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बुलेटिन
BULLETIN

मेघालय का भूजल गुणावत्ता
GROUND WATER QUALITY OF MEGHALAYA

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GROUNDWATER QUALITY OF MEGHALAYA

ABSTRACT

Periodic groundwater quality assessment (2018-2024) highlighting the findings, significant trends and groundwater contamination status

1.0 INTRODUCTION

Groundwater is a primary source of water supply for irrigation, domestic and industrial. It is a crucial factor in India's socioeconomic growth. Despite possessing only 4% of the world's fresh water resources, India sustains over 16% of the global population and presently faces an acute water crisis. According to the safe water index survey, India ranks second to last among 123 countries. Though groundwater is less susceptible to pollution compared to surface water, reckless exploitation and overuse of groundwater resources may result in declining groundwater levels and diminished water quality. In addition, there is mounting concern about the degradation of groundwater quality caused by both geogenic processes and human activities. The potential contamination of groundwater used for public and rural domestic purposes is of particular concern. Furthermore, atmospheric precipitation, inland surface water, recharge water quality, and geochemical processes also impact groundwater quality. Groundwater contamination can have a significant impact on human health, economic development, and social well-being. In the Northeast, as in other parts of India, anthropogenic activities can negatively impact groundwater quality.

To effectively manage groundwater, it is necessary to have comprehensive data on its current and potential quality. Therefore, a thorough understanding of water resource quality in the State of Meghalaya is paramount for prudent groundwater management. Furthermore, a periodic groundwater quality assessment is important to alert people who utilize it for domestic and irrigation purpose. Numerous studies have been carried out on the poor quality of groundwater.

Our efforts in the present study are to fulfill the following objectives:

1. To present current groundwater quality scenario, parameter wise for each district.
2. To identify present day hot spots of poor-quality groundwater through spatial variation analysis of latest pre-monsoon 2024 quality data.
3. To assess temporal variation of groundwater quality showing improvement/deterioration during the period from 2018 to 2024, providing insights for effective water quality management measures.

2.0 STUDY AREA

Meghalaya (Figure 1)—in Sanskrit is alaya (“abode”) and megha (“of the clouds”)— is a state located in northeastern part of India. It is geographically termed the Shillong Plateau or the Meghalaya Plateau. It is bounded by the Indian state of Assam (Goalpara, Kamrup and Nagaon districts of Assam) to the north and (Karbi Anglong district and North Cachar Hills of Assam) to the northeast and by Bangladesh to the south and southwest. The state capital is Shillong, situated in east-central Meghalaya. It is located between Latitude 20°1'N & 26°5'N and Longitude 85°49'E & 92°52'E. Meghalaya occupies a total land area of 22,429 square kms. The total population is reported to be 1,774,778. The whole state has been divided into twelve districts namely East Garo Hills, North Garo Hills, South Garo Hills, West Garo Hills, South West Garo Hills, East Khasi Hills, East Jaintia Hills, West Jaintia Hills, South West Khasi Hills, West Khasi Hills, Eastern West Khasi Hills, Ri Bhoi.

In Meghalaya climate varies with altitude. Between November and April, the climate is mostly dry while from May to October it rains heavily. This is then followed by winter from December to February. The northern Meghalaya receives an average yearly rainfall between 2500 to 3000 mm and the annual shower is around 2600 mm in the western part of the north eastern state while the south eastern Meghalaya gets yearly rainfall above 4000 millimeters. Meghalaya has diverse natural vegetation - the Garo hills tropical mixed forests to the high-altitude pine forests. A number of rivers, such as Umtrew, Umiam, Umkhen in the northern parts and Umiew (Shella), Umngot, Umngi (Balat) in the southern part flow through the Shillong pleateau.

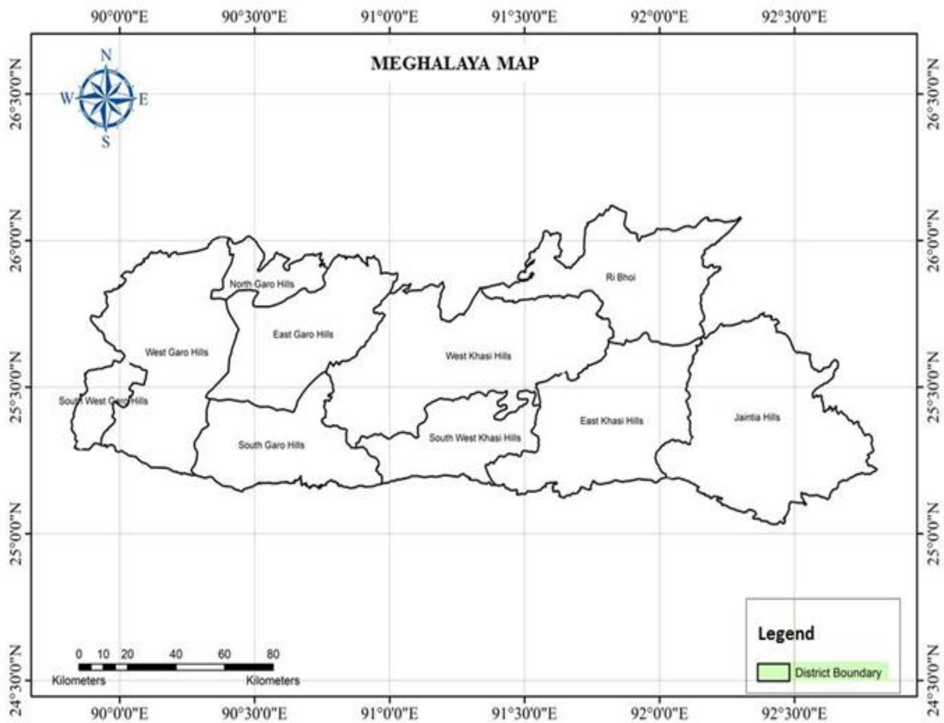

Figure 1. Map of Meghalaya

3.0 HYDROGEOLOGY

Meghalaya's general hydrogeological framework is shown in Figure 2 and can be classified as follows:

1. Unconsolidated sediments like sand, silt and clay, with thick, continuous aquifer are found in western, northern and southern fringes of Meghalaya. There groundwater occurs under unconfined to semi-confined conditions with depth to water level at 3-5 mbgl.

2. Another formation with Garo group comprised of coarse sandstone, siltstone, clay, conglomerate, silty clay and fossiliferous limestone along with Barail group having shale, minor coal lenses carbonaceous shale are in West Garo Hills area. Depth to water level rests at 4-9 mbgl.

3. Jaintia group and Khasi group are comprised of shale, sandstone, marble, calcareous shale, Arkosic sandstone. They have discontinuous aquifer in the cavernous limestones and sandstones area with groundwater with depth to water level at 2-4 mbgl.

4. Shillong group with quarzite, phyllite, quartzsericite schist, etc. and Meghalaya Archaean gneissic complex formed of granite gneiss, biotite gneiss, mica schist, etc. both have groundwater under unconfined to semi-confined conditions. The aquifer formed by weathered and fractured zones extends to 150 mbgl. In this formation has depth to water level rests at 7-17 mbgl.

