ASSESSMENT OF THE INFLUENCE OF HYDRAULIC AND GEOCHEMICAL FACTORS ON AQUIFER EVALUATION IN THE KYAUKPADAUNG AREA

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Abstract

The research area is located in Kyaukpadaung Township, Nyaung-U District, Mandalay Region. The area is lied between North latitude 20° 41' 56" to 21° 02' 7" and East longitude 95° 02' 58" to 95° 30' 37". The two stratigraphic units are 1) the Irrawaddy Formation (Late Miocene-Pliocene), and 2) the Pegu Group (Mid-Miocene). The Irrawaddy aquifer is the main aquifer of the research area. Chemical Analysis is important to specify the characteristics of groundwater. The concentration of hydrogen ions (pH) is between 6.67 and 7.77. The total dissolved solids are a maximum of 650 ppm. Electrical conductivity (E.C) is not more than 1000 μ mho/cm. The water type is classified by the methods of TDS, Piper, and Kurlov. According to the TDS, Piper, and Kurlov's method, the research area is the freshwater types and the research area can be classified into 2 types and 4 types. The concentration of Bicarbonate ions is widely distributed in most of the water of the studied region and the amount present in groundwater is relatively higher than other anions. The specific yield of the groundwater is 1000 to 2000 gallons per hour for 4-inch diameter wells and the depth of the water-bearing horizon ranges from 40 ft to 270 ft in the Irrawaddy aquifer. Calculated by the pumping test, the transmissivity of the aquifer (KD) is 202 m^2/day. Calculated by the recovery test, the transmissivity of the aquifer (KD) is 43.94 m^2/day. The irrigation water types were analyzed by the methods of SAR, and MAR. According to these methods, the SAR method gets the 5 water types and the MAR gets suitable and permissible water types. The groundwater of the research area is evaluated as suitable for drinking water, domestic uses, and irrigation water.

Keywords: TDS, Piper, Kurlov's, and SAR

Introduction

Location, Site, and Accessibility

The research area is situated in Kyaukpadaung Township, Nyaung-U District, Mandalay Region. The area is located between North latitude 20° 41' 56" to 21° 02' 7" and East longitude 95° 02' 58" to 95° 30' 37". The total coverage of the area is about 1,797 square kilometers. Figure (1) shows the location map of the research area. The population of the study area is about 261,089 (census 2019). The elevation of the research area lies above 300 mean sea level. The area is easily accessible during the whole season. The drainage pattern of the study area is the Dendritic Pattern. Figure (2) shows the drainage map of the research area. This area has two seasons. There is 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).

General Geology

The three stratigraphic units that make up the current region and its surroundings are showed on the geological map (2014): 1) Alluvium (Holocene), 2) Irrawaddy Formation (Late Miocene-Pliocene), and 3) Upper Pegu Group (Mid-Miocene), also describes the geological succession and hydrogeological significance of the study area's aquifer.

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The research area is part of the Minbu basin, which is a part of the western margin of Central Myanmar. It is almost entirely made up of Cenozoic sediments, mostly sandstones and clays or shales. Paleogene-Neogene sediments, deposited in shallow marine, fluvial, and deltaic environments, comprise most of the study area. The layers can be separated into four lithologic units.

Sedimentary Rocks

3. Quaternary Deposits (Pleistocene)

2. Irrawaddy formation (Late Miocene - Pliocene)

1. Upper Pegu Group (Oligocene-Miocene)

Igneous Rock

1. Igneous Rocks (Pre -Tertiary)

The best exposures of these rock units can be seen in the whole area. The present area includes many sedimentary structures such as calcareous pellets. Like concentrations, root-like structures, nodules, and cross-bedding. Figure (3) shows the Regional Geological Map of the research area.

