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Assessment of Drinking Water Quality from Open Sources, Mizoram, Northeast India

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Abstract In developing and hilly states like Mizoram, there are several mountainous and rural areas where treated water supply is not available for consumption. As it is a must for such areas to rely on water collected from open sources like stream, well and spring nearby; studying the physicochemical and bacteriological condition plays a crucial role. The research involves the study of water samples that were collected from fifteen water stations where the water is utilized as drinking water from the month of January, 2021 to December, 2021. The parameters used for analyzing water samples were Colour, Odour, Temperature, Electrical Conductivity, Turbidity, Total Dissolved Solid, Total Suspended Solid, pH, Dissolved Oxygen, Biological Oxygen Demand, Total Alkalinity, Total Hardness, Chloride, Magnesium, Nitrogen Nitrite, Nitrogen Ammonia, Total Phosphate, Calcium, Sodium, Potassium, Faecal Coliform, Total Coliform. The results from the study were compared with the standard limit set by WHO, BIS, CPCB. The study reveals that all the water quality parameters were within the given standards except for pH, turbidity, Dissolved Oxygen, Nitrogen Ammonia, Total Phosphate, Faecal coliform and Total coliform in certain stations at particular seasons.

Keywords: *mizoram, drinking water, standard limit, monsoon, positive, coliform, community*

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1. Introduction

Improving access to safe drinking water can result in tangible benefits to health. As water is essential to sustain life, a satisfactory supply must be available to all [1]. Of the global available water, only 2.7% consists of available freshwater, while just 1% of it is accessible, as most of the available freshwater are in hidden part of the hydrologic cycles and in glaciers [2]. On global estimation, 89% of people have access to water suitable for drinking. The water quantity and quality is an alarming environmental problem, inappropriate management of ground water and surface water together with massive uses caused harmful threat to the availability and quality of water [3]. Recently, many developing countries have set safe water resources as their major public health goal, which slightly improved the situation. In rural areas, population growth and economic development continue to increase demand of water, which leads to water reduction [4]. Therefore, there is a long way before gaining the harmony between human resources and environment [5]. The major impact action of urbanization includes sewage disposal, solid waste landfilling, more built-up area, changes in land use pattern and excessive abstraction of surface and groundwater. Contaminated urban runoff and untreated sewage stress the surface water rendering them unfit for freshwater supply [6].

Determining the various physicochemical and biological properties of water provide the basis for judging the suitability of water for its designated uses and to improve existing conditions. Current information provided by water quality programme is required for optimum management and development for the beneficial uses [7]. Surface water is unequally distributed on earth and the availability of useable freshwater is declining at an alarming which causes major concern in terms of water quality and quantity [8]. Various factors influence the composition of stream water, causing variation from place to place [9]. The stream and river water quality is highly sensitive to anthropogenic influences (industrial, urban and agricultural activities thereby increasing consumption of water resources) as well as natural processes (changes in precipitation inputs, erosion, weathering of earths crustal material) degrade the surface waters and impair their use for drinking, industrial, agricultural, recreation or other purposes [10]. The total constituents of river water come from dissolution of the earth's rocks. A major determinant of river water chemistry is the dissolution of rocks in the catchment area locally as well, but this differs with geology and with the magnitude of inputs through the type, amount and distribution of precipitation, surrounding vegetation, catchment hydrology and land use [11,12]. With the recent increase in global population, waste disposal has impacted negatively on surface water bodies [13]. The waste accounts for a reasonable level of water contamination. These contaminants in turn influence important physical, chemical and biological quality parameters of the water, and thereby affect human health [14].

Mizoram with a geographical area of 21,087 km^2, lies in the north-eastern part of India sandwiched between Bangladesh and Myanmar on the Southern end. The state is situated between 21° 56' to 24°31'N latitudes and 92°16' to 93°26'E longitudes. It has a pleasant climate; the temperature varies from 11°C to 21°C in winter and varies between 20°C to 29°C in summer [15].