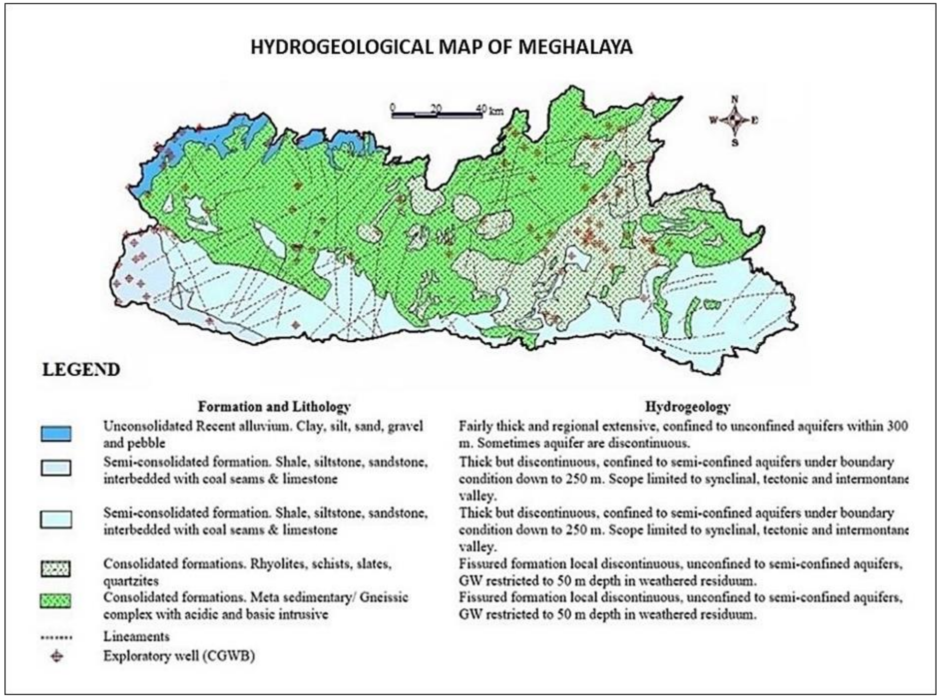

Figure 2. Hydrogeological map of Meghalaya

4.0 GROUND WATER QUALITY MONITORING

Monitoring of groundwater quality is an effort to obtain information on chemical quality through representative sampling in different hydrogeological units. Groundwater is commonly tapped from phreatic aquifers. The main objective of groundwater quality monitoring program is to get information on the distribution of water quality on a regional scale as well as create a background data bank of different chemical constituents in groundwater. The probable causes of deterioration in groundwater quality are depicted in Figure 3.

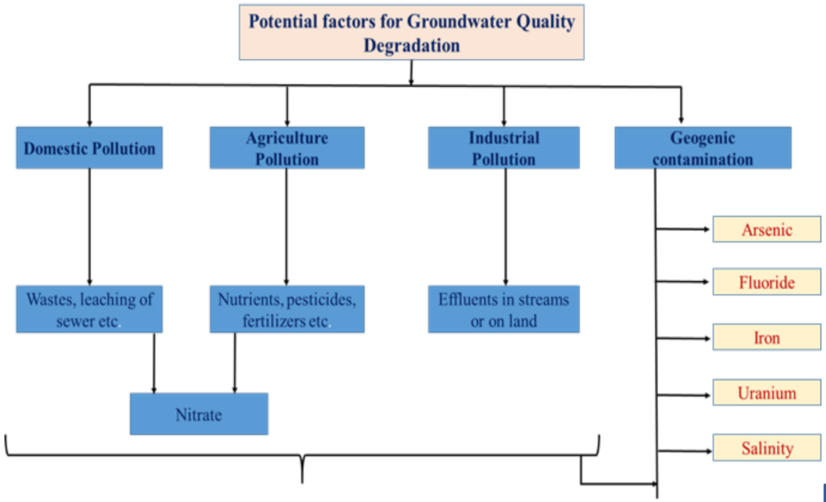

Fig. 3: Schematic diagram illustrating the potential factors contributing to the degradation of groundwater quality.

The chemical quality of shallow groundwater is being monitored by Central Ground Water Board twice in a year (Pre-monsoon and Post- monsoon). During pre-monsoon 2024 samples were collected from 75 locations all over the state (Figure 4).

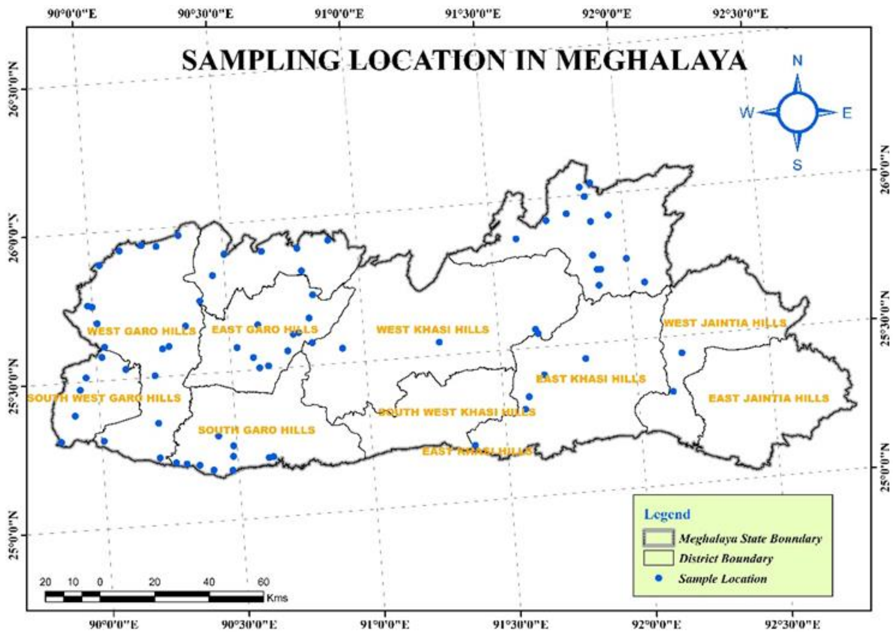

Figure 4. Ground water quality sampling locations in Meghalaya

5.0 METHODOLOGY

To establish the groundwater chemistry of the state, samples from different corners of Meghalaya have been collected during the month of March/April (pre-monsoon) of 2024, which is generally a dry period, leading to maximum concentration of elements in the water samples. Standard procedures and guidelines of sampling, storing, and transferring were strictly followed as prescribed by American Public Health Association (APHA 2017). 1000 mL of samples were collected in high-density polyethylene bottles (HDPE) without preservatives for physical and major solutes analysis. On-site sampling and sample filtration using 0.45 µm membrane by syringe filtration technique in 60 mL HDPE bottles were carried out to analyze Uranium and heavy metals. Immediately after filtration, 0.5 mL trace elemental grade HNO_3 acid is added as preservatives. Caution was being taken while bottling the samples to avoid interference from the air headspace.

Standard analysis procedures (APHA, 2017) were employed for analyzing the groundwater samples (Table 1). During the analysis, QA/QC protocols were followed, including blank run, external calibration, and standardization by NIST certified standard reference materials, retesting, etc.

Table 1: Analytical methods/equipment for Groundwater quality analysis.

Parameters	Method adopted	Instrument/technique used
PHYSICO-CHEMICAL		
pH	Electrometric method	pH meter
Conductivity	Electrometric method	Conductivity meter
Turbidity	Turbidimetric method	Nephalo-turbidity meter
TDS	Electrometric	Conductivity/TDS Meter
Alkalinity	Titrimetric method	(Titration by H_2SO_4)
Chloride (Cl)	Argentometric /Chromatographic method	(Titration by $AgNO_3$)/Ion Chromatograph
Sodium (Na)	Flame Emission Spectroscopy/ Chromatographic method	Flame photometer/ Ion Chromatograph
Potassium (K)	Flame Emission Spectroscopy/ Chromatographic method	Flame photometer / Ion Chromatograph
Total Harness	Titrimetric method	(Titration by EDTA)
Calcium (Ca)	Titrimetric method/ Chromatographic method	(Titration by EDTA)/ Ion Chromatograph
Fluoride (F^-)	Electrometric method/ Chromatographic method	Ion Meter/ Ion Chromatograph
Sulphate (SO_4^{-2})	Turbidimetric method/ Chromatographic method	UV-visible Spectrophotometer/ Ion Chromatograph
Nitrate (NO_3^-)	Ultraviolet screening/ Chromatographic method	UV-visible Spectrophotometer/ Ion Chromatograph
Phosphate	Molybdophosphoric acid/ Chromatographic method	UV-VIS Spectrophotometer / Ion Chromatograph
Dissolved Oxygen (DO)	Electrometric	DO meter
HEAVY METALS AND RADIOACTIVE URANIUM		
Uranium (U)	Plasma Spectroscopy/Fluorescence Spectrometry	ICP-MS/Uranium analyzer
Iron (Fe)	Colorimetric method/Atomic absorption spectroscopy/Palsma Spectroscopy	UV-visible Spectrophotometer/AAS
Arsenic	Hydride generation/ Plasma Spectroscopy	AAS/ICPMS
Cr, Mn, Fe, Ni, Cu, Zn, Se, Ag, Cd and Pb	Atomic Spectroscopy/ Plasma Spectroscopy	AAS/ICPMS

6.0 GROUNDWATER QUALITY SCENARIO

The main objectives of groundwater quality monitoring are to assess the suitability of groundwater for drinking purposes as the quality of drinking water is a powerful environmental determinant of the health of a community. Bureau of Indian Standards (BIS) vide its document IS: 10500:2012, Edition 3.2 (2012-15) has recommended the quality standards for drinking water. The groundwater samples collected from phreatic aquifers are analyzed for all the major inorganic parameters and trace metals. Based on the results, it is found that groundwater of Meghalaya is mostly of mixed type, evident from the total salinity of water being below 500 mg/l (corresponding to electrical conductance of 750 µs/cm at 25°C). They are of mixed cations and mixed anions type when the electrical conductance is between 750 and 3000 µs/cm. However, other types of water are also found among these general classifications, which may be due to the local variations in hydro-chemical environments due to anthropogenic activities. Most of the parameters studied are well within the safe limits. Nevertheless, occurrence of high concentrations of some water quality parameters such as Iron and Manganese have been observed in some parts of Meghalaya.

