HYDROCHEMICAL ANALYSIS AND EVALUATION OF GROUNDWATER QUALITY IN PYAWBWE-NYAUNGYAN-PAYANGAZU AREA, THAZI AND PYAWBWE TOWNSHIPS

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Abstract

Pyawbwe-Nyaungyan-Payangazu area is located in the southeastern part of Dry Zone, between 20° 31′ 12″ to 20° 45′ 54″ North latitude and 95° 53′ 24″ and 96° 14′ 24″ East Longitude. This area spreads over an area of 995.52 sq. km falling within the semiarid region and frequently facing water scarcity as well as quality problems. The major sources of employment are agriculture, horticulture and animal husbandry, engaging almost 80% of the workforce. On the basis of geological conditions and stratigraphic position, three types of aquifers are recognized in the study area, viz;- alluvial, Irrawaddian and Peguan. In accordance with their morphological characteristics and occurrence, alluvial aquifers are subdivided into those of compound alluvial fans, alluvial unit I and II. Water samples are collected from 140 wells and were subjected to analysis for chemical characteristics. The water samples from the compound alluvial fan aquifer is clustered in Ca^{2+}-Mg^{2+} Cl^{-}-SO_4^{2-} dominant section and minor water types identified is Na^{+}-K^{+} Cl^{-}-SO_4^{2-} types. Most of the groundwater samples from alluvial unit I are mostly fall in Na^{+}-K^{+}-Cl^{-}-SO_4^{2-} water types and some are fall in Ca^{2+}-Mg^{2+}-Cl^{-}-SO_4^{2-} type. In alluvial unit II the groundwater samples fall in Cl^{-}-Na^{+} water types and SO_4^{2-}-Na^{+} water types. The Irrawaddian aquifer, water are fresh and slightly saline Na^{+}-K^{+} Cl^{-}-SO_4^{2-} water type. The groundwater quality of the area is moderately hard to very hard, fresh to slightly alkaline in nature. Most of the water samples were found to be within in WHO guideline value. The suitability of groundwater for irrigation was assessed from (TDS, EC, SAR, MAR, Na% or RSC). Most of the groundwater samples in this area fall in the suitable range for irrigation purpose either from EC and MAR values.

Keywords: Groundwater quality, Chemical characters, Chemical classification, Suitability

Introduction

The Pyawbwe-Nyaungyan-Payangazu area is located in the Pyawbwe and Thazi Townships, and constitutes the eastern margin of dry zone. This study area is bounded by East Longitude 95° 53′ 24″ and 96° 14′ 24″ and North Latitude 20° 31′ 12″ to 20° 45′ 54″ and refers to one inch to one miles scale topographic map Nos: 93 D/1, 93 D/2, 84 P/13 and 84 P/14. The total coverage area is about 995.52 square kilometer.(see in fig.1)

Description of Aquifers

Based on the geologic and hydrogeologic condition of the Pyawbwe-Nyaungyan-Payangazu Area, five aquifer units can be classified. The present study is emphasized on alluvial aquifer units because most of the tube wells were sunk in these units. Hence, in the study area three major types of aquifer are recognized as follow:

(I) Alluvial Aquifers
(II) Irrawaddian Aquifers
(III) Peguan Aquifers

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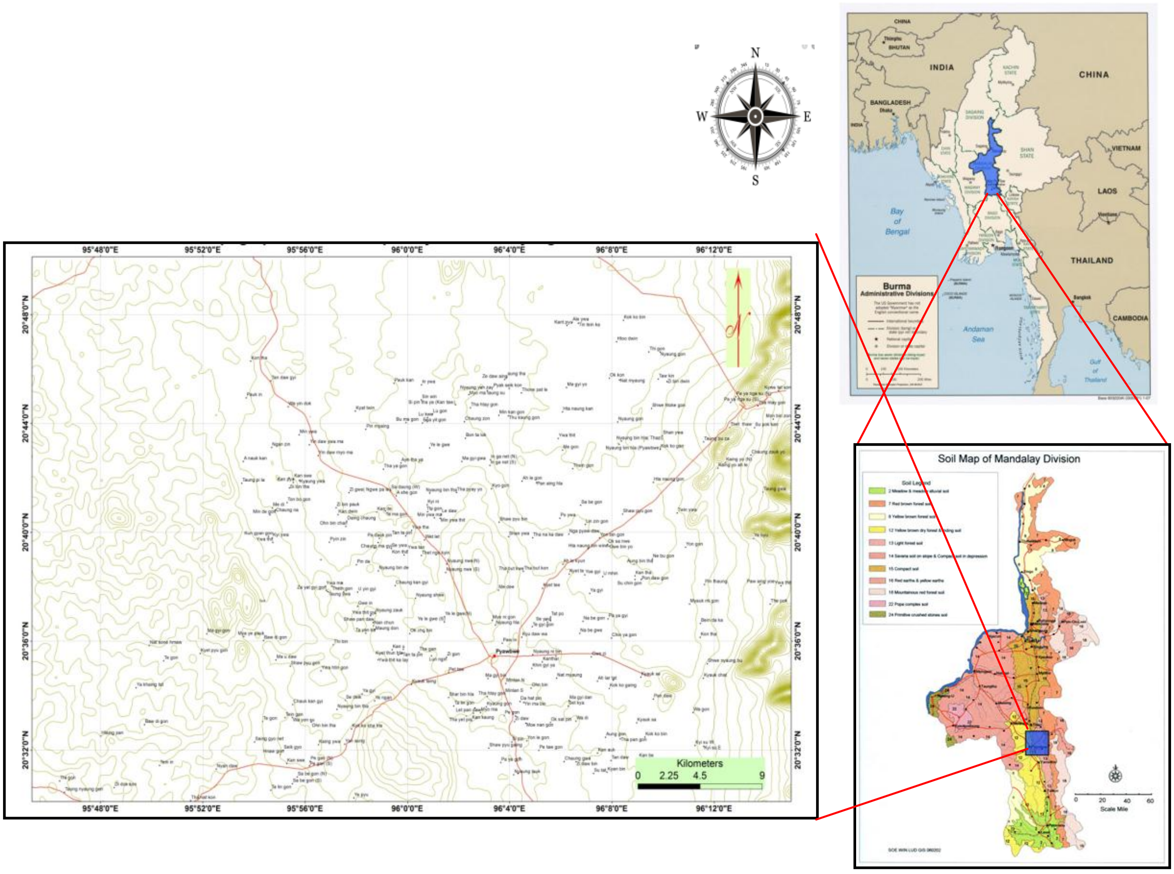

Figure 1 Location map of the study area

Among these, alluvial aquifers and Irrawaddian aquifers are more important groundwater resources for various utilizations especially for agriculture because they contain good quality water of considerable amount and nearly all the cultivated lands are situated on these aquifers. Alluvial aquifers can be sub-divided on the basis of their geomorphology, nature of sediments and their distribution and hydrogeological conditions among the alluvial ones (see in fig.2). They are as follows:

1. Compound alluvial fan Aquifer, (Bajada) (Qal_f)
2. Alluvial aquifer Unit I (between Samon Chaung and Irrawaddian ridges) (Qal_1)
3. Alluvial aquifer Unit II (between Irrawaddian ridges and Bago Yoma) (Qal_2)

