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Seasonal monitoring of groundwater quality in Aizawl, Mizoram, Northeast India

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Abstract Rapid rise in population, modern intensive agriculture, and industrial development significantly stressed the water resources and deteriorated the groundwater quality. Therefore, the present study aimed to assess the groundwater quality in a hilly landscape of Aizawl city, Mizoram, Northeast India. Groundwater extracted from multiple sources is the primary water source to meet the basic needs of local residents. Thus, there exist an urgent need to monitor the groundwater quality to safeguard public health. To this end, six physico-chemical characteristics demonstrated varying ranges at different sites/seasons such as temperature (18.5°C-26°C), pH (5.35-7.9), turbidity (0.1NTU-80.9NTU), Total Dissolved Solids (TDS) 16 mg/L -268 mg/L)), Chloride (3.16 mg/L -86.02 mg/L), Dissolved Oxygen (DO (1.75 mg/L - 6.46 mg/L)). Further, heavy metals like Manganese (Mn (0- 0.6892 mg/L)) slightly exceeded the permissible concentrations while Copper (Cu (0 -0.0189 mg/L)) was noted to be below the regulatory limits. The findings revealed that all the water quality parameters were below the permissible limit set, except turbidity and Mn. Groundwater of Aizawl was therefore found to be suitable for domestic use other than drinking. Henceforth, proper management of the groundwater is required through frequent monitoring and application of green technologies such as phytoremediation to improve the water quality for sustainable use.

Keywords: *Water quality, groundwater, physico-chemical properties, heavy metals, phytoremediation*

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1. Introduction

Groundwater is the most important natural resource for multiple human uses and sustenance of public health [1]. Approximately one-third of the global population depends on groundwater for drinking water [2] and about 50% of the total water utilized for domestic purpose is derived from groundwater [3]. However, the rapid increase in population and development has led to various environmental pollutions and decline in surface water resources to meet the basic needs of the people [4]. Indian states like Punjab, Haryana, Himachal Pradesh, Uttar Pradesh Gujarat, Andhra Pradesh, Kerala, and Delhi depends on groundwater to meet their basic needs, however, this groundwater is contaminated with several heavy metals (Lead, Cadmium, Zinc, and Mercury) that can cause detrimental health effects on human [5-6]. Groundwater is a significant component of the global water cycle and plays a crucial role in supporting various ecosystems, agriculture, and human needs, thereby linked to UN-SDGs.The evaluation of groundwater quality is further required to supplement domestic water supply, which is the basic need for human life and a critical factor for United Nations sustainable development goal (specifically, SDG 6) [7]. SDG 6 includes targets related to improving access to safe and affordable drinking water, sanitation facilities, and the sustainable management of water resources. Several studies on the assessment of water quality have been carried out in the Northeastern states, including Mizoram [8-14] however, no systematic and comprehensive study has been done in ground water (handpump tube wells) in Aizawl city which serves as a primary drinking water source for many households in almost all the localities. Moreover, there exist negligible studies to assess on heavy metals contamination of ground water in Aizawl.

In Aizawl City as well as in all the other towns and villages of Mizoram, public bore wells have been drilled and installed by the Public Health Engineering Department (PHED) of the State Government. It was done with the purpose to meet the water requirements of the households in that area whereas borewell installation for private use is virtually not done till date. In Aizawl city, the treated water is supplied through pipeline connections by the PHED which is not sufficient to meet the daily requirements of water for drinking and other household activities of the local people. Moreover, as river is the sole input source of water for pipeline connections, the quantity supplied through this connection is highly variable due to seasonality of rainfall and also due to technical difficulties which often occurred in the vast network of pipelines on the rough terrain of Aizawl City. Majority of the families are depending on secondary sources of water like rain water, tuikhur (water storage point fed by water seepages from rock strata), and hand pump tube wells installed by the State Government. In the proposed study area, it has been observed during survey that majority of the local people are dependent on hand pump and tube wells derived groundwater which is used for drinking as well as other domestic uses without any proper treatment or sanitization. Therefore, in present study six physico-chemical parameters (Temperature, pH, Turbidity, Total Dissolved Solids (TDS), chloride, and Dissolved Oxygen (DO)) and two heavy metals (Manganese (Mn) and Copper (Cu)) were analysed in groundwater samples to assess their suitability for drinking and other domestic purposes as consumption of contaminated water could lead to detrimental human health effects. Hence, the suitability of the groundwater can be managed through frequent monitoring of the water samples and application of phytoremediation which a green and novel strategy to prevent the seepage of contaminant into the groundwater [15-18].