6.1 QUALITY ASSESSMENT OF GROUNDWATER IN UNCONFINED AQUIFERS

Unconfined aquifers are extensively tapped for water supply and irrigation across the state therefore; its quality is of paramount importance. The chemical parameters like EC, Fluoride, Iron, Arsenic etc. are main constituents defining the quality of groundwater in unconfined aquifers. Therefore, presence of these parameters and the changes in chemical quality with respect to these in groundwater in samples collected during NHS pre-monsoon monitoring in 2024 are discussed below.

1. Electrical Conductivity (EC) (µS/cm @25^{0}C)
2. Fluoride (mg/L)
3. Iron (mg/L)
4. Arsenic (mg/L)
5. Manganese (mg/L)

6.1.1 THE ELECTRICAL CONDUCTIVITY

Electrical conductivity or Total dissolved solids or Salinity is the dissolved salt content in a water body. Different substances dissolve in water giving it taste and odor. Electrical conductivity represents total number of cations and anions present in groundwater, indicating ionic mobility of different ions, total dissolved solids and saline nature of water. In general water having EC < 1500 µS/cm, is considered as fresh water, EC 1500 –15000 µS/cm, is considered as brackish water and >15000 µS/cm is considered as saline water. Salinity always exists in groundwater but in variable amounts. It is mostly influenced by aquifer material, solubility of minerals, duration of contact and factors such as the permeability of soil, drainage facilities, quantity of rainfall and above all, the climate of the area. BIS has recommended a drinking water standard for total dissolved solids (TDS) a limit of 2000 mg/L (corresponding to EC of about 3000 µS/cm at 25°C) in case of absence of alternate source. Water having TDS more than 2000 mg/L are not suitable for drinking purposes.

PRESENT DAY SCENARIO IN MEGHALAYA: ELECTRICAL CONDUCTIVITY (EC)

Distribution of Electrical Conductivity (EC)

- The EC value of groundwater in Meghalaya varies from 14.29 µS/cm at Tyrsad, East Khasi Hills district to 509.90 µS/cm at Byrnihat, Ri Bhoi district at 25°C.
- It is found that no sample has exceeded EC above 3000 µS/cm.
- The map showing spatial distribution of EC (Figure 5) in pre-monsoon 2024 signifies that all the locations have EC less than 750 µS/cm and shown as uniform EC.
- The Table 2 provides the number of samples analyzed per district, along with their minimum, maximum, and mean EC values based on pre-monsoon NHS 2024 data.
- Trend analysis (Table 3 & 4), of seven years showing no significant change during 2018 to 2024.
- Graphical representation of trend in EC for groundwater samples in Meghalaya is shown in Figure 6 and since 2018 no sample has exceeded the 3000 µS/cm mark.

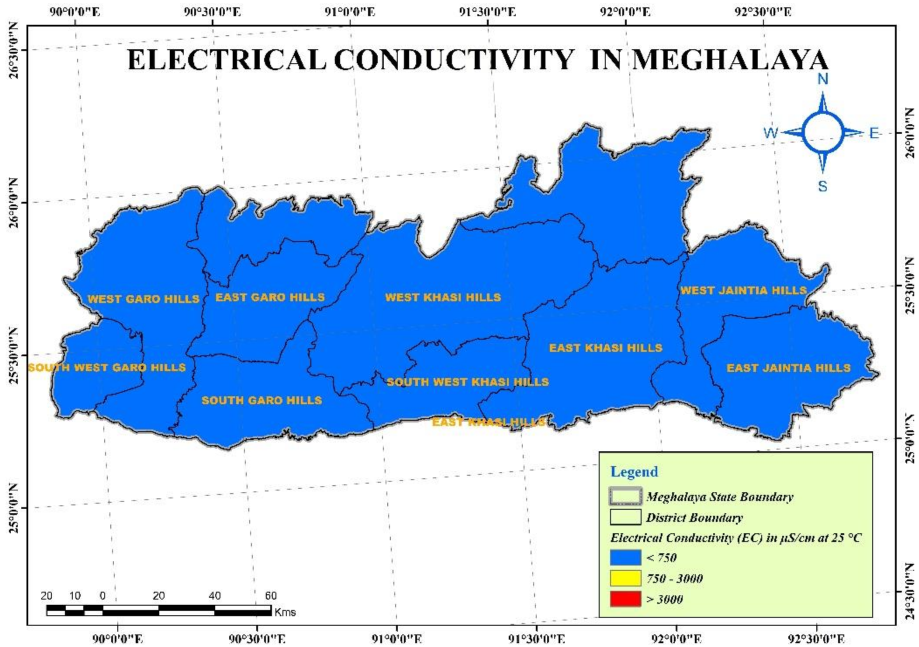

Figure 5: Map showing distribution of Electrical Conductivity in Meghalaya based on pre-monsoon NHS 2024 Data

Table 2: District wise range and distribution of EC in shallow groundwater of Meghalaya during pre-monsoon 2024

Sl. No.	District	EC (Pre-monsoon)				% of samples EC <3000 µS/cm @25°C	% of samples EC>3000 µS/cm @25°C
		No. of samples analyzed	Min	Max	Mean		
			(in µS/cm @25°C)				
1	East Garo Hills	10	26.15	213.60	71.75	100	0
2	East Khasi Hills	5	14.29	193.50	92.71	100	0
3	North Garo Hills	6	55.81	227.80	118.22	100	0
4	Ri-Bhoi	14	18.45	509.90	130.81	100	0
5	South Garo Hills	10	39.33	216.80	105.04	100	0
6	South West Garo Hills	6	115.60	186.50	139.78	100	0
7	West Garo Hills	17	30.41	227.60	108.78	100	0
8	West Jaintia Hills	2	15.20	55.80	35.50	100	0
9	West Khasi Hills	5	28.68	175.70	93.01	100	0

Table 3: Comparative change in number of locations having EC > 3000 µS/cm in various districts

Sl. No.	District	No. of locations having Electrical Conductivity >3000 µS/cm @25°C						
		2018	2019	2020	2021	2022	2023	2024
1	East Garo Hills	0	0	0	0	0	0	0
2	East Jantia Hills	0	0	0	0	0	0	0
3	East Khasi Hills	0	0	0	0	0	0	0
4	North Garo Hills	0	0	0	0	0	0	0
5	Ri-Bhoi	0	0	0	0	0	0	0
6	South Garo Hills	0	0	0	0	0	0	0
7	South West Garo Hills	0	0	0	0	0	0	0
8	West Garo Hills	0	0	0	0	0	0	0
9	West Jaintia Hills	0	0	0	0	0	0	0
10	West Khasi Hills	0	0	0	0	0	0	0
Total		0	0	0	0	0	0	0

Table 4: Periodic variation in suitability classes of groundwater Electrical Conductivity (EC) of Meghalaya

Periodic variation in suitability classes of Salinity in groundwater of Meghalaya									
Parameter	Class	Percentage of samples							Periodic Variation 2018-2024
		2018	2019	2020	2021	2022	2023	2024	
		n=20	n=14	n=13	n=31	n=34	n=113	n=75	
Salinity as EC	EC < 3000 µS/cm @25°C	100	100	100	100	100	100	100	0
	EC > 3000 µS/cm @25°C	0	0	0	0	0	0	0	0

