# COMPARATIVE HYDROCHEMICAL ASSESSMENT OF GROUNDWATER FROM DIFFERENT LIMESTONE AQUIFERS: A CASE STUDY FROM PYIN OO LWIN AREA, MANDALAY REGION

Zin Nwe Khaing[1], Zaw Myo Oo[2], Min Han Nyein[3]

## Abstract

The study area is located Pyin Oo Lwin Township, Mandalay Region. It lies between north latitude 21°57 'N and 22° 05'N between east longitude 96° 23'E and 96° 33'E. The study area is composed of mostly ridge and valley terrain and slightly occurs narrow flat land, it located within western part of the Shan Plateau region. The present area is mainly composed of five lithostratigraphic units mainly composed limestone and dolomite ranging in age from middle Ordovician to Devonian. May Myo dolomite aquifer, the thickness of the fracture zone is at (85 ft to 275 ft). Zebingyi aquifer can be occurred at Zebingyi and Bantha village. Naungbaw aquifer, the thickness of the fracture zone is at (300 ft to 355 ft) depth. The use of water for any purpose is guided under standard set of the WHO and other related agencies. The water quality for irrigation is calculated by Total Dissolved Solid, Sodium Absorption Ratio, Magnesium Hazard, Residual Sodium Bicarbonate, Potential Salinity, Kelly's Ratio. Most of the TDS values of collected water samples from these areas do no exceed 1000ppm, but well no. (POL-3, 4, 7, and 17) contain higher than the 1000ppm. All of the water resource can be used for drinking purpose because of the low range of standard guideline value but some water samples contains high EC value.

**Keywords**: Pyin Oo Lwin, Groundwater, Total Dissolved Solid, Tube well, EC.

## Introduction

Pyin Oo Lwin Township is located in Mandalay Region. It lies between north latitude 21°57 'N and 22° 05'N between east longitude 96° 23'E and 96° 33'E. The study area is located about 3600 ft above the sea level. This area refers to the one inch military Topographic map of 93 B/8, 93 B/5, 93 B/12, 93 C/9. The area of the town is (70 Sq. Km).

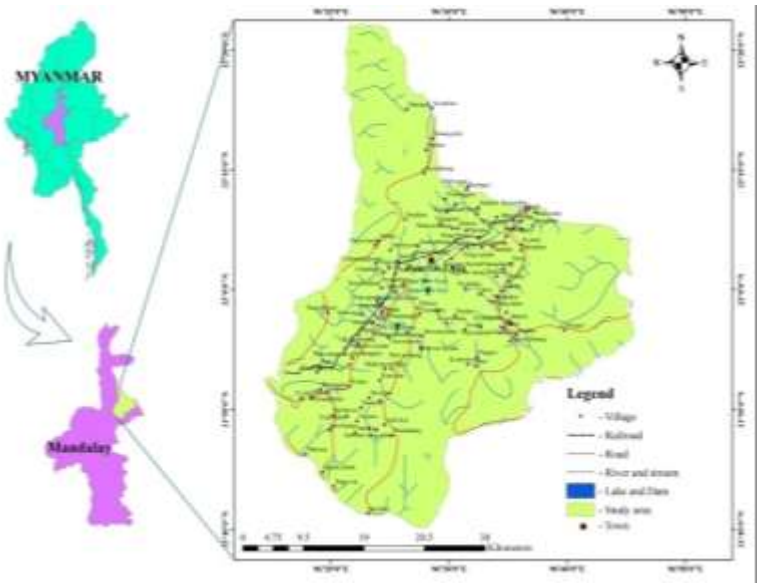


**Figure 1.1** location Map of the Pyin Oo Lwin Area

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## Drainage

The drainage system is controlled by topography and structure of rocks. Dendritic pattern is mainly developed and shows the reflection of homogeneous feature of bed rocks and underlying folded structure localized drainage patterns such as trellis, redial, and parallel drainage patterns are also observed in the area. The drainage map of the study area is shown in (Fig.1.2)

