GROUNDWATER CHEMICAL QUALITY BULLETIN

Andhra Pradesh

ABSTRACT

Periodic ground water quality assessment (2019-24) highlighting the findings, significant trends and groundwater contamination status

CGWB-SR, Andhra Pradesh

1. INTRODUCTION

Ground water is an important resource widely used for drinking, irrigation and industrial purpose. Ground Water plays an important role in the sustainable socio-economic development. In regions with scarcity of fresh surface water sources dependence on ground water increases exponentially. They fulfil substantial proportions of irrigation and drinking water needs. However, heightened reliance on groundwater across various sectors has resulted in declining water quality and dwindling water levels. The ground water quality is dependent upon chemical characteristic of rocks and minerals composition of aquifer material. Due to redox reaction, ions can be dissolved from minerals by dissolution and crystallization within aquifer and concentrate beyond permissible limits. Poor ground water quality can also be due to excessive use of fertilizers, urbanization and industrial effluent discharge. According to UNESCO more than 80% of health issues are caused due to consumption of poor-quality water. Inorganic contaminants including Salinity, Fluoride, Nitrate, Arsenic, Iron and Uranium are important in determining the suitability of ground water for drinking purposes.

Therefore, 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 Andhra Pradesh State is lacking. Our efforts in the present study are to fulfil the following objectives:

- To present current GW quality scenario, parameter wise for each district.
- To identify present day hot spots of poor-quality ground water through spatial variation analysis of latest 2024 quality data.
- To assess temporal variation of ground water quality showing improvement / deterioration during the period from 2019 to 2024, providing insights for effective water quality management measures

2. STUDY AREA

Andhra Pradesh State is the 7th largest state in India covering geographical area of 1,63,000 Km2. It lies between NL 12° 37’ and 19° 09’ and EL 76° 45’ and 84° 47’. The State is bordered on the east by Bay of Bengal (~970 km), south by Tamilnadu and Karnataka, west by Karnataka and Telangana and north by Telangana, Chattisgarh and Odisha states.

A wide variety of geological formations occur in Andhra Pradesh State, ranging from the oldest Archaean crystalline formations to recent alluvium. The geological set up map is presented in the Fig. 1. A major part of the area is underlain by gneissic complex with a structural fill of sedimentary formations and basin fill of meta-sedimentary formations. The gneissic complex is overlain by basaltic lava flows in the north-western part and is intruded by several younger rocks namely granites, dolerites, pegmatite and quartzite etc. As per 2023 Groundwater resource assessment, Total Annual Ground Water Recharge of the State has been assessed as 27.8 BCM and Annual Extractable Ground Water Resource is 26.41 BCM. The Total Current Annual Ground Water extraction is 7.88 BCM.

Godavari and Krishna rivers and their tributaries drain the northern and central part and Pennar river drains in southern part of state before joining Bay of Bengal (Fig 2.2). There are 3 major basins and 11 medium river basins in the state. The major river basins are Godavari, Krishna and Pennar and medium basins are Vansadhara, Nagavali, Sarada, Yeleru, Gundlakamma, Paleru (A), Manneru, Uppateru, Swarnamukhi, Palar and minor drainages between Musi and Gundlakamma river. The drainage pattern is generally dendritic with wide valleys in western peniplain. The drainage in Eastern Ghat is coarse and dendritic with steep and narrow valleys. Youthful streams and valleys mark the eastern coastal tract intersected

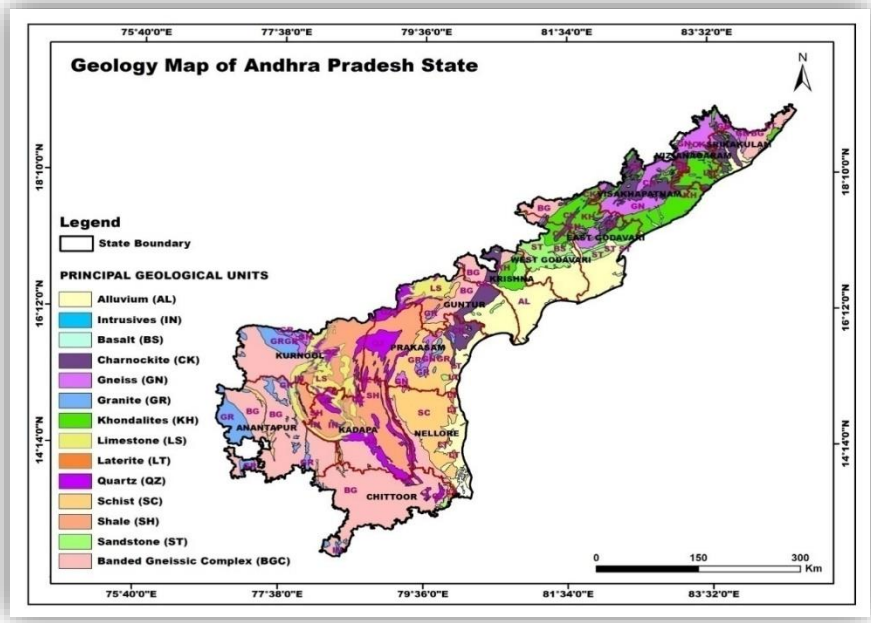

Figure 1: Map showing major aquifers and geomorphic divisions of Andhra Pradesh

by innumerable feeder and distributary canal system. The mature river courses of Godavari, Krishna and Pennar meanders through the vast areas and are covered by deltas as well as coastal plains. The deltas of rivers are very extensive and characterized by considerable thickness of alluvial material.

Most of the smaller streams feed innumerable tanks. River Penna flows across the southern part of the state with its tributaries Chitravati, Papaghni, Kundu, Sagileru and

Cheyyeru and drains major part of Rayalaseema region and Nellore district of coastal region. The drainage basins are characterized by undulating topography comprising a series of ridges and valleys intersperse by hill ranges. Vansadhara and Nagavalli rivers with their distributaries drain the northeastern part of the state in Srikakulam district. Visakhapatnam district is mostly drained by local rivulets like Sarada. River Yeleru drains most of the East Godavari district while Yerrakalava, Tammileru drain West Godavari district. Nellore district is drained by Pennar, Swarnamukhi and Araniar rivers.

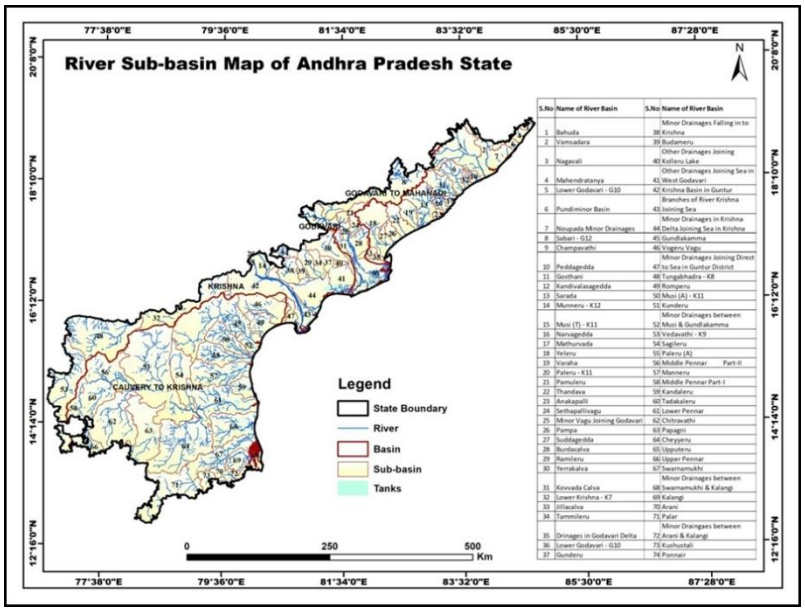

Fig.2: Drainage and River sub-basin map of Andhra Pradesh state

3.0 GROUND WATER QUALITY MONITORING

Groundwater quality monitoring involves sampling water from different aquifers to assess its chemical composition. It aims to understand regional water quality and create a baseline dataset for effective management and protection. The Central Ground Water Board (CGWB), SR, Hyderabad office has implemented a bi-annual groundwater quality monitoring program commencing in 2023.

However in earlier years sampling was only carried out during the month of May i.e. the pre-monsoon season. Water samples were collected for basic parameters, from the National Hydrograph Stations distributed across the state. In 2023 trend stations fixed with respect to samples based on 2022 background monitoring, the samples from these trend wells collected during both Pre and Post-Monsoon of each year up to 2027. During 2024 about 333 number of samples collected from the designated trend stations for Basic Parameters and 218 acidified samples from hotspot areas for Heavy Metal analysis in Andhra Pradesh. This report presents a comparative analysis of groundwater quality trends observed in the years 2019, 2022, 2023 & 2024 within the CGWB observation well network. Spatial distribution of sampling locations has been given in figure 3 and the district wise numbers are furnished in table 1.

