THE USE OF GEOCHEMICAL PARAMETERS & HYDRO CHEMISTRY TO DETERMINE THE POT ABILITY OF SUB SURFACES WATER - A case study of Jimma Arjo Woreda area, East Wollega Zone, Ethiopia

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ABSTRACT

The study area is located at 8^0 33' to 8^0 55' N Latitude and 36^0 22' to 36^0 44' E longitude. The aim of the study is to assess the physico- chemical parameters of subsurface water quality with special constituent level of major and trace elements concentrations, distributions and identifies the possible of water source in relation to domestic and agricultural purposes. The geological setting of the area consists of exposure of volcanic rocks that cover the sediment part and quaternary sediments. Rain fall is a vital source of subsurface water by infiltration and percolation through the soil zone; and unsaturated materials chemically reacted with the gases, minerals and organic compounds that occur naturally within subsurface. The physico- chemical characteristics of sub surface water samples have been determined according to the standard methods of APHA and identify the chemical composition of ground water sample analysis and interpretation, like pH, EC, Cl, HCO_3,F, NO_3,TDS, SO_4, Ca, Mg, Na, and K which are related to solid water interaction. By using laboratory test the physical and chemical characteristics of subsurface water samples have been determined according national and international standards such like WHO for drinking water and there major and trace element concentrations are compared with the maximum acceptable concentration standards. The major cations of the water compositions being analyzed to using qualitative method, average values can be ordered as Mg< Ca<Na where as the major anions ordered as HCo_3> Cl> So_4.

Keywords:

Concentration,
Domestic,
Geological,
infiltration,
Parameters,
Subsurface,

I. INTRODUCTION

Water is life", "Health is Wealth" are popular sayings relating to life and wealth. However, surface and subsurface water is not properly managed the quality in the vicinity of sub surface water and groundwater can be detrimental to life, health and wealth. The study area is located in Jimma Arjo Woreda East Wollega zone, which is bounded in $8^{0}33'$ to $8^{0}55'$N latitude and $36^{0}22'$ to $36^{0}44'$E longitude for the identification of subsurface water quality of the study area. To overcome the objective of this research the data of geology, hydro geological formation, and physico-chemical water analysis and characterizes according to the given data and compared with the national and international standards such like WHO, maximum and minimum allowable concentration limits. The quality of water is as important as its availability. Quantitative of water is nothing without quality. Water in the form of rain and snow through is pure, but it can undergo many complex chemical changes and get enriched in various elements after coming in contact with surface and sub-surface material. In additional anthropogenic sources or man activities also have considerable influence on water quality (Singhal and Gupta, 1999).The main quality controls are geological, metrological conditions, biological factors. and physicochemical factors (temperature ,chemical properties of elements solubility of chemical compounds, PH, TDS, etc), because water is such an excellent solvent it can contains a lot of dissolved chemicals, since sub surface soil has a lot of opportunity to dissolves substances as in subsurface water quality.

Subsurface water is water that exists in the pore spaces and fractures in rocks and sediments beneath the earth's surface and it is the major source of fresh water that caters to the domestic water demand arising due to escalating population and modern agricultural practices in many developing countries. Groundwater can be in sedimentary terrain where it is less difficult to exploit except for its chemical composition. It can also be in the Basement Complex terrain where it can be a bit difficult to locate especially in areas underlain by crystalline unfractured or un weathered rocks. It originates as rainfall or snow, and then moves through the soil and rock into the ground water system, where it eventually makes its way back to the surface streams, lakes, or oceans. Subsurface water constitutes are significant part of active fresh water resources of the world and is obviously dependable source for all the needs. Groundwater quality comprises the physical, chemical, and biological qualities of ground water. Temperature, turbidity, color, taste, and odor make up the list of physical water quality parameters. Recently recharged ground water generally contains high inorganic carbon concentrations. Major and minor elements compositions of natural sub surface water depend on the availability of major and minor elements in easily soluble phases or on sorption's sites, and the red ox state of the water in the aquifer (Graham ***et al*** 1996).