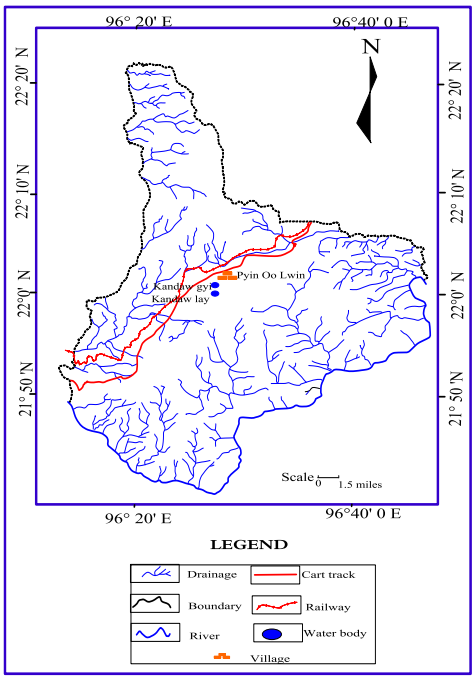


**Figure** 1.2. Drainage map of the study area

## Purpose of Study

The main objectives of the present investigation are as follows;

1. To know type of groundwater aquifer.
2. To know the quality of groundwater.
3. To evaluate the suitability of groundwater.
4. To compare the WHO standard for drinking water purpose.

## Methods of Study

The following works had been carried out during the study;

1. The water levels of tube wells are measured by using water level indicator and location of tube wells by GPS.
2. Collection of water sample from the field for chemical analysis and then brought back to the National Health laboratory.
3. Measurement of cations (main $Ca^{++}$, $Mg^{++}$, $Na^{++,}$ $Fe^{++}$ and $K^{+}$) and anions (mainly $HCO_3^-$,$CO_3^-$, $SO_4^-$ and $CL^-$), TDS, TH, pH, and EC were determined and classified by Piper Diagram Method.
4. Water samples were evaluated using the guideline values from World Health Organization, 2011.

5. Calculations of Magnesium Absorption Ratio (MAR), Residual Sodium Bicarbonate (RSBC), Sodium Absorption Ratio (SAR) and Percentage Sodium were investigated to know irrigation water quality.

## Regional Geologic Setting

The present area is mainly limestone unit of the five lithostratigraphic units ranging in age from middle Ordovician to Devonian. The Sitha Formation is exposed in the south eastern part of the study area. It is followed by the Kyaingtaung Formation (late Ordovician) which is exposed in the southern part of the present area. The phacoidal limestone Nyaungbaw Formation is mainly found in the eastern part of the study area. The Zebingyi Formation is exposed in the south-western part of the study area. The contact between the Zebingyi Formation and the Nyaungbaw Formation appears to be a conformable and gradational one. The Maymyo Dolomite Formation is widely distributed in the Northern part of the area. The stratigraphic contact between the Maymyo Dolomite Formation and the Zebingyi Formation is ascertained. See in the Figure (1.3).

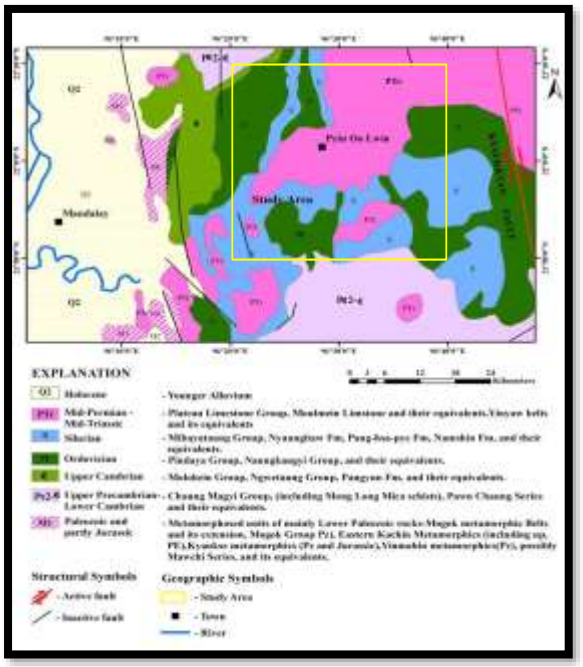


**Figure 1.3** Regional Geological Map of the Study Area (From the Geological Map of the Myanmar,2014)

## STRATIGRAPHY

The study area mainly composed of Ordovician Unit, Silurian Unit and Devonian unit. These units are as follows.

