Appraisal and comparison of contamination in potable water sources during pre, syn and post monsoon periods in Southwest Lawngtlai district, Mizoram, India

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Abstract

The quality of groundwater South-west Lawngtlai district, Mizoram has been assessed in the present work using the samples from ground water sources (WL) in three different seasons as pre-monsoon, monsoon and post-monsoon. The main objective of this study is to investigate the physico-chemical, bacteriological, estimation of heavy metals or trace elements and other cations and anions characteristics used for domestic and household purposes. The main sources of heavy metals/ trace elements along with different parameters in potable water were controlled by the geological composition of the host rock and with other local anthropogenic activities due to increasing urbanization, agricultural runoff containing fertilizers, pesticides, insecticides and industrial effluent. Turbidity has been found exceeding the permissible limits of 5 NTU in some stations.

The concentration of Aluminum (Al), Barium (Ba), Gallium (Ga), Iron (Fe), Lithium (Li), Strontium (Sr) and Zinc (Zn) is well within the prescribed limits recommended by BIS and WHO. In all the samples the concentration of Silver (Ag), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Molybdenum (Mo) and Nickel (Ni) is found below limit of detection (BLD). The concentration of Arsenic (As), Manganese (Mn) and Lead (Pb) in some stations has been recorded exceeding the permissible limits of 0.05 mg /me, 0.3 mg /me and 0.05 mg /me respectively. especially in the low- lying area of reducing environment such a high concentration of Arsenic in potable may be induced due to the dissolution of rocks, minerals and ores. The occasional high concentration of lead in water sample may be due to gasoline coming out of vehicles as most of the water sources are situated on or near the highway. Most of the value of total coliforms (MPN) has been found exceeding the permissible limits of 10 MPN/100 ml in water sample from all the water sources. The higher value of coliforms in water samples may be attributed to the use of pit latrines, piggeries and poultries, which are predominant in the study area. The total hydrochemistry of the area under study is dominated by alkaline earths and weak acids. Most of the surface, sub-surface and groundwater in the study area can be classified as Ca-Mg-HCO_3 facies while in some samples calcium or magnesium is sometimes replaced by sodium. It is highly recommended that the drinking water of the affected areas should be filtered and should be treated chemically or physically for toxic metals.

Keywords: Ground water, Heavy metals, Arsenic, Bacteria, MPN, Piper Diagram.

Introduction

Groundwater is the most important source of water supply for drinking, irrigation and industrial purposes. Increasing population and its necessities have led to the deterioration of surface and sub- surface[10]. Since water behaves as dynamic system, containing living as well as non-living, organic, inorganic, soluble as well as insoluble substances. So, its quality is likely to change day by day and from source to source. Any change in the natural quality may disturb the equilibrium system and would become unfit for designated uses.

Groundwater is believed to be comparatively much clean and free from pollution than surface water. But prolonged discharge of industrial effluents, domestic sewage and solid waste dump causes the water pollution results in creating a serious health problem. Further rapid growth of population in urban areas has also affected water quality due to over exploitation of resources and improper waste disposal practices. Groundwater quality depends on the type of polluting sources in the surroundings. Some of these impurities play a vital role in metabolism.

Elements such as Co, Cr, Fe, Mn, Mo, Ni, Se, Sn, V and Zn are essential for growth[18] whereas other elements such as As, Bi, Cd, Hg, Pb and Ti, have no apparent metabolic function and are termed non-essential elements. Some are very toxic to human if trace amounts of As, Hg, Pb, Cr and Cd are present[6,17]. Heavy metals enter into groundwater from variety of sources; it can either be natural or anthropogenic[1].

Potable water is the water of sufficiently high quality that can be consumed or used with minimal risk of immediate or long term harm. Moreover, its chemical constituents are controlled by geological structure and mineralogy of

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watersheds, geological processes within the aquifers and composition of precipitation[3]. An attempt has been made to access the quality of ground water from a section of Lawngtlai District of Mizoram, India.

Study area

Mizoram is a landlocked state in Northeast India whose southern part shares 722 kilometers long international borders with Myanmar and Bangladesh and northern part shares domestic borders with Manipur, Assam and Tripura. It lies from 21°56'N to 24°31'N latitudes and 92°16'E to 93°26' E longitude. It covers an area of 21081 sq. kms. The capital of Mizoram, Aizawl is to its northeast. The area under study is situated in the SW of Lawngtlai district of Mizoram.

The district is one of the administrative districts of Mizoram State. In the southern part of Mizoram, the administrative headquarters of the district– Lawngtlai is located having international boundaries with Bangladesh in the west and Myanmar in the east. The district is bound by Lunglei district in the north and Saiha districts in the south. It location is between 92°51'40" E to 92°56'12" E longitudes and 22°28'20" N to 22°34'58" N latitudes and falling within the Survey of India topo sheet No. 84B/10, 84B/11 and 84B/12. The average elevation is approximately 847 to 2785 ft from sea level. It covers an area of 2258 km^2 and most of the area is covered by the green forest.

Low elevated hills occur in the western part of the district along the Bangladesh border. They have gentle to moderate slopes and possess gully erosion. They are linked by National Highway 54 with Aizawl, the state capital of Mizoram at a distance of 296 km. It can be easily approachable from Aizawl via Lunglei, Guwahati and Shillong. The 'Lai' people are the native inhabitants and some other tribes Chakma, Lushai, Bru and Mara live in the area. The location of the study area is shown in fig.1.

Climate and rainfall: Lawngtlai town and its surrounding areas have average winter temperature range between 8°C to 24°C (46.4 to 75.2° F) and in summer, it varies between 18°C to 32°C (64.4 to 89.6° F). A clear and cool weather starts appearing from September and remains till January the next year. During the cold season, minimum temperature may go as down as 5°C. The area falls under the direct influence of South-west monsoon and heavy precipitation starts falling heavily from May to September and with little rain in the dry period. During the rainy season, it remains heavily clouded. There is an increase of cloudiness from March onwards. The average annual rainfall in the study area is about 2558 mm.

