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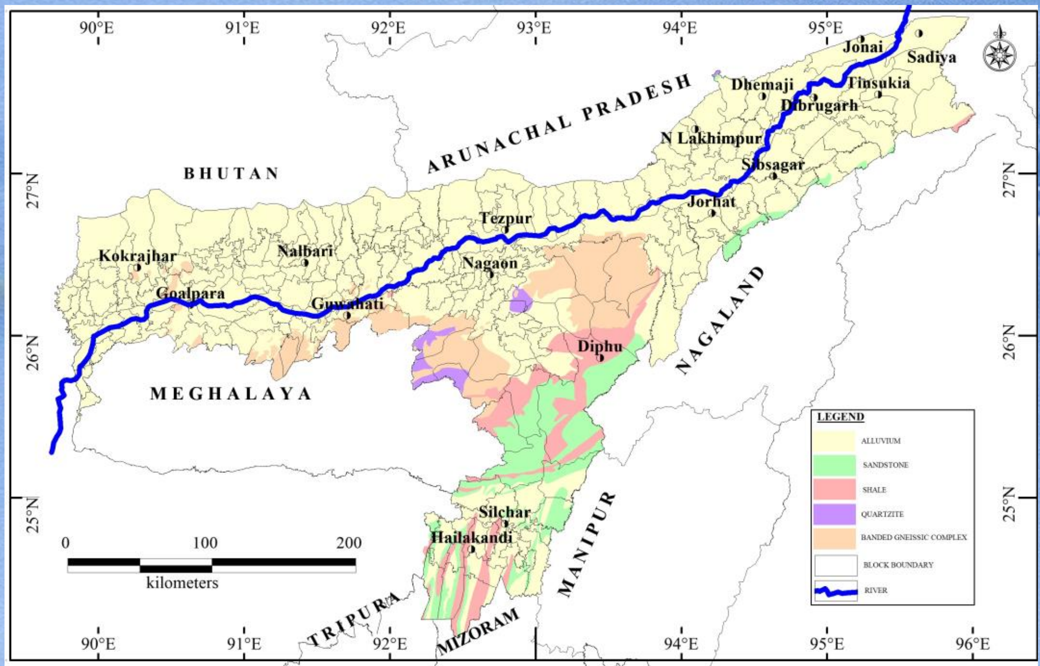
असम का भूजल गुणावत्ता
GROUND WATER QUALITY OF ASSAM



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Central Ground Water Board
उत्तर पूर्वीक्षेत्र
NORTH EASTERN REGION
गुर्वाहाटी
GUWAHATI
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BULLETIN

GROUNDWATER QUALITY
OF ASSAM

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ABSTRACT

Periodic ground water quality assessment (2017-2024) 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 Assam is paramount for prudent groundwater management. Furthermore, a periodic ground water 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. However, an extensive temporal and spatial study of Assam State is lacking.

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

1. To present current Ground water quality scenario, parameter wise for each district
2. To identify present day hot spots of poor-quality ground water through spatial variation analysis of latest 2024 pre-monsoon quality data.
3. To assess temporal variation of ground water quality showing improvement/deterioration during the period from 2017 to 2024, providing insights for effective water quality management measures.

2.0 STUDY AREA

Assam **(Figure 1),** located in the foothills of the eastern Himalayas, is the largest state in north-eastern India and occupies a middle position within the basin of the Brahmaputra and Barak rivers. The state encompasses nearly 2.4% of India's total geographical area, with total area of 78,438 km2 (30,285 sq miles). The region's terrain is uneven, with hills, plains, and waterways. Assam shares its borders with Arunachal Pradesh to the east, West Bengal, Meghalaya, and Bangladesh to the west, Arunachal Pradesh and Bhutan to the north, and Nagaland, Manipur, Mizoram, Meghalaya, and Tripura to the south. Assam is situated between north latitudes 24°08' to 28°02' and east longitudes 89°42' E to 96° and it can be divided into three primary physiographic regions, each with distinct hydrogeological characteristics. The southwest monsoons that bring humidity into Assam bestow an average yearly rainfall of 3048 mm or more on the Brahmaputra valley and its environs. These monsoons are vital to Assam's existence, engendering a biodiversity that rivals equatorial rainforests. In addition, the region's topography and warm, humid climate propel vegetation growth. As a result, Assam boasts 51 forest and sub-forest types and a confluence of diverse flora patterns. As of January 26, 2024, there are 35 districts in the state of Assam, India viz. Baksa, Barpeta, Bongaigaon, Bishwanath, Bajali, Cachar, Charaideo, Chirang, Darrang, Dhemaji, Dhubri, Dibrugarh, Dima Hasao, Goalpara, Golaghat, Hailakandi, Hojai, Jorhat, Kamrup Metropolitan, Kamrup, Karbi Anglong, Karimganj, Kokrajhar, Lakhimpur, Majuli, Morigaon, Nagaon, Nalbari, Sivasagar, Sonitpur, South Salmara-Mankachar, Tamulpur, Tinsukia, Udalguri and West Karbi Anglong.

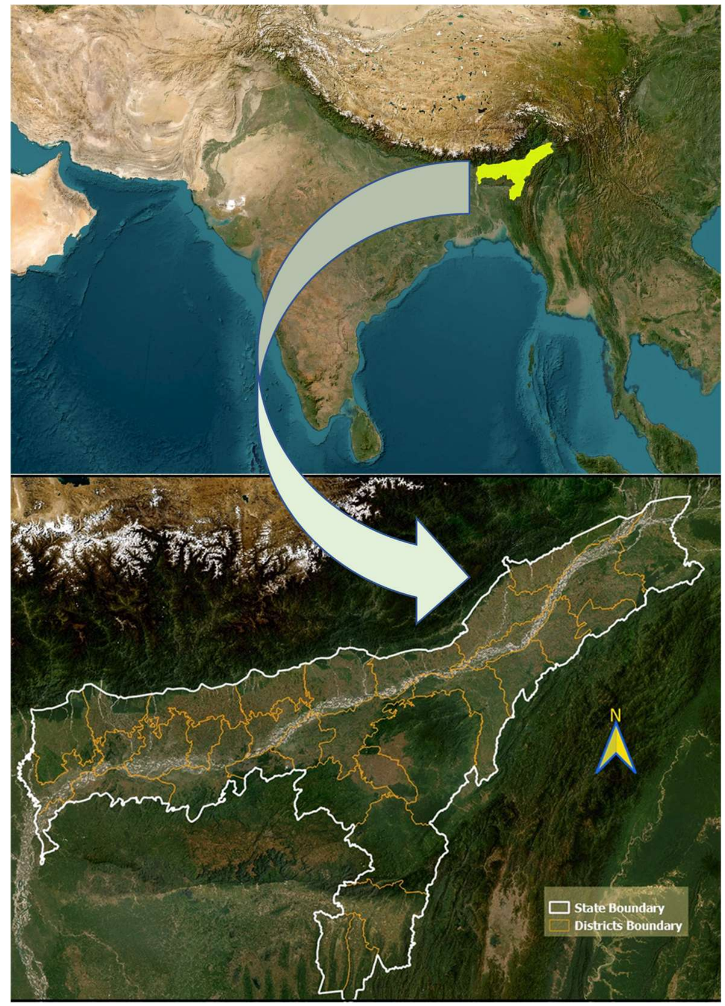
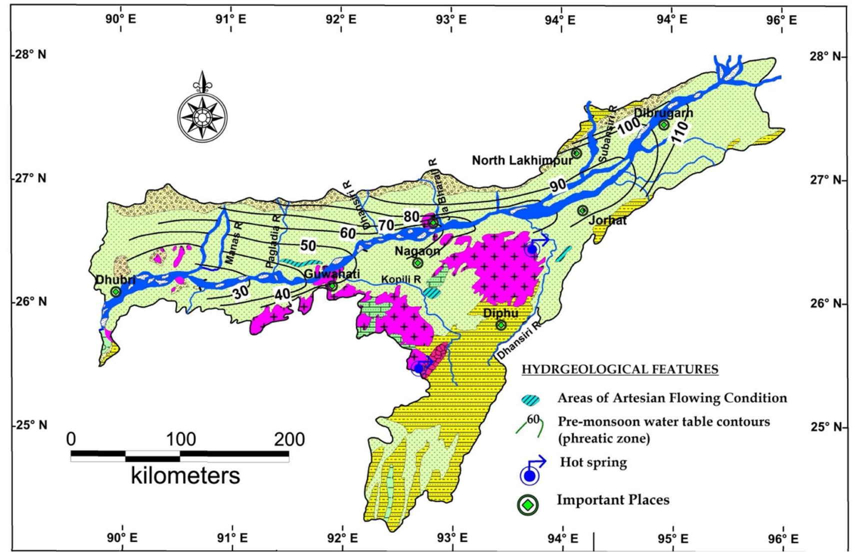


Figure 1. Map of Assam

3.0 HYDROGEOLOGY

Assam's general hydrogeological framework can be classified as follows:

1. Regions with porous unconsolidated formations - mainly Quaternary alluvium.
2. Regions with porous semi-consolidated formations - primarily Tertiary sedimentary.
3. Regions with consolidated formations - comprising weathered and fissured basal crystalline rocks, as well as effusive and intrusive rocks of Archaean and Precambrian ages.



UNCONSOLIDATED FORMATION QUATERNARY - UPPER TERTIARY			SEMI-CONSOLIDATED FORMATION TERTIARY-UPPER PALAEOZOIC			CONSOLIDATED FORMATION PRECAMBRIAN-ARCHEAN		
LITHOLOGY	GROUNDWATER CONDITION	LEGEND	LITHOLOGY	GROUNDWATER CONDITION	LEGEND	LITHOLOGY	GROUNDWATER CONDITION	LEGEND
Recent alluvium Clay, Silt, Sand, Gravel, Pebble, Calcareous Concretions	Fairly thick and regionally extensive confined/unconfined aquifers down to 300m		Siltstine, grit, claystone, sandstone, shales, conglo-merate,	Moderately thick but discontinuous confined to semi-confined aquifer under boundary conditions down to 200m		Sandstone, shale limestone, phyllite schist, quartzite, slates	Groundwater occurences restricted to weathered mantle, fissured and fractured zone within 100m	
	Moderately thick discontinous aquifer, confined/unconfined under bouldery conditions.							
	Marginal areas of ground water basins having restricted lenticular aquifer to phreatic zone within shallow depth		Limestone (Karst)	Groundwater storage in caverns and solution channel		Gneissic complex and associated basic and ultrabasic complex		
Older Alluvium, Laterite, River Terraces Silt, Sand, gravel, pebble, cobble,boulder, ferruginous concretionm lithomargic Clay	Highly permeable boulder/gravel aquifer restricted mainly in the piedmont zone characterised high seasonal fluctuations of ground water level. Bhabar and terrace zones down to 100m							

Figure 2. Hydrogeology map of Assam

4.0 GROUND WATER QUALITY MONITORING

Monitoring of ground water quality is an effort to obtain information on chemical quality through representative sampling in different hydrogeological units. Ground Water is commonly tapped from phreatic aquifers. The main objective of ground water quality monitoring programme 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 ground water. The probable causes of deterioration in ground water quality are depicted in Figure 3.