Mizoram hydrography is a direct reflection of the drainage and climatic condition. The drainage system in Mizoram comprises of three drainages – Barak, Karnaphuli and Kolodyne. The northerly flowing rivers drains into the Barak basin (Ganga-Brahmaputra basin), southerly flowing river drains into the Kolodyne basins and in the west rivers drains into the Karnaphuli. Under the influence of southwest monsoon, it receives heavy rainfall during the month of May to September. The surface water is found distributed in numerous streams and rivers flowing through the hilly terrain, which is the chief source of water for the people as underground water is not easily accessible due to hilly terrain [16]. The Geological unit of Mizoram is characterized by very low permeability and infiltration rate, it acts as a run off zone, resulting in having a low ground water potential. The supply of treated water in the State is limited, and majority of rural people depend on untreated water for drinking purposes. As on 1st April 2015, around 74,456 houses have been provided water connections in the urban area. Although the amount of fresh water available at present is enough to meet the current requirement of the state, however, the availability of desired quality and quantity of water may get strained in some places under impact of urbanization, increase in population, change in lifestyle, economic development, change in land use pattern, agriculture production, climate changes, etc. For conservation and artificial recharge structures for replenishing ground water; also, harvesting rainwater during monsoon season, with improved collection, storage and distribution facilities, the State Government has taken meaningful initiatives in this direction [17].

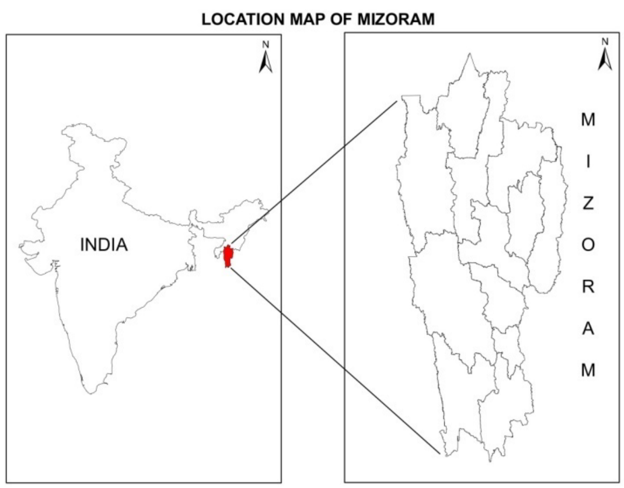

Figure 1. Location Map of Mizoram

The present study is to clarify the water quality of the state, which are directly consumed by the rural area for drinking, cooking and other household purposes; which could be an addition report for the state government to their initiatives regarding proper conservation and management system. It would be useful for raising awareness among the people, to sustain and protect their water sources.

2. Materials and Methods

The water data was collected from Mizoram Pollution Control Board, it consisted of the water analyzed parameters from the month of January, 2021 to December, 2021. Fifteen Stations in Mizoram which were used as a source of drinking water purposes categorized under designated usage was selected for the present study. The parameters and their methods used for analyzing water samples were, Physical: Colour, Odour, Temperature (Thermometric method), Electrical Conductivity (Conductometric method), Turbidity (Turbidimetric method), Total Dissolved Solid (Gravimetric method), Total Suspended Solid (Gravimetric method); Chemical: pH (Float method), Dissolved Oxygen (Winkler's method), Biological Oxygen Demand (Winkler's method), Total Alkalinity (Visual titration method), Total Hardness (Complexometric titration solution), Chloride (Argentometric titration), Magnesium (EDTA titration method), Nitrogen Nitrite (Diazotization method), Nitrogen Ammonia (Colorimetric method), Total Phosphate (Colorimetric method), Calcium (EDTA titrimetric method), Sodium (Flamephotometric method), Potassium (Flamephotometric method); Bacterial: Faecal Coliform (Multiple tube dilution method), Total Coliform (Multiple tube dilution method).

The months of January to April were categorized as Pre-Monsoon; May to August as Monsoon and September to December as Post-Monsoon, mean value of four months for each season were displayed accordingly. Some data were not available during certain period of time due to- Covid-19 containment zone of the site which cannot be visited for collecting the water sample; dried up during low-rainfall season; and breaking down of machines for which analysis cannot be performed, it is displayed on the Table as NA(Not Applicable). Standards for drinking water set by World Health Organization (WHO), Bureau of Indian Standard (BIS) and Central Pollution Control Board (CPCB) were used for measuring and studying the water quality for the seasons in each station. For statistical analysis Two-way Analysis of Variance (ANOVA) was performed to test the main effects of seasons and sites as well as their interaction effects on the water quality parameters using Statistical Package for Social Science (SPSS).

