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CHEMICAL ANALYSIS OF GROUNDWATER FOR DOMESTIC USES AND IRRIGATION WATER IN BAGO TOWNSHIP, BAGO REGION

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Abstract

The research area, Bago is situated on the Eastern Part of the Bago Yoma. The topography of the research area is slight moderate plain and its gently slope towards the east. This area is about 228.712 square kilometer. The sources of water supply are water from tube well and reservoir. The main aquifer in western part is Irrawaddy Formation and in the eastern part it is Alluvial Aquifer. The yield of Irrawaddy is 500 to 2000 gallons per hour. pH falls between 6.5 to 7.7. TDS falls in 50-340 ppm. Total salinity is low and electrical conductivity (E.C) is always not more than 530 µ mho/cm. Iron content is rising up to 3 ppm. The results analyzed by KURLOV'S METHOD, SSP% method, SAR method MAR method, RSBC method, TDS and PIPER method can be classified the water types, drinking water, domestic use and Irrigation water. According to the above these methods and WHO Drinking Water Standard, the groundwater of the research area is suitable for the drinking water, domestic uses and Irrigation water.

Keywords: pH, TDS, groundwater, SAR method and PIPER method

Introduction

The research area is lying about 10 m to 20 m above sea level. Population of Bago City is dense. The population is about 435,000 (census 2019). It lies on the bank of the Bago River. The city area is situated bank of the Bago River and the eastern extremity of the Bago Yoma.

Location and Size

Bago Township is situated in the southern part of the Bago Region. The research area lies between North Latitudes 17° 25' 00" to 16°35' 30"and East Longitudes 96° 25' 00" to 96° 32' 00". The area coverage is about 228.712 km^2 (figure 1).

Purpose of Research

The purpose of research includes the following:

(1) To obtain groundwater that is truly representative of the geologic formation.
(2) To investigate the chemical quality of the water.
(3) To research the characteristics of aquifer based on aquifer function.

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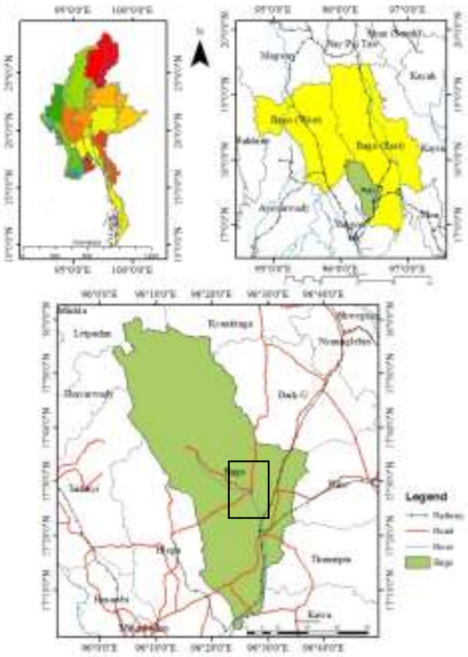


Figure (1) Location map of the research area

Methods of Research

Before commencement of the field work, the author visits to exit wells gathering of available data, such as relevant, topographic maps, meteorological data and chemical data of groundwater in research area. These collected data are examined systematically and then they are reviewed and analyzed in the Water Resources Utilization Department in Yangon. During the field, the measurements of water level, well depth, the position of wells by G.P.S are made.

Topography

The research area is located at the East of the Pegu Yoma anticline where Miocene to Pliocene rocks crop out. The research area is an elevation of between 30-60 feet above sea level. The research area is bounded by Waw, Payagyi, Daike-U, Hlegu and Tanatpin townships. The research area is sloping to the gently east. The eastern parts of the research area are the tidal affected area.