| Stratigraphic Succession | Geologic Age |
|---|---|
| 5. Maymyo Dolomite Formation | Middle to Late Devonian |
| 4. Zebingyi Formation | Early Devonian |
| 3. Nyaungbaw Formation | Silurian |
| 2. Kyaingtaung Formation | Late Ordovician |
| 1. Sitha Formation | Middle Ordovician |

## Chemical Composition of Groundwater in Study Area

### General Statement

Geochemical properties and principals that govern the behavior of dissolved chemical constituents in groundwater are referred to as hydrogeochemistry. The chemical composition of groundwater is related to the solid product of rock, weathering and changes with respect to time and space. The present research area, mainly composed the limestone units of the Ordovician to Devonian; the Maymyo dolomite formation, Nyaungbaw formation and Zebingyi formation selected for aquifer assessment.

The use of water for any purpose is guided by standard set by the WHO and other related agencies. In this study, the results of analyzed chemical parameters in the study area were correlated with those of the WHO.(Research Journal of Environmental and Earth Sciences 3 (2): 131-141,2011). In the present study, the following are analyzed; Total Dissolved Solids, Electrical Conductivity, Hydrogen Ion Concentration, Total Hardness, Total Alkalinity, MajoCations (Calcium ($Ca^{2+}$), Magnesium ($Mg^{2+}$), Potassium ($K^{+1}$), Iron ($Fe^{+2}$), Sodium ($Na^{+1}$)), Major Anions (Chloride ($CL^{-1}$), Sulfate ($SO_4^{-2}$), Bicarbonate ($HCO_3^{-1}$) ,Carbonate ($CO_3^{-2}$)).

**Table 1.1 Comparative study of chemical composition for three different limestone formations**

| Formation | TDS (mg/L) | EC Micro mho/cm | PH | TH | Major Cations (mg/L) | | | | Major Anions (mg/L) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $Ca^{2+}$ | $Mg^{+2}$ | $Na^{+1}$ | $K^{+1}$ | $Cl^{-1}$ | $SO4^{-2}$ | $HCO3^{-1}$ |
| May Myo dolomite Formation | 240-1150 | 370-1796 | 6.8-7.7 | 140-360 | 24-112 | 2-23 | 2-43 | 2-45 | 25-100 | 15-235 | 40-175 |
| Nyaungbaw Formation | 390-1000 | 600-1562 | 7.2-7.5 | 270-332 | 24-85 | 14-33 | 8-31 | 16.8-25 | 36-60 | 50-167 | 86-140 |
| Zebingyi Formation | 530-1010 | 530-1010 | 6.8-7.1 | 100-360 | 16-72 | 4.8-17 | 6.44 | 5.47 | 50 | 10-157 | 23-79 |

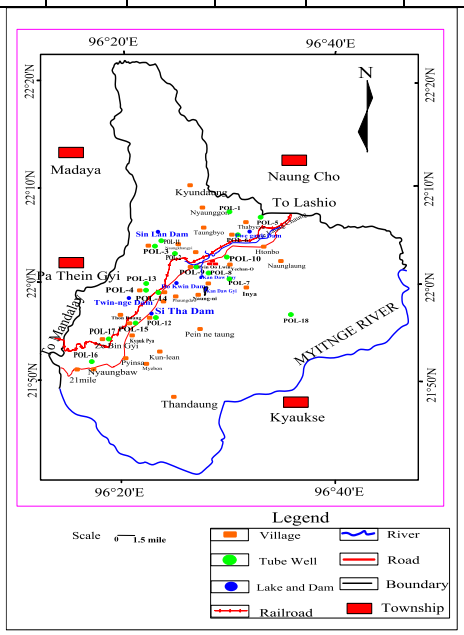


**Figure 1.4** Location map of the tube well location from which water samples are taken

## Chemical Distribution of Groundwater

The result of the chemical analysis of the various groundwater of the study area are expressed in parts per million (ppm), in equivalents per million (epm) and percentage of equivalents per million (% epm). Graphical presentation of the chemical composition of the groundwater are shown in bar graph using percentage of equivalents per million. (Figure 1.5).

