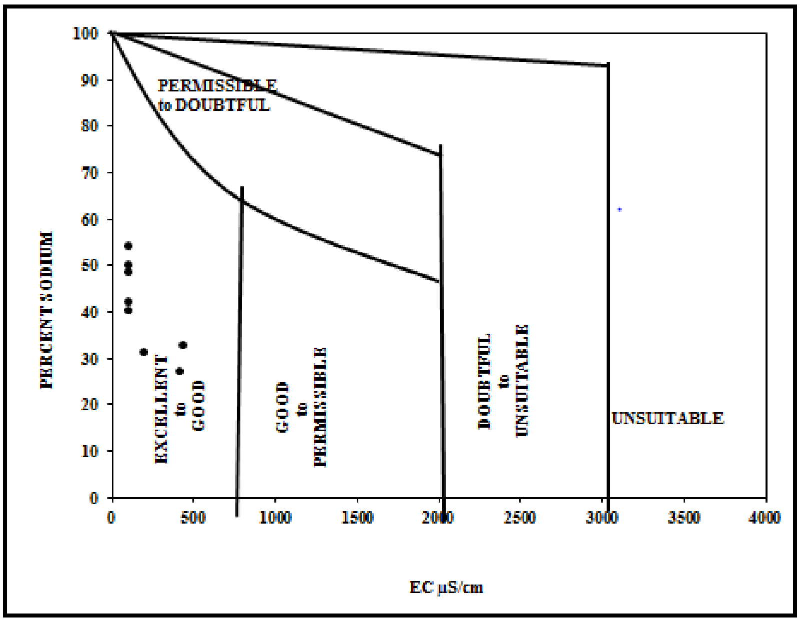

Fig.5 Suitability of irrigation water based on EC and sodium percent (Wilcox Diagram)

The osmotic activity of crops is often decreased by the high salinity in water and thus interferes with the consumption of water and nutrients from the soil [10]. Sodium Adsorption Ratio (SAR) is an important parameter for determining the suitability of water for irrigation because it is a measure of alkali/sodium risk to crops. SAR is determined by Equation (2) where the concentrations of ions are in meq/l,

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{2+} + Mg^{2+})/2}} \qquad (2)$$

SAR is based on the effect of exchangeable sodium in water on the physical condition of the soil. When SAR values are higher, irrigation water may cause permeability issues due to enlargement of clayey soils [10]. The SAR of water of this region varies from 0.79 to 1.54. Thus, the SAR value of all samples collected is under the maximum permissible limit i.e. SAR less than 10. The higher the SAR values in the water, the higher the danger of sodium that leads to the development of alkaline soil [13] while a higher salt concentration in water results in formation of saline soil. The classification of water based on SAR as recommended by [13] is given in Table 6. In general, the water of this region is suitable for irrigation.

Table 6: Alkalinity hazard classes of surface water

SAR	Alkalinity hard	Water class	Number of samples
< 10	S1	Low	8
10–18	S2	Medium	Nil
18–26	S3	High	Nil
> 26	S4	Very high	Nil

Residual sodium carbonate (RSC) is calculated in order to find out the harmful effect of CO_3^{2-} and HCO_3^{-} on the quality of water for agricultural purpose [5]. The RSC value was determined using the Equation (3), where the ionic concentrations are in meq/l.

$$RSC = (CO_{3-} + HCO_{3-}) - (Ca^{2+} + Mg^{2+}) \qquad (3)$$

With respect to RSC, 100% of water samples of this area are safe for irrigation, and none of the sample is falling under doubtful and unsuitable categories (Table 7). This shows that most of the water is suitable for irrigation purpose.