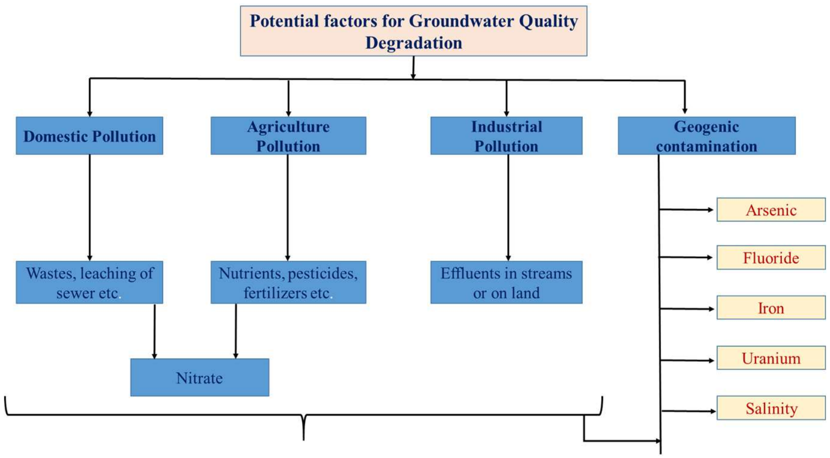


Figure 3. Schematic diagram illustrating the potential factors contributing to the degradation of groundwater quality.

The chemical quality of shallow ground water is being monitored by Central Ground Water Board twice in a year (Pre-monsoon and Post- monsoon) since 2023 through 317 locations located all over the state (Figure 4).

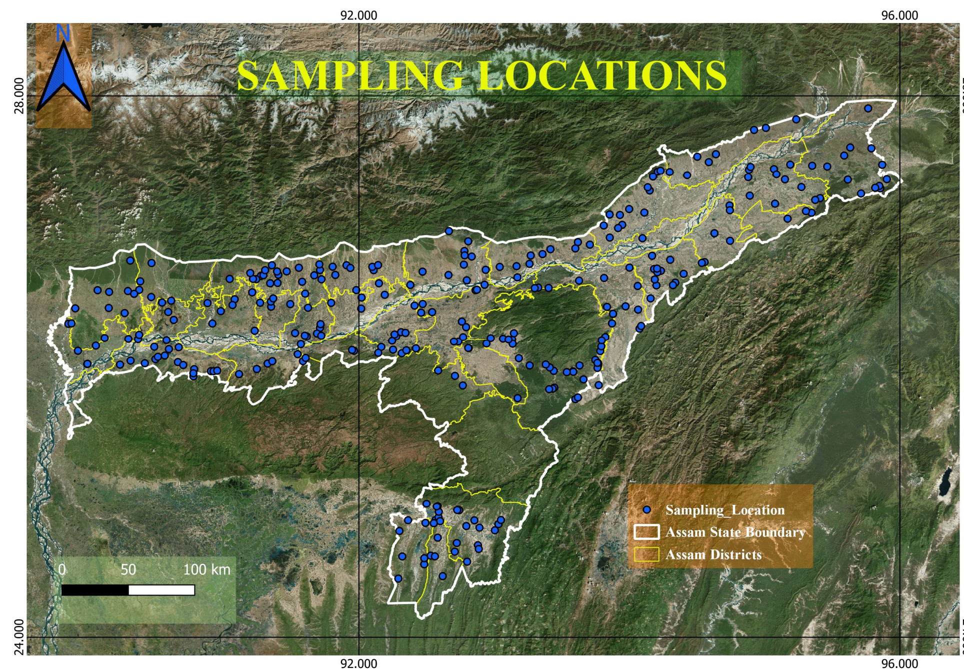


Figure 4. Ground water quality sampling locations in Assam

4.0 METHODOLOGY

To establish the ground water chemistry of the state, samples from different corners of the Assam have been collected during the month of March/April (pre-monsoon) which is generally a dry period, leading to maximum concentration of elements in the water samples and November (Post-monsoon). 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 GW 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

5.0 GROUND WATER QUALITY SCENARIO

The main objectives of ground water quality monitoring are to assess the suitability of ground water 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 ground water samples collected from phreatic aquifers are analysed for all the major inorganic parameters and trace metals. Based on the results, it is found that ground water of the Assam is mostly of calcium bicarbonate (Ca-HCO3) type when the total salinity of water is 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. Nevertheless, occurrence of high concentrations of some water quality parameters such as Iron, Manganese and sporadic occurrence of Fluoride, Nitrate and Arsenic have been observed in some parts of Assam.

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

1. Electrical Conductivity (> 3000 µS/cm)
2. Fluoride (>1.5 mg/litre)
3. Nitrate (>45 mg/litre)
4. Iron (>1.0 mg/litre)
5. Arsenic (>0.01 mg/litre)
6. Uranium (>30 ppb)

5.1.1 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 < 1500µS/cm, is considered as fresh water, EC 1500 – 15000µS/cm, is considered as brackish water and >15000µS/cm is considered as saline water. Salinity always exists in ground water 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 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 ASSAM ELECTRICAL CONDUCTIVITY (EC)

- The EC value of ground waters in the State varies from 19.15 at Pathalipam, Lakhimpur district to 1940 µS/cm at Karbi Anglong district at 25°C.
- Grouping water samples based on EC values, it is found that none of them have EC above 3000µS/cm.
- The map showing aerial distribution of EC (Figure 5) in pre-monsoon signifies that slightly high EC is concentrated in some districts viz. Kamrup (M), Kamrup, Nagaon, Karbi-anglong and Morigaon.
- The Table 2 provides the number of samples analyzed per district, along with their minimum, maximum, and mean EC values and number of samples beyond 3000 µS/cm based on pre-monsoon NHS 2024 Data.
- Trend analysis (Table 3&4), of eight years showing no significant change in EC. Some anomaly has been observed in 2023 in one location which may be of anthropogenic origin.

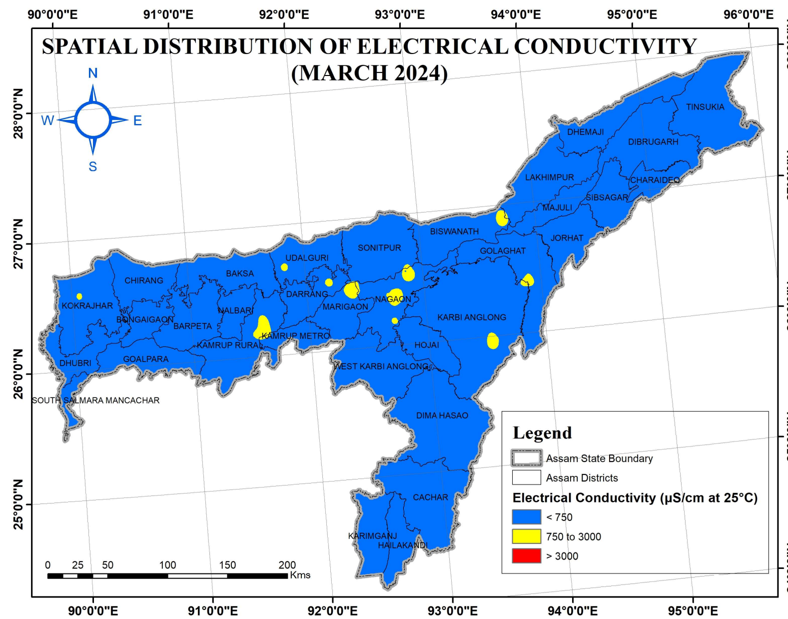


Figure 5: Map showing distribution of Electrical Conductivity in Assam based on pre-monsoon NHS 2024 Data

Table 2: District wise Range and distribution of EC in shallow GW of Assam (pre-monsoon NHS 2024)

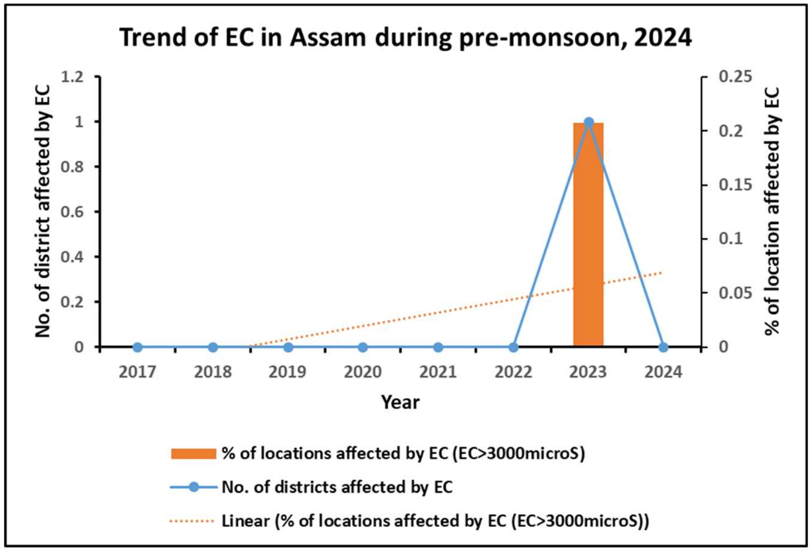
			Electrical Conductivity (µS/cm)						
Sl. No.	District	No. of sample analysed	Permissible limit (in accordance with TDS)	Desirable limit	Min	Max	Mean	No. of sample (%) <=3000	No. of sample (%) >3000
1	Baksa	19	3000.00		100.50	349.90	193.11	100.00	0.00
2	Barpeta	9	3000.00		120.40	446.20	249.03	100.00	0.00
3	Biswanath	10	3000.00		70.33	1357.00	314.25	100.00	0.00
4	Bongaigaon	4	3000.00		126.30	383.50	268.95	100.00	0.00
5	Cachar	19	3000.00		108.00	577.00	275.65	100.00	0.00
6	Charaideo	3	3000.00		209.10	401.00	275.75	100.00	0.00
7	Chirang	4	3000.00		56.91	205.80	101.70	100.00	0.00
8	Darrang	5	3000.00		406.60	843.10	563.72	100.00	0.00
9	Dhemaji	7	3000.00		120.90	501.10	260.19	100.00	0.00
10	Dhubri	10	3000.00		40.74	346.70	172.65	100.00	0.00
11	Dibrugarh	11	3000.00		98.86	546.00	323.74	100.00	0.00
12	East Karbi Anglong	6	3000.00		279.60	563.60	418.88	100.00	0.00
13	Goalpara	18	3000.00		36.80	395.70	148.78	100.00	0.00
14	Golaghat	12	3000.00		128.70	625.00	374.73	100.00	0.00
15	Hailakandi	5	3000.00		102.20	323.00	231.74	100.00	0.00
16	Hojai	4	3000.00		136.60	978.30	526.10	100.00	0.00
17	Jorhat	15	3000.00		92.92	816.20	296.51	100.00	0.00
18	Kamrup	21	3000.00		51.40	1716.00	433.32	100.00	0.00
19	Karbi Anglong	25	3000.00		102.20	1940.00	461.51	100.00	0.00
20	Karimganj	9	3000.00		112.70	683.10	373.50	100.00	0.00
21	Kokrajhar	9	3000.00		58.85	876.40	216.42	100.00	0.00
22	Lakhimpur	14	3000.00		19.15	408.70	232.93	100.00	0.00
23	Majuli	1	3000.00		287.40	287.40	287.40	100.00	0.00
24	Morigaon	9	3000.00		83.66	1456.00	455.42	100.00	0.00
25	Nagaon	13	3000.00		104.40	1404.00	571.65	100.00	0.00
26	Nalbari	6	3000.00		150.90	393.80	270.68	100.00	0.00
27	Sivasagar	5	3000.00		165.70	639.60	304.08	100.00	0.00
28	Sonitpur	13	3000.00		72.19	462.70	201.33	100.00	0.00
29	Tinsukia	14	3000.00		63.27	677.40	259.32	100.00	0.00
30	Udalgudi	8	3000.00		121.30	1117.00	348.19	100.00	0.00
31	West Karbi Anglong	4	3000.00		91.67	419.40	224.24	100.00	0.00
		312							

