ASSESSMENT OF THE GROUNDWATER QUALITY IN NYAUNG U TOWNSHIP, MANDALAY REGION

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Abstract

The research area is underlain by the Recent 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 2500 gallons per hour for 4 inches diameter well and the depth of the water-bearing horizon ranges from 40 ft to 350 ft in the aquifer. The concentration of hydrogen ions (pH) is between 6.5 and 7.7. Mostly, the total dissolved solids are 1900 ppm in the research area. Total salinity is low and electrical conductivity (E.C) is 160-2820 μ mho/cm. The concentration of Chloride ions is widely distributed in most of the water of the studied region and the amount present in groundwater is relatively higher than in other anions. The results of chemical data analyzed by the SSP% method, the SAR method and the MAR method show that some tube wells can be assessed as not suitable for use as irrigation water. Kurlov's Method and PIPER method can be classified the water types, drinking water, domestic use and Irrigation water. If high amount of Iron concentration, it 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 into 6 water types. According to the above methods and the WHO Drinking Water Standard, the data can assess whether the groundwater of the research area is suitable for drinking water, domestic use, and irrigation water, except that some tube wells are not suitable.

Keyword: SSP%, SAR and MAR

Location, Size and Accessibility

The study area is situated in the middle part of the Dry Zone of Central Myanmar. The study area is bounded by Taungtha Township in the Northeast, Kyaukpadaung Township in the Southeast and East, Chauk Township in the West and Pakkoku Township in the West and Northwest. The study area is lying between North Latitude 20° 51' 38" to 25° 18' 33" and East Longitude 94° 39' 32" to 95° 13' 50" respectively. The whole area is roughly about 572.75 square miles. The study area is easily accessible. The study area can be traveled by car, train, ship and motorcycle. The location map is shown in Fig. (1). Nyaung U Township has flat plains and hills. The main ridge is Thurain Taung. It is located in 9.6 km away from township. It is 16 km long and about 350 m high.

Purpose of the study

The purposes of this research are described as follows;

- To detail the study of the major rock types.
- To draw the geological map and hydrogeological map.
- To classify the quality of groundwater, groundwater movement and types of groundwater in the study area.
- To analyze the chemical characteristics of the groundwater of the study area.
- To interpret groundwater for drinking, domestic, agricultural and industrial use.

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Method of Study

Before the fieldwork, I collected township data, UTM map data, population data, Literature and Laboratory techniques for the study area. Method of study has two methods. There are Field Methods and Laboratory Methods.

Field Methods

During the fieldwork, the location of the well by G.P.S (Global Positioning System), the measurement of water level, well depth, well logging and Collection of rocks and water samples, to set the information from the local people who need and well water was taken into the recorded.

Laboratory Methods

In the laboratory of Utilization of Water Resources Department, measurement of Cations (Ca^{2+}, Mg^{2+}, Na^{+}, $K^{+,}$ and Fe^{2+}) and anions (HCO_3^-, SO_4^- and Cl^-) total dissolved solids (TDS), total hardness (TH), p^H and electrical conductivity (EC), smell, salinity, color, were made.

Previous Investigation

Most previous works in this study area emphasized on geology, hydrogeology and others. They are listed as follows:

- Khin San (1993). Geology of Gwegyo-Taungzin Area, Chauk and Nyaung-U Townships, Magway and Mandalay Division M.Sc Thesis, MU.
- Khin Thet Oo (2005). Geology and Paleontology of Yenangyaung Oil Field, Magway Division M.Sc Thesis, MGU.
- Win Swe (1981). A major strike-slip fault in Burma. Contribution to Burmese Geology, vol.1, pp-63-72.
- Duny. L.W (2017). Hydrogeology of the dry zone- Central Myanmar.

Drainage Pattern

Nyaung U of the main river is Ayeyarwady. Nyaung U has many streams. All streams are freshwater type. The drainage pattern of the study area is dendritic and parallel pattern. According to the pattern, the bedrock of the study area is shale and sandstone. The drainage map of the study area is shown in Figure (2).