Western Oromia is the region of heaviest rainfall; it is the wettest part of the region with only two to four dry months in the year. The mean annual rainfall for the research area is about 2800 mm, in Arjo/Wollega. As we observe from above the research area gets much enough rain fall. In Arjo district especially in Arjo town, rainfall has an uneven distribution both in time and in space. This is partly due to the presence of one major and one small rainy season, in large part of the region. A subsidiary effect is that a large amount of rainfall on the highlands is concentrated as runoff in river valleys, which drain into the low-lying areas where annual rainfall is low. In almost all river basins some 80% of the runoff results from annual precipitation falling in four months from June to October in all most throughout the district.(National Metrological Agency, Addis Ababa, Ethiopia, 2011).

Physiographic and vegetation

The major part of the study area can be described as rolling and undulating topography with dendrite drainage pattern. The elevation of the study area ranges from 1500-2600m a.s.l. The common physiographic features are mountains ridges plateaus and basins (Solomon and Mulugeta,2000) . The total study area is highly vegetated and type of vegetation cover depends on the physiographic and climatic condition. It is mainly covered by large trees, grass and bushes.

Location and Accessibility of the study area

Jimma Arjo is found in East Wollega zone of Oromia region and is 379 Km to West of Addis Ababa. It is bordered on the southwest by the Didessa river which separate it from the Ilubabor zone, on the north west by Diga lake, on the north east by Guto Wayu, and on the south east by Nunu Kumba Woreda.

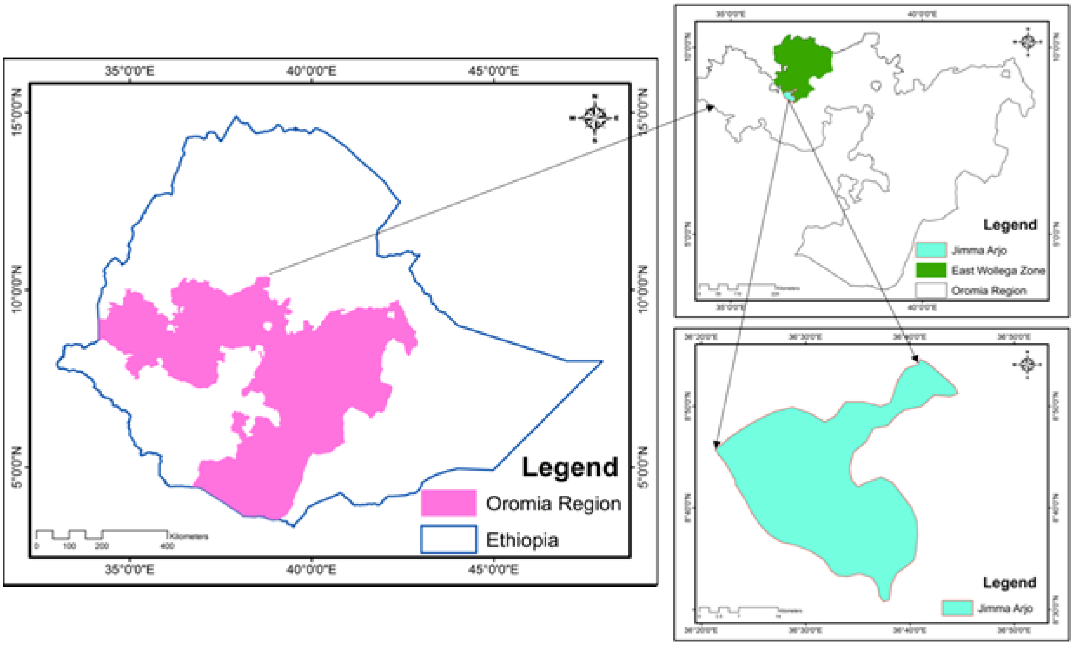

Figure -1 : Location map of the study area

Topography

According to the agro-climatic classification of Ethiopia, the relief/land form of the study area can be grouped into three major physiographic units based on their elevation. The lowlands with <1500m a.s.l, mid altitude with 1500-2300m a.s.l and highlands with >2300m a.s.l with 30%,58% and 12% coverage respectively.