Table 3: Comparative change in number of locations having EC > 3000 µS/cm in various districts (Pre-monsoon NHS 2024)

Sl. No.	District	No. of locations having Electrical Conductivity > 3000 (µs/cm) 25C							
		2017	2018	2019	2020	2021	2022	2023	2024
1	Baksa	0	0	0	0	0	0	0	0
2	Barpeta	0	0	0	0	0	0	0	0
3	Biswanath	0	0	0	0	0	0	0	0
4	Bongaigaon	0	0	0	0	0	0	0	0
5	Cachar	0	0	0	0	0	0	0	0
6	Charaideo	-	-	-	-	-	-	-	0
7	Chirang	0	0	0	0	0	0	0	0
8	Darrang	0	0	0	0	0	0	0	0
9	Dhemaji	0	0	0	0	0	0	0	0
10	Dhubri	0	0	0	0	0	0	0	0
11	Dibrugarh	0	0	0	0	0	0	0	0
12	East Karbi Anglong	0	0	0	0	0	0	0	0
13	Goalpara	0	0	0	0	0	0	0	0
14	Golaghat	0	0	0	0	0	0	0	0
15	Hailakandi	0	0	0	0	0	0	0	0
16	Hojai	0	0	0	0	0	0	0	0
17	Jorhat	0	0	0	0	0	0	0	0
18	Kamrup	0	0	0	0	0	0	0	0
19	Karbi Anglong	0	0	0	0	0	0	0	0
20	Karimganj	0	0	0	0	0	0	0	0
21	Kokrajhar	0	0	0	0	0	0	0	0
22	Lakhimpur	0	0	0	0	0	0	0	0
23	Majuli	0	0	0	0	0	0	0	0
24	Morigaon	0	0	0	0	0	0	1	0
25	Nagaon	0	0	0	0	0	0	0	0
26	Nalbari	0	0	0	0	0	0	0	0
27	Sivasagar	0	0	0	0	0	0	0	0
28	Sonitpur	0	0	0	0	0	0	0	0
29	Tinsukia	0	0	0	0	0	0	0	0
30	Udalgudi	0	0	0	0	0	0	0	0
31	West Karbi Anglong	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	1	0

Table 4: Periodic variation in suitability Classes of groundwater Electrical Conductivity (EC) of Assam (Pre-monsoon NHS 2024)

Periodic variation in suitibility classes of Salinity in groundwater of Assam										
Parameter	Class	percentage of samples								Periodic Variation 2017-2024
		2017 (n=114)	2018 (n=122)	2019 (n=165)	2020 (n=165)	2021 (n=255)	2022 (n=182)	2023 (n=483)	2024 (n=312)	
Salinity as EC	<750 µS/cm	95.61	79.51	94.55	92.73	94.90	95.05	98.34	94.87	-0.74
	750-3000 µS/cm	4.39	20.49	5.45	7.27	5.10	4.95	1.45	5.13	0.74
	>3000 µS/cm	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00



5.1.2 NITRATE

Naturally occurring nitrate forms when nitrogen and oxygen combine in soil, primarily sourced from atmospheric nitrogen. Groundwater nitrate mainly comes from chemical fertilizers, animal manure leaching, and sewage discharge. Identifying natural vs. man- made sources is challenging. Chemical and microbiological processes like nitrification and denitrification also affect groundwater nitrate levels.

As per the BIS standard for drinking water the maximum desirable limit of nitrate concentration in groundwater is 45 mg/l. Though nitrate is considered relatively non-toxic, a high nitrate concentration in drinking water is an environmental health concern arising from increased risks of methemoglobinemia particularly to infants. Adults can tolerate little higher concentration.

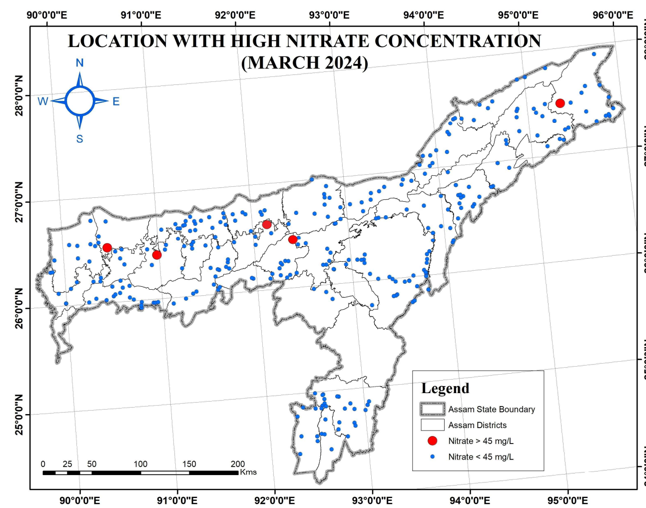


Figure 6: Map showing distribution of Nitrate in Assam based on pre-monsoon NHS 2024 Data

PRESENT DAY SCENARIO IN ASSAM
NITRATE

Distribution of Nitrate

- The nitrate value of ground waters in the State varies from 0.02 mg/L at Meleng Kaparadharia, Jorhat district to 111.17 mg/L at Howly, Barpeta district.
- Grouping water samples based on Nitrate values, it is found that 1.60% of them have nitrate above the permissible limit of 45 mg/L
- The map showing aerial distribution of nitrate (Figure 6) signifies that high nitrate concentrated is observed in three districts viz. Barpeta, Chirang, Darrang, Morigaon and Tinsukia district (one location each).
- The Table 5 provides for the number of samples analyzed per district, along with their minimum, maximum, and mean nitrate values and number of samples more than 45 mg/L based on pre-monsoon NHS 2024 Data.
- Trend analysis (Table 6&7), of eight years showing no significant change except only in five location in Barpeta, Chirang, Darrang, Morigaon and Tinsukia district showing concentration of nitrate more than 45 mg/L, in 2024.

Table 5: District wise Range and distribution of Nitrate in shallow GW of Assam (Pre-monsoon NHS 2024)

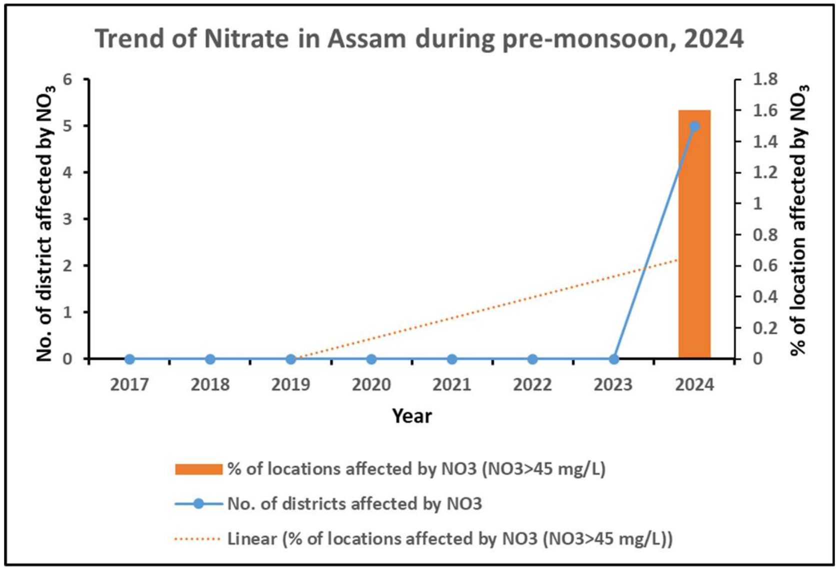
Nitrate (mg/L)									
Sl. No.	District	No. of sample analysed	Permissible limit	Desirable limit	Min	Max	Mean	No. of sample (%) <=45	No. of sample (%) >45
1	Baksa	19	45.00	45.00	0.05	24.52	3.07	100.00	0.00
2	Barpeta	9	45.00	45.00	0.18	111.17	18.28	88.89	11.11
3	Biswanath	10	45.00	45.00	1.22	36.26	9.98	100.00	0.00
4	Bongaigaon	4	45.00	45.00	0.40	6.71	4.60	100.00	0.00
5	Cachar	19	45.00	45.00	0.17	9.72	1.54	100.00	0.00
6	Charaideo	3	45.00	45.00	2.89	3.64	3.33	100.00	0.00
7	Chirang	4	45.00	45.00	4.22	80.05	24.11	75.00	25.00
8	Darrang	5	45.00	45.00	2.42	45.26	17.40	80.00	20.00
9	Dhemaji	7	45.00	45.00	0.46	9.75	3.40	100.00	0.00
10	Dhubri	10	45.00	45.00	0.25	29.92	7.45	100.00	0.00
11	Dibrugarh	11	45.00	45.00	0.03	4.45	1.43	100.00	0.00
12	East Karbi Anglong	6	45.00	45.00	0.67	2.88	1.94	100.00	0.00
13	Goalpara	18	45.00	45.00	0.39	15.82	2.57	100.00	0.00
14	Golaghat	12	45.00	45.00	0.09	33.43	4.13	100.00	0.00
15	Hailakandi	5	45.00	45.00	0.60	8.76	3.62	100.00	0.00
16	Hojai	4	45.00	45.00	0.43	31.40	8.28	100.00	0.00
17	Jorhat	15	45.00	45.00	0.02	12.36	3.18	100.00	0.00
18	Kamrup	21	45.00	45.00	0.25	44.61	7.68	100.00	0.00
19	Karbi Anglong	25	45.00	45.00	0.04	27.41	6.63	100.00	0.00
20	Karimganj	9	45.00	45.00	0.34	4.03	2.10	100.00	0.00
21	Kokrajhar	9	45.00	45.00	0.75	15.29	6.65	100.00	0.00
22	Lakhimpur	14	45.00	45.00	0.65	10.23	3.91	100.00	0.00
23	Majuli	1	45.00	45.00	1.79	1.79	1.79	100.00	0.00
24	Morigaon	9	45.00	45.00	0.88	49.16	9.87	88.89	11.11
25	Nagaon	13	45.00	45.00	1.37	34.61	7.97	100.00	0.00
26	Nalbari	6	45.00	45.00	0.75	18.62	5.45	100.00	0.00
27	Sivasagar	5	45.00	45.00	0.05	8.64	2.99	100.00	0.00
28	Sonitpur	13	45.00	45.00	0.28	13.78	4.50	100.00	0.00
29	Tinsukia	14	45.00	45.00	0.63	50.08	9.65	92.86	7.14
30	Udalgudi	8	45.00	45.00	1.12	16.24	5.97	100.00	0.00
31	West Karbi Anglon	4	45.00	45.00	0.94	5.10	2.51	100.00	0.00
		312							

Table 6: Comparative Change in number of locations having Nitrate > 45 mg/L (Pre-monsoon NHS 2024)