Drainage system: Mizoram has innumerable rivers and streams. Some of the rivers such as Tlawng (Dhaleswari), Tuirial (Sonai) and Tuivawl flow towards north and join the river Barak in Cachar district of Assam[22,23]. The drainage system of Lawngtlai may be divided into three main parts viz. Chhimtuipui, Sekulh and Tuichawng drainage systems. Generally, the drainage system as a whole is said to be dendritic to sub-dendritic and the streams are youthful stage and nullahs have much straightened and deep courses. In some areas, drainage shows parallel and trellis pattern forming deep gorges and water gaps. Chhimtuipui river originates from the western part of Myanmar near Vanum village at an altitude of 2,325 m. It forms an international boundary line between India and Myanmar for a distance of 92.56 Km.

Objectives

1. To quantify physico-chemical and bacteriological test.
2. To determine the level of concentration of various heavy metals or trace elements and compare according to BIS and WHO Standards.
3. To assess the impact of rock-water interaction on the quality of potable water and develop a data-base on water quality.
4. To demarcate vulnerable water sources in order to suggest remedial measure.

Material and Methods

Field Work: Field work mainly involves survey and sampling of potable water samples. Various sources of potable water were identified during the survey of study area. Further, in consultation with the people the suitable sites were selected for alternative source of potable water i.e. Tuikhur, River and Dug well. However, the present work focuses on the samples from Dug-Wells only. Sample location map is presented in fig. 2.

Fig. 1: Location Map of the Study Area

Survey and selection of sampling sites: A detailed survey of sampling sites was performed before starting sampling and analysis of potable water. The water source was Dug well, widely distributed throughout the areas in and around various townships (Fig. 3). During the survey of the area, dug well was found only in Vaseikai village. Six locations were selected for Dug well at Vaseikai village.

Sample collection scheme: To evaluate contamination of potable water, water samples were collected. The samples were collected during pre-monsoon, Monsoon and post Monsoon. These samples were taken for detailed hydrological and hydrogeochemical investigations. Sampling was performed according to the recommendations of the APHA, AWWA and WERF[4]. For the present work, as the water samples were homogeneous, it was sufficed to take the grab sample only. Water samples were collected in a wide mouth bottle of 250 ml capacity with airtight caps. Before collection of samples, polythene bottles were cleaned thoroughly, rinsed with distilled water and again rinsed with representative water samples.

Two bottles of 250 ml each for each location, one acidified with 2-3 ml of diluted. HNO_3 and non- acidified were collected. Samples for bacteriological examination were also collected in clean and sterilized narrow mouthed neutral glass bottles of 500 ml capacity.

Sample Code: Detailed locations of Dug-well water samples are given with their codes respectively. The code assigned is WL-1 to WL- 6): WL-01 Vaseikai (Mawii hotel), WL-02 Vaseikai (Sumo counter), WL-03 Vaseikai (Badbonia Road), WL-04 Vaseikai (Chakma veng), WL-05 Vaseikai (Hoipa kua) and WL-06 Vaseikai (Mizo veng).

Analysis: Physical parameters include pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Turbidity. Chemical parameter selected for this work include Total Alkalinity (TA), Total Hardness (TH) Bicarbonate (HCO_3), Sulphate (SO_4), Total Chlorite (TCl), Fluoride (F), Nitrate (NO_3), Calcium (Ca), Magnesium (Mg) and heavy metal toxic elements like Arsenic (As), Silver (Ag), Aluminum (Al), Barium (Ba), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Gallium (Ga), Potassium (K), Lithium (Li), Manganese (Mn), Molybdenum (Mo), Sodium (Na), Iron (Fe), Nickel (Ni), Lead (Pb), Strontium (Sr) and Zinc (Zn). The bacteriological examination includes tests for Total Coliforms and the result are reported as most probable number (MPN).

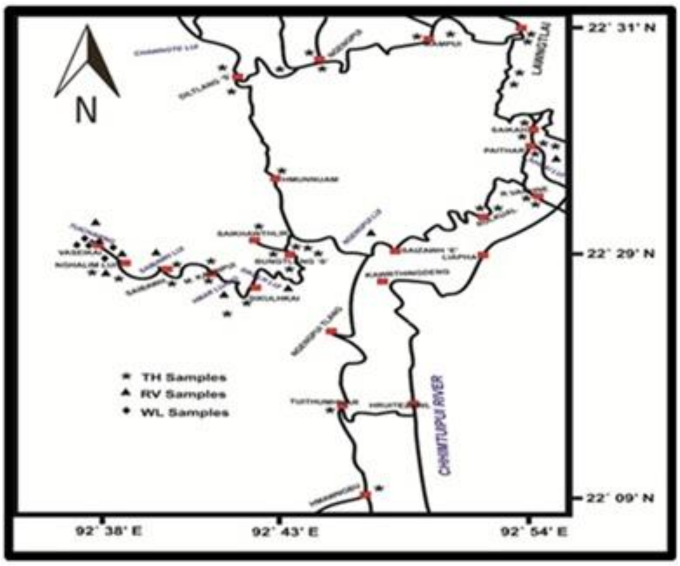
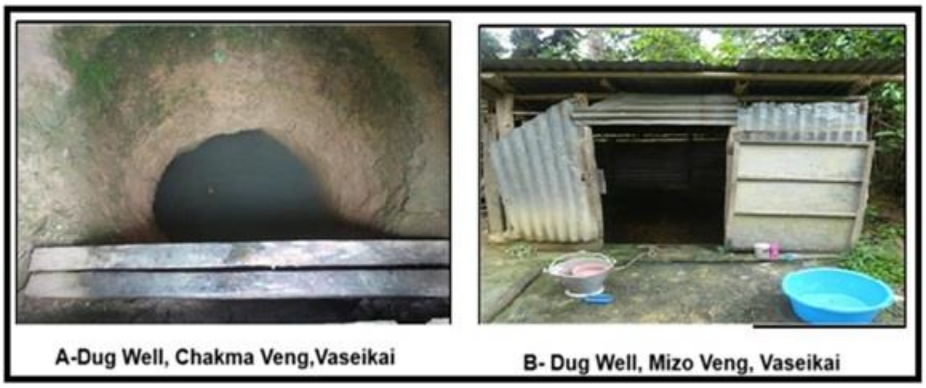


Fig. 2: Sample- Location Map


A-Dug Well, Chakma Veng,Vaseikai

B- Dug Well, Mizo Veng, Vaseikai

Fig. 3: Dug Wells

Physical parameters such as colour, odor, pH, EC and TDS were tested *in situ*. Colour of the water samples was determined by the visual method while pH, EC and TDS were tested by portable pH, EC and TDS meters (Eutech, Oakton). The EC and TDS values were recorded in µmhos/cm and mg/I respectively.