Climate and drainage pattern

The Woreda rain falls in between the traditional dega(high land which occurs 23%),Woina dega (middle altitude) which occurs 50%) and kola(low land which occurs about 27%).The altitude of the area ranges from 1500-2600m a.s.l . The weather is cold during the rainy season in the highland. According to the annual rainfall mapping the study area gets annual rainfall upto 2800mm. The study area is characterized by subtropical (Woina Dega) climatic zone and 10^0c to 23^0c mean annual temperature. The average annual temperature is about 17.2^0c.The main rainy season in this region is from June to August during summer season and the Dry season is during December to February (National Metrological Agency, Addis Ababa, Ethiopia, 2011).

Geology the study area

The genetic type of geologic formation is essential for the formation of ground water flow and transport connects with the rock type. It the genetic type of rocks that determine peculiarities of ground hydro geological cross section structure, type of porosity, values and character of spatial heterogeneity of flow and transport parameter. In the hydro geological units of quaternary, such as volcanic deposits and the alluvium, the sub surface water circulation maintains a closer relationship to the superficial morphology. The igneous and metamorphic rocks of Ethiopia can be categorized as hard rocks, which are devoid of primary water bearing structures. However, from the hydrological point of view, they are rather homogeneous in two respects. They have virtually no primary porosity and they have secondary porosity due to fracturing and weathering, which permits the flow and storage of groundwater. Metamorphic rocks usually tend to have porosity less and are frequently discontinuous or ineffective pore spaces. Their permeability is, therefore, low as well. As discussed earlier fracturing either associated with regional deformation or weathering may create significant porosity and permeability, which is the most important feature for their groundwater potential. Degree of fracturing in crystalline rocks has generally been found to decrease with depth, because the rock becomes more massive and hard with depth under higher pressure and temperature conditions. The research area is situated in parts of the central highland plateau of the East Wollega/Jimmaa Arjo Woreda. The tertiary rock exposed in the area is basalt. This rock is mapped almost all in and around the Jimma Arjo. The ground water occurrence around these rocks exhibit greater variation in their water bearing properties because they possess different porosity.

Hydrogeology of the study area

The head water of the most important rivers of Jimma Arjo Woreda is Abay basin and it originates from spring and seepages that emerge from the vast mass of tertiary volcanic rocks on the plateau. The main recharge of the ground water for the study area is precipitation rain fall that comes from the surrounding high land area. Our study area is relatively high land and low land and gentle slope to undulating land forms. The most important features governing the ground water flow and storage in volcanic rocks are: vertical permeability due to primary and secondary fractures and develop secondary porosity, horizontals permeability due to horizons containing openings due to lava flow and gas expansion during solidification after that prospect or vesicles developed, occurrence of impervious horizons and dikes**.**

II. MATERIALS AND METHODS

In order to understand the hydro geological setting of the area the available geological maps and existing reports were studied. As there were some data gaps, an intensive geological investigation was carried out in the study area, to study the nature of the rock, topographical expressions, intensity and depth of weathering, and demarcation of litho logical contacts on a larger scale than the presently available maps. Subsurface water level and GPS locations were recorded during the field survey.

The water samples were collected and stored in capacity clean plastic bottles and before collection the bottles was carefully washed in order to avoid any impurity in the bottle. The physico- chemical characteristics of sub surface water sample compositions is tested in laboratory and analyzed by using qualitative method. During the water sampling it is important to collect a portion of material in small enough in volume to be transported conveniently and handled in the laboratory while still accurately representing the material to be sampled. The physico-chemical characteristic of water samples has been determined according to the standard methods of APHA. Concentration of calcium, magnesium, bicarbonate, chloride and total hardness determined by titri-metric method. Calcium and magnesium determined by EDTA titration, for HCO_3, Hcl titration to a methyl orange point. Chloride also determined by titration with $AgNo_3$ solution. Flame emission photometry used for the determination of sodium and potassium. In this method water sample of the light emitted by a particular spectral line measured with the help of photoelectric cell and a galvanometer. Sulphate analyzed by gravimetric method. The concentration of nitrate and fluoride determine with the help of double beam U.V. spectrophotometer.

