GROUNDWATER CHEMICAL QUALITY BULLETIN

of Kerala State for Pre- Monsoon 2024

CENTRAL GROUND WATER BOARD
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1.0 INTRODUCTION

The quality of groundwater is a very sensitive issue. Groundwater is never pure and contains varying amounts of dissolved solids, the type and concentration depend on its source, surface and sub-surface environment, rate of groundwater movement, the residence time, the solubility of minerals present and the amount of dissolved carbon dioxide. In addition to natural changes, anthropogenic activities such as sewage disposal, agricultural practices, industrial pollution etc. also contribute significantly to changes in groundwater quality. Once the contaminants have entered to the sub-surface geological environment, they may remain concealed for many years and may get dispersed over wide areas. Weathering of rock and mineral solubility controls the major ion composition of groundwaters. With increasing anthropogenic activities, a substantial amount of dissolved matter is added to groundwater. The ground water resources are being utilized for drinking, irrigation and industrial purposes. However, due to rapid growth of population, urbanization, industrialization and agriculture activities, ground water resources are under stress. There is growing concern on the deterioration of ground water quality due to geogenic and anthropogenic activities.

Kerala is a state with varied hydrogeological situations resulting from diversified geological, climatological and topographic settings. Water-bearing rock formations (aquifers), range in age from Archaean to Recent. The natural chemical composition of ground water is influenced predominantly by type & depth of soils and subsurface geological formations through which ground water passes. Ground water quality is also influenced by contribution from the atmosphere and surface water bodies. Quality of ground water is also influenced by anthropogenic factors. For example, overexploitation of ground water in coastal regions may result in sea water ingress and consequent increase in salinity of ground water, excessive use of fertilizers and pesticides in agriculture and improper disposal of urban/industrial waste can cause contamination of ground water resources.

A diverse range of dissolved inorganic compounds present in different concentrations characterizes groundwater. These compounds originate from the chemical and biochemical interactions between water and geological substances. Inorganic impurities such as salinity, chloride, fluoride, nitrate, iron, and arsenic play a crucial role in assessing the suitability of groundwater for drinking purposes.

2.0 HYDROGEOLOGY

Geologically, 88% of the State is underlain by crystalline rocks of Archaean age, which is a part of the peninsular shield. The crystalline complex of Kerala is composed of khondalites, charnockites, gneisses, schists, migmatites, acidic and basic intrusive and rocks of the Wayanad supracrystals. Along the western portion of the state the crystalline rocks are overlain by the sedimentary formations of Tertiary age and recent alluvial formations. The Tertiary sequence of formations have been divided into four beds viz. Alleppey, Vaikom, Quilon and Warkali, the age of which ranges from Eocene to Lower

Miocene. Laterites of Sub-recent age derived from the crystallines as well as sedimentary formations are seen all along the midlands. Along the coastal plains, sedimentaries and laterites are overlain by alluvium of recent age as shown in figure 2.1.

In hard rock terrain, comprising weathered crystallines and laterites, ground water occurs under phreatic conditions in the weathered residuum and the shallow fractures hydraulically connected to it, whereas it is under semi-confined to confined conditions in the deep fracture zones. In the alluvial terrain, ground water in the shallow aquifer systems is in phreatic condition. Granular zones in the Tertiary sedimentary formations at deeper levels form potential confined to semi-confined aquifers.

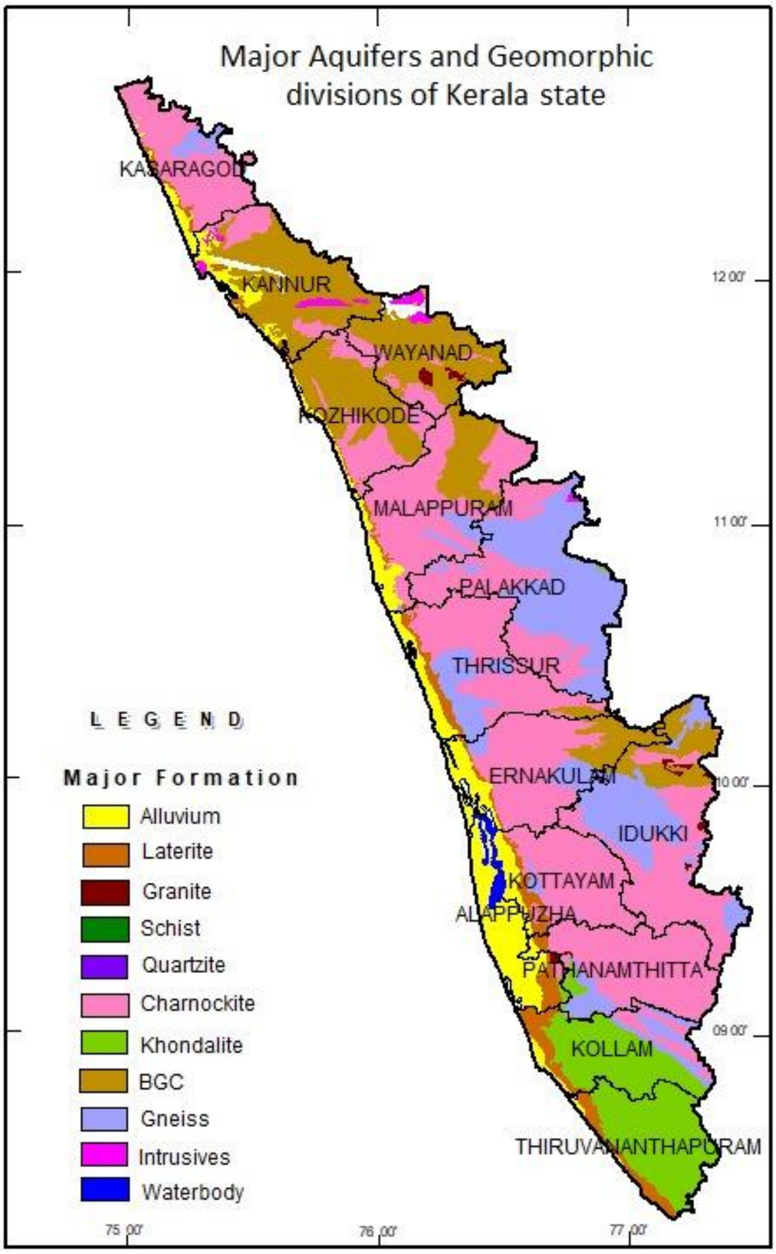

Fig 2.1. Map showing major aquifers and geomorphic divisions of Kerala State

3.0 GROUND WATER QUALITY MONITORING

The International Standard Organization (ISO) has defined monitoring as," The programmed process of samplings, measurements and subsequent recording or signaling or both, of various water characteristics, often with the aim of assessing, conformity to specified objectives". A systematic plan for conducting water quality monitoring is called Monitoring Program, which includes monitoring network design, preliminary survey, resource estimation, sampling, analysis, data management & reporting.

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 through dug wells in a major part of the country and through springs and hand pumps in hilly areas. The main objective of ground water quality monitoring program is to get information on the distribution of water quality on a regional scale as well as lattice is to create a background data bank of different chemical constituents in ground water.

One of the main objectives of the ground water quality monitoring is to assess the suitability of ground water for drinking purpose. The quality of drinking water is a powerful environmental determinant of the health of a community. The problem of the quality of water resources in general, and groundwater resources in particular, is becoming increasingly important in both industrialized and developing nation. In developing countries like India, the essential concerns as regards water resources are their quantity, availability, sustainability and suitability. Groundwater plays a leading role because it has of fundamental importance to all living beings.

Even though water is the most frequently occurring substance on earth, lack of safe drinking water is more prominent in the developing countries. Due to increasing world population, extraction of groundwater is also increasing for irrigations, industries, municipalities and urban and rural households' day by day. During dry season extensive withdrawal of groundwater for irrigation purpose is lowering the water table in the aquifer and also changing the chemical composition of water.

The physical and chemical quality of ground water is important in deciding its suitability for drinking purposes. Bureau of Indian Standards (BIS) formally known as Indian Standard Institute (ISI) vide its document IS: 10500:2012, Edition 3.2 (2012-15) has recommended the quality standards for drinking water. On this basis of classification, the natural ground water of Kerala has been categorized as desirable, permissible or unfit for human consumption.