**n= nos. of samples*

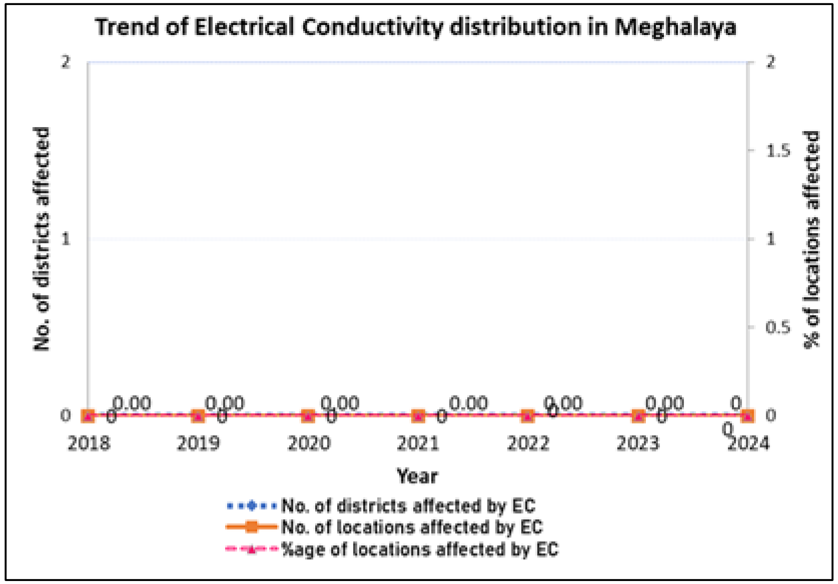

Figure 6: Graphical representation of trend in EC for Meghalaya

FLUORIDE

Fluorine does not occur in the elemental state in nature because of its high reactivity. It exists in the form of fluorides in a number of minerals of which Fluorspar, Cryolite, Fluorite & Fluorapatite are the most common. Most of the fluoride found in groundwater is naturally occurring from the breakdown of rocks and soils or weathering and deposition of atmospheric particles. Most of the fluorides are sparingly soluble and are present in groundwater in small amount.

BIS has recommended a desirable/acceptable limit of 1.0 mg/L of fluoride concentration in drinking water and maximum permissible limit of 1.5 mg/L in case no alternative source of drinking water is available. It is well known that small amount of fluoride (upto1.0 mg/L) have proven to be beneficial in reducing tooth decay. However, high concentrations (>1.5mg/L) have resulted in staining of tooth enamel while at still higher levels of fluoride (> 5.0 mg/L) further critical problems such as stiffness of bones occur.

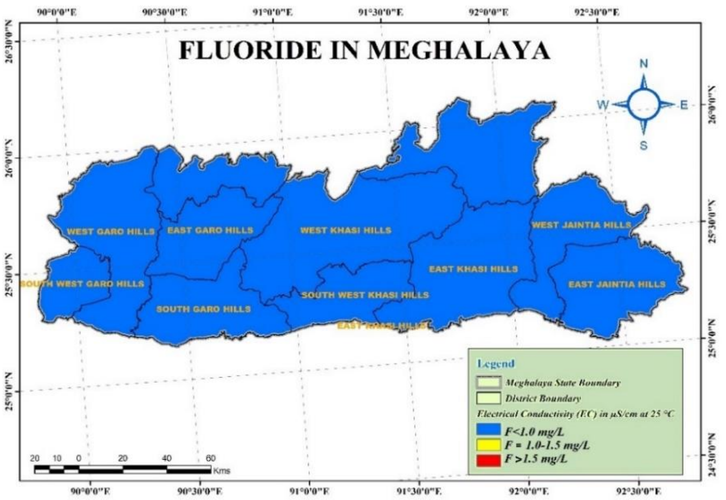

Figure 7: Map showing distribution of Fluoride in Meghalaya based on pre-monsoon NHS 2024 Data

PRPRESENT DAY SCENARIO IN MEGHALAYA: FLUORIDE

Distribution of Fluoride (F)

- The Fluoride value of groundwater in the State varies from 0.004 mg/L at Patharkhamma Barigaon in Ri Bhoi district to 0.94 mg/L at Dawagittingri in East Garo Hills.
- Grouping water samples based on Fluoride values, it is found that 100% of them have fluoride below the acceptable limit of 1.0 mg/L.
- The map showing spatial distribution of Fluoride (Figure 7) signifies that all samples are safe based on fluoride concentration and shown to be blue in color.
- The Table 5 provides for the number of samples analyzed per district, along with their minimum, maximum, and mean Fluoride values based on pre-monsoon NHS 2024 Data.
- Trend analysis (Table 6 and 7), of seven years showing trend in Fluoride content of all samples to be below permissible limit throughout 2018 to 2024.
- Graphical representation of trend in Fluoride for groundwater samples in Meghalaya is shown in Figure 8 and since 2018 no change in the trend is observed.

Table 5: District wise range and distribution of Fluoride in shallow groundwater of Meghalaya during pre-monsoon 2024

Sl. No.	District	Fluoride (Pre-monsoon)				% of samples with Fluoride <1.5 mg/L	% of samples with Fluoride >1.5 mg/L
		No. of samples analyzed	Min	Max	Mean		
			(in mg/L)				
1	East Garo Hills	10	0.112	0.94	0.29	100	0
2	East Khasi Hills	5	0	0	0	100	0
3	North Garo Hills	6	0.09	0.32	0.19	100	0
4	Ri-Bhoi	14	0.00	0.10	0.07	100	0
5	South Garo Hills	10	0.13	0.44	0.24	100	0
6	South West Garo Hills	6	0.08	0.46	0.21	100	0
7	West Garo Hills	17	0.10	0.58	0.36	100	0
8	West Jaintia Hills	2	0.00	0.04	0.04	100	0
9	West Khasi Hills	5	0.40	0.51	0.45	100	0

Table 6: Comparative change in number of locations having Fluoride >1.5 mg/L

Sl. No.	District	No. of locations having Fluoride >1.5 mg/L						
		2018	2019	2020	2021	2022	2023	2024
1	East Garo Hills	0	0	0	0	0	0	0
2	East Jantia Hills	0	0	0	0	0	0	0
3	East Khasi Hills	0	0	0	0	0	0	0
4	North Garo Hills	0	0	0	0	0	0	0
5	Ri-Bhoi	0	0	0	0	0	0	0
6	South Garo Hills	0	0	0	0	0	0	0
7	South West Garo Hills	0	0	0	0	0	0	0
8	West Garo Hills	0	0	0	0	0	0	0
9	West Jaintia Hills	0	0	0	0	0	0	0
10	West Khasi Hills	0	0	0	0	0	0	0
Total		0	0	0	0	0	0	0

Table 7: Periodic variation in suitability classes of groundwater Fluoride of Meghalaya

Periodic variation in suitability classes of Fluoride in groundwater of Meghalaya									
Parameter	Class	Percentage of samples							Periodic Variation 2018-2024
		2018	2019	2020	2021	2022	2023	2024	
		n=20	n=14	n=13	n=31	n=34	n=113	n=75	
Fluoride	$F^- < 1.5$ mg/L	100	100	100	96.78	100	100	100	0
	$F^- > 1.5$ mg/L	0	0	0	3.22	0	0	0	0

**n= nos. of samples*

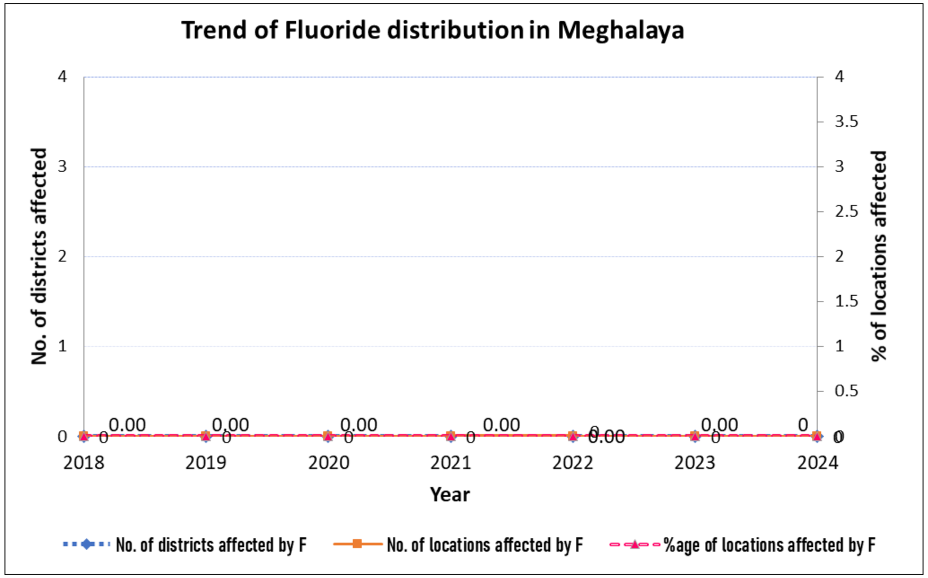

Figure 8: Graphical representation of trend in Fluoride for Meghalaya

6.1.3 IRON

Iron is a common constituent in soil and groundwater. It is present in water either as soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colorless because the iron is completely dissolved. When exposed to air, the water turns cloudy due to oxidation of ferrous iron into reddish brown ferric oxide.