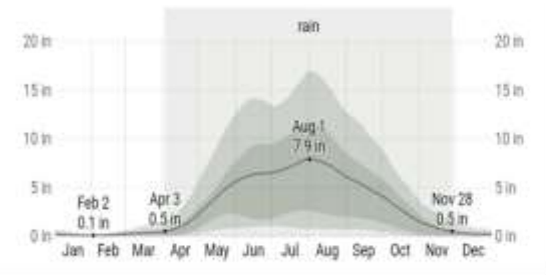
Drainage

Tidal action also takes place in the stream channel in the eastern part of the area. The main river is the Bago River. The drainage pattern of the area is coarse dendritic or tree-like pattern (figure 2). Drainage pattern is important because the part of the drainage pattern indicate changes in under groundwater condition, type of rock and geologic structure.

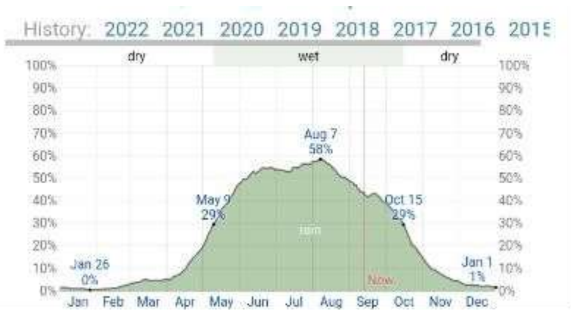
Climate

The research area, the wet season is oppressive and overcast, the dry season is muggy and partly cloudy and it is hot year-round. Over the course of the year, the temperature typically varies from 64°F to 100°F. Bago experiences extreme seasonal variation in monthly rainfall. The rainy period of the year lasts for 7.8 months from April to November, with a sliding 31-day rainfall of at least 0.5 inches. The month with the most rain in Bago in August with an average rainfall of 7.4 inches. It receives more than 126 inches of rain per annum. When the temperature is high; there is more evaporation and transpiration which reduces the amount of water in the river. The data recorded from the Kaba-Aye Meteorological Station. The weather graphs are shown in figure (3A, B, C and D).

Figure (2) Drainage map of research area



A. Rainfall



B. Precipitation

C. Humidity

D. Temperature

Figure (3) Climate condition of the research area A. Mean Rainfall, B. Mean Precipitations, C. Mean annual Humidity and D. Mean Temperature

Regional Geologic Setting

Bago (Pegu) Region occupies the southernmost on land segment of the Central Myanmar Belt. It is bordered on the north by Magway and Mandalay Regions, on the east by Kayin and Mon States, on the south by Yangon and Ayeyarwady Regions, and on the west by Rakhine State. Except for the low hills of the Bago (Pegu) Yoma, running north-south across the center of the Region, the foot hills of the Eastern Highlands Province in the eastern part and those of the WR in the west, Bago Region is composed mostly of flat alluvial plains. Except for the small northwestern part, the Bago Region has not received enough geological investigations as much as it deserves. It is probably because Bago Yoma, known to be underlain almost entirely by Miocene clastic sedimentary rocks, is considered less attractive of for the economic mineral potential. Generally, people are more interested in the reported economic mineral occurrences or in areas where there have been some local mining activities. Moreover, the Bago Yoma is very thinly populated and thickly wooded, hence it was largely reserved forest area. It is hardly accessible for the rigorous geological field work although it is surrounded by fairly thickly populated agricultural flat lands. The northwestern part of Bago Region, however was intensively investigated because of its oil potential. The geology of Bago Region is in fact interesting and is unique because the Region embraces the southern segment of the Western Ranges (WR), the southern segment of the Central Myanmar Belt (CMB) and a narrow western part of the Eastern Highlands Province (EHP). Therefore, the geological succession of the Bago Region is composed of a mixture of some rock units of the WR, the CMB and a few of the EHP.