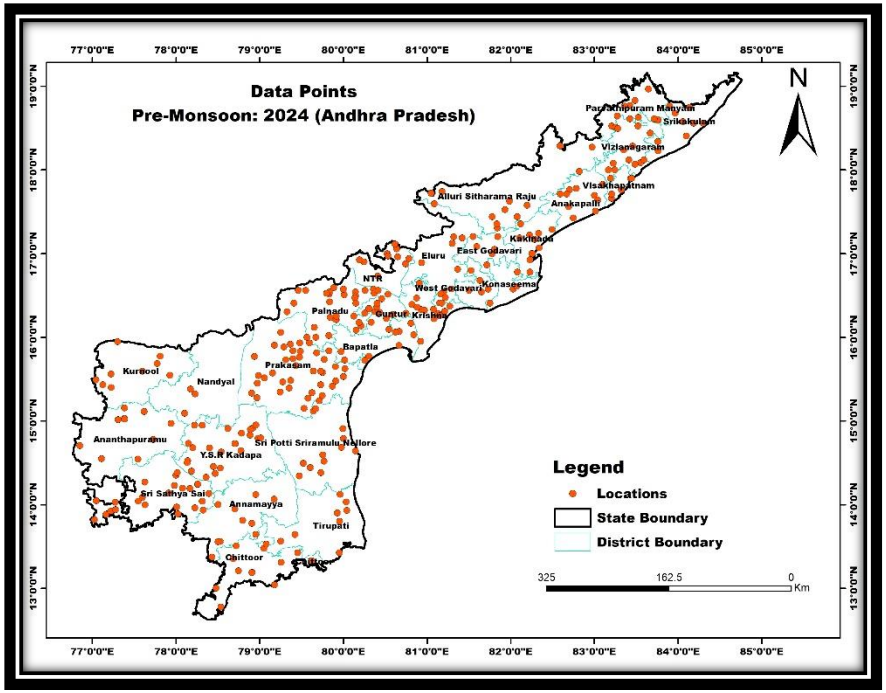

Figure 3: Spatial distribution of basic parameter sampling locations

Table- 1 : District wise distribution of water Quality Monitoring Stations

Sl. No.	District	No. of water quality monitoring stations			
		2019	2022	2023	2024(Pre)
1	Alluri Sita Rama Raju	36	42	40	14
2	Anakapalli	**23**	**24**	**27**	**9**
3	Ananthapur	8	38	62	12
4	Annamayya	**14**	**39**	**73**	**12**
5	Bapatla	23	30	33	8
6	Chittoor	16	43	61	9
7	East Godavari	25	25	25	5
8	Eluru	**31**	**34**	**37**	**9**
9	Guntur	22	24	32	15
10	Kakinada	**26**	**27**	**23**	**11**
11	Konaseema	28	31	31	4
12	Krishna	**21**	**33**	**56**	**16**
13	Kurnool	16	28	27	9
14	Nandyal	**14**	**25**	**25**	**4**
15	NTR	21	23	27	10
16	Palnadu	**37**	**55**	**70**	**30**
17	Parvathipuram Manyam	22	31	24	10
18	Prakasham	**15**	**68**	**102**	**41**
19	SPS Nellore	23	45	51	11
20	Sri Satya Sai	23	70	85	24
21	Srikakulam	41	45	49	9
22	Tirupathi	19	32	30	10
23	Visakhapatnam	20	12	20	6
24	Vizianagaram	30	46	45	16
25	West Godavari	19	20	26	5
26	YSR Kadapa	20	50	67	24
	Total	**593**	**940**	**1148**	**333**

4.0 GROUND WATER QUALITY SCENARIO

The primary objective of groundwater quality monitoring is to assess its suitability for human consumption, given the established correlation between water quality and public health. In order to evaluate groundwater against prescribed standards, inorganic parameters including the trace metals are analysed in samples collected from phreatic aquifers, adhering to the guidelines outlined in IS 10500:2012 (Reaffirmed 2018) by the Bureau of Indian Standards.

Groundwater in Andhra Pradesh predominantly exhibits a Calcium-Magnesium Bicarbonate (Ca-Mg-HCO3) facies when electrical conductivity (EC) values are below 750 µS/cm and in between 750 to 3000 µS/cm. Hence these waters could be considered as fresh in nature or having characteristics of rain water mostly. Waters with EC exceeding 3000 µS/cm typically exhibit a sodium chloride (Na-Cl) facies. Nevertheless, local hydro-geochemical variations induced by anthropogenic activities may result in deviations from these general classifications. Analysis reveals elevated concentrations of key water quality parameters, including salinity (EC), fluoride, nitrate, Arsenic and uranium, within specific regions of Andhra Pradesh. These parameters exhibit spatial and temporal variability, necessitating further investigation to understand underlying causes and potential impacts.

4.1 QUALITY ASSESSMENT OF GROUNDWATER IN UNCONFINED AQUIFERS

Given the extensive reliance on unconfined aquifers for water supply and irrigation, their chemical quality is of critical importance. Key parameters influencing groundwater quality within these aquifers include TDS, fluoride, nitrate, and uranium. The subsequent sections will analyse the presence and temporal variations of these constituents in groundwater samples collected during the years 2019, 2022, 2023 and 2024 National Hydrological Survey (NHS).

1. Electrical Conductivity (> 3000 µS/cm) at 250 C
2. Fluoride (>1.5 mg/litre)
3. Nitrate (>45 mg/litre)
4. Uranium (0.03 mg/L)
5. Arsenic (0.01 mg/L)

4.1.1 THE ELECTRICAL CONDUCTIVITY

Electrical conductivity (EC), a surrogate for Total Dissolved Solids (TDS) and salinity, quantifies the dissolved ion content of water. It reflects the combined ionic mobility of cations and anions, providing an indirect measure of water salinity. A general classification of water based on EC is as follows:

- Freshwater: EC < 1500 µS/cm
- Brackish water: EC 1500 - 15000 µS/cm
- Saline water: EC > 15000 µS/cm

While groundwater inherently contains varying levels of salinity influenced by aquifer lithology, mineral solubility, residence time, soil permeability, drainage conditions, rainfall, and climate, the Bureau of Indian Standards (BIS) recommends a TDS limit of 500 mg/L (equivalent to approximately 750 µS/cm at 25°C) for drinking water. In the absence of alternative sources, this limit can be relaxed to 2000 mg/L (approximately 3000 µS/cm at 25°C). Waters exceeding 2000 mg/L TDS are generally unsuitable for potable consumption.

Distribution of Electrical Conductivity (EC) During Pre-Monsoon 2024

The electrical conductivity (EC) of groundwater in the state exhibits a wide range, spanning from a minimum of 150 µS/cm at Vontlamamidi in Alluri Sita Rama Raju district to a maximum of 10920 µS/cm at Gantyada in Vishakhapatnam district. A categorization of groundwater samples based on EC reveals the following distribution:

- EC < 750 µS/cm – 7.8%
- EC 750- 3000 µS/cm- 77.2%
- EC > 3000 µS/cm- 15%

Figure 4 shows the spatial distribution of electrical conductivity in the phreatic aquifer of Andhra Pradesh in ground water. Table 2 provides for the number of samples analysed per district, along with their minimum, maximum, and mean EC values based on NHS 2024 pre- monsoon data. EC more than 3000 µS/cm was observed mostly in parts of West Godavari, Palnadu, Krishna, Anakapalli, Tirupathi, Eluru, Guntur, East Godavari, Kurnool and Kakinada districts.