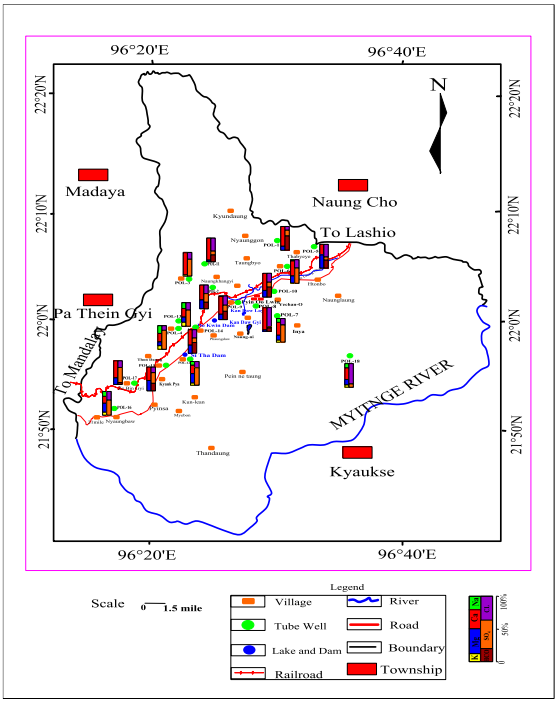


**Figure 1.5** Chemical Composition of Groundwater in the Study Area

## Classification of Type of Groundwater in the Study Area

1. Total Dissolved Solid
2. Piper Method

Based on the Concentration of Total Dissolved Solids. This classification is suggested by Freeze and Cherry (1979) as follow;

| Water Type | Concentration of TDS (ppm) |
|---|---|
| Fresh water | 0-1000 |
| Brackish water | 1000-10,000 |
| Salty water | 10,000-100,000 |
| Brine water | More than 100,000. |

According to Gorell's classification, all the water encountered in the study area is fresh water. Although most of TDS values of collected water samples from these areas do not exceed 1000 ppm, however, POL-3, POL-4, POL-7, POL-17 contain 1100 ppm,1050 ppm,1150 ppm, 1010 ppm respectively. Therefore, TDS of these wells are very slightly higher than the 1000 ppm. See in the table (1.2).

**Table 1.2 Water Type of the Study Area (Suggested by Freeze and Cherry (1979))**

(a) For May Myo Dolomite formation of the Pyin Oo Lwin area

| Sample No | TDS (ppm) | Type of Water |
|---|---|---|
| POL-1 | 740 | Fresh |
| POL-2 | 900 | Fresh |
| POL-3 | 1100 | Brackish |
| POL-4 | 1050 | Brackish |
| POL-5 | 690 | Fresh |
| POL-6 | 810 | Fresh |
| POL-7 | 1150 | Brackish |
| POL-8 | 240 | Fresh |
| POL-9 | 300 | Fresh |
| POL-10 | 320 | Fresh |
| POL-11 | 680 | Fresh |
| POL-12 | 950 | Fresh |

(b) For Naungbaw formation of the Pyin Oo Lwin area

| Sample No | TDS (ppm) | Type of Water |
|---|---|---|
| POL-13 | 1000 | Fresh |
| POL-14 | 400 | Fresh |
| POL-15 | 390 | Fresh |
| POL-16 | 810 | Fresh |

(c) For Zebingyi formation of the Pyin Oo Lwin area

| Sample No | TDS (ppm) | Type of Water |
|---|---|---|
| POL-17 | 1010 | Brackish |
| POL-18 | 530 | Fresh |

**Piper Method**

It is expressed as percentages of total cations in milliequivalents per liter, plot as a single point on the left triangle, while anions, similarly expressed as percentages of total anions, appear as a point in the right triangle. Piper diagram of water samples from the study area shown in Figure and Table.