Geological Structure of the Research Area

Sagaing fault is a major tectonic structure that cuts through the central Myanmar, broadly dividing the country into a western half moving north with the India plate and an eastern half attached to the Eurasian plate. The Sagaing fault moves at an average of 18-20 mm each year. The Sagaing fault is a right-lateral Strike Slip fault (dextral fault, meaning that an observer on one side of the fault would see the other side moving to his right during an Earthquake. The Sagaing fault is running nearly in N-S direction in the western part of the research area. (Deym 1968; Win Swe, 1972; Curray et.al.,1979). The research area lies among the Sagaing Fault, Kyaukkyan Fault and Papun Fault. Sagaing Fault is situated in the west of the research area, Kyaukkyan Fault and Papun Fault are in the east. The earthquake risk of the research area is mainly caused by the movement along the Sagaing Fault which is a right-lateral strike-slip fault that runs north-south along the eastern flank of Bago Yoma. High magnitude events indicate that the Sagaing Fault is the principal source of seismic hazards in Myanmar. The Regional Geological Map is shown in (figure 4).

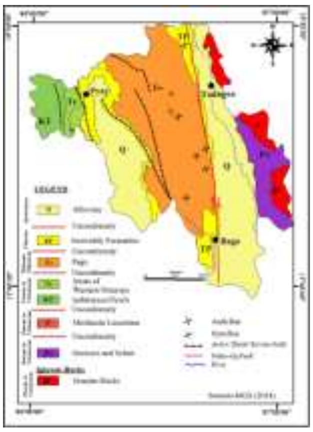


Figure (4) Regional Geological Map of the Bago

Hydrogeologic Characteristics of Research Area

Collection of Data

One-inch topographic map was used in collection of the water samples of the area under investigation. The collected samples were analyzed at Health Department. Tube-wells data were collected from the Water Resources and Utilization Department (W.R.U.D) and Ministry of Agriculture and Irrigation Department. There are two main types of lithology and aquifer, i.e. there are Alluvial Aquifer and Irrawaddy Formation. According to lithologic logs the water bearing horizons consist of yellow and blue coloured sand, sand with clay and gravel. According to well logs data the aquifer type is confined type. The depth of aquifer is ranging from 19ft to 70ft from the ground surface. The groundwater chemical analysis of the research area is shown in Table No. (1).

Table 1. Chemical analysis of the research area

Tube Well No.	TDS	EC	pH	Na	k+	Ca2+	Mg2+	Fe2+	Cl-	SO4=	HCO3-	Aquifer Types
1	340	530	6.74	17	0.6	11.2	22.1	2.5	64	66.2	54	Alluvial
2	210	330	6.76	16	0.5	14.4	8.64	3	56	25.9	36	Alluvial
3	95	150	7.22	16	1	8.24	3.36	2	26	17.1	18	Alluvial
4	50	70	6.75	8.2	0.9	1.6	1.44	0	14	3.84	12	Irrawaddy
5	165	250	7.3	144	3.8	42.7	9.62	1	0	20	11.52	Irrawaddy
6	90	130	6.5	17	4.4	4.81	1.44	0.3	15	11.5	20	Irrawaddy
7	170	260	6.7	38	4.2	9.62	3.84	0.2	20	46.1	46	Irrawaddy
8	235	360	6.8	22	4.9	12.8	5.28	0.2	25	76.8	40	Alluvial
9	70	110	6.6	4.1	1.4	1.6	2.4	0.12	15	15.4	16	Alluvial
10	110	160	6.6	21	2.6	7.21	2.4	0.5	19	23	30	Irrawaddy
11	230	350	6.7	36	4	16.8	8.16	0.2	74	30.7	40	Alluvial
12	320	490	6.7	18	2.5	54.5	11.4	0.3	69	61.4	30	Alluvial
13	160	240	6.6	25	3	10.4	6.72	0.15	39	23	40	Irrawaddy
14	230	350	7.7	24	2.7	14.4	2.4	0.13	21	88.3	24	Alluvial
15	110	160	6.8	17	3.8	7.21	3.84	0.35	25	19.2	24	Alluvial

Aquifers

The Irrawaddy aquifer found the western part of the research area. The alluvial aquifer mainly composed of the easter part of the research area. Irrawaddy rocks mainly composed of siltstone, clay, shale and sandstone which generally dipping towards the east and the south with a very low angle. Yield of the tube-wells vary from place to place is depending on the well's size, thickness of aquifer, well's design and well's development. The southern part of the research area, the depth reaches up to 480 feet. The water bearing horizon of Irrawaddy Formation is encountered at the depth ranging between 60 feet and 530 feet. In the research area, well no. T5 with the depth yields 2000 gallons per hour from the depth 480ft.