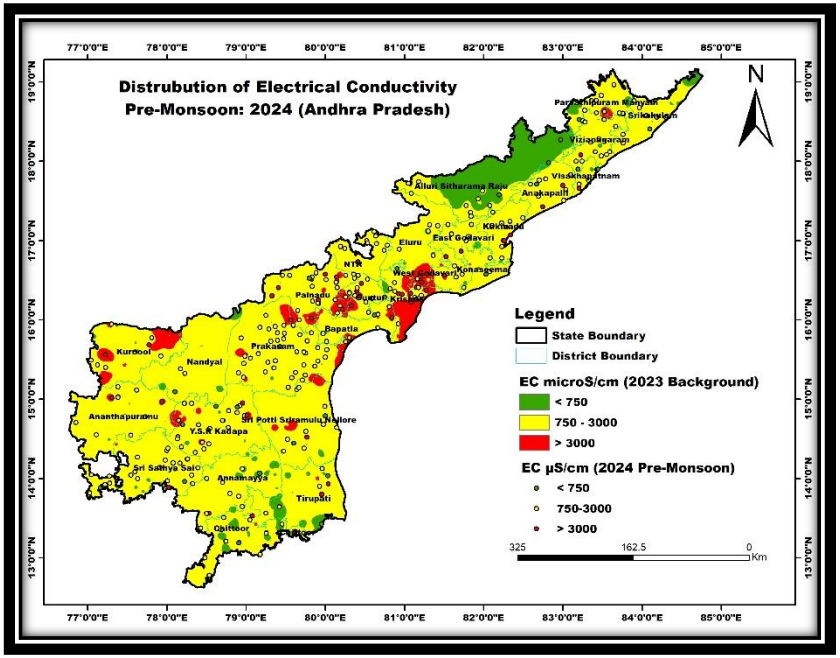

Figure 4: Spatial distribution of EC during May 2024

Table 2: District wise Range and distribution of EC in µS/cm in GW of Andhra Pradesh

Sl No	Districts	No. of samples analyzed	Permissible Limit µS/cm	Min	Max	Mean	% of samples		
							<750 µS/cm	750-3000 µS/cm	>3000 µS/cm
1	Alluri Sita Rama Raju	14	3000	154	2480	1073	28.6	71.4	0.0
2	Anakapalli	9	3000	737	3780	1821	11.1	66.7	22.2
3	Ananthapur	12	3000	1084	4201	2243	0.0	83.3	16.7
4	Annamayya	12	3000	366	4960	1786	8.3	83.3	8.3
5	Bapatla	8	3000	1020	4686	2090	0.0	87.5	12.5
6	Chittoor	9	3000	547	3763	1458	22.2	66.7	11.1
7	East Godavari	5	3000	1044	3289	1998	0.0	80.0	20.0
8	Eluru	9	3000	972	5015	2300	0.0	66.7	33.3
9	Guntur	15	3000	506	6620	2909	6.7	66.7	26.7
10	Kakinada	11	3000	1557	10730	3353	0.0	72.7	27.3
11	Konaseema	4	3000	746	2270	1637	25.0	75.0	0.0
12	Krishna	16	3000	655	5712	2743	6.3	50.0	43.8
13	Kurnool	9	3000	1230	5515	2332	0.0	77.8	22.2
15	Nandyal	4	3000	618	2452	1331	25.0	75.0	0.0
17	NTR	10	3000	902	4358	2243	0.0	90.0	10.0
18	Palnadu	30	3000	732	6312	2474	3.3	63.3	33.3
14	Parvathipuram Manyam	10	3000	695	1773	1291	10.0	90.0	0.0
19	Prakasham	41	3000	425	10890	1716	2.4	95.1	2.4
16	SPS Nellore	11	3000	630	4200	1480	18.2	72.7	9.1
20	Sri Satya Sai	24	3000	466	3204	1533	8.3	87.5	4.2
21	Srikakulam	9	3000	643	1862	1248	11.1	88.9	0.0
22	Tirupathi	10	3000	537	5965	2230	20.0	50.0	30.0
23	Visakhapatnam	6	3000	740	10920	2870	16.7	66.7	16.7
24	Vizianagaram	16	3000	750	3150	1285	0.0	93.8	6.3
25	West Godavari	5	3000	1581	9382	3886	0.0	60.0	40.0
26	YSR Kadapa	24	3000	170	6912	1743	12.5	79.2	8.3

TEMPORAL VARIATION OF EC IN GROUND WATER DURING THE PERIOD FROM 2019 TO 2024

Table 3 shows the temporal variation and the temporal comparison of districts wise no. of locations exceeding EC value of 3000 µS/ cm has been given in table 4. Trend of EC in the state in figure-5.

Table 3: Periodic variation in suitability Classes of groundwater in EC

Parameter	Class	Percentage of samples				Periodic Variation
		2019	2022	2023	2024 Pre	
		(n=593)	(n=940)	(n=1148)	(n=333)	
Salinity as EC	<750 µS/cm	15.2	18.9	20.5	7.8	-7.4
	750-3000 µS/cm	70.2	70.7	69.9	77.2	7.0
	>3000 µS/cm	14.7	10.3	9.7	15.0	0.3

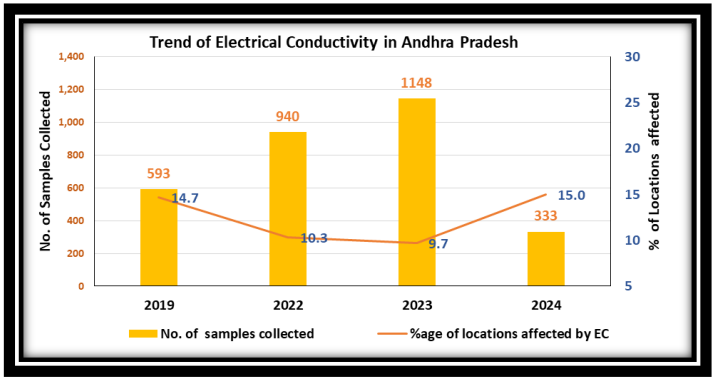

Fig-5: Trend of EC in Andhra Pradesh State

Table 4: Comparative change in number of locations having EC > 3000 µS/cm in various Districts

Sl. No.	District	No. of locations having EC > 3000 µS/cm			
		2019	2022	2023	2024
1	Alluri Sita Rama Raju	1	0	0	0
2	Anakapalli	0	1	1	2
3	Ananthapur	0	3	3	2
4	Annamayya	1	4	4	1
5	Bapatla	6	5	8	1
6	Chittoor	0	1	1	1
7	East Godavari	1	1	1	1
8	Eluru	9	5	11	3
9	Guntur	6	5	6	4
10	Kakinada	4	6	2	3
11	Konaseema	3	2	1	0
12	Krishna	7	9	17	7
13	Kurnool	8	5	7	2
14	Nandyal	0	1	0	0
15	NTR	3	3	2	0
16	Palnadu	15	10	16	1
17	Parvathipuram Manyam	0	0	1	1
18	Prakasham	1	12	12	10
19	SPS Nellore	5	1	3	1
20	Sri Satya Sai	1	7	4	1
21	Srikakulam	3	4	2	0
22	Tirupathi	1	3	2	3
23	Visakhapatnam	1	0	0	1
24	Vizianagaram	0	2	1	1
25	West Godavari	6	4	2	2
26	YSR Kadapa	5	3	4	2
	Total	**87**	**97**	**111**	**50**

4.1.2 NITRATE

Nitrate, a naturally occurring species formed through the atmospheric nitrogen fixation process, is primarily introduced into groundwater via anthropogenic activities, including agricultural runoff (fertilizers and animal manure) and sewage discharge. The differentiation between natural and anthropogenic nitrate sources often presents analytical challenges. In-situ biogeochemical processes, such as nitrification and de-nitrification, significantly influence nitrate concentrations within the aquifer system.

The Bureau of Indian Standards (BIS) has established a maximum permissible limit (MPL) of 45 mg/L for nitrate in drinking water. While nitrate itself exhibits relatively low toxicity, elevated concentrations pose a significant health risk, particularly for infants due to the potential for methemoglobinemia. Adults demonstrate a higher tolerance to nitrate exposure.

PRESENT DAY SCENARIO IN ANDHRA PRADESH W.R.T NITRATE (NO_3) Primary anthropogenic sources contributing to nitrate contamination of groundwater include: excessive application of nitrogen-based fertilizers, bacterial nitrification of organic nitrogen compounds, and leaching from animal and human waste repositories. Atmospheric deposition of nitrogenous compounds also serves as a potential input.

In the State, nitrate in ground water samples varies from 0.2 to 2070 mg/L. Highest nitrate value was observed at Prabhalaveedu of Viziyanagaram district. BIS permits a maximum concentration of 45 mg/L nitrate in drinking water. Almost 41.1% of the samples exceeded the permissible limit of nitrate. Nitrate contamination was found majorly in all the districts except Konaseema and Nandyal district. Table 5 shows the district wise details of samples exceeding the permissible limit. Figure 6 shows the occurrence of nitrate during Pre-Monsoon 2024.

