RESEARCH PAPER

Trilinear Water Facies Classification of Lawngtlai Town, Mizoram

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Abstract
Lawngtlai town is located in the southern part of the state of Mizoram bordering Bangladesh to its west and Saiha district to the east. The perennial problem of scarcity of water leading to quests for various possible means of water sources consuming without prior treatment ~~is~~ common. It is important to assess the geochemistry, the type and concentrations of dissolved constituents to ensure water sources suitability. Different water sources at different locations were collected, evaluated and analyzed as per standard methods followed by the comparison based on World Health Organization and Bureau of Indian Standards. Trilinear diagrams are constructed using triangular coordinates to classify the current hydrochemical facies. Ternary diagrams for cation and anion show dominance of potassium+sodium and bicarbonate respectively. The total hydrochemistry of the area is dominated by alkaline earths and weak acids. Bicarbonate, sodium, and Calcium emerge as the most abundant and water can be categorized as Ca-Na-HCO_3 type'.

Keywords: Trilinear and Ternary diagrams; Parameters; Standards; Anion and Cation
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1. Introduction

Hydrochemistry is the key to fathoming the origin and chemical composition of groundwater and its relationship with rock and soil composition. Trilinear plotting methods have been widely used to delineate variability, trends and relationships between groups of different water sources and help in understanding the sources of cations and anions. Groundwater geochemistry may influence the utility of aquifer systems as sources of water. Presence of different dissolved constituents in water determines whether the resource is suitable for drinking water supplies, irrigation, household purposes, or other uses, without prior treatment [1]. Changes in the concentration of certain constituents are likely to happen day by day and from source to source. Any alteration in the natural quality may disturb the equilibrium system and would become unfit for designated uses [2]. Rapid urbanization, industrialization, population growth etc. has aggravated the environmental population immensely. The hydro chemical study reveals the water quality. On one hand it provides a clue to understand the change in quality due to rock-water interaction and on the other hand suggests its suitability for various purposes. The major chemical elements, namely Ca, Mg, Na, K, Cl, HCO3, and SO4 are often present in groundwater. These major anions and cations of groundwater play a significant role in assessing and classifying water quality. The problems of drinking water such as scarcity, contamination etc. in local and regional water sources are also very common in the study area. Therefore, the need for safe and sufficient water has to be ensured from its sources. The geochemical and chemical constituents of river water quality could be influenced by human activities and organic processes like water interacting with the lithogenic structure that the river flows through [15].

The main sources of potable water in the township are the Kaladan River, seepage water (tuikhurs) and hand pumps (groundwater). Most of the tuikhurs and hand pumps water resources are inadequate. In fact, the local population comes across an acute shortage of potable water, especially during the dry period. Since people living in the study area consume water for their drinking and domestic purposes without any treatment, the township Lawngtlai, in southern Mizoram, has been selected for the present study. The main objectives are the assessment of water parameters and determination of major ion chemistry of water sources, and to classify the suitability.

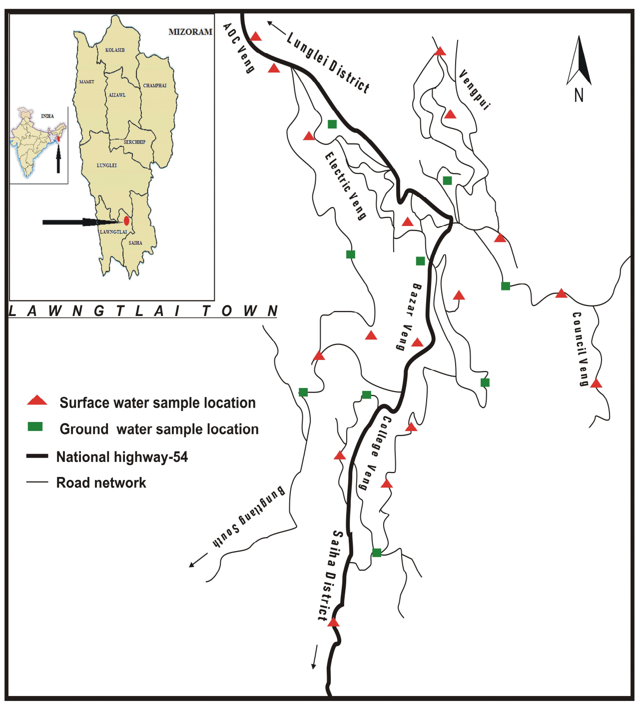

Fig. 1. Sample collection map of Lawngtlai town.