2. Study Site

The study area, Aizawl city is the capital of the state Mizoram, situated in Northeast India. It is located in the north of the Tropic of cancer in the northern part of Mizoram and is situated on a ridge1132 meters above sea level with the Tlawng river valley on its west and Tuirial river valley to the east. It falls between 23º 40' N to 23º 50' N latitudes and 92º40' E to 92º 49' E longitudes. It covers a total area of 3,576 sq.km (Figure 1). The entire Aizawl district is under the direct influence of south–west monsoon, with average rainfall of 3155.3 mm [19]. In summer, the temperature ranges from 20-30 °C and in the winter 11-21°C [20]. The PHED of the state provides water supply in rural and urban areas as piped water. However, piped water supply in insufficient to meet the needs of the people, therefore locals have to depend on handpumps, groundwater and rainwater, which has led to significant increase in rainwater harvesting facilities [21-22].

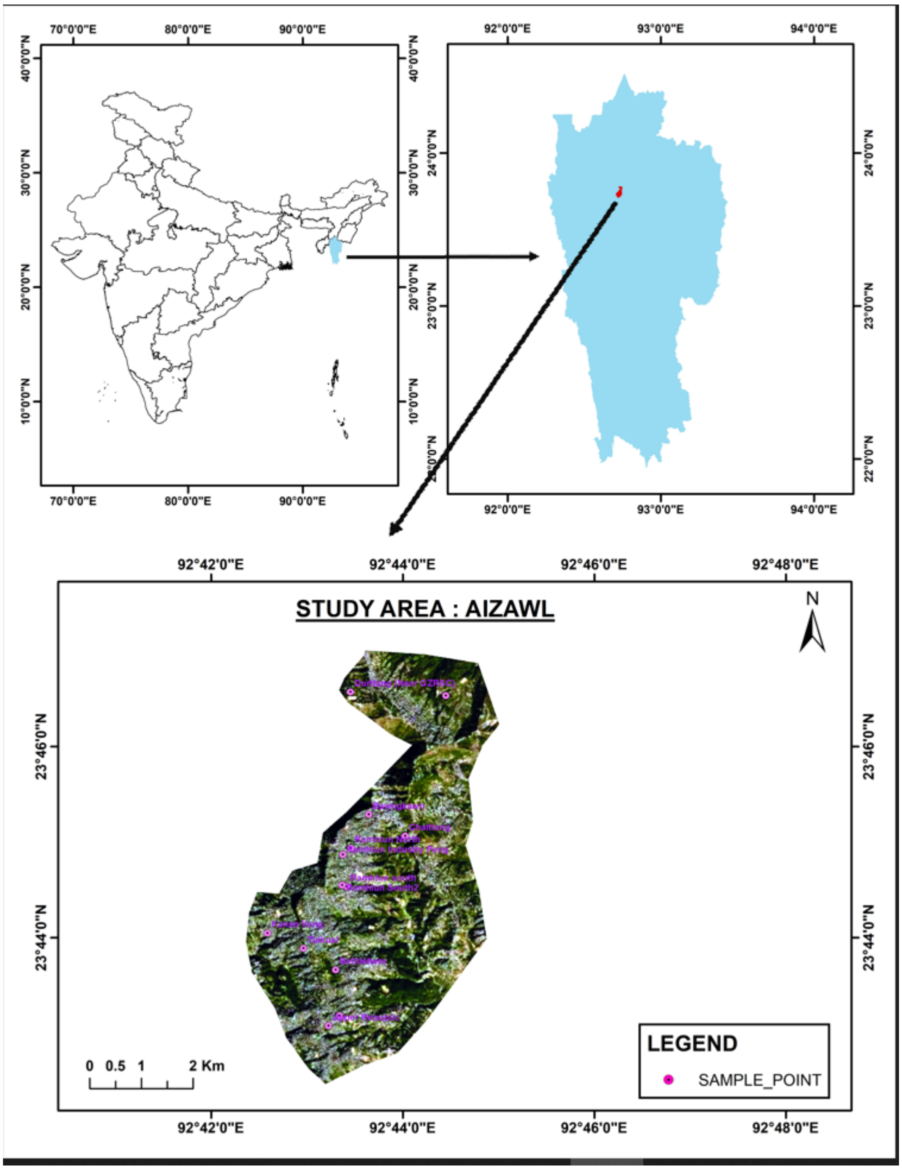

Figure 1. Map showing different selected study sites

3. Methodology

In the present study, 14 groundwater samples were collected from 14 different localities of Aizawl City under five major zonations viz. North, South, Central, East and West parts of Aizawl City, seasonally for 2 years (January 2018-December 2019) (Table 1). Samples were collected according to the standard method for the analysis of physico-chemical characteristics of water namely: Temperature, pH, Turbidity, Total Dissolved Solids (TDS), chloride, and Dissolved Oxygen (DO) were analysed following the methods as outlined in the `Standard Methods for Examination of Water and Wastewater` as prescribed by APHA [23] and compared with standards given by ICMR, BIS, USPH, and WHO. Analysis for heavy metals was also conducted following standard method using Atomic Absorption Spectrophotometer (AAS).

Table 1. Description of different selected study sites

Sample No.	Locality	Types	GPS location
Site 1	Bawngkawn	Handpump	N23 45.28 E92 43.642
Site 2	Chaltlang	Handpump	N23 45.06 E92 43.382