The fifteen water stations includes Tlawng Upper Stream (TUS), Tlawng lower stream (TLS), Serlui Stream, Reiek kai (SSR), Vaipuanpho Stream, Reiek kai (VSR), Tlawng River, Pialthleng, Zotlang, Lunglei (TRPZL), Vaitui Tuikhur, Theiriat, Lunglei (VTTL), Saikah Stream, Lawngtlai (SSL), P.H.E. Reservoir, Helipad, New Siaha (PRHNS), Tuikum River, Serchhip (TRS), Lahmun River, Phaizau, Mamit (LRPM), Tuichhuahsen Stream, Kolasib (TSK), Tuipui River, Champhai (TRC), P.H.E. Water Reservoir, (Tlawng river) Tuikhuahtlang, Aizawl (PWRTA), P.H.E. Water Reservoir, (Awizo Stream water) Rulchawm village (PWRR) and Tlawng River, Suarpui, Bairabi (TRSB).

3. Results and Discussion

3.1. Colour and Odour

The colour and odour were clear and odourless all under suggested condition, except for Tlawng River, whose colour was recorded as yellow, as huge amount of sediments disposal were taking place nearby (Table 1). No health-based guideline value is proposed for colour in drinking-water, yet drinking water should not have visible colour.

3.2. Temperature

Serlui Stream, Vaipuanpho Stream and Lahmun River recorded the highest temperature at 26°C during Post-Monsoon season while Tuipui River recorded the lowest temperature at 13°C during Pre-Monsoon season (Table 1).

3.3. Electrical Conductivity

The electrical conductivity on all stations for each season were all under standard set by BIS which is 200-800 µs/cm; highest-354 µs/cm in P.H.E Water Reservoir, Tuikhuahtlang during Monsoon season; lowest-62 µs/cm in P.H.E Reservoir, Helipad during Pre-Monsoon season (Table 1).

3.4. Turbidity

For turbidity, each station on all seasons were exceeding the permissible limit set by WHO that is <0.5 NTU, and the acceptable limit set by BIS of 1 NTU, which was again exceeded, however, most of them fall under the permissible limit set by BIS of 5 NTU; for Pre-Monsoon season all stations were under the permissible limit of BIS; while in Monsoon season Tlawng Upper Stream, Tlawng Lower Stream, Serlui Stream, Vaipuanpho stream were showing extremely high reading of turbidity, also, Tuichhuahsen Stream, Tuipui River and Tlawng River were also exceeding the permissible limit of BIS; during Post-Monsoon season Saikah Stream and Tlawng River Suarpui were showing extremely high reading, also, Tlawng Upper Stream, Tlawng Lower Stream, Serlui Stream, Tuikum River, Lahmun River, Tuichhuahsen Stream, Tuipui River were also exceeding the permissible limit set by BIS; highest-67 NTU in Tlawng Upper Stream during Monsoon season, and lowest-1.7 NTU in Tlawng River, Pialthleng (Table 1).

3.5. Total Dissolved Solid (TDS) and Total Suspended Solid (TSS)

The total dissolved solid(TDS) and total suspended solid(TSS) were all under standard set by WHO that is <600 mg/l and acceptable limit set by BIS which is 500 mg/l; permissible limit by BIS of 2000 mg/l; highest-110 mg/l(TDS) in Tlawng River, Pialthleng during Monsoon season, also, highest-30 mg/l (TSS) in Tuipui River; lowest-50 mg/l(TDS) in Tlawng River, Pialthleng for both Pre and Post-Monsoon, also, Saikah Stream and Tuipui River for Pre-Monsoon season; lowest-10 mg/l(TSS) in Tlawng River Pialthleng during Pre and Post-Monsoon, in Saikah Stream for all season, also, in Tuipui River during Pre-Monsoon season (Table 1).