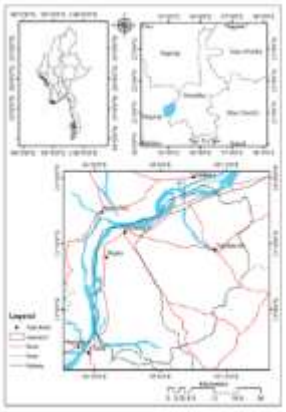

Figure 1. Location Map of the Study area

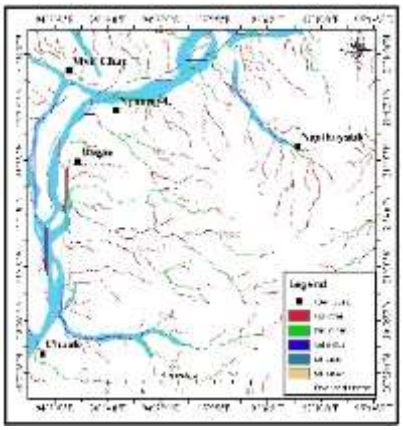

Figure 2. Drainage Map of the Study Area

Climatological Features

The study area is located in the dry zone of Myanmar. This area has two seasons. They are a dry season (mid-November-mid-May) and a wet season (remainder of the year). Annual rainfall sets during the May to October monsoon period. The study area receives rainfall from the southwest monsoon which moves from the Bay of Bengal and Andaman Sea. The average annual rainfall is about 638 mm (25 inches). The monthly mean minimum Temperature (°C) of the study area are 13.9°C, 13.3°C and 13°C in January 2017,2018 and 2019. The monthly mean maximum Temperature (°C) of the study area is 40.7°C, 44.5°C in May 2017,2019 and 42°C, in April 2018. The humidity falls from 71% to 78% during the months of March, April and May. The average annual humidity was 82% in 2017, 2018 and 2019. The monthly total rainfall, monthly mean maximum Temperature (°C), monthly mean minimum temperature and monthly mean humidity (%) graph during the period of 2017, 2018 and 2019 are shown in Figures (3,4,5 and 6) respectively.

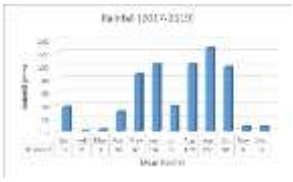

Figure 3 Average Monthly Rainfall,

Figure 4 Average Mean Maximum Temperature,

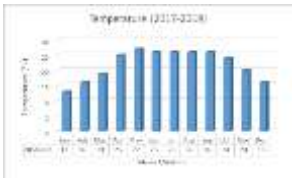

Figure 5. Average Mean MinimumTemperature,

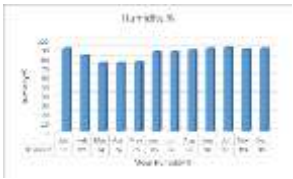

Figure 6. Average Meam Humidity

Natural Vegetation and Agriculture

Natural vegetation that can be found in the study area are Tamar, Tanaung, Tamarind, Kokko, Mango and Plum etc. Agriculture crops are bean, pulse, rice, groundnut, onion, maize, cotton, pea, plum, sugarcane, sunflower and watermelon. The grazing of cattle, cheap and goats occur in most villages.

Population and Land Use

Nyaung U township is composed of 17 urban wards, 75 village tracts and 220 villages. Total household of the Nyaung U is 53,896. The total population of the Nyaung U is 255,875. The total land used of the Nyaung U is 366,563 acres.