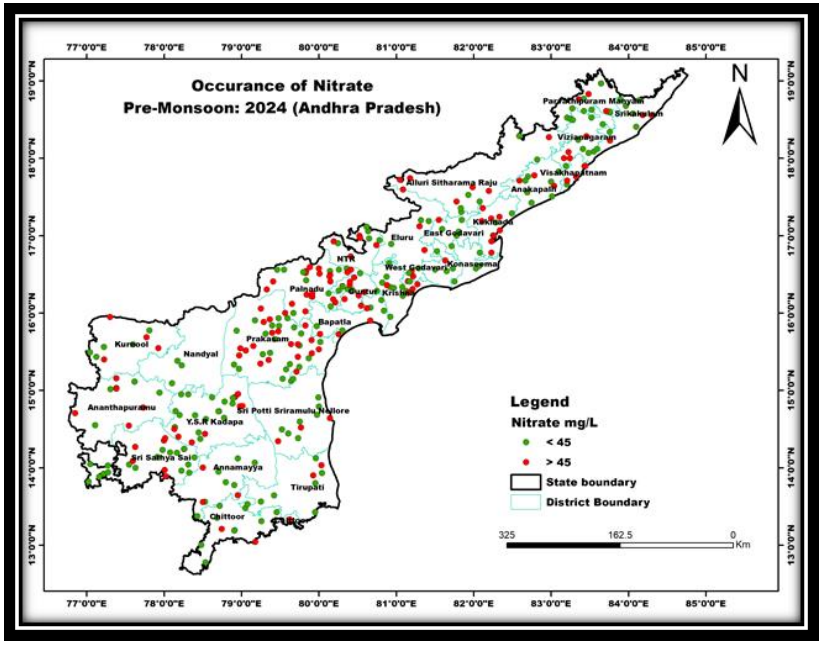

Fig 6: Occurance of Nitrate in GW (May-2024)

Table 5 District wise details of samples exceeding the permissible limit

Sl. No	District	No of samples analysed	Desirable limit mg/L	Permissible Limit (mg/L)	Min	Max	Mean	No. of samples (%)	
								>45	<45
1	Alluri Sita Rama Raju	14	45	No relaxation	0.2	103.3	39.9	50.0	50.0
2	Anakapalli	9	45	No relaxation	3.0	58.6	25.6	22.2	77.8
3	Ananthapur	12	45	No relaxation	4.0	189.5	55.2	50.0	50.0
4	Annamayya	12	45	No relaxation	3.0	84.9	36.6	33.3	66.7
5	Bapatla	8	45	No relaxation	4.1	85.4	40.7	37.5	62.5
6	Chittoor	9	45	No relaxation	0.6	156.2	36.7	22.2	77.8
7	East Godavari	5	45	No relaxation	1.7	46.3	24.0	20.0	80.0
8	Eluru	9	45	No relaxation	14.8	137.5	57.4	55.6	44.4
9	Guntur	15	45	No relaxation	2.7	217.3	73.8	60.0	40.0
10	Kakinada	11	45	No relaxation	21.5	198.0	81.9	72.7	27.3
11	Konaseema	4	45	No relaxation	3.2	28.2	13.8	0.0	100.0
12	Krishna	16	45	No relaxation	2.7	82.4	27.3	25.0	75.0
13	Kurnool	9	45	No relaxation	1.4	189.1	54.7	44.4	55.6
14	Nandyal	4	45	No relaxation	1.0	44.7	19.8	0.0	100.0
15	NTR	10	45	No relaxation	3.7	178.0	61.8	50.0	50.0
16	Palnadu	30	45	No relaxation	0.2	560.0	86.6	66.7	33.3
17	Parvathipuram Manyam	10	45	No relaxation	2.9	138.5	43.0	30.0	70.0
18	Prakasham	41	45	No relaxation	0.9	300.4	58.8	48.8	51.2
19	SPS Nellore	11	45	No relaxation	3.1	110.1	38.6	27.3	72.7
20	Sri Satya Sai	24	45	No relaxation	2.6	320.7	56.4	29.2	70.8
21	Srikakulam	9	45	No relaxation	8.0	93.6	33.4	33.3	66.7
22	Tirupathi	10	45	No relaxation	1.1	63.0	25.5	20.0	80.0
23	Visakhapatnam	6	45	No relaxation	4.0	96.6	65.7	83.3	16.7
24	Vizianagaram	16	45	No relaxation	0.9	192.2	41.0	31.3	68.8
25	West Godavari	5	45	No relaxation	8.5	54.2	26.4	20.0	80.0
26	YSR Kadapa	24	45	No relaxation	0.9	2070.2	131.6	33.3	66.7

TEMPORAL VARIATION OF NITRATE DURING THE PERIOD FROM 2019 TO 2024

Table 6 and Figure. 7shows the year wise variation of the percentage of samples exceeding the nitrate permissible limit and the district wise no. of locations exceeding the permissible limit has been given **in table 7.** It has been observed, sharp increase in trend of nitrate in figure 7 in 2024 (41.1% samples contaminated) as the most of the samples collected from the nitrate contaminated trend wells observed during 2022.

Table 6: Periodic variation in suitability Classes of Nitrate in groundwater

Parameter	Class	Percentage of samples				Periodic Variation
		2019	2022	2023	2024 Pre	
		(n=593)	(n=940)	(n=1148)	(n=333)	
Nitrate as NO3	< 45 mg/L	67.3	68.6	76.6	58.9	-8.4
	> 45 mg/L	32.7	31.4	23.4	41.1	8.4

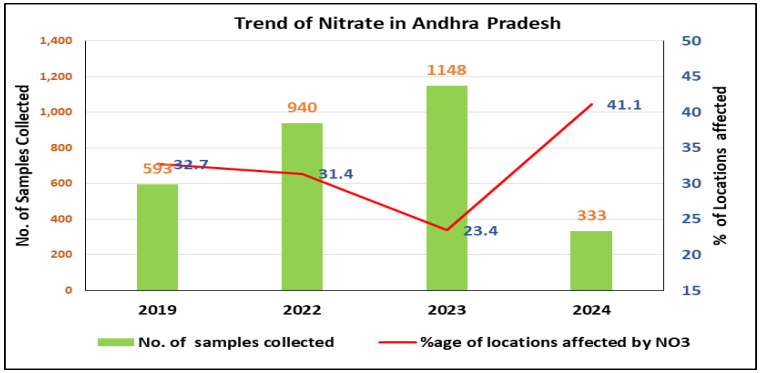

Fig-7: Trend of Nitrate in Andhra Pradesh

Table 7: Comparative change in number of locations having Nitrate > 45 mg/L in various Districts

Sl. No.	District	No. of locations having NO3 > 45 mg/L			
		2019	2022	2023	2024
1	Alluri Sita Rama Raju	11	9	7	7
2	Anakapalli	15	7	12	2
3	Ananthapur	5	12	12	6
4	Annamayya	2	10	9	4
5	Bapatla	6	11	2	3
6	Chittoor	4	6	7	2
7	East Godavari	7	7	4	1
8	Eluru	9	9	5	5
9	Guntur	9	12	7	9
10	Kakinada	11	12	5	8
11	Konaseema	3	2	2	0
12	Krishna	3	3	3	4
13	Kurnool	8	12	13	4
14	Nandyal	3	5	3	0
15	NTR	9	10	11	5
16	Palnadu	21	34	36	20
17	Parvathipuram Manyam	13	10	5	3
18	Prakasham	3	31	43	20
19	SPS Nellore	5	10	15	3
20	Sri Satya Sai	11	27	29	7
21	Srikakulam	14	11	11	3
22	Tirupathi	1	7	2	2
23	Visakhapatnam	7	5	2	5
24	Vizianagaram	7	12	10	5
25	West Godavari	2	4	4	1
26	YSR Kadapa	5	17	10	8
	Total	**194**	**295**	**269**	**137**

4.1.3 FLUORIDE

Fluorine, a highly reactive element, exists primarily as fluoride ions in mineral form. Through weathering and dissolution processes, these fluoride ions are released into groundwater. The concentration of fluoride in groundwater is influenced by geological factors including rock type, climate, and the duration of water-rock interaction.

Excessive fluoride intake can lead to dental and skeletal fluorosis. To safeguard public health, the Bureau of Indian Standards (BIS) has established permissible limits of 1.5mg/L and desirable limit of 1 mg/L for fluoride in drinking water. While low fluoride levels are beneficial for dental health, surpassing these limits poses significant health risks. Implementing effective de- fluoridation technologies is crucial in regions affected by high fluoride concentrations.