1.1. Description of the Study Area

Lawngtlai is one of the administrative districts of Mizoram state. The administrative headquarters of the district– Lawngtlai is located in the southern part of Mizoram, (Fig.1) having international boundaries with Bangladesh in the west and Myanmar in the east. It is located between 92° 51’40” E to 92° 56’12” E longitudes and 22° 28’ 20” N to 22° 34’58” N latitudes, covering an area of 2258 sq km.

Geology of the area is represented by Middle Bhuban and Upper Bhuban Formation of Surma Group [3]. They are mainly dominated by sandstones, shales and siltstones, and their intermixtures vary in proportions. The moist tropical to moist sub-tropical prevails in this region with an average annual rainfall of 2558 mm.

2. Materials and Methods

2.1. Sample Collection

Sample collected location map of groundwater and sub-surface water is shown in (Fig. 1). The perennial tuikhurs and hand pumps which were relatively more in usage than the others were selected. Water samples were collected in clean polythene bottles from different sources by using standard techniques following the grab sampling method [4]. Sample bottles were thoroughly washed with acidic water and rinsed with representative water samples. 26 samples were collected during post-monsoon season in 2019. Out of 26 samples, 8 samples were from groundwater and 18 samples from sub-surface water.

2.2. In situ physical parameters testing

In situ testing of the water samples was done immediately at the site to find out the physico-chemical properties like pH, EC, TDS and Turbidity. Digital Nephelo Turbidity Meter-132 systronics was used to measure the values of turbidity using formazine as standard. The content of pH, TDS and EC were measured by Eutech digital Instruments.

2.3. Chemical Analysis of Ions

The chemical analysis was carried out for Calcium, Magnesium, Chloride and Sulphate by volumetric titrimetric method. Bicarbonate determination was carried out using acid titration, with methyl orange as indicator. The determination of Nitrate concentration was done by UV-Spectrophotometric method. The value of Iron, Sodium, Potassium was determined by Microwave Plasma- Atomic Emission Spectroscopy. All the results are compared with standard limits prescribed by WHO and BIS [5,6].

2.4. Chemical Classification of Ground Water Using Trilinear Diagrams

Trilinear analysis of major ions has contributed extensively to the understanding of groundwater movement, and geochemistry [7]. The concentrations of the six ions are converted into milliequivalents per liter, a unit of concentration equal to the concentration in milligrams per liter divided by the equivalent weight (atomic weight divided by valence). Based on convention, three cations (calcium, magnesium, and the alkali metals- sodium and potassium) and three anions (bicarbonate, chloride and sulphate) are plotted relative to one another [8]. Fundamental interpretations of the chemical nature of a water sample are based on the location of the sample ion values within the central field are shown in (Fig. 2)

