Volume 2

BULLETIN

GROUND WATER QUALITY OF ARUNACHAL PRADESH

Central Ground Water Board

केंद्रीय भूजल बोर्ड

MINISTRY OF JAL SHAKTI

जल शक्ति मंत्रालय

Department of Water Resources, River Development and Ganga Rejuvenation

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GOVERNMENT OF INDIA

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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 serves as a primary source of water supply for urban, industrial, and agricultural needs in India, playing an increasingly vital role in irrigation. It is a key factor in the country's socioeconomic development. In Asia, over one billion individuals rely directly on this resource for their water supply, with projections indicating that the population residing in water-scarce regions (defined as less than 1,000 m^3/person per year) may exceed 800 million. Despite possessing only 4% of the world's freshwater resources, India supports over 16% of the global population and currently faces a severe water crisis. The Safe Water Index survey indicates that India ranks second to last among 123 nations in terms of safe drinking water access. Although groundwater is generally less vulnerable to pollution compared to surface water, indiscriminate exploitation and over-extraction of groundwater resources can lead to declining water tables and deteriorating water quality. Additionally, there is growing concern regarding groundwater quality degradation stemming from both geogenic processes and anthropogenic activities. The potential contamination of groundwater utilized for public and rural domestic purposes is particularly alarming. Furthermore, factors such as atmospheric precipitation, inland surface water quality, recharge water quality, and geochemical processes significantly influence groundwater quality. Groundwater contamination poses substantial risks to human health, economic development, and social well-being. In Northeast India, as in other regions, anthropogenic activities adversely affect groundwater quality, necessitating urgent attention and management strategies to safeguard this critical resource.

To effectively manage groundwater resources, comprehensive data on both current and potential water quality is essential. Consequently, a detailed understanding of the water resource quality in the state of Arunachal Pradesh is critical for informed groundwater management. Additionally, periodic assessments of groundwater quality are vital for informing users—particularly those relying on it for domestic and agricultural purposes—about potential risks. While numerous studies have documented the poor quality of groundwater, a comprehensive temporal and spatial analysis specific to Arunachal Pradesh has not been conducted.

The present study aims to achieve the following objectives:

1. To delineate the current groundwater quality scenario, categorized by parameters for each district.
2. To identify contemporary hotspots of degraded groundwater quality through spatial variation analysis of the latest 2024 quality data.
3. To evaluate the temporal variations in groundwater quality, highlighting trends of improvement or deterioration from 2017 to 2024, thereby providing insights for effective water quality management strategies.

2.0 STUDY AREA

Also known as “Land of the Rising Sun”, Arunachal Pradesh is a mountaineous area in extreme northeastern part of India. It has an area of 83,743 square kilometers. The state capital is Itanagar. It has a total population of 1382611. Arunachal Pradesh is bounded by Bhutan to the west, Tibet Autonomous Region of China to the north, Myanmar and Nagaland to the south and southeast while Assam to the south and southwest. Arunachal Pradesh spreads within Latitude 26.28° N and 29.30° N and Longitude of 91.20° E and 97.30° E and has an area of 83,743 km^2. Arunachal Pradesh exhibits a climate that varies with elevation and topography. The foothill regions are characterized by a hot and humid subtropical climate, while higher altitudes experience subtropical highland and alpine climates. Summer temperatures in the valleys can reach mid-30°C, and winter temperatures drop to around 13°C, with snowfall in the highest areas. The state receives an average annual rainfall of approximately 3,300 mm, with 70-80% occurring during the wet southwest monsoon from May to October. Till date there is 28 districts in Arunachal Pradesh viz. Tawang, West Kameng, East Kameng, Papum Pare, Kurung Kumey, Kra Daadi, Lower Subansiri, Upper Subansiri, West Siang, East Siang, Siang, Upper Siang, Lower Siang, Dibang Valley, Lower Dibang Valley, Lohit, Anjaw, Changlang, Tirap, Longding, Namsai, Pakke-Kessang, Lepa-Rada, Shi-Yomi, Kamle, Itanagar.

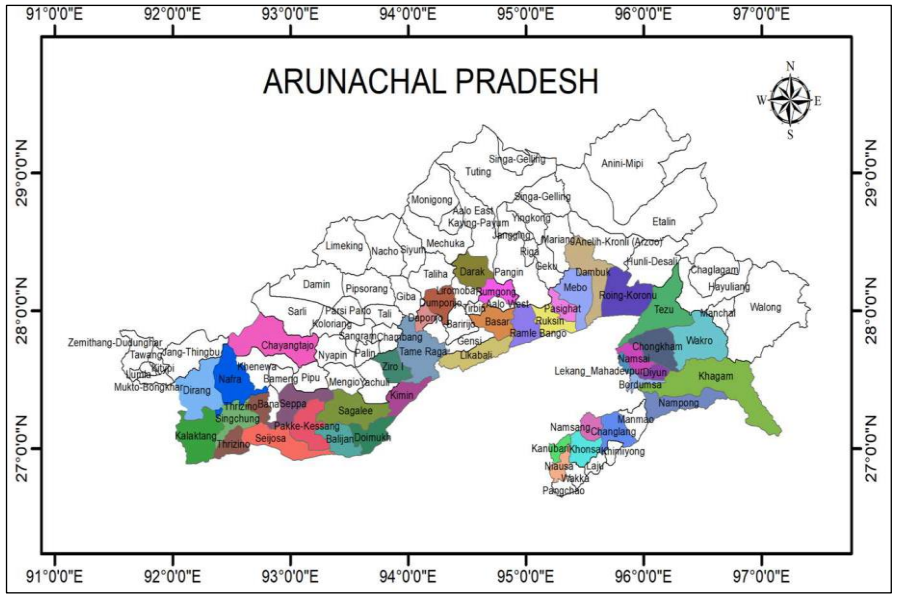
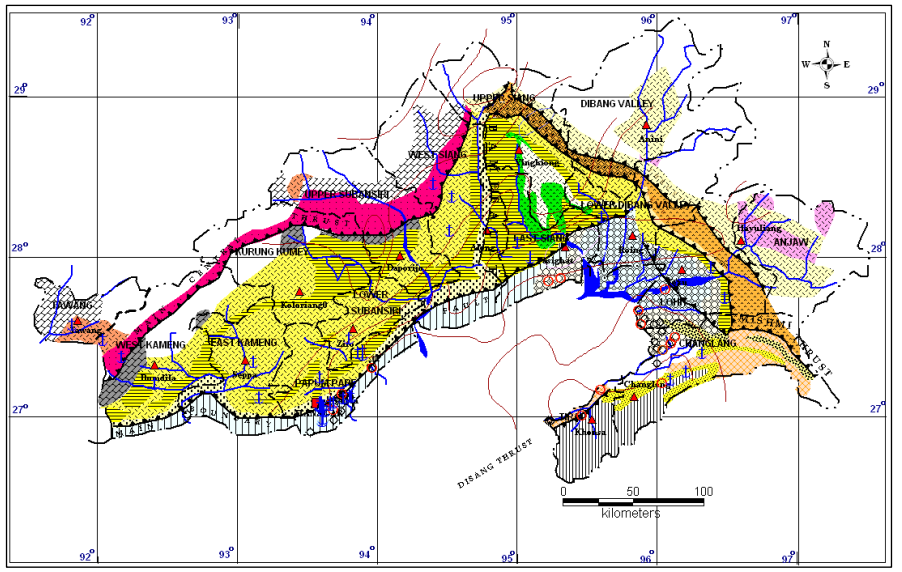