Regional Geologic Setting

General Geology

The study area is situated in the Central Cenozoic Belt of Myanmar. The area has a lowland topography. The regional trend of the strata is NWW-SSE parallel to the major tectonic structure. The formations in this area are recognized by the sandstones, clays, shales and conglomerates. According to the geological Map (2014), the present area and its environs are divided into the three stratigraphic units: (1) Alluvium (Holocene), (2) Irrawaddy Formation (Late Miocene-Pliocene) and (3) Upper Pegu Group (Mid-Miocene) as shown in Fig. (7) and geological succession and hydrogeological significance of aquifer of the study area are shown in Table No. (1). The aquifer types and well location map are shown in Fig. (8). The present area falls within the Minbu basin which is a segment of the western margin of Central Myanmar and Comprises an almost completely Cenozoic succession, dominantly of sandstones and days or shales. The study area comprises mainly Paleogene-Neogene sediments, deposited in shallow marine to fluvial and deltaic environments. The strata can be differentiated into four lithologic Units.

1. Upper Pegu Group (Oligocene - Miocene)
2. Irrawaddy formation (Late Miocene - Pliocene)
3. Older Alluvium (Pleistocene)
4. Younger Alluvium (Recent)
5. Igneous Rocks (Pre -Tertiary)

Upper Pegu Group (Oligocene-Miocene)

The Oligocene and Miocene layers of molasse facies of the Minbu Basin in Central Myanmar are referred to as the Pegu Group which is exposed in a north-south trending linear belt fringing the Eocene belt nearly along the whole stretch of the Minbu Basin. Each subgroup is subdivided into at least three formal lithostratigraphic units, and it is divided into the Lower Pegu Group in the Oligocene, and the Upper Pegu Group, in the Miocene. The Oligocene strata of the Lower Pegu Group are exposed only at the Gwegyo Hills west of Kyaukpadaung in the extreme western part of Mandalay Region.

Irrawaddy formation (Late Miocene- Pliocene)

Poorly consolidated. Thick-bedded or massive, large-scale cross-bedded. Medium to coarse-grained, locally pebbly, non-marine gritty sandstone and interbedded minor shale or clay of Late Miocene-Pliocene age of Central Myanmar is referred to as the Irrawaddy Formation. They are also exposed in small patches near Singu and northeast of Tagaung, both in the northern part of the Mandalay Region.

Quaternary Deposits

The Quaternary deposits are exposed in the Magway Region and Mandalay Region. River terrace deposits and plateau gravels are the older Quaternary. The Ayeyarwady River is exposed to younger alluvium, especially in the Chauk-Yenangyaung region.

Igneous Rocks

The volcanic rocks of Mt. Popa area include andesites, basalts, rhyolites and ignimbrites which range in age from Late Miocene to Late Quaternary.

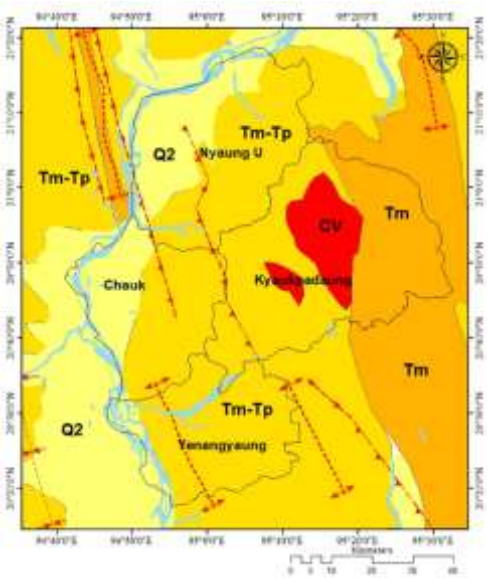

Figure 7 Regional Geological Map of the study Area. (MGS-2014)