Site 3	Ramhlun South(upper)	Handpump	N23 44.53 E92 43.410
Site 4	Republic Vengthlang	Handpump	N23 43.18 E92 43.341
Site 5	Republic Upper	Handpump	N23 43.07 E92 43.223
Site 6	Tuikual	Handpump	N23 43.88 E92 42.963
Site 7	Kanan	Handpump	N23 43.57 E92 42.389
Site 8	Ramhlun South (lower)	Handpump	N23 44.55 E92 43.366
Site 9	Tap water	Tap water	N23 43.58 E92 42.399
Site 10	Bethlehem	Handpump	N23 43.66 E92 43.296
Site 11	Durtlang (near college)	Handpump	N23 46.57 E92 43.453
Site 12	Durtlang (near church)	Handpump	N23 46.53 E92 44.448
Site 13	Ramhlun North	Handpump	N23 44.93 E92 43.455
Site 14	Ramhlun Industry peng	Handpump	N23 44.86 E92 43.371

4.Results and Discussion

4.1. Physico-chemical Parameters

The seasonal assessment of water quality provides a better understanding on the variations in the water quality. The physico-chemical parameters analyzed were compared with permissible limit set by several scientific or regulatory agencies which is represented in Table 2.

4.1.1. Temperature

The temperature values of water from all fourteen sites were recorded in the pre-monsoon, monsoon and post-monsoon seasons, respectively. The temperature of water ranged from 18.5°C (site 12 in pre-monsoon season) and 26°C (sites 3, 4, 5, 10, 13, 14 in monsoon season) throughout the study period (Figure 2). In general, present study observed that temperature of groundwater was lowest in pre-monsoon season and highest in monsoon season. The increase in temperature in monsoon season could be possibly due to the increased percolation due to rainfall, which traps the heat retained in the different layers of soil surface. In addition, increased seepage of water also resulted in greater growth of microorganisms which could raise the temperature of the ground through their increased metabolic activities. The decline in temperature in pre-monsoon season on account of dry weather and less moisture, allowing the soil to be airy and thus, release more heat into the atmosphere. However, the temperature values recorded were within the permissible standards set by various scientific agencies. A similar trend was observed by [24-26].