From the analytical results, it is seen that majority of water samples collected from observation / monitoring wells of CGWB in a major part of the State fall under desirable or permissible category and hence are suitable for drinking purposes. However, a small percentage of well waters are found to have concentrations of some constituents beyond the permissible limits. Such waters are not fit for human consumption and are likely to be harmful to health on continuous use.

4.0 GROUND WATER QUALITY SCENARIO IN KERALA

The quality of groundwater in Kerala has been evaluated by sampling and analysis of water samples collected from Groundwater Monitoring wells. About **545** Groundwater Monitoring wells were considered for water quality during April 2024 representing pre-monsoon water quality as shown in Fig 4.1. The summarized results of groundwater quality ranges are given in **Table - 4.1.**

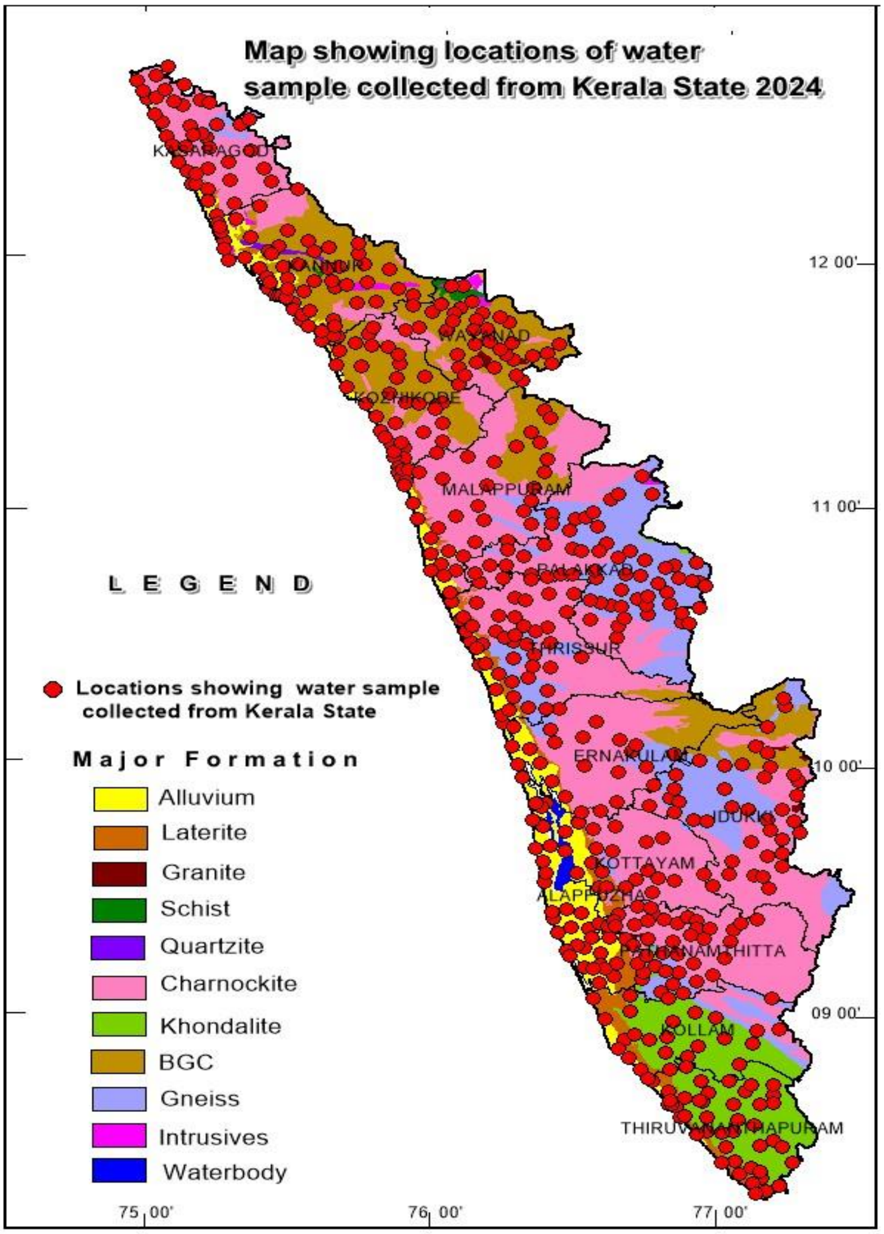

Fig. 4.1. Map showing Spatial Distribution of Groundwater Quality Monitoring Stations in Kerala based on Pre- Monsoon-2024

Table - 4.1. Summarized results of groundwater quality ranges, (April 2024)

S. No	Parameters	Quality	Range	No. of sample	Percentage
1	Electrical Conductivity µs/cm at 25°c	Fresh	< 750	512	93.94
		Moderately or slightly mineralized	750- 3000	33	6.06
		Highly mineralized	> 3000	0	0
2	Fluoride mg/L	Desirable limit	< 1.0	538	98.71
		Permissible limit	1.0 - 1.5	5	0.92
		Beyond permissible limit	>1.5	2	0.37
3	Nitrate mg/L	Permissible limit	< 45	511	93.76
		Beyond permissible limit	> 45	34	6.24

The groundwater samples collected from dug wells tapping phreatic aquifers are analyzed for all the major inorganic parameters. Based on the results, it is found that ground water of the state is mostly of calcium bicarbonate (Ca-HCO_3) type when the total dissolved solids of water is below 500 mg/L (corresponding to electrical conductance of 750 µS/cm at 25^0C). They are of mixed cations and HCO_3-anion type when the electrical conductance is >750. 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 nitrate and fluoride have been observed in some pockets in the districts of the state.

Water Quality Monitoring Stations of CGWB,KR is given in Table 4.2. The present bulletin is based on the changing scenario in water quality in these wells from years 2022 to 2024.

Table 4.2: District wise distribution of water Quality Monitoring Stations

Sl No	District	No. of Water Quality Monitoring Stations		
		2022	2023	2024
1	Alappuzha	18	23	37
2	Ernakulum	28	26	24
3	Idukki	20	20	41
4	Kannur	18	23	54
5	Kasaragod	22	22	43
6	Kollam	18	24	25
7	Kottayam	25	28	23
8	Kozhikode	18	23	42
9	Malappuram	28	31	33
10	Palakkad	20	32	62
11	Pathanamthitta	14	18	37
12	Thiruvananthapuram	22	30	45
13	Thrissur	28	25	43
14	Wyanad	16	17	36
	Total	295	342	545

5.0 GROUND WATER QUALITY HOT SPOTS IN UNCONFINED AQUIFERS OF KERALA

Unconfined aquifers are extensively tapped for water supply across the state therefore; its quality is of paramount importance. The chemical parameters like TDS, Chloride, Fluoride, Iron, Arsenic and Nitrate etc are main constituents defining the quality of ground water in unconfined aquifers. Therefore, presence of these parameters in ground water beyond the permissible limit in the absence of alternate source has been considered as groundwater quality hotspots.

Groundwater quality hot spot maps of the state have been prepared depicting four main parameters based on their distribution shown on the separate maps. These maps depict the spatial distribution of the following constituents in ground water tapping the unconfined aquifers.

I. Electrical Conductivity
II. Fluoride (>1.5 mg/L)
III. Nitrate (>45mg/L)
IV. Iron (>1.0 mg/L)

5.1 ELECTRICAL CONDUCTIVITY

Conductivity measurements are used routinely in many industrial and environmental applications as a fast, inexpensive and reliable way of measuring the ionic content in a solution. For example, the measurement of product conductivity is a typical way to monitor and continuously trend the performance of water purification systems. In many cases, conductivity is linked directly to the total dissolved solids (TDS).

Salinity is the saltiness or dissolved salt contents of a water body. Salt content is an important factor in water use. Salinity can be technically defined as the total mass in grams of all the dissolved substances per Kilogram of water. Different substances dissolve in water giving it taste and odour. In fact, humans and other animals have developed senses which are, to a degree, able to evaluate the potability of water, avoiding water that is too salty or putrid.

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, and quantity of rainfall and above all, the climate of the area. The salinity of groundwater in coastal areas in addition to the above may be due to air borne salts originating from air water interface over the sea and also due to over pumping of fresh water which overlays saline water in coastal aquifer systems.