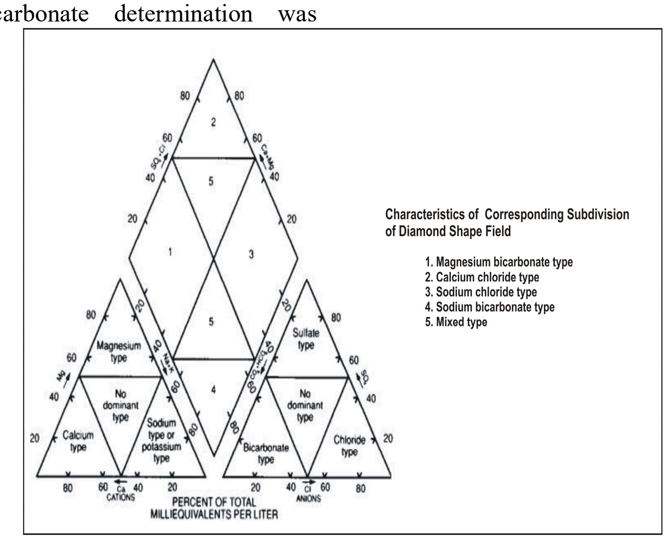

Fig. 2. Piper Trilinear classification of subdivision of diamond shape field.

3. Results and Discussion

3.1. Comparison of the results with standards

The physico-chemical parameters result obtained were presented in Table.1 and 2. The obtained parameters were compared according to the standards specified by WHO and BIS. The value of pH varies from 6.7 to 7.5, which are found to be well within the acceptance limit for drinking water. All of the pH values are constant whereas total alkalinity is found highest in SW-12, SW13 and SW-13. The high alkalinity in these samples may be due to addition of sodium which could have increased the alkalinity value. The value of alkalinity in water provides an idea of natural salts present in water [9]. In the samples analyzed, total alkalinity has been observed with a value of 25.24 mg/I to 67.34 mg/I. The value of total alkalinity being less than 200 mg/I is desirable for drinking and domestic purposes. The EC value ranges from 65 µmhos/cm to 136 µmhos/cm. The lower value of EC may be due to the presence of lesser amounts of dissolved salts which is indicative of less solubility of minerals and ions from the host rock and has insignificant rock-water intercalation. Further, it characterizes dominance of more silica content in the host rock. The value of TDS has been observed ranging from a minimum of 43 mg/I to a maximum of 107 mg/I. Here the decrease in TDS' value is in agreement with the EC results. For turbidity, it is observed that majority of the values are slightly higher than the desirable limit but still within the permissible limit of 5 NTU. The hardness of water is mainly due to dissolved calcium and magnesium salt. The hardness measured in all the water samples was rather low, ranging between minimum of 32.53 mg/I to maximum of 65.27 mg/I. The concentration of iron in groundwater samples is much more than in the sub-surface water. All of the hand pumps samples have exceeded the standard level due to the corrosive action of the groundwater causing the pump pipes to rapidly rust, resulting in release of iron into the water. However, this iron is classified as a secondary contamination, and it does not have a direct impact on human health.

Table 1. Physico-Chemical Variation of Water Sources of Lawngtlai Town During Post Monsoon Season:

SAMPLES	pH	EC	TDS	Turbidity	Alkalinity	Hardness	Fe
GW-03	7.4	100	86	2.6	44.11	44.25	0.82
GW-06	7.1	135	96	2.3	44.27	48.44	1.21
GW-07	7.0	89	64	1.3	61.34	42.47	0.83
GW-08	7.2	98	77	1.7	25.47	36.59	2.11
GW-09	7.3	132	97	2.3	33.48	44.14	0.52
GW-15	7.1	109	75	2.5	25.24	58.62	0.34
GW-16	7.5	136	107	3.1	41.27	41.31	2.32
GW-17	7.4	105	64	2.6	36.22	44.27	0.62
SW-01	7.3	66	58	1.5	43.46	32.53	0.02
SW-02	7.1	72	43	0.9	42.14	47.27	0.03
SW-04	7.1	108	92	0.5	62.37	35.64	0.02
SW-05	7.3	132	83	2.6	57.42	46.41	0.04
SW-10	7.1	81	65	1.9	64.21	48.19	0.02
SW-11	6.8	99	64	1.1	40.12	57.74	0.02
SW-12	6.9	94	80	1.5	67.24	45.68	0.01
SW-13	6.8	101	62	2.5	65.45	46.84	0.02
SW-14	7.4	117	92	2.3	60.52	63.29	0.01
SW-18	6.9	98	68	1.2	33.16	48.87	0.01
SW-19	6.9	100	71	1.1	55.52	42.21	0.02
SW-20	7.1	94	70	2.5	38.21	39.66	0.01
SW-21	7.2	90	70	2.3	44.14	41.27	0.01
SW-22	7.3	112	97	1.9	35.12	61.25	0.01
SW-23	6.9	122	104	2.7	46.29	65.27	0.02
SW-24	7.1	65	47	1.7	44.34	44.36	0.02
SW-25	7.4	88	43	1.5	33.24	35.48	0.01
SW-26	6.7	68	50	2.2	37.54	46.57	0.01