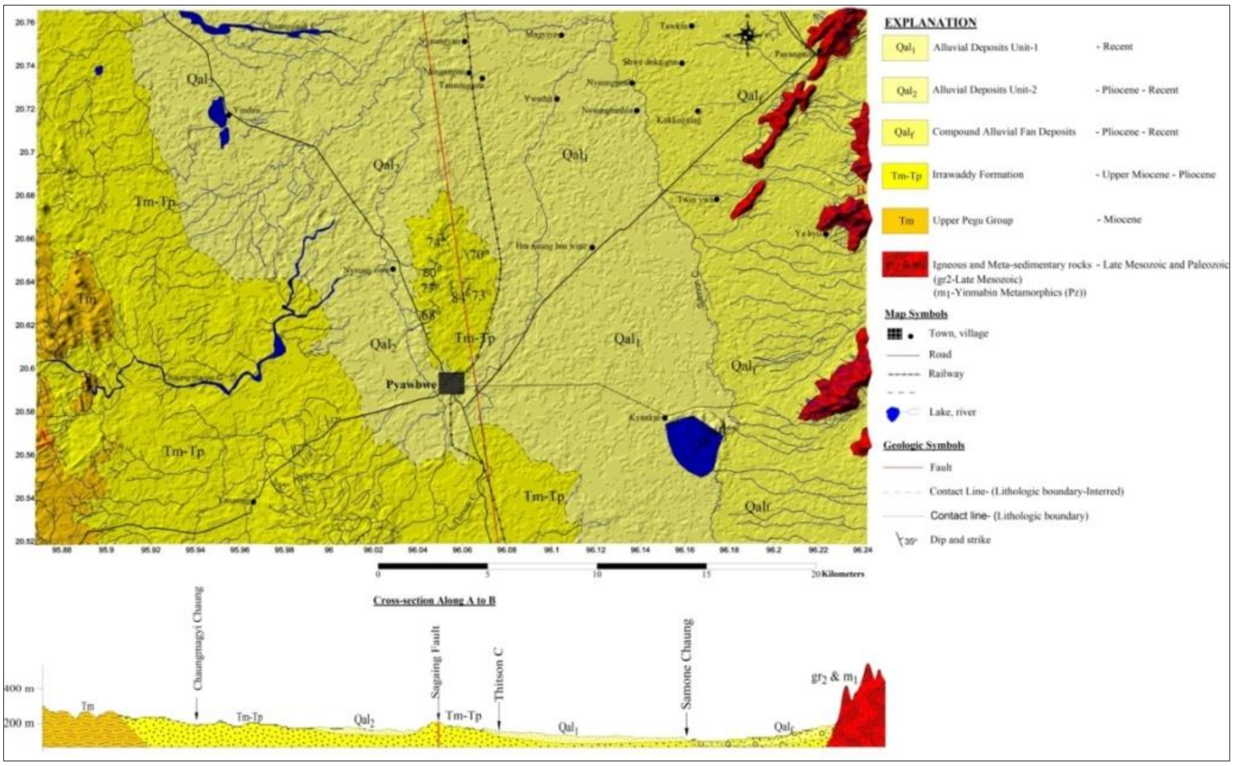

Figure 2 Geological Map of the Pyawbwe-Nyaungyan Payangazu Area

Methodology

Water samples were collected from 140 wells in the study area. These wells are used either for domestic and/or agricultural purposes. The wells were chosen to represent all the aquifers, and on the basis of their geographical location (Fig.3). The aim of such classification is to examine the relationship of the hydrochemistry and hydrochemical facies with the local hydro-environmental factors in each aquifer. Wells in each of these aquifers were defined in a single group. All water samples were analysed for the major ions: Ca2+, Mg2+, Na+, K+, SO42-, HCO3-, Cl-, and CO3-. Analyses were performed in the laboratories of the Water Resources Utilization Department (WRUD).

Results and Interpretations

Assessment of groundwater quality for domestic and irrigation purposes has been evaluated on the basis of standard guidelines. Different analysis can be used to get the real groundwater condition whether it is suitable for utilization or not.

Chemical Types and Trends of Groundwater

Generally, the chemical composition of groundwater is primarily dependent on the types of chemical reaction as well as the geochemical processes taking place within the groundwater system. The hydrogeochemical characteristics of the major and minor ions with a view to determining the groundwater types and visualizing trends of groundwater chemistry, the Piper trilinear diagrams are used.