Figure 1: Administrative map showing block boundary (assessment unit).

3.0 HYDROGEOLOGY

The hydrogeology of the state is classified into three main units: consolidated, semi-consolidated, and unconsolidated formations. Consolidated formations, primarily crystalline rocks like gneiss and schist, are mainly found in hill ranges and have limited groundwater potential, although weathered zones can yield water. Semi-consolidated Tertiary formations, including various rock groups, show moderate to poor yield influenced by aquifer geometry. In contrast, the unconsolidated alluvial sediments of Quaternary age, especially in valley areas, serve as significant groundwater repositories with good potential. Groundwater exploration indicates variable discharge and transmissivity across these units, with springs observed in all formations. The region's geology influences recharge and groundwater availability, making the alluvial and terrace deposits crucial for water resource development.



Map Symbol	Description		Groundwater Potentiality
	Thrust		
	Newer Alluvium	Unconsolidated Formation	Moderate yield, 30-50m³/hr. Drawdown within 10 to 15m.
	Older Alluvium		
	Namsang & Dihing Formations	Semi-consolidated Formation	Low yield, up to 20m³/hr. Draw down within 25m.
	Siwalik Group		
	Surma & Naharkatia Groups		
	Barail Group	Consolidated Formation	Low yield, 5 to 15m³/hr in fissured formation
	Disang Group		
	Yingkiong Group		
	Lower Gondwana Group		
	Dirang & Lumla Formations		
	Bomdila Group		
	Se La Group		
	Mishmi Formation		
	Tidding Formation		
	Yang Sangchu Formation		
IGNEOUS ROCKS			
	Tertiary Tourmaline Granite		Yield up to 5m³/hr in metasediments and igneous rocks
	Lohit Granitoid		
	Abor Volcanic		
	Palaeoproterozoic		

Figure 2: Hydrogeology map of Arunachal Pradesh.

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.

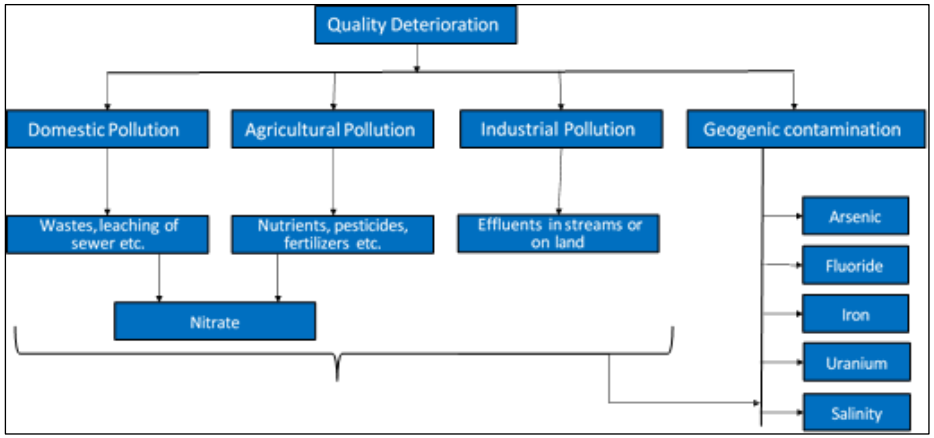


Figure 3: Schematic diagram illustrating the potential factors contributing to the degradation of groundwater quality.

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 2024 through 20 locations located over the state (Figure 4).

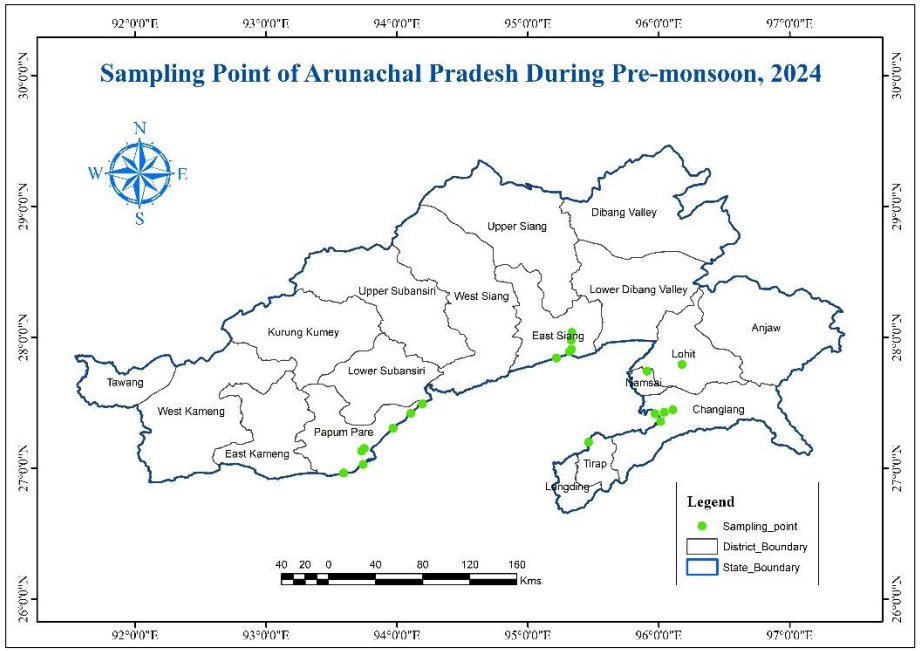


Figure 4: Ground water quality sampling locations in Arunachal Pradesh.