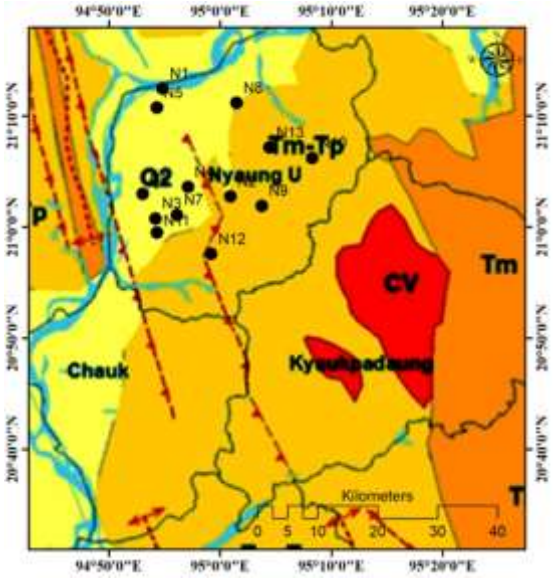

Figure 8. Aquifer types and well location map

Table 1. Geological Succession and Hydrogeological Significance of Aquifer

Unit		Stratigraphic Units	Lithology	Hydrogeological Significance
Quaternary	Recent	Younger Alluvial	Alluvial clay, silt, sand and gravel	Bearing Aquifer
	Pleistocene	Older Alluvium	Clay, silt, sand, gravel and plateau gravel	Aquifer with high yield
Tertiary	Late Miocene to Early Pliocene	Irrawaddy Formation	Loosely cement sandstone with minor clay and shale	Aquifer with moderately to fairly high yield
	Oligocene-Miocene	Pegu Group	Rapid alternation of shale, siltstone and sandstone	Limited aquifer with low yield
	Pre-Tertiary	Igneous Rocks	Andesite, Olivine Basalt and Basalt	Fractures and joints

Hydrogeologic Characteristics of the Research Area

Collection of Data

One-inch topographic map was used in the 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 the Ministry of Agriculture and Irrigation Department. There are two main types of lithology and aquifer, i.e. there are Alluvial Aquifer and the Irrawaddy Formation. According to lithologic logs the water-bearing horizons consist of yellow and blue-colored sand, sand with clay and gravel. According to well-log data, the aquifer type is confined type. The depth of the aquifer ranges from 40 ft to 340ft from the ground surface. The groundwater chemical analysis of the research area is shown in Table No. (2).

Table 2. Chemical analysis of the research area

Tube Well No.	TDS mg/l	EC micro mho/cm	pH	Na mg/l	k^+ mg/l	$Ca2^+$ mg/l	$Mg2^+$ mg/l	$Fe2^+$ mg/l	Cl^- mg/l	$SO4^=$ mg/l	$HCO3^-$ mg/l	Aquifer Types
N1	100	160	6.66	6	2.94	21.64	6.72	4.5	37	20.16	24	Alluvial
N2	770	1190	6.76	63	7.5	216.43	13	3.5	239	141	84	Irrawaddy
N3	1900	3000	7.76	0	0	117	110	0	499	330	84	Alluvial
N4	1300	2000	7.67	0	0	19	27	0	300	81	220	Alluvial
N5	660	1030	7.7	108	0	33.67	16	0	58	65	66	Alluvial
N6	1800	2820	7.2	34	0	53	139	0.01	461	391	80	Alluvial
N7	1590	2480	7.8	125	0.53	72	23	0.3	360	53	40	Alluvial
N8	830	1300	7.6	0	0	44	19	0.02	200	34	98	Irrawaddy
N9	1000	1550	7.52	75	0.62	192	26	1	230	161	40	Irrawaddy
N10	430	660	7.8	112	0.45	72	40	0	80	34	104	Irrawaddy
N11	780	1200	7.6	19	9.53	106	16	0.3	138	357	28	Alluvial
N12	660	1007	6.8	110	1.67	78	34	0.1	123	138	100	Irrawaddy
N13	900	1016	7.4	40	2.67	104	44	0.65	155	80	82	Irrawaddy

Aquifers

The Irrawaddy aquifer found the eastern part of the research area. The alluvial aquifer mainly composed of the western part of the research area. Irrawaddy rocks mainly composed of siltstone, clay, shale and sandstone. The water bearing horizon of Irrawaddy Formation is encountered at the depth ranging between 40 feet and 350 feet. In the research area, well no. N8 with the depth yields 2500 gallons per hour from the depth 570 ft.

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

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 the 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 is shown in Table No. (3).