The concentration of iron in natural water is controlled by both physico-chemical and microbiological factors. It is contributed to groundwater mainly from weathering of ferruginous minerals of igneous rocks such as hematite, magnetite and sulphide ores of sedimentary and metamorphic rocks. The permissible Iron concentration in groundwater is less than 1.0 mg/L as per the BIS Standard for drinking water.

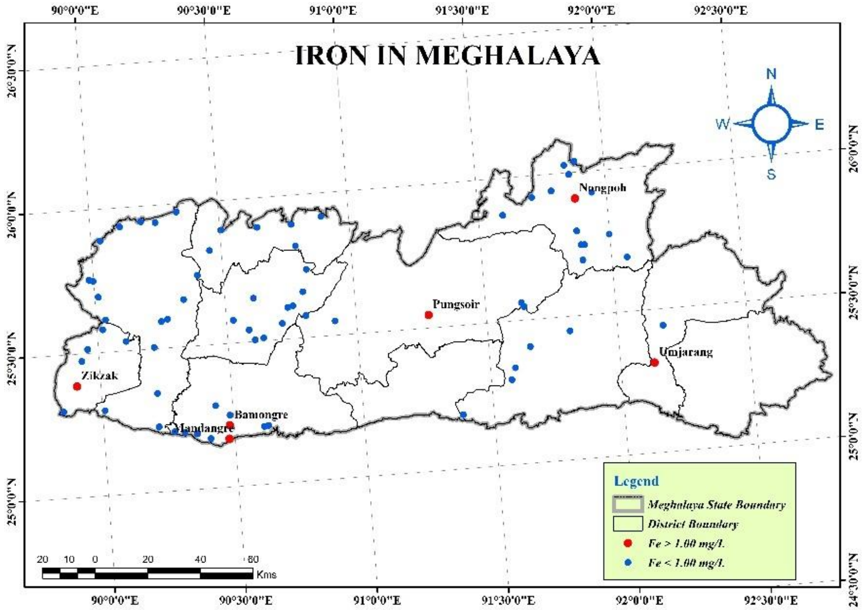

Figure 9: Map showing distribution of Iron in Meghalaya based on pre-monsoon NHS 2024 data

PRPRESENT DAY SCENARIO IN MEGHALAYA: IRON

Distribution of Iron

- The Iron value of groundwater in the State varies from 0.002 mg/L at Nongpoh in Ri Bhoi district to 8.007 mg/L at Byrnihat in the same district.
- Grouping water samples based on Iron values, it is found that an 8.0% of them have iron above the permissible limit of 1.0 mg/L.
- The map showing spatial distribution of Iron (Figure 9) signifies that high Iron concentration is observed in scattered manner in a few districts of Meghalaya, viz. North Garo Hills, Ri Bhoi, SW Garo Hills and West Garo Hills.
- The Table 8 provides for the number of samples analyzed per district, along with their minimum, maximum, and mean Iron values and number of samples more than 1.0 mg/L based on pre-monsoon NHS 2024 data.
- Trend analysis (Table 9 and 10), of seven years showing zigzag trend in Iron content from 2018 to 2024.
- Graphical representation of trend in Iron for groundwater samples in Meghalaya is shown in Figure 10 since 2018 to pre-monsoon of 2024. No significant change in the trend is observed.

Table 8: District wise range and distribution of Iron in shallow groundwater of Meghalaya during pre-monsoon 2024

Sl. No.	District	Iron (Pre-monsoon)				% of samples with Iron <1.0 mg/L	% of samples with Iron >1.0 mg/L
		No. of samples analyzed	Min	Max	Mean		
			(in mg/L)				
1	East Garo Hills	10	0.03	0.81	0.26	100	0
2	East Khasi Hills	5	0.00	0.05	0.05	100	0
3	North Garo Hills	6	0.06	4.14	0.96	83.34	16.66
4	Ri-Bhoi	14	0.00	8.01	0.77	92.86	7.14
5	South Garo Hills	10	0.02	1.00	0.38	100	0
6	South West Garo Hills	6	0.04	1.78	0.49	83.34	16.66
7	West Garo Hills	17	0.01	2.72	0.52	82.36	17.64
8	West Jaintia Hills	2	0.00	0.01	0.01	100	0
9	West Khasi Hills	5	0.02	0.19	0.09	100	0

Table 9: Comparative change in number of locations having Iron >1.0 mg/L

Sl. No.	District	No. of locations having Iron>1.0 mg/L						
		2018	2019	2020	2021	2022	2023	2024
1	East Garo Hills	0	0	0	0	0	0	0
2	East Jantia Hills	0	0	0	0	0	0	0
3	East Khasi Hills	1	1	2	0	1	1	0
4	North Garo Hills	0	1	0	1	0	2	1
5	Ri-Bhoi	0	0	1	1	1	0	1
6	South Garo Hills	0	0	0	0	0	1	0
7	South West Garo Hills	0	0	0	1	0	3	1
8	West Garo Hills	0	0	0	4	0	4	3
9	West Jaintia Hills	0	0	0	0	0	1	0
10	West Khasi Hills	0	0	0	0	1	0	0
Total		1	2	3	7	3	12	6

Table 10: Periodic variation in suitability classes of Iron in groundwater of Meghalaya

Periodic variation in suitability classes of Iron in groundwater of Meghalaya									
Parameter	Class	Percentage of samples							Periodic Variation 2018-2024
		2018	2019	2020	2021	2022	2023	2024	
		n=20	n=14	n=13	n=31	n=34	n=113	n=75	
Iron	Fe < 1.0 mg/L	95	85.72	76.93	77.42	91.18	89.39	92	-3
	Fe > 1.0 mg/L	5	14.28	23.07	22.58	8.82	10.61	8	3

**n= nos. of samples*

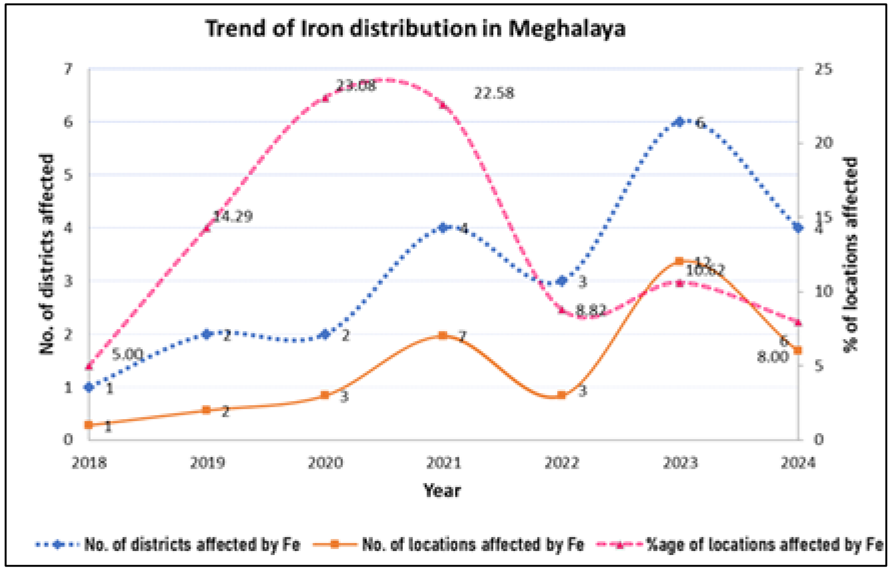

Figure 10: Graphical representation of trend in Iron for Meghalaya

6.1.4 ARSENIC

Arsenic, a naturally occurring element, is widely distributed throughout the Earth's crust and can be found in various environmental mediums such as water, air, food, and soil. It exists in two primary forms: organic and inorganic. While natural processes like biological activities, weathering reactions, and volcanic emissions contribute to arsenic release, human activities also play a significant role. Anthropogenic sources include mining activities, fossil fuel combustion, the use of arsenical pesticides, herbicides, and crop desiccants, as well as arsenic additives in livestock feed, especially poultry feed. Although the use of arsenical products like pesticides and herbicides has declined over recent decades, their use in wood preservation remains common. The maximum permissible limit for arsenic according to the Bureau of Indian Standards (BIS) is 10 parts per billion (ppb).