Chemical Composition of Groundwater

The collected samples are analyzed at the Water Resources and Utilization Department (W.R.U.D) and Ministry of Agriculture and Irrigation Department, the cations and anions and TDS, EC, pH, total alkalinity and total hardness.

Classification by KURLOV'S (1928) Method

The Kurlov's formula is written by using ionic concentrations that are expressed in milliequivalent percent (meq/l). The highest amount of ion is expressed first and lesser ion in second and so on. The anions are written above the line and cations are written below the line. The degree of mineralization (m) is placed in front of the format while pH, temperature, Fe^{++} etc., is placed behind. Based on Kurlov's Method, the chemical classification of groundwater types in the research area shows 1. Chloride -Sulphate- Magnesium, 2. Chloride-Sodium-Calcium-Magnesium, 3. Chloride-Sulphate-Sodium-Calcium, 4. Chloride-Bicarbonate-Sodium, 5. Sulphate-Bicarbonate Sodium, 6. Sulphate-Sodium-Calcium, 7. Chloride-Sulphate-Sodium-Magnesium, 8. Chloride-Sulphate-Bicarbonate-Sodium, 9. Chloride-Sodium, 10. Chloride-Sulphate-Calcium, 11. Sulphate-Sodium-Magnesium, and 12. Chloride-Sulphate-Bicarbonate-Sodium.

Classification of Piper Diagram

This method is proposed by Piper (1944) and by Hill (1940). This method of tri linear diagram is widely use to depict chemical data and show the relative concentrations of the major cations (Ca^{+2}, Mg^{++} and K^{+}) and anions $(CO_3^-, HCO_3^-, Cl^-$ and $SO_4^=)$. Cations are plotted on the left triangle and anions on the right triangle. Piper diagram are show in figure (5). Kurlov's method and Piper method are compared the result of the research area in groundwater types, which in table (2).

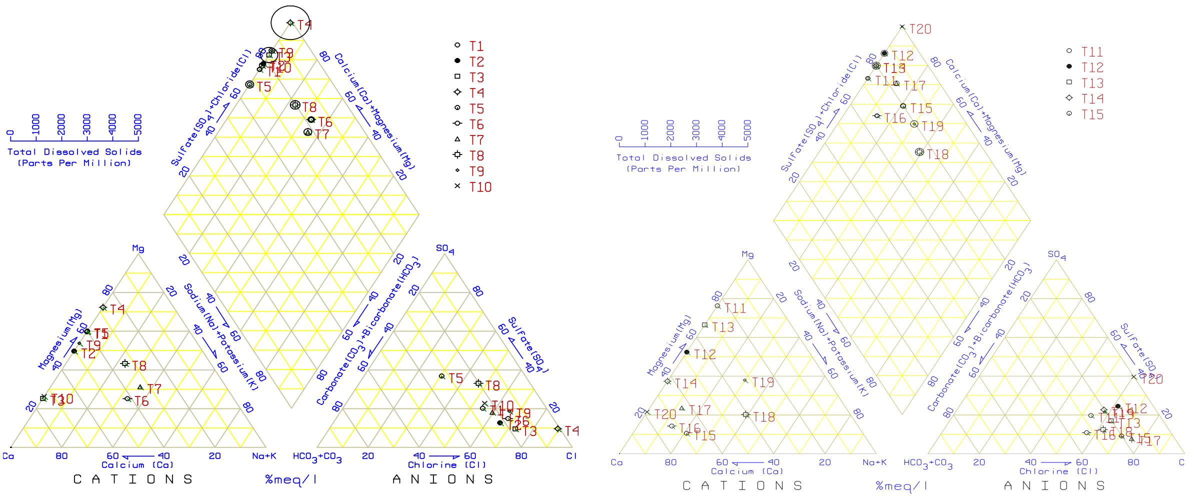


Figure (5) Classification of the Piper diagram, after Piper (1944) and by Hill (1940)