4.0 METHODOLOGY

To assess the groundwater chemistry of Arunachal Pradesh, samples were collected from various locations during March and April (pre-monsoon), a typically dry period that maximizes element concentration, as well as in November (post-monsoon). Sampling adhered to standard procedures established by the American Public Health Association (APHA, 2017). For physical and major solute analysis, 1000 mL samples were collected in high-density polyethylene (HDPE) bottles without preservatives. On-site sampling included filtration through a 0.45 µm membrane using a syringe filtration technique, with the filtrate stored in 60 mL HDPE bottles for uranium and heavy metal analysis. Immediately post-filtration, 0.5 mL of trace-element grade HNO3 was added as a preservative to minimize contamination. Care was taken during bottling to avoid air headspace interference.

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 Arunachal Pradesh is mostly of mixed cations and mixed anions type. 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 Iron has been observed in some parts of the Arunachal Pradesh.

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/I (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 ARUNACHAL PRADESH: ELECTRICAL CONDUCTIVITY (EC)

Distribution of Electrical Conductivity (EC)

- The EC value of ground waters in the State varies from 27.16 at Rajgarh, Lower Subansiri district to 428.6 µS/cm at Ruksin, East Siang district at 25°C.
- Grouping water samples based on EC values, it is found that none of them have EC above 3000µS/cm and all samples are in between 27.16 to 428.6 µS/cm.
- The map showing aerial distribution of EC (Figure 5) in pre-monsoon signifies that EC is well distributed and within the range of prescribed limit throughout the state.
- The Table 2 and Figure 6 provide 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, Figure 7), of eight years showing no significant change.

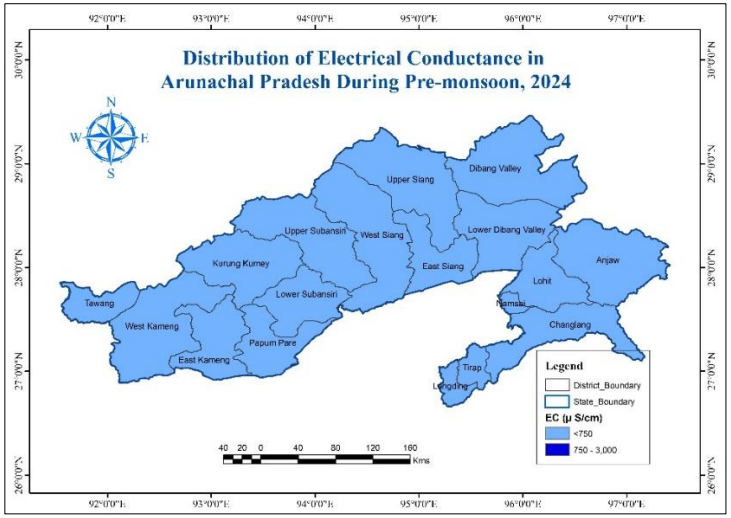


Figure 5: Map showing distribution of Electrical Conductivity in Arunachal Pradesh based on pre-monsoon NHS 2024 Data.

Table 2: District wise EC distribution during pre-monsoon, 2024.

		Electrical Conductivity (µS/cm)							
Sl. No	District	No. of sample analysed	Permissible limit	Desirable limit	Min	Max	Mean	% of sample <=3000	% of sample >3000
1	Changlang	4	3000.00	3000.00	117.40	311.40	178.05	100.00	0.00
2	East Siang	5	3000.00	3000.00	52.60	428.60	144.47	100.00	0.00
3	Lohit	2	3000.00	3000.00	49.62	332.80	191.21	100.00	0.00
4	Lower Subansiri	2	3000.00	3000.00	27.16	49.79	38.48	100.00	0.00
5	Papumpare	6	3000.00	3000.00	96.74	229.50	164.54	100.00	0.00
6	Tirap	1	3000.00	3000.00	147.70	147.70	147.70	100.00	0.00
		20							

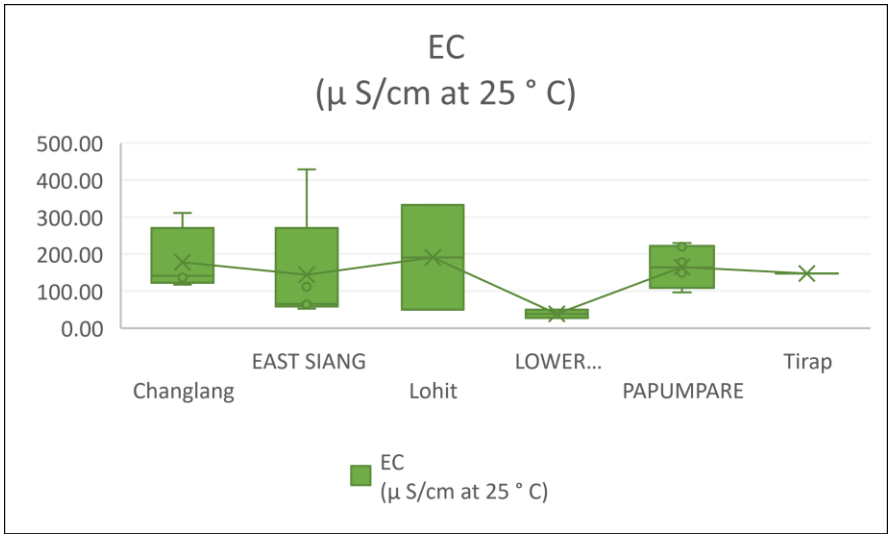


Fig 6: Box plot of EC in different districts.