Turbidity: Turbidity of the samples was determined by a Nepheloturbiditymeter (Systronics Digital Nepheloturbiditymeter- 132) in NTU using hydrazine sulphate and hexamethylene tetramene as standards. Calculations were done using the following formula:

Turbidity= Nephelometer reading x 0.4 x dilution factor

Total alkalinity: Total alkalinity was determined by titration with a standard solution of a strong acid indicated by means of colour. Phenolphthalein indicator enables the measurement of that alkalinity fraction contributed by the hydroxide and half by carbonate. Indicators responding to the pH range 4-5 are used to measure the alkalinity contributed by hydroxide, carbonate and bicarbonate ions.

Calculations were done using the following formulae:

$$\text{Phenolphthalein alkalinity as mg/l } CaCO_3 = \frac{A \times N \times 50000}{\text{ml sample}}$$

$$\text{Total alkalinity as mg/l } CaCO_3 = \frac{B \times N \times 50000}{\text{ml sample}}$$

where A= ml titrant required for sample to reach phenolphthalein end point, B = total ml titrant required to reach second end point and N= Normality of the acid.

The results obtained from the phenolphthalein and total alkalinity determinations offer a means for the stoichiometric classification of the three principal forms of alkalinity present in the water samples. Carbonate alkalinity is present when the phenolphthalein alkalinity is not zero but less than the total alkalinity. Hydroxide alkalinity is present if the phenolphthalein alkalinity is more than half of the total alkalinity. Bicarbonate alkalinity is present if the phenolphthalein alkalinity is less than half of the total alkalinity.

Total hardness: Hardness is a measure of polyvalent cations (ions with a charge greater than +1) in water. It generally represents the concentration of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions. Total hardness of the samples was measured by the EDTA titrimetric method. Calculations were done using the following formulae:

$$\text{Hardness (EDTA) as mg/l } CaCO_3 = (\text{ml EDTA titrant} \times 1000 \times N)/\text{ ml sample}$$

where N = mg $CaCO_3$ equivalent to 1.0 ml EDTA.

Calcium: Calcium was calculated by using EDTA titrimetric method using ethylenediamine tetra acetic acid Calculation:

$$\text{Ca (mg/l)} = \text{ml EDTA titrant} \times 400.80/\text{ ml sample}$$

Magnesium: Magnesium ions were calculated from the total hardness obtained by the EDTA titrimetric method and the calcium ions estimated by using the formula,

$$\text{Mg (mg/l)} = \frac{\text{TH}-(2.497 \times \text{Ca})}{4.115}$$

where TH= Total hardness and Ca= Amount of calcium estimated by EDTA titration.

Sulphate: Estimation of sulphate ions was done by turbidimetric method by using the formulae:

$$\text{Sulphate } (SO_4^{2-}) \text{ mg/l} = \text{mg } SO_4 \times 1000/\text{ml sample}$$

Total Chloride: Chloride was estimated by volumetric titration of neutral or slightly alkaline sample against silver nitrate solution using potassium chromate as an indicator. The formulae used was:

$$Cl^-\text{(mg/l)} = (A-B) \times N \times 35.45 \times 1000/\text{ ml sample}$$

where A= ml $AgNO_3$ for sample, B= ml $AgNO_3$ for blank and N= normality of $AgNO_3$ solution.

Fluoride: Fluoride contents in drinking water samples were determined using Spectro quant Pharo 300 model. The measuring ranges were:

a. Measuring range 0.10-1.80 mg/I F^-:
b. Measuring range 0.025-0.500 mg/I F^-:

Nitrate: The determination of nitrate concentration in the samples was done by ultraviolet spectrophotometric method. Measurement of UV absorption at 220 nm enables rapid determination of NO_3^-.

Heavy Metals/Trace Elements: All the Heavy metals/toxic elements were measured on Agilent 4100 MP- AES, at Central Instrumentation Laboratory (CIL), Mizoram University. Stock single element solutions containing 1000 mg/I of Cr, Ni, Pb or V were used to prepare standard reference solutions and to carry out spike experiments [12].

Total Coliform: The total coliform group includes the aerobic and the facultative anaerobic, Gram- negative, non-spore- forming, rod- shaped bacteria that ferment lactose with gas production within 48 hours at 35°C (Plate-VI C and D). This group includes the *Escherichia coli*, Enterobacter, Klebsiella and Citrobacter. Determination of most probable number (MPN) was done.

Confirmatory Test: The fermentative tube was filled with 10 ml Brilliant Green Lactose Bile (BGLB) broth and

Durham's vial was put in an inverted position in each fermentation tube. The positive tubes were shaken gently and one loopful of sample was transferred to each fermentative tube having BGLB broth. These tubes were incubated at 35-37°C for 48 hours. The tubes producing gas was recorded as positive and MPN/100 ml was calculated.

$$\text{MPN/100 ml} = \frac{\text{MPN table value x 10}}{\text{Starting value}}$$

Results

Water samples from WL (groundwater) have been collected for Pre, syn and post monsoon. The results of physico-chemical and bacteriological parameters for each water source are presented in tables 1-3. Further, samples at various locations are arranged in their original source wise in order to understand the degree of rock-water interaction. Different water sources exhibit variation in parameters in the host rock types.

Physical parameters

pH: Pre-monsoon season shows variation in pH value from a minimum of 6.7 to a maximum of 7.9 having a mean value of WL sample ranging from 7.4 to 7.7 having a mean value of 7.5 (Table 1).