Table 2. Compares ion with Kurlov's (1928) Method and Piper Method

Tube Well No.	Kurlov's Method	Piper Method
T_1	Cl SO_4 Mg	Ca Mg Cl
T_2	Cl Na Ca Mg	Ca Mg Cl
T_3	Cl SO_4 Na Ca	Ca Cl
T_4	Cl HCO_3 Na	Mg Cl
T_5	SO_4 HCO_3 Na	Ca Mg HCO_3 Cl SO_4
T_6	Cl HCO_3 Na	Ca Mg Na Cl
T_7	SO_4 HCO_3 Na	Ca Mg Na SO_4
T_8	SO_4 Na Ca	Ca Mg Na SO_4 Cl
T_9	Cl SO_4 Na Mg	Ca Mg Cl SO_4
T_{10}	Cl SO_4 HCO_3 Na	Ca HCO_3 Cl
T_{11}	Cl Na Ca	Ca HCO_3 Cl
T_{12}	Cl SO_4 Ca	Ca Mg Cl SO_4
T_{13}	Cl HCO_3 Na	Mg Cl
T_{14}	SO_4 Na Mg	Ca HCO_3 Cl
T_{15}	Cl SO_4 HCO_3 Na	Ca Cl SO_4 HCO_3

Chemical Analysis of the Groundwater

Chemical Analysis is important to specify the actual characteristic of groundwater. Determination of pH, total dissolved solids, T.D.S, electric conductivity E.C, dissolved cations of Na^+, K^+, Ca^{++}, Mg^{++} and Fe^{++} and dissolved anions of CO_3^-, HCO_3^-, Cl^- and $SO_4^=$ are made in the laboratory.

In groundwater resources evaluation, the quality of groundwater is as important as its quantity. The chemical and physical constituents of groundwater determine its usefulness for municipal, commercial, industrial, agricultural and domestic water supplies.

The chemical composition of groundwater also indicates the geologic history of rocks, groundwater recharge and discharge, movement and storage. In recent decades, exploitation of groundwater has increased greatly, mainly for irrigation purpose because most of the areas have little access rainfall. Groundwater of the research area is being used from shallow tube wells and deep tube wells. Poor quality of water adversely affects the human health and the plant growth.

Purified water is free from disease producing chemical constituents and microorganisms that are dangerous to health, majority of the rural people do not have potable water for domestic use. Groundwater is applied to rural water supply system without proper treatment for drinking water and irrigation water. Groundwater may also be contaminated by weathering of rocks and applying fertilizer for agriculture purpose.

Major Cations

Cations, which commonly contained in tube-wells including iron Fe^{++} cations have been determined. Common cations are Sodium Na^{+}, Potassium K^{+}, calcium Ca^{++} and Magnesium Mg^{++} are represent shown in figure (6,7,8 and 9).

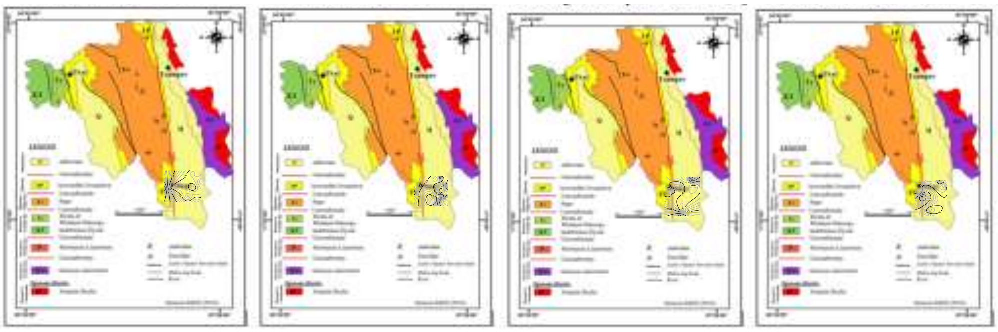


Figure (6,7,8 and 9) Distribution map of the Major Cations in research area.