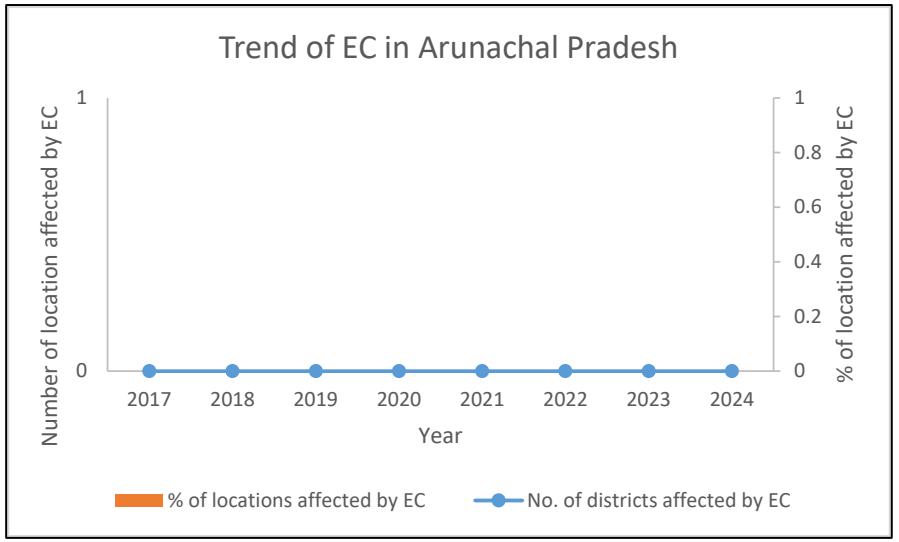


Figure 7: Trend analysis of EC from 2017-2024.

Table 3: Periodic Variation in suitability classes of salinity in groundwater of Arunachal Pradesh.

Periodic variation in suitability classes of Salinity in groundwater of Arunachal Pradesh										
Parameter	Class	percentage of samples								Periodic Variation 2017-2024
		2017	2018	2019	2020	2021	2022	2023	2024	
		(n=32)	(n=21)	(n=19)	(n=20)	(n=18)	(n=17)	(n=40)	(n=20)	
Salinity as EC	<750 µS/cm	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.00
	750-3000 µS/cm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	>3000 µS/cm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	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.

PRESENT DAY SCENARIO IN ARUNACHAL PRADESH: NITRATE

Distribution of Nitrate

- The nitrate value of ground waters in the State varies from 0.45 mg/L at Satmile New, East Siang district to 20.61 mg/L at Nirjuli Village, Papumpare district.
- Grouping water samples based on Nitrate values, it is found that none of them have nitrate above the permissible limit of 45 mg/L.
- The Table 4 provides the number of samples analyzed per district, along with their minimum, maximum, and mean nitrate values which is also shown by box plot (Figure 8) on the basis of pre-monsoon NHS 2024 Data.
- Trend analysis (Table 5, Figure 9), of six years showing no significant change.

Table 4: District wise Nitrate distribution during pre-monsoon, 2024.

Nitrate (mg/L)									
Sl. No.	District	No. of sample analysed	Permissible limit	Desirable limit	Min	Max	Mean	% of sample <=45	% of sample >45
1	Changlang	4	45.00	45.00	1.12	2.53	1.97	100.00	0.00
2	East Siang	5	45.00	45.00	0.45	10.75	4.22	100.00	0.00
3	Lohit	2	45.00	45.00	1.57	2.32	1.94	100.00	0.00
4	Lower Subansiri	2	45.00	45.00	3.99	4.58	4.28	100.00	0.00
5	Papumpare	6	45.00	45.00	2.47	20.61	7.47	100.00	0.00
6	Tirap	1	45.00	45.00	7.68	7.68	7.68	100.00	0.00
		20							

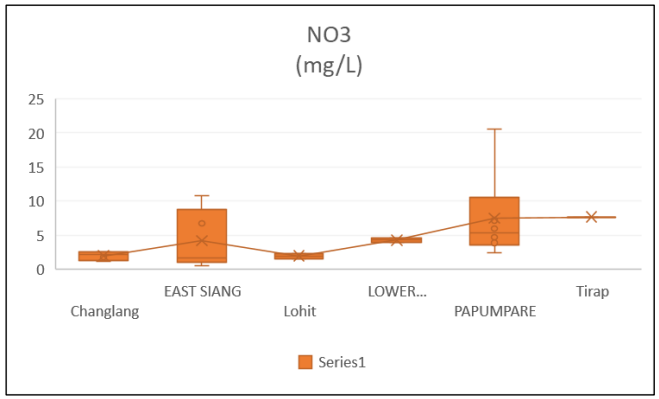


Fig 8: Box plot of NO_3 in different districts.

Table 5: Periodic Variation in suitability classes of nitrate in groundwater of Arunachal Pradesh.

Periodic variation in suitability classes of Nitrate in groundwater of Arunachal Pradesh										
Parameter	Class	percentage of samples								Periodic Variation 2017-2024
		2017	2018	2019	2020	2021	2022	2023	2024	
		(n=32)	(n=21)	(n=19)	(n=20)	(n=18)	(n=17)	(n=40)	(n=20)	
Nitrate as NO_3	< 45 mg/L	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.00
	>45 mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

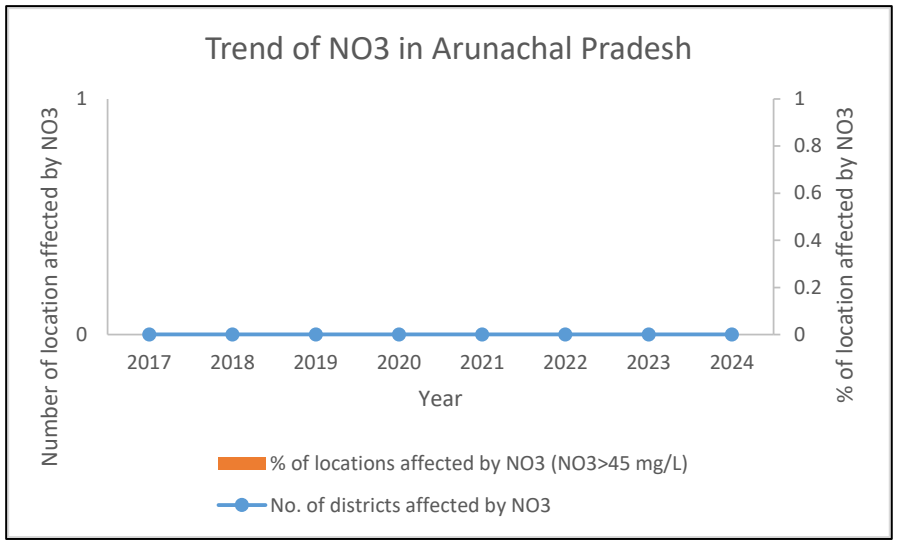


Figure 9: Trend analysis of NO_3 from 2017-2024.