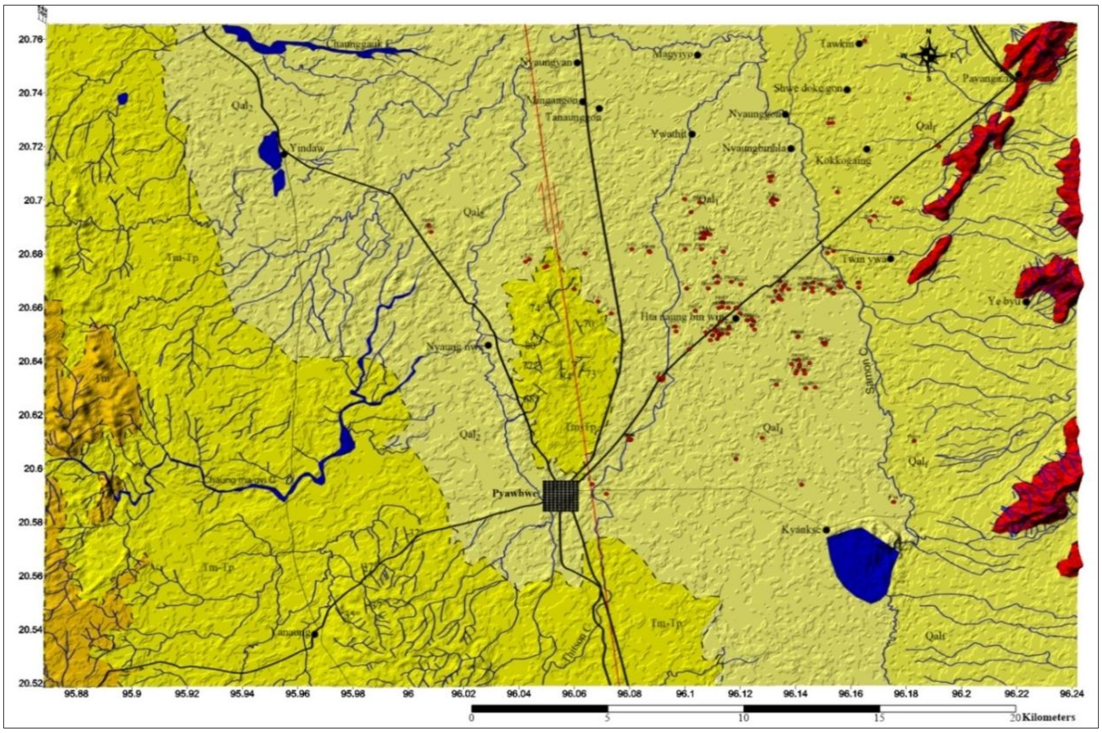

Figure 3 Groundwater sampling location map of Pyawbwe-Nyaungyan-Payangazu Area

Analytical result presents the abundance of these ions in the following order: Na > Ca > Mg > K =HCO_3> Cl > SO_4. Bicarbonate is the dominant anion found in the groundwater of the study area. Its concentration is generally higher than 100 ppm, with mean value of 121 ppm. Chloride is found in considerable amount (25 – 1752 ppm), with mean value of 97 ppm, followed by sulphate (11.52 – 417.6 ppm) with mean value of 71.2 ppm. Sodium dominates the cationic components of the groundwater, with the mean value of 89 ppm, followed by calcium, with mean value of 31.4 ppm. Next to calcium is magnesium with mean value of 15.06 ppm and followed by potassium with mean value of 1.8 ppm.

Classification by Piper Trilinear Diagram

Statistical distribution diagrams such as Piper trilinear, is used to gain better insight into the hydrochemical processes operating in the groundwater system. The Piper trilinear diagram was used for the purpose of characterizing the water types present in the area. It permits the cation and anion compositions of many samples to be represented on a single graph in which major groupings or trends in the data can be discerned visually. Water types are often used in the characterization of waters as a diagnostic tool.

Piper trilinear diagrams are shown in figure (4) and the classification shows that there is a mixture of two types of water with variable concentration of major ions. There are Ca-Mg-Cl-SO_4 type and Na+K-Cl-SO_4 type water. The first type of groundwater mostly found in the eastern part of the study area, especially in compound alluvial fan aquifers. The second groundwater types mostly found in the alluvial unit I, II and Irrawaddian and means that groundwater in the area is mainly made up of mixture of earth alkaline and alkaline metals and predominantly Cl^- - $SO_4^=$ water type.