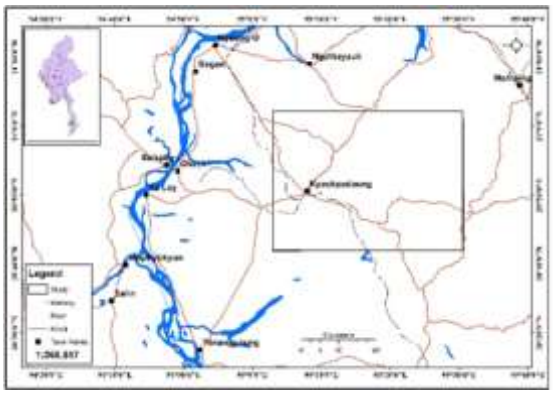


Figure 1. Location map of the research area

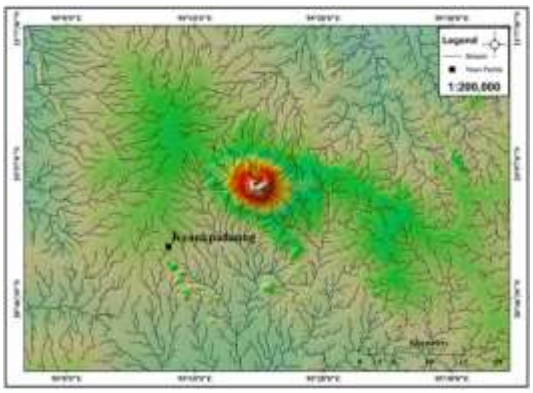


Figure 2. Drainage map of the research area

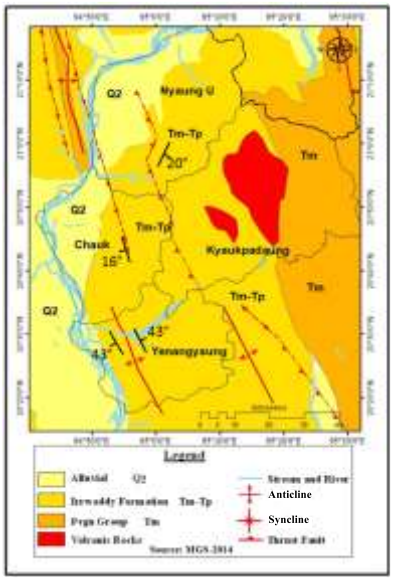


Figure 3. The Regional Geological Map of the research area.

Material and Methods

Purpose of the study

The purpose of this research is described as follows;

1. To classify the groundwater types
2. To analyze the quality of groundwater
3. To determine the hydraulic characteristics
4. To assess the suitable amount of drinking water and irrigation water

Method of the study

There are five main sections to achieve the objectives of this research.

1. To examine cation and anion parameters
2. To classify TDS, the Piper Diagram Method, and Kurlov's Method
3. To calculate the Pumping test and Recovery test
4. To compute the Sodium Adsorption Ratio (SAR)
5. To compute the Magnesium Adsorption Ratio (MAR)

Chemical analysis parameters of the research area

Chemical Analysis is important to specify the characteristics of groundwater. Determination of pH, total dissolved solids (TDS), electric conductivity E.C, dissolved cations of Na+, K+, Ca++, Mg++, and Fe++, and dissolved anions are classified in the laboratory. Table (4) shows the result data of the chemical analysis parameters in the research area. Figures (4, 5, 6, 7, 8, 9, 10, 11, 12, and 13) show the chemical parameter distribution map of the research area.

Classification of water based on TDS Levels

Total Dissolved Solids (TDS) (Gorrell, H.A. (1958)) refers to the inorganic salts and small amounts of organic matter present in water, measured primarily in milligrams per liter (mg/L) or parts per million (ppm) shown in table (1). The classification and measurement of TDS are crucial for assessing water quality, especially in drinking water and environmental monitoring. Table (5) is the result of the TDS method.

Table 1. Water can be classified according to its TDS concentration

Classification	**TDS Range (mg/L)**
Fresh Water	Less than 1,000 mg/l
Brackish Water	1,000 to 10,000 mg/L
Saline Water	10,000 to 35,000 mg/L
Hypersaline	Greater than 35,000

Classification of Piper Diagram

This method is proposed by Piper (1944) and Hill (1940). The tri-linear diagram is widely used to depict chemical data and show the relative concentrations of the major cations (Ca^{+2}, $Mg^{+2,}$ 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 the Figure (14). Kurlov's method and Piper's method compare the results of the research area in groundwater types, in Table (5).

