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त्रिपुरा की भूजल गुणवत्ता

Groundwater Quality of Tripura

भारत सरकार

GOVERNMENT OF INDIA

जल शक्ति मंत्रालय

MINISTRY OF JAL SHAKTI

जल संसाधन, नदी विकास और गंगा संरक्षण विभाग

Department of Water Resources, River Development and Ganga Rejuvenation

केंद्रीय भूजल बोर्ड

Central Ground Water Board

उत्तर पूर्वीक्षेत्र

NORTH EASTERN REGION

गुर्वाहाटी

GUWAHATI

DECEMBER 2024

.ETIN GROUNDWATER QUALIT

BULLETIN GROUNDWATER QUALITY OF TRIPURA

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ABSTRACT

Periodic pre-monsoon ground water quality assessment (2017-2024) highlighting the findings, significant trends and groundwater contamination status

INTRODUCTION

Groundwater quality holds immense importance in the northeastern Indian state of Tripura, where it serves as a lifeline for the state. As the primary source of water for drinking, irrigation, and industrial activities, groundwater's significance cannot be overstated. In Tripura, like in many other parts of India, groundwater quality directly influences public health, agricultural productivity, and the overall sustainability of water resources.

Ensuring the safety and purity of groundwater is crucial in mitigating health risks posed by contaminants such as arsenic, fluoride, and other hazardous substances that can infiltrate water supplies. High-quality groundwater not only supports robust agricultural practices by providing clean irrigation water but also sustains the diverse ecosystems and communities that depend on this vital resource. Consequently, monitoring and managing groundwater quality is essential for fostering sustainable development and securing a healthy future for Tripura's inhabitants.

To effectively manage groundwater in Tripura, comprehensive data on its current and potential quality is essential. A thorough understanding of water resource quality is critical for prudent management. Periodic groundwater quality assessments are also vital to inform users for domestic and irrigation purposes. Despite numerous studies on poor groundwater quality, extensive temporal and spatial research in Tripura remains limited.

Our study aims to achieve the following objectives:

1. Present the current groundwater quality scenario, parameter-wise, for each district.
2. Identify current hotspots of poor-quality groundwater through spatial variation analysis of 2024 pre monsoon data.
3. Assess the temporal variation in groundwater quality from 2017 to 2024 in the pre monsoon, providing insights for effective management measures.

STUDY AREA

Tripura, located in northeastern India, borders Bangladesh to the north, south, and west, and Assam and Mizoram to the east. It spans 10,491.69 square kilometers (4,050 square miles), about 0.32% of India's area. The state features a predominantly hilly terrain with valleys, plains, and dense forests. Tripura lies between latitudes 22°56'N to 24°32'N and longitudes 91°09'E to 92°20'E, divided into three distinct physiographic regions with unique hydrogeological traits.

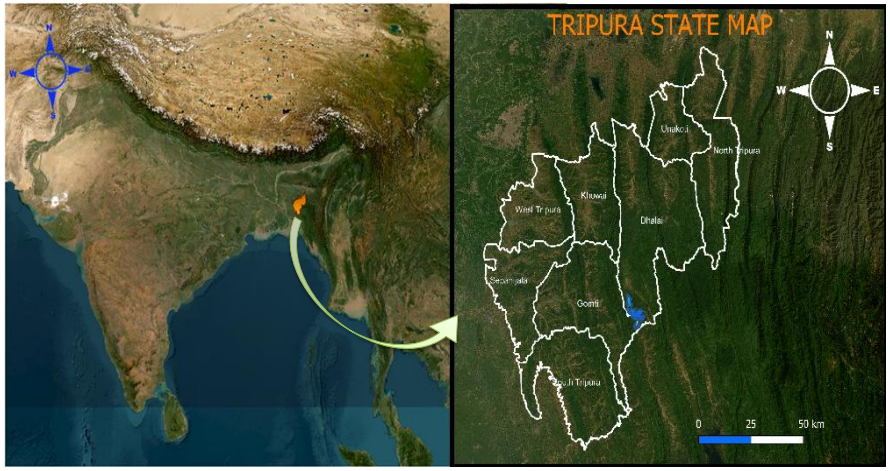

FIGURE 1 STUDY AREA

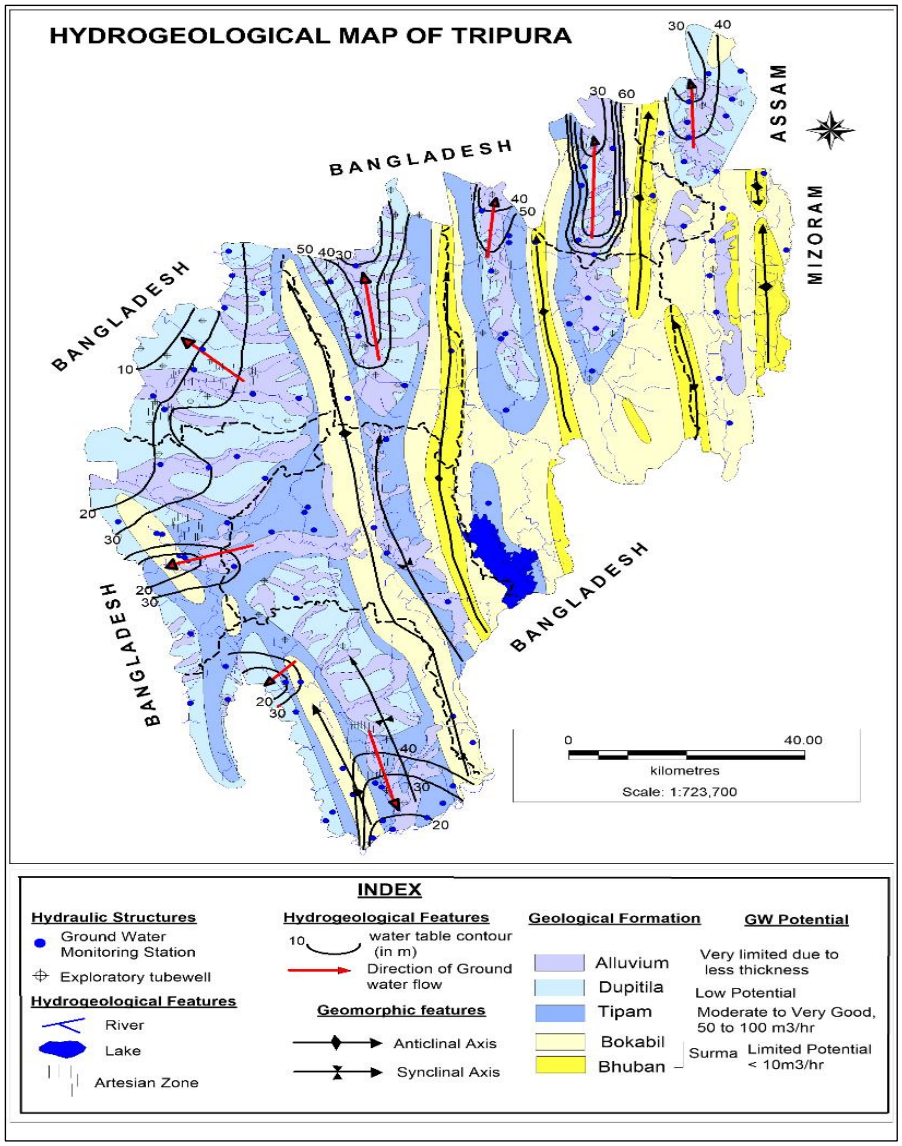

FIGURE 2 MAP SHOWING MAJOR AQUIFERS AND GEOMORPHIC DIVISIONS OF TRIPURA

The southwest monsoon brings annual rainfall of around 2,100 mm, crucial for agriculture and the state's lush vegetation. Tripura's forests, covering 60% of the land, support diverse flora and fauna.

As of 30th November, 2024, Tripura has eight districts: Dhalai, Gomati, Khowai, North Tripura, Sepahijala, South Tripura, Unakoti, and West Tripura. Each district plays a vital role in the state's socio-economic development, and the unique geographical and climatic conditions make Tripura significant for groundwater quality studies.

GROUND WATER QUALITY MONITORING

Groundwater quality monitoring entails the systematic collection of representative samples from diverse hydrogeological units to evaluate its chemical composition. Groundwater is predominantly extracted from phreatic aquifers. The principal objective of a groundwater quality monitoring program is to acquire comprehensive data on the spatial distribution of water quality across regions, while simultaneously establishing a foundational database of various chemical constituents present in the groundwater. The potential factors contributing to the degradation of groundwater quality are illustrated in Figure 3.