PRESENT DAY SCENARIO IN ANDHRA PRADESH W.R.T FLUORIDE

An analysis of groundwater samples revealed that out of 333 collected samples 72.7% samples fell within the desirable range, 17.1% within the permissible range, and 10.2% exceeded the permissible limit. A geographical distribution map **(figure 8)** indicates that groundwater with excessive fluoride levels is predominantly found in the districts of NTR, Sri Satya Sai, Alluri Sita Rama Raju, Anakapalli, Ananthapur, Chittoor, Krishna, Kurnool, Palnadu, Prakasham, Tirupathi, Visakhapatnam, YSR Kadapa. It is to be noted that Annamayya, Bapatla, East Godavari, Eluru, Guntur, Kakinada, Konaseema, Nandyal, Parvathipuram Manyam, SPS Nellore, Srikakulam, Vizianagaram, West Godavari etc found to be having fluoride less than permissible limit in all collected samples from different locations. The maximum concentration of 5.7 mg/L was observed at Sagileru of YSR Kadapa district. The district wise maximum, minimum, mean and percentage of samples exceeding the permissible limit has been given in **table 8.**

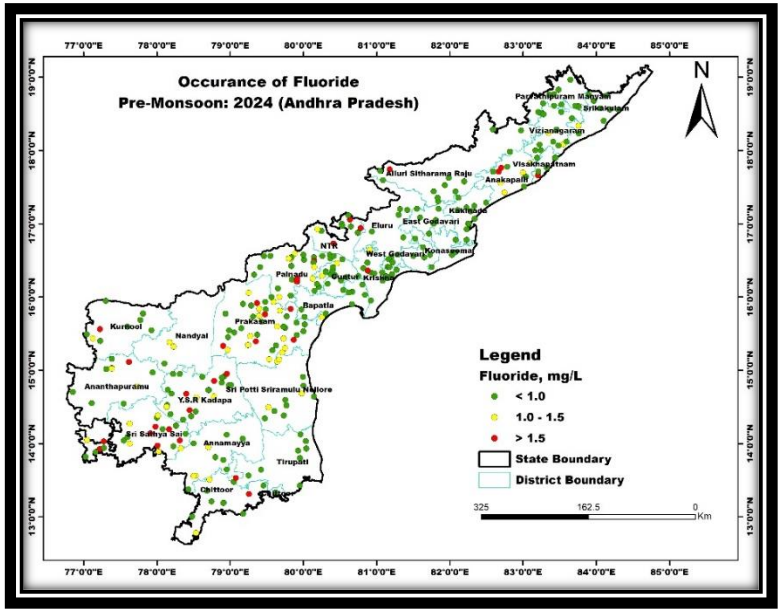

Figure 8: map showing distribution of fluoride based on NHS-2024 (Pre-Monsoon)

Table-8: **District wise details of samples exceeding the permissible limit**

Sl. No	District	No of samples analysed	Desirable limit mg/L	Permissible Limit (mg/L)	Min	Max	Mean	No. of samples (%)	
								>1.5	<1.5
1	Alluri Sita Rama Raju	14	1	1.5	0.0	1.7	0.2	7.1	92.9
2	Anakapalli	9	1	1.5	0.4	2.3	1.3	22.2	77.8
3	Ananthapur	12	1	1.5	0.1	2.3	0.9	16.7	83.3
4	Annamayya	12	1	1.5	0.2	1.5	0.9	0.0	100.0
5	Bapatla	8	1	1.5	0.1	1.0	0.5	0.0	100.0
6	Chittoor	9	1	1.5	0.1	1.8	0.8	11.1	88.9
7	East Godavari	5	1	1.5	0.0	0.1	0.1	0.0	100.0
8	Eluru	9	1	1.5	0.2	0.9	0.4	0.0	100.0
9	Guntur	15	1	1.5	0.0	1.4	0.6	0.0	100.0
10	Kakinada	11	1	1.5	0.0	0.4	0.1	0.0	100.0
11	Konaseema	4	1	1.5	0.0	0.0	0.0	0.0	100.0
12	Krishna	16	1	1.5	0.1	2.1	0.5	6.3	93.8
13	Kurnool	9	1	1.5	0.5	2.6	0.9	11.1	88.9
14	Nandyal	4	1	1.5	0.9	1.4	1.1	0.0	100.0
15	NTR	10	1	1.5	0.3	4.2	1.2	30.0	70.0
16	Palnadu	30	1	1.5	0.2	2.8	0.9	13.3	86.7
17	Parvathipuram Manyam	10	1	1.5	0.2	1.1	0.5	0.0	100.0
18	Prakasham	41	1	1.5	0.0	3.1	1.1	14.6	85.4
19	SPS Nellore	11	1	1.5	0.1	1.5	0.6	0.0	100.0
20	Sri Satya Sai	24	1	1.5	0.4	3.2	1.3	29.2	70.8
21	Srikakulam	9	1	1.5	0.2	1.2	0.5	0.0	100.0
22	Tirupathi	10	1	1.5	0.0	2.1	0.7	10.0	90.0
23	Visakhapatnam	6	1	1.5	0.2	1.5	0.6	16.7	83.3
24	Vizianagaram	16	1	1.5	0.3	1.2	0.7	0.0	100.0
25	West Godavari	5	1	1.5	0.0	0.3	0.1	0.0	100.0
26	YSR Kadapa	24	1	1.5	0.1	5.7	1.1	16.7	83.3

Table 9: Periodic variation in suitability Classes of Fluoride in groundwater

Parameter	Class	Percentage of samples				Periodic Variation
		2019	2022	2023	2024 Pre	
		(n=593)	(n=940)	(n=1148)	(n=333)	
Fluoride as F	< 1.0 mg/L	80.1	74.7	75.7	72.7	-7.4
	1-1.5 mg/L	11.6	15.0	13.0	17.1	5.5
	> 1.5 mg/L	8.3	10.3	11.3	10.2	1.9

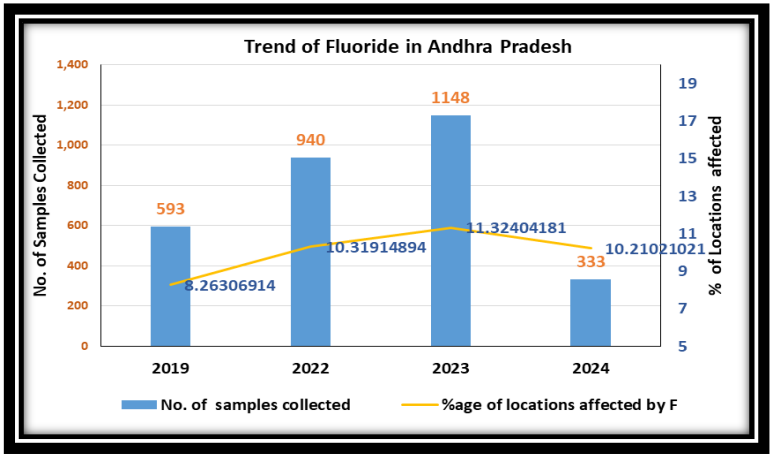

Fig-9: Trend of Fluoride in Andhra Pradesh

Table 10 shows the no. of locations affected by fluoride contamination from 2019 to 2024. Table 9 gives the Periodic in suitability Classes of Fluoride in groundwater and the trend analysis given in figure-9.

Table 10: Comparative Change in number of locations having F>1.5

Sl. No.	District	No. of locations having F > 1.5 mg/L			
		2019	2022	2023	2024
1	Alluri Sita Rama Raju	2	5	2	1
2	Anakapalli	3	1	3	2
3	Ananthapur	3	4	12	2
4	Annamayya	0	1	4	0
5	Bapatla	2	2	1	0
6	Chittoor	0	0	1	1
7	East Godavari	1	1	3	0
8	Eluru	0	1	0	0
9	Guntur	0	0	0	0
10	Kakinada	0	0	0	0
11	Konaseema	2	0	0	0
12	Krishna	0	1	0	1
13	Kurnool	5	8	3	1
14	Nandyal	2	1	1	0
15	NTR	2	4	4	3
16	Palnadu	5	10	19	4
17	Parvathipuram Manyam	0	1	0	0
18	Prakasham	2	23	25	6
19	SPS Nellore	0	1	11	0
20	Sri Satya Sai	10	22	27	7
21	Srikakulam	0	1	1	0
22	Tirupathi	1	2	2	1
23	Visakhapatnam	1	0	0	1
24	Vizianagaram	3	2	0	0
25	West Godavari	0	1	0	0
26	YSR Kadapa	5	5	11	4
	Total	**49**	**97**	**130**	**34**

4.1.4 URANIUM

Uranium, a naturally occurring radioactive element, is ubiquitously present in both groundwater and surface water bodies. Anthropogenic sources, including nuclear industry effluents, coal combustion by-products, and phosphate fertilizer runoff, exacerbate natural uranium levels. Human exposure primarily occurs through ingestion of contaminated water and food, inhalation, and occupational contact. Exceeding the BIS standard of 30 ppb uranium in drinking water poses a significant health risk, with potential for chronic kidney damage.