III. WATER QUALITY ANALYSIS OF THE STUDY AREA

The analytical result of selected elements in water samples from Jimma Arjo area is presented below. It gives the analytical techniques for different element parameters are shows the natural concentration of the analyzed elements covers in these data set, it improves additional information on water standards (WHO and Ethiopian) ranges concentration of the analytical data for selected parameters in water samples and their comparison with different water standards.

Table 1- Selected Physico chemical water analysis results of Study area

Parameters	Techniques	Units	Minimum .Concentrations	Maximum Concentrations	Average .Concentrations	WHO standards	Ethiopian standards
Na	AAS	mg/l	4.3	61.4	32.85	200.0	200.0
Ca	AAS	mg/l	11.4	18.0	14.7	200.0	75.0
Mg	AAS	mg/l	5.02	11.03	8.025	150.0	50.0
K	AAS	Mg/l	0.9	1.6	1.25	12.o	15.0
SO_4^{-2}	AAS	mg/l	1.02	1.99	1.505	400.0	250-400.0
Cl	Titration	mg/l	7.4	8.4	7.9	250.0	600-1000
HCO_3	Titration	mg/l	62.59	86.89	74.74	--------	-----
NO_3^{-1}	AAS	mg/l	0.39	0.52	0.455	45.0	50.0
F	Titration	mg/l	0.54	1.5	1.02	1.5	0.5
Mn	AAS	mg/l	Trace	Trace	Trace	0.1	----
PH	PH meter		5.7	6.8	6.25	6.5-8.5	6.5-8.5
TDS	TDS	mg/l	90.0	259.56	174.78	1000.0	1000.0
EC	EC meter	µS/cm	1150	650	900.365	-------	----
$CaCO_3$	Titration	mg/l	79.0	370	224.5	---------	-------

Source: Water Mineral and Energy Department, East Wollega Zone; Nekemte; Ethiopia

V. DISCUSSION

Physico-chemical parameters

The physic-chemicals of the following parameters such as PH, EC, TDS, Th, alkalinity and water type of sub surfaces are discussed as the following.

Electrical Conductance (EC)

Most sub surface dissolved in water dissociated in to ions that can conduct an electric current evaluable indicator of the amount of dissolved material in the water. The larger conductance indicates more mineralized water. Low electrical conductance is the conductance of cubic centimeters of any substance compared with the high conductor; indicating that it is good insulator. The water samples collected from borehole have high values of electrical conductance which indicates there is the amount of ions from dissolved materials; when compared with the conductance of pure water that have low electrical conductance . Hence, the water sample collected from borehole have high electrical conductance that indicates it contains dissolved materials in the water.

Total Dissolved Solids (TDS)

Total dissolved solids are a measure of the total amount of minerals dissolved in water and are therefore, every use full parameters in the evaluation of water quality. Water with a TDS above 500 mg/l is not recommended for use as drinking water. Water with a TDS above 1,500 to 2,600 mg/l (EC greater than 2.25 to 4mmho/cm) is generally considered problematic for irrigation use on crops with low or medium salt tolerance. According to WHO; TDS maximum tolerance limit of the constituent of the Jimma Arjo Woreda is suitable for drinking purpose since its TDS is 174.78mg/l.