Sl. No.	District	No. of locations having Nitrate > 45mg/litre							
		2017	2018	2019	2020	2021	2022	2023	2024
1	Baksa	0	0	0	0	0	0	0	0
2	Barpeta	0	0	0	0	0	0	0	1
3	Biswanath	0	0	0	0	0	0	0	0
4	Bongaigaon	0	0	0	0	0	0	0	0
5	Cachar	0	0	0	0	0	0	0	0
6	Charaideo	-	-	-	-	-	-	-	0
7	Chirang	0	0	0	0	0	0	0	1
8	Darrang	0	0	0	0	0	0	0	1
9	Dhemaji	0	0	0	0	0	0	0	0
10	Dhubri	0	0	0	0	0	0	0	0
11	Dibrugarh	0	0	0	0	0	0	0	0
12	East Karbi Anglong	0	0	0	0	0	0	0	0
13	Goalpara	0	0	0	0	0	0	0	0
14	Golaghat	0	0	0	0	0	0	0	0
15	Hailakandi	0	0	0	0	0	0	0	0
16	Hojai	0	0	0	0	0	0	0	0
17	Jorhat	0	0	0	0	0	0	0	0
18	Kamrup	0	0	0	0	0	0	0	0
19	Karbi Anglong	0	0	0	0	0	0	0	0
20	Karimganj	0	0	0	0	0	0	0	0
21	Kokrajhar	0	0	0	0	0	0	0	0
22	Lakhimpur	0	0	0	0	0	0	0	0
23	Majuli	0	0	0	0	0	0	0	0
24	Morigaon	0	0	0	0	0	0	0	1
25	Nagaon	0	0	0	0	0	0	0	0
26	Nalbari	0	0	0	0	0	0	0	0
27	Sivasagar	0	0	0	0	0	0	0	0
28	Sonitpur	0	0	0	0	0	0	0	0
29	Tinsukia	0	0	0	0	0	0	0	1
30	Udalgudi	0	0	0	0	0	0	0	0
31	West Karbi Anglong	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	5

Table 7: Periodic variation in suitability Classes of Nitrate in groundwater of Assam (Pre-monsoon NHS 2024)

Periodic variation in suitibility classes of Nitrate in groundwater of Assam										
Parameter	Class	percentage of samples								Periodic Variation 2017-2024
		2017 (n=114)	2018 (n=122)	2019 (n=165)	2020 (n=165)	2021 (n=255)	2022 (n=182)	2023 (n=483)	2024 (n=312)	
Nitrate as NO3	< 45 mg/L	100.00	100.00	100.00	100.00	100.00	100.00	99.38	98.40	-1.60
	>45 mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.62	1.60	1.60



5.1.3 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. The type of rocks, climatic conditions, nature of hydro geological strata and time of contact between rock and the circulating groundwater affect the occurrence of fluoride in natural water.

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. Water having fluoride concentration more than 1.5mg/l is not suitable for drinking purposes. High Fluoride >1.5mg/L is mainly attributed due to geogenic conditions. The fluoride content in ground water from observation wells in a major part of the State is found to be less than 1.0 mg/L.

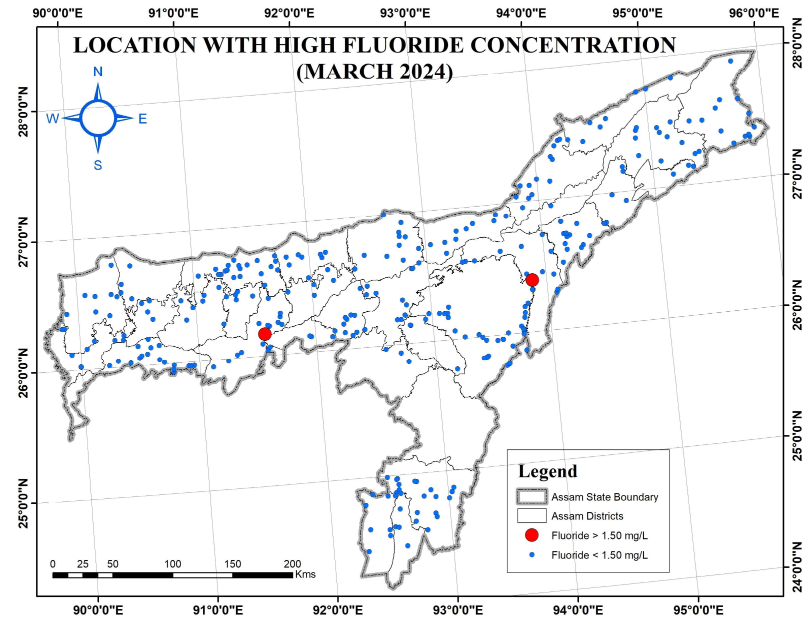


Figure 7: Map showing distribution of Fluoride in Assam based on pre-monsoon and post-monsoon NHS 2024 Data

PRESENT DAY SCENARIO IN ASSAM :FLUORIDE

Distribution of Fluoride (F)

- The fluoride value of ground waters in the State varies from 0.008 mg/L at Diphu, Karbi Anglong district to 2.37 mg/L at Garampani Hot Spring, Karbi Anglong district.
- Grouping water samples based on Fluoride values, it is found that 0.64% of them have fluoride above the permissible limit of 1.5 mg/L.
- The map showing aerial distribution of Fluoride (Figure 7) signifies that high fluoride concentrated is observed in Kamrup and Karbi Anglong district (one location each)
- The Table 8 provides for the number of samples analyzed per district, along with their minimum, maximum, and mean fluoride values and number of samples more than 1.5 mg/L based on pre-monsoon NHS 2024 Data.
- Trend analysis (Table 9, 10), of eight years showing slight decreasing trend in Fluoride content.

Table 8: District wise Range and distribution of Fluoride in shallow GW of Assam (Pre-monsoon NHS 2024)

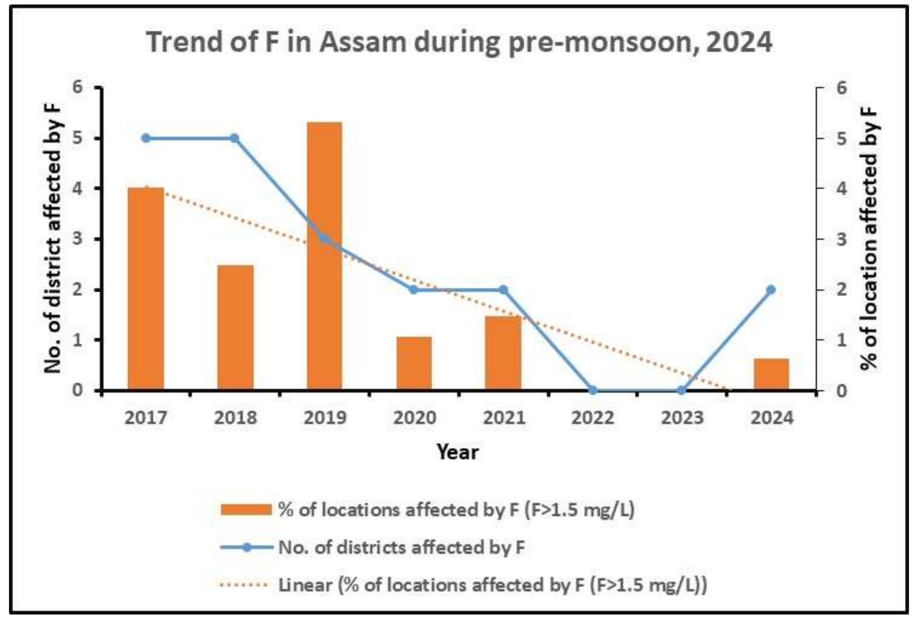
Fluoride (mg/L)									
Sl. No.	District	No. of sample analysed	Permissible limit	Desirable limit	Min	Max	Mean	No. of sample (%) <=1.50	No. of sample (%) >1.50
1	Baksa	19	1.50	1.00	0.02	0.50	0.13	100.00	0.00
2	Barpeta	9	1.50	1.00	0.02	0.49	0.16	100.00	0.00
3	Biswanath	10	1.50	1.00	0.54	1.05	0.92	100.00	0.00
4	Bongaigaon	4	1.50	1.00	0.11	0.15	0.13	100.00	0.00
5	Cachar	19	1.50	1.00	0.00	0.93	0.37	100.00	0.00
6	Charaideo	3	1.50	1.00	0.38	0.64	0.34	100.00	0.00
7	Chirang	4	1.50	1.00	0.05	0.09	0.06	100.00	0.00
8	Darrang	5	1.50	1.00	0.64	0.71	0.27	100.00	0.00
9	Dhemaji	7	1.50	1.00	0.55	0.93	0.73	100.00	0.00
10	Dhubri	10	1.50	1.00	0.04	0.40	0.16	100.00	0.00
11	Dibrugarh	11	1.50	1.00	0.02	0.82	0.18	100.00	0.00
12	East Karbi Anglong	6	1.50	1.00	0.45	0.90	0.50	100.00	0.00
13	Goalpara	18	1.50	1.00	0.00	1.09	0.30	100.00	0.00
14	Golaghat	12	1.50	1.00	0.02	0.66	0.14	100.00	0.00
15	Hailakandi	5	1.50	1.00	0.16	0.54	0.34	100.00	0.00
16	Hojai	4	1.50	1.00	0.89	0.89	0.45	100.00	0.00
17	Jorhat	15	1.50	1.00	0.25	0.60	0.41	100.00	0.00
18	Kamrup	21	1.50	1.00	0.00	2.26	0.59	95.24	4.76
19	Karbi Anglong	25	1.50	1.00	0.01	2.37	0.29	96.00	4.00
20	Karimganj	9	1.50	1.00	0.31	1.11	0.63	100.00	0.00
21	Kokrajhar	9	1.50	1.00	0.04	0.22	0.10	100.00	0.00
22	Lakhimpur	14	1.50	1.00	0.52	1.09	0.87	100.00	0.00
23	Majuli	1	1.50	1.00	0.98	0.98	0.98	100.00	0.00
24	Morigaon	9	1.50	1.00	0.68	1.46	0.94	100.00	0.00
25	Nagaon	13	1.50	1.00	0.46	1.35	0.86	100.00	0.00
26	Nalbari	6	1.50	1.00	0.13	0.33	0.19	100.00	0.00
27	Sivasagar	5	1.50	1.00	0.24	0.33	0.28	100.00	0.00
28	Sonitpur	13	1.50	1.00	0.04	0.57	0.11	100.00	0.00
29	Tinsukia	14	1.50	1.00	0.54	0.99	0.75	100.00	0.00
30	Udalgudi	8	1.50	1.00	0.16	0.61	0.37	100.00	0.00
31	West Karbi Anglong	4	1.50	1.00	0.18	0.56	0.40	100.00	0.00
		312							

Table 9: Comparative Change in number of locations having Fluoride >1.5 mg/L (Pre-monsoon NHS 2024)

Sl. No.	District	No. of locations having Fluoride > 1.5mg/litre							
		2017	2018	2019	2020	2021	2022	2023	2024
1	Baksa	0	0	0	0	0	0	0	0
2	Barpeta	0	0	0	0	0	0	0	0
3	Biswanath	0	0	0	0	0	0	0	0
4	Bongaigaon	0	0	0	0	0	0	0	0
5	Cachar	2	3	0	0	0		0	0
6	Charaideo	-	-	-	-	-	-	-	0
7	Chirang	0	0	0	0	0	0	0	0
8	Darrang	0	0	0	0	0	0	0	0
9	Dhemaji	0	0	0	0	0	0	0	0
10	Dhubri	0	0	0	0	0	0	0	0
11	Dibrugarh	0	0	0	0	0	0	0	0
12	East Karbi Anglong	0	0	0	0	0	0	0	0
13	Goalpara	0	0	0	0	2	0	0	0
14	Golaghat	0	0	0	0	0	0	0	0
15	Hailakandi	0	1	0	0	0	0	0	0
16	Hojai	0	0	0	0	0	0	0	0
17	Jorhat	0	0	0	0	0	0	0	0
18	Kamrup	1	1	8	1	1	0	0	1
19	Karbi Anglong	1	0	0	0	0	0	0	1
20	Karimganj	0	0	0	0	0	0	0	0
21	Kokrajhar	0	0	0	0	0	0	0	0
22	Lakhimpur	1	0	0	0	0	0	0	0
23	Majuli	0	0	0	0	0	0	0	0
24	Morigaon	0	0	1	0	0	0	0	0
25	Nagaon	0	0	2	1	0	0	0	0
26	Nalbari	0	0	0	0	0	0	0	0
27	Sivasagar	0	0	0	0	0	0	0	0
28	Sonitpur	0	0	0	0	0	0	0	0
29	Tinsukia	0	0	0	0	0	0	0	0
30	Udalgudi	0	0	0	0	0	0	0	0
31	West Karbi Anglong	0	0	0	0	0	0	0	0
	Total	5	5	11	2	3	0	0	2