In monsoon season, the pH value varies from a minimum of for WL sample from 6.7 to 7.3 (mean 7.1) (Table 2). During post monsoon the pH value in WL sample shows a variation ranging from 7.1 to 7.6 with a mean value of 7.3 (Table 3).

Electrical Conductivity (EC): The electrical conductivity value shows quite a large variation in different seasons in different years. For WL sample it varies from 115 µmhos/cm to 234 µmhos/cm with a mean value of 195 µmhos/cm in the same period. During pre-monsoon season, EC value ranges from 121 µmhos/cm to 239 µmhos/cm (mean 200 µmhos/cm) for WL sample (Table 1). In monsoon, it ranges from 113 µmhos/cm to 227 µmhos/cm (mean 190.5 µmhos/cm) (Table 2). During post-monsoon season, EC value ranges from 120 µmhos/cm to 247 µmhos/cm (mean 212.5 µmhos/cm) for WL sample (Table 3).

Total Dissolved Solids (TDS): The total dissolved solids (TDS) value varies from a minimum of 90 mg/I to 169 mg/I (mean 138 mg/I) during the same period (Tables 1- 3).

Table 1
Physicochemical parameters pre-monsoon

Value	pH	EC	TDS	TURB	TA	TH	TCl	Fe	Na	MPN	**As**
Mean	7.5	200	143	2.4	64.14	143.18	33.40	0.05	10.00	32	0.04
Min	7.4	121	122	2.1	52.00	118.25	20.41	0.03	5.58	18	0.03
Max	7.7	239	176	3.1	81.23	148.58	48.25	0.07	16.28	41	0.06
Value	Ag	Al	Ba	Ca	Cd	Co	Cr	Cu	F	Ga	HCO_3
	BLD	0.015	0.25	10.97	BLD	BLD	BLD	BLD	0.66	0.01	64.14
Mean	0.00	0.01	0.18	9.23	0.00	0.00	0.00	0.00	0.49	0.00	52.00
Min	0.00	0.02	0.31	12.03	0.00	0.00	0.00	0.00	0.74	0.02	81.23
Max	0.00	0.02	0.31	12.03	0.00	0.00	0.00	0.00	0.74	0.02	81.23
Value	K	Li	Mg	Mn	Mo	Ni	NO_3	Pb	SO_4	Sr	Zn
Mean	1.86	0.015	15.05	0.12	BLD	BLD	0.45	0.041	4.25	0.16	0.04
Min	0.87	0.01	14.12	0.06	BLD	BLD	0.30	0.022	3.08	0.02	0.02
Max	2.14	0.02	16.60	0.27	0.00	0.00	0.64	0.08	5.05	0.20	0.07

Table 2
Physicochemical parameters monsoon

Value	pH	EC	TDS	TURB	TA	TH	TCl	Fe	Na	MPN	**As**
Mean	7.1	190	134	3.2	63.36	130.99	31.12	0.02	7.87	36	0.03
Min	6.7	113	100	2.8	49.23	113.22	18.57	0.01	4.05	21	0.02
Max	7.3	227	165	3.5	79.47	148.56	43.68	0.04	12.34	56	0.05
Value	Ag	Al	Ba	Ca	Cd	Co	Cr	Cu	F	Ga	HCO_3
Mean	BLD	0.01	0.22	10.40	BLD	BLD	BLD	BLD	0.62	0.01	63.36
Min	0.00	0.01	0.13	8.83	0.00	0.00	0.00	0.00	0.43	0.00	49.23
Max	0.00	0.02	0.27	11.67	0.00	0.00	0.00	0.00	0.70	0.02	79.47
Value	K	Li	Mg	Mn	Mo	Ni	NO_3	Pb	SO_4	Sr	Zn
Mean	1.72	0.01	14.07	0.09	BLD	BLD	0.42	0.035	4.18	0.14	0.023
Min	0.67	0.01	12.86	0.04	0.00	0.00	0.27	0.02	3.11	0.03	0.01
Max	2.00	0.02	15.41	0.22	0.00	0.00	0.64	0.071	5.00	0.18	0.05

Table 3
Physicochemical parameters post- monsoon

Value	pH	EC	TDS	TURB	TA	TH	TCl	Fe	Na	MPN	**As**
Mean	7.3	212	157	3.0	65.50	139.30	33.25	0.06	9.25	34	0.04
Min	7.1	120	136	2.6	56.08	124.87	21.54	0.04	4.34	20	0.03
Max	7.6	247	172	3.5	83.64	152.25	47.54	0.07	14.05	42	0.06
Value	Ag	Al	Ba	Ca	Cd	Co	Cr	Cu	F	Ga	HCO_3
Mean	BLD	0.02	0.25	10.26	BLD	BLD	BLD	BLD	0.65	0.01	65.50
Min	0.00	0.01	0.16	9.22	0.00	0.00	0.00	0.00	0.50	0.00	56.08
Max	0.00	0.03	0.33	11.02	0.00	0.00	0.00	0.00	0.72	0.02	83.64
Value	K	Li	Mg	Mn	Mo	Ni	NO_3	Pb	SO_4	Sr	Zn
Mean	1.81	0.01	15.10	0.11	BLD	BLD	0.43	0.041	4.22	0.15	0.03
Min	0.92	0.01	14.19	0.08	0.00	0.00	0.29	0.025	3.17	0.06	0.022
Max	2.12	0.02	16.61	0.25	0.00	0.00	0.64	0.076	5.08	0.19	0.06

During pre-monsoon, TDS value of WL sample ranges between 122 mg/I to 176 mg/I (mean 143 mg/I) during the same period (Table 1). The TDS value of for WL sample ranges between 100 mg/I to 165 mg/I with a mean value of 134.5 mg/I (Table 2). During post-monsoon, it varies from a minimum of 136 mg/I to 172 mg/I (mean 157 mg/I) in the same period (Table 3).

Turbidity: The value of turbidity ranges from 4.3 NTU to 9.8 NTU (Table 1) during pre- monsoon. During monsoon season, for WL sample it can be observed that it ranges from 2.8 NTU to 3.5 NTU (Table 2). The turbidity value varies from 2.6 NTU to 3.5 NTU (Table 3).