Classification of Piper Diagram, (Piper, 1944) and Hill, 1940)

This method was proposed by Piper (1944) and Hill (1940). This method of the tri-linear diagram is widely used 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 diagrams are shown in Fig. (9). Kurlov's method and Piper method compare the results of the research area in groundwater types shown in Table No. (3).

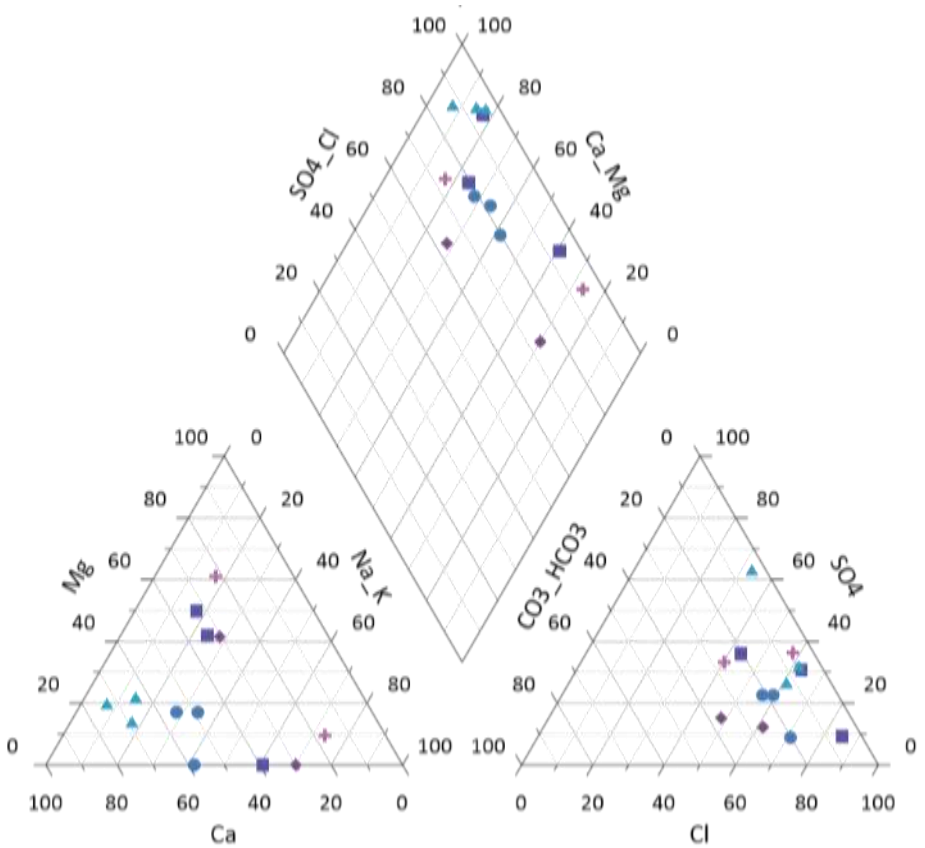

Figure 9. Classification of the Piper diagram, after Piper (1944) and by Hill (1940)

Table 3. Compares ion with Kurlov's (1928) Method and Piper Method

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

Chemical Analysis of the Groundwater

Chemical Analysis is important to specify the actual characteristics 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 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.

Major Cations

Cations, that are 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 represented shown in Fig. (10,11,12 and 13).