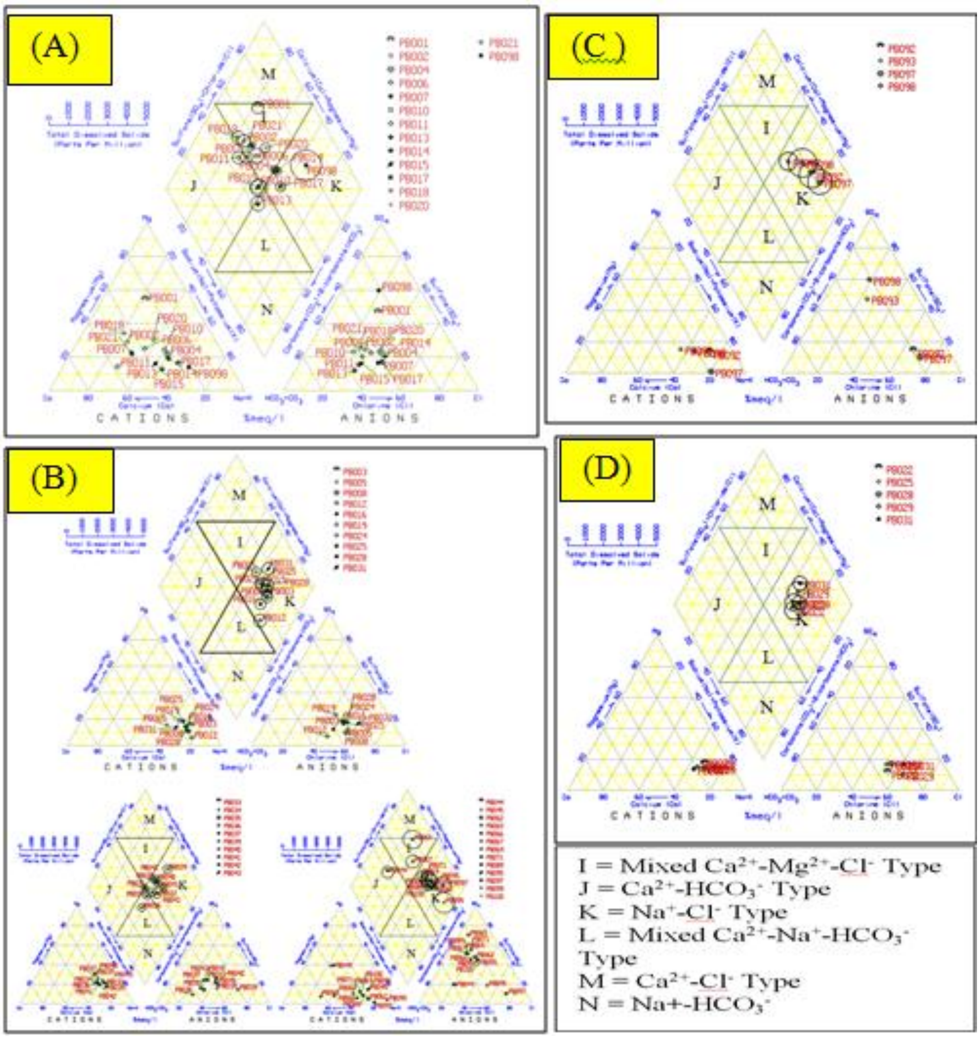

Figure (4) Piper Trilinear Diagram for chemical component of groundwater samples
(A) Compound alluvial aquifer (B) Alluvial aquifer unit I
(C)Alluvial aquifer unit II (D) Irrawaddian aquifer

Water Quality for Domestic Purposes

PH is a measure of the intensity of acidity or alkalinity condition of solution. Most of the water samples are slightly alkaline due to present of bicarbonates. The pH values of water samples varied between 6.22 to 9.4. The pH is slightly above the WHO guideline for drinking water which is between 6.5 to 8.5.

The electrical conductivity (E.C.) of groundwater samples range between 400 to 4400 µmho/cm. In most of the water samples from the study area, the electrical conductivity does not exceed the WHO standard. Some of the water samples are above the WHO standard of 1500 µmho/cm. This is due to high concentration of chloride, sulphate and bicarbonate. From the analysis, the TDS in the area is slightly high (260 -2800 ppm) and some of the water samples are above the WHO guideline of 1000 ppm.

Calcium (Ca^+) content is very common in groundwater of the study area, because they are available in most of the rocks, abundantly and directly related to hardness. Calcium concentration varies between 10.2 to 156.06 ppm and does not exceed the WHO standard. Calcium ion is commonly present in natural waters and often resulting from the dissolution of calcium-rich rocks; which is evidenced in the study area. It may occur as carbonates and sulphate of calcium, as in limestone and dolomite from the eastern highland.

Magnesium (Mg^+) usually occurs in lesser concentration than calcium due to the fact that dissolution of magnesium rich minerals is slow process. Magnesium concentration varies between 1.44 to 89.16 ppm. The water of calcium, together with those of magnesium, are responsible for the hardness of water. It the concentration of calcium and magnesium in drinking water is more than the permissible limit, it causes unpleasant taste to the water.

Sodium concentration more than 50 ppm makes the water salt taste and cause health problems. Sodium concentrations were found in between 14 to 397.15 ppm. In general sodium salts are not actually toxic substance to humans because of the efficiency with which mature kidneys excrete sodium. Most of the water samples, sodium concentrations values were found within the permissible limit (200 ppm) as WHO guideline.

Potassium is slightly less common than sodium in igneous rocks, but more abundant in all the sedimentary rocks. The main source of potassium in groundwater is weathering of potash silicate minerals, potash fertilizers and also due to surface water for irrigation. Potassium varies from 0.00 to 7 ppm.

The value of iron ($Fe2^+$) in the study area range between 0.01 to 3 ppm, and the maximum value was recorded in Twinywa (PB014). WHO guideline indicates a permissible iron value of 0.3 ppm. Most of the water samples are exceeds the WHO limit.

The primary source of bicarbonate (HCO_3^-) and carbonate (CO_2^-) ions in groundwater is the dissolved CO_2 in rainwater that on entering in the soil dissolves more CO_2. The bicarbonate and carbonate are present in natural waters and have been associated with the alkalinity and hardness of water. The major sources of these ions in water include the dissolution of limestone, dolomite chalk, chert, and other carbonate-rich rocks (Todd, 1980). Bicarbonate concentration varied from 32 to 312 ppm. The concentration of these ions ranges between 32 to 312 ppm. WHO recommends a concentration of 200 ppm for potable water supply.

The chloride (Cl^-) concentration due to domestic sewage, fertilizers applications and/or leaching from upper soil layers in semi-arid climates. Chloride concentration varies between 25 to 1752 ppm and found few samples exceed the WHO guide line of 250ppm.