Total chloride in all the stations is much lower (6.28—19.37 mg/I) than the desirable limits value of 250 mg/l. Nitrate values in all the samples are quite low ranged from 0.11mg/I to 0.79 mg/I as compared to the standard level 45 mg/I. The reasons for low content of nitrate in all water samples in the study area, may be attributed to denitrification, plant assimilation of nitrate before entering the streams and less use of fertilizers [10,11]. Sodium value is generally higher than sulphate having a minimum range of 4.21 mg/I to a maximum of 14.05 mg/I and1.05 mg/I to 5.14 mg/I respectively. Both values obtained are found below the permissible limits. Potassium content is much lower as compared to sodium in all water samples ranging from 0.23 mg/I to 2.47 mg/I. Although the availability of potassium may be controlled by biological factors; the concentrations are low because of the high degree of stability of potassium-bearing alumino-silicate mineral. Calcium and magnesium are found to be in ranged of 3.19 mg/I to 9.11 mg/I and 3.12 mg/I to 6.74 mg/I respectively. In all the samples, it can be seen that all the physico-chemical parameters except iron are much lower than in the standard value given by WHO and BIS.

Table 2. Ionic Variation of Water Sources of Lawngtlai Town During Post Monsoon Season:

SAMPLES	Na+	K+	Ca+2	Mg+2	NO3-	SO4-2	HCO3-1	Cl-1
GW-03	12.1	1.18	5.11	4.28	0.34	3.17	44.11	8.36

GW-06	7.2	2.47	5.18	4.24	0.20	3.67	44.27	7.28
GW-07	9.3	0.64	3.19	3.17	0.21	1.32	61.34	6.28
GW-08	9.1	1.47	5.44	5.29	0.31	2.12	25.47	9.64
GW-09	5.7	2.15	4.28	4.10	0.27	1.44	33.48	9.12
GW-15	4.8	0.79	6.29	5.57	0.17	3.02	25.24	12.42
GW-16	4.3	1.71	4.14	3.49	0.17	1.08	41.27	11.26
GW-17	5.5	2.01	4.03	3.26	0.11	1.15	36.22	10.44
SW-01	8.3	0.25	4.34	4.24	0.62	1.12	43.46	7.39
SW-02	11.3	0.33	6.24	3.13	0.43	1.14	42.14	6.44
GW-03	14	1.18	5.11	4.28	0.34	3.17	62.37	8.44
SW-04	9.4	1.34	5.32	6.11	0.21	3.14	57.42	6.54
SW-05	5.1	1.48	6.37	4.43	0.79	5.14	64.21	11.24
SW-11	4.8	0.54	6.17	3.18	0.12	3.01	40.12	10.26
SW-12	5.2	1.47	9.11	4.56	0.57	2.15	67.24	9.27
SW-13	5.8	1.08	4.16	3.34	0.16	2.47	65.45	8.75
SW-14	5.3	1.21	4.11	3.52	0.12	2.49	60.52	8.55
SW-18	4.2	0.41	3.47	3.12	0.12	1.06	33.16	13.04
SW-19	5	0.61	5.08	3.46	0.11	1.05	55.52	9.21
SW-20	6.5	1.34	5.18	5.25	0.14	4.05	38.21	10.47
SW-21	6.1	1.42	5.32	5.30	0.16	3.07	44.14	9.14
SW-22	5.4	0.23	8.32	6.74	0.57	2.04	35.12	19.37
SW-23	7.5	0.82	7.54	5.53	0.54	3.17	46.29	18.54
SW-24	5.4	0.55	6.38	4.38	0.49	2.56	44.34	13.45
SW-25	6.5	1.03	7.11	5.02	0.26	2.00	33.24	9.22
SW-26	4.3	1.12	8.06	4.78	0.11	2.06	37.54	16.35