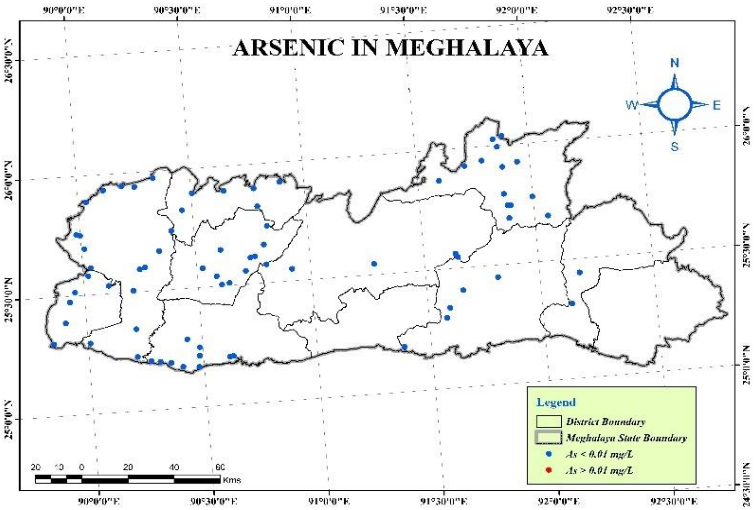

Figure 11: Map showing distribution of Arsenic in Meghalaya based on pre-monsoon NHS 2024 Data

PRPRESENT DAY SCENARIO IN MEGHALAYA: ARSENIC

Distribution of Arsenic

- The Arsenic value of groundwater in the State varies from 0.000003 mg/L at Pahanmawlier in Ri Bhoi district to 0.0016 mg/L at Kharkutta, North Garo Hills.
- Grouping water samples based on permissible limit of Arsenic in drinking water, it is found that all the samples have Arsenic below the permissible limit of 0.01 mg/L.
- The map showing spatial distribution of Arsenic (Figure 11) signifies that in all the districts Arsenic concentration is well within the permissible limit.
- The Table 11 provides for the number of samples analyzed per district, along with their minimum, maximum, and mean Arsenic values and number of samples more than 0.01 mg/L based on pre-monsoon NHS 2024 data.
- Trend analysis (Table 12 and 13), of seven years showing the same trend in Arsenic content since 2019 to pre-monsoon 2024.
- Graphical representation of trend in Arsenic for groundwater samples in Meghalaya is shown in Figure 12 since 2019 to pre-monsoon of 2024. The trend remains the same all throughout the years.

Table 11: District wise range and distribution of Arsenic in shallow groundwater of Meghalaya during pre-monsoon 2024

Sl. No.	District	Arsenic (Pre-monsoon) No. of samples analyzed	Min (in µg/L)	Max (in µg/L)	Mean (in µg/L)	% of samples with Arsenic > 10 µg/L	% of samples with Arsenic < 10 µg/L
1	East Garo Hills	10	0.01	0.24	0.07	100	0
2	East Khasi Hills	5	0.04	0.22	0.10	100	0
3	North Garo Hills	6	0.02	1.63	0.44	100	0
4	Ri-Bhoi	14	0.00	0.65	0.08	100	0
5	South Garo Hills	10	0.03	0.36	0.14	100	0
6	South West Garo Hills	6	0.02	0.71	0.20	100	0
7	West Garo Hills	17	0.02	0.77	0.15	100	0
8	West Jaintia Hills	2	0.01	0.02	0.01	100	0
9	West Khasi Hills	5	0.01	0.04	0.03	100	0

Table 12: Comparative change in number of locations having Arsenic >0.01 mg/L

Sl. No.	District	No. of locations having Arsenic > 10 µg/L 2019	2020	2021	2022	2023	2024
1	East Garo Hills	0	0	0	0	0	0
2	East Jantia Hills	0	0	0	0	0	0
3	East Khasi Hills	0	0	0	0	0	0
4	North Garo Hills	0	0	0	0	0	0
5	Ri-Bhoi	0	0	0	0	0	0
6	South Garo Hills	0	0	0	0	0	0
7	South West Garo Hills	0	0	0	0	0	0
8	West Garo Hills	0	0	0	0	0	0
9	West Jaintia Hills	0	0	0	0	0	0
10	West Khasi Hills	0	0	0	0	0	0
Total		0	0	0	0	0	0

Table 13: Periodic variation in suitability Classes of Arsenic in groundwater of Meghalaya

Periodic variation in suitability classes of Arsenic in groundwater of Meghalaya								
Parameter	Class	Percentage of samples 2019 n=14	2020 n=13	2021 n=31	2022 n=34	2023 n=113	2024 n=75	Periodic Variation 2019-2024
Arsenic	As < 10 µg/L	100	100	100	100	100	100	0
	As > 10 µg/L	0	0	0	0	0	0	0

**n= nos. of samples*

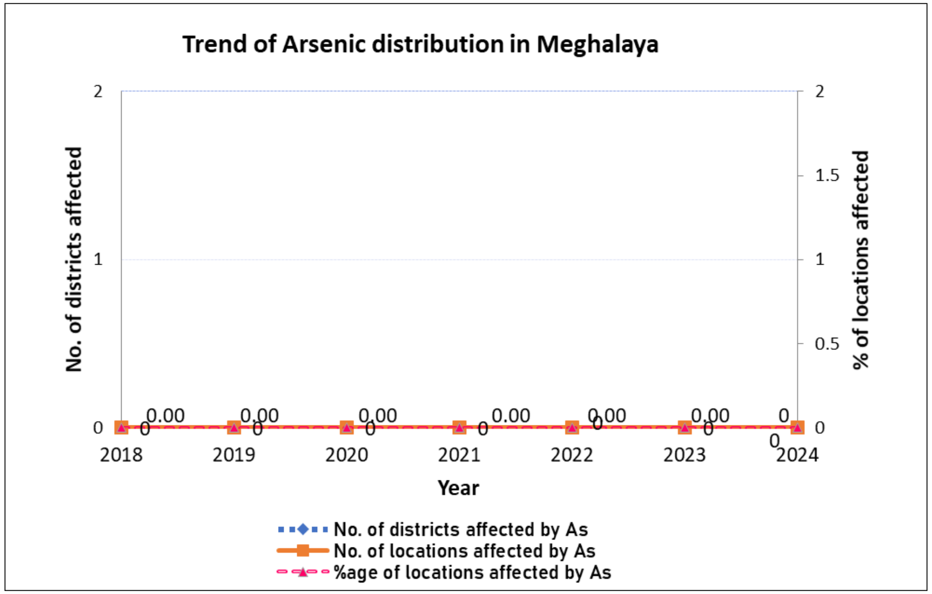

Figure 12: Graphical representation of trend in Arsenic for Meghalaya

6.1.5 MANGANESE

Manganese is the twelfth-most abundant element in the earth's crust and an essential micronutrient. It is found naturally in groundwater, rocks, minerals, and soil and hence released into groundwater through various dissolution processes. Therefore, most common reasons of manganese contamination in water is geogenic.

As per the BIS standard for drinking water the acceptable limit of manganese concentration in groundwater is 0.1 mg/L and permissible limit is 0.3 mg/L. Chronic overexposure of manganese in drinking water has neurotoxic effects. This can cause damage in intellectual function and motor skills in children. Manganese is required as an essential nutrient in diet with a recommended maximum daily intake of 10 mg/day for an adult. But concentrations in drinking water need to be monitored in order to prevent excessive manganese intake.