Table 10: Periodic variation in suitability Classes of Fluoride in groundwater of Assam (Pre-monsoon NHS 2024)

Periodic variation in suitibility classes of Fluoride in groundwater of Assam										
Parameter	Class	percentage of samples								Periodic Variation 2017-2024
		2017 (n=114)	2018 (n=122)	2019 (n=165)	2020 (n=165)	2021 (n=255)	2022 (n=182)	2023 (n=483)	2024 (n=312)	
Fluoride as F	< 1.0 mg/L	88.60	91.80	89.70	96.97	94.12	98.90	98.55	95.19	6.60
	1.0-1.50 mg/L	7.02	4.10	3.64	1.82	4.71	1.10	1.24	4.17	-2.85
	>1.50 mg/L	4.39	4.10	6.67	1.21	1.18	0.00	0.21	0.64	-3.74



5.1.4 IRON

Iron is a common constituent in soil and ground water. 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 ground water 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 ground water is less than 1.0 mg/L as per the BIS Standard for drinking water.

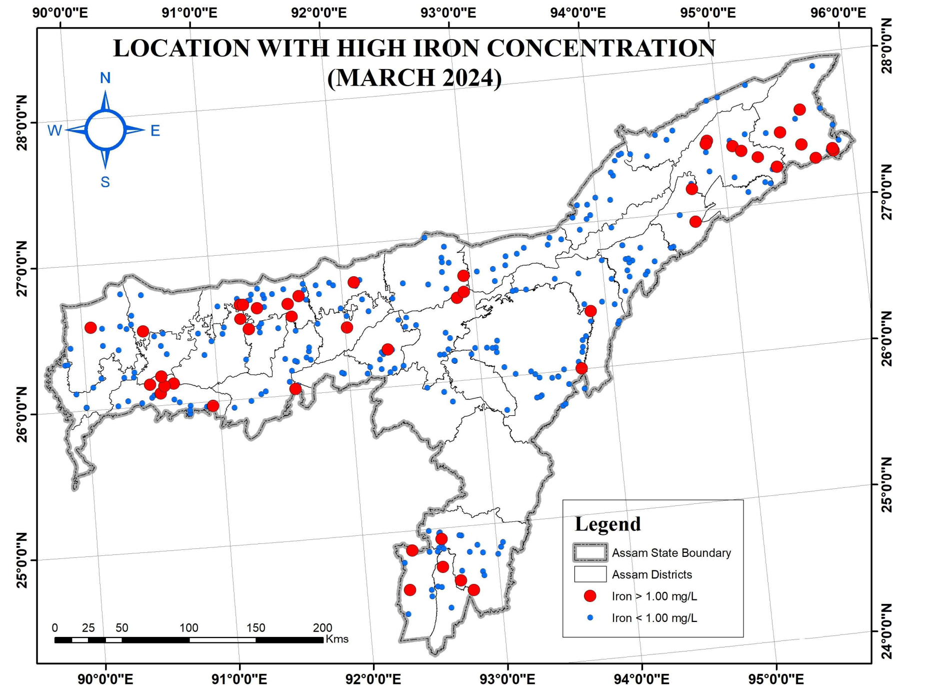


Figure 8: Map showing distribution of Iron in Assam based on pre-monsoon and post-monsoon NHS 2024 Data

.PRESENT DAY SCENARIO IN ASSAM: IRON

Distribution of Iron

- The iron value of ground waters in the State varies from 0.0013 mg/L at Dekapam, Dhemaji district to 21.07 mg/L at Patharkandi, Karimganj district.
- Grouping water samples based on Iron values, it is found that an average of 17.95% of them have iron above the permissible limit of 1.0 mg/L.
- The map showing aerial distribution of Iron (Figure 8) signifies that high iron concentrated is observed in almost all the district of Assam.
- The Table 10 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 12&13), of eight years showing increasing trend in Iron content.

Table 11: District wise Range and distribution of Iron in shallow GW of Assam (Pre-monsoon NHS 2024)

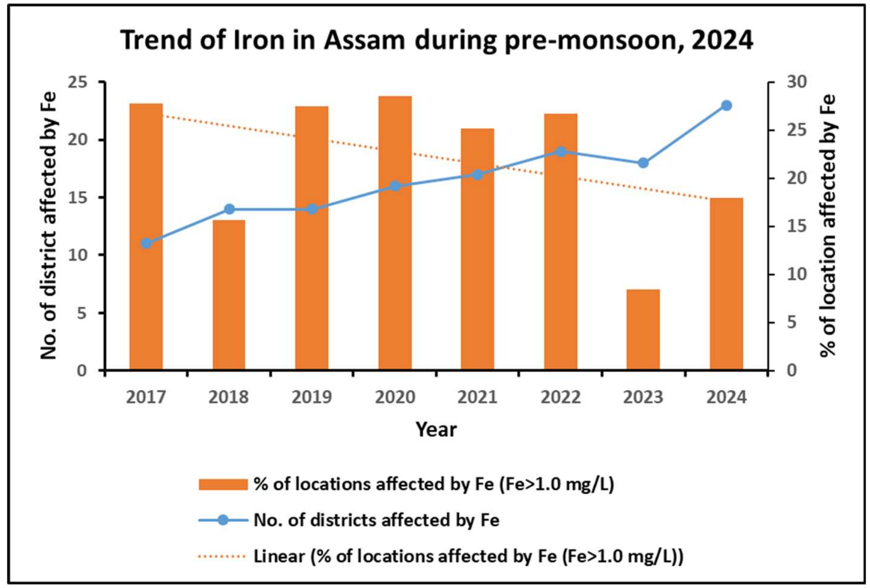
Iron (mg/L)										
Sl. No.	District	No. of sample analysed	Permissible limit	Desirable limit	Min	Max	Mean	No. of sample (%) <=1.00	No. of sample (%) >1.00
1	Baksa	19	1.00	1.00	0.04	4.75	1.03	73.68	26.32
2	Barpeta	9	1.00	1.00	0.13	16.93	3.54	88.89	11.11
3	Biswanath	10	1.00	1.00	0.00	0.12	0.04	100.00	0.00
4	Bongaigaon	4	1.00	1.00	0.00	0.00	0.00	100.00	0.00
5	Cachar	19	1.00	1.00	0.01	20.43	1.48	84.21	15.79
6	Charaideo	3	1.00	1.00	0.27	0.71	0.49	100.00	0.00
7	Chirang	4	1.00	1.00	0.04	1.26	0.37	75.00	25.00
8	Darrang	5	1.00	1.00	0.15	1.14	0.41	80.00	20.00
9	Dhemaji	7	1.00	1.00	0.00	0.05	0.02	100.00	0.00
10	Dhubri	10	1.00	1.00	0.03	0.36	0.16	100.00	0.00
11	Dibrugarh	11	1.00	1.00	0.06	14.63	3.38	45.45	54.55
12	East Karbi Anglong	6	1.00	1.00	0.10	2.70	1.04	66.67	33.33
13	Goalpara	18	1.00	1.00	0.17	12.92	1.56	66.67	33.33
14	Golaghat	12	1.00	1.00	0.00	0.32	0.06	100.00	0.00
15	Hailakandi	5	1.00	1.00	0.04	6.53	1.55	80.00	20.00
16	Hojai	4	1.00	1.00	0.24	3.26	1.09	75.00	25.00
17	Jorhat	15	1.00	1.00	0.01	1.69	0.19	93.33	6.67
18	Kamrup	21	1.00	1.00	0.05	1.83	0.44	90.48	9.52
19	Karbi Anglong	25	1.00	1.00	0.00	9.27	1.06	88.00	12.00
20	Karimganj	9	1.00	1.00	0.07	21.08	3.52	88.89	11.11
21	Kokrajhar	9	1.00	1.00	0.01	3.12	0.49	88.89	11.11
22	Lakhimpur	14	1.00	1.00	0.00	0.14	0.04	100.00	0.00
23	Majuli	1	1.00	1.00	0.03	0.03	0.03	100.00	0.00
24	Morigaon	9	1.00	1.00	0.12	2.44	0.59	88.89	11.11
25	Nagaon	13	1.00	1.00	0.00	1.56	0.54	84.62	15.38
26	Nalbari	6	1.00	1.00	0.14	1.90	0.66	83.33	16.67
27	Sivasagar	5	1.00	1.00	0.18	10.92	5.16	60.00	40.00
28	Sonitpur	13	1.00	1.00	0.10	6.82	1.52	61.54	38.46
29	Tinsukia	14	1.00	1.00	0.06	6.30	2.52	50.00	50.00
30	Udalgudi	8	1.00	1.00	0.42	8.49	1.67	75.00	25.00
31	West Karbi Anglong	4	1.00	1.00	0.07	0.71	0.32	100.00	0.00
		312							

Table 12: Comparative Change in number of locations having Iron >1.0 mg/L (Pre-monsoon NHS 2024)

Sl. No.	District	No. of locations having Iron > 1mg/litre							
		2017	2018	2019	2020	2021	2022	2023	2024
1	Baksa	0	0	3	0	0	0	4	5
2	Barpeta	0	0	1	0	0	1	0	1
3	Biswanath	0	0	0	0	2	1	0	0
4	Bongaigaon	0	1	0	2	2	2	2	0
5	Cachar	12	4	6	8	5		4	3
6	Charaideo	-	-	-	-	-	-	-	0
7	Chirang	0	0	0	0	0	0	0	1
8	Darrang	0	0	0	0	1	1	0	1
9	Dhemaji	2	1	1	0	2	1	1	0
10	Dhubri	0	0	0	0	0	0	0	0
11	Dibrugarh	0	0	1	1	1	0	0	6
12	East Karbi Anglong	0	0	0	0	0	0	3	2
13	Goalpara	1	0	0	0	3	0	2	6
14	Golaghat	0	0	0	0	0	0	1	0
15	Hailakandi	1	2	0	2	1	1	1	1
16	Hojai	0	0	0	0	0	0	0	1
17	Jorhat	0	0	0	5	0	5	2	1
18	Kamrup	4	1	12	5	9	2	3	2
19	Karbi Anglong	1	2	2	4	2	8	0	3
20	Karimganj	6	1	2	3	3	4	4	2
21	Kokrajhar	0	0	0	0	0	1	0	1
22	Lakhimpur	3	1	1	4	4	2	3	0
23	Majuli	0	0	0	0	0	0	0	0
24	Morigaon	3	0	0	0	2	2	0	1
25	Nagaon	5	0	1	1	4	4	1	2
26	Nalbari	0	0	0	1	0	0	0	1
27	Sivasagar	0	0	0	1	0	0	0	2
28	Sonitpur	3	1	0	2	1	3	3	5
29	Tinsukia	2	0	2	3	4	2	1	7
30	Udalgudi	0	0	0	0	0	2	2	2
31	West Karbi Anglong	0	0	0	0	0	0	1	0
	Total	43	14	32	42	66	42	41	56

Table 13: Periodic variation in suitability Classes of Iron in groundwater of Assam (Pre-monsoon NHS 2024)

Periodic variation in suitibility classes of Iron in groundwater of Assam										
Parameter	Class	percentage of samples								Periodic Variation 2017-2024
		2017 (n=114)	2018 (n=122)	2019 (n=165)	2020 (n=165)	2021 (n=255)	2022 (n=182)	2023 (n=483)	2024 (n=312)	
Iron as Fe	< 1.0 mg/L	62.28	88.52	80.61	74.55	74.12	76.92	79.92	82.05	19.77
	>1.0 mg/L	37.72	11.48	19.39	25.45	25.88	23.08	20.08	17.95	-19.77



5.1.4 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).