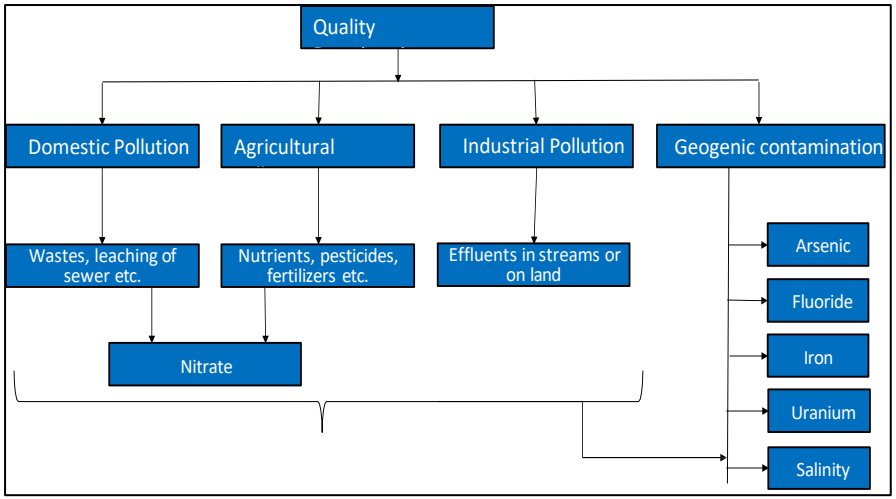

FIGURE 3 SCHEMATIC DIAGRAM ILLUSTRATING THE POTENTIAL FACTORS CONTRIBUTING TO THE DEGRADATION OF GROUNDWATER QUALITY.

The chemical quality of shallow ground water is being monitored by Central Ground Water Board twice in a year (Pre-monsoon and post-monsoon) through 90 locations located all over the state (Figure 4). The district-wise distribution of water Quality Monitoring Stations of CGWB is given in Table 1. The present bulletin is based on the changing scenario in water quality in network observation wells of CGWB in year 2017 and 2024.

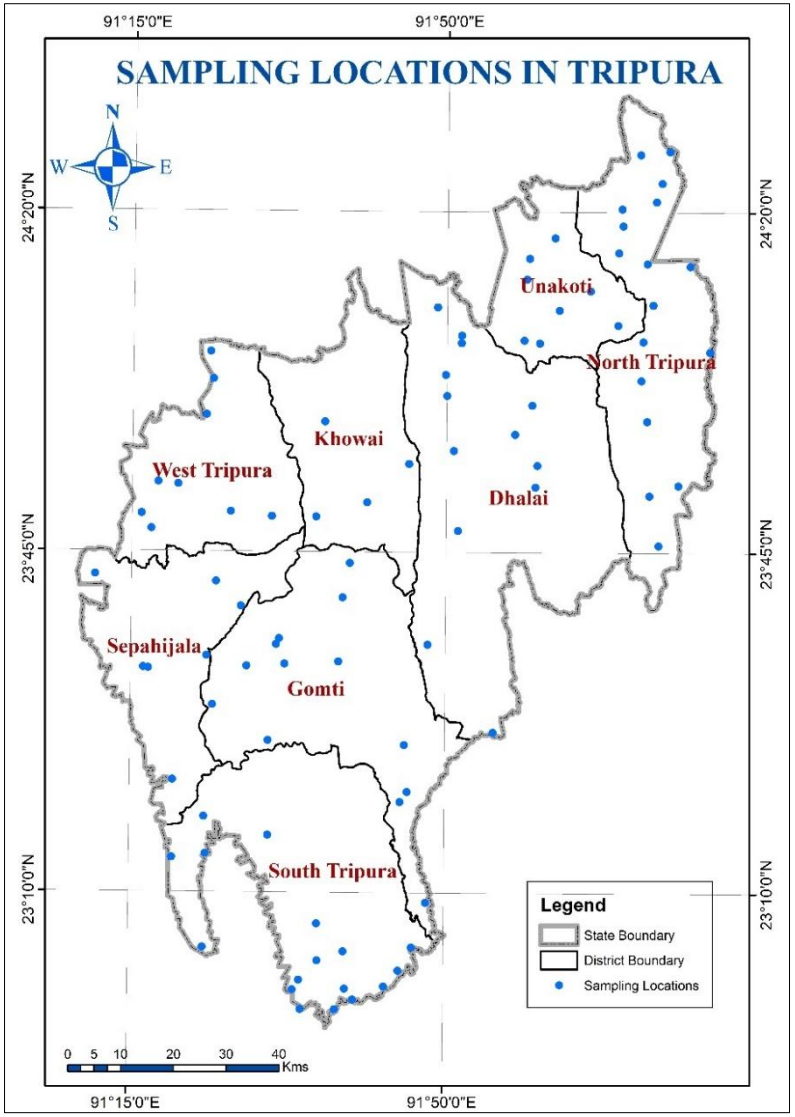

FIGURE 4 MAP SHOWING 90 GROUNDWATER QUALITY MONITORING STATIONS IN TRIPURA

TABLE I YEARWISE DISTRIBUTION OF GROUNDWATER QUALITY MONITORING STATION IN THE DISTRICTS OF TRIPURA

District	No of quality monitoring stations							
	2017	2018	2019	2020	2021	2022	2023	2024
Dhalai	14	7	12	13	11	11	10	13
Gomti	7	11	10	10	11	8	9	10
Khowai	-	4	5	8	6	5	6	4
North Tripura	20	14	22	18	17	18	18	17
Sepahijala	12	10	7	8	7	4	5	7
South Tripura	29	23	18	22	21	9	14	20
Unakoti	10	8	11	10	8	10	10	10
West Tripura	2	7	5	10	9	6	9	9

GROUND WATER 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 crucial environmental determinant of community health. The Bureau of Indian Standards (BIS), in its document IS: 10500:2012, Edition 3.2 (2012-15), has recommended quality standards for drinking water. Groundwater samples collected from phreatic aquifers in Tripura during the pre-monsoon season of 2024 were analyzed for major inorganic parameters. Based on the results, it was observed that the groundwater in Tripura is predominantly of magnesium bicarbonate (Mg-HCO_3) type and mixed type. The electrical conductivity (EC) of groundwater in the state ranges from 60 to 809.3 µS/cm at 25°C, indicating varying levels of salinity. However, significant water quality concerns have been identified in Tripura. Manganese (Mn) concentrations exceeding 0.3 mg/L and nitrate (NO_3^-) levels above 45 mg/L have been detected in several areas. These elevated levels of manganese and nitrate pose potential health risks and may be attributed to natural geological conditions and anthropogenic activities.

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 TDS, Fluoride, Nitrate, Iron, Arsenic and Uranium etc are the main constituents defining the quality of ground water in unconfined aquifers of the state. Therefore, presence of these and the changes in chemical quality with respect to these parameters in ground water in samples collected during NHS monitoring 2017 & 2024 are discussed below.

Electrical Conductivity (> 3000 µS/cm)

Fluoride (>1.5 mg/L)

Nitrate (>45 mg/L)

Iron (>1.0 mg/L)

Arsenic (>0.01 mg/L)

Uranium (>0.03 mg/L)

THE ELECTRICAL CONDUCTIVITY

Electrical conductivity (EC), total dissolved solids (TDS), and salinity are key indicators of the dissolved salt content in water, which influence its taste and odor. EC serves as a proxy for the total concentration of cations and anions in groundwater, reflecting ionic mobility, TDS levels, and the saline nature of the water. Groundwater is classified based on EC as fresh (<1500 µS/cm), brackish (1500–15,000 µS/cm), or saline (>15,000 µS/cm). Salinity levels are influenced by factors such as the composition of aquifer material, mineral solubility, duration of water-rock interaction, soil permeability, drainage conditions, precipitation, and the prevailing climate. The Bureau of Indian Standards (BIS) recommends a TDS limit of 500 mg/L (approximately 750 µS/cm at 25°C) for potable water, which may be extended to 2000 mg/L (about 3000 µS/cm) in the absence of alternative sources. However, water with TDS exceeding 2000 mg/L is deemed unsuitable for drinking purposes.

PRESENT DAY SCENARIO IN TRIPURA (ELECTRICAL CONDUCTIVITY)

The EC values of groundwater in Tripura vary from a minimum of 60.68 µS/cm at Ananda Bandhu Para in the Karbook block of South Tripura district to a maximum of 809.3 µS/cm at 45 Miles in the Mungia-Kami block of Khowai district, measured at 25°C. Grouping water samples based on EC values reveals that 98.88% of the samples fall within the fresh water category (<750 µS/cm), while only 1.11% fall within the range of 750–3000 µS/cm. The spatial distribution of EC indicates that most of the groundwater in Tripura is fresh and suitable for drinking purposes, aligning with the lower EC category (Figure 5). The few locations exceeding 750 µS/cm are scattered and represent minimal saline influence, likely due to localized factors.