BIS has recommended a drinking water standard for total dissolved solids a limit of 500 mg/L (corresponding to EC of about 750 μS/cm at 25^0C) that can be extended to a TDS of 2000 mg/L (corresponding to EC of about 3000 μS/cm at 25^0C) in case of no alternate source. Water having TDS more than 2000 mg/L is not suitable for drinking purpose. In Fig 5.1.2, the EC values (in μS/cm at 25^0C) of ground water from observation/monitoring wells have been used to show distribution patterns of electrical conductivity in different ranges of suitability for drinking purposes. It is apparent from the map that majority of the waters having EC values less than 750μS/cm at 25^0C occur mostly all over the State.

Groundwater with EC ranging between 750 and 3000μS/cm at 25^0C falling under 'permissible' range are confined mainly to parts of Alappuzha, Ernakulam, Kannur, Kozhikode, Malappuram, Palakkad, Thrissur, Trivandrum and Wyanad. The highest value of EC in the state was found in the Palakkad district with a value of 2366 μS/cm, no relatively high values of EC greater than 3000 μS/cm are observed elsewhere in the state. Table 5.1.1 given below provides for the number of samples analyzed per district, along with their minimum, maximum, mean EC values and districts with high EC water (750 to 3000 μS/cm) based on NHS 2024 pre monsoon data and there are no areas in the state that can be identified as water quality hotspots from salinity point of view

The occurrences of Electrical Conductivity in ground water have been shown on the contour map as Fig 5.1.1.

Table 5.1.1 District-wise percentage of samples having EC >750 μS/cm

Sl No	District	No. of Samples Analyzed	Min	Max	Mean	No. of samples (%)		
						<750	750-3000	>3000
1	Alappuzha	37	42	1711	376	34(91.89)	3(8.11)	0
2	Ernakulam	24	46	2225	376	21(87.5)	3(12.5)	0

3	Idukki	41	50	689	199	41(100)	0(0)	0
4	Kannur	54	40	1503	201	52(96.3)	2(3.7)	0
5	Kasaragod	43	46	323	124	43(100)	0(0)	0
6	Kollam	25	38	541	221	25(100)	0(0)	0
7	Kottayam	23	38	728	199	23(100)	0(0)	0
8	Kozhikode	42	29	779	231	41(97.62)	1(2.38)	0
9	Malappuram	33	106	1027	346	30(90.91)	3(9.09)	0
10	Palakkad	62	86	2366	541	46(74.19)	16(25.81)	0
11	Pathanamthitta	37	35	622	127	37(100)	0(0)	0
12	Thiruvananthapuram	45	50	878	272	43(95.56)	2(4.44)	0
13	Thrissur	43	48	1925	269	41(95.35)	2(4.65)	0
14	Wyanad	36	44	770	225	35(97.22)	1(2.78)	0
	Total	545				512(93.94%)	33(6.06%)	0

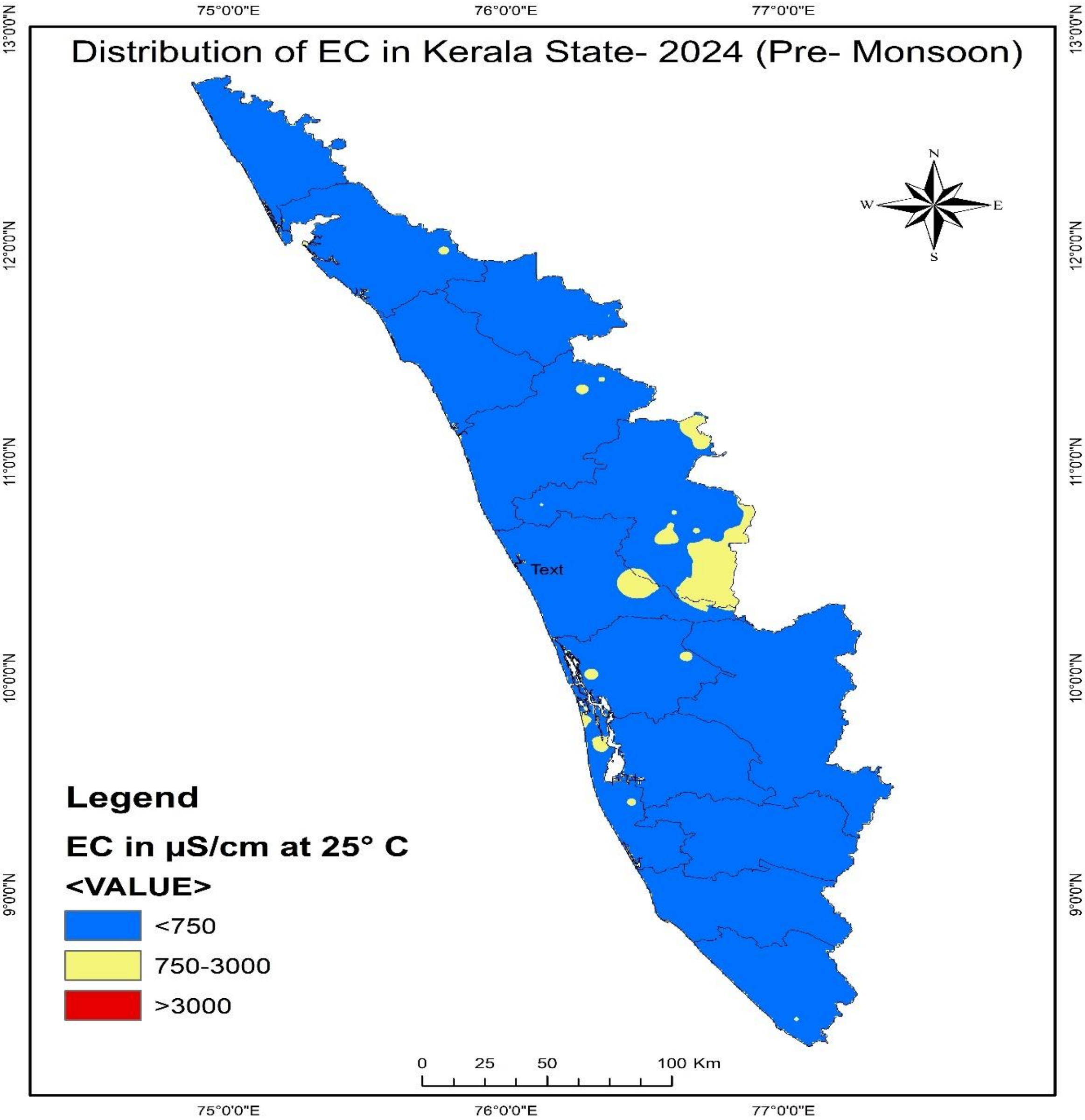

Fig 5.1.1 Spatial distribution of Electrical Conductivity during April 2024

Table 5.1.2: Comparative change in no. of locations having EC>750µs/cm in districts

Sl No	District	No of locations with EC>750		
		2022	2023	2024
1	Alappuzha	1	0	3
2	Ernakulam	2	2	3
3	Idukki	0	0	0
4	Kannur	0	0	2
5	Kasargod	0	0	0
6	Kollam	0	0	0
7	Kottayam	0	0	1
8	Kozhikode	1	1	0
9	Malappuram	0	1	3
10	Palakkad	5	9	16
11	Pathanamthitta	1	0	0
12	Thiruvananthapuram	1	3	2
13	Thrissur	2	2	2
14	Wyanad	1	0	1
	Total	14	18	33

TEMPORAL VARIATION OF EC IN GROUND WATER DURING THE PERIOD FROM 2022 TO 2024

In comparison to 2022 (Table 5.1.2), it has been observed that there is increase in the no. of Districts having EC more than 750 µS/cm in 2024 due to higher number of samples analyzed. As of now the trend of EC in Kerala(Table 5.1.3&Fig 5.1.2) can be shown to be stable.