PRESENT DAY SCENARIO IN ASSAM: ARSENIC

Distribution of Arsenic

- The arsenic value of ground waters in the State varies from 0.0007 µg/L at Chandardigha, Dhubri district to 85.19 µg/L at Patharkandi, Karimganj district.
- Grouping water samples based on arsenic values, it is found that an average of 2.88% of them have arsenic above the permissible limit of 0.01 mg/L.
- The map showing aerial distribution of arsenic (Figure 9) signifies that sporadic occurrence of arsenic is observed in few pockets of Barpeta, Goalpara, Golaghat, Karbi-anglong, Kokrajhar, Lakhimpur, Sibsagar, Nalbari, Karimganj (One location each).
- The Table 14 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 15&16), of eight years showing increasing trend in arsenic content since 2017 in terms of number of districts affected, however number of locations affected is low as compared to 2017.

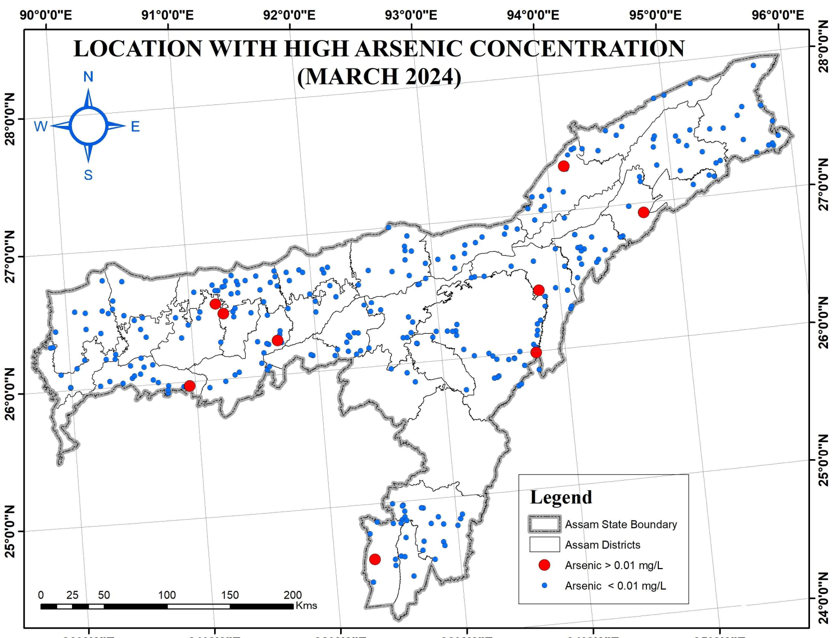


Figure 9: Map showing distribution of Arsenic in Assam based on pre-monsoon and post-monsoon NHS 2024 Data

Table 14: District wise Range and distribution of Arsenic in shallow GW of Assam (Pre-monsoon NHS 2024)

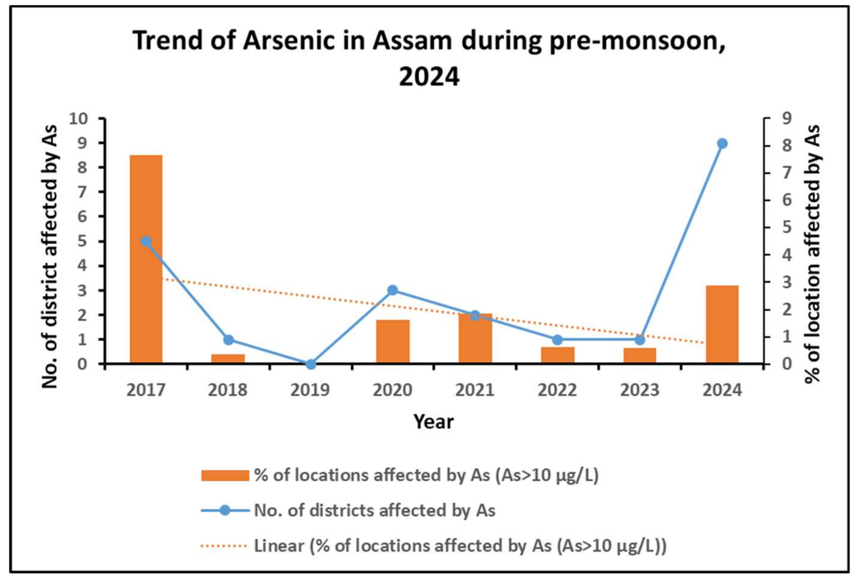
Arsenic (µg/L)										
Sl. No.	District	No. of sample analysed	Permissible limit	Desirable limit	Min	Max	Mean	No. of sample (%) <=10	No. of sample (%) >10
1	Baksa	19	0.01	0.01	0.11	2.37	0.74	100.00	0.00
2	Barpeta	9	0.01	0.01	0.19	67.62	8.35	88.89	11.11
3	Biswanath	10	0.01	0.01	0.07	4.11	0.72	100.00	0.00
4	Bongaigaon	4	0.01	0.01	0.02	0.15	0.08	100.00	0.00
5	Cachar	19	0.01	0.01	0.09	6.52	0.66	92.86	7.14
6	Charaideo	3	0.01	0.01	0.23	0.39	0.21	100.00	0.00
7	Chirang	4	0.01	0.01	0.17	0.36	0.24	100.00	0.00
8	Darrang	5	0.01	0.01	0.07	6.01	1.38	100.00	0.00
9	Dhemaji	7	0.01	0.01	0.13	2.86	0.89	100.00	0.00
10	Dhubri	10	0.01	0.01	0.00	4.58	0.89	100.00	0.00
11	Dibrugarh	11	0.01	0.01	0.12	2.30	0.74	100.00	0.00
12	East Karbi Anglong	6	0.01	0.01	0.35	9.35	2.43	100.00	0.00
13	Goalpara	18	0.01	0.01	0.03	24.11	1.63	94.44	5.56
14	Golaghat	12	0.01	0.01	0.02	25.78	2.78	91.67	8.33
15	Hailakandi	5	0.01	0.01	0.06	6.49	1.76	100.00	0.00
16	Hojai	4	0.01	0.01	0.07	0.27	0.20	100.00	0.00
17	Jorhat	15	0.01	0.01	0.01	4.22	0.94	100.00	0.00
18	Kamrup	21	0.01	0.01	0.05	22.74	1.60	95.24	4.76
19	Karbi Anglong	25	0.01	0.01	0.05	20.75	1.50	96.00	4.00
20	Karimganj	9	0.01	0.01	0.06	85.20	10.35	88.89	11.11
21	Kokrajhar	9	0.01	0.01	0.02	1.23	0.45	100.00	0.00
22	Lakhimpur	14	0.01	0.01	0.02	16.94	1.73	92.86	7.14
23	Majuli	1	0.01	0.01	0.02	0.02	0.02	100.00	0.00
24	Morigaon	9	0.01	0.01	0.04	6.04	2.10	100.00	0.00
25	Nagaon	13	0.01	0.01	0.02	2.76	0.76	100.00	0.00
26	Nalbari	6	0.01	0.01	0.15	35.06	7.56	83.33	16.67
27	Sivasagar	5	0.01	0.01	0.37	13.37	3.87	80.00	20.00
28	Sonitpur	13	0.01	0.01	0.14	2.03	0.70	100.00	0.00
29	Tinsukia	14	0.01	0.01	0.07	3.23	0.64	100.00	0.00
30	Udalgudi	8	0.01	0.01	0.17	1.08	0.55	100.00	0.00
31	West Karbi Anglong	4	0.01	0.01	0.05	0.84	0.29	100.00	0.00
		312							

Table 15: Comparative Change in number of locations having Arsenic >0.01 mg/L (Pre-monsoon NHS 2024)

Sl. No.	District	No. of locations having Arsenic > 0.01mg/litre							
		2017	2018	2019	2020	2021	2022	2023	2024
1	Baksa	0	0	0	0	0	0	0	0
2	Barpeta	0	0	0	0	0	0	0	1
3	Biswanath	0	0	0	0	0	0	0	0
4	Bongaigaon	0	0	0	0	0	0	0	0
5	Cachar	0	0	0	1	0	0	1	0
6	Charaideo	-	-	-	-	-	-	-	0
7	Chirang	0	0	0	0	0	0	0	0
8	Darrang	0	0	0	0	0	0	0	0
9	Dhemaji	0	0	0	0	0	0	0	0
10	Dhubri	0	0	0	0	0	0	0	0
11	Dibrugarh	0	0	0	0	0	0	0	0
12	East Karbi Anglong	0	0	0	0	0	0	0	0
13	Goalpara	0	0	0	0	0	0	0	1
14	Golaghat	0	0	0	0	0	0	0	1
15	Hailakandi	0	0	0	0	0	0	0	0
16	Hojai	0	0	0	0	0	0	0	0
17	Jorhat	0	0	0	0	0	0	0	0
18	Kamrup	1	0	0	1	1	0	0	1
19	Karbi Anglong	2	0	0	0	0	0	0	1
20	Karimganj	0	1	0	0	0	0	0	1
21	Kokrajhar	0	0	0	0	0	0	0	0
22	Lakhimpur	0	0	0	0	0	0	0	1
23	Majuli	0	0	0	0	0	0	0	0
24	Morigaon	6	0	0	0	0	1	0	0
25	Nagaon	11	0	0	0	0	0	0	0
26	Nalbari	0	0	0	0	0	0	0	1
27	Sivasagar	0	0	0	0	0	0	0	1
28	Sonitpur	0	0	0	0	0	0	0	0
29	Tinsukia	0	0	0	0	0	0	0	0
30	Udalgudi	0	0	0	0	0	0	0	0
31	West Karbi Anglong	0	0	0	0	0	0	0	0
	Total	20	1	0	2	1	1	1	9

Table 16: Periodic variation in suitability Classes of Arsenic in groundwater of Assam (Pre-monsoon NHS 2024)

Periodic variation in suitibility classes of Arsenic in groundwater of Assam										
Parameter	Class	percentage of samples								Periodic Variation 2017-2024
		2017 (n=114)	2018 (n=122)	2019 (n=165)	2020 (n=165)	2021 (n=255)	2022 (n=182)	2023 (n=483)	2024 (n=312)	
Arsenic as As	< 0.01 mg/L	82.46	99.18	100.00	98.79	99.61	99.45	98.14	97.12	14.66
	>0.01 mg/L	17.54	0.82	0.00	1.21	0.39	0.55	1.86	2.88	-14.66



GROUND WATER QUALITY SCENARIO FOR AGRICULTURE IN ASSAM

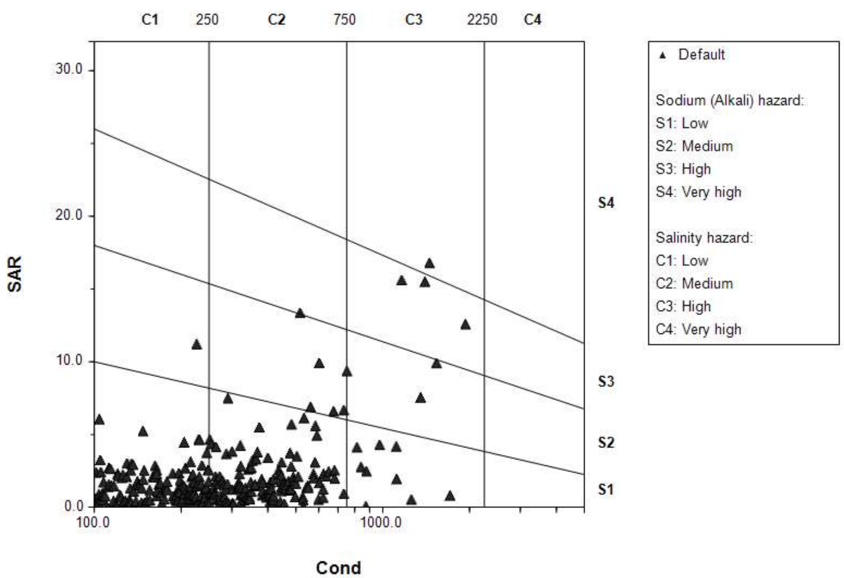


Figure 10: USSL salinity diagram for classification of ground water in Assam during pre-monsoon 2024.