Hydrogen ion concentration (pH)

The pH of water is a measure of its reactive characteristics. Low value of pH, particularly below 4.0 indicates corrosive acidic matter that will tend to dissolve highly in water and other substance that it contains. High value of hydrogen particularly above 8.5 indicates alkaline water that tends to form basic scale. The mean measure of pH in the study area is 6.25which indicate the subsurface water tends to acidic, but since it approaches to the standards of WHO and as well to the standards of Ethiopian it is suitable for drinking purpose

Bicarbonate (HCO_3)

Bicarbonates and carbonates are the most common causes of alkalinity in natural water. The main source of bicarbonate in ground water include CO_2 in the soil, carbon dioxide in the atmosphere and carbon dioxide released due to bacterial oxidation of organic matter. Water containing large amount of bicarbonate ranges between 62.59 to 86.89 mg/l in the study area.

Carbonate ($Caco_3$)

Alkalinity: is a measure of the capacity of water to neutralize acids. It is primarily due to the pressure of bicarbonate, carbonate, and hydroxides. The alkalinity of the area is 224.50mg/l of $CaCO_3$ mg/l which is under the tolerance limit of 500%mg/l, so high alkalinity indicates having of the basic property.

Major Ions

Chloride (Cl)

Chloride is one of the major inorganic anion in water, and it is presents in all potable water supplies and in sewage. High Cl in water give an undesirable test to water and beverages and large amount may act corrosively and metal pipes and may be harmful to plant life. Chlorides in drinking water generally not harmful to human being until a high concentration is reached, although the chlorides may be injurious some people suffering from disease of kidney and heart. The Chloride concentration in the study area is less than W.H.O, permissible limits and varies between 0.54 to 0.56 mg/l. **(**table 2c**)**

Sulfate (So_4)

Sulfate combines with calcium to form an adherent, heat retarding scale. In Ground water, sulfate generally occurs as soluble salts of calcium, magnesium and sodium. Water containing about 500mg/l of sulfate tastes bitter, water containing about 1000mg/l may be cathartic. The concentration limits of sulfate in W.H.O have presided highest desirable limits of 200mg/l and maximum permissible limit of 400mg/l in drinking water ,but although it so in our study area the content of subsurface water of SO_4 very negligible which ranges from 1.02 to 1.99mg/l.

Calcium (Ca)

It is one of the most important cautions presents in the ground water. The main source of calcium in ground water are rain water, leaching from fertilizers, soil, weathering of calcium, silicate minerals and use of surface water for irrigation, the dissolved Co_2 control the calcium ion. The analytical results of calcium show concentration between 13.40mg/l to 49.08mg/l in the study area. The highest desirable limit of calcium in drinking water is 75mg/l and maximum permissibility limit is 200mg/l W.H.O in drinking water. The value of calcium ranges under desirable limit of W.H.O in the study area.

Magnesium (Mg)

Magnesium is a common and moderately, toxic element and it is one of the most important contributors to the hardness of water. The concentration of magnesium in sub-surface water is less than calcium. The analytical results of magnesium show concentration between 5.02mg/l to 11.03mg/l in the study area. Magnesium deficiency is associated with structural functional changes in the study area.

Sodium (Na)

Sodium chloride is also used in the production of caustic soda, chlorine and many industrial chemicals. Significant quantities are used in the food processing, slaughtering, and meat packing, dairy, fishing, grain and brewing industries. The concentration ranges between 4.3 mg/l to 61.4mg/l in the study area.

Potassium (k)

Potassium is less common cations in the ground water. potassium salts are of the therapeutic value in the treatment of familiar periodic paralysis while no desirable or excessive limit for potassium have been set, though 10mg/l - 12mg/l based on European Economic community standard and 12mg/l of W.H.O , the maximum permissible limit of potassium is 12mg/l. The potassium ranges from 0.6mg/l to 1.6mg/l in the study area.

Trace elements

Fluoride (F)

Fluoride concentration between 0.5 and 1.5 mg/l in drinking water has a beneficial effect on the structure and resistance to decay of children's teeth. Fluoride in excess of 1.5mg/l in some areas cause mottled enamel in children's teeth. Fluoride in excess of 6.0 mg/l cause pronounced mottling and disfiguration of teeth. The nation environmental pollution due to fluoride in subsurface water is a matter of greater concern. There is no wide variation of fluoride content in the study area, ranges between 0.54-0.56mg/l. The whole study area is showing under the permissible limits of W.H.O, drinking water standard.