Table 5.1.3: Periodic variation in suitability Classes of groundwater Electrical Conductivity (EC) of Kerala

Parameter	Class	Percentage of Samples			Periodic variation(2022-2024)
Salinity as EC		2022	2023	2024	
		N=295	N=342	N=545	
	<750µs/cm	95.26	94.74	93.94	-1.3
	750-3000	4.74	5.26	6.06	+1.3
	>3000	0	0	0	

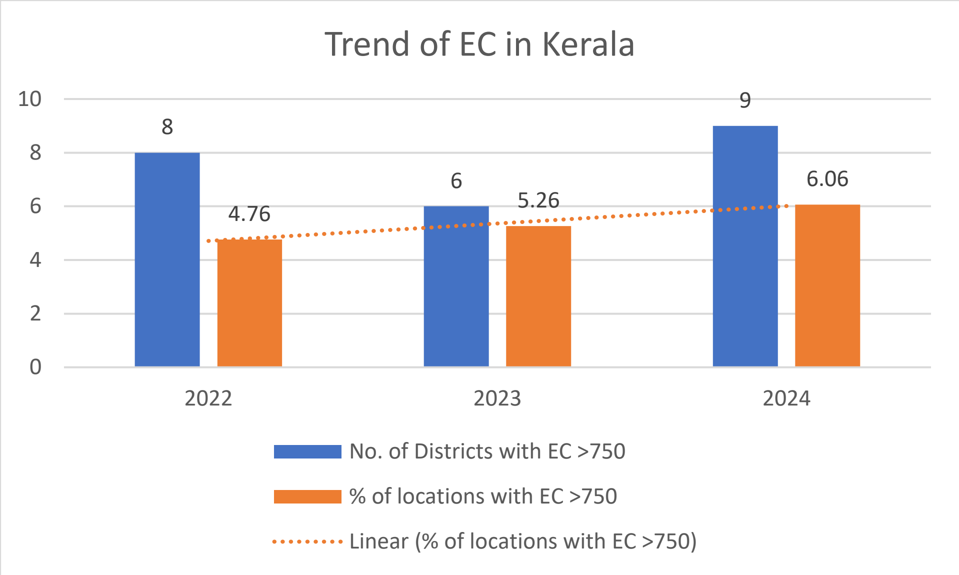

Fig 5.1.2 Trend of EC in Kerala

5.2 FLUORIDE

Fluorine is a fairly common element but it does not occur in the elemental state in nature because of its high reactivity. Fluorine is the most electronegative and reactive of all elements that occur naturally within many types of rock. It exists in the form of fluorides in a number of minerals of which fluorspar, cryolite, fluorite and fluorapatite are the most common. Fluorite (CaF_2) is a common fluoride mineral. 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 ground water in small amounts.

The occurrence of fluoride in natural water is affected by the type of rocks, climatic conditions, nature of hydrogeological strata and time of contact between rock and the circulating ground water. Presence of other ions, particularly bicarbonate and calcium ions also affect the concentration of fluoride in ground water. It is well known that small amounts of fluoride (less than 1.0 mg/L) have proven to be beneficial in reducing tooth decay. Community water supplies commonly are treated with NaF or fluorosilicates to maintain fluoride levels ranging from 0.8 to 1.2 mg/L to reduce the incidence of *dental carries*.

However, high concentrations such as 1.5 mg/L of F and above have resulted in staining of tooth enamel while at still higher levels of fluoride ranging between 5.0 and 10 mg/L, further pathological changes such as stiffness of the back and difficulty in performing natural movements may take place. BIS has recommended an upper desirable limit of 1.0 mg/L of F^- as desirable concentration of fluoride in drinking water, which can be extended to 1.5 mg/L of F in case no alternative source of water is available. Water having fluoride concentration of more than 1.5 mg/L are not suitable for drinking purposes. The fluoride content in groundwater from observation wells in a major part of the state is found to be less than 1.0 mg/L. The distribution of ground water samples with fluoride concentration have been depicted on the map as Fig. 5.2.1. It is observed that only two locations all in Palakkad District have fluoride concentrations greater than 1.5 mg/L.

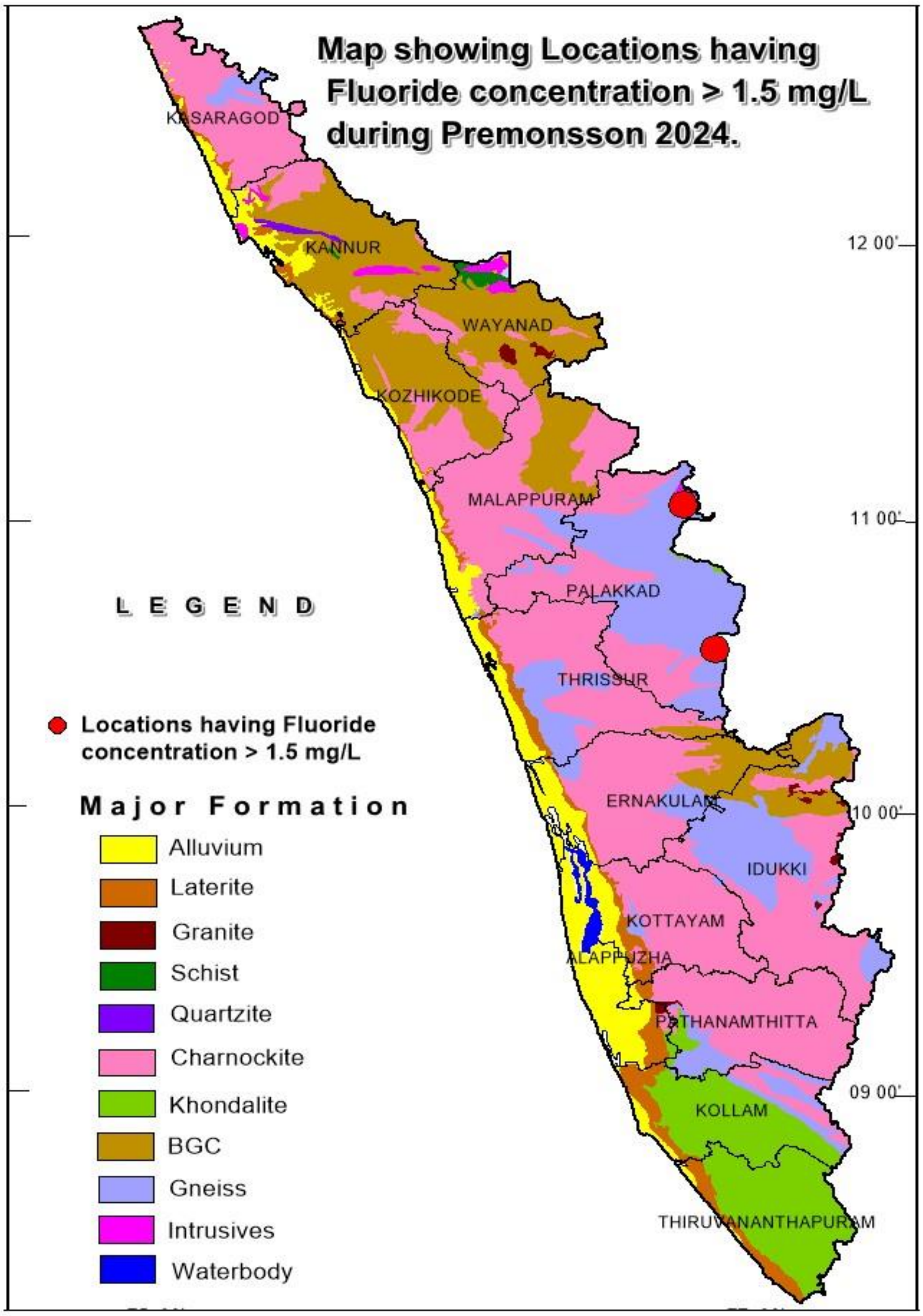

Fig 5.2.1 Locations having Fluoride concentration > 1.5 mg/L during April 2024.

The Table given below provides for the number of samples analyzed per district, along with their minimum, maximum, and mean Fluoride values based on NHS 2024 pre monsoon data.