Sulphate ($SO_4^=$) occurs naturally in water due to leaching from gypsum, other common minerals and discharge of domestic sewages tends to increase its concentration. The concentration of sulphate in the study ranges between 11.52 to 417.6 ppm. Sulphate are related to the types of minerals in the soil and bedrock. Sulfer in the form of sulphate is an essential plant nutrient and is considered toxic to plants or animals at lower concentration, but at higher concentrations, it imparts a bitter taste and may cause laxative effects.

Total hardness is an important parameter of water for its use in domestic purpose. Calcium and magnesium are important parameter for total hardness in groundwater. These ions react with soap to form precipitates, and with certain ions present in water to form scale. The acceptable limits for domestic use 75 ppm. Total hardness of groundwater ranged from 53.6 to 601.1 ppm. By the WHO standard, maximum permissible value is 500 ppm. Classification of water was done based on hardness given by Sawyer (1960) and is listed in Table (1). Excess hardness is undesirable mostly for economic or aesthetic reasons. Most of the samples are moderately hard to very hard water.

Table 1 Hardness Classification of Groundwater (after Sawyer and McCarty, 1960)

Hardness as $CaCO_3$	Water Class
0 – 75	Soft
75 – 150	Moderately hard
150 – 300	Hard
Over 300	Very hard

Comparison with WHO Guideline Value for Drinking Water

Groundwater samples compared with the WHO guideline value. Most of the groundwater samples from these aquifers are slightly saline and pH value is high and listed in Table (2), (3), (4) and (5)

Table 2 Alluvial fans groundwater samples compared with the WHO (2011)

Parameter	Range		Mean	WHO (2011)
	Minimum	Maximum		
PH (unit)	6.47	9.4	7.66	6.5 - 8.5
Electrical Conductivity (µmho/cm)	400	1890	885	1500
Sodium (mg/L)	14	318	64	200
Potassium (mg/L)	0.05	6	2.77	----
Calcium (mg/L)	16.23	55.31	31.53	200
Magnesium (mg/L)	6	21.6	12.34	150
Iron (mg/L)	0.01	0.6	0.26	0.3 – 1.0
Chloride (mg/L)	39	125	56.56	250
Sulphate (mg/L)	21.7	307.6	76.1	250
Bicarbonate (mg/L)	70	220	129.37	variable
Carbonate (mg/L)	-	-	-	-
TDS (mg/L)	260	1228.5	744.25	1000
Total Hardness (mg/L)	72	227	149.5	500

Table (3) Alluvial Unit I groundwater samples compared with the WHO (2011)

Parameter	Range		Mean	WHO (2011)
	Minimum	Maximum		
PH (unit)	6.67	9.4	7.54	6.5 - 8.5
Electrical Conductivity (µmhos/cm)	500	1600	843.39	1500
Sodium (mg/L)	43	221.48	85.7	200
Potassium (mg/L)	0.08	7	1.21	----
Calcium (mg/L)	15.4	156.06	32.25	200
Magnesium (mg/L)	1.44	52.8	11.34	150
Iron (mg/L)	0	0.8	0.19	0.3 – 1.0
Chloride (mg/L)	30	259	75.45	250
Sulphate (mg/L)	19.8	386.72	79.43	250
Bicarbonate (mg/L)	70	212	107.94	variable
Carbonate (mg/L)	-	-	-	-
TDS (mg/L)	325	1040	548.2	1000
Total Hardness (mg/L)	58	437	127	500

Table 4 Alluvial Unit II groundwater samples compared with the WHO (2011)

Parameter	Range		Mean	WHO (2011)
	Minimum	Maximum		
PH (unit)	7.9	8.5	8.24	6.5 - 8.5
Electrical Conductivity (μmhos/cm)	810	2980	1620	1500
Sodium (mg/L)	109	397	215.5	200
Potassium (mg/L)	-	-	-	----
Calcium (mg/L)	29.65	68.13	50.3	200
Magnesium (mg/L)	15.7	21.6	7.49	150
Iron (mg/L)	-	-	-	0.3 – 1.0
Chloride (mg/L)	57	373	190	250
Sulphate (mg/L)	80.64	307.6	172.94	250
Bicarbonate (mg/L)	118	214	149.5	variable
Carbonate (mg/L)				-
TDS (mg/L)	526.5	1937	1053	1000
Total Hardness (mg/L)	135	243	198	500

Table 5 Irrawaddian groundwater samples compared with the WHO (2011)