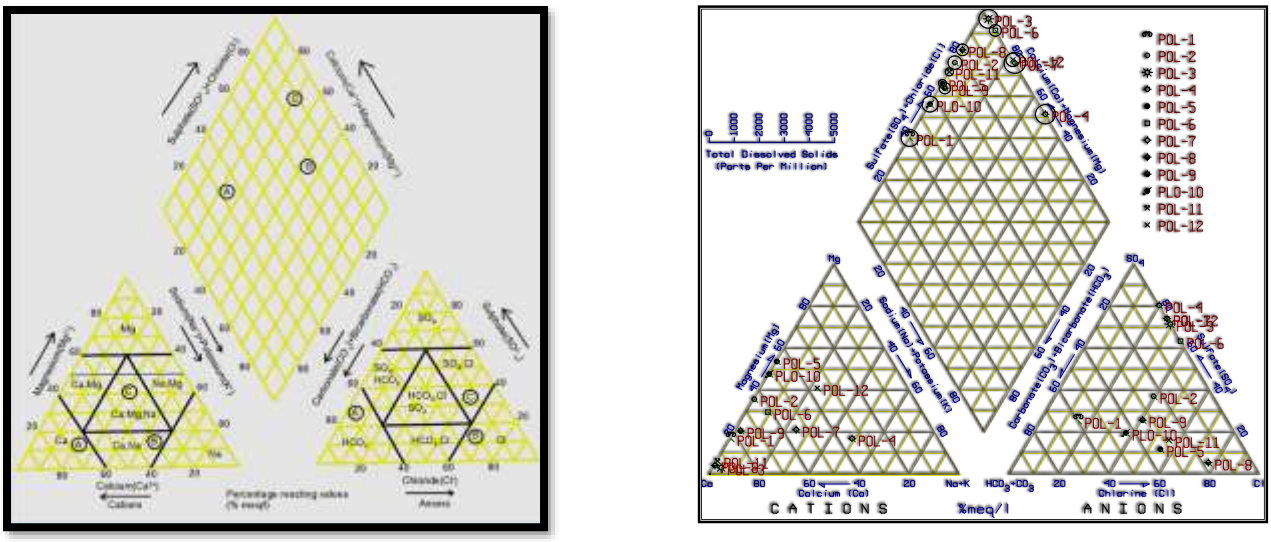


**Figure 1.6** Piper Diagram for May Myo Dolomite formation in the Pyin Oo Lwin Area

**Table 1.3 Groundwater Classification by Piper diagram**

(a) For May Myo Dolomite formation of the Pyin Oo Lwin Area

| No | | Water Type by Piper Methods |
|---|---|---|
| POL-1 | Ca $SO_4$-$HCO_3$ | Calcium Sulphate Bicarbonate water |
| POL-2 | Ca $HCO_3$-CL-$SO_4$ | Calcium Bicarbonate Chloride Sulphate water |
| POL-3 | Ca $SO_4$ | Calcium Sulphate water |
| POL-4 | Ca-Na $SO_4$ | Calcium Sodium Sulphate water |
| POL-5 | Ca-Mg HCO3-Cl | Calcium Magnesium Bicarbonate Chloride water |
| POL-6 | Ca $SO_4$ | Calcium Sulphate water |
| POL-7 | Ca-Mg-Na $SO_4$ | Calcium Magnesium Sodium Sulphate water |
| POL-8 | Ca Cl | Calcium Chloride water |
| POL-9 | Ca $HCO_3$-CL-$SO_4$ | Calcium Bicarbonate Chloride Sulphate water |
| POL-10 | Ca- Mg $HCO_3$-Cl-$SO_4$ | Calcium Magnesium Bicarbonate Chloride Sulphate water |
| POL-11 | Ca $HCO_3$-CL | Calcium Bicarbonate Chloride water |
| POL-12 | Ca-Mg-Na $SO_4$ | Calcium Magnesium Sodium Sulphate water |