Table 1. Mean value of Physical Parameters of Different Sites for Pre-Monsoon, Monsoon and Post-Monsoon Season

Stations	Colour	Odour	Temperature (°C)			Electrical Conductivity (µs/cm)			Turbidity (NTU)			Total Dissolved Solids (TDS) (mg/l)			Total Suspended Solids (TSS) (mg/l)		
	Yearly	Yearly	Pre	Mon	Post	Pre	Mon	Post	Pre	Mon	Post	Pre	Mon	Post	Pre	Mon	Post
TUS	Clear	Odourless	20	22	23	168	191	139	4.2	67	7.7	NA	NA	NA	NA	NA	NA
TLS	Clear	Odourless	20	22	23	171	156	117	4.1	64	7.9	NA	NA	NA	NA	NA	NA
SSR	Clear	Odourless	20	22	26	304	212	181	2.8	53	7.6	NA	NA	NA	NA	NA	NA
VSR	Yellow	Odourless	20	22	26	116	160	133	5.3	28	3.9	NA	NA	NA	NA	NA	NA
TRPZL	Clear	Odourless	18	25	20	81	133	146	1.7	3.2	3.4	50	110	50	10	20	10
VTTL	Clear	Odourless	17	NA	21	278	NA	139	1.8	NA	2.6	NA	NA	NA	NA	NA	NA
SSL	Clear	Odourless	20	21	22	77	138	140	1.9	3.7	16.9	50	70	70	10	10	10
PRHNS	Clear	Odourless	20	19	18	62	149	155	2.3	4.6	3.6	NA	NA	NA	NA	NA	NA
TRS	Clear	Odourless	15	18	17	87	163	109	2.1	4.1	5.9	NA	NA	NA	NA	NA	20
LRP	Clear	Odourless	22	24	26	244	225	181	3.8	4.4	6.1	NA	NA	NA	NA	NA	NA
TSK	Clear	Odourless	24	24	22	128	221	164	2.4	6.1	5.6	NA	NA	NA	NA	NA	NA
TRC	Clear	Odourless	13	21	18	88	174	169	2.8	6.3	7.3	50	NA	70	10	NA	30
PWRTA	Clear	Odourless	19	27	24	178	354	130	1.8	3.2	3	NA	NA	NA	NA	NA	NA
PWRR	Clear	Odourless	16	20	19	111	157	118	1.8	4.1	3.7	NA	NA	NA	NA	NA	NA
TRSB	Clear	Odourless	23	24	21	186	209	125	4.3	7.1	42.7	NA	NA	NA	NA	NA	NA

Table 2. Mean Value of Chemical Parameters of Different Sites for Pre-Monsoon, Monsoon and Post-Monsoon Season

Stations	pH			Dissolved Oxygen (mg/l)			Biological Oxygen Demand (mg/l)			Total Alkalinity (mg/l)			Total Hardness (mg/l)		
	Pre	Mon	Post	Pre	Mon	Post	Pre	Mon	Post	Pre	Mon	Post	Pre	Mon	Post
TUS	8.1	7.6	7.7	5.6	6.8	6	0.7	1.1	1.4	103	60	63	75	51	50
TLS	8.2	7.5	7.6	5.2	6.9	6.1	0.9	1.1	1.6	95.4	57	64	78	49	49
SSR	8.3	7.1	7.8	5.5	7.7	5.6	0.9	1	1.2	141	61	69	##	81	53
VRS	7.6	7.2	7.9	5.3	6.6	5.7	0.9	1.2	1.3	38.8	43	39	39	38	28
TRPZL	7.2	7	7.2	6.9	7.3	6.9	1.7	1.4	1.1	43.6	41	40	37	36	30
VTTL	7.2	NA	6.3	7	NA	7.3	NA	NA	NA	32.4	NA	30	72	NA	18
SSL	7.5	7	7	7.3	6.1	7.4	1.6	1.6	1.1	47.9	36	35	47	33	27
PRHNS	7.5	7.3	7.2	7.7	7.5	8.8	1.7	1.1	1.2	35.7	22	36	20	27	26
TRS	7.6	7.4	7.4	6.5	6.3	6.3	1.3	1.1	1.1	53.7	41	39	36	42	25
LRP	7.8	7.2	7.6	7.8	6.4	6.1	1.4	1.3	1.2	121	65	25	NA	58	80
TSK	7.5	7.3	7	7.8	7.1	7.8	1.7	1.5	1.3	65	27	63	47	26	60
TRC	7.5	7.5	7.1	4	5.8	5.4	0.7	0.6	0.5	61.8	44	42	27	37	24
PWRTA	7.9	7.4	7.7	6	21	6.9	0.7	1.3	0.9	91.2	38	58	71	73	50
PWRR	7.8	7.2	6.9	9.4	7.8	8.1	1	1.2	1.1	88	35	28	56	16	16
TRSB	7.5	7.3	7.5	6.6	6.3	5.3	1.6	1.5	1.2	117	53	87	85	41	61