Two-way ANOVA revealed that the values of temperature recorded in groundwater were significant ($p<0.001$) both between sites and seasons. A positive and significant correlation of temperature was obtained with TDS (0.542(29%)) On the contrary, a negative and significant correlation was obtained with Cu (-0.539(-28%))

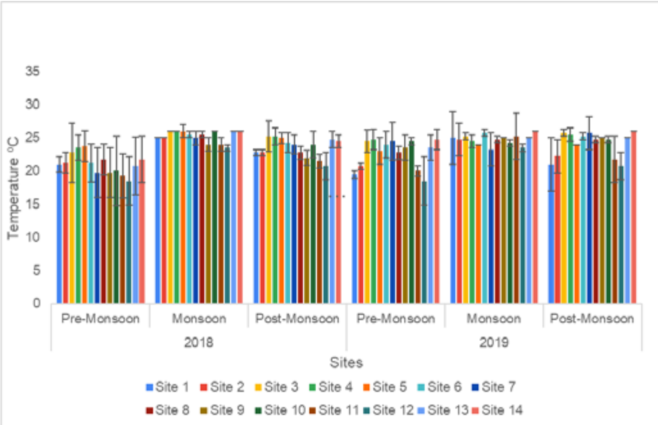

Figure 2. Seasonal variation of temperature of groundwater in different study sites

4.1.2. pH

The pH values of all the samples from the 14 different sites have been recorded seasonally i.e., pre-monsoon, monsoon, and post-monsoon seasons (Figure 3). The range of pH recorded in 2018 was from 5.725 (site 13 in pre-monsoon season) to 7.9 (site 9 in pre-monsoon season). However, the range of pH in the year 2019 was from 5.35 (site 13 in post monsoon season) to 7.45 (site 12 in monsoon season). Therefore, the pH throughout the study period (2018-19) ranged from 5.35 to 7.9. The pH ranges were found to be lower during pre-monsoon and post-monsoon seasons compared to monsoon season. Particularly at site 13, the pH level was observed to be lower than the permissible limits set by various agencies in the pre-monsoon and post monsoon seasons in the years 2018- 2019. This could be due to the dilution of groundwater from high percolation of surface runoff water in the rainy or monsoon season, which eventually lowers the acidity and hence results in an increase in the pH values. The low pH level in dry seasons might be due to continuous weathering of minerals in the aquifers and the effects of acid rain. The pH level of groundwater was lower in dry seasons than monsoon season, and even more so in confined aquifers than in unconfined aquifers, usually due to the disintegration of minerals and dissolved carbon dioxide [27-29].

Two-way ANOVA revealed that the values of pH recorded in groundwater were significant ($p<0.001$) between the sites. A negative and significant correlation was obtained with, Mn (-0.557(-32%)).