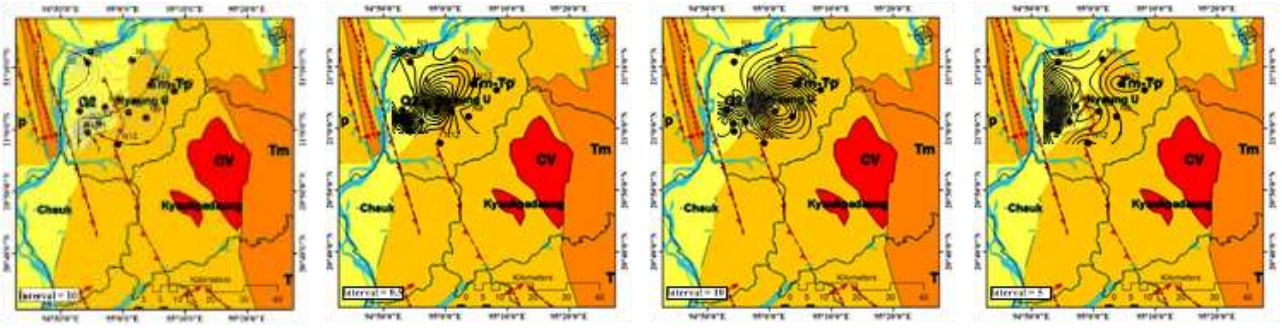

Figure 10,11,12 and 13 Distribution map of the Major Cations in research area.

Major Anions

Anions play a vital role in the quality determination of groundwater. Only major anions of Bicarbonate (HCO_3^-), Sulphate ($SO_4^{=}$) and Chloride (Cl^-) ions should be taken into account are represent shown in Fig. (14,15 and 16).

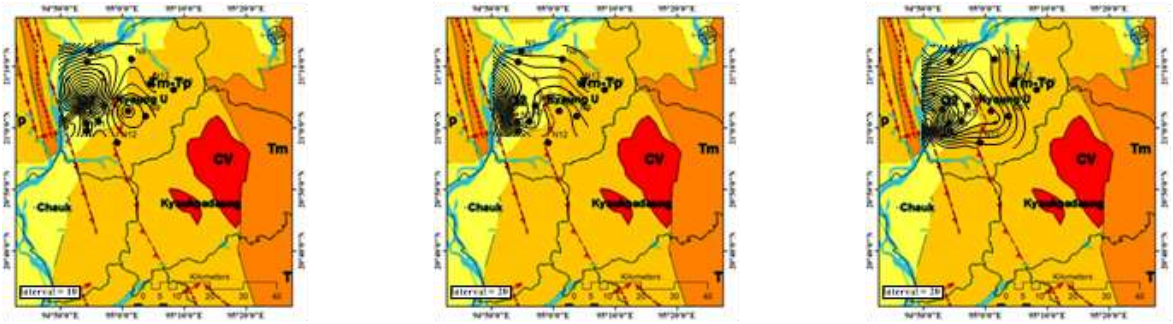

Figure 14,15 and 16. Distribution map of the Major Anions in the research area.

Domestic Purposes for Water Quality

The pH values of water samples are ranging from 6.6 to 7.8. The electrical conductivity (E.C) of groundwater samples is ranging from 160 to 2820 µmhos/cm. TDS concentration is ranging from 100 ppm to 1800 ppm. Sodium concentration is more than 125 ppm which makes the water salt taste and health problems. Calcium concentration is ranging from 19 ppm to 216.43 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 4.5 ppm. Bicarbonate concentration in the research area is ranging from 24 ppm to 220 ppm. The concentration of sulfate in the research area is ranging from 34 ppm to 357 ppm. The water quality shows the domestic uses and drinking water of water quality in Table No. (4).

Table 4. 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	19-216 mg/l	Good
Magnesium	30 mg/l	150 mg/l	13-139 mg/l	Good
Sodium	0- mg/l	200 mg/l	6-125 mg/l	Good
Potassium	0- mg/l	200 mg/l	0.53 –9.53 mg/l	Good
Sulphate	0- mg/l	400 mg/l	34 – 357 mg/l	Good
Chloride	200 mg/l	600 mg/l	37-499 mg/l	Good
Iron	0.5 mg/l	1.5 mg/l	0 – 4.5 mg/l	Poor
TDS	0- mg/l	1000 mg/l	100-1800 mg/l	Poor
pH	6.5	8.5	6.6 – 7.8	Potable
EC	0-micro mho/cm	1500 micro mhos/ cm	160–2820 micro mhos/cm	Doubtful

Agriculture purposes for Groundwater Quality

Agriculture is the basis of the Myanmar economy. The quality of water for irrigation is classified by Sodium Adsorption Ratio (SAR), Magnesium Adsorption Ratio (MAR) and Soluble Sodium Percentage (SSP or Na %). The respective values of all water quality parameters are summarized in each table.