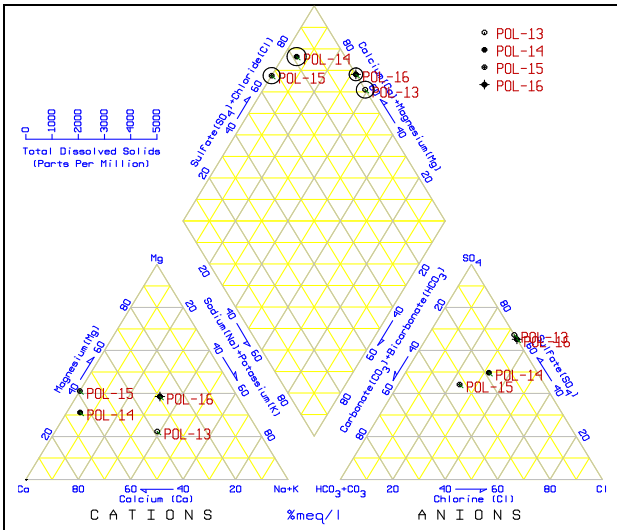


**Figure 1.7** Piper Diagram for Naungbaw formation in the Pyin Oo Lwin Area

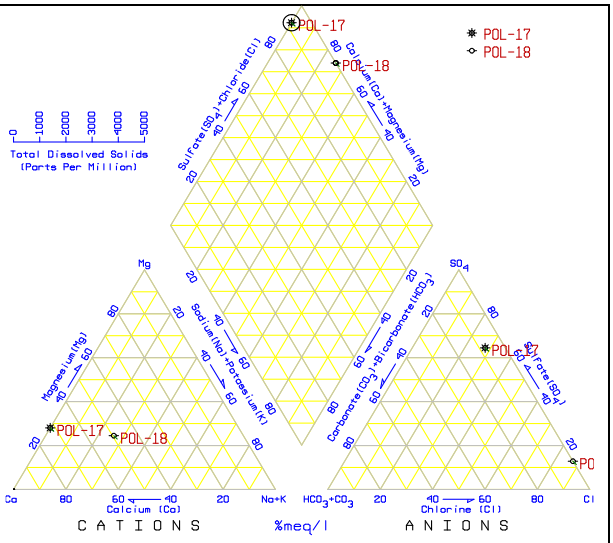


**Figure 1.8** Piper Diagram for Zebingyi formation in the Pyin Oo Lwin Area

**Table 1.3 Groundwater Classification by Piper diagram**

(b)For Naungbaw formation of the Pyin Oo Lwin Area

| No | | Water Type by Piper Methods |
|---|---|---|
| POL-13 | Ca-Mg-Na $SO_4$ | Calcium Magnesium Sodium Sulphate water |
| POL-14 | Ca $SO_4$-CL | Calcium Sulphate Chloride water |
| POL-15 | Ca-Mg HCO3-CL-$SO_4$ | Calcium Magnesium Bicarbonate Chloride Sulphate water |
| POL-16 | Ca-Mg-Na $SO_4$ | Calcium Magnesium Sodium Sulphate water |

**Table 1.3 Groundwater Classification by Piper diagram**

(c) For Zebingyi formation of the Pyin Oo Lwin Area

| No | | Water Type by Piper Methods |
|---|---|---|
| POL-17 | Ca $SO_4$ | Calcium Sulphate water |
| POL-18 | Ca-Mg-Na CL | Calcium Magnesium Sodium Chloride water |

## Utilization of Groundwater in Pyin Oo Lwin Area for Irrigation

Irrigation water criteria are dependent on the type of plants, amount of irrigation water used, soil and climate, as some plants are highly sensitive to a certain concentration of an element in the irrigation waters. The amount of water available for flushing the irrigated soil is decisive for the appearance of side-effects such as increase of unwanted compounds in the top layer of the soil. Soil and Climate condition are ultimately determining the degree of danger for unfavourable possibilities. A high evaporation and a soil of low permeability give a poor drainage and a

dangerous built up of soil-moisture salinity. A high amount of water for flushing will then be required.

In evaluating the quality of water for irrigation sodium is significant factor. A high percentage of Na in water in relation to Ca+Mg tends to break down the soil structure and the soil becomes more plastic and this will restrict water movement.