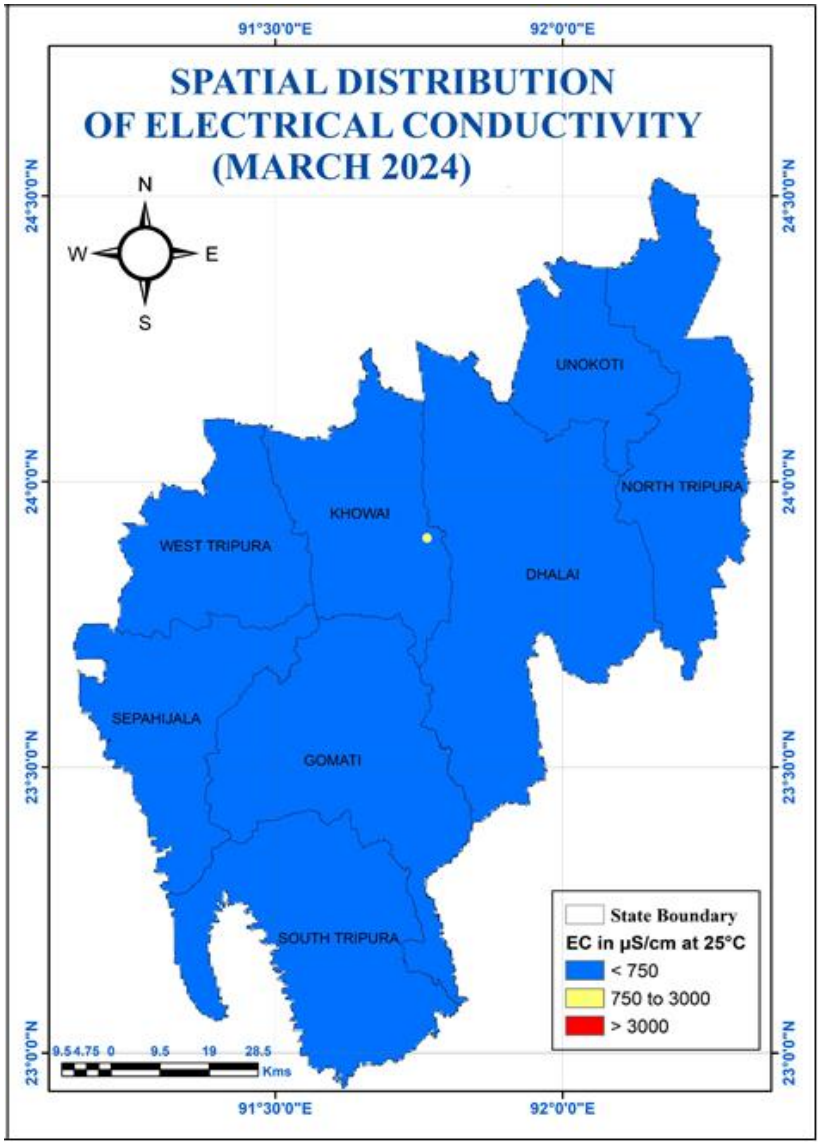

FIGURE 5 MAP SHOWING DISTRIBUTION OF ELECTRICAL CONDUCTIVITY IN TRIPURA (MARCH 2024)

This data highlights the overall high quality of groundwater in the state, with the majority of areas maintaining EC levels well within permissible limits for drinking water as per BIS standards. A detailed table of district-wise EC analysis, including minimum, maximum, and mean values, is provided in Table 2.

TABLE 2 DISTRICT WISE RANGE AND DISTRIBUTION OF EC IN SHALLOW GROUNDWATER OF TRIPURA

District	Number of samples analysed	Permissible Limit (µS/cm at 25°C)	Desirable Limit (µS/cm at 25°C)	Max	Min	Mean	Percentage of Samples		
							<750	750-3000	>3000
Dhalai	13	3000		482.90	65.52	234.91	100	-	-
Gomti	10	3000		367.40	163.30	229.15	100	-	-
Khowai	4	3000		809.30	171.70	454.93	75	25	-
North Tripura	17	3000		652.50	106.80	358.14	100	-	-
Sepahijala	7	3000		504.90	263.50	364.14	100	-	-
South Tripura	20	3000		346.80	60.68	193.71	100	-	-
Unakoti	10	3000		434.70	96.54	205.88	100	-	-
West Tripura	9	3000		460.20	113.00	295.89	100	-	-

TEMPORAL VARIATION OF EC IN GROUND WATER DURING THE PERIOD FROM 2017 TO 2024

The EC values across all districts of the state have remained within 3000 µS/cm from 2017 to the 2024 pre-monsoon season (Table 3). Although there has been a marginal increase in EC, the values have consistently stayed within this range.

TABLE 3 COMPARATIVE CHANGE IN NUMBER OF LOCATIONS HAVING EC > 3000 µS/CM IN THE DISTRICTS

District	Number of location having EC > 3000 µS/cm							
	2017	2018	2019	2020	2021	2022	2023	2024
Dhalai	0	0	0	0	0	0	0	0
Gomti	0	0	0	0	0	0	0	0
Khowai	0	0	0	0	0	0	0	0
North Tripura	0	0	0	0	0	0	0	0
Sepahijala	0	0	0	0	0	0	0	0
South Tripura	0	0	0	0	0	0	0	0
Unakoti	0	0	0	0	0	0	0	0
West Tripura	0	0	0	0	0	0	0	0

TABLE 4 PERIODIC VARIATION IN SUITABILITY CLASSES OF GROUNDWATER ELECTRICAL CONDUCTIVITY (EC) OF TRIPURA

Parameter	Class	Percentage of samples								Periodic Variation (2017-2024)
		2017	2018	2019	2020	2021	2022	2023	2024	
		n=89	*n=76*	*n=83*	*n=91*	*n=79*	*n=71*	*n=81*	*n=90*	
Salinity as EC	<750 µS/cm	89	76	83	91	79	71	81	89	0
	750-3000 µS/cm	0	0	0	0	0	0	0	1	1.11
	>3000 µS/cm	0	0	0	0	0	0	0	0	0

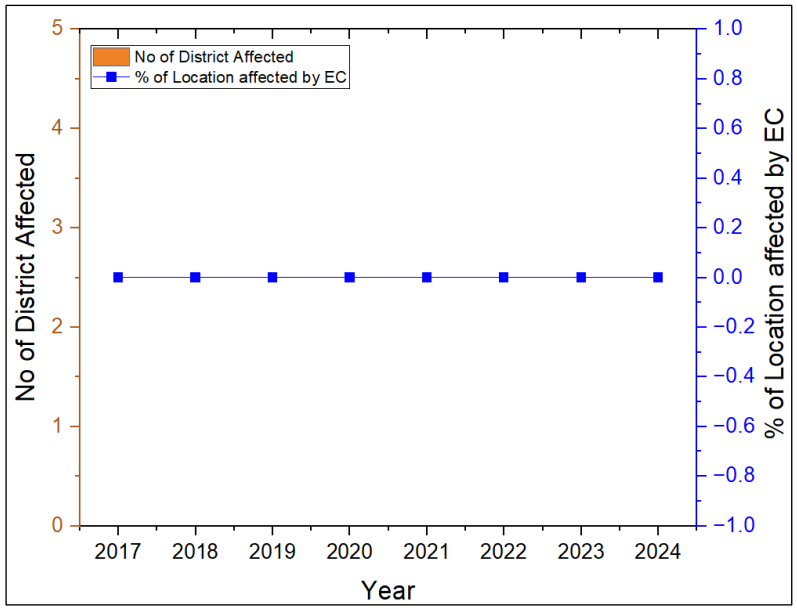

FIGURE 6 TREND OF EC IN TRIPURA

NITRATE

Nitrate in the environment occurs naturally when nitrogen and oxygen combine in the soil, primarily derived from atmospheric nitrogen. In groundwater, nitrate contamination is predominantly attributed to anthropogenic sources such as chemical fertilizers, leaching from animal manure, and sewage discharge. Distinguishing between natural and anthropogenic sources is complex. Also, chemical and microbiological processes, including nitrification and denitrification, significantly influence nitrate concentrations in groundwater.

According to the Bureau of Indian Standards (BIS) for drinking water, the maximum permissible concentration of nitrate in groundwater is 45 mg/L. Although nitrate is generally considered to have low toxicity, elevated levels in drinking water pose environmental health risks, particularly due to the potential for methemoglobinemia in infants. Adults can tolerate slightly higher concentrations without adverse effects.

PRESENT DAY SCENARIO IN TRIPURA (NO_3-)

Nitrate contamination in groundwater primarily arises from excessive fertilizer application, bacterial nitrification of organic nitrogen, seepage from animal and human waste, and atmospheric deposition. In Tripura, nitrate concentrations in groundwater vary between 0.13 mg/L and 55.96 mg/L. The highest concentration, 55.96 mg/L, has been recorded at Chandra Kumar Para in the Dhalai district, while the lowest, 0.13 mg/L, is observed at Kamalpur in the same district. Other locations with elevated nitrate levels include Panisagar in North Tripura, as well as Madhuban and A.D. Nagar in West Tripura.