Total alkalinity (TA): Since carbonate and hydroxide ions are absent in all water sources, the values of total alkalinity are mainly due to the presence of bicarbonate ions. Therefore, the values of bicarbonate ions are same as the values of total alkalinity in all WL samples. During pre-monsoon 2015, for WL samples, it varies from 49.23 mg/l to 79.47 mg/l (mean 63.36 mg/l) (Table 1). Higher value of TA is recorded in the monsoon season in WL sample ranging from a maximum of 56.08 mg/l to 83.64 with a mean value of 65.50 mg/l (Table 2). The value of TA varies from 55.06 mg/l to 83.32 mg/l with a mean value of 63.48 mg/l during the post monsoon period (Table 3).

Total Hardness (TH): During pre-monsoon, TH value shows variation from 118.25 mg/l to 148.58 mg/l (mean 143.18 mg/l) (Table 1). In monsoon season, the values range between 113.22 mg/l to 148.56 mg/l (Table 2). During post monsoon, variation is recorded from a minimum of 124.87 mg/l to a maximum of 152.25 mg/l with a mean value of 139.3 mg/l (Table 3).

Total Chloride (TCl): The value of total chloride during pre-monsoon it ranges from 20.41 mg/l to 48.25 mg/l (mean 33.40 mg/l) (Table 1). The total chloride content shows variation from 18.57 mg/l to 43.68 mg/l (mean 31.12 mg/l) (Table 2) in the monsoon season. During post-monsoon season, higher value is recorded in the same season in WL sample ranging from a maximum of 21.54 mg/l to 47.54 with a mean value of 33.25 mg/l (Table 3).

Iron (Fe): During pre-monsoon, it ranges between 0.03 mg/I to 0.07 mg/I (Table 1). In monsoon season, the minimum value for of 0.04 mg/l to a maximum of 0.07 mg/l (Table 2) for WL sample. Iron concentration in post-monsoon season ranges from 0.03 mg/I to 0.08 mg/I for WL samples.

Sodium (Na): Concentration of sodium ranges from 3.88 mg/I to 12.44 mg/l (mean 7.74 mg/l for all WL samples, But the value is slightly lower ranging from a minimum of 4.34 mg/l to a maximum of 14.05 mg/l with a mean value of 9.25 mg/l during the monsoon period (Table 2). Sodium concentration in post-monsoon season ranges from 5.77 mg/I to 16.56 (mean 10.09) for WL samples (Table 3).

Calcium (Ca): Calcium is one of the main dominant cations in all the water sources in the study area. During pre-monsoon, calcium concentration in WL sample varies from 9.23 mg/l to 12.03 mg/l (mean 10.97 mg/l) (Table 1). In monsoon season, the minimum values for WL sample vary from 8.83 mg/l to 11.67 mg/l (mean 10.40) (Table 2). Calcium concentration has been obtained ranging from a minimum of 4.02 mg/l to a maximum of 10.00 mg/l (mean 6.33 mg/l) (Table 3) during post-monsoon.

Magnesium (Mg): Magnesium concentration during pre-monsoon varies from 14.12 mg/l to 16.60 mg/l (mean 15.05 mg/l) (Table 1). In monsoon season, the minimum values for WL sample vary from 12.86 mg/l to 15.41 mg/l (mean 14.07) (Table 2). In the post monsoon, the variation is from a minimum of 14.19 mg/l to a maximum of 16.61 mg/l with a mean value of 15.10 mg/l (Table 3).

Potassium (K): During pre-monsoon, concentration of potassium varies from 0.87 mg/l to 2.14 mg/l (mean 1.87 mg/l) (Table 1). In monsoon season, the minimum values for WL sample vary from 0.67 mg/l to 2.00 mg/l with a mean value of 1.72 mg/I (Table 2). In post-monsoon, WL samples show slightly higher values ranging from a minimum of 0.92 mg/l to a maximum of 2.12 mg/l (mean 1.81 mg/l) (Table 3).

Fluoride (F): During pre-monsoon, Fluoride concentration ranges from 0.49 mg/l to 0.74 mg/l (Table1). The content shows variation from 0.43 mg/l to 0.70 mg/l (Table 2) in the monsoon season. During post-monsoon season, it varies from a maximum of 0.50 mg/l to 0.72 (Table 3).

Nitrate (NO_3): During pre-monsoon, concentration of nitrate in WL sample varies from 0.30 mg/l to 0.64 mg/l (mean 0.45 mg/l) (Table 1). In monsoon season, the minimum values for WL sample varies from 0.27 mg/l to 0.64 mg/l with a mean value of 0.42 mg/I (Table 2). TH sample of post-monsoon records variation from 0.29 mg/l to a maximum of 0.64 mg/l (mean 0.43 mg/l) (Table 3).

Sulphate (SO_4): During pre-monsoon, sulphate value shows variation from 3.08 mg/l to 5.05 mg/l (mean 4.25 mg/l) (Table 1). Variation in sulphate concentration has been recorded from 1.02 mg/I to 4.25 mg/I (mean 3.04 mg/l) (Table 1). During monsoon, it ranges from 3.11 mg/l to 5.00 mg/l (mean 4.18 mg/l) (Table 2). In post monsoon, the value is slightly higher ranging from a minimum of 3.17 mg/l to a maximum of 5.08 mg/l with a mean value of 4.22 mg/l (Table 3).

Arsenic (As): Most of the arsenic concentration in all water samples ranges from BLD to 0.06 mg/I (Table 1-3). Higher value of arsenic concentration has been found in WL samples during all the season (Fig.4-6).

Aluminum (Al): During pre-monsoon, monsoon and post-monsoon, most of the aluminum concentration in WL sample ranges from 0.01 mg/I to 0.02, 0.01 mg/I to 0.03 mg/I (Table 1-3).

Barium (Ba): Barium concentration has been recorded high ranging from 0.18 mg/l to 0.31 mg/l, 0.13 mg/I to 0.27 mg/I and from 0.16 mg/I to 0.33 mg/I during pre-monsoon, monsoon and post-monsoon respectively (Tables 1-3).