Major Anions

Anions are playing a vital role in quality determination of groundwater. Only major anions of Carbonate (CO_3^-), Bicarbonate (HCO_3^-), Sulphate ($SO_4^{=}$) and Chloride (Cl^-) ions should be taken into account are represent shown in figure (10,11 and 12).

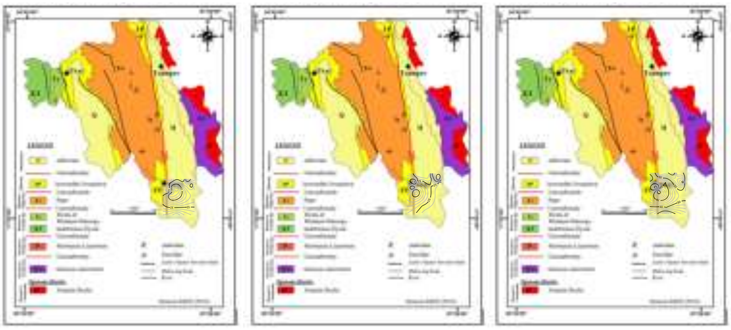


Figure (10,11 and 12) Distribution map of the Major Anions in research area.

Domestic Purposes for Water Quality

The pH values of water samples are ranging from 6.5 to 7.7. It is found that all of pH values fall in the W.H.O guideline for drinking water of 6.5 to 8.5.

The electrical conductivity (E.C) of groundwater samples is ranging from 70 to 530 µmhos/cm. It is observed that most of the samples do not exceed the W.H.O standard of 1500 µmhos/cm.

TDS concentration is ranging from 50 ppm to 340 ppm. Total dissolved solid values fall in fresh water quality range that is not more than 1000 ppm. The groundwater is fresh water according to H.A Gorrell classification.

Sodium concentration is more than 50 ppm that makes the water salt taste and health problems. Sodium concentration of the research area is ranging from 8.5 ppm to 144 ppm. Sodium concentration of all samples from younger alluvial aquifer falls in maximum permissible limit of 200 ppm as W.H.O guideline.

Calcium concentration is ranging from 1.6 ppm to 54.51 ppm and does not exceed the W.H.O standard of 200 mg/L.

The value of iron in the research area is ranging from 0.0 ppm to 3 ppm. W.H.O guideline indicates a permissible iron value of 0.3 ppm. Some water samples of the research area are exceeded the W.H.O limit.

Bicarbonate concentration in the research area is ranging from 11.52 ppm to 54 ppm. W.H.O standard recommends a concentration of 200 ppm for potable water. Water quality in three tube wells in the research area exceeds W.H.O. standard.

The concentration of sulphate in the research area is ranging from 3.84 ppm to 88.84 ppm. One tube well exceeds W.H.O. standard. High sulphate tends to form hard scale in boilers and plumbing units. For drinking water, sulphate concentration should not exceed 250 ppm because the water will have a bitter taste and can produce laxative effect at higher level. The water quality shows the domestic uses and drinking water of water quality in the Table No. (3).

Table 3. WHO standard guideline for the drinking water in research area

Characteristics	Guideline value		The range obtained from groundwater	Remark
	Desirable	Max Permissible		
Calcium	75 mg/l	200 mg/l	1.6-54.51 mg/l	Good
Magnesium	30 mg/l	150 mg/l	1.44-22.8 mg/l	Good
Sodium	0- mg/l	200 mg/l	4.13 –144 mg/l	Good
Potassium	0- mg/l	200 mg/l	0.6 –4.86 mg/l	Good
Sulphate	0- mg/l	400 mg/l	3.84 – 88.32 mg/l	Good
Chloride	200 mg/l	600 mg/l	0 –74 mg/l	Good
Iron	0.5 mg/l	1.5 mg/l	0 – 3 mg/l	Poor
TDS	0- mg/l	1000 mg/l	50 – 340 mg/l	Good
pH	6.5	8.5	6.5 – 7.7	Potable
EC	0-micro mho/cm	1500 micro mhos/ cm	70–530 micro mhos/cm	Good

Agriculture purposes for Groundwater Quality

Agriculture is the basis of the Myanmar economy. The research area is situated in the eastern part of the Bago (Pegu) Yoma. It is one of the most productions of paddy in the country.