An analysis of the state's groundwater reveals that:

- **4.44% of the locations** exceed the permissible limit of 45 mg/L.
- **3.33% of the locations** have nitrate concentrations approaching the permissible limit, indicating potential risk.
- The remaining locations exhibit nitrate levels well below the permissible threshold, ensuring safe drinking water quality.

Spatial distribution analysis (Figure 7) highlights that areas with nitrate concentrations above 45 mg/L are predominantly found in parts of North Tripura, West Tripura, and Dhalai districts.

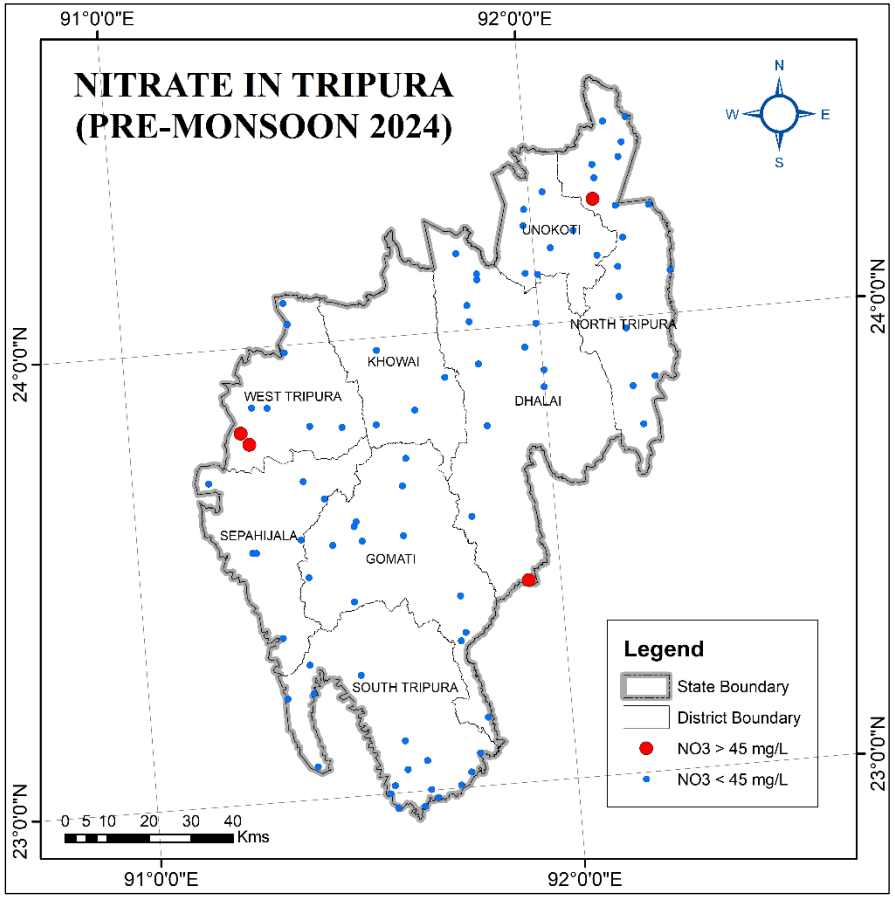

FIGURE 7 MAP SHOWING DISTRIBUTION OF NITRATE IN HARYANA BASED ON 2024 PRE-MONSOON DATA

The **Table 5** below presents the number of groundwater samples analyzed for each district during the **pre-monsoon 2024** period, along with their minimum, maximum, and mean nitrate concentrations based on the **NHS 2024 data**.

TABLE 5 DISTRICT WISE RANGE AND DISTRIBUTION OF NITRATE IN SHALLOW GW OF TRIPURA

District	Number of sample analysed	Permissible Limit (mg/L)	Desirable Limit (mg/L)	Min	Max	Mean	Percentage of Samples	
							<45	>45
Dhalai	13	45		0.13	55.96	8.69	92.31	7.69
Gomti	10	45		0.50	6.29	2.26	100	
Khowai	4	45		0.47	1.47	0.84	100	
North Tripura	17	45		0.17	55.67	9.76	94.12	5.88
Sepahijala	7	45		1.51	8.43	4.17	100	
South Tripura	20	45		0.85	15.63	6.39	100	
Unakoti	10	45		0.82	7.36	3.68	100	
West Tripura	9	45		1.74	55.09	20.61	77.78	22.22

TEMPORAL VARIATION OF NITRATE IN GROUND WATER DURING THE PERIOD FROM 2017 TO 2024

The number of locations in Tripura with nitrate (NO_3^-) concentrations exceeding 45 mg/L in groundwater has shown a significant increase over recent years. As observed, there were no such locations in 2017. However, this number rose to 3 in 2023 and further increased to 4 in 2024, indicating a concerning trend of nitrate contamination in the state's groundwater resources.

TABLE 6 COMPARATIVE CHANGE IN NUMBER OF LOCATIONS HAVING NITRATE > 45 mg/L

District	Number of samples analysed	Number of locations having Nitrate > 45 mg/L							
		2017	2018	2019	2020	2021	2022	2023	2024
Dhalai	13	0	0	0	0	0	0	0	1
Gomti	10	0	0	0	0	0	0	0	0
Khowai	4	0	0	0	0	0	0	0	0
North Tripura	17	0	0	0	0	0	0	1	1
Sepahijala	7	0	0	0	0	0	0	0	0
South Tripura	20	0	0	0	0	0	0	0	0
Unakoti	10	0	0	0	0	0	0	0	0
West Tripura	9	0	0	0	0	0	0	1	2

TABLE 7 PERIODIC VARIATION IN SUITABILITY CLASSES OF NITRATE IN GROUNDWATER OF TRIPURA

Parameter	Class	Percentage of samples								Periodic Variation (2017-2024)
		2017 *n=89*	2018 *n=76*	2019 *n=83*	2020 *n=91*	2021 *n=79*	2022 *n=71*	2023 *n=81*	2024 *n=90*	
Nitrate as NO_3^-	<45 mg/L	89	76	83	91	79	71	79	86	-3.37%
	>45 mg/L	0	0	0	0	0	0	2	4	4.44%

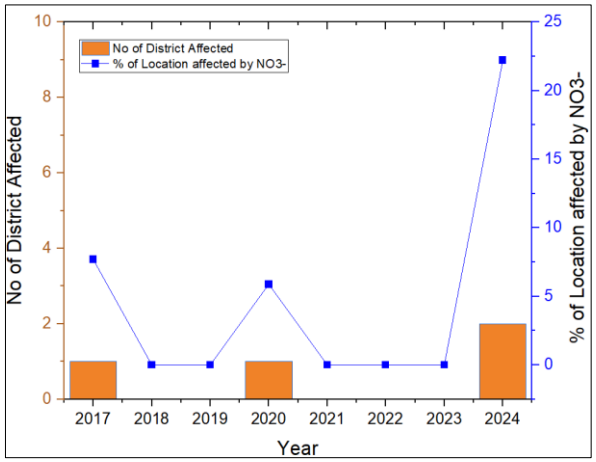

FIGURE 8 TREND OF NITRATE IN TRIPURA

FLUORIDE

Fluorine does not occur in its elemental state in nature due to its high reactivity. Instead, it is predominantly found as fluoride in various minerals, with fluorspar, cryolite, fluorite, and fluorapatite being the most common. The fluoride present in groundwater primarily originates from natural sources, including the breakdown of rocks and soils, weathering processes, and atmospheric deposition. Most fluoride compounds are sparingly soluble and therefore occur in limited concentrations in groundwater. The occurrence of fluoride in natural waters is influenced by several factors, including the type of rocks, climatic conditions, hydrogeological characteristics, and the duration of interaction between the groundwater and rock formations.

The Bureau of Indian Standards (BIS) has established a desirable limit of 1.0 mg/L for fluoride concentration in drinking water and a maximum permissible limit of 1.5 mg/L in cases where alternative sources of drinking water are unavailable. Fluoride levels up to 1.0 mg/L are known to be beneficial in preventing dental caries. However, concentrations exceeding 1.5 mg/L can lead to dental fluorosis, characterized by staining of tooth enamel, while concentrations above 5.0 mg/L may result in severe health issues, such as skeletal fluorosis and stiffness of bones. Groundwater with fluoride concentrations exceeding 1.5 mg/L is considered unsuitable for drinking purposes, with elevated levels primarily attributed to geogenic factors. Analysis of groundwater from observation wells in most regions of the state indicates fluoride concentrations below 1.0 mg/L, suggesting that fluoride levels in these areas are within acceptable limits for safe consumption.

PRESENT DAY SCENARIO IN TRIPURA (F-)

Fluoride in small amounts in drinking water is beneficial for dental health, but excessive amounts can be harmful. In Tripura, the fluoride concentration in groundwater during the pre-monsoon season of 2024 ranges from a minimum of 0.1464 mg/L at Sanicherra to a maximum of 1.3325 mg/L at Ananda Bazar, both located in North Tripura.