3.2. Trilinear Diagram analyses

The concentration of ions in various location of the study area, is presented in Table 2. The major ion composition is used to classify groundwater and sub-surface water into various types based on the dominant cations and anions given by Piper-Hill diagram to infer hydro-geochemical facies using the trilinear diagram. These plots include two triangles, one for plotting anions and the other for plotting cations. The fields of cation and anion are combined to show a single point in a diamond-shape field, from which inference is drawn on the basis of hydro-geochemical facies concept. These trilinear diagrams are useful in bringing out chemical relationships among water samples in more definite terms rather than with other possible plotting methods. The three trilinear plots show the essential chemical character of potable water according to the relative concentrations of its constituents [12]. Major ion data of representative samples from the study area, are presented by plotting them on Piper trilinear diagram for post-monsoon season are shown in Fig. 3.

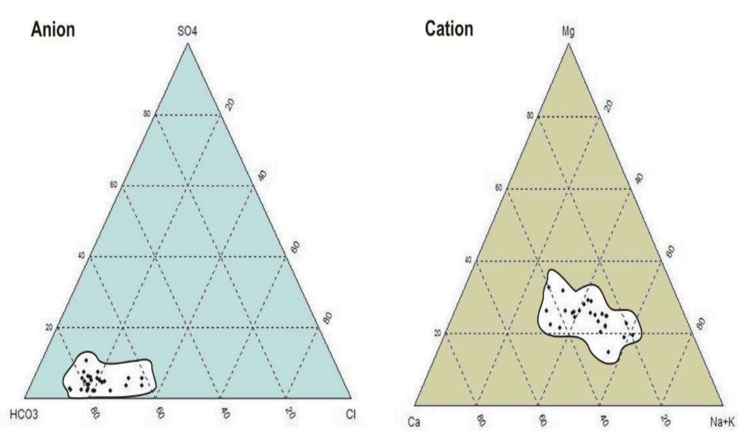

Fig.3. Major Ions of Groundwater and Sub-Surface Samples Plotted During Post-Monsoon 2019

A ternary cation diagram of sub-surface water and groundwater mainly shows the dominance of the sum of potassium and sodium. It can be observed that clustering for calcium and magnesium has been found to fall between 20% to 55% and 18% to 35% respectively whereas sodium and potassium together contribute 25% to 60% to the total cations. Bicarbonate ion is the main dominant anion in both sub-surface and groundwater contributing over 90% to the total anions. In the present study, both sub-surface water and groundwater are dominated by Na>Ca>Mg>K except in some samples where Na is replaced by Ca in cationic abundance. The order of abundance in anionic chemistry is HCO3>Cl>SO4>NO3. The plots of chemical data on trilinear diagram in Fig. 4, reveal that majority sub-surface and groundwater samples fall in the field of 1 suggesting that alkaline earths exceed alkalies, and weak acids exceed strong acids respectively. Thus, the total hydrochemistry in the area under study is dominated by alkaline earths and weak acids. Chloride and sulphate do not exceed bicarbonate in any of the samples. Most sub-surface waters and groundwater in the study area occur as Ca-Na-HCO3 facies while in few samples' sodium is sometimes replaced by magnesium giving rise to Ca-Mg-HCO3 facies. It can be observed that there is no significant change in the hydrochemical facies indicating that most of the major ions are natural in origin [13, 14].