PRESENT DAY SCENARIO AND TEMPORAL VARIATION OF URANIUM IN ANDHRA PRADESH STATE

During 2019, 588 samples were collected (215 samples collected from the effected districts Alluri Sita Ramaraju, Ananthapur, Annamaya, Baptala, Chittor, Guntur, Kurnool, NTR, Sri Satya Sai, Tirupathi, YSR Kadapa etc.) from the monitoring stations of Andhra Pradesh. Only 29 samples were found above 0.03 mg/L (30 ppb) and these stations were designated as U - Hotspots. During Pre-monsoon 2022 about 339 samples were collected from these hotspot and surroundings. Out of which 177 (52.2%) samples were observed more than 30 ppb. In 2024 about 218 samples

were collected from theses hotspot surrounding and 78 (35.8%) samples were found above 30 ppb.

In 2024 the uranium content in ground water ranges from 0 to 4600 ppb (0 to 4.6 mg/L). The highest was recorded at recorded at Ellava Nellore (Ramasamudram Mandal) of Annamayya district. Figure 10 shows the occurrence of uranium in ground water of the state during 2024 pre-monsoon.

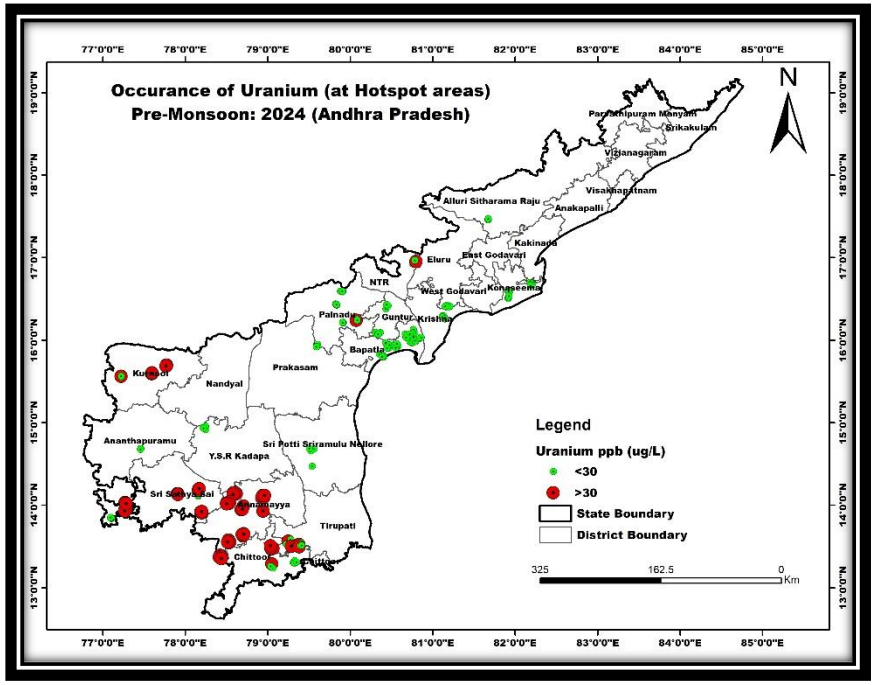

Figure 10: Occurrence of Uranium in Ground waters of Andhra Pradesh during May-2024

Table 11 shows the district wise ranges, minimum, maximum, and mean of uranium. Table 12 and figure -11 shows the Comparative Change in number of Locations having U>30ppb and Periodic variation in suitability Classes of Uranium content in groundwater respectively during 2019, 2022 and 2024 pre-monsoon seasons. However, during 2022 and 2024 samples were only collected from trend stations.

Table 11: District wise Range and distribution of Uranium in Ground Water

Sl. No	District	No of samples analysed	Desirable limit ug/L (ppb)	Permissible Limit (mg/L)	Min	Max	Mean	No. of samples (%)	
								>30	<30
1	Alluri Sita Rama Raju	5	30	No relaxtation	0.0	0	0	0.0	100.0
2	Ananthapur	3	30	No relaxtation	5.4	22	16	0.0	100.0
3	Annamayya	35	30	No relaxtation	5.7	4600	890	91.4	5.7
4	Bapatla	33	30	No relaxtation	0.0	22	2	0.0	100.0
5	Chittoor	9	30	No relaxtation	0.6	40	13	11.1	88.9
6	East Godavari	5	30	No relaxtation	0.0	1	0	0.0	100.0
7	Guntur	8	30	No relaxtation	0.0	14	4	0.0	100.0
8	Konaseema	10	30	No relaxtation	0.0	4	1	0.0	100.0
9	Krishna	10	30	No relaxtation	0.0	6	1	0.0	100.0
10	Kurnool	13	30	No relaxtation	27.4	1282	230	76.9	23.1
11	NTR	5	30	No relaxtation	6.3	34	15	20.0	80.0
12	Palnadu	20	30	No relaxtation	0.0	109	11	5.0	95.0
13	Prakasham	5	30	No relaxtation	2.6	16	7	0.0	100.0
14	SPS Nellore	5	30	No relaxtation	0.1	30	8	0.0	100.0
15	Sri Satya Sai	32	30	No relaxtation	0.0	1239	254	71.9	28.1
16	Tirupathi	15	30	No relaxtation	3.2	1882	200	66.7	33.3
17	YSR Kadapa	5	30	No relaxtation	0.0	0	0	0.0	100.0

Table 12: Periodic variation in suitability Classes of groundwater in Uranium

Parameter	Class	Percentage of samples			Periodic Variation
		2019	2022	2024 Pre	
		(n=215)	(n=339)	(n=218)	
Uranium as U	< 30ppb	86.5	47.8	64.2	-22.3
	>30 ppb	13.5	52.2	35.8	22.3

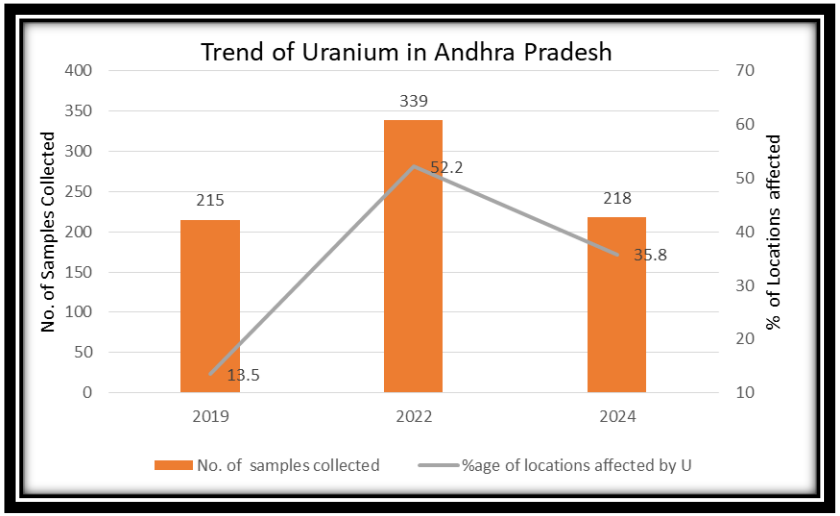

Fig-11: Trend of Uranium Hotspot districts in Andhra Pradesh

4.1.5 ARSENIC

Arsenic, a naturally occurring element, is widely dispersed in the Earth's crust. This toxic substance can be found in various environmental components including water, air, soil, and food. It primarily exists in two forms: organic and inorganic. While natural processes such as volcanic eruptions and weathering contribute to arsenic release, human activities like mining, burning fossil fuels, and using arsenic-based chemicals for agriculture and industry are also major contributors. Though the use of arsenic-containing pesticides and herbicides has decreased, its application in wood preservation persists. Arsenic contamination in drinking water poses severe health risks. Long-term exposure can lead to a range of adverse effects, including cancer, skin lesions, and cardiovascular disease. It can also impact neurological development, particularly in children. Additionally, arsenic can cause respiratory issues, reproductive problems, and damage to vital organs. The severity of these effects depends on the level of arsenic exposure and the individual's overall health. BIS has prescribed a permissible limit of 10 ppb for Arsenic in drinking water.