Classification of Kurlov's Method

The Kurlov method (Kurlov, (1962)) utilizes the types of groundwater based on chemical composition. This method involves calculating the percentage of milliequivalents of cations and anions present in water samples. The classification is based on specific ion content, particularly when the concentration of any ion reaches or exceeds 25%. The primary ions analyzed include sodium, potassium, calcium, magnesium, chloride, sulphate, and bicarbonate. Table (5) is the result of the kurlov's method.

Pumping out the test in the study area

A pumping test (Cooper and Jacob's, (1946)) also known as a "well test" or "aquifer test," is a fundamental technique in hydrogeology used to assess the properties of an aquifer, such as its hydraulic conductivity, transmissivity, storativity, and the extent of its influence. The data collected during the test are analyzed using mathematical models to estimate aquifer parameters such as hydraulic conductivity, transmissivity, storativity, and the radius of influence of the well. Pumping tests provide valuable information about the behavior and characteristics of aquifers, which is crucial for designing and managing groundwater extraction systems, remediation efforts, and sustainable groundwater management. The pumping-out test is measured by the discharge rate and drawdown. It also measures the drawdown of the piezometers surrounding the pumped well at a certain time during the pumping of the well. This measurement indicates how much water stored in the aquifer can be released and the cone of depression has increased at a certain time during pumping. The test is pumped out for 24 hours, and a recovery test of 12 hours is measured. Figure (15) shows that Constant-rate pumping test data are plotted on a Semi-logarithmic scale.

Recovery test in the Study area

The recovery test ((Theis, (1935)) is an aquifer test used to assess the rate at which water levels in a well return to their original levels after pumping has stopped. It's an important tool for evaluating the hydraulic properties of an aquifer and the efficiency of a well. The objectives of the recovery test are to measure the residual drawdown to calculate the transmissivity of the aquifer and check the result of pumping test data. Residual drawdown is the difference between the original water level before the start of pumping and water level measurement at a time after the cessation of pumping in a well. Residual drawdown data is more reliable than pumping test data because recovery occurs at a constant rate. Figure (16) shows that Recovery test data are plotted on a Semi-logarithmic scale.

Sodium Adsorption Ratio (SAR)

If the water used for irrigation is high in Na and low in Ca the ion-exchange complex may become saturated with Na which destroys the soil structure, due to the dispersion of the clay particles and reduces the plant growth. Concentrations of ions are expressed in meq/L. The classification of the irrigation water types (SAR) (Richards L. A. (1954)) is shown in table (5). Figure (17) The Classification of the Sodium Adsorption Ratio (SAR) results on the Sodium vs. Electrical conductivity Chart. The SAR is computed using the following equation:

$$\text{SAR} = \frac{Na^{+}}{\frac{\sqrt{Ca^{2+} + Mg^{2+}}}{2}}$$

The concentration of ions is expressed in meq/L. The higher cumulative concentration of HCO_3^- than Ca^{2+} and Mg^{2+} concentration is an indication that residual carbonate will react with sodium, thereby resulting in sodium hazard.

Table 2. Classification and use of irrigation waters (Wilcox. L.V. (1955))

USSL Classification	Remarks	
C_1 - S_1	Excellent Water	More suitable for agriculture
C_2- S1	Good Water	Suitable for agriculture
(C_1- S_2), (C_2- S_2), (C_3 - S_2) (C_3 - S_1)	Moderate Water	Fairly suitable for agriculture
(C_1- S_3), (C_2- S_3), (C_3 - S_3), (C_4 - S_3), (C_4 - S_2), (C_4 -S_1), (C_1- S_4), (C_2 - S_4), (C_3 - S_4), (C_4 - S_4)	Bad Water	Need some treatments for agriculture

Magnesium Adsorption Ratio (MAR)

Magnesium Adsorption Ratio (MAR) was calculated using the Ca^{2+} and Mg^{2+} content of the water samples by the equation proposed by Raghunath (1987):

$$\text{MAR} = \left(\frac{Mg^{2+}}{Mg^{2+} + Ca^{2+}}\right) \times 100\%$$

where the concentration of ions is expressed in meq/l. Table (3) shows of the water classified based on the MAR values. Table (5) shows the result of the MAR.