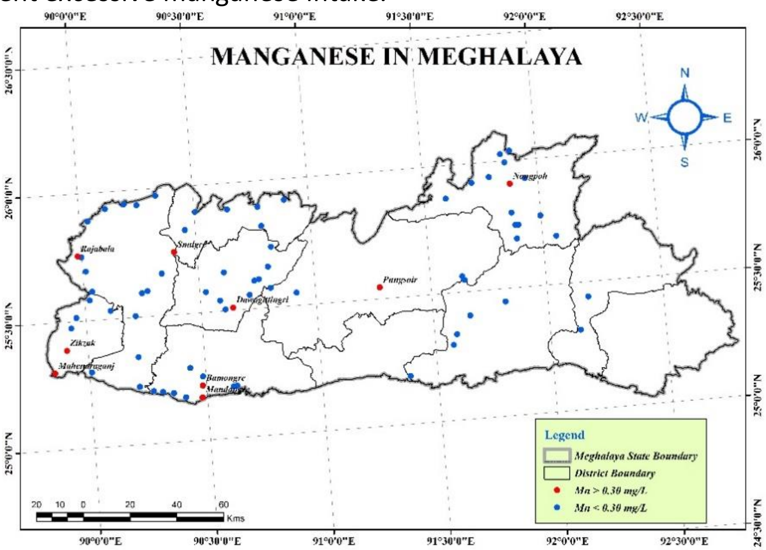

Figure 13: Map showing distribution of Manganese in Meghalaya based on pre-monsoon NHS 2024 data

PRESENT DAY SCENARIO IN MEGHALAYA: MANGANESE

Distribution of Manganese

- The Manganese value of groundwater in the State varies from 0.00001 mg/L at Umsamlem in Ri Bhoi district to 1.283 mg/L at Rajabala, West Garo Hills.
- Grouping water samples based on safety limits of Manganese in drinking water, it is found that 16% of them have Manganese above the acceptable limit of 0.1 mg/L and 12% are beyond permissible limit of 0.3 mg/L.
- The map showing aerial distribution of Manganese (Figure 13) signifies that high Manganese concentration samples are observed in districts viz. South Garo Hills, Ri Bhoi, South West Garo Hills and West Garo Hills.
- The Table 14 provides the number of samples analyzed per district, along with their minimum, maximum, and mean Manganese values and number of samples more than 0.3 mg/L based on pre-monsoon NHS 2024 Data.
- Trend analysis (Table 15 and 16), of six years shows that Manganese concentration of samples beyond permissible limit is found to be in zigzag manner since 2019 to pre-monsoon of 2024.
- Graphical representation of trend in Manganese for groundwater samples in Meghalaya is shown in Figure 14 and no change in the trend is observed as such.

Table 14: District wise range and distribution of Manganese in shallow groundwater of Meghalaya during pre-monsoon 2024

Sl. No.	District	Manganese (Pre-monsoon)				% of samples with Manganese <0.3 mg/L	% of samples with Manganese >0.3 mg/L
		No. of samples analyzed	Min	Max	Mean		
			(in mg/L)				
1	East Garo Hills	10	0.02	0.19	0.05	100	0
2	East Khasi Hills	5	0.00	0.27	0.10	100	0
3	North Garo Hills	6	0.00	0.72	0.24	66.67	33.33
4	Ri-Bhoi	14	0.00	0.69	0.09	92.86	7.14
5	South Garo Hills	10	0.00	1.03	0.25	80	20
6	South West Garo Hills	6	0.04	1.13	0.47	66.67	33.33
7	West Garo Hills	17	0.00	1.28	0.23	88.24	11.76
8	West Jaintia Hills	2	0.00	0.00	0.00	100	0
9	West Khasi Hills	5	0.00	0.04	0.02	100	0

Table 15: Comparative change in number of locations having Manganese > 0.3 mg/L

Sl. No.	District	No. of locations having Manganese>0.3 mg/L					
		2019	2020	2021	2022	2023	2024
1	East Garo Hills	1	1	1	0	1	0
2	East Jantia Hills	0	0	0	0	0	0
3	East Khasi Hills	0	0	0	1	3	0
4	North Garo Hills	0	0	0	0	0	2
5	Ri-Bhoi	1	0	1	2	3	1
6	South Garo Hills	0	0	0	0	0	2
7	South West Garo Hills	0	1	3	1	1	2
8	West Garo Hills	2	2	2	1	0	2
9	West Jaintia Hills	1	0	0	1	0	0
10	West Khasi Hills	0	0	0	0	1	0
Total		5	4	7	6	9	9

Table 16: Periodic variation in suitability classes of Manganese in groundwater of Meghalaya

Periodic variation in suitability classes of Manganese in groundwater of Meghalaya								
Parameter	Class	Percentage of samples						Periodic Variation 2019-2024
		2019	2020	2021	2022	2023	2024	
		n=14	n=13	n=31	n=34	n=113	n=75	
Manganese	Mn < 0.3 mg/L	64.29	69.24	77.42	82.36	92.04	88	23.71
	Mn > 0.3 mg/L	35.71	30.76	22.58	17.64	7.96	12	-23.71

**n= nos. of samples*

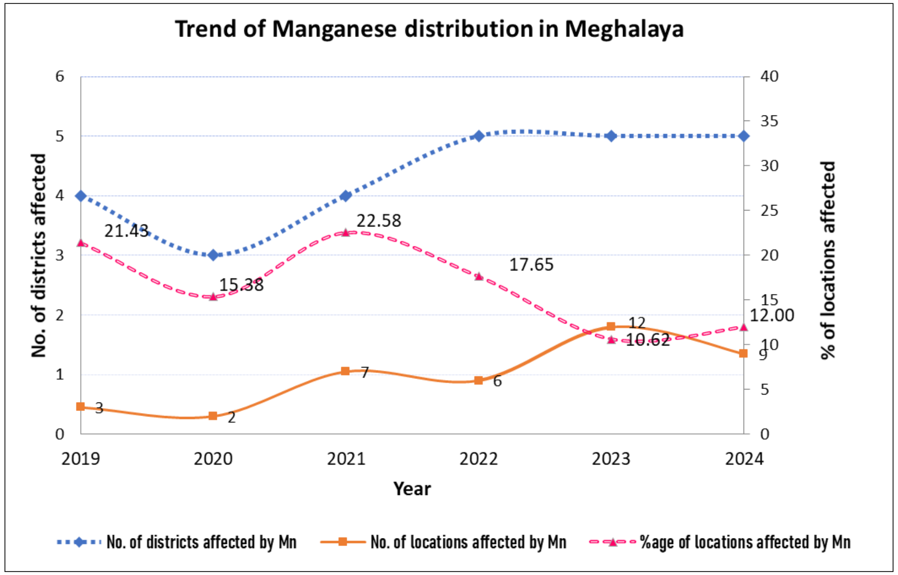

Figure 14: Graphical representation of trend in Manganese for Meghalaya

GROUND WATER QUALITY SCENARIO FOR AGRICULTURE IN MEGHALAYA

Table 17: Classification of pre-monsoon 2024 groundwater samples of Meghalaya for irrigation purposes.

Parameters	Range	Classification	Number of samples
Salinity hazard (EC) (µS/cm)	<250	Excellent	73
	250-750	Good	2
	750-2000	Permissible	0
	2000-3000	Doubtful	0
	>3000	Unsuitable	0
Alkalinity hazard (SAR)	<10	Excellent	75
	10--18	Good	0
	18-26	Doubtful	0
	>26	Unsuitable	0
Percent Sodium (%Na)	<20	Excellent	2
	20-40	Good	19
	40-60	Permissible	18
	60-80	Doubtful	30
	>80	Unsuitable	6
Kelly's Index (KI)	<1	Suitable	37
	>1	Unsuitable	38
Residual sodium carbonate (RSC)	<1.25	Suitable	71
	1.25-2.5	Marginally suitable	4
	>2.5	Unsuitable	0
Soluble Sodium Percentage (SSP)	<50	Suitable	37
	>50	Unsuitable	38

Based on some of the indices like SAR, RSC most of the samples are safe for irrigation purposes but according to calculation of %Na, SSP, KI samples having higher contribution from Na are classified as not being suitable for irrigation purposes during the pre-monsoon season.