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.

PRESENT DAY SCENARIO IN ARUNACHAL PRADESH: FLUORIDE

Distribution of Fluoride (F)

- The fluoride value of ground waters in the State varies from 0.12 mg/L at Sonajuli, Papumpare district to 1.51 mg/L at Holangi, Papumpare district.
- Grouping water samples based on Fluoride values, it is found that only one location has fluoride above the permissible limit of 1.5 mg/L.
- The map showing aerial distribution of Fluoride (Figure 10) signifies that high fluoride concentrated is observed in Papumpare district (one location).
- The Table 6 & Figure 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 7, Figure 12), of eight years showing increasing trend in Fluoride content. This is for the location having highest fluoride content which is near permissible limit.

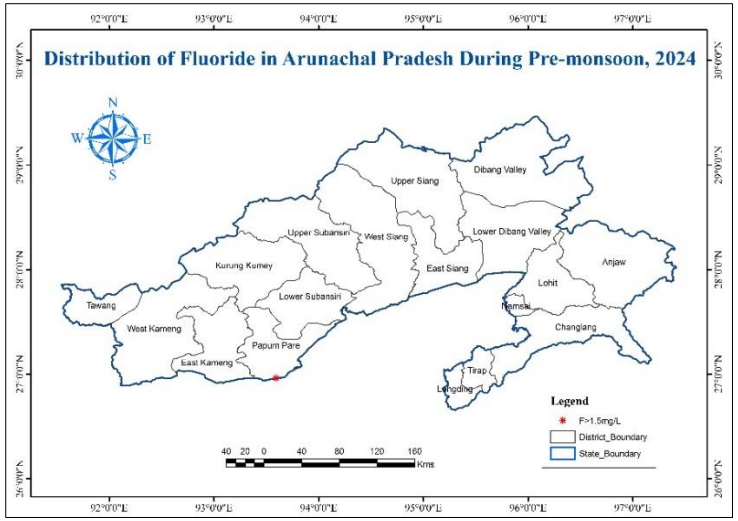


Figure 10: Point map of Fluoride in Arunachal Pradesh based on pre-monsoon NHS 2024 Data.

Table 6: District wise Fluoride distribution during pre-monsoon, 2024.

Fluoride (mg/L)									
Sl. No.	District	No. of sample analysed	Permissible limit	Desirable limit	Min	Max	Mean	% of sample <=1.50	% of sample >1.50
1	Changlang	4	1.50	1.00	0.82	1.09	0.94	100.00	0.00
2	East Siang	5	1.50	1.00	0.43	0.98	0.74	100.00	0.00
3	Lohit	2	1.50	1.00	0.30	0.67	0.49	100.00	0.00
4	Lower Subansiri	2	1.50	1.00	0.78	0.87	0.83	100.00	0.00
5	Papumpare	6	1.50	1.00	0.12	1.51	0.86	83.33	16.67
6	Tirap	1	1.50	1.00	0.75	0.75	0.75	100.00	0.00
		20							

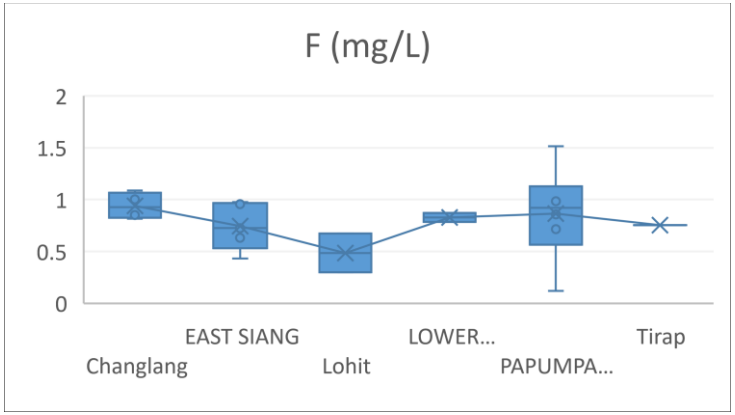


Fig 11: Box plot of NO_3 in different districts.

Table 7: Periodic Variation in suitability classes of Fluoride in groundwater of Arunachal Pradesh.

Periodic variation in suitability classes of Fluoride in groundwater of Arunachal Pradesh										
Parameter	Class	percentage of samples								Periodic Variation 2017-2024
		2017	2018	2019	2020	2021	2022	2023	2024	
		(n=32)	(n=21)	(n=19)	(n=20)	(n=18)	(n=17)	(n=40)	(n=20)	
Fluoride as F	< 1.0 mg/L	100.00	100.00	100.00	100.00	100.00	100.00	100.00	80.00	-20.00
	1.0-1.50 mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	15.00
	>1.50 mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	5.00

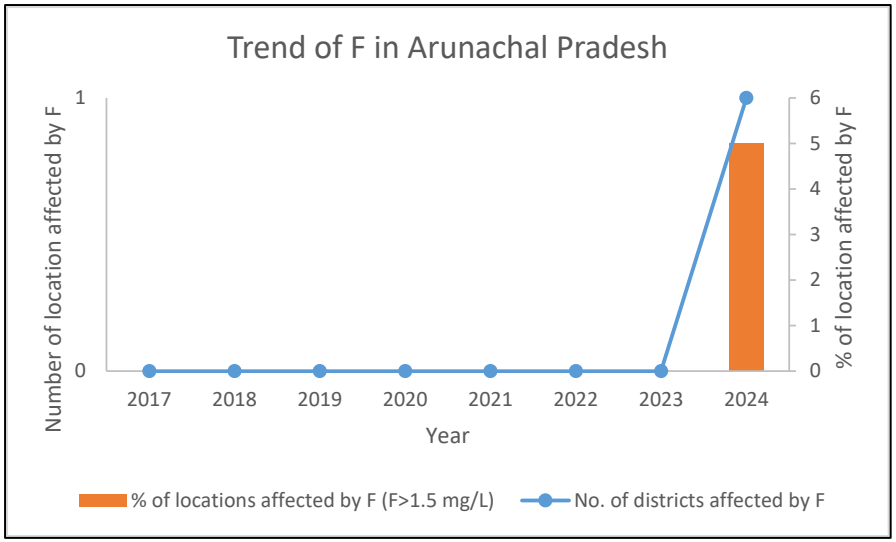


Figure 12: Trend analysis of F from 2017-2024.