3.6. pH of Water

The standard limit for pH as set by WHO is <8, in which Tlawng Upper Stream, Tlawng Lower Stream and Serlui Stream were beyond the limit during Pre-Monsoon season; standard limit set by BIS and CPCB is 6.5 to 8.5, which in Vaitui Tuikhur has lower reading during Post-Monsoon season; highest-8.3 in Serlui Stream for Pre-Monsoon season and lowest-6.3 in Vaitui Tuikhur for Post-Monsoon season (Table 2).

3.7. Dissolved Oxygen

For Dissolved Oxygen standard limit set for drinking water without conventional treatment but after disinfectant by CPCB is 6 mg/l or more, in Tlawng Upper Stream, Tlawng Lower Stream, Serlui Stream, Vaipuanpho Stream, and Tuipui River were below the standard level during Pre-Monsoon season; only Tuipui River was below the standard during Monsoon season; then, in Serlui Stream, Vaipuanpho Stream, Tuipui River and Tlawng River Suarpui were below the standard for Post-Monsoon season; highest-9.4 mg/l in P.H.E Water Reservoir, Rulchawm during Pre-Monsoon season; lowest-4 in Tuipui River during Pre-Monsoon season (Table 2).

3.8. Biological Oxygen Demand

The Biological Oxygen Demand standard limit set by CPCB is 2 mg/l or less, in which all stations for each season were within the standard; highest-1.7 mg/l in Tlawng River, Pialthleng, P.H.E Reservoir, Helipad and Tuichhuahsen Stream during Pre-Monsoon season; lowest-0.5 in Tuipui River during Post-Monsoon season (Table 2).

3.9. Total Alkalinity

For Total Alkalinity, all the stations for each season were all within the standard limit set by BIS which is 200 mg/l as acceptable limit; highest-140 mg/l in Serlui Stream during Pre-Monsoon season; lowest-21.6 mg/l in P.H.E Reservoir, Helipad during Monsoon season (Table 2).

3.10. Total Hardness

The Total Hardness standard limit set by BIS is 200 mg/l as acceptable limit, all the stations for each season were within the standard limit; highest-135.5 mg/l in Serlui Stream during Pre-Monsoon; lowest-16 mg/l in P.H.E Water Reservoir during Monsoon and Post-Monsoon season (Table 2).

3.11. Chlorides

For Chlorides, standard limit set by both WHO and BIS is 250 mg/l, in which all the stations were within the standard limit for all seasons; highest-43 mg/l in Vaitui Serlui Stream during Pre-Monsoon season; lowest-6 mg/l in Saikah Stream during Monsoon season (Table 3).

3.12. Magnesium

The Magnesium standard limit set by BIS is 30 mg/l as acceptable limit, in which all stations for each season were within the standard limit; highest-8.5 mg/l in P.H.E Water Reservoir, Tuikhuahtlang during Pre-Monsoon season; lowest-0.9 mg/l in Tuipui River during Post-Monsoon season (Table 3).

3.13. Nitrogen Nitrite and Nitrogen Ammonia

The Nitrogen Nitrite standard limit set by WHO is 1 mg/l, in which all the stations for each season were within the standard limit; highest-0.8 mg/l in Tuipui River during Monsoon season; lowest-0.01 mg/l in Tlawng River, Pialthleng and P.H.E Reservoir, Helipad both during Pre-Monsoon season. For Nitrogen Ammonia, the standard limit set by WHO is 1.5 mg/l, in which Tlawng Upper Stream and Tlawng Lower Stream were exceeding it both during Monsoon season; highest-8.323 mg/l in Tlawng Upper Stream during Monsoon season; lowest-0.165 mg/l in Vaipuanpho Stream during Post-Monsoon season (Table 3).