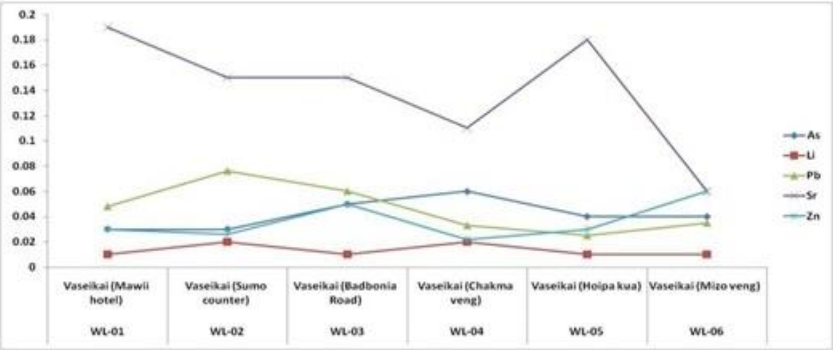


Fig. 4: Heavy metals in groundwater of pre-monsoon

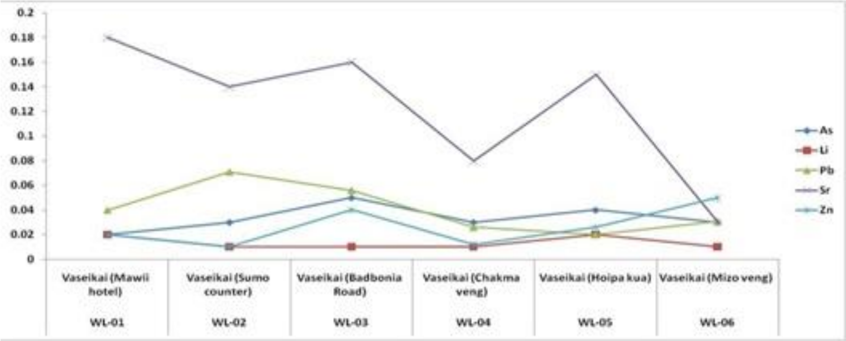


Fig. 5: Heavy metals in groundwater of monsoon

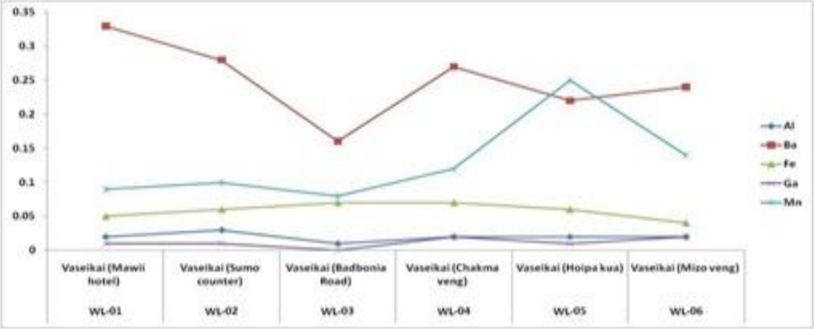


Fig. 6: Heavy metals in groundwater of post monsoon

Gallium (Ga): Gallium concentration in all water sources is constant having a value of 0.02 mg/I during pre-monsoon, monsoon and post-monsoon. Concentration of gallium is found to be zero (BLD) in some stations of WL samples (Tables 1-3).

Lithium (Li): Concentration of lithium in all water sources is constant having a range of 0.01 mg/I to 0.02 mg/I throughout the seasons in (Tables 1-3).

Manganese (Mn): Manganese concentration varies from 0.06 mg/l to 0.27 mg/l during pre-monsoon (Table1). During monsoon, value has been recorded from a minimum of 0.04 mg/l to a maximum of 0.22 mg/l in WL sample (Table 2). Concentration of manganese is higher in post-monsoon season ranging from 0.08 mg/I to 0.25 mg/I in WL samples. (Table 3).

Lead (Pb): Lead concentration in pre-monsoon is slightly higher in WL sample (Fig. 4), ranging from 0.022 mg/l to 0.08 mg/l (mean 0.041 mg/I) (Table 1). During monsoon, it varies from 0.02 mg/l to 0.071 mg/l (mean 0.035 mg/I) (Fig. 5 and table 2). During post-monsoon season, value of lead concentration in WL sample varies from a maximum of 0.025 mg/l to 0.076 (mean 0.041 mg/I) (Fig. 6 and table 3).

Strontium (Sr): Strontium concentration in WL sample varies from 0.02 mg/l to 0.20 mg/l during pre-monsoon (Table 1 and Fig. 4). During monsoon, these values change from a minimum of 0.03 mg/l to a maximum of 0.18 mg/l in WL sample (Table 2 and fig. 5). Concentration of strontium is slightly higher in post-monsoon season ranging from 0.06 mg/I to 0.19 mg/I in WL samples (Table 3 and fig. 6).

Zinc (Zn): Zinc concentration in pre-monsoon ranges from 0.02 mg/l to 0.07 mg/l (mean 0.04 mg/I) (Table 1 and fig. 4). During monsoon period, Zinc content shows almost constant as compared to pre-monsoon season value ranging from 0.01 mg/l to 0.05 mg/l (mean 0.023 mg/I) (Table 2 and fig. 5). During post-monsoon season of, value of zinc concentration in WL sample varies from a maximum of 0.022 mg/l to 0.06 (mean 0.03 mg/I) (Table 3 and fig. 6).

Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu), Molybdenum (Mo), Nickel (Ni) and Silver (Ag): Concentration of Ag, Cd, Co, Cr, Cu, Mo and Ni has been found to be below limit of detection (BLD) (Tables 1-3).

Most Probable Number (MPN): MPN varies from 18 to 41/ 100 ml water (Table 1) in pre-monsoon. In monsoon season, MPN varies from a minimum of 56/ 100 ml water (Table 2), in W water ranges from 20 to 42/ 100 ml water (Table 3) in post-monsoon season.