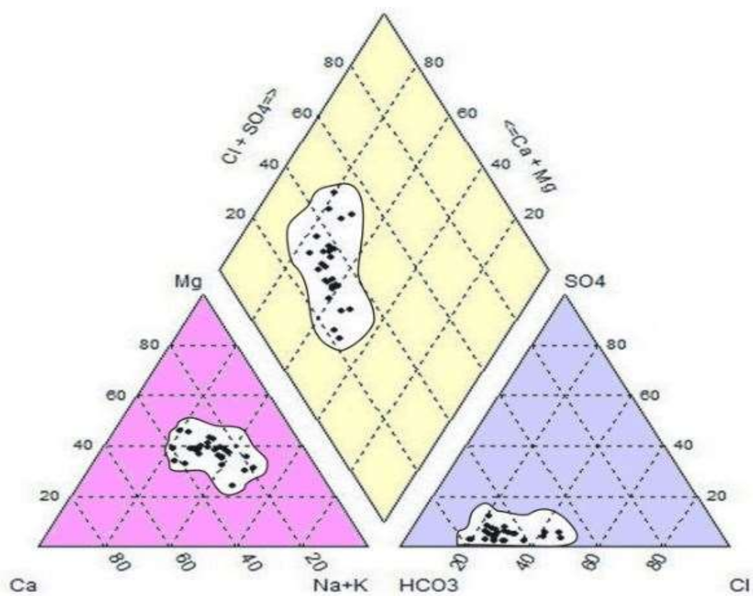

Fig. 4. Piper-Trilinear Diagram of Groundwater and Sub-Surface Samples Plotted During Post-Monsoon 2019

Furthermore, an extensive compilation of groundwater analysis from a wide variety of aquifers of host rock, has been provided by White et al. [15]. For the aquifer material, it includes sedimentary rocks (sandstone, shale, limestone and dolomite), igneous rocks (granite and basalts), a metamorphic quartzite and unconsolidated sand and gravel. Different water samples are plotted to indicate their respective aquifer rock types. Surprisingly, all but one of the aquifer rock types is dominated by bicarbonate anion. The only exception is the water from oil and gas field regions in which chloride is the dominant anion. Without primary carbonate minerals, the source of bicarbonate in granite, basalt and quartzite aquifers is carbon dioxide gas in atmospheric air and soil vapour and low concentration of carbonate minerals present as weathering products. Generally, calcium is the dominant cation in several aquifers (limestone, dolomite, quartzite and sand/gravel) whereas it is present in excess concentration in those dominated by another cation such as sodium (silicic igneous rock, sandstone, and shale-claystone) and magnesium (gabbro-basalt). The predominant source of cation in ground water is the weathering of silicate and carbonate minerals in the aquifer host rock. According to White [16], majority of the plotted data has been clustered in the fields of sandstone and shale/claystone in the diamond-shaped quadrant. In the anion triangle, no sample has been obtained falling in any identical field rather having excess amount of chloride whereas in the cation triangle sample from ground water and sub-surface water are clustering in the fields of quartzite which is rock mainly composed of quartz mineral. Since quartz is an essential constituent of sandstone and shale being silicic in nature, thus it is in accordance with the result obtained in the diamond-shaped section.

The hydrochemical classification of Lawngtlai town groundwater and sub-surface water is generally Ca-Na-HCO3 type, which is mainly attributed to the geology of the area which comprises sedimentary rocks of mainly sandstone and shale. Ground water in the study area is natural in origin and occurs under water table conditions in the predominant weathering of carbonate and silicate minerals present in the host rock of aquifer.

4. Conclusion

The present investigation revealed that physical and chemical parameters of groundwater and sub-surface water in the study area are well within the permissible limits prescribed by WHO and BIS and thus suitable for drinking, irrigation and household purposes. Piper trilinear diagram shows that the geological composition of aquifers are mainly sandstone and shale. The hydrochemistry of the area shows that alkaline earths (Ca + Mg) exceed alkaline (Na + K). In the anion weak acid (HCO3) the predominated resulting facies is Ca-Na-HCO3. In some samples, sodium is replaced by magnesium giving rise to Ca-Mg-HCO3 facies type of water.

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