Table 3. Mean Value of Chemical Parameters of Different Sites for Pre-Monsoon, Monsoon and Post-Monsoon Season

Stations	Chlorides (mg/l)			Magnesium (mg/l)			Nitrogen Nitrite (mg/l)			Nitrogen Ammonium (mg/l)			Total Phosphate (mg/l)		
	Pre	Mon	Post	Pre	Mon	Post	Pre	Mon	Post	Pre	Mon	Post	Pre	Mon	Post
TUS	16	9.4	11	6	5.4	2.1	0.017	0.06	0.02	0.57	8.323	0.2	0.07	0.4	0.07
TLS	10	9.4	16	7	5.2	2	0.018	0.07	0.02	0.6	2.228	0.2	0.07	0.4	0.07
SSR	43	20	17	6	5.5	1.8	0.028	0.09	0.02	0.62	1.139	0.3	0.21	0.3	0.11
VRS	12	15	7.5	5	3.5	1.7	0.015	0.06	0.01	0.42	0.262	0.2	0.06	0.2	0.07
TRPZL	6.5	12	18	5	4	2.1	0.01	0.02	0.01	0.44	0.313	0.2	0.07	0.1	0.06
VTTL	38	NA	7.1	5	NA	1.4	0.224	NA	0.03	0.29	NA	0.3	0.06	NA	0.07
SSL	7.5	6	7.2	5	4.8	1.6	0.018	0.03	0.03	0.59	1.24	0.8	0.08	0.1	0.09
PRHNS	5.1	6.6	6.4	3	2.9	1.9	0.01	0.03	0.01	0.54	0.328	0.2	0.1	0.1	0.07
TRS	5.8	9.6	13	4	3.3	1.5	0.012	0.04	0.02	0.31	0.508	0.3	0.09	0.1	0.07
LRP	13	9	11	6	4	4.3	0.017	0.1	0.02	0.32	0.291	0.2	0.07	0.1	0.08
TSK	8	9.6	28	5	2.9	3.3	0.014	0.04	0.04	0.44	0.52	0.3	0.09	0.1	0.09
TRC	7.7	16	7.5	4	3.2	0.9	0.007	0.8	0.16	0.41	0.555	0.3	0.06	0.1	0.06
PWRTA	10	23	34	9	5.1	4.3	0.012	0.02	0.02	0.41	0.269	0.3	0.06	0.1	0.08
PWRR	12	8.4	9.1	6	2.5	1.2	0.011	0.02	0.01	0.21	0.323	0.2	0.08	0.1	0.25
TRSB	9	8.7	8	6	4	1.6	0.014	0.04	0.05	0.47	0.555	0.6	0.07	0.1	0.15

3.14. Total Phosphate

The Total Phosphate standard limit were set by WHO which is 0.1 mg/l, in which Serlui Stream exceeds it all during Pre, Post and Monsoon season, Tlawng Upper Stream, Tlawng Lower Stream, Serlui Stream and Vaipuanpho Stream were exceeding it during Monsoon season, P.H.E Water Reservoir, Rulchawm and Tlawng River, Suarpui were exceeding it during Post-Monsoon season; highest-0.443 mg/l in Tlawng Lower Stream during Monsoon season; lowest-0.055 mg/l in Lahmun River during Monsoon season (Table 3).

3.15. Calcium

For Calcium, standard limit set by BIS is 75 mg/l, in which all stations for each season were all within the standard limit; highest-44.6 mg/l in Serlui Stream during Pre-Monsoon season; lowest-3 mg/l P.H.E Reservior, Helipad during Pre-Monsoon season (Table 4).

3.16. Sodium

The Sodium standard limit set by WHO that is 50 mg/l, in which all stations were within the standard limit; highest-1.75 mg/l in Tlawng Lower Stream and Tuipui River both during Pre-Monsoon season; lowest-1 mg/l in Tlawng Upper Stream, Tlawng River, Pialthleng, P.H.E Reservoir, Helipad, Tuikum River, Lahmun River, Tuichhuahsen Stream, P.H.E Water Reservoir, Tuikhuahtlang and P.H.E Water Reservoir, Rulchawm (Table 4).