**Table 1.4 Comparison of water quality with the limits set out by FAO for irrigation water**

| Salinity | Spec. conduct at 25°C in micromhos | Na Class | S.A.R with spec .100 | Conduct. of 5000 | FAO Guideline |
|---|---|---|---|---|---|
| C1 | <250 | S1 | <10 | <2.5 | Excellent |
| C2 | 250-750 | S2 | 10-18 | 2.5-6.5 | Good |
| C3 | 750-2250 | S3 | 18-26 | 6.5-11 | Fair |
| C4 | >2250 | S4 | >26 | >11 | Poor |

## Electrical Conductivity (EC)

Electrical Conductivity in the study area show that most of samples are medium to high saline. This sample is safe under permeable soil and moderate leaching for irrigation. Well no. (POL-8,9,10,14,15) are moderately saline. (Table (1.5), (1.6 (a, b, c))).

**Table 1.5 Quality of irrigation water in relation to EC after Richard (1954)**

| No | Electrical conductivity ($\mu$mhos/cm) | Type of water | Suitability for irrigation | Remarks |
|---|---|---|---|---|
| 1 | Below 250 | Low saline water | Entirely safe | Nil |
| 2 | 250-750 | Moderately saline | Safe under practically all condition | POL-8,9,10,14,15 fall in this zone |
| 3 | 750-2250 | Medium to high saline | Safe under permeable Soil and moderate leaching | POL-1,2,3,4,5,6,7,11,12,13,16,17,18 |
| 4 | i.Above 2250<br>ii.2250-4000<br>iii.4000-6000<br>iv.Above 6000 | High salinity<br>Very high salinity<br>Excessive salinity<br>class | <br>Unfair for irrigation<br>Unfair for irrigation<br>Unfair for irrigation | <br>Nil<br>Nil<br>Nil |

(Source; Res.J. Environ. Earth Sci., 3 (2) 131-141, 2011)

**Table 1.6 Physico-chemical characteristics and suitability for irrigation**

(a) For May Myo Dolomite Formation of the Pyin Oo Lwin Area

| Sample no | PH | EC | TDS | MH | SAR | Na% | PS | RSBC | KR | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| POL-1 | 7.4 | 1156* | 740 | 17.01 | - | - | 1.33 | -1.12 | - | Suitable |
| POL-2 | 6.8 | 1406* | 900 | 0.36 | - | - | 2.5 | -1.75 | - | Suitable |
| POL-3 | 6.8 | 1718* | **1100*** | 3.45 | 0.07 | 3.02 | 3.84 | - | 0.02 | Suitable |
| POL-4 | 7.2 | 1640* | **1050*** | 33.11 | 1.53 | 48.41 | 3.47 | - | 0.63 | Suitable |
| POL-5 | 7.4 | 1078* | 690 | 54.05 | - | - | 1.57 | -0.31 | | Suitable |
| POL-6 | 7.1 | 1265* | 810 | 32.49 | 0.17 | 8.53 | 2.66 | - | 0.06 | Suitable |
| POL-7 | 7.2 | 1796* | **1150*** | 28.06 | 0.66 | 24.02 | 4.14 | - | 0.21 | Suitable |
| POL-8 | 7.6 | 370 | 240 | 4.28 | - | - | 2.93 | -3.74 | - | Suitable |
| POL-9 | 7.7 | 470 | 300 | 21.08 | 0.06 | - | 1.64 | -2.47 | 0.02 | Suitable |
| POL-10 | 7.5 | 510 | 320 | 29.42 | - | - | 2.44 | -2.31 | 1.63* | Unsuitable |
| POL-11 | 7.4 | 1062* | 680 | 6.27 | - | - | 1.62 | -1.67 | - | Suitable |
| POL-12 | 7.2 | 1484* | 950 | 53.24 | 0.51 | 22.55 | 2.77 | - | 0.19 | Suitable |

(b) For Naungbaw Formation of the Pyin Oo Lwin Area

| Sample no | PH | EC | TDS | MH | SAR | Na% | PS | RSBC | KR | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| POL-13 | 7.2 | 1562* | 1000 | 36.62 | 1.09 | 39.38 | 3.43 | - | 0.43 | Suitable |
| POL-14 | 7.5 | 630 | 400 | 32.81 | 0.02 | - | 3.01 | -3.28 | 0.005 | Suitable |
| POL-15 | 7.3 | 600 | 390 | 41.12 | - | - | 1.97 | -2.47 | - | Suitable |
| POL-16 | 7.2 | 1265* | 810 | 56.73* | 0.49 | 31.93 | 2.73 | - | 0.31 | Unsuitable |