Table. (3) Water classification based on the MAR Values

Parameter	Range	Class
MAR	< 25	Suitable
	25 - 50	Permeability
	50 - 75	Doubtful
	> 75	Unsuitable

Results and Outcomes

The result of the chemical analysis parameter in the research area

Table 4. the result data of the chemical analysis parameter in the research area

No.	TDS	EC	pH	TH	TA	Na+	k+	Ca+2	Mg+2	Cl-	SO4-2	HCO3-
1	285	440	7	134	88	36	3	35	11	47	11	88
2	505	780	7	266	98	53	7	76	18	96	155	98
3	310	490	7	204	50	21	4	71	7	55	90	50
4	650	1000	8	124	90	102	3	42	4	73	123	90

No.	TDS	EC	pH	TH	TA	Na+	k+	Ca+2	Mg+2	Cl-	SO4-2	HCO3-
5	260	410	7	164	54	23	4	54	7	61	32	54
6	265	415	8	168	60	19	4	55	8	65	53	60
7	310	480	7	184	66	20	3	50	14	54	93	66
8	250	375	8	146	52	19	3	35	14	72	45	52
9	270	420	8	176	78	17	3	58	8	78	28	78
10	540	835	8	230	184	63	5	59	20	80	89	184
11	310	480	8	180	82	24	4	52	12	64	66	82
12	290	450	8	178	42	18	4	48	14	67	85	42
13	350	540	7	202	142	26	4	54	16	64	49	142
14	710	1000	8	338	178	126	5	107	17	89	181	178
15	300	465	8	168	90	27	20	54	8	64	31	90
16	140	220	8	58	20	0	0	21	1	64	4	20
17	455	700	7	310	100	56	6	97	16	74	99	100

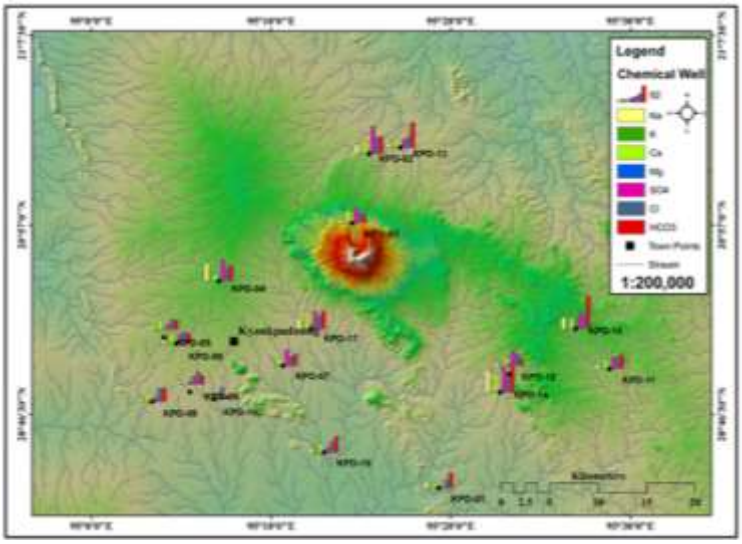
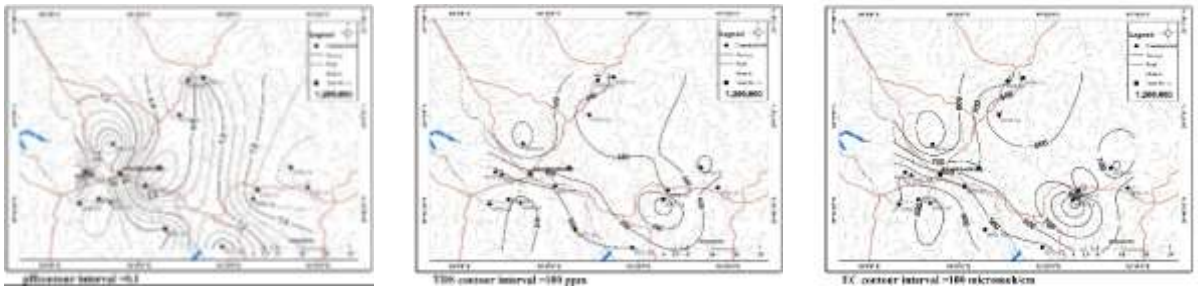