Table 4. Mean Value of Chemical Parameters of Different Sites for Pre-Monsoon, Monsoon and Post-Monsoon Season

Stations	Calcium (mg/l)			Sodium (mg/l)			Potassium (mg/l)		
	Pre	Mon	Post	Pre	Mon	Post	Pre	Mon	Post
TUS	19.2	11.45	16.2	1	NA	NA	0.5	NA	NA
TLS	31	10.85	16.2	1.75	NA	NA	0.5	NA	NA
SSR	44.6	23	18.2	1.5	NA	NA	NA	NA	NA
VSR	10.7	11.25	8	1.5	NA	NA	0.5	NA	NA
TRPZL	6.8	7.4	8.4	1	NA	NA	NA	NA	NA
VTTL	20	NA	4.8	1.5	NA	NA	0.5	NA	NA
SSL	10.2	5.6	8	2	NA	NA	NA	NA	NA
PRHNS	3	4.05	8.4	1	NA	NA	NA	NA	NA
TRS	6	11.2	6.8	1	NA	NA	NA	NA	NA
LRP	35	16.6	24.8	1	NA	NA	NA	NA	NA
TSK	10	6.85	17	1	NA	NA	NA	NA	NA
TRC	7.7	9	8	1.75	NA	NA	1	NA	NA
PWRTA	14.4	20.6	12.8	1	NA	NA	0.5	NA	NA
PWRR	12	3.65	4.4	1	NA	NA	0.5	NA	NA
TRSB	23.7	9.8	21.4	1.3	NA	NA	0.5	NA	NA

3.17. Potassium

For Potassium, standard limit set by WHO is <10 mg/l, in which all the available stations were within the standard limit, highest-1 mg/l in Tuipui River during Pre-Monsoon season; lowest-0.5 mg/l in all the other available stations during Pre-Monsoon season (Table 4).

3.18. Faecal Coliform and Total Coliform

The Faecal Coliform standard limit as set by BIS is such that it should not be detectable in any 100 ml sample, in which almost all the stations that were tested were positive, except for Saikah Stream during Monsoon season; highest-384.5 MPN in Tlawng Lower Stream during Monsoon season; lowest-6.5 MPN in Saikah Stream during Post-Monsoon season. For Total Coliform, the standard limit set by BIS is such that it shall not be detectable in any 100 ml sample, in which all the stations that were tested were positive; highest-1872.5 MPN in Tlawng Lower Stream during Pre-Monsoon season; lowest-176.25 MPN in Saikah Stream during Post-Monsoon season (Table 5).

Table 5. Mean Value of Bacteriological Parameters of Different Sites for Pre-Monsoon, Monsoon and Post-Monsoon Season

Stations	Faecal Coliform (MPN)			Total Coliform (MPN)		
	Pre	Mon	Post	Pre	Mon	Post
TUS	196	431	171	1286	1750	755
TLS	299	385	171	1873	1750	755
SSR	NA	NA	NA	NA	NA	NA
VSR	NA	NA	NA	NA	NA	NA
TRPZL	NA	11.6	135	NA	551	860
VTTL	NA	NA	NA	NA	NA	NA
SSL	NA	0	6.5	NA	338	176
PRHNS	NA	NA	NA	NA	NA	NA
TRS	NA	NA	NA	NA	NA	NA
LRP	NA	NA	NA	NA	NA	NA
TSK	NA	NA	NA	NA	NA	NA
TRC	NA	8	18.3	NA	516	238
PWRTA	NA	NA	NA	NA	NA	NA
PWRR	NA	NA	NA	NA	NA	NA
TRSB	NA	NA	NA	NA	NA	NA

A two-way ANOVA revealed that Temperature, Electrical conductivity, Turbidity, Dissolved Oxygen, Total Alkalinity, Total Hardness, Magnesium, Chlorides, Nitrogen Nitrite and Calcium were significantly affected by the interaction between seasons and sites ($p<0.05$). Meanwhile, there was not a statistically significant interaction between the effects of sites and seasons on pH, BOD, Nitrogen Ammonia, and Total Phosphate ($p<0.05$). Simple main effect analysis revealed that seasons has shown no significant effect on DO, BOD and Chlorides ($p<0.05$); also sites has no significant effect on Nitrogen Ammonia and Total Phosphate ($p<0.05$). For Colour, Odour, TDS, TSS, Sodium, Potassium, Faecal and Total Coliform Bacteria, the present analysis was not performed due to lack of changes and insufficient monthly data.