Suitability of irrigation water depends upon many factors including the quality of water, soil type, salt tolerance, characteristics of the plants, climate and drainage characteristics of soil. Groundwater always contains small number of soluble salts dissolved in it. To assess the quality of water for irrigation, sodium plays a significant role. A high percentage of Na in water tends to break down the soil structure, the soil becomes more plasticity and this will be restricted water movement to root zone.

The quality of water for irrigation is classified by Sodium Adsorption Ratio (SAR), Magnesium Adsorption Ratio (MAR), Soluble Sodium Percentage (SSP or Na %) and Residual Sodium bicarbonate (RSBC). The respective values of all water quality parameters are summarized in each table. The results were compared with standard parameter in each case for each type of groundwater.

Sodium Adsorption Ratio (SAR)

Sodium Adsorption Ratio (SAR) is most commonly used to assess suitability of irrigation water. The SAR measures sodicity in terms of the relative concentration of sodium ions to the sum of calcium and magnesium ions in water sample Figure. 5. Sodium concentration in water effects deterioration of the soil properties reducing permeability. SAR is calculated using the following formula:

$$S.A.R. = \frac{Na+}{\sqrt{Ca+2+Mg2+/2}}$$

Where, the ionic concentrations are expressed in meq /L. The result of the Sodium Adsorption Ration (SAR) is shown in Figure. (13) and Table No. (6).

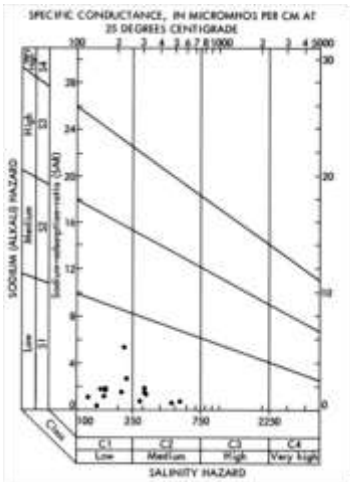


Figure (13) Sodium Adsorption Ration (SAR)

Magnesium Adsorption Ratio (MAR)

Magnesium content of water is considered as one of the most important qualitative criteria in determining the quality of water for irrigation. Generally, calcium and magnesium maintain a state of equilibrium in most water. More magnesium in water will adversely affect crop yield as the soil become more saline, Raghunath, H. M., (1987). The values of magnesium adsorption ratio of each aquifer are tabulated in Table (6).

$$\mathrm{M.A.R.} = \frac{\mathrm{Mg2+}}{\mathrm{Ca2+ + Mg2+}} \times 100$$

The value of magnesium adsorption ratio of research area is ranging from 21.52 to 76.77 %. Acceptable limit of the magnesium adsorption ratio is 50 %.

Residual Sodium Bicarbonate (RSBC)

The concentration of bicarbonate and carbonate influences the suitability of water for irrigation purposes. The high RSBC water has high pH. Therefore, land irrigation with such water becomes infertile owing to deposition of sodium carbonate (Eaton, F.M 1950). The method of classification based on Residual Sodium Bicarbonate (After Eaton, F.M 1950) is showed in Table No. (4).

$$RSBC = HCO_3 - Ca \quad meq/L$$

The residual sodium carbonate values of water samples ranging from - 0.03 to 1.8 RSBC is expressed in meq/L units. The result of the Residual Sodium Bicarbonate (RSBC) is shown in Table No. (6).