Sodium Adsorption Ratio (SAR), (Richardson, 1954)

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

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

Table 5. Water classification based on the SAR Values

Class	SAR	Hazard and limitation
S1	<10	No Harmful effect of sodium
S2	10-18	An appreciable sodium hazard in fine-textured soils of high critical flocculation concentration but could be used on sandy soils with good permeability
S3	18-26	Harmful effects could be anticipated in most soils and amendments such as gypsum would be necessary to exchange sodium ions
S4	>26	Generally unsatisfactory for irrigation

Where the ionic concentrations are expressed in meq /L. The result of the Sodium Adsorption Ration (SAR) is shown in the Fig. (17) and Table No. (8).

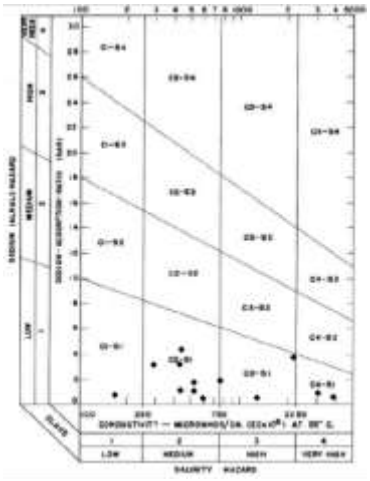

Figure 13. Sodium Adsorption Ration (SAR)

Magnesium Adsorption Ratio (MAR), (Raghunath, 1987)

The magnesium content of water is considered 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 becomes more saline, Raghunath, H. M., (1987). The values of the magnesium adsorption ratio of each aquifer are tabulated in Table No. (8).

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

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

Soluble Sodium Percentage (%), (Wilcox,1955)

Sodium concentration plays an important role in the 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:

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

The methods of classification of groundwater based on Na% (Wilcox,1955) is shown in Table No. (7). The result of the SSP% are shown in Table No. (8).

Table 7. 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 8.0 Summary Table for various methods of irrigation water quality in the Research Area

Tube Well No.	EC	SAR	MAR	SSP%
1	160	0.3	34	17
	Good	Good	Suitable	Good
2	1190	1.1	9	20
	Permissible	Good	Suitable	Good

Tube Well No.	EC	SAR	MAR	SSP%
3	3000	0	61	0
	Doubtful	nil	Suitable	Permissible
4	2000	0	20	0
	Doubtful	nil	Suitable	Doubtful
5	1030	3.8	44	61
	Permissible	Good	Suitable	Doubtful
6	2820	0.6	81	10
	Doubtful	Good	Suitable	Excellent
7	2480	3.3	35	50
	Doubtful	Good	Suitable	Doubtful
8	1300	0	42	0
	Permissible	Nil	Suitable	Excellent
9	1550	1.3	18	22
	Permissible	Good	Suitable	Good
10	660	2.6	48	41
	Good	Good	Suitable	Doubtful
11	1200	0.5	20	14
	Permissible	Good	Suitable	Good
12	1007	2.6	42	42
	Permissible	Good	Suitable	Permissible
13	1016	0.8	41	17
	Permissible	Good	Suitable	Good

Results and Outcomes

The results of chemical data analyzed by the SSP% method, the SAR method and the MAR method show that some tube wells can be assessed as not suitable for use as irrigation water. The crop should be irrigated by the tolerable plants. Kurlov's Method and PIPER method can be classified the water types, drinking water, domestic use and Irrigation water. If high amount of Iron concentration, it 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 analyzed into 6 water types. According to the above methods and the WHO Drinking Water Standard, the data can assess whether the

groundwater of the research area is suitable for drinking water, domestic use, and irrigation water, except that some tube wells are not suitable.

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