Figure 4. The chemical parameter distribution map of the research area

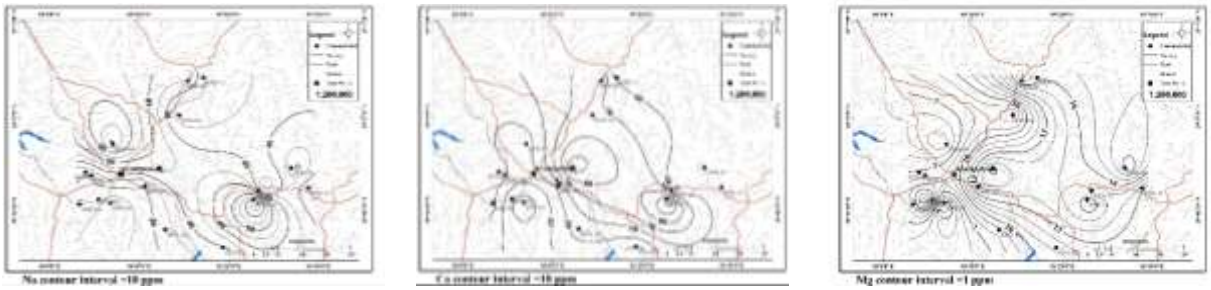
Chemical Analysis is important to specify the characteristics of groundwater. Determination of pH, total dissolved solids (T.D.S), and Electrical Conductivity (E.C) maps are shown in Figures (5,6, and 7) representing.



Figures 5,6, and 7. Contour distribution map of the pH, TDS, and E.C. in the research area.

Major Cations

Cations commonly contained in tube wells have been determined. Common cations are Sodium Na^{+}, Calcium $Ca^{+2,}$ and Magnesium Mg^{+2} are represented in Figure. (8,9, and 10).



Figures 8,9, and 10. Contour distribution map of the Na, Ca, and Mg in the research area

Major Anions

Anions play on 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 representing shown in Figures (11,12, and 13).

Figures 11,12, and 13. Contour distribution map of the HCO_3, SO_4, and Cl in the research area

The result of the classification of Piper Diagram (Piper, (1944))

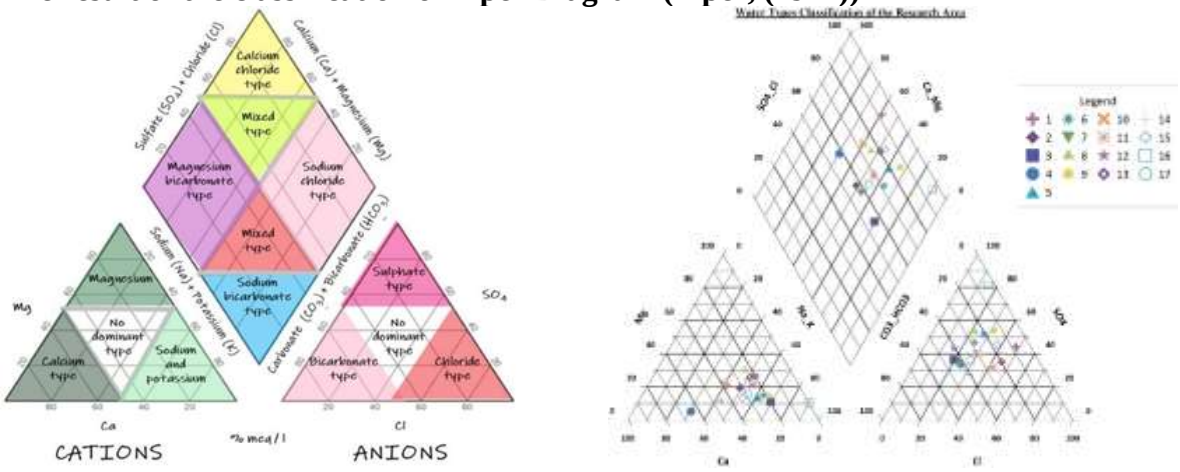


Figure 14. Tri-linear diagrams are shown the classification of the Piper method

Calculation of Pumping out test (Copper and Jacob's, 1946)