Nitrate (No_3)

Water containing large amounts of nitrate (more than 100mg/l is bitter tasting and may cause physiological distress).Water from shallow wells containing more than 45mg/l has been reported to cause methaemoglobinaemia in infants. Small amounts of nitrate help reduce cracking of high pressure boiler steel. The nitrate content in ground water in study are varies from 0.39-0.0.52mg/l. It is observed that all wells are having under the permissible limit W.H.O. Drinking water standard indicated no ground water pollution. The high nitrate connection may be attributed due to combined effects of contamination from domestic sewage and run off from fortitude fields.

Manganese (Mn)

More than 0.2mg/l precipitates upon oxidation, causes undesirable tastes, deposits on foods during cooking, stains plumbing fixtures and laundry, and fosters growths in reservoirs, filters, and distribution systems. Most industrial users object to water containing more than 0.2mg/l. The concentration of manganese in study area is less than W.H.O. which is negligible and under 0.1mg/l.

Water types

The major ion composition of subsurface water used to classification water in to various types based on the dominant cations and anions. The Water types of the area are dominated by $Na\text{-}HCo_3$ due high concentration of sodium from cation and bicarbonate from anions.

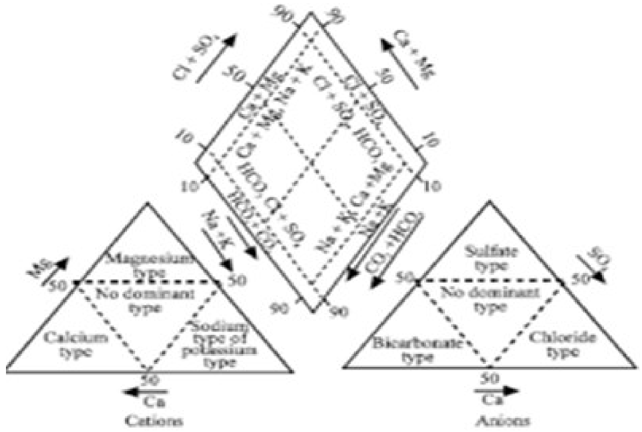

Figure-2 : Piper Diagrams of the water samples

From the Piper diagram Figure 5 to conclude the following points.

- Bicarbonate contents are high than chloride and sulfate contents in the water samples.
- Sodium plus potassium (Na + K) contents are higher than the concentration of calcium and magnesium.
- Most of the subsurface water types are combined from the sodium types of cations and bicarbonates types of anions which give $Na\text{-}Hco_3^-$.

VI. CONCLUSION AND RECOMMENDATIONS

- The major cations of the water compositions by analyzing using qualitative method of mean average can be ordered as Mg< Ca<Na where as the major anions ordered as $HCo_3 > Cl > So_4$.
- The mean value of fluoride constituent is 1.02mg/l in the study area which is under standard of W.H.O and above the standard of Ethiopia, so it has no effect.
- Subsurface water of the study area is widely used for human drink and domestic use.
- The concentration of sodium in the water is within the maximum tolerance limits except the 25% of the samples are greater than the recommended limit for drinking is 200mg/l (W.H.O).
- The trend in the quality of ground water is based on the chemical analysis data of water samples collected from different wells of the study area.
- As we have taken the data from water and mineral energy office there is no standard set for HCO_3, EC, and CaCO3 and it should have sated as national and international.
- The organic chemical constituents and organisms have to be tested for the subsurface water in the area.
- The essential minerals should be added to the desirable limits in the ground water to improve the quality for the drinking purpose.
- Some required minerals are under the desirable limits but for human life the need of these minerals are not meeting in the permissible limits, hence the concentration of the minerals should be added up to permissible limits as W.H.O. standards for the human health.

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