WATER QUALITY PLOTS AND INTERPRETATION

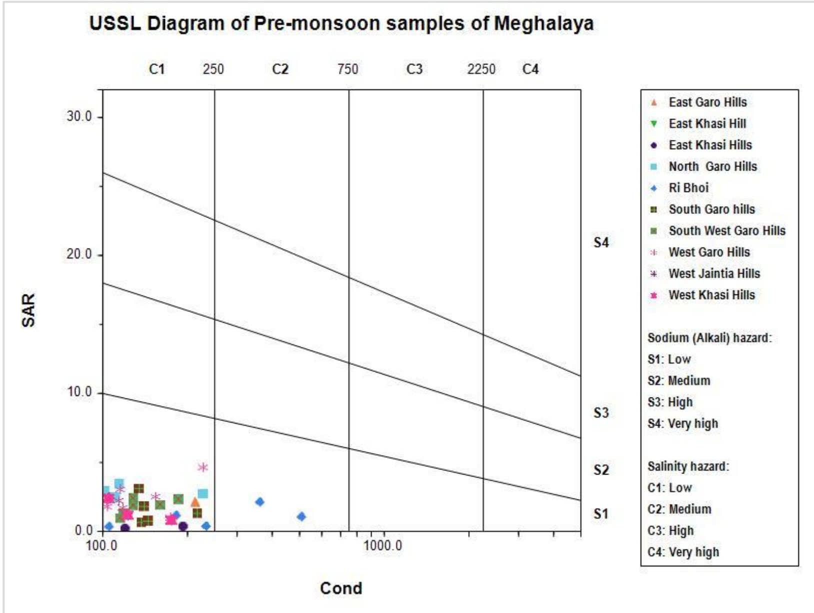

Figure 15: USSL salinity diagram for classification of groundwater in Meghalaya during pre-monsoon 2024

Almost all the samples during pre-monsoon season are categorized as C1-S1 implying low salinity and low sodium hazard as depicted from the USSL diagram. Two samples from Ri Bhoi district, viz. Byrnihat and Nongpoh have relatively higher EC and SAR values as compared to other samples and hence they are classified as C2-S1 indicating medium salinity and low sodium hazard.

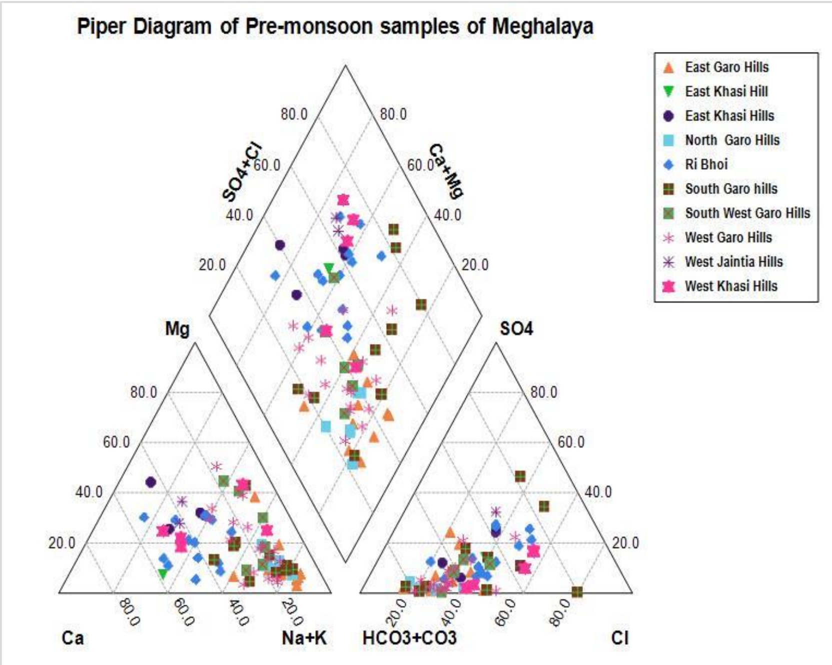

Figure 16: Piper plot for classification of groundwater in Meghalaya during pre-monsoon 2024

The Piper plot classifies all the groundwater samples of the State into different hydrochemical facies. Most of the samples are of mixed type with $CaNaHCO_3$ and CaMgCl classification while a few samples from South Garo Hills are classified as Na-Cl type and few from East Khasi Hills as $Ca\text{-}HCO_3$ type. The samples falling under the mixed CaMgCl type are indication of anthropogenic contamination sources like domestic wastewater while presence of $CaNaHCO_3$ type suggests recharge of freshwater and mineral dissolution.

DISTRICT WISE ASSESSMENT OF GROUNDWATER USING WATER QUALITY INDEX (WQI)

Water Quality Index (WQI) is being calculated for all the samples collected during pre-monsoon 2024. The samples were classified accordingly as shown below:

Table 18: Classification of pre-monsoon 2024 samples based on WQI

Classification range of WQI	Water quality status	No. of samples	% of samples	Classification based on
<50	Excellent	74	98.66	Yenugu et al. 2020
50-100	Good	1	1.33	
101-200	Poor water	0	0	
201-300	Very poor water	0	0	
>300	Water unsuitable for drinking	0	0	

According to the analysis based on WQI 98.66% of samples are classified as excellent while 1.33% falls under the good category. There is no poor-quality water sample in the state as per WQI calculations.

DISTRICT WISE CONTAMINANT STATUS SUMMARY BASED ON NHS 2024 PRE-MONSOON DATA

Table 19: Summary of groundwater quality in various districts of Meghalaya, highlighting basic parameters (Electrical Conductivity, Fluoride) and heavy metals (Iron, Arsenic, Magnesium)

Summary of GW quality (Pre-Monsoon 2024)						
District	Total no. of samples analyzed	EC	F	Fe	Mn	As
		µS/cm @25°C	mg/L	mg/L	mg/L	µg/L
East Garo Hills	10	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
East Khasi Hills	5	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North Garo Hills	6	0 (0%)	0 (0%)	1 (16.66%)	2 (33.33%)	0 (0%)
Ri-Bhoi	14	0 (0%)	0 (0%)	1 (7.14%)	1 (7.14%)	0 (0%)
South Garo Hills	10	0 (0%)	0 (0%)	1 (0%)	2 (20%)	0 (0%)
South West Garo Hills	6	0 (0%)	0 (0%)	1 (16.66%)	2 (33.33%)	0 (0%)
West Garo Hills	17	0 (0%)	0 (0%)	3 (17.64%)	2 (11.76%)	0 (0%)
West Jaintia Hills	2	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
West Khasi Hills	5	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

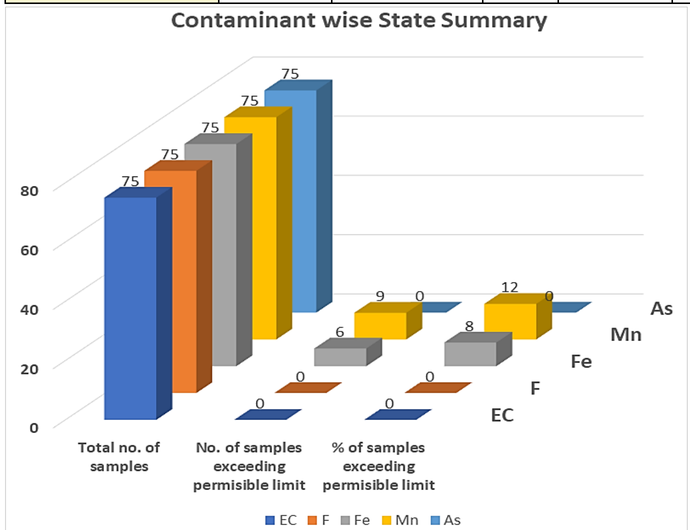

Figure 17: Graph showing contaminant wise state summary

The groundwater quality assessment in Meghalaya revealed no significant change in levels of contamination across various parameters. The physical parameters (pH, EC, TDS and Turbidity) and major ions (Na, K, Ca, Mg, Cl-, F-, SO_4^{2-}, NO_3^-, CO_3^{-2}, HCO_3^-, Alkalinity and Total Hardness) have been found to be well within the safe limits as prescribed by BIS drinking water specification (IS 10500: 2012). Iron (Fe) and Manganese (Mn) emerged as the predominant contaminants, with 8% and 12% of the 75 samples analyzed found to be beyond their respective permissible limits. Sporadic occurrences of these two trace metals have been observed in few of the districts. The concentration of other heavy metals viz. Arsenic, Cadmium, Lead, Nickel, Chromium, Zinc, Copper, Mercury, Selenium and radioactive element Uranium are found out to be within the permissible limits of BIS.

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