Pumping-out test data is calculated by using Jacob's Method. The Jacob's Method is based on the Theis' Equation.

$$KD = \frac{2.3Q}{4\pi\Delta S}$$

Where, KD = the transmissivity of the aquifer, m^2/day

Q= the constant well discharge, m^3/day

ΔS= the drawdown difference, m

Q= 288 m^3/day

ΔS= 0.26 m

$$KD = \frac{2.3Q}{4\pi\Delta S} = \frac{2.3\times288}{4\times3.14\times0.26} = 202\ m^2/day$$

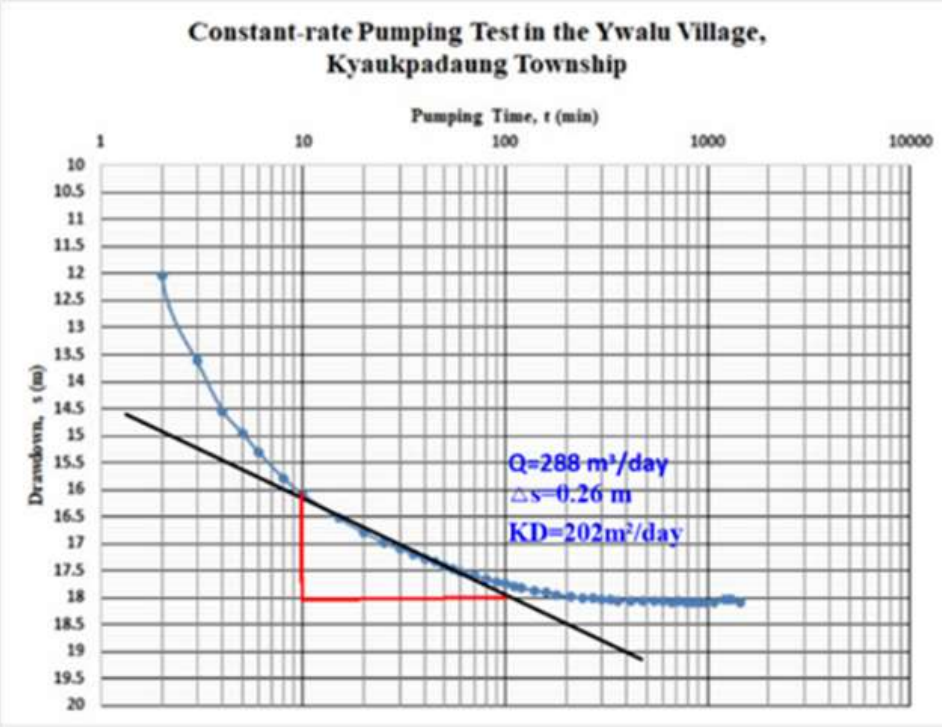


Figure 15. shows that Constant-rate pumping test data are plotted on a Semi-logarithmic scale.

Calculation of Recovery Test Data (Theis, 1935)

Theis' recovery method is widely used for the analysis of recovery tests. Theis' recovery equation (1935) is described as follows:

$$KD = \frac{2.3Q}{4\pi\Delta S'}$$

Where, KD = the transmissivity of the aquifer, m^2 / day

Q = the constant well discharge, m^2 / day

Δ = the residual drawdown, m

Theis Recovery Method

$Q = 288\ m^3$ / day

$\Delta S' = 1.2m$

$$KD = \frac{2.3Q}{4\pi\Delta S'} = \frac{2.3\times288}{4\times3.14\times1.2} = 43.94\ m^2/day$$