As per the Bureau of Indian Standards (BIS) recommendations, fluoride concentrations up to 1.0 mg/L in drinking water are considered desirable, while levels between 1.0 mg/L and 1.50 mg/L are permissible. Concentrations exceeding 1.50 mg/L are deemed injurious to health. Based on these guidelines, it is observed that:

- The majority of groundwater samples in Tripura fall within the desirable range (<1.0 mg/L).
- Some samples, such as those from Ananda Bazar, are within the permissible range (1.0–1.50 mg/L).

The spatial distribution of fluoride concentrations indicates that fluoride levels across the state remain well within permissible limits, with no samples exceeding 1.50 mg/L. It is noteworthy that higher fluoride concentrations are often associated with areas exhibiting specific geological and hydrogeological characteristics. However, in the case of Tripura, groundwater fluoride levels are generally low and safe for consumption.

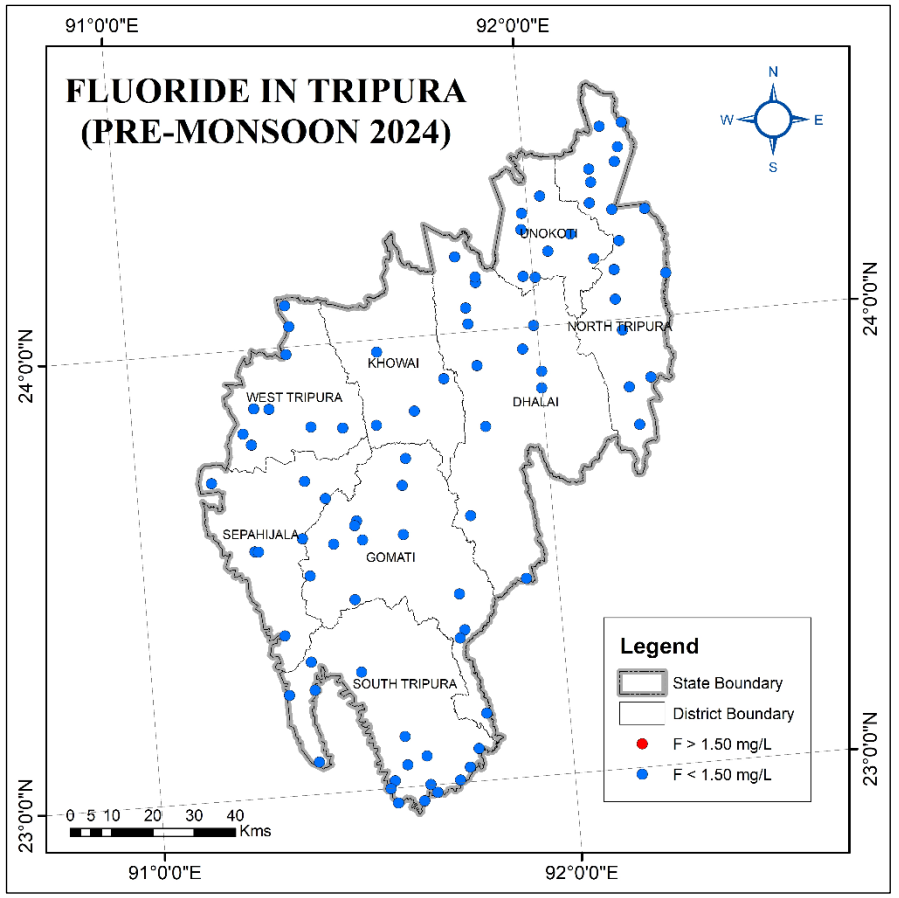

FIGURE 9 MAP SHOWING DISTRIBUTION OF FLUORIDE (PRE-MONSSON 2024)

The **Table 8** below presents the number of groundwater samples analyzed for each district during the **pre-monsoon 2024** period, along with their minimum, maximum, and mean fluoride concentrations based on the **NHS 2024 data**.

TABLE 8DISTRICT WISE RANGE AND DISTRIBUTION OF FLUORIDE IN SHALLOW GW OF TRIPURA

District	Number of samples analysed	Permissible Limit (mg/L)	Desirable Limit (mg/L)	Min	Max	Mean	Percentage of Samples	
							< 1.50	> 1.50
Dhalai	13	1.50	1.00	0.37	1.09	0.41	100	--
Gomti	10	1.50	1.00	0.54	0.94	0.72	100	--
Khowai	4	1.50	1.00	0.47	1.27	1.01	100	--
North Tripura	17	1.50	1.00	0.15	1.33	0.55	100	--
Sepahijala	7	1.50	1.00	0.25	0.46	0.35	100	--
South Tripura	20	1.50	1.00	0.20	0.67	0.18	100	--
Unakoti	10	1.50	1.00	0.42	0.42	0.04	100	--
West Tripura	9	1.50	1.00	0.58	0.58	0.13	100	--

TEMPORAL VARIATION OF FLUORIDE IN GROUND WATER DURING THE PERIOD FROM 2017 TO 2024

From 2017 to 2024, no location in Tripura has been detected with high fluoride concentrations, except for the year 2019, when one location in North Tripura exhibited elevated fluoride levels. This observation is likely due to several factors, including improvements in water quality monitoring, the successful implementation of water treatment and management practices, and the natural variation of fluoride content in groundwater. In 2019, the isolated case in North Tripura may have been a result of localized geological conditions or contamination, which was promptly identified and addressed through targeted interventions. Consequently, the overall trend shows no widespread or significant fluoride contamination in the state's water sources in recent years.

TABLE 9 COMPARATIVE CHANGE IN NUMBER OF LOCATIONS HAVING F > 1.5 mg/L

District	Number of samples analysed	Number of locations having Fluoride > 1.50 mg/L							
		2017	2018	2019	2020	2021	2022	2023	2024
Dhalai	13	0	0	0	0	0	0	0	0
Gomti	10	0	0	0	0	0	0	0	0
Khowai	4					0	0	0	0
North Tripura	17	0	0	1	0	0	0	0	0
Sepahijala	7	0	0	0	0	0	0	0	0
South Tripura	20	0	0	0	0	0	0	0	0
Unakoti	10	0	0	0	0	0	0	0	0
West Tripura	9	0	0	0	0	0	0	0	0
Total	**90**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**

TABLE 10 PERIODIC VARIATION IN SUITABILITY CLASSES OF FLUORIDE IN GROUNDWATER OF TRIPURA

Parameter	Class	Percentage of samples								Periodic Variation (2017-2024)
		2017 *n=89*	2018 *n=76*	2019 *n=83*	2020 *n=91*	2021 *n=79*	2022 *n=71*	2023 *n=81*	2024 *n=90*	
Nitrate as F^-	<1.50 mg/L	89	76	82	91	79	71	81	90	1.12%
	>1.50 mg/L	0	0	1	0	0	0	0	0	0.00%

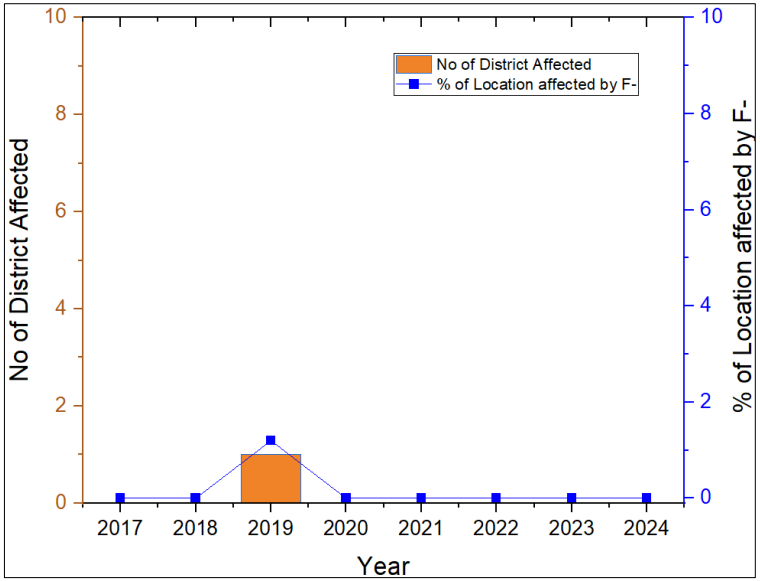

FIGURE 10 TREND OF FLUORIDE IN TRIPURA

ARSENIC

Arsenic is a naturally occurring element that is widely found in the Earth's crust and can be present in various environmental sources, including water, air, food, and soil. It exists in two main forms: organic and inorganic. Natural processes such as biological activities, weathering, and volcanic emissions contribute to the release of arsenic into the environment. However, human activities also play a significant role in its presence. These activities include mining, burning fossil fuels, and the use of arsenic-based pesticides, herbicides, crop desiccants, and feed additives, particularly in poultry feed. While the use of arsenical pesticides and herbicides has decreased in recent years, their application in wood preservation remains prevalent. According to the Bureau of Indian Standards (BIS), the permissible limit for arsenic is set at 10 parts per billion (ppb).