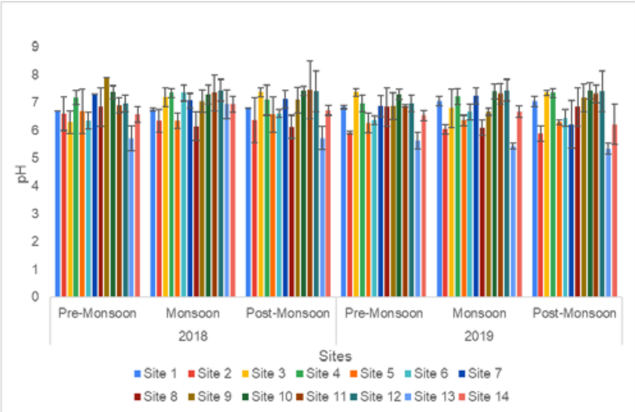

Figure 3. Seasonal variation of pH of groundwater in different study sites

4.1.3. Turbidity

The turbidity of all samples were recorded for two years on the basis of pre monsoon, monsoon and post monsoon seasons respectively (Figure 4). The turbidity of groundwater ranged from 0.1 NTU (site 9 in post-monsoon season) to 15.275 NTU(site 14 in post-monsoon season) in the year 2018, whereas, 0.2NTU (site 10 in pre-monsoon season) to 80.9 NTU (site 11 in post-monsoon season) in the year 2019. Therefore, the range of turbidity in the two years (2018-19) was from 0.1 NTU to 80.9 NTU. Seasonal variations revealed that turbidity was usually lowest in pre-monsoon season, followed by the monsoon season while it was highest in post monsoon season depending on its exposure to the surface. In the present assessment, the increase in turbidity of groundwater during monsoon and post monsoon seasons is due rainfall which increases the surface runoff. The decline of turbidity in pre-monsoon could be due to lack of surface runoff and frequent seepage of sewage which also slows down the weathering of rocks. Almost all sites showed turbidity levels within permissible limits set by BIS, however, some sites have exceeded permissible limits in post monsoon season in both the years. Site 2, 13, and 14 have far exceeded the acceptable standard of turbidity during the year 2018, whereas sites 2,3,4,5,6,7,11,13 and 14 exceeded the standard in 2019. These exceeding observations for turbidity were mostly observed in the monsoon and post monsoon seasons. The turbidity of boreholes is generally higher during monsoon and that of hand dug wells were higher in summer [30]. The overland flow of water during monsoon may be a great contributor to the high level of turbidity, which exceeded the acceptable standards set by WHO.

Two-way ANOVA revealed that the values of turbidity recorded in groundwater were significant ($p<0.001$) between the seasons. A negative and highly significant correlation was obtained with DO (-0.735(53%))

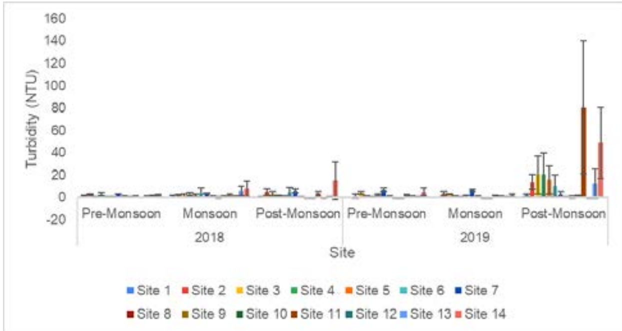

Figure 4. Seasonal variation of turbidity of groundwater in different study sites

4.1.4 Total Dissolved Solids (TDS)

The Total Dissolved Solids(TDS) for all 14 sites were recorded for the Year 2018 and 2019 (Figure 5). In the year 2018, the TDS of groundwater ranged from 39.5 mg/L (site 9 in post monsoon season) to 268 mg/L (site 6 in monsoon season) , whereas in 2019, the range of TDS in groundwater ranged from 16mg/L (site 9 in pre-monsoon and post-monsoon sesasons) to 246.25 mg/L (site 6 in pre-monsoon season). The overall range of Total Dissolved Solids during 2018-19 was from 16 mg/L to 268mg/L. The values of Total Dissolved Solids in groundwater varied in different seasons. TDS of water indicates the measure of the total dissolved organic or inorganic molecules. Water is also polluted by the high amount of TDS produced by the extortion of fossil fuels which makes water unfit for drinking and domestic uses [31]. Large amount of TDS makes water unsuitable for drinking as the amount of dissolved oxygen gets reduced [32]. The percolation of sediments along-with water degrades the quality of water by increasing the amount of TDS [33]. Overuse of groundwater and anthropogenic factors have contributed to the high level of TDS [34].