Table 4. Classification based on Residual Sodium Bicarbonate (After Eaton, F.M 1950)

Residual Sodium bicarbonate	Classification
< 1.25	Excellent
1.25 – 2.5	Good
2.5 - 3	Fair
> 3	Poor

Soluble Sodium Percentage (%)

Sodium concentration plays an important role in evaluation of groundwater quality for irrigation because sodium causes an increase in the hardness of the soil as well as a reduction in its permeability. The sodium percentage (Na %) is calculated using the formula given below:

$$SSP = \frac{(Na + \quad + \quad K+)}{Ca\ 2 + \quad + Mg2 + \quad + \ Na + \ + \quad K +} \times 100$$

The methods of classification of groundwater based on Na% (Wilcox,1955) is shown in Table No. (4). The result of the SSP% are shown in Table No. (6).

Table 5. Classification of Groundwater based on Na % (Wilcox, 1955)

(Na %) Percentage of Sodium	Classification
< 20	Excellent
20 - 40	Good
40 -60	Permissible
60 - 80	Doubtful
> 80	Unsuitable

Table 6. Summary Table for various methods of irrigation water quality in Research Area

Tube Well No.	EC	SAR	MAR	RSBC	SSP%
1	530	0.67	76.44	0.33	24.10
	Good	Good	Unsuitable	Excellent	Good
2	330	0.82	49.70	-0.13	33.13
	Good	Good	Suitable	Excellent	Good
3	150	1.19	40.21	-0.12	51.20
	Good	Good	Suitable	Excellent	Permissible
4	70	1.13	59.75	0.12	65.70
	Good	Good	Unsuitable	Excellent	Doubtful
5	250	5.15	27.09	-1.94	68.53
	Good	Good	Suitable	Excellent	Doubtful
6	130	1.79	33.05	0.09	70.79
	Good	Good	Suitable	Excellent	Doubtful
7	260	2.62	39.70	0.27	68.92
	Good	Good	Suitable	Excellent	Doubtful
8	360	1.31	40.43	0.02	50.13
	Good	Good	Suitable	Excellent	Permissible
9	110	0.48	71.21	0.18	43.81
	Good	Good	Unsuitable	Excellent	Permissible
10	160	1.70	35.44	0.13	63.42
	Good	Good	Suitable	Excellent	Doubtful
11	350	1.77	44.43	-0.18	52.14
	Good	Good	Suitable	Excellent	Permissible
12	490	0.57	25.64	-2.23	18.74
	Good	Good	Suitable	Excellent	Excellent
13	240	1.50	51.54	0.14	52.23
	Good	Good	Unsuitable	Excellent	Permissible
14	350	1.50	21.52	-0.33	54.31
	Good	Good	Suitable	Excellent	Permissible
15	160	1.28	46.76	0.03	55.67
	Good	Good	Suitable	Excellent	Permissible

Results and Outcomes

The research area is underlain by Recent to Pliocene age. It is mainly composed of yellow to red, fine to coarse sand, gravel, yellow to red of lateritic soil and yellowish clay. The main aquifer is Irrawaddy aquifer and Alluvial aquifer. The specific yield of the groundwater is 1000 to 2000 gallons per hour for 4 inches diameter well and the depth of water bearing horizon is ranging from 40 ft to 270 ft in Irrawaddy aquifer. The yield of alluvial aquifer is up to 600 gallons per hour for 4 inches diameter well and the depth of water bearing horizon is ranging from 40 ft to 90 ft. The concentration of hydrogen ion (pH) is between 6.5 and 7.7. Mostly, total dissolved solids are always less than 340 ppm in the research area. Total salinity is low and electrical conductivity (E.C) is not more than 530 μ mho/cm. The concentration of Chloride ion is widely distributed in most of the water of the studied region and the amount present in groundwater relative higher than other anions. The results analyzed by KURLOV'S METHOD, SSP% method, SAR method MAR method, RSBC method, TDS and PIPER method can be classified the water types, drinking water, domestic use and Irrigation water. If high amount of Iron concentration, which can be reduced of amount with aeration methods and sand filtering methods. According to the KURLOV's Method and Piper Method, Water Types can be classified by 12 water types. According to the above these methods and WHO Drinking Water Standard, the groundwater of the research area is suitable for the drinking water, domestic uses and Irrigation water.

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