Discussion

The area of the South-west Lawngtlai district, where the present work has been carried out is covered by rock exposures belonging to Middle Bhuban and Upper Bhuban Formation of Surma Group[13]. They are mainly dominated by sandstones, shales and siltstones and their intermixtures in varying proportions. The area is mountainous and hilly with a small strip of low-lying riverine plain. The hills are steep and separated by rivers, which flow either to north or to the south, creating deep gorges. The main rivers in the study area include Tuichawng River, Ngengpui River, Sikulh River, Hmar Luang River, Nghalim River and a number of tributaries.

The alteration products of weathering are dissolved constituents and secondary minerals. Water first enters the sub-surface (soil zone) and comes into close contact with organic and inorganic matter. The natural organic matter in the soil is composed of degradable plant debris and roots of dead vegetation to humic substances that have been partially decomposed by soil processes. This organic matter plays a vital role in the movement of dissolved organic matter due to the attraction of the solid phase for the dissolved phase and consequent removal of dissolved organic carbon from solution through adsorption.

Complexation of ion may result due to the alkaline (base); when there are no hydroxyl ions, the solution is a pure acid with pH = 1. The pH of water is a measure of the acid-base equilibrium and, is most controlled by carbon dioxide—bicarbonate—carbonate system. The reaction of dissolved carbon dioxide with water is important in establishing pH in natural water systems. The pH value of groundwater sources (WL) is found to be more during pre and post-monsoon as compared to surface and sub-surface water. Values of EC in WL samples, in monsoon seasons are showing lower EC as compared to the samples of pre-monsoon and post-monsoon seasons. It may be due to the presence of more ions. Total dissolved solids is an important parameter of drinking water quality testing that denotes the presence (or absence) of various kinds of minerals and salt impurities dissolved in water. TDS value in WL sample, WL-01 has lowest value of 90 mg/I whereas highest value of 183 mg/I is found in WL-04 in pre-monsoon. Samples from WL-03 and WL-04 have been recorded with high value of TDS content. The higher value of TDS in these samples may be attributed to the presence of colloidal or finely divided suspended matter which does not readily settle. The presence of colloidal or finely divided suspended matter may be due to the direct discharge of solid waste or construction activities around the area[19].

Electrical conductivity and total dissolved solids are directly proportional to each other i.e. with an increase in the value of electrical conductivity, the value of total dissolved solids also increases. Higher value of TDS is found in WL samples due to increase in concentration of minerals in the dry period of the year. Turbidity is a water quality term referring to cloudiness of water and is a qualitative characteristic which is imparted by solid particles obstructing the transmittance of light through water. It consists of suspended and colloidal matter, such as clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms. Turbidity may indicate the presence of disease causing organisms. These organisms include bacteria, viruses and parasites that can cause symptoms such as nausea, cramps, diarrhea and associated headaches[11].

Since pH values in all the samples of WL are in the range of 6.5 to 7.9, the major cause of alkalinity seems to be the presence of bicarbonate ion. Thus, the bicarbonate ions may be regarded as the main dominant anion in all the samples of the area under study. The dissociation of bicarbonate and carbonate ions is effective largely above a pH of 8.2.

It has been widely observed that variation of total hardness value in groundwater (WL) is highest which is in between 113.22 mg/I to 152.22 mg/I. Groundwater (dug well) is usually harder than surface or sub-surface water due to the fact that groundwater is in contact with geologic formations for a longer period of time than surface and sub-surface water. The values of all the water sources recorded are well within the permissible limits of 200 mg/I[7,24]. Higher value of total hardness is observed during pre-monsoon and post-monsoon seasons and lower during monsoon season in all the samples which may be due to decrease in water volume and increase of rate of evaporation of water.

The concentration of chloride in all WL samples is much lower ranging from 7.12 mg/I to 48.65 mg/I than the prescribed value of 250 mg/I by WHO. All WL samples are having much more chloride concentration than sodium concentration in all the seasons (Table 1-3). Chloride concentration in WL sample has been recorded ranging from a minimum of 16.55 mg/I and a maximum of 48.65 mg/I having a mean value of 32.19 mg/I. The amount of chloride is slightly higher in WL sample due to anthropogenic activity and natural processes such as the passage of water through natural salt formations in the earth or it may be an indication of pollution from industrial or domestic use.

Concentration of nitrate in WL sample has a value of 0.27 mg/I to 0.64 mg/I. In all the seasons, it can be observed that there is no variation in nitrate concentration in all the water samples. The reason for low content of nitrate in all water samples in the study area may be attributable to denitrification, plant assimilation of nitrate before entering the streams and also the less use of fertilizers. The content of sodium in WL sample ranges from 3.88 mg/I to 16.56 mg/I. In general, concentration of sodium in all samples (WL) is less, this may be due to the absence of natron ($Na_2CO_3.10H_2O$), rock salt (halite) and evaporation in the study area. The value of magnesium concentration in dug well (WL) records high in the range of 10.23 mg/I to 17.54 mg/I.

The concentration of lead (Pb) in WL-02 and WL-03 samples in pre-monsoon and post-monsoon seasons show a higher concentration of Pb I (Table 1 and 3). This may be attributed to gasoline coming out of vehicles as most of the tuikhurs, rivers and dug wells are situated on or near the highway. Most of the concentration of Pb in monsoon season is slightly lower as compared to pre-monsoon and post-monsoon seasons in all the water samples (Tables 1-3).

Highest concentration of Zn has been recorded in WL-03 and WL-06 samples (Table 1-3) having a value of 0.06 mg/I and 0.07 mg/I, respectively. However, values are under desirable limits of 5 mg/I as prescribed.

Iron content in WL sample is almost constant in all the samples (Table 1-3). Reasonable amount of iron is expected in small zones of highly depleted oxygen beneath the peaty soils. Manganese concentration in WL sample ranges between 0.04 mg/I to 0.27 mg/I. All of WL samples are below the permissible limits but are still higher than the desirable limits (Tables 1-3). Shallow wells contain colloidal manganese, leaving the water with a black tint. These sediments are responsible for the staining properties of water containing high concentration of manganese[8]. Manganese is classified under the Secondary Maximum Contaminant Level (SMCL) standards, indicating that it is recommended but are not enforced.