Two-way ANOVA revealed that the values of Total Dissolved Solids recorded in groundwater were significant ($p<0.001$) between the sites. A positive and significant correlation of TDS was obtained with temperature 0.542(29%)), Chloride (0.791(62%)).

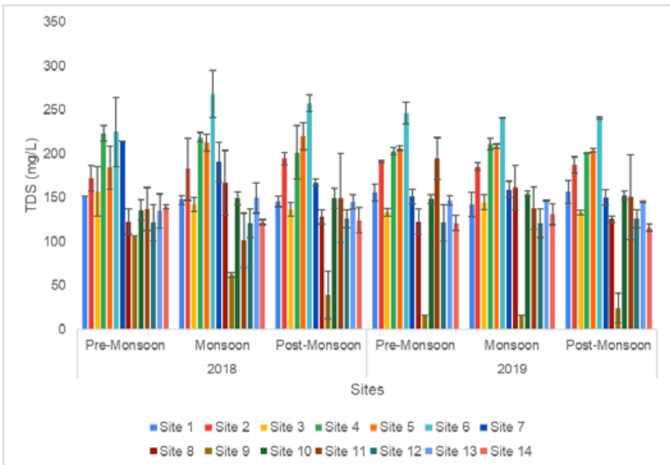

Figure 5. Seasonal variation of TDS of groundwater in different study sites

4.1.5. Chloride

The chloride levels in the groundwater samples were observed and recorded during study period (i.e., 2018-19) (Figure 6). In 2018, the chloride levels ranged from 5.075 mg/L (site 9 in post monsoon season) to 86.025 mg/L (site 6 in pre monsoon season). In 2019 , the chloride levels ranged from 3.1625 mg/L(site 9 in post monsoon season) to 81.51 mg/L (site 2 in mosoon season). The overall range of chloride levels during 2018-19 ranged from 3.1625mg/L to 86.025mg/L. Chloride compounds from potassium fertilizers had influenced groundwater chloride levels significantly, leading to rise in chloride concentrations in the summer when compared to rainy season [35-36]. The reason for the slight decrease in chloride concentration in monsoon was mainly due to dilution of groundwater by rainfall [37]. In the present study, the chloride levels in all the sites were found to be variable in the different seasons. The overall range of chloride levels was from 3.1625mg/L to 86.025mg/L. These levels were well within the acceptable standards set by scientific agencies.

Two-way ANOVA revealed that the values of Chloride recorded in groundwater were significant ($p<0.001$) both between the sites and seasons. A positive and significant correlation of Chloride was obtained with TDS (0.791(62%)), On the contrary, a negative and significant correlation was obtained with pH pH (-0.513(-26%)), DO (-0.529(-27%)).