PRESENT DAY SCENARIO IN TRIPURA (As)

The arsenic concentration in groundwater in Tripura ranges from 0.000005 mg/L to 0.001403 mg/L. According to the Bureau of Indian Standards (BIS), an arsenic concentration of up to 0.01 mg/L in drinking water is considered acceptable. Based on this recommendation, all groundwater samples analyzed in Tripura have arsenic levels well within the permissible limit. A map illustrating the spatial distribution of arsenic content in groundwater for pre-monsoon 2024 (Figure 11) confirms that no locations in the state exhibit arsenic concentrations exceeding the BIS standard of 0.01 mg/L.

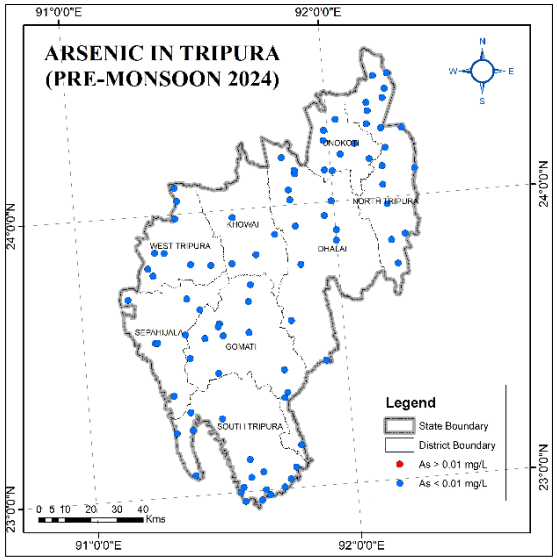

FIGURE 11MAP SHOWING DISTRIBUTION OF ARSENIC (PRE-MONSSON 2024)

The **Table 11** below presents the number of groundwater samples analyzed for each district during the **pre-monsoon 2024** period, along with their minimum, maximum, and mean fluoride concentrations based on the **NHS 2024 data**.

TABLE 11 DISTRICT WISE RANGE AND DISTRIBUTION OF ARSENIC IN SHALLOW GW OF TRIPURA

District	Number of samples analysed	Permissible Limit (mg/L)	Desirable Limit (mg/L)	Min	Max	Mean	Percentage of Samples	
							< 0.01mg/L	>0.01mg/L
Dhalai	13	0.01		0.01	1.18	0.26	100	-
Gomti	10	0.01		0.04	0.21	0.09	100	-
Khowai	4	0.01		0.14	1.16	0.40	100	-
North Tripura	17	0.01		0.04	0.93	0.33	100	-
Sepahijala	7	0.01		0.22	0.62	0.43	100	-
South Tripura	20	0.01		0.00	0.57	0.19	100	-
Unakoti	10	0.01		0.08	0.62	0.31	100	-
West Tripura	9	0.01		0.06	1.40	0.60	100	-

TEMPORAL VARIATION OF ARSENIC IN GROUND WATER DURING THE PERIOD FROM 2017 TO 2024

From 2017 to 2024, no location in Tripura has not detected location with arsenic concentrations exceeding 0.01 mg/L, which is the permissible limit set by the Bureau of Indian Standards (BIS) for drinking water. This consistent observation can be attributed to factors such as effective water quality management, regular monitoring programs, and the naturally low levels of arsenic in the region's groundwater. The absence of high arsenic concentrations suggests that the state's water sources remain safe and free from significant arsenic contamination during this period.

TABLE 12 COMPARATIVE CHANGE IN NUMBER OF LOCATIONS HAVING ARSENIC > 0.01 mg/L

District	Number of samples analysed	Number of locations having Arsenic > 0.01 mg/L							
		2017	2018	2019	2020	2021	2022	2023	2024
Dhalai	13	0	0	0	0	0	0	0	0
Gomti	10	0	0	0	0	0	0	0	0
Khowai	4	0	0	0	0	0	0	0	0
North Tripura	17	0	0	0	0	0	0	0	0
Sepahijala	7	0	0	0	0	0	0	0	0
South Tripura	20	0	0	0	0	0	0	0	0
Unakoti	10	0	0	0	0	0	0	0	0
West Tripura	9	0	0	0	0	0	0	0	0
Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

TABLE 13 PERIODIC VARIATION IN SUITABILITY CLASSES OF ARSENIC IN GROUNDWATER OF TRIPURA

Parameter	Class	Percentage of samples								Periodic Variation (2017-2024)
		2017	2018	2019	2020	2021	2022	2023	2024	
		n=89	*n=76*	*n=83*	*n=91*	*n=79*	*n=71*	*n=81*	*n=90*	
Arsenic as As	<0.01 mg/L	89	76	83	91	79	71	81	90	0.00%
	>0.01 mg/L	0	0	0	0	0	0	0	0	0.00%

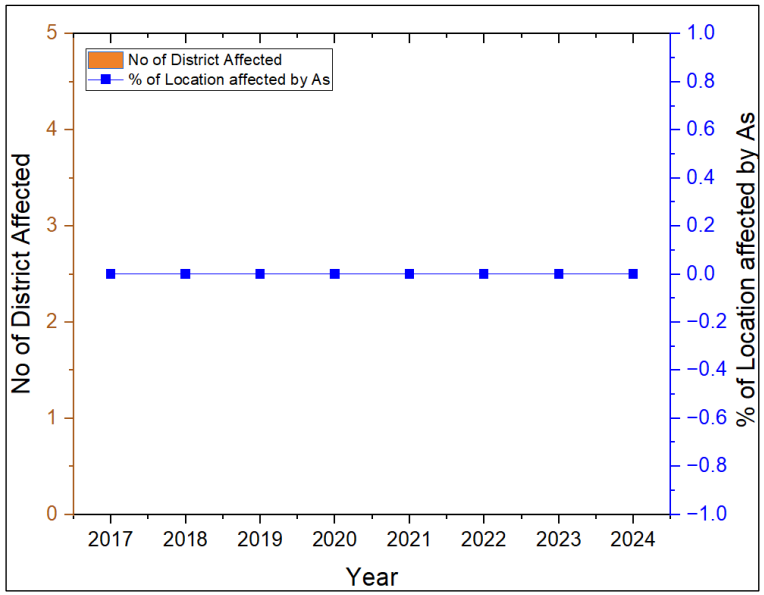

FIGURE 12TREND OF ARSENIC IN TRIPURA

IRON

Iron is a common component of soil and groundwater, occurring in water either as soluble ferrous iron or insoluble ferric iron. Water containing ferrous iron appears clear and colorless due to the complete dissolution of the iron. However, upon exposure to air, ferrous iron oxidizes to form reddish-brown ferric oxide, causing the water to turn cloudy. The concentration of iron in natural water is influenced by both physicochemical and microbiological factors. Groundwater iron is primarily derived from the weathering of ferruginous minerals in igneous rocks, such as hematite and magnetite, as well as sulfide ores in sedimentary and metamorphic rocks. According to the Bureau of Indian Standards (BIS) for drinking water, the permissible concentration of iron in groundwater is less than 1.0 mg/L.

PRESENT DAY SCENARIO IN TRIPURA (Fe)

The iron concentration in groundwater in Tripura ranges from 0.00019 mg/L at Motu Mogpara to 0.33438 mg/L at Magroom in South Tripura. According to the Bureau of Indian Standards (BIS), an iron concentration of up to 1.0 mg/L in drinking water is considered acceptable. Based on this recommendation, all groundwater samples analyzed in Tripura have iron levels well within the permissible limit. A map illustrating the spatial distribution of iron content in groundwater for pre-monsoon 2024 confirms that no locations in the state exhibit iron concentrations exceeding the BIS standard of 1.0 mg/L.

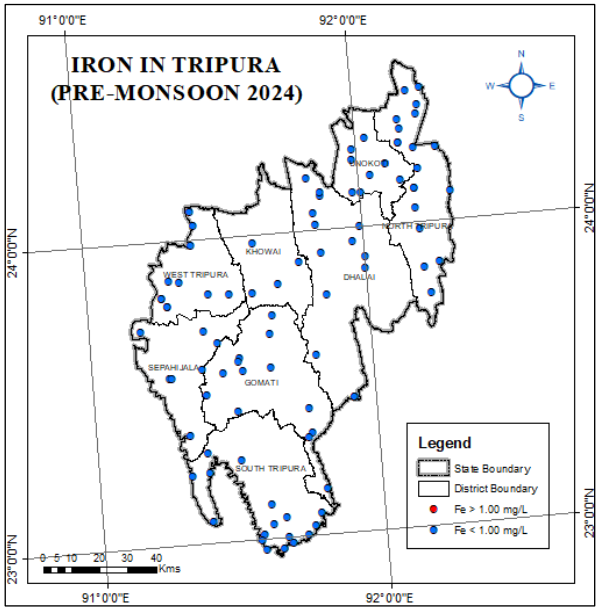

FIGURE 13 MAP SHOWING DISTRIBUTION OF As (PRE-MONSSON 2024)

The **Table 14** below presents the number of groundwater samples analyzed for each district during the **pre-monsoon 2024** period, along with their minimum, maximum, and mean fluoride concentrations based on the **NHS 2024 data**.