Parameter	Range		Mean	WHO (2011)
	Minimum	Maximum		
PH (unit)	6.67	7.76	7.44	6.5 - 8.5
Electrical Conductivity (μmhos/cm)	1100	1600	1425	1500
Sodium (mg/L)	69	99	90.3	200
Potassium (mg/L)	0.1	1.0	0.68	----
Calcium (mg/L)	18.02	26.03	22.18	200
Magnesium (mg/L)	12.00	13.84	13.04	150
Iron (mg/L)	0.2	0.3	0.275	0.3 – 1.0
Chloride (mg/L)	134	266	199	250
Sulphate (mg/L)	42.24	76.8	57.62	250
Bicarbonate (mg/L)	146	184	168	variable
Carbonate (mg/L)				-
TDS (mg/L)	715	1040	926.25	1000
Total Hardness (mg/L)	96	122	109	500

Water Quality for Irrigation Purposes

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 amount of soluble salts dissolved in it. Water chemistry differs depending on the source of water, the degree to which it has been evaporated, the type of rock and mineral it has encountered and the time it has been in contact with reactive minerals. Hence, enough information of groundwater chemistry is very essential to properly evaluated groundwater quality for irrigation purpose. Paddy crops, vegetables and food crops are the common agricultural product of the people in the study area. The area falls under semi-arid region with average rainfall around 800 mm, which is not sufficient for domestic and agriculture purpose. Canal network is strong, but having less output due to less water from the source.

Classification based on chemical indices – Sodium adsorption ratio (SAR), Mg adsorption ratio (MAR), Soluble sodium percentage (SSP or Na %), Residual sodium carbonate (RSC) were calculated. The result was compared with standard parameter in each case for each type of groundwater.

Comparison with standard Guideline Value for Irrigation

In the study area, the assessment of groundwater for irrigation has been evaluated on basis of standard guidelines. Different analysis can be used to get the real groundwater condition whether it is suitable for agriculture or not. Comparisons of different aquifer with standard guidelines are shown in Table (6), (7), (8) and (9).

According to the comparison, most of the water samples are affected by high electrical conductivity, sodium, and magnesium hazards as concerned with irrigation water. In the present study, it is evident that high salinity of groundwater persists at majority of sites. Similarly analytical solution clearly indicates that groundwater in most part of the study area is not suitable for irrigation purpose. It is suggested that suitable measure in terms of enhancement of drainage has be made in area where high salinity is observed for satisfactory crop growth. Artificial recharge and control on extraction of groundwater is the only long term and feasible solution for problem.

Table 6 Alluvial fan groundwater assessment for irrigation purposes

Sr. No.	Well No.	TDS	EC	SAR	MAR	Na%	RSC	Suitability for Irrigation
1	PB001	338	520	0.68	68.65	22.51	2.22	Unsuitable
2	PB002	546	840	0.79	38.89	25.42	1.34	suitable
3	PB004	286	440	1.49	43.43	49.51	0.28	Suitable
4	PB006	715	1100	0.00	39.22	0.04	0.96	Unsuitable
5	PB007	273	420	0.70	32.65	30.78	0.33	Suitable
6	PB010	1040	1600	0.00	45.98	0.23	1.39	Unsuitable
7	PB011	520	800	0.90	19.73	27.63	0.80	Suitable
8	PB013	617.5	950	2.19	26.41	51.19	0.49	Suitable
9	PB014	260	400	1.75	39.43	51.31	0.37	Suitable
10	PB015	585	900	2.02	30.01	46.14	0.22	Suitable
11	PB017	292.5	450	2.30	39.17	57.76	0.04	Suitable
12	PB018	585	900	0.74	43.15	21.46	1.33	Suitable
13	PB020	390	600	1.18	48.43	38.33	0.35	suitable
14	PB021	650	1000	1.08	31.59	31.61	0.45	Unsuitable
15	PB098	877.5	1350	5.45	39.16	64.41	2.24	Unsuitable
16	PB099	1228.5	1890	16.02	35.42	90.28	1.56	Unsuitable