Lithium, a natural trace element is mobilized by rain from rock and soil and WL has been found exceeding the desirable limits of 0.07 mg/I[7]. Concentration of strontium ranges from 0.06 mg/I to 0.19 mg/I in WL sample. Arsenic contamination in all the samples of WL, has not been recorded. In WL water samples, it has been observed that all the samples are having small amount of aluminum concentration having a range from 0.01 mg/I to 0.03 mg/I in all the seasons (Table 1-3). Dissolved aluminum concentrations in waters with near-neutral pH values usually range from 0.001 to 0.05 mg/I[24]. Aluminum concentration in all the water sources is well within the acceptance limits of 0.03 mg/I prescribed by[7].

WL sample has greatest value of barium contamination where value ranges from 0.18 mg/I to 0.33 mg/I. WL- 01 sample has a maximum value in post-monsoon season. Barium may be present in water due the discharge and disposal of drilling wastes, copper smelting and motor vehicle parts and accessories manufacturing. The values obtained in all the water sources are well within the acceptance limits of 0.07 mg/l as prescribed. All of the water sources have constant values of gallium in all the pre, syn and post monsoon seasons (Table 1-3) and the value is below limit of detection.

The most probable number (MPN) in WL sample is almost constant in pre- monsoon and post-monsoon seasons (Table 1-3). Increase in coliform population in all the water samples, during monsoon may be due to poor sanitary conditions and improper treatment of animal manure in the community (Table 2). A ternary diagram is a barycentric plot on three variables that represents the relative percentage of different composition of components.

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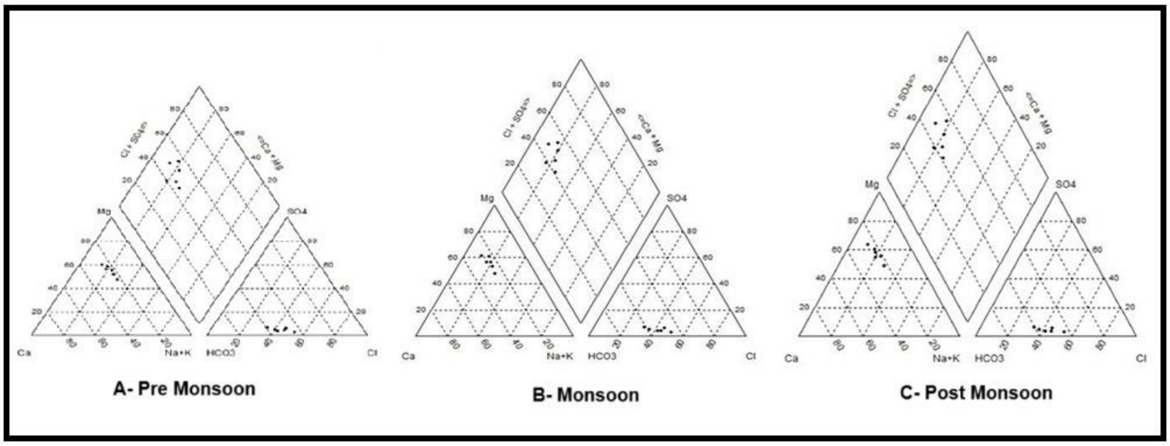

A- Pre Monsoon B- Monsoon C- Post Monsoon

Fig. 7: Piper tri-linear diagram for Ground Water

In WL sample, the amount of HCO_3^- is much reduced, contributing only 60-70% to the total anions in all the seasons. It can be observed that the Cl^- is found increasing in groundwater samples, having a contribution of 25-42% throughout the year (Fig. 7).

The increasing order of cationic in groundwater (WL) is Mg>Ca>Na>K whereas the order of dominating anionic in both surface and groundwater is same as the order in sub surface water. Ca-Mg-type of water is predominated in all the samples (no alkalies are found exceeding alkaline earth). No sample of WL is found having Mg-HCO_3 and Na-HCO3 types of water throughout the seasons.

Conclusion

The samples from all ground water sources (WL) were collected at different sites and have been evaluated for their physico-chemical and bacteriological parameters. Characteristically the behaviour of water quality in three different seasons as pre-monsoon, monsoon and post-monsoon, have been studied. All the physical parameter values are well within the permissible limits. However, value of turbidity has been found exceeding the permissible limits of 5 NTU in some stations. It is recommended that continuous turbidity monitoring equipment needs to be cleaned and calibrated on a regular basis and for additional protection.

The aquifer rocks are mostly the intercalation of shale and sandstone with absence of carbonate rocks i.e., Limestone. The consistent values of pH at or near 7 (neutral points) indicate the absence of limestone and confirm 'silicic' nature of aquifers in various water sources of the area. Lower value of EC is suggesting the low solubility of salts from host rocks, which is in accordance with the silicic host rock.

Most of the value of total coliforms (MPN) has been found exceeding the permissible limits of 10 MPN/100 ml in water sample from all the water sources. The higher value of coliforms in water samples may be attributed to the use of pit latrines, piggeries and poultries, which is predominant in the study area. Transfer of human excreta and waste from piggeries and poultry farms by rainwater to the water sources seems to be the major cause behind the sudden increase in coliform during monsoon season. It is suggested that moving pit latrines, waste disposal from the piggeries and poultry farms away from locations upstream of the tuikhurs and proper sanitation will greatly reduce the contamination of coliforms.

Ternary diagram for cation shows mainly domination of potassium and sodium in all seasons whereas calcium and magnesium are the most dominant cations in WL waters. Bicarbonate ion is the main dominant anion in all water source samples, irrespective of seasonal variation. Piper Tri-linear diagram supports the geological composition of aquifers as sandstone and shale/claystone. The total hydrochemistry of the area under study is dominated by alkaline earths and weak acids. Most of the surface, sub-surface and groundwater in the study area can be classified as Ca-Mg-HCO_3 facies while in some samples calcium or magnesium is sometimes replaced by sodium.

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