PRESENT DAY SCENARIO AND TEMPORAL VARIATION OF ARSENIC IN ANDHRA PRADESH

During 2019, 588 samples collected (215 samples collected from the effected districts Alluri Sita Ramaraju, Ananthapur, Annamaya, Baptala, Chittor, Guntur, Kurnool, NTR, Sri Satya Sai, Tirupathi, YSR Kadapa etc)) from the monitoring stations of Andhra Pradesh. Out of 588 samples 23 samples were found above 0.01 mg/L (10 ppb) and these stations were designated as Arsenic Hotspots. These Samples belongs to the districts of Alluri Sita Ramaraju, Ananthapur, Baptala, Eluru, Guntur, Konaseema, Krishna, Kurnool, Palnadu, Prakasham and Nellore. In 2024 about 218 samples were collected from Andhra Pradesh and 14 (6.4%) samples were found above 10 ppb (0.01 mg/L). The arsenic content more than 0.01 mg/L locations belongs to the districts of Ananthapur, Baptala, Guntur, SPS Nellore, Palnadu and Prakasham.

The range of arsenic content in the ground waters of Andhra Pradesh varies from 0 to 41 ppb (0.041 mg/L) and the highest was recorded at Papayapalem of Baptala district during the pre- monsoon season of 2024. Figure 12 depicts the occurrence of arsenic in the ground water of the state and table 13 shows the district wise range and distribution of arsenic in the ground waters. Table 14 shows variation in suitability classes of Arsenic content in groundwater of the state and figure 14 shows the trend in number of Locations having As> 10 ppb.

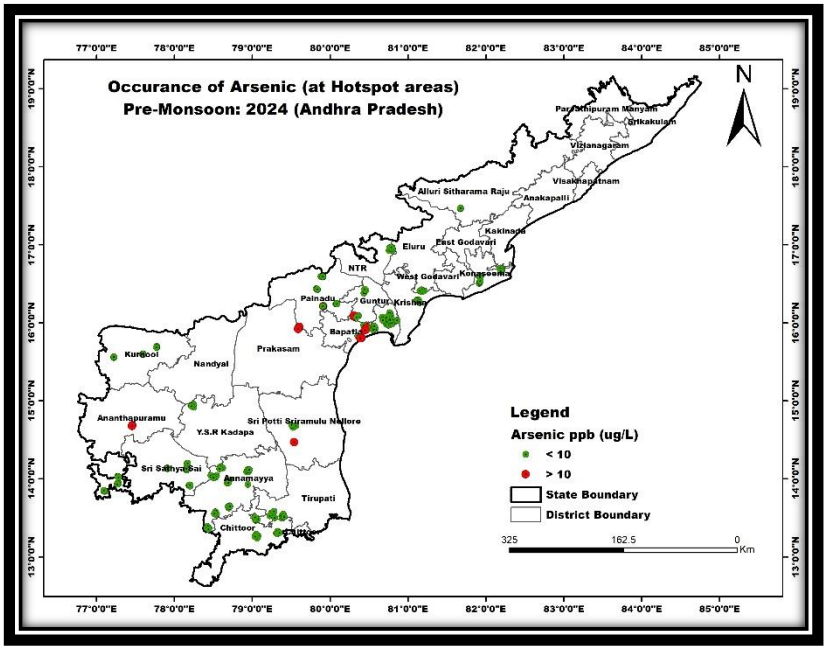

Figure 12: Occurrence of Arsenic in Ground waters of Andhra Pradesh during Pre-Monsoon 2024.

Table 13: District wise Range and distribution of Arsenic in Ground Water

Sl. No	District	No of samples analysed	Desirable limit ug/L (ppb)	Permissible Limit (mg/L)	Min	Max	Mean	No. of samples (%)	
								>10	<10
1	Alluri Sita Rama Raju	5	10	No relaxtation	0.0	0.0	0.0	0.0	100.0
2	Ananthapur	3	10	No relaxtation	1.4	11.9	8.3	66.7	33.3
3	Annamayya	35	10	No relaxtation	0.0	1.3	0.1	0.0	100.0
4	Bapatla	33	10	No relaxtation	0.0	41.2	4.9	12.1	87.9
5	Chittoor	9	10	No relaxtation	0.0	0.0	0.0	0.0	100.0
6	East Godavari	5	10	No relaxtation	0.0	2.7	0.7	0.0	100.0
7	Guntur	8	10	No relaxtation	0.0	14.6	4.7	25.0	75.0
8	Konaseema	10	10	No relaxtation	0.0	3.7	0.9	0.0	100.0
9	Krishna	10	10	No relaxtation	0.0	8.8	2.2	0.0	100.0
10	Kurnool	13	10	No relaxtation	0.1	3.3	1.4	0.0	100.0
11	NTR	5	10	No relaxtation	0.0	0.0	0.0	0.0	100.0
12	Palnadu	20	10	No relaxtation	0.0	10.1	2.0	5.0	95.0
13	Prakasham	5	10	No relaxtation	2.4	24.1	15.0	80.0	20.0
14	SPS Nellore	5	10	No relaxtation	0.0	39.1	8.6	20.0	80.0
15	Sri Satya Sai	32	10	No relaxtation	0.0	0.2	0.0	0.0	100.0
16	Tirupathi	15	10	No relaxtation	0.0	4.7	0.3	0.0	100.0
17	YSR Kadapa	5	10	No relaxtation	0.0	0.0	0.0	0.0	100.0

Table 14: Periodic variation in suitability Classes of groundwater in Arsenic

Parameter	Class	Percentage of		Periodic Variation
		2019	2024 Pre	
		(n=215)	(n=218)	
Arsenic as As	< 10ppb	89.3	93.6	4.3
	>10 ppb	10.7	6.4	-4.3

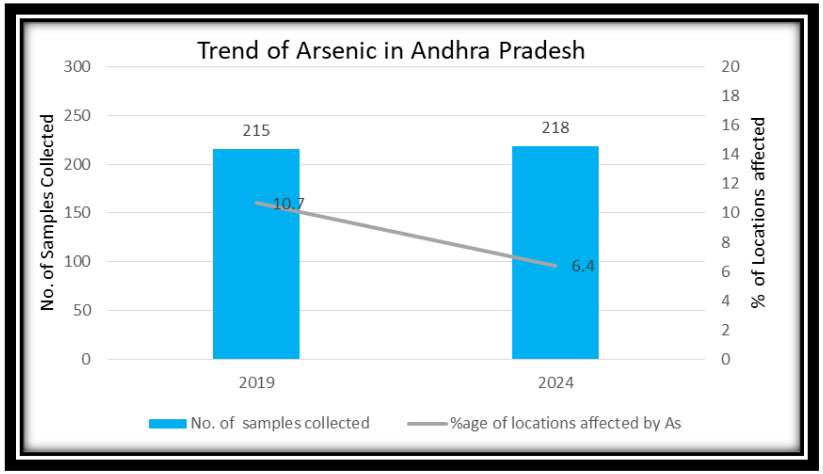

Fig-13: Trend of Arsenic Hotspot districts in Andhra Pradesh

6. SUMMARY

The ground water quality during pre-monsoon season of 2024 has been compared with 2019, 2022 & 2023 pre-monsoon seasons. Wide spread nitrate contamination has been a concern for the ground water of the state. Some of the sample exceeding one or more parameters including uranium and arsenic indicates the water is not suitable for human consumption without treatment.

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

The **Table 15** provides a detailed summary of groundwater quality across various districts in Andhra Pradesh, focusing

on basic parameters (electrical conductivity, nitrate, fluoride).

Basic Parameters:

• EC (Electrical Conductivity): 15% of samples exceed the limit of 3000 µS/cm at 25 °C, was observed in parts of West Godavari, Palnadu, Krishna, Anakapalli, Tirupathi, Eluru, Guntur, East Godavari, Kurnool and Kakinada districts.

• NO3 (Nitrate): 41.1% of samples exceed limits, Nitrate contamination was found majorly in all the districts except Konaseema and Nandyal district.

• F (Fluoride): Overall, 10.2% of samples surpass permissible limits, with notable numbers in NTR, Sri Satya Sai, Alluri Sita Rama Raju, Anakapalli, Ananthapur, Chittoor, Krishna, Kurnool, Palnadu, Prakasham, Tirupathi, Visakhapatnam, YSR Kadapa districts.

State Summery

The Table 16 provides a summary of groundwater quality in the state of Andhra Pradesh, broken down by the number of samples collected and the percentage of those samples that are contaminated with various parameters.