Table 17: Classification of pre-monsoon ground water samples of Assam for irrigation purposes.

Parameters	Range	Classification	Number of samples
Salinity hazard (EC) (µS/cm)	<250	Excellent	164
	250-750	Good	132
	750-2000	Permissible	16
	2000-3000	Doubtful	0
	>3000	Unsuitable	0
Alkalinity hazard (SAR)	<10	Excellent	312
	10--18	Good	0
	18-26	Doubtful	0
	>26	Unsuitable	0
Percent Sodium (% Na)	<20	Excellent	66
	20-40	Good	71
	40-60	Permissible	84
	60-80	Doubtful	64
	>80	Unsuitable	27
Kelly's Index (KI)	<1	Suitable	198
	>1	Unsuitable	114
Residual sodium carbonate (RSC)	<1.25	Suitable	269
	1.25-2.5	Marginally suitable	24
	>2.5	Unsuitable	19
Soluble Sodium Percentage (SSP)	<50	Suitable	197
	>50	Unsuitable	115

As per the RSC value-based classification of irrigation water given by Lloyd and Heathcote, 86.21% samples in pre-monsoon season are suitable for irrigation and only 7.69% samples fall under marginally suitable and 6.09% samples falls under unsuitable category.

DISTRICT WISE CONTAMINANT WISE STATUS SUMMARY BASED ON NHS 2023 PRE- MONSOON DATA

Table 18: Summary of Groundwater Quality in Various Districts of Assam, Highlighting Basic Parameters (Electrical Conductivity, Nitrate, Fluoride) and Heavy Metals (Iron, Arsenic, Uranium)

Summery of GW quality (Pre-monsoon 2023)								
District	Total no. of Basic samples	EC	NO3	F	Total no. of HM Samples	Fe	As	U
		(µs/cm) 25°C	mg/l	mg/l		ppm	ppb	ppb
Baksa	19	0 (0%)	0 (0%)	0 (0%)	19	5(26.32%)	0 (0%)	0 (0%)
Barpeta	9	0 (0%)	1 (11.11%)	0 (0%)	9	1 (11.11%)	1 (11.11%)	0 (0%)
Biswanath	10	0 (0%)	0 (0%)	0 (0%)	10	0 (0%)	0 (0%)	0 (0%)
Bongaigaon	4	0 (0%)	0 (0%)	0 (0%)	4	2(67%)	0 (0%)	0 (0%)
Cachar	19	0 (0%)	0 (0%)	0 (0%)	19	3(15.79%)	0 (0%)	0 (0%)
Charaideo	3	0 (0%)	0 (0%)	0 (0%)	3	0 (0%)	0 (0%)	0 (0%)
Chirang	4	0 (0%)	1 (25%)	0 (0%)	4	1 (25%)	0 (0%)	0 (0%)
Darrang	5	0 (0%)	1 (20%)	0 (0%)	5	1(20%)	0 (0%)	0 (0%)
Dhemaji	7	0 (0%)	0 (0%)	0 (0%)	7	0 (0%)	0 (0%)	0 (0%)
Dhubri	10	0 (0%)	0 (0%)	0 (0%)	10	0 (0%)	0 (0%)	0 (0%)
Dibrugarh	11	0 (0%)	0 (0%)	0 (0%)	11	6(54.55%)	0 (0%)	0 (0%)
East Karbi Anglong	6	0 (0%)	0 (0%)	0 (0%)	6	2(33.33%)	0 (0%)	0 (0%)
Goalpara	18	0 (0%)	0 (0%)	0 (0%)	18	6(33.33%)	1 (5.56%)	0 (0%)
Golaghat	12	0 (0%)	0 (0%)	0 (0%)	12	0 (0%)	1 (8.33%)	0 (0%)
Hailakandi	5	0 (0%)	0 (0%)	0 (0%)	5	1 (20%)	0 (0%)	0 (0%)
Hojai	4	0 (0%)	0 (0%)	0 (0%)	4	1 (25%)	0 (0%)	0 (0%)
Jorhat	15	0 (0%)	0 (0%)	0 (0%)	15	1 (6.67%)	0 (0%)	0 (0%)
Kamrup	21	0 (0%)	0 (0%)	1 (4.76%)	21	2 (9.52%)	1 (4.76%)	0 (0%)
Karbi Anglong	25	0 (0%)	0 (0%)	1 (4%)	25	3 (12%)	1 (4%)	0 (0%)
Karimganj	9	0 (0%)	0 (0%)	0 (0%)	9	2 (22.22%)	1 (11.11%)	0 (0%)
Kokrajhar	9	0 (0%)	0 (0%)	0 (0%)	9	1 (11.11%)	0 (0%)	0 (0%)
Lakhimpur	14	0 (0%)	0 (0%)	0 (0%)	14	0 (0%)	1 (7.14%)	0 (0%)
Majuli	1	0 (0%)	0 (0%)	0 (0%)	1	0 (0%)	0 (0%)	0 (0%)
Morigaon	9	0 (0%)	1 (11.11%)	0 (0%)	9	1 (11.11%)	0 (0%)	0 (0%)
Nagaon	13	0 (0%)	0 (0%)	0 (0%)	13	2 (15.38%)	0 (0%)	0 (0%)
Nalbari	6	0 (0%)	0 (0%)	0 (0%)	6	1 (16.67%)	1 (16.67%)	0 (0%)
Sivasagar	5	0 (0%)	0 (0%)	0 (0%)	5	2 (40%)	1 (20%)	0 (0%)
Sonitpur	13	0 (0%)	0 (0%)	0 (0%)	13	5 (38.46%)	0 (0%)	0 (0%)
Tinsukia	14	0 (0%)	1 (7.14%)	0 (0%)	14	7(50%)	0 (0%)	0 (0%)
Udalgudi	8	0 (0%)	0 (0%)	0 (0%)	8	2(25%)	0 (0%)	0 (0%)
West Karbi Anglong	4	0 (0%)	0 (0%)	0 (0%)	4	0 (0%)	0 (0%)	0 (0%)
Total	312	0 (0%)	5 (1.60%)	2 (0.64%)	312	56 (17.95%	9 (2.88%)	0 (0%)

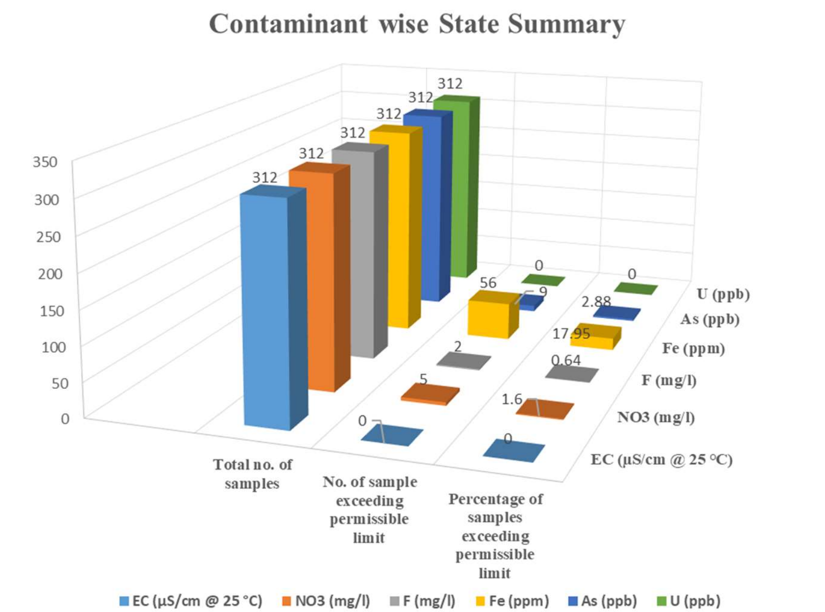


Figure 11: Graph showing contaminant wise state summary

The groundwater quality assessment in Assam revealed no significant change in levels of contamination across various parameters. Iron (Fe) emerged as the predominant contaminant, with average 20.20% of samples crossing the permissible limits of 1.0 mg/L followed by manganese. Sporadic occurrences of nitrate, fluoride and arsenic exceeding permissible limits have been observed in few districts. The concentration of heavy metals viz. Uranium, Copper, Cadmium, Mercury, Chromium, Zinc, Copper, Mercury, Selenium etc. are found out to be within the permissible limit of BIS.

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

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

Clasiification range of WQI	Water quality status	No. of samples	% of samples	Classification based on
<50	Excellent	254	81.41	Yenugu et al. 2020
50-100	Good	55	17.63	
101-200	Poor	3	0.96	
201-300	Very poor	0	0.00	
>300	Unsuitable for drinking	0	0.00	

The WQI of the samples are mostly classified as excellent and good. Less than 1.0% of the samples are classified as poor water. These few samples are from Karbi Anglong, Morigaon and Nagaon districts

Summary

The groundwater quality assessment for Assam 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 (81.41%) fall in the "Excellent" category, while 17.63% are classified as "Good." "Poor," while 0.96% fall in "Very Poor," and No samples fall under "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. It is observed that Increasing trend in arsenic content since 2017 in terms of number of districts affected, however number of locations affected is low as compared to 2017.

The US Salinity Laboratory (USSL) Diagram analysis shows that most groundwater samples fall under the C1S1, C2S1 category, indicating the low salinity levels with low concentrations of sodium and chloride ions and overall low Total Dissolved Solids (TDS). Some samples fall under medium to high salinity but no sample fall under very high sodium and salinity hazard suggesting a slight deterioration in the water samples in term of irrigation.