Table 5.2.1 District-wise percentage of wells with fluoride in between 1.0 to 1.5 mg/L & >1.5mg/L

Sl No	District	No. of Samples Analyzed	Min	Max	Mean	No. of samples (%)		
						<1.0	1.0-1.5	>1.5
1	Alappuzha	37	0	0.9	0.11	37	0	0
2	Ernakulum	24	0	0.2	0.05	24	0	0
3	Idukki	41	0	0.5	0.09	41	0	0
4	Kannur	54	0	0.18	0.03	54	0	0
5	Kasaragod	43	0	0.13	0.04	43	0	0
6	Kollam	25	0	0.3	0.1	25	0	0
07	Kottayam	23	0	0.2	0.04	23	0	0
8	Kozhikode	42	0	0.57	0.05	42	0	0
9	Malappuram	33	0	0.36	0.08	33	0	0
10	Palakkad	62	0	2.02	0.46	53	5	2
11	Pathanamthitta	37	0	0.5	0.08	37	0	0
12	Thiruvananthapuram	45	0	0.43	0.08	45	0	0
13	Thrissur	43	0	0.62	0.1	43	0	0
14	Wyanad	36	0	0.45	0.1	36	0	0
	Total	545				538(98.71%	5(0.92%)	2(0.37%)

TEMPORAL VARIATION OF FLUORIDE IN GROUND WATER DURING THE PERIOD FROM 2022 TO 2024

In comparison to 2022 (Table 5.2.2), it has been observed that there is increase in the no. of locations having F more than 1mg/L in 2024 due to higher number of samples analysed from various locations and these are all in Palakkad Dt which is known for being the fluoride hotspot of Kerala State

Table 5.2.2 Comparative change in no. of locations having F in between 1.0 to 1.5 mg/L & >1.5mg/L in various districts

Sl no	District	No of locations with F>1			No of locations with F>1.5		
		2022	2023	2024	2022	2023	2024
1	Alappuzha	0	0	0	0	0	0
2	Ernakulam	0	0	0	0	0	0
3	Idukki	1	0	0	0	0	0
4	Kannur	0	0	0	0	0	0
5	Kasargod	0	0	0	0	0	0
6	Kollam	0	0	0	0	0	0
7	Kottayam	0	0	0	0	0	0
8	Kozhikode	0	0	0	0	0	0
9	Malappuram	0	0	0	1	0	0
10	Palakkad	0	4	5	0	1	2
11	Pathanamthitta	0	0	0	0	0	0
12	Thiruvananthapuram	0	0	0	0	0	0
13	Thrissur	0	0	0	0	0	0
14	Wyanad	0	0	0	0	0	0

	Total	1	4	5	1	1	2

Table 5.2.3: Periodic variation in suitability Classes of groundwater fluoride (F) of Kerala

Parameter	Class	Percentage of Samples			Periodic variation(2022-2024)
Fluoride as F		2022	2023	2024	
		N=295	N=342	N=545	
	<1.0mg/L	99.32	98.54	98.71	-0.61
	1.0-1.5	0.34	1.17	0.92	+0.58
	>1.5mg/L	0.34	0.29	0.37	+0.03

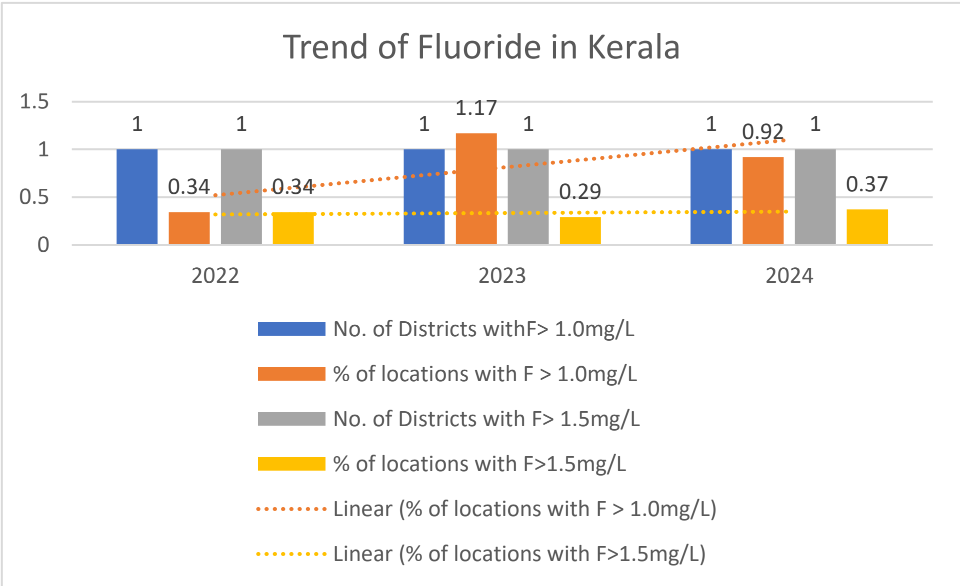

Fig 5.2.2 Trend of F in Kerala

Remedial Measures for Fluoride

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

(a) Adsorption and ion exchange

This technique functions on the adsorption of fluoride ions onto the surface of an active agent such as activated alumina, red mud, bone char, brick pieces column, mud pot and natural adsorbents where fluoride is removed by ion exchange or surface chemical reaction with the solid bed matrix.

Activated alumina: Activated alumina is a highly porous aluminum oxide exhibiting high surface area. Alumina has a high preference for fluoride compared to other anionic species, and hence is an attractive adsorbent. The crystal structure of alumina contains cation lattice discontinuities giving rise to localized areas of positive charge which makes it attract various anionic species. It also does not shrink, swell, soften nor disintegrate when immersed in water. The maximum absorption capacity of activated alumina for fluoride is found to be 3.6 mg F/g of alumina.

Ion-Exchange resins: Synthetic chemicals, namely, anion and cation exchange resins have been used for fluoride removal. Some of these are Polyanion (NCL), Tul-sion A - 27, Deacedite FF (IP), Amberllte IRA 400, LewatitMIH - 59, and AmberliteXE - 75. These resins have been used in chloride and hydroxy form. The fluoride exchange capacity of these resins depends upon the ratio of fluoride to total anions in water.

(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. It is opined that this technique is preferable at all levels because of the low price and ease of handling, is highly versatile and can be used in various scales from household level to community scale water supply.

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. Several researchers have attempted to improve the technique by increasing the removal efficiency of fluoride using Poly Aluminium Chloride (PAC) and Poly Aluminium Hydroxy Sulphate (PAHS).

(c) Membrane techniques

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, however, there are certain procedural disadvantages that limit their usage on a large scale.

5.3 NITRATE

Nitrate is a naturally occurring compound that is formed in the soil when nitrogen and oxygen combine. The primary source of all nitrates is atmospheric nitrogen gas. This is converted into organic nitrogen by some plants by a process called nitrogen fixation. Dissolved Nitrogen in the form of Nitrate is the most common contaminant of ground water. Nitrate in groundwater generally originates from non-point sources such as leaching of chemical fertilizers & animal manure, groundwater pollution from septic and sewage discharges etc. It is difficult to identify the natural and man-made sources of nitrogen contamination of ground water. Some chemical and micro-biological processes such as nitrification and denitrification also influence the nitrate concentration in ground water.

As per the BIS Standard for drinking water the maximum desirable limit of Nitrate concentration in ground water is 45 mg/L with no relaxation. 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 concentrations.

The Table given below provides for the number of samples analyzed per district, along with their minimum, maximum, and mean nitrate values based on NHS 2024 pre monsoon data

Table 5.3.1: District-wise percentage of wells having Nitrate > 45 mg/L

Sl No	District	No. of Samples Analyzed	Min	Max	Mean	No. of samples (%)	
						<45	>45
1	Alappuzha	37	0	45	4.7	36	1
2	Ernakulum	24	1.5	69	13.2	23	1
3	Idukki	41	0.04	68	14.3	39	2
4	Kannur	54	0	56	8.0	53	1
5	Kasaragod	43	0	46	7.8	42	1
6	Kollam	25	0	48	16.5	23	2
7	Kottayam	23	1	71	12.6	22	1
8	Kozhikode	42	0	90	12.3	41	1
9	Malappuram	33	0.32	89	28.2	28	5
10	Palakkad	62	0.1	64	10.7	60	2
11	Pathanamthitta	37	0.04	56	11.4	35	2
12	Thiruvananthapuram	45	0	148	27.4	36	9
13	Thrissur	43	0	101	19.2	38	5
14	Wyanad	36	0	62	9.7	35	1
	Total	545				511(93.76%)	34(6.24%)

TEMPORAL VARIATION OF NITRATE IN GROUND WATER DURING THE PERIOD FROM 2022 TO 2024

In comparison to 2022 (Table 5.3.2), it has been observed that there is increase in the no. of locations having nitrate more than 45mg/L in 2024 due to higher number of samples analysed from various locations and these are distributed in all 14 districts of Kerala State but mostly concentrated in Thiruvananthapuram Dt. It may be noted that Thiruvananthapuram Dt has a comparatively high number of locations with high nitrate concentrations throughout the years of comparison and that compared to EC and F which showed an increase in trend probably due to the higher number of samples there was a decrease in trend for nitrate which may mean that some process has contributed to decrease in nitrate values over the years in comparison.