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.

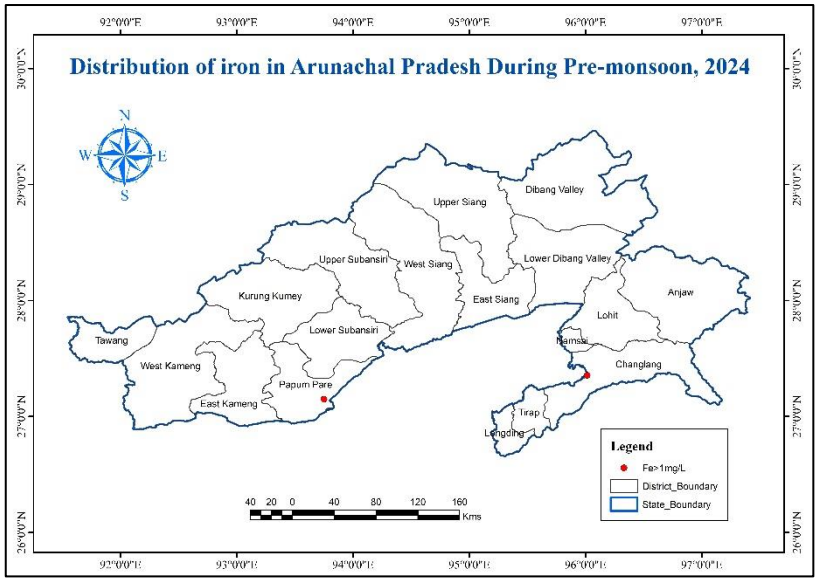


Figure 13: Point map of iron in Arunachal Pradesh based on pre-monsoon NHS 2024 Data.

PRESENT DAY SCENARIO IN ARUNACHAL ADESH: IRON

Distribution of Iron

- The iron value of ground waters in the State varies from 0.0024 mg/L at Oyan, East Siang district to 5.66 mg/L at Jairampur, Changlang district.
- Grouping water samples based on Iron values, it is found that an average of 10% of them have iron above the permissible limit of 1.0 mg/L.
- The map showing aerial distribution of Iron (Figure 13) signifies that high iron concentrated is observed in Papumpare and Changlang districts of Arunachal Pradesh with one location in each district.
- The Table 8 provides for the number of samples analyzed per district, along with their minimum, maximum, and mean iron values and number of samples more than 1.0 mg/L based on pre-monsoon NHS 2024 Data. Figure 14 shows the box plot of the same.
- Trend analysis (Table 9, Figure 15), of eight years showing slight increasing trend in Iron content.

Table 8: District wise Iron distribution during pre-monsoon, 2024.

Iron (mg/L)									
Sl. No.	District	No. of sample analysed	Permissible limit	Desirable limit	Min	Max	Mean	% of sample <=1.00	% of sample >1.00
1	Changlang	4	1.00	1.00	0.07	5.67	1.56	75.00	25.00
2	East Siang	5	1.00	1.00	0.00	0.25	0.06	100.00	0.00
3	Lohit	2	1.00	1.00	0.08	0.66	0.37	100.00	0.00
4	Lower Subansiri	2	1.00	1.00	0.01	0.01	0.01	100.00	0.00
5	Papumpare	6	1.00	1.00	0.01	1.96	0.52	83.33	16.67
6	Tirap	1	1.00	1.00	0.04	0.04	0.04	100.00	0.00
		20							

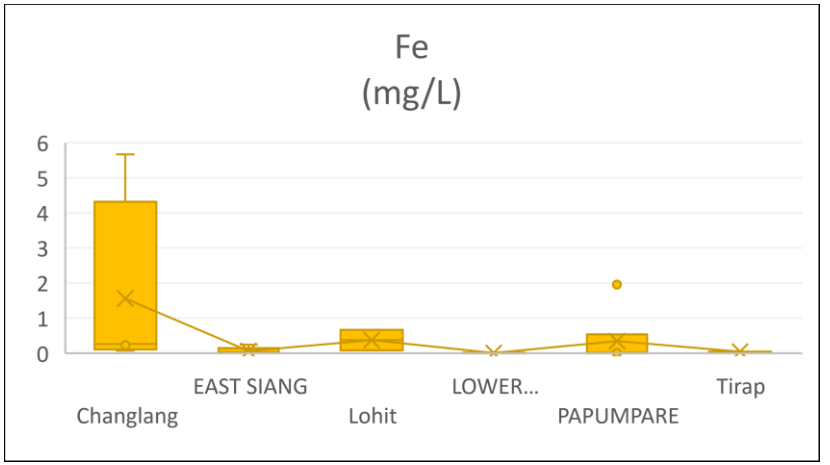


Fig 14: Box plot of NO_3 in different districts.

Table 9: Periodic Variation in suitability classes of Iron in groundwater of Arunachal Pradesh.

Periodic variation in suitability classes of Iron in groundwater of Arunachal Pradesh										
Parameter	Class	percentage of samples								Periodic Variation 2017-2024
		2017	2018	2019	2020	2021	2022	2023	2024	
		(n=32)	(n=21)	(n=19)	(n=20)	(n=18)	(n=17)	(n=40)	(n=20)	
Iron as Fe	< 1.0 mg/L	90.63	85.71	94.74	85.00	83.33	70.59	77.50	90.00	-0.63
	>1.0 mg/L	9.38	14.29	5.26	15.00	16.67	29.41	22.50	10.00	0.63

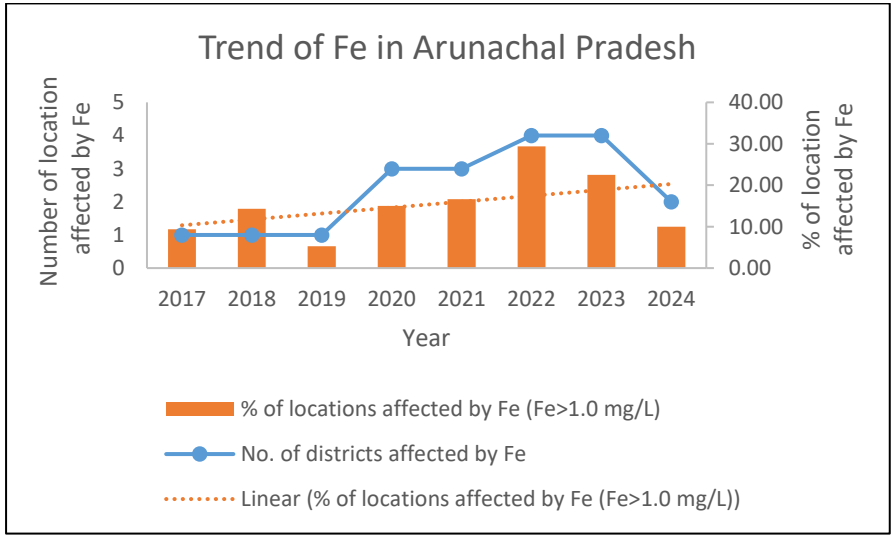


Figure 15: Trend analysis of Fe from 2017-2024.