Table 7 Alluvial unit I groundwater assessment for irrigation purposes

Sr. No.	Well No.	TDS	EC	SAR	MAR	Na%	RSC	Sustainability for Irrigation
1	PB003	390	600	3.74	52.50	72.64	0.44	Unsuitable
2	PB005	455	700	2.14	36.10	57.06	0.01	suitable
3	PB008	520	800	4.40	40.79	73.19	0.59	suitable
4	PB012	585	900	5.32	25.60	77.82	1.73	suitable
5	PB016	487.5	750	4.08	41.47	71.90	0.82	suitable
6	PB019	455	700	3.14	51.95	63.46	-0.24	Unsuitable
7	PB024	520	800	4.48	48.46	70.50	-0.14	suitable
8	PB028	585	900	4.31	47.18	69.53	-0.07	suitable
9	PB031	507	780	3.82	38.15	63.82	-0.98	suitable
10	PB033	390	600	3.47	54.32	64.66	-0.06	Unsuitable
11	PB034	390	600	2.40	45.72	54.62	-0.35	suitable
12	PB035	383.5	590	2.46	61.90	50.38	-1.33	Unsuitable
13	PB036	357.5	550	2.82	49.56	57.58	-0.99	suitable
14	PB037	390	600	2.82	50.93	56.25	-1.16	Unsuitable
15	PB039	403	620	3.13	60.55	60.50	-0.70	Unsuitable
16	PB040	390	600	2.73	58.01	55.51	-0.97	Unsuitable
17	PB041	325	500	2.87	49.20	58.77	-0.04	suitable
18	PB042	390	600	2.89	49.51	59.89	-0.71	suitable
19	PB043	390	600	3.83	53.01	66.86	-0.35	Unsuitable
20	PB044	897	1380	1.40	49.67	25.05	-5.27	Unsuitable
21	PB045	390	600	4.02	45.85	67.88	-0.33	suitable
22	PB062	568.75	875	4.36	19.05	72.73	-0.09	suitable
23	PB065	1040	1600	1.78	10.14	29.98	-6.24	Unsuitable
24	PB066	533	820	3.10	15.66	62.66	-0.30	suitable
25	PB067	1001	1540	2.33	13.20	41.71	-2.78	Unsuitable
26	PB069	650	1000	2.90	23.99	56.85	-0.68	Unsuitable
27	PB071	630.5	970	3.42	32.44	62.02	-0.72	suitable
28	PB089	539.5	830	4.47	24.96	67.12	-0.27	suitable
29	PB095	611	940	4.82	47.62	68.08	-0.72	suitable
30	PB097	929.5	1430	8.66	5.25	80.30	-0.45	Unsuitable
31	PB100	890.5	1370	5.33	24.52	64.79	-1.60	Unsuitable

Table 8 Alluvial unit II groundwater assessment for irrigation purposes

Sr. No.	Well No.	TDS	EC	SAR	MAR	Na%	RSC	Sustainability for Irrigation
1	PB090	871	1340	6.26	45.27	72.92	0.64	Unsuitable
2	PB091	1937	2980	11.08	30.05	78.04	1.35	Unsuitable
3	PB093	526.5	810	3.48	34.98	56.12	1.76	suitable
4	PB098	877.5	1350	5.45	39.16	64.41	2.24	Unsuitable

Table 9 Irrawaddian groundwater assessment for irrigation purposes

Sr. No.	Well No.	TDS	EC	SAR	MAR	Na%	RSC	Sustainability for Irrigation
22	PB022	910	1400	4.36	53.3	69.1	0.89	Unsuitable
24	PB025	715	1100	4.01	54.5	66.4	0.30	Unsuitable
26	PB029	1040	1600	4.05	43.5	65.6	0.52	Unsuitable
33	PB038	1040	1600	2.73	46.7	55.3	0.58	Unsuitable

Conclusions

Generally, the groundwater quality of the area is moderately hard to very hard, fresh to slightly alkaline in nature. The major ions in most of the locations were found to be within in WHO guideline for drinking water. Although, some of the water samples exceed the WHO guideline value.

The suitability of groundwater for irrigation was assessed from total dissolved solid (TDS), electrical conductivity (EC), sodium adsorption ratio (SAR), magnesium adsorption ratio (MAR), percentage sodium RSC. Most of the groundwater samples in this area fall in the unsuitable range for irrigation purpose.

In the present study, it is evident that high salinity of groundwater persists at majority of sites. Similarly analytical solution clearly indicates that groundwater in most part of the study area is not suitable for irrigation purpose. It is suggested that suitable measure in terms of enhancement of drainage has be made in area where high salinity is observed for satisfactory crop growth. Artificial recharge and control on extraction of groundwater is the only long term and feasible solution for problem.

Dilution is the only economical way to reduce the salt concentration in irrigation water. Dilution can be done by using nonsaline water add and it mixed with saline water to dilute the salt. Water infiltration problems caused by excess sodium are easier to prevent by continually adding soluble calcium to the irrigated water or soil and by leaching the sodium. Gypsum or other source of calcium (eg., calcium chloride) can be used to treated water. Acid and gypsum reduce the sodium hazard to soil structure posed by high RSC water. Lime residue can be minimized by lowering water pH to below 6.5. Lowering pH is accomplished by injecting acid.

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