Table 7: Quality of water on the basis of residual sodium carbonate

RSC	Quality	Number of samples
< 1.25	Good	8
1.25–2.5	Doubtful	Nil
> 2.5	Unsuitable	Nil

V. Conclusion

The present study was carried out to investigate suitability of surface water for drinking and irrigation purpose in a part of Kulfo River basin, Arba Minch, Ethiopia. For this purpose, 6 river water and 2 spring water samples were collected on May 2018. The region comprises of alluvial sediments and volcanic rocks such as aphanitic basalt, vesicular basalt near the banks of river. Hydrogeologicaly this region is characterized as different distinct layers of the top soil, highly weathered, moderately weathered and fractured/massive rocks. These formations function as unconfined aquifer and the rainfall is the principle source of recharge. River water of the study region is generally alkaline and fresh in nature. The concentration of cations is in the order of Na^+ > Ca^{2+} > Mg^{2+} > K^+, while for the anions it is Cl^- >HCO_{3-} > CO_3^{2-}. Na-HCO_3, and mixed Ca-Mg-Cl-SO_4 type of water are dominant in the study area. The concentration of ions in the water samples was compared with the WHO (2004) to know the suitability of water for drinking. The sodium, calcium, magnesium, potassium, chloride and bicarbonate concentrations are within the permissible limits. River water is suitable for drinking purpose in the all part of the study area. The Wilcox diagrams relating sodium percentage and total concentration show that all of the water samples fall in the field of excellent to good for irrigation purpose. River water is suitable for irrigation purpose in the all part of the study area.

Acknowledgments

The authors would like to thank the Department of Geology, Collage of Natural Science and Arba Minch University, Ethiopia

References

[1]. Ayers, RS and Westcot, DW, A Qualidade da Água na Agricultura (in Portuguese), UFPB Universidade Federal da Paraíba: João Pessoa, Brazil, 2(Ed.) 1999, pp.218.
[2]. Benignos, A Rural Water Supply Manual Design, Malina, 2012
[3]. Carroll D, Rainwater as a chemical agent of geological processes, A review U.S. Geological survey water- supply paper 1535, 1962
[4]. Davis SN, Wiest RJ, Hydrogeology, Wiley, New York, 1966, vol 463.
[5]. Eaton, FM, 'Significance of carbonates in irrigation water', Journal of Soil Science, 1950, vol. 69, pp. 123133.
[6]. Ethiopian Standard, Drinking water—specification, 1stedn, Quality and Standards Authority of Addis Ababa, Ethiopia, 2001
[7]. Freeze RA, Cherry JA, Groundwater. PrenticeHall, Englewood Cliffs, 1979, pp. 604
[8]. Nickson RT, McArthur JM, Shrestha B, Kyaw -Nyint TO, Lowry D, Arsenic and other drinking water quality issues, Muzaffargarh District, Pakistan. Appl Geochem, 2005, vol. 20, pp. 55–68
[9]. Piper AM, A graphic procedure in the geochemical interpretation of water analysis. Trans Geophysics Union, 1944, vol.25, pp.914–923
[10]. Saleh A, Al-Ruwaih F, Shehata M, Hydrogeochemical processes operating within the main aquifers of Kuwait. J Arid Environ,1999, 42:195–209,
[11]. Sawyer, CN & McCarty, DL, 'Chemistry of sanitary engineers' New York: McGraw-Hill, 1967, 2nd ed., pp. 518
[12]. Tato k, Rainfall in Ethiopia - Ethiopian Geograph, 1964, vol 2, pp.28-36.
[13]. Todd DK, Groundwater Hydrology. Wiley, Canada, 2001, pp 280–281
[14]. Wilcox LV, Classification and use of irrigation waters USDA Circular 969, Washington, DC, United State of Africa, 1955
[15]. World health organisation (WHO), Fluoride in drinking-water, background document for development of WHO guidelines for drinking water quality 17, 2004
[16]. Zannetin B, Justin-VE, Nicoleti M, and petruccioni C, The Evolution of the Chencha Escarpment and the GanjuliGraben (Lake Abaya) in the Southern Ethiopian Rift, 1978
[17]. Zinabu Gebremariam, The Ethiopian Rift Valley Lakes: Human interactions and water, 2002

IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG) is UGC approved Journal with Sl. No. 5021, Journal no. 49115.

Jagadeshan G."Suitability of Water for Drinking and Irrigation Purpose in A Part Of Kulfo River Basin, Arba Minch, Ethiopia. "IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG) 7.6 (2019): 15-21.