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 ARUNACHAL PRADESH: ARSENIC

Distribution of Arsenic

- The arsenic value of ground waters in the State varies from 0.009 µg/L at Rajgarh, Lower Subansiri district to 0.0059 mg/L at Doimukh, Papumpare district.
- Grouping water samples based on arsenic values, it is found that none of the samples have arsenic above the permissible limit of 0.01 mg/L.
- The Table 10 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. Figure 16 shows the box plot of the same.
- Trend analysis (Table 11, Figure 17), of eight years showing similar trend in arsenic content since 2017.

Table 10: District wise Arsenic distribution during pre-monsoon, 2024.

	Arsenic (µg/L)								
	District	No. of sample analysed	Permissible limit	Desirable limit	Min	Max	Mean	% of sample <=10	% of sample >10
1	Changlang	4	10.00	10.00	0.03	0.27	0.13	100.00	0.00
2	East Siang	5	10.00	10.00	0.02	0.14	0.06	100.00	0.00
3	Lohit	2	10.00	10.00	0.04	0.17	0.11	100.00	0.00
4	Lower Subansiri	2	10.00	10.00	0.01	0.03	0.02	100.00	0.00
5	Papumpare	6	10.00	10.00	0.13	5.98	1.16	100.00	0.00
6	Tirap	1	10.00	10.00	0.04	0.04	0.04	100.00	0.00
		20							

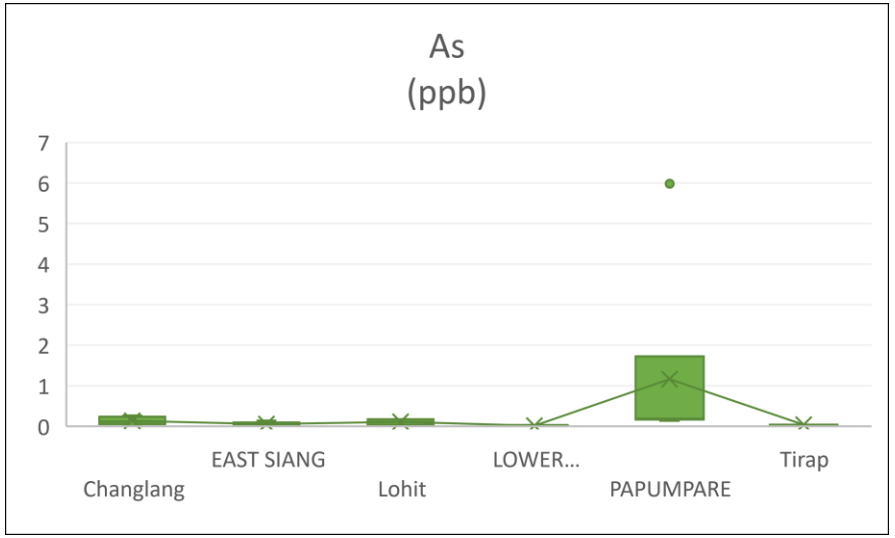


Fig 16: Box plot of Arsenic in different districts.

Table 11: Periodic Variation in suitability classes of Arsenic in groundwater of Arunachal Pradesh.

Periodic variation in suitability classes of Arsenic in groundwater of Arunachal Pradesh										
Parameter	Class	percentage of samples								Periodic Variation 2017-2024
		2017	2018	2019	2020	2021	2022	2023	2024	
		(n=32)	(n=21)	(n=19)	(n=20)	(n=18)	(n=17)	(n=40)	(n=20)	
Arsenic as As	< 0.01 mg/L	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.00
	>0.01 mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

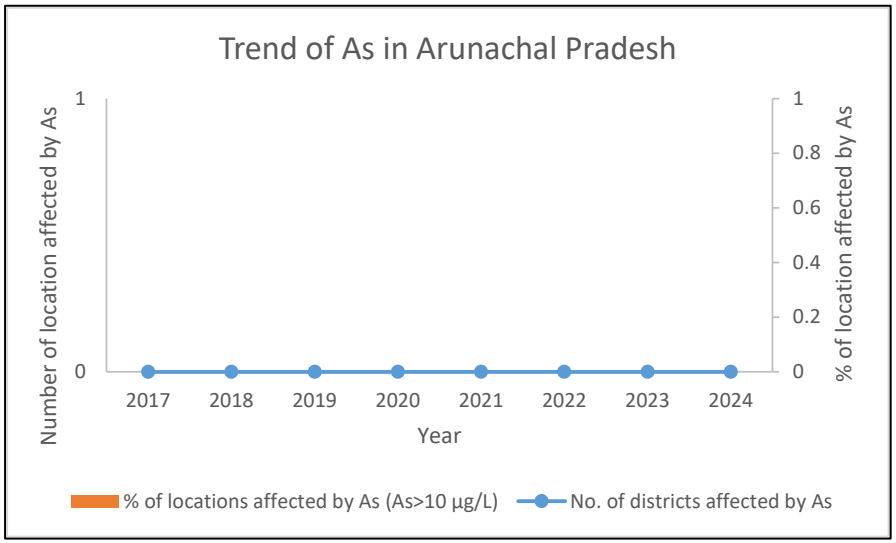
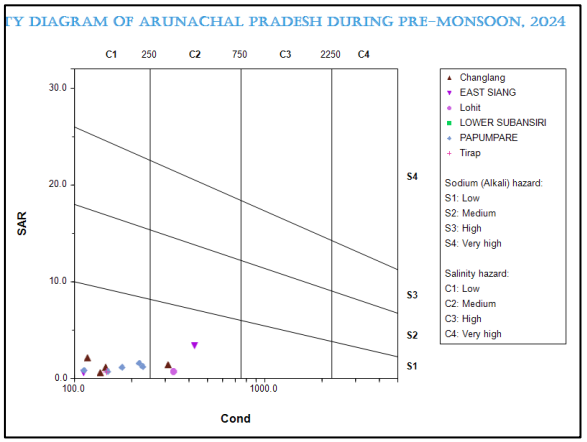


Figure 17: Trend analysis of As from 2017-2024.