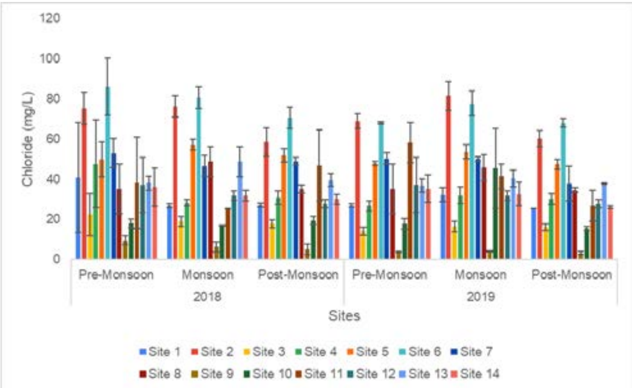

Figure 6. Seasonal variation of chloride of groundwater in different study sites

4.1.6. Dissolved Oxygen (DO)

The level of Dissolved Oxygen (DO) in the two years i.e., 2018-19 were tested and recorded (Figure 7). In the year 2018, the level of DO ranged from 1.85 mg/L (site 2 in monsoon season) to 6.2 mg/L (site 9 in pre-monsoon season), whereas in the year 2019, it ranged from 1.75 mg/L (site 14 in monsoon season) to 6.46 mg/L (site 9 in pre-monsoon). The total range of DO in the two years (i.e., 2018-19) was from 1.75 mg/L to 6.46 mg/L. It was observed that the level of DO was the lowest in monsoon season and highest in pre-monsoon season. The amount of DO in groundwater can differ in different seasons. In the present study, the total range of DO in the two years i.e., 2018 – 2019 ranged from 1.75 mg/L to 6.46 mg/L. Further, it was observed that the level of DO was lowest in monsoon season and highest in pre-monsoon season, but overall; the results were within permissible limits. This may be due to the fact that soil and aquifer are more aerated during dry seasons in contrast to rainy season and there may be consumption of dissolved oxygen by aerobic microorganisms.

Two-way ANOVA revealed that the values of Dissolved Oxygen recorded in groundwater were significant ($p<0.001$) both between the sites and seasons. A negative and significant correlation was obtained with Turbidity (-0.735(-53%)), Chloride (-0.529(-27%)), and Mn (-0.582 -33%).

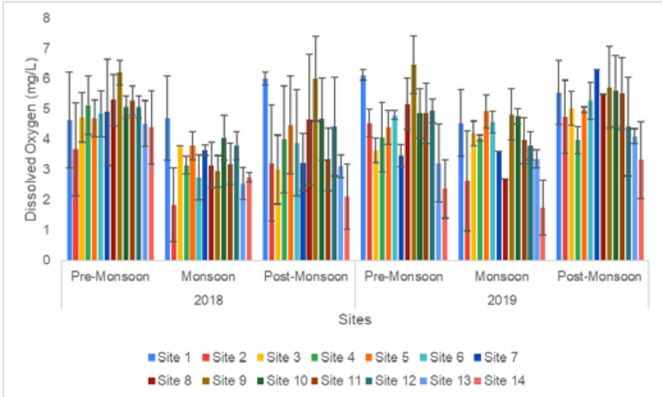

Figure 7. Seasonal variation of Dissolved Oxygen of groundwater in different study sites

4.2. Heavy metals

4.2.1. Manganese (Mn)

The manganese (Mn) levels in the groundwater of all the fourteen sites ranges from 0 mg/L to 0.6892 mg/L throughout the study period (2018-2019) with highest values (0.329 mg/L) observed in site 13 in post monsoon season 2018 and (0.6892 mg/L) observed in site 14 in post monsoon in 2019 (Figure 8). In the present study the levels of Mn exceed the permissible limits prescribed by various agencies. Manganese contamination occurs more frequently in groundwater than surface water [38] This may be because of the seepage of manganese from the minerals present in the earth's crust and the aquifers. Therefore, heavy mines can be detrimental to aquatic environment as it releases heavy amounts of manganese [39]. A negative and significant correlation was obtained with pH (-0.557(-30%)), DO (-0.582(-33%)).

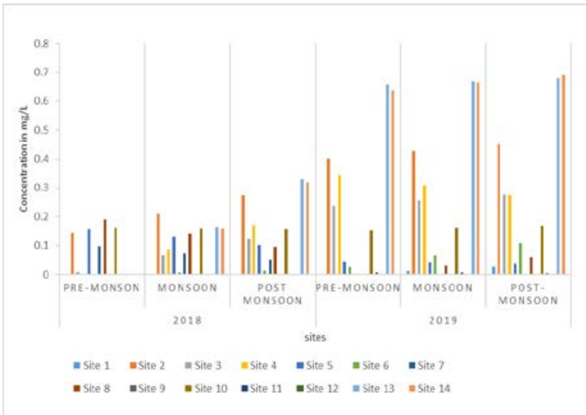

Figure 8. Seasonal variation of Manganese of groundwater in different study sites