Table 5.3.2 Comparative change in no. of locations having NO3>45mg/L in various districts

Sl no	District	No of locations with NO3>45		
		2022	2023	2024

1	Alappuzha	1	2	1
2	Ernakulam	1	0	1
3	Idukki	5	2	2
4	Kannur	2	1	1
5	Kasargod	1	0	1
6	Kollam	1	2	2
7	Kottayam	1	0	1
8	Kozhikode	0	1	1
9	Malappuram	5	3	5
10	Palakkad	2	2	2
11	Pathanamthitta	2	2	2
12	Thiruvananthapuram	5	6	9
13	Thrissur	2	2	5
14	Wyanad	0	0	1
	Total	28	23	34

The specified limits are not to be exceeded in public water supply. If the limit is exceeded, water is considered to be unfit for human consumption. The occurrences of Nitrate in ground water beyond permissible limit (45 mg /L) have been shown on the map as a point source Fig 5.3.1.

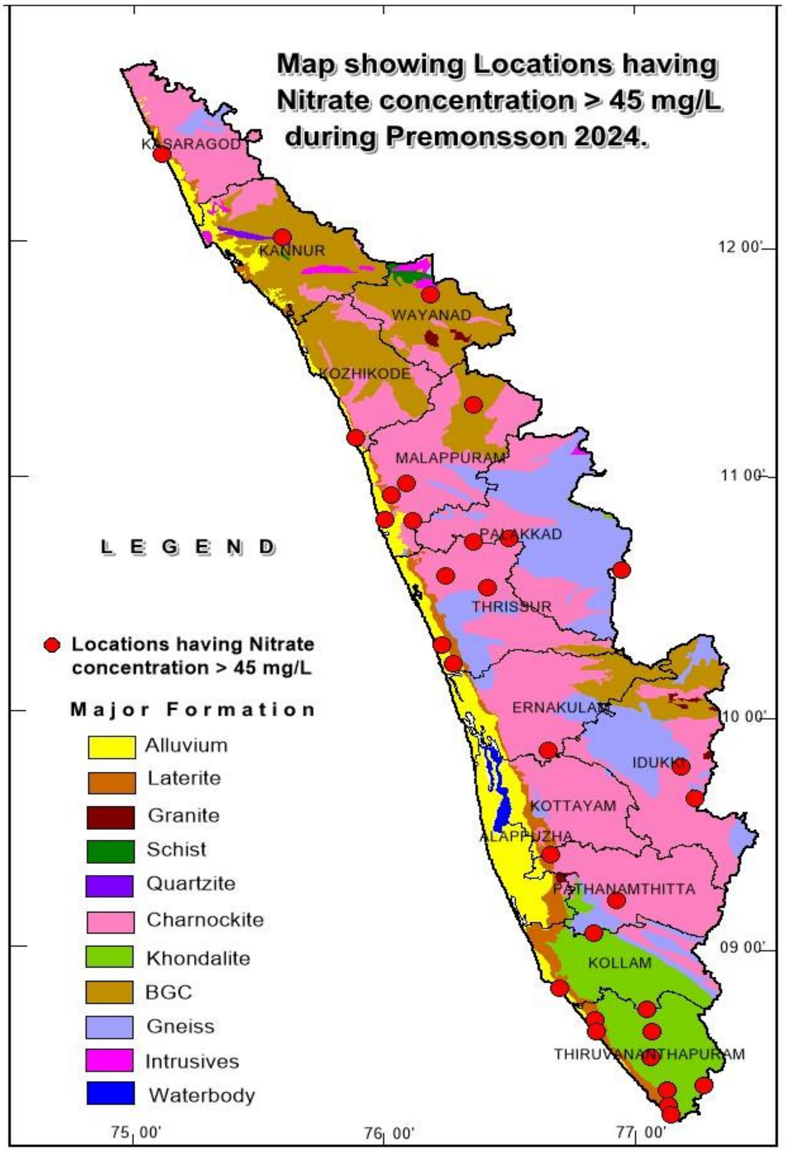

Fig 5.3.1 Locations having Nitrate concentration > 45 mg/L during April 2024.

Table 5.3.3: Periodic variation in suitability Classes of groundwater nitrate(NO3) of Kerala

Parameter	Class	Percentage of Samples			Periodic variation(2022-2024)
Nitrate as NO3		2022	2023	2024	
		N=295	N=342	N=545	
	<45mg/L	90.51	93.27	93.76	+3.25
	>45mg/L	9.49	6.73	6.24	-3.25

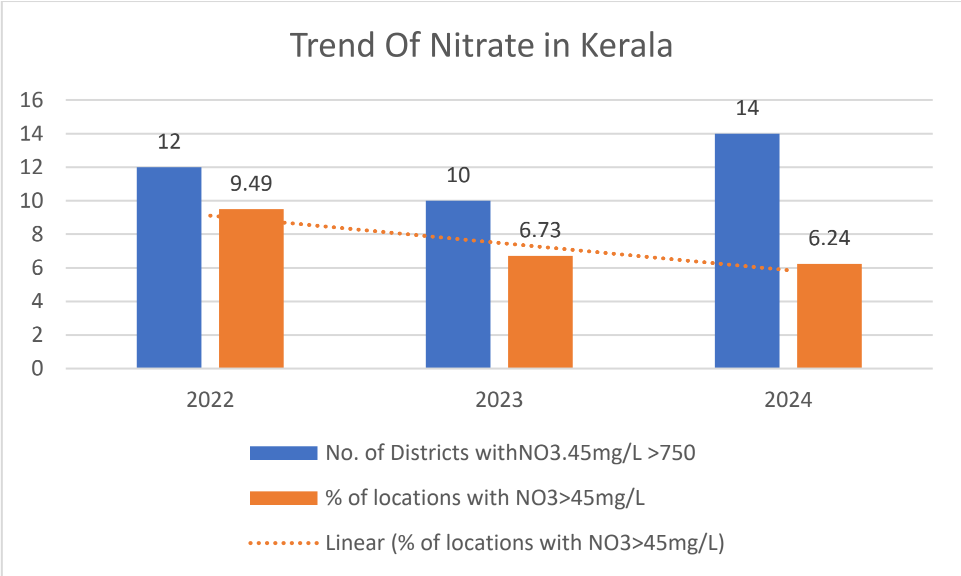

Fig 5.3.2 Trend of Nitrate in Kerala

Remedial Measures for Nitrate

For removal of nitrate both non-treatment techniques like blending and treatment processes such as ion-exchange, reverse osmosis, biological denitrification 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.

a) 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.

b) 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)

The mechanism of nitrate pollution in subsurface porous unconfined/confined aquifer is governed by complex biogeochemical processes. 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 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. For nitrate removal, operating trans-membrane pressure of RO unit generally ranges from 20 to 100 bar.

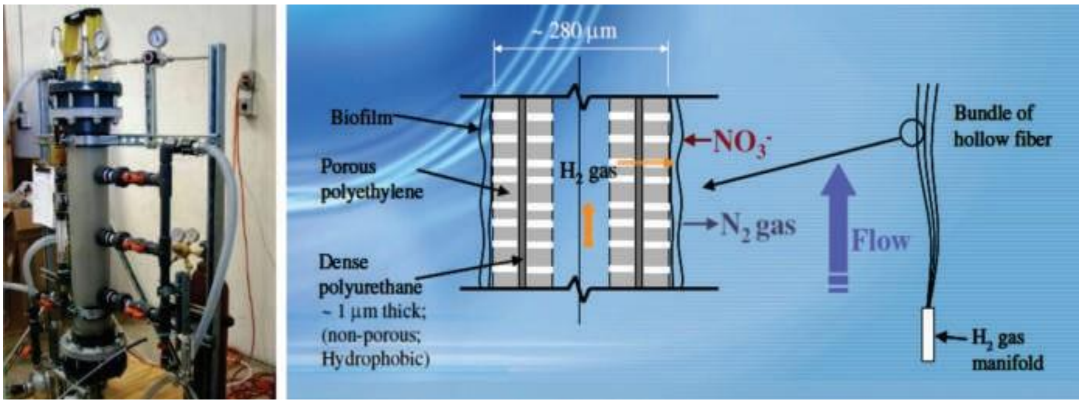

Fig. 5.3.3 Advanced Nitrate Reduction Hollow Fiber Membrane Reactor (Source: Hand Book for Drinking Water Treatment, JJM, Ministry of Jal Shakti, Gov. of India)

5.4 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 groundwater mainly from weathering of ferruginous minerals of igneous rocks such as hematite, magnetite and sulphide ores of sedimentary and metamorphic rocks.