GROUND WATER QUALITY SCENARIO FOR AGRICULTURE IN ARUNACHAL PRADESH



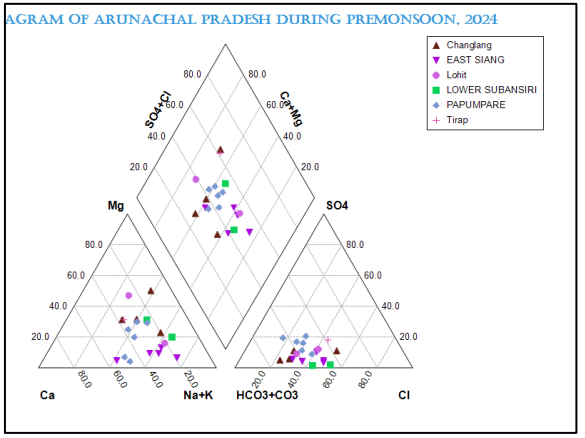


Figure 18: USSL salinity diagram and piper plot for classification of ground water in Arunachal Pradesh during pre-monsoon 2023.

Table 12: Classification of ground water samples of Arunachal Pradesh for irrigation purposes.

Parameters	Range	Classification	Number of samples
Salinity hazard (EC) (µS/cm)	<250	Excellent	17
	250-750	Good	3
	750-2000	Permissible	0
	2000-3000	Doubtful	0
	>3000	Unsuitable	0
Alkalinity hazard (SAR)	<10	Excellent	20
	10--18	Good	0
	18-26	Doubtful	0
	>26	Unsuitable	0
Percent Sodium (% Na)	<20	Excellent	0
	20-40	Good	6
	40-60	Permissible	9
	60-80	Doubtful	5
	>80	Unsuitable	0
Kelly's Index (KI)	<1	Suitable	13
	>1	Unsuitable	7
Residual sodium carbonate (RSC)	<1.25	Suitable	20
	1.25-2.5	Marginally suitable	0
	>2.5	Unsuitable	0
Soluble Sodium Percentage (SSP)	<50	Suitable	13
	>50	Unsuitable	7

As per the RSC value-based classification of irrigation water given by Lloyd and Heathcote, 100% samples are suitable for irrigation.

Summery of GW quality (Pre-monsoon 2023)								
District	Total no. of Basic samples	EC	NO_3	F	Total no. of HM Samples	Fe	As	U
		(µs/cm) 25°C	mg/l	mg/l		ppm	ppb	ppb
Changlang	4	0 (0%)	0 (0%)	0 (0%)	4	1 (25%)	0 (0%)	0 (0%)
East Siang	5	0 (0%)	0 (0%)	0 (0%)	5	0 (0%)	0 (0%)	0 (0%)
Lohit	2	0 (0%)	0 (0%)	0 (0%)	2	0 (0%)	0 (0%)	0 (0%)
Lower Subansiri	2	0 (0%)	0 (0%)	0 (0%)	2	0 (0%)	0 (0%)	0 (0%)
Papumpare	6	0 (0%)	0 (0%)	1 (16.67%)	6	1 (16.67%)	0 (0%)	0 (0%)
Tirap	1	0 (0%)	0 (0%)	0 (0%)	1	0 (0%)	0 (0%)	0 (0%)
Total	20	0 (0%)	0 (0%)	1 (5%)	20	2 (10%)	0 (0%)	0 (0%)

CONTAMINANT WISE STATUS SUMMARY BASED ON NHS 2024 DATA

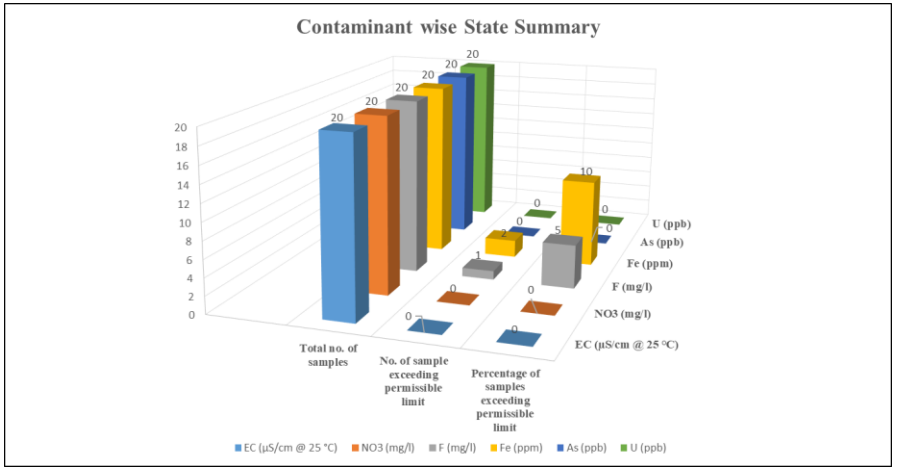


Figure 6: Graph showing contaminant wise state summary.

The groundwater quality assessment in Arunachal Pradesh revealed no significant change in levels of contamination across various parameters. Iron (Fe) emerged as the predominant contaminant, with average 10% of samples crossing the permissible limits of 1.0 mg/L, followed by fluoride with 5% of the samples. The concentration of heavy metals viz. Uranium, Cadmium, 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 season. The samples were classified accordingly as shown below:

Table 13: Classification of ground water samples of Arunachal Pradesh according to WQI

Classification range of WQI	Water quality status	No. of samples	% of samples	Classification based on
<50	Excellent	20	100.00	Yenugu et al. 2020
50-100	Good	0	0.00	
101-200	Poor	0	0.00	
201-300	Very poor	0	0.00	
>300	Unsuitable for drinking	0	0.00	

The WQI of the samples are all classified as excellent. None of the samples are classified as poor water.

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