4.2.2. Copper (Cu)

The Copper (Cu) levels in the groundwater of all the fourteen sites ranges from 0 mg/L to 0.0189 mg/L throughout the study period (2018-2019) with highest values (0.0189 mg/L) observed site 12 in pre-monsoon season 2018 and 0.00945 mg/L site 12 in pre-monsoon season in 2019 (Figure 9). The slight decrease in copper levels from pre-monsoon to monsoon and least in post monsoon has been observed. Copper levels will inevitably fluctuate as the ground undergoes changes due to change in weather conditions in different seasons. Furthermore, a slight decrease in copper levels from pre-monsoon to monsoon and least in post monsoon had been observed. This might be due to increased seepage of water in monsoon season. A negative and significant correlation was obtained with temperature (-0.539(-28%)).

Frequent monitoring of the groundwater samples with incorporation of phytoremediation and application of green chemicals can be the novel strategy to reduce the contaminants from water body and hence to prevent their seepage into groundwater [15-17]. Further, phytotechnologies of surface water pollution can also contain the groundwater pollution in an eco-sustainable way [40-44].

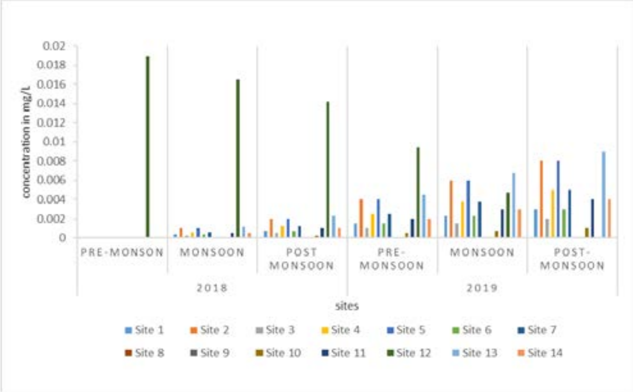

Figure 9. Seasonal variation of Copper of groundwater in different study site

Table 2. Water quality standards for different physico-chemical parameters and heavy metals and range of values recorded in present investigation

	Parameter	Water quality standards				Water quality range during present investigation
		ICMR	BIS	USPH	WHO	
		Physico-chemical properties				
1	Temperature(C°)	N/A	40	N/A	30	18.5°C -26°C
2	pH (Nano mole L^{-1})	6.0-8.5	6.5-8.5	6.0-8.5	6.5-9.2	5.35-7.9
3	Turbidity (NTU)	2.5	1	5	5	0.1NTU-80.9NTU
4	TDS (mg/L)	500	300	500	1000	16 mg/L -268 mg/L
5	Chloride(mg/L)	200	250	250	250	3.16 mg/L -86.02 mg/L
6	DO (mg/L)	N/A	3	4.0-6.0	4.0-6.0	1.75 mg/L - 6.46 mg/L
		Heavy metals				
7	Manganese (Mn) mg/L	N/A	0.1	N/A	0.4	0- 0.6892 mg/L
8	Copper (Cu)	N/A	2	N/A	2	0 -0.0189 mg/L

5. Conclusion

The seasonal monitoring of groundwater samples in the present study revealed that most of the physico-chemical parameters were recorded higher in monsoon and post-monsoon seasons, except for TDS and DO. The pH values of the water samples at site 13 was slightly acidic, whereas site 9 and 12 were observed to be slightly basic. In present groundwater quality monitoring of Aizawl, all the physico-chemical parameters were within the permissible limit except for Turbidity. The Mn contents were higher at site 14 while Cu content was high at site 12. However, Mn content was slightly high than permissible limit, unlike Cu. Even though, the majority of the water quality parameters were within acceptable limits, management of groundwater for safe use is required as the usage of contaminated water can cause several health effects to human. High turbidity and Mn values can perturb the aquatic ecosystem health.

Although the Mn is essential trace elements for human metabolism, however its higher concentrations can adversely influence human health Phytoremediation and application of green chemicals can be the novel strategy to reduce the contaminants from water body and hence to prevent their seepage into groundwater.

Conflict of interest

Authors declare no conflict of interest

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