TABLE 14 DISTRICT WISE RANGE AND DISTRIBUTION OF ARSENIC IN SHALLOW GW OF TRIPURA

District	Number of samples analysed	Permissible Limit (mg/L)	Desirable Limit (mg/L)	Min	Max	Mean	Percentage of Samples	
							< 1.00 mg/L	>1.00 mg/L
Dhalai	13	1.00		0.0043	0.3301	0.0776	100	--
Gomti	10	1.00		0.0017	0.0426	0.0133	100	--
Khowai	4	1.00		0.0027	0.0035	0.0031	100	--
North Tripura	17	1.00		0.0035	0.1853	0.0384	100	--
Sepahijala	7	1.00		0.0089	0.2330	0.0508	100	--
South Tripura	20	1.00		0.0002	0.3344	0.0470	100	--
Unakoti	10	1.00		0.0022	0.0640	0.0323	100	--
West Tripura	9	1.00		0.0119	0.1610	0.0599	100	--

TEMPORAL VARIATION OF IRON IN GROUND WATER DURING THE PERIOD FROM 2017 TO 2024

Based on the 2024 pre-monsoon data for Tripura, it has been observed that there are no locations with iron concentrations exceeding 1.0 mg/L in groundwater samples, indicating a substantial reduction in high iron concentrations compared to previous years. This improvement can likely be attributed to effective water resource management practices, regular monitoring, and targeted mitigation measures such as the installation of iron removal units and public awareness campaigns. Also, natural factors such as improved groundwater recharge during monsoons and reduced dependence on iron-rich aquifers may have contributed to this positive trend.

TABLE 15 COMPARATIVE CHANGE IN NUMBER OF LOCATIONS HAVING Fe > 1.0 mg/L

District	Number of samples analysed	Number of locations having Iron > 1.00 mg/L							
		2017	2018	2019	2020	2021	2022	2023	2024
Dhalai	13	2	0	1	2	5	3	2	0
Gomti	10	0	0	2	4	5	3	4	0
Khowai	4					2	1	1	0
North Tripura	17	3	1	0	0	5	2	1	0
Sepahijala	7	2	0	1	0	4	0	0	0
South Tripura	20	3	6	1	4	4	3	3	0
Unakoti	10	4	0	1	4	1	0	0	0
West Tripura	9	0	0	1	2	2	0	0	0
Total		14	7	7	16	28	12	11	0

TABLE 16 PERIODIC VARIATION IN SUITABILITY CLASSES OF ARSENIC IN GROUNDWATER OF TRIPURA

Parameter	Class	Percentage of samples								Periodic Variation (2017-2024)
		2017	2018	2019	2020	2021	2022	2023	2024	
		n=89	*n=76*	*n=83*	*n=91*	*n=79*	*n=71*	*n=81*	*n=90*	
Iron as Fe	<1 mg/L	75	69	76	75	51	59	70	90	-20.00%
	>1 mg/L	14	7	7	16	28	12	11	0	100.00%

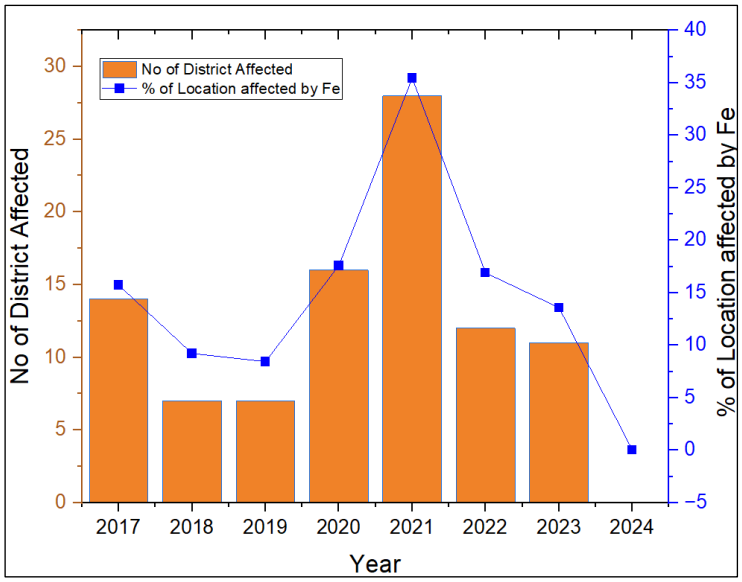

FIGURE 14 TREND OF IRON IN TRIPURA

URANIUM

Uranium is a naturally occurring element found in both groundwater and surface water, and it poses health risks primarily due to its radioactive nature. Its presence in water sources can stem from natural deposits, emissions from the nuclear industry, coal combustion, and the use of phosphate-based fertilizers. Human exposure to uranium typically occurs through drinking water, food, air, and occupational environments. Prolonged consumption of water with uranium concentrations exceeding 0.03 µg/L (ppb), as per Bureau of Indian Standards (BIS) guidelines, can lead to damage to internal organs, highlighting the importance of monitoring and managing its levels in water sources.

PRESENT DAY SCENARIO IN TRIPURA (Fe)

The uranium concentration in groundwater in Tripura, based on pre-monsoon 2024 data, ranges from 0.0000899737 µg/L to 0.339779682 µg/L. According to the Bureau of Indian Standards (BIS), a uranium concentration of up to 30 µg/L (0.03 mg/L) in drinking water is considered acceptable. All groundwater samples analyzed in Tripura have uranium levels well below the permissible limit. A spatial distribution map of uranium content in groundwater for 2024 confirms that no locations in the state exhibit uranium concentrations exceeding the BIS standard, indicating that uranium contamination in groundwater is not a concern in Tripura.

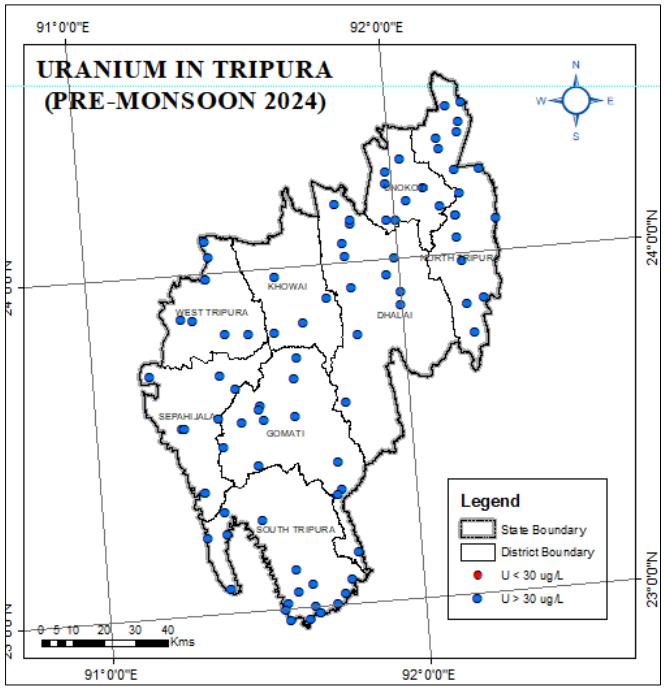

FIGURE 15 MAP SHOWING DISTRIBUTION OF U (PRE-MONSSON 2024)

The **Table 14** below presents the number of groundwater samples analyzed for each district during the **pre-monsoon 2024** period, along with their minimum, maximum, and mean fluoride concentrations based on the **NHS 2024 data**.

TABLE 17 DISTRICT WISE RANGE AND DISTRIBUTION OF URANIUM IN SHALLOW GW OF TRIPURA

District	Number of samples analysed	Permissible Limit (ug/L)	Desirable Limit (ug/L)	Min	Max	Mean	Percentage of Samples	
							< 30	>30
Dhalai	13	30.00		0.001	0.098	0.037	100	-
Gomti	10	30.00		0.006	0.224	0.039	100	-
Khowai	4	30.00		0.009	0.186	0.063	100	-
North Tripura	17	30.00		0.001	0.176	0.044	100	-
Sepahijala	7	30.00		0.002	0.222	0.077	100	-
South Tripura	20	30.00		0.000	0.118	0.020	100	-
Unakoti	10	30.00		0.006	0.340	0.088	100	-
West Tripura	9	30.00		0.007	0.059	0.023	100	-

TEMPORAL VARIATION OF URANIUM IN GROUND WATER DURING THE PERIOD FROM 2017 TO 2024

It has been observed (Table 18) that no locations in Tripura are affected by high uranium concentrations, as all groundwater samples analyzed from 2018 to 2024 remain well within the permissible limit of 30 µg/L set by the Bureau of Indian Standards (BIS). This indicates that uranium contamination is not a concern in the state.