(c) For Zebingyi Formation of the Pyin Oo Lwin Area

| Sample no | PH | EC | TDS | MH | SAR | Na% | PS | RSBC | KR | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| POL-17 | 7.1 | 1578 | **1010*** | 28 | - | - | 3.01 | -3.21 | - | Suitable |
| POL-18 | 6.8 | 828 | 530 | 32.77 | 0.36 | 26.12 | 1.52 | - | 0.24 | Suitable |

## Drinking Water

Most of the people obtain drinking water from private tube wells and W.R.U.D tube wells. The standard proposed by National Drinking Water Quality Standard, Myanmar, 1990 is shown in table and it is compared with the obtained value of groundwater analysis data from the study Area. According to the chemical analyses, some water samples contain high EC value.

**Table 1.7 Comparison with National Drinking Water Quality Standard**

| Characteristics | Guideline Value | | The range obtained value from ground water | Remarks |
|---|---|---|---|---|
| | Desirable | Max Permissible | | |
| **Calcium** | 75 mg/L | 200 mg/L | 16- 112 mg/L | Good |
| **Magnesium** | 30 mg/L | 150 mg/L | 2- 3.3 mg/L | Good |
| **Sodium** | - mg/L | 200 mg/L | 2.22- 31.26 mg/L | Good |
| **Potassium** | - mg/L | 200mg/L | 2.35- 45.36 mg/L | Good |
| **Sulphate** | - mg/L | 400 mg/L | 10- 235 mg/L | Good |
| **Chloride** | 200 mg/L | 600 mg/L | 19- 100 mg/L | Good |
| **Iron** | 0.5 mg/L | 1.5 mg/L | | |
| **TDS** | - mg/L | 1000 mg/L | 240- 1150 mg/L | Good (Except POL-3,4,7,17) |
| **pH** | 6.5 | 9.2 | 6.8- 7.7 | Good |
| **Hardness $CaCO_3$** | - mg/L | 500 mg/L | 100- 360 mg/L | Good |
| **Colour (Pt.Co.Scale)** | 5 | 50 | | |
| **Turbidity (NTU)** | 5 | 20 | | |
| **Aluminium** | - mg/L | 0.2 mg/L | | |
| **Copper** | - mg/L | 1 mg/L | | |
| **Manganese** | - mg/L | 0.3 mg/L | | |
| **Zinc** | 5 – mg/L | 15 mg/L | | |
| **EC** | - micromho/cm | 1500 micormhos/cm | 370-1796 micromhos/cm | Good (Except POL-3,4,7,13,17) |

## Summary and Conclusion

Pyin Oo Lwin Township is located in Mandalay Region. It lies between north latitude 21°50 'N and 22° 10'N between east longitude 96° 10'E and 96° 40'E. The study area is located about 3600 ft above the sea level. The study area is mainly composed of five lithostratigraphic units ranging in age from middle Ordovician to Devonian. TDS value is 240 ppm to 1150 ppm for May Myo dolomite aquifer and 390 ppm to 1000 ppm for Naungbaw formation. EC value is 370 micro mho/cm to 1796 micro mho/cm for May Myo dolomite formation and 600 micro mho/cm to 1562 micro mho/cm for Naungbaw formation and 530 micro mho/cm to 1010 micro mho/cm for Zebingyi formation. And then pH value fall 6.8 to 7.7 for May Myo dolomite formation and 7.2 to 7.5 for Naungbaw formation. The pH value is ranging from 6.8 to 7.1 for

Zebingyi formation. Robinove (1958) classification which is based on total dissolved solid (TDS) shows that almost all the water samples of the study area can be regarded as fresh water. All the water falls in the S1C2 and S1C3 types S1C1 means low Sodium water with Medium salinity water S1C3 means low Sodium water with High salinity water. So, all the water are suitable for irrigation water. Other methods used Sodium Absorption Ration, Residual Sodium Bicarbonate, Kellys Ration, Magnesium Hazard, Potential Salinity. All of the samples are suitable for irrigation water. The chemical content of the water is compared with WHO guideline and it was found that some water sample contain high EC value for drinking purpose.

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