Table 6. Two-Way ANOVA Showing the Effect of Sites and Seasons on Temperature ($p<0.05$)

Temperature			
Source	df	F	Sig.
Sites	13	51.783	0
Seasons	2	13.853	0
Sites*Seasons	26	11.829	0.015

Table 7. Two-Way ANOVA Showing the Effect of Sites and Seasons on EC ($p<0.05$)

EC			
Source	df	F	Sig.
Sites	13	4.231	0
Seasons	2	7.657	0.001
Sites*Seasons	26	1.899	0.01

Table 8. Two-Way ANOVA Showing the Effect of Sites and Seasons on Turbidity ($p<0.05$)

Turbidity			
Source	df	F	Sig.
Sites	13	5.588	0
Seasons	2	21.034	0
Sites*Seasons	26	5.72	0

Table 9. Two-Way ANOVA Showing the Effect of Sites and Seasons on pH ($p<0.05$)

pH			
Source	df	F	Sig.
Sites	13	5.307	0
Seasons	2	18.698	0
Sites*Seasons	26	1.181	0.268

Table 10. Two-Way ANOVA Showing the Effect of Sites and Seasons on DO ($p<0.05$)

DO			
Source	df	F	Sig.
Sites	13	14.423	0
Seasons	2	2.664	0.074
Sites*Seasons	26	2.642	0

Table 11. Two-Way ANOVA Showing the Effect of Sites and Seasons on BOD ($p<0.05$)

BOD			
Source	df	F	Sig.
Sites	13	5.543	0
Seasons	2	0.372	0.69
Sites*Seasons	26	1.544	0.06

Table 12. Two-Way ANOVA Showing the Effect of Sites and Seasons on Total Alkalinity ($p<0.05$)

Total Alkalinity			
Source	df	F	Sig.
Sites	13	11.21	0
Seasons	2	41.417	0
Sites*Seasons	26	1.719	0.026

Table 13. Two-Way ANOVA Showing the Effect of Sites and Seasons on Total Hardness ($p<0.05$)

Total Hardness			
Source	df	F	Sig.
Sites	13	14.224	0
Seasons	2	21.316	0
Sites*Seasons	26	2.744	0

Table 14. Two-Way ANOVA Showing the Effect of Sites and Seasons on Chlorides (*p*<0.05)

Chlorides			
Source	df	F	Sig.
Sites	13	7.472	0
Seasons	2	0.152	0.859
Sites*Seasons	26	3.794	0

Table 15. Two-Way ANOVA Showing the Effect of Sites and Seasons on Magnesium (*p*<0.05)

Magnesium			
Source	df	F	Sig.
Sites	13	4.363	0
Seasons	2	64.57	0
Sites*Seasons	26	1.614	0.043

Table 16. Two-Way ANOVA Showing the Effect of Sites and Seasons on Nitrogen Nitrite (*p*<0.05)

Nitrogen Nitrite			
Source	df	F	Sig.
Sites	13	10.453	0
Seasons	2	12.83	0
Sites*Seasons	26	7.265	0

Table 17. Two-Way ANOVA Showing the Effect of Sites and Seasons on Nitrogen Ammonia (*p*<0.05)

Nitrogen Ammonia			
Source	df	F	Sig.
Sites	13	1.319	0.211
Seasons	2	5.104	0.007
Sites*Seasons	26	0.999	0.474

Table 18. Two-Way ANOVA Showing the Effect of Sites and Seasons on Total Phosphate (*p*<0.05)

Total Phosphate			
Source	df	F	Sig.
Sites	13	1.516	0.12
Seasons	2	6.741	0.002
Sites*Seasons	26	1.1	0.351

Table 19. Two-Way ANOVA Showing the Effect of Sites and Seasons on Calcium (*p*<0.05)

Calcium			
Source	df	F	Sig.
Sites	13	10.679	0
Seasons	2	7.024	0.001
Sites*Seasons	26	3.021	0

4. Conclusion

The exceedance of acceptable limit or permissible limit set might not be instantly harmful to human health, but it is a clear signal for the need of an action. Developing more sources of pollution nearby water station, long-term exposure, will have irreversible negative impact on human health, quality and quantity of freshwater.

For management of community drinking-water quality to be effective and sustainable, it requires involvement, awareness and active support of local communities at different stages of decision-making in water-related issues. People's participation in the management, protection, and conservation of drinking water sources is extremely crucial. In addition, Enforcement of Water Pollution Act and increasing construction of waste water treatment center in all major towns by the Government is highly recommended.

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