Recommendations

REMEDIAL MEASURES FOR ARSENIC

a) Precipitation processes

This includes coagulation/filtration, direct filtration, coagulation assisted microfiltration, enhanced coagulation, lime softening, and enhanced lime softening. Adsorption co-precipitation with hydrolyzing metals such as Al^{3+} and Fe^{3+} is the most common treatment technique for removing arsenic from water. Sedimentation followed by rapid sand filtration or direct filtration or microfiltration is used to remove the precipitate. Coagulation with iron and aluminum salts and lime softening is the most effective treatment process. To improve efficiency of this method, a priory oxidation of As (III) to As (V) is advisable. Hypochlorite and permanganate are commonly used for the oxidation. The major techniques based on this process include; Bucket treatment unit, Fill and draw treatment unit, Tubewell-attached arsenic treatment unit and Iron arsenic treatment unit.

b) Adsorptive processes

Adsorption on to activated alumina, activated carbon and iron/ manganese oxide based or coated filter media. Adsorptive processes involve the passage of water through a contact bed where arsenic is removed by surface chemical reactions. The activated alumina-based sorptive media are being used in Bangladesh and India. Granular ferric hydroxide is a highly effective adsorbent used for the adsorptive removal of arsenate, arsenite, and phosphorous from natural water. In the Sono 3-Kolshi filter, used in Bangladesh and India zero valent iron fillings, sand, brick chips and wood coke are used as adsorbent to remove arsenic and other trace elements from groundwater.

c) Ion-exchange processes

This is similar to that of activated alumina, however, in this method the medium is synthetic resin of relatively well-defined ion exchange capacity. In these processes, ions held electrostatically on the surface of a solid phase are exchanged for ions of similar charge dissolved in water. Usually, a synthetic anion exchange resin is used as a solid. Ion exchange removes only negatively charged As(V) species. If As (III) is present, it is necessary to oxidise it.

d) Membrane processes

This includes nano-filtration, ultrafiltration, reverse osmosis and electrodialysis in which synthetic membranes are used for removal of many contaminants including arsenic. They remove arsenic through filtration, electric repulsion, and adsorption of arsenic-bearing compounds.

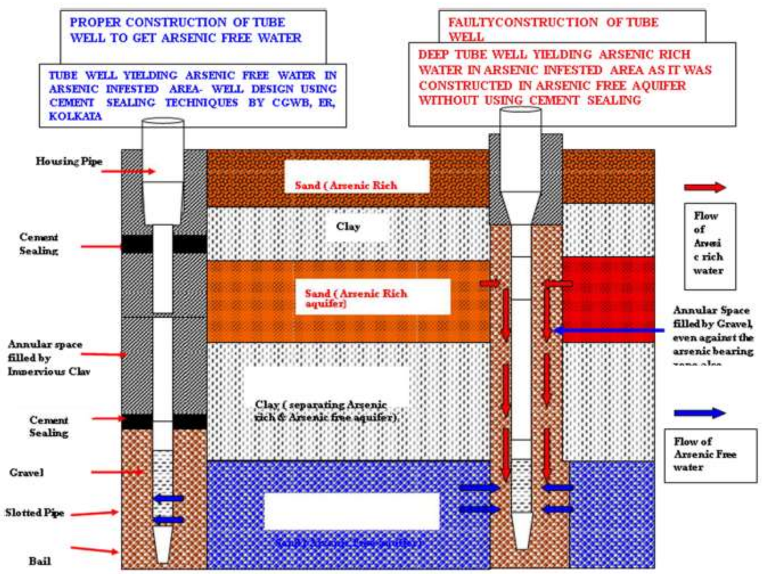
e) Arsenic safe alternate aquifers

This technique advocates tapping of safe alternate aquifers right within the affected areas. Detailed CGWB exploration, isotope and hydro-chemical modeling carried out by CGWB along with other agencies like BARC has indicated that the deep aquifers (>100 m bgl) underneath the contaminated shallow aquifer, have been normally found as arsenic free.

Cement sealing technique of CGWB towards Mitigation of Arsenic Contamination

Based on the findings of the studies and experience of ground water exploration, CGWB has developed certain methods for constructing

arsenic free wells by employing suitable designing of wells and cement sealing techniques (Scheme 1). Such techniques of construction of contaminant free bore wells/tube wells are shared with the state ground water departments to use them in similar terrains.
In the multi-aquifer system, the cement sealing technique was adopted to prevent the mixing of arsenic contaminated water with arsenic free ground water. So far, 522 exploratory wells tapping arsenic safe aquifers have been constructed by CGWB under NAQUIM programme with this technique. The innovative cement sealing technique of CGWB has been shared with the state agencies to utilize to construct arsenic free wells.



Scheme 1: Cement sealing technique to prevent the mixing of arsenic contaminated water with arsenic free ground water

REMEDIAL MEASURES FOR FLUORIDE

(a) Adsorption and ion exchange

In adsorption process fluoride enriched water is passed through a contact bed of adsorbent used, the Fluoride gets adsorbed on adsorbent surface and easily gets removed by ion exchange or surface chemical reaction. After a period of operation, saturated adsorbents must be refilled or regenerated. Various adsorbents used for fluoride removal include Activated Alumina (AA), Bone char, Bauxite, Hematite, Magnesia, various rare earth materials, fly ash, limestone and clay, polymeric resins, granular ceramics.

(b) Coagulation-precipitation

Precipitation methods are based on the addition of chemicals (coagulants and coagulant aids) and the subsequent precipitation of a sparingly soluble fluoride salt as insoluble. Fluoride removal is accomplished with separation of solids from liquid. Aluminium salts (eg. Alum), lime, Poly Aluminium Chloride, Poly Aluminium Hydroxy sulphate and Brushite are some of the frequently used materials in defluoridation by precipitation technique. **The best example for this technique is the famous *Nalgonda technique*.**

Nalgonda Technique

Nalgonda technique involves addition of Aluminium salts, lime and bleaching powder followed by rapid mixing, flocculation, sedimentation, filtration and disinfection. The Nalgonda technique can be used for raw water having fluoride concentration between 1.5 and 20 mg/L and the total dissolved solids should be <1500 mg/L, and total hardness < 600 mg/L. The alkalinity of the water to be treated must be sufficient to ensure complete hydrolysis of alum added to it and to retain a minimum residual alkalinity of 1 - 2 meq/L in the treated water to achieve a pH of 6.5 - 8.5 in treated water.

(c) Ionic Separation Processes

Reverse osmosis, nanofiltration, dialysis and electro dialysis are physical methods that have been tested for defluoridation of water. Though they are effective in removing fluoride salts from water, owever, there are certain procedural disadvantages that limit their usage on a large scale.

REMEDIAL MEASURES FOR IRON/MANGANSESE

(i) Oxidation and filtration

Before iron and manganese can be filtered, they need to be oxidized to a state in which they can form insoluble complexes. Ferrous iron (Fe^{2+}) is oxidized to ferric iron (Fe^{3+}), which readily forms the insoluble iron hydroxide complex $Fe(OH)_3$. Manganese (Mn^{2+}) is oxidized to (Mn^{4+}), which forms insoluble (MnO_2). The common chemical oxidants in water treatment are chlorine, chlorine dioxide, potassium permanganate and ozone. The dose of potassium permanganate, however, must be carefully controlled. Too little permanganate will not oxidize all the iron and manganese, and too much will allow permanganate to enter the distribution system and cause a pink color.

Ozone may be used for iron and manganese oxidation. Ozone may not be effective for oxidation in the presence of humic or fulvic materials. If not dosed carefully, ozone can oxidize reduced manganese to permanganate and result in pink water formation as well. Manganese dioxide particles, also formed by oxidation of reduced manganese, must be carefully coagulated to ensure their removal.

A low-cost method of providing oxidation is to use the oxygen in air as the oxidizing agent. Water is simply passed down a series of porous trays to provide contact between air and water. No chemical dosing is required. This method is not effective for water in which the iron is complexed with humic materials or other large organic molecules.

Oxidation and Filtration Method for Fe and Mn Removal from Ground Water. In general, manganese oxidation is more difficult than iron because the reaction rate is slower. A longer detention time (10 to 30 minutes) following chemical addition is needed prior to filtration to allow the reaction to take place. Manganese greensand is by far the most common medium in use for removal of iron and manganese through pressure filtration. Greensand is a processed material consisting of nodular grains of the zeolite mineral glauconite. The material is coated with manganese oxide. The ion exchange properties of the glauconite facilitates the bonding of the coating. This treatment gives the media a catalytic effect in the chemical oxidation reduction reactions necessary for iron and manganese removal. This coating is maintained through either continuous or intermittent feed of potassium permanganate.

Anthra/sand (also iron-man sand) are other types of media available for removal of iron and manganese. They consist of select anthracite and sand with a chemically bonded manganese oxide coating.

Electromedia is a proprietary multi-media formulation which uses a naturally occurring zeolite and does not require potassium permanganate regeneration. Finally, macrolite, is a manufactured ceramic material with a spherical shape and a rough, textured surface. The principal removal mechanism is physical straining rather than contact oxidation or adsorption. Each medium has its advantages and disadvantages. Selection of a medium and oxidant should be based on pilot testing in which all necessary design criteria can be determined.

ii) *Ion Exchange*

Ion exchange should be considered only for the removal of small quantities of iron and manganese because there is a risk of rapid clogging. Ion exchange involves the use of synthetic resins where a pre-saturate ion on the solid phase (the “adsorbent,” usually sodium) is exchanged for the unwanted ions in water. One of the major difficulties in using this method for controlling iron and manganese is that if any oxidation occurs during the process, the resulting precipitate can coat and foul the media. Cleaning would then be required using acid or sodium bisulfate.

iii) *Combined Photo-Electrochemical (CPE) Method*

Different processes, such as electrochemical (EC), photo (UV), and combined photo-electrochemical (CPE) methods are used. A cell containing aluminium electrode as anode, graphite electrode as cathode and UV lamp are used and filled with waste water enriched with iron and manganese as an electrolytic solution. A limited quantity of sodium chloride salt is added to enhance the electric conductivity through the solution. A comparison between different methods was undertaken to evaluate the applied conditions and the efficiency of Fe and Mn removal at different times and initial concentrations. The results revealed that CPE method was the best choice for the simultaneous removal of both iron and manganese in a short time < 10 min.

iv) *Sequestration*

This method is the addition of chemicals to groundwater aimed at controlling problems caused by iron and manganese without removing them. These chemicals are added to groundwater at the well head or at the pump intake before the water has a chance to come in contact with air or chlorine. If the water contains less than 1.0 mg/L iron and less than 0.3 mg/L manganese, using polyphosphates followed by chlorination can be an effective and inexpensive method for mitigating iron and manganese problems. No sludge is generated in this method. Below these concentrations, the polyphosphates combine with the iron and manganese preventing them from being oxidized. Any of the three polyphosphates (pyrophosphate, tripolyphosphate, or metaphosphate) can be used. Applying sodium silicate and chlorine simultaneously has also been used to sequester iron and manganese. However, while this technique is reliable in the case of iron treatment, it has not been found to be effective in manganese control.

REMEDIAL MEASURES FOR NITRATE

i. Adsorption/Ion Exchange
ii. Reverse Osmosis
iii. Electrodialysis
iv. Bio-chemical Denitrification (By using denitrifying bacteria and microbes)
v. Catalytic Reduction/Denitrification (using hydrogen gas)

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" and few samples fall under poor quality.
- Sporadic occurrences of *nitrate, fluoride, arsenic* exceeding permissible limits have been observed in few districts. *Iron and Manganese* were found to be the predominant contaminant and are of geogenic origin.
- **Localized Issues:** A few samples exhibit marginal or unsuitable characteristics in terms of Kelly's Index, RSC, Percent Sodium and Soluble Sodium Percentage, suggesting localized sodium dominance concerns.
- **Irrigation Suitability:** The observations suggest favourable conditions for irrigation, with minimal risks related to salinity, alkalinity, or sodium hazards, except for isolated cases requiring attention.

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