The permissible Iron concentration in ground water is 1.0 mg/L as per the BIS Standard for drinking water. The occurrences of iron in ground water beyond permissible limit (> 1.0 mg /litre) have been shown on the maps as point sources (Fig 5.4.1). It is based on the chemical analysis of water samples mostly collected from the groundwater observation wells in pre monsoon 2024. The iron point value map indicates central part of Kerala having more iron content in groundwater compare to other parts. The most iron affected districts are Thrissur, Alappuzha, Kasargod and Kollam

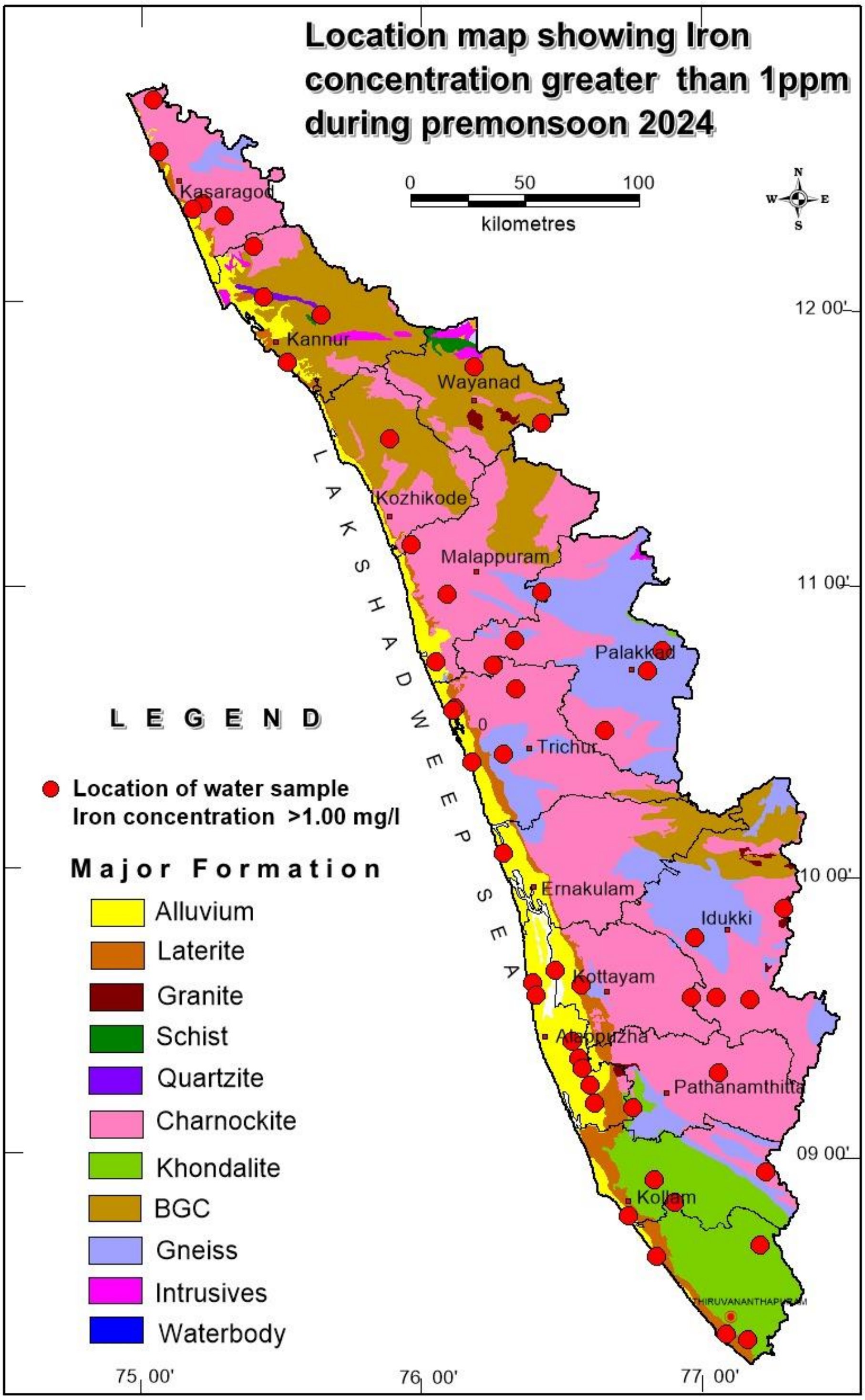

Fig. 5.4.1 Map showing areas of Iron contaminated (> 1.0mg/L) groundwater in Kerala,2024

The Table given below provides for the number of samples analyzed per district, along with their minimum, maximum, and mean iron values based on NHS 2024 pre monsoon data

Table 5.4.1: District-wise percentage of wells having Iron > 1 mg/L

	District		Min	Max	Mean	No. of samples (%)

Sl No		No. of Samples Analyzed				<1.0	>1.0
1	Alappuzha	37	0.11	3.2	0.74	28	9
2	Ernakulum	21	0.06	1.04	0.36	20	1
3	Idukki	41	0.06	7.88	0.45	37	4
4	Kannur	54	0.04	10.89	0.59	50	4
5	Kasaragod	42	0.22	8.85	0.73	37	5
6	Kollam	25	0.28	3.37	0.74	21	4
07	Kottayam	22	0.28	3.24	0.61	20	2
8	Kozhikode	40	0.25	3.01	0.51	38	2
9	Malappuram	33	0.21	1.1	0.38	31	2
10	Palakkad	62	0	4.22	0.45	56	6
11	Pathanamthitta	33	0.22	1.32	0.43	32	1
12	Thiruvananthapuram	45	0.23	3.07	0.59	41	4
13	Thrissur	43	0.05	7.62	0.73	38	5
14	Wyanad	36	0.24	1.62	0.47	34	2
	Total	534				483(90.44%	51(9.55%)

TEMPORAL VARIATION OF IRON IN GROUND WATER DURING THE PERIOD FROM 2022 TO 2024

In comparison to 2021 (Table 5.4.2), it has been observed that there is increase in the no. of locations having iron more than 1.0mg/L in 2024 due to higher number of samples analysed from various locations and these are distributed in all 14 districts of Kerala State but mostly concentrated in Alappuzha Dt

Table 5.4.2 Comparative change in no. of locations having Fe>1.0mg/L in various districts

Sl no	District	No of locations with Fe>1.0		
		2021	2023	2024
1	Alappuzha	4	4	9
2	Ernakulam	3	4	1
3	Idukki	2	0	4
4	Kannur	1	2	4
5	Kasargod	2	2	5
6	Kollam	0	3	4
7	Kottayam	3	0	2
8	Kozhikode	1	1	2
9	Malappuram	2	1	2
10	Palakkad	2	1	6
11	Pathanamthitta	0	0	1
12	Thiruvananthapuram	1	2	4
13	Thrissur	5	4	5
14	Wyanad	1	0	2
	Total	27	24	51

Table 5.4.3: Periodic variation in suitability Classes of groundwater Iron(Fe) of Kerala

Parameter	Class	Percentage of Samples			Periodic variation(2021-2024)
Iron as Fe		2021	2023	2024	
		N=351	N=342	N=534	
	<1.0mg/L	92.31	92.98	90.45	-1.86
	>1.0mg/L	7.69	7.02	9.55	+1.86

Remedial Measures for Iron

a) **Oxidation and filtration:** Before iron can be filtered, it needs to be oxidized to a state in which it can form insoluble complexes. Ferrous iron (Fe^{2+}) is oxidized to ferric iron (Fe^{3+}), which readily forms the insoluble iron hydroxide complex $Fe(OH)_3$. 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 too much will allow permanganate to enter the distribution system and cause a pink color.