TABLE 18 COMPARATIVE CHANGE IN NUMBER OF LOCATIONS HAVING URANIUM > 30 ug/L

District	Number of location having Uranium > 30 µg/L						
	2018	2019	2020	2021	2022	2023	2024
Dhalai	0	0	0	0	0	0	0
Gomti	0	0	0	0	0	0	0
Khowai	0	0	0	0	0	0	0
North Tripura	0	0	0	0	0	0	0
Sepahijala	0	0	0	0	0	0	0
South Tripura	0	0	0	0	0	0	0
Unakoti	0	0	0	0	0	0	0
West Tripura	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0

TABLE 19 PERIODIC VARIATION IN SUITABILITY CLASSES OF URANIUM IN GROUNDWATER OF TRIPURA

Parameter	Class	Percentage of samples							Periodic Variation (2017-2024)
		2018	2019	2020	2021	2022	2023	2024	
		n=76	*n=83*	*n=91*	*n=79*	*n=71*	*n=81*	*n=90*	
Uranium	<30 ug/L	76	83	91	79	71	81	90	0.00%
	>30 ug/L	0	0	0	0	0	0	0	0.00%

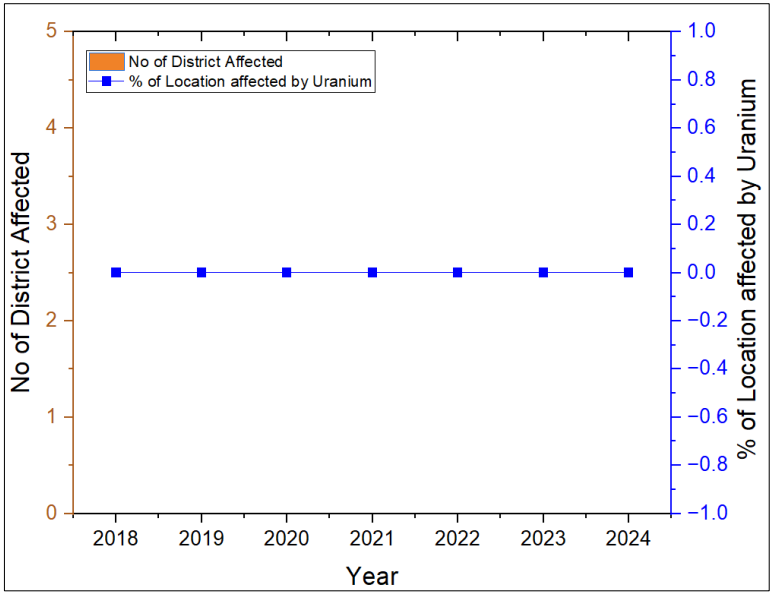

FIGURE 16 TREND OF URANIUM IN TRIPURA

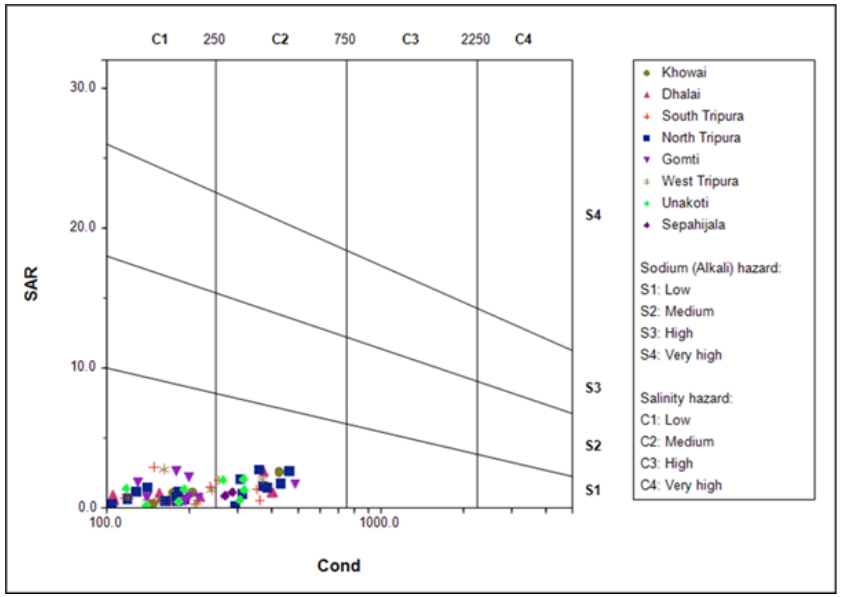

FIGURE 17 US SALINITY LABORATORY DIAGRAM

QUALITY ASSESSMENT OF GROUNDWATER FOR IRRIGATION

The US SALINITY Laboratory Diagram shows that most of the analyzed groundwater samples fall in the C1S1 category, which is the lowest level of salinity on the diagram. This means that the water has a low concentration of both sodium and chloride ions, and a low overall TDS. Figure 17 shows the USSSL diagram of Tripura state. The next most common category for the groundwater samples is C2S1, which is slightly higher in salinity than C1S1, but still relatively low overall.

☐ The water quality is predominantly excellent to good across most parameters, with the majority of samples falling in the "Suitable" or "Excellent" categories.

☐ A few samples exhibit marginal or unsuitable characteristics, particularly in terms of Kelly's Index and Soluble Sodium Percentage, which could indicate localized issues of sodium dominance.

☐ Overall, the observations suggest favorable conditions for irrigation with minimal risk of salinity, alkalinity, or sodium hazards, except for isolated cases requiring attention.

TABLE 20 CLASSIFICATION OF PRE-MONSOON GROUND WATER SAMPLES OF TRIPURA FOR IRRIGATION PURPOSES

Parameters	Range	Classification	Number of Samples
Salinity Hazard (µS/cm)	< 250	Excellent	50
	250 - 750	Good	39
	750 - 2000	Permissible	1
	2000 - 3000	Doubtful	-
	> 3000	Unsuitable	-
Alkalinity Hazard (SAR)	< 10	Excellent	90
	10 -18	Good	-
	18 - 26	Doubtful	-
	> 26	Unsuitable	-
Kelly's Index (KI)	< 1	Suitable	78
	> 1	Unsuitable	12
Residual Sodium Carbonate (RSC)	< 1.25	Suitable	89
	1.25 - 2.50	Marginally Suitable	1
	> 2.50	Unsuitable	-
Soluble Sodium Percentage (SSP)	< 50	Suitable	69
	> 50	Unsuitable	21

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

The Water Quality Index (WQI) for samples collected during the pre-monsoon season of 2024 in Tripura indicates that the majority of the water sources are of excellent quality, with a smaller proportion classified as good as shown in Table 21.

TABLE 21 WQI CLASSIFICATION FOR TRIPURA

Classification range of WQI	Water Quality Status	No of samples	% of samples
< 50	Excellent	87	96.67
50 -100	Good	3	3.33
101 - 200	Poor Water	0	0
201 - 300	Very Poor	0	0
> 300	Water unsuitable for drinking	0	0

The WQI results suggest that the water quality in Tripura during the pre-monsoon season of 2024 is predominantly excellent, with a small percentage classified as good. No samples indicate poor, very poor, or unsuitable water quality, reflecting a generally safe and reliable drinking water supply in the region.

SUMMARY

The groundwater quality assessment for Tripura during the pre-monsoon season of 2024 reveals predominantly excellent conditions, with some localized concerns. The Water Quality Index (WQI) analysis indicates that the majority of the samples (96.67%) fall in the "Excellent" category, while 3.33% are classified as "Good." No samples fall under "Poor," "Very Poor," or "Unsuitable for Drinking" categories, reflecting a generally safe and reliable drinking water supply in the region.

Nitrate concentration shows a concerning trend, with some locations exceeding permissible limits, highlighting the need for focused monitoring. However, there is an improvement in groundwater quality concerning iron concentration, and all other parameters, including salinity, fluoride, arsenic, uranium, and heavy metals, remain well within permissible limits.

The US Salinity Laboratory (USSL) Diagram analysis shows that most groundwater samples fall under the C1S1 category, indicating the lowest salinity levels with low concentrations of sodium and chloride ions and overall low Total Dissolved Solids (TDS). The next most common category is C2S1, reflecting slightly higher salinity but still within acceptable limits for irrigation.

Key observations:

- **Water Quality:** The water quality is predominantly excellent to good across most parameters, with the majority of samples classified as "Suitable" or "Excellent."
- **Localized Issues:** A few samples exhibit marginal or unsuitable characteristics in terms of Kelly's Index and Soluble Sodium Percentage, suggesting localized sodium dominance concerns.
- **Irrigation Suitability:** The observations suggest favorable conditions for irrigation, with minimal risks related to salinity, alkalinity, or sodium hazards, except for isolated cases requiring attention.

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