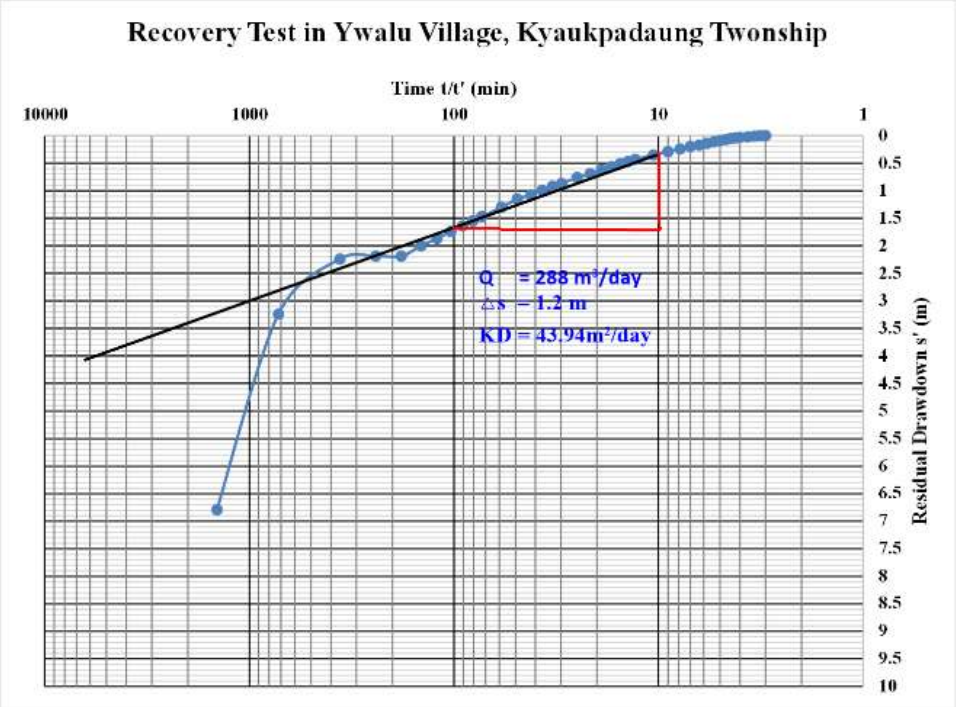


Figure 16. shows that Recovery test data are plotted on a Semi-logarithmic scale.