Table 15: Summary of Groundwater Quality in Andhra pradesh: Samples Collected and Contamination Percentage

No. of Samples Contaminated (% age of samples contaminated) for Basic Parameters				
Andhra Pradesh State Summery	**Total No. of Basic Samples**	**EC**	**NO_3**	**F**
(Pre-Monsoon)	333	50 (15.0%)	137 (41.1%)	34 (10.2%)
No. of Samples Contaminated (% age of samples contaminated) for Arsenic and Uranium				
Andhra Pradesh State Summery	**Total No. of Basic Samples**	**As**	**U**	
(Pre-Monsoon)	218	14 (6.4%)	78 (35.8%)	

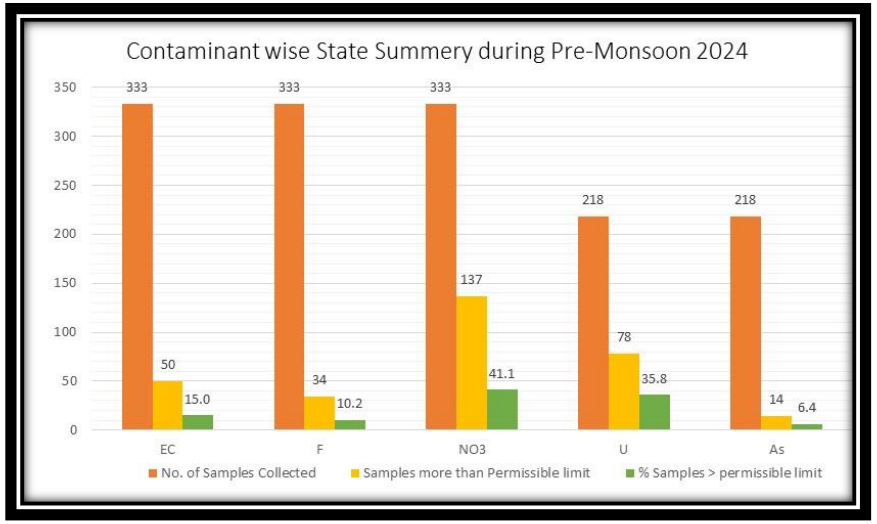

Fig-14: Contaminant wise State Summery districts in Andhra Pradesh

Table 16: Summary of Groundwater Quality in Various Districts of Andhra Pradesh, Highlighting Basic Parameters (Electrical Conductivity, Nitrate, Fluoride & Uranium)

Districts	Total No. of Basic Samples	No of samples(% of samples) Over Permissible limit						Districts	Total No. of Basic Samples	As Above Permissible limit		U Above Permissible limit	
		EC		NO3		F							
		No	%	No	%	No	%			No	%	No	%
Alluri Sita Rama Raju	14	0	0.0	7	50.0	1	7.1	Alluri Sita Rama Raju	5	0	0.0	0	0.0
Anakapalli	9	2	22.2	2	22.2	2	22.2	Anakapalli	0	--	--	--	--
Ananthapur	12	2	16.7	6	50.0	2	16.7	Ananthapur	3	2	66.7	0	0.0
Annamayya	12	1	8.3	4	33.3	0	0.0	Annamayya	35	0	0.0	32	91.4
Bapatla	8	1	12.5	3	37.5	0	0.0	Bapatla	33	4	12.1	0	0.0
Chittoor	9	1	11.1	2	22.2	1	11.1	Chittoor	9	0	0.0	1	11.1
East Godavari	5	1	20.0	1	20.0	0	0.0	East Godavari	5	0	0.0	0	0.0
Eluru	9	3	33.3	5	55.6	0	0.0	Eluru	0	--	--	--	--
Guntur	15	4	26.7	9	60.0	0	0.0	Guntur	8	2	25.0	0	0.0
Kakinada	11	3	27.3	8	72.7	0	0.0	Kakinada	0	--	--	--	--
Konaseema	4	0	0.0	0	0.0	0	0.0	Konaseema	10	0	0.0	0	0.0
Krishna	16	7	43.8	4	25.0	1	6.3	Krishna	10	0	0.0	0	0.0
Kurnool	9	2	22.2	4	44.4	1	11.1	Kurnool	13	0	0.0	10	76.9
Nandyal	4	0	0.0	0	0.0	0	0.0	Nandyal	0	--	--	--	--
NTR	10	0	0.0	5	50.0	3	30.0	NTR	5	0	0.0	1	20.0
Palnadu	30	1	3.3	20	66.7	4	13.3	Palnadu	20	1	5.0	1	5.0
Parvathipuram Manyam	10	1	10.0	3	30.0	0	0.0	Parvathipuram Manyam	0	--	--	--	--
Prakasham	41	10	24.4	20	48.8	6	14.6	Prakasham	5	4	80.0	0	0.0
SPS Nellore	11	1	9.1	3	27.3	0	0.0	SPS Nellore	5	1	20.0	0	0.0
Sri Satya Sai	24	1	4.2	7	29.2	7	29.2	Sri Satya Sai	32	0	0.0	23	71.9
Srikakulam	9	0	0.0	3	33.3	0	0.0	Srikakulam	0	--	--	--	--
Tirupathi	10	3	30.0	2	20.0	1	10.0	Tirupathi	15	0	0.0	10	66.7
Visakhapatnam	6	1	16.7	5	83.3	1	16.7	Visakhapatnam	0	--	--	--	--
Vizianagaram	16	1	6.3	5	31.3	0	0.0	Vizianagaram	0	--	--	--	--
West Godavari	5	2	40.0	1	20.0	0	0.0	West Godavari	0	--	--	--	--

7. RECOMMENDATIONS & CONCLUSION

With respect to the tests carried out, the state of Andhra Pradesh generally has good quality water according to drinking and domestic water standards. However, in a some localized areas, contaminants are found in the groundwater. The primary concern in Andhra Pradesh is the high nitrate levels present in almost all districts, likely due to the use of fertilizers in agriculture, sewage, and other anthropogenic sources. Fluoride also as major contaminate as it is found in about 34 samples out of 333 samples during the pre-monsoon of 2024. Additionally, certain locations exhibit contamination from uranium & arsenic which can be attributed to geo-genic origins. As nitrate & Fluoride including are the major contaminates found in groundwater of Andhra Pradesh following remediation's recommended for the localities with high nitrate and fluorides.

Nitrate: For removal of nitrate both non-treatment techniques like blending and treatment processes such as ion exchange, reverse osmosis, biological de-nitrification and chemical reduction are useful. The most important thing is that neither of these methods is completely effective in removing all the nitrogen from the water.

- Methods involving no treatment: In order to use any of these options the nitrate problem must be local-scale. Common methods are:
  - Raw water source substitution
  - Blending with low nitrate waters

  This greatly reduces expenses and helps to provide safer drinking water to larger numbers of people.

- Methods involving Treatment: They are as follows:
  - Adsorption/Ion Exchange
  - Reverse Osmosis
  - Electrodialysis
  - Bio-chemical Denitrification (By using denitrifying bacteria and microbes)
  - Catalytic Reduction/Denitrification (using hydrogen gas)

  Complex biogeochemical processes govern the mechanism of nitrate pollution in subsurface porous unconfined/confined aquifer. Apart from recharge conditions, groundwater chemistry may be impacted by the mineral kinetics of water-rock interactions. Consequently, suitable nitrate removal technologies should be selected. Nitrate is a very soluble ion with limited potential for co-precipitation or adsorption. This makes it difficult to remove by processes such as chemical coagulation, lime softening and filtration, which are commonly used for removing most of the chemical pollutants such as fluoride, arsenic and heavy metals. According to King et al., 2012 nitrate treatment technologies can be classified in two categories in two categories, i.e. nitrate reduction and nitrate removal

options. Nitrate removal technologies involve physical processes that does not necessarily involve any alteration of the chemical state of nitrate ions. Bio-chemical reduction options aim to reduce nitrate ions to other states of nitrogen, e.g. ammonia, or a more innocuous form as nitrogen gas. In-situ bioremediation is also effectively used in used in nitrate treatment of contaminated groundwater. Reverse Osmosis, catalytic reduction and blending are effective methods for nitrate removal from groundwater.

Fluoride: The fluoride remedial measures broadly adopted are ex-situ techniques. They can be classified into three major categories.

- Adsorption and ion exchange
- Ion-Exchange resins
- Coagulation-precipitation
- Nalgonda Technique

The choice of method depends quantum of water to be treated i.e. domestic level or community level or large scale and implementation. It also depends on factors such as the level of contamination, water quality standards, and available resources. Combination approaches may also be necessary for effective contamination removal in some cases. In present day scenario, Reverse Osmosis (RO) Method using controlled TDS (TDS not less than 500 mg/l as per BIS acceptable value) seems economically and practically more feasible than other methods. Additionally, piped treated water supply in affected locations and method of dilution by employing Rainwater Harvesting method also seems effective.