Ozone may be used for iron oxidation. Ozone may not be effective for oxidation in the presence of humic or fulvic materials. 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. 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. 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.

b) Ion Exchange Ion exchange should be considered only for the removal of small quantities of iron 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 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.

c) 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 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 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.

d) Sequestration is the addition of chemicals to groundwater aimed at controlling problems caused by iron e without removing it. 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 , using polyphosphates followed by chlorination can be an effective and inexpensive method for mitigating iron problems. No sludge is generated in this method. Below these concentrations, the polyphosphates combine with the iron preventing it 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. However, while this technique is reliable in the case of iron treatment, it has not been found to be effective in manganese control.

5.5 ARSENIC

No arsenic levels higher than the permissible limit of 0.01mg/L(10ppb) has been noted in Kerala so far in monitoring conducted in Ground Water Monitoring Network Stations

5.6 URANIUM

In Kerala state, there are no sample locations where the uranium in groundwater exceeds the permissible limit (30 ppb).

6 SUMMARY

The analytical results show no concerning contamination, however, some districts in Kerala had groundwater samples exceeding permissible limits for Nitrate, Fluoride, and Iron in pre-monsoon 2024.

This decline in water quality may stem from geogenic and/or anthropogenic sources. While most samples from Central Ground Water Board observation wells meet drinking water standards for basic parameters and heavy metals, some exceed permissible limits, posing health risks with prolonged use.

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

The Table 6.1 provides a detailed summary of groundwater quality across various districts in Kerala, focusing on basic parameters (electrical conductivity, nitrate, fluoride) and heavy metal (iron).

Table 6.1: Summary of Groundwater Quality in Various Districts of Kerala, Highlighting Basic Parameters (Electrical Conductivity, Nitrate, Fluoride) and Heavy Metal (Iron)

Sl No	District	No of samples collected (premonsoon 2024)	No of samples for EC exceeding BIS limit		No of samples for F exceeding BIS limit		No of samples for NO3 exceeding BISlimit	No of samples collected (premonsoon 2024)	No of samples for Fe exceeding BIS limit
			>750µs/cm	>3000µs/cm	1.0mg/L-1	>1.5mg/L	>45mg/L		>1.0mg/L
1	Alappuzha	37	3(8.11%)	0	0	0	1(2.7%)	37	9(24.32%)
2	Ernakulam	24	3(12.5%)	0	0	0	1(4.17%)	21	1(4.76%)
3	Idukki	41	0	0	0	0	2(4.88%)	41	4(9.76%)
4	Kannur	54	2(3.7%)	0	0	0	1(1.85%)	54	4(7.41%)
5	Kasargod	43	0	0	0	0	1(2.33%)	42	5(11.9%)
6	Kollam	25	0	0	0	0	2(8%)	25	4(16%)
7	Kottayam	23	0	0	0	0	1(4.35%)	22	2(9.09%)
8	Kozhikode	42	1(2.38%)	0	0	0	1(2.38%)	40	2(5%)
9	Malappuram	33	3(9.09%)	0	0	0	5(15.15%)	33	2(6.06%)
10	Palakkad	62	16(25.81%)	0	5(0.92%)	2(0.37%)	2(3.23%)	62	6(9.68%)
11	Pathanamthitta	37	0	0	0	0	2(5.4%)	33	1(3.03%)
12	Thiruvananthapuram	45	2(4.44%)	0	0	0	9(20%)	45	4(8.89%)
13	Thrissur	43	2(4.65%)	0	0	0	5(11.63%)	43	5(11.63%)
14	Wyanad	36	1(2.78%)	0	0	0	1(2.78%)	36	2(5.56%)
	Total	545	33(6.06%)	0(0%)	5(0.92%)	2(0.37%)	34(6.24%)	534	51(9.55%)

Basic Parameters:

- EC (Electrical Conductivity): Nil samples exceed permissible limits. Only 6.06% exceeds desirable limits
- NO3 (Nitrate): 6.24% of samples exceed permissible limits, with notable levels in Trivandrum and Malappuram district.
- F (Fluoride): Overall, just 2 samples (0.37%) surpasses permissible levels in the locations Kadambra South And Moochankundu of Palakkad district

Heavy Metals:

- Fe (Iron): Detected in 9.55% of samples, notably in districts like Alappuzha, Kasargod, Kollam and Thrissur districts.

STATE SUMMARY

The groundwater quality assessment in Kerala has not revealed notable levels of contamination across various parameters. Iron (Fe) emerged as the predominant contaminant, with 9.55 % of samples surpassing permissible limits, followed by nitrate (NO3) at 6.24 %, and Fluoride (F) at 0.37% as shown in fig 6.1.

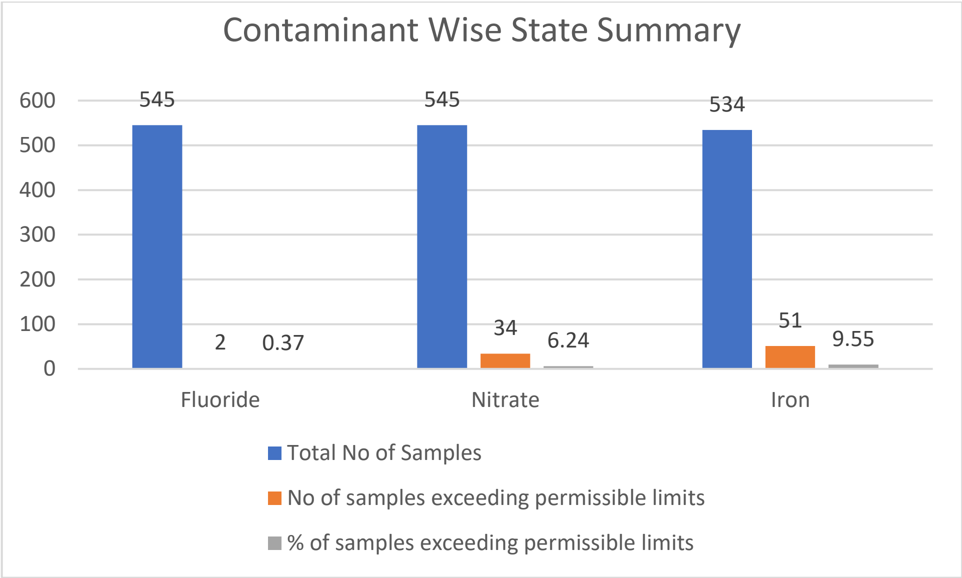

Fig 6.1. Graph showing contaminant wise state summary

RECOMMENDATIONS

1. Ground water in Kerala State in fresh and potable in most of the areas. Water supply in this state is mainly dependant on surface water and dug well. Proper protection measures need to be taken to avoid contamination of ground water.
2. Even though salinity is not a major concern in the state, there are problems of ground water contamination like nitrate, iron and fluoride contamination. The quality surveillance needs to be increased by State Government Organisations. Ground water quality shall be monitored twice in a year for all major elements, trace metals and bacteriological contaminations.
3. Fast developing urban & industrial areas need special attention/quality surveillance by the State government authorities.
4. Lack of proper sewage and sanitation, improper disposal of domestic and industrial solid wastes in the State results in ground water and surface water contaminations. This issue need to be addressed by the authorities. Village sewages shall be disposed of properly after proper treatment. In water logging areas, where ground water is being contaminated by polluted surface water, proper drainage shall be created for avoiding the water logging conditions.
5. Comprehensive studies on ground water quality of both shallow and deep ground waters may be taken up analysing major elements, heavy metals, pesticides and microbial contamination . Areas identified in this report where higher concentrations of heavy metals, nitrates and fluorides need to be given special attentions.

6. The existing data base on quality with different organizations like CGWB, PHED, State pollution control board, academic institutions need to integrated and a comprehensive data base need to be established.

7. Scientific research projects on ground water contamination especially geo-genic contamination like Iron and fluoride need to be taken up immediately

8. Proper management strategies need to be drawn up to combat the problems of geo-genic contamination. Cost effective community level treatment plants need to be established. The treatment plants as recommended in this report shall be constructed with trained manpower as in- charges, so that these treatment plants may work efficiently for longer periods.