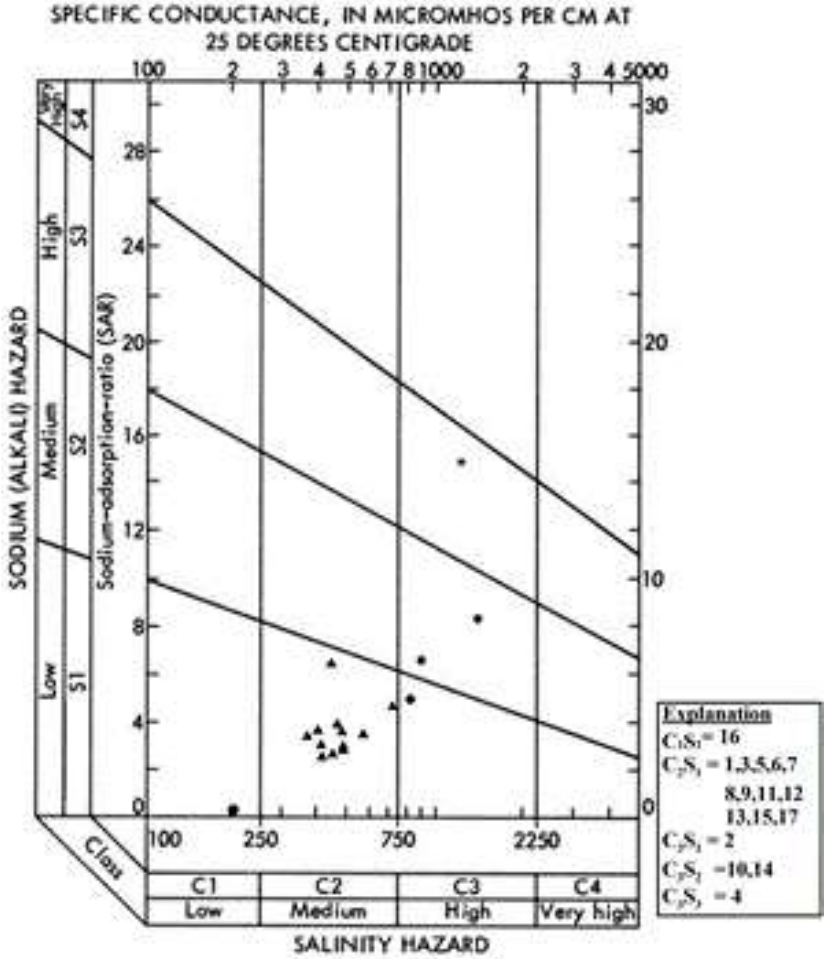


Figure 17. The Classification of the Sodium Adsorption Ratio (SAR) results in Sodium vs. Electrical Conductivity Chart

Table 5. Summarized the result of the chemical analysis data

No.	TDS	Piper	Kurlov's	SAR	MAR
1	Fresh	Mixed	HCO_3-ClCa-Na	C2S1	Permissible
2	Fresh	Mixed	SO_4-ClCa-Na	C3S1	Permissible
3	Fresh	NaCl	SO4-ClCa	C2S1	Suitable
4	Fresh	Mixed	SO_4-ClNa-Ca	C3S3	Suitable
5	Fresh	NaCl	Cl-HCO_3Ca	C2S1	Suitable
6	Fresh	NaCl	Cl-HCO3Ca	C2S1	Suitable
7	Fresh	NaCl	SO_4-ClCa-Mg	C2S1	Permissible
8	Fresh	Mixed	ClCa-Mg	C2S1	Permissible
9	Fresh	NaCl	Cl-HCO3Ca	C2S1	Suitable
10	Fresh	Mixed	HCO_3-Cl-SO_4Ca-Na	C3S2	Permissible
11	Fresh	NaCl	Cl-SO_4-HCO_3Ca	C2S1	Permissible
12	Fresh	NaCl	Cl-SO_4Ca-Mg	C2S1	Permissible
13	Fresh	NaCl	HCO_3-ClCa-Mg	C2S1	Permissible
14	Fresh	Mixed	SO_4-HCO_3-ClNa-Mg	C3S2	Suitable
15	Fresh	NaCl	Cl-SO_4Ca	C2S1	Suitable
16	Fresh	NaCl	ClCa	C1S1	Suitable
17	Fresh	NaCl	Cl-SO_4-HCO_3Ca-Na	C2S1	Suitable

Discussion

The research area is the Fresh Water Type. According to the SAR method, the irrigation water types fall in C1S1, C2S2, C3S1, C3S2, and C3S3. SAR water types (C3S2) are a moderate sodium hazard, especially in fine-textured soils with low leaching capacity. Can be used in coarse-textured or well-drained soils. SAR water types (C3S3) are a Significant risk of sodium accumulation; careful management and possibly soil changes are required to mitigate impacts. MAR water types are permissible water types.

Summary and Conclusion

The research area is located in Kyaukpadaung Township, Nyaung-U District, Mandalay Region. The Irrawaddy aquifer is the main aquifer of the research area. Chemical Analysis is important to specify the characteristics of groundwater. The concentration of hydrogen ions (pH) is between 6.67 and 7.77. The total dissolved solids are a maximum of 650 ppm. Electrical conductivity (E.C) is not more than 1000 μ mho/cm. According to the TDS, Piper, and Kurlov's method, the research area is the freshwater types and the research area can be classified into 2 types and 4 types. The concentration of Bicarbonate ions is widely distributed in most of the water of the studied region and the amount present in groundwater is relatively higher than other

anions. The specific yield of the groundwater is 1000 to 2000 gallons per hour for 4-inch diameter wells and the depth of the water-bearing horizon ranges from 40 ft to 270 ft in the Irrawaddy aquifer. Calculated by the pumping test, the transmissivity of the aquifer (KD) is 202 m^2/day. Calculated by the recovery test, the transmissivity of the aquifer (KD) is 43.94 m^2/day. The irrigation water types were analyzed by the SAR method and MAR method. According to the SAR method, the irrigation water types fall in C1S1, C2S2, C3S1, C3S2, and C3S3. According to the MAR method, the water types are permissible. The groundwater of the research area is suitable for drinking water, domestic uses, and irrigation water.

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