CENTRAL GROUND WATER BOARD
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GOVERNMENT OF INDIA

GROUND WATER QUALITY IN SHALLOWAQUIFER OF KERALA

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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 the 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 diversifiedgeological, climatological and topographic settings. Water-bearing rock formations (aquifers),range in age from Archaean to Recent. The natural chemical composition of ground water isinfluenced predominantly by type & depth of soils and subsurface geological formationsthrough which ground water passes. Ground water quality is also influenced by contributionfrom the atmosphere and surface water bodies. Quality of ground water is also influenced byanthropogenic factors. For example, overexploitation of ground water in coastal regions mayresult in sea water ingress and consequent increase in salinity of ground water, excessive useof fertilizers and pesticides in agriculture and improper disposal of urban/industrial waste cancause contamination of ground water resources.

A diverse range of dissolved inorganic compounds present in different concentrationscharacterizes groundwater. These compounds originate from the chemical and biochemicalinteractions between water and geological substances. Inorganic impurities such as salinity,chloride, fluoride, nitrate, iron, and arsenic play a crucial role in assessing the suitability ofgroundwater 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.

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.

a. Crystalline Aquifers

The shallow aquifers of the crystalline rocks are made up of the highly decomposed weathered zone or partly weathered and fractured rocks. Thick weathered zone is seen along the midland area either beneath the laterites or exposed. In the hill ranges thin weathered zone is seen along topographic lows and area with lesser elevation and gentle slope. In areas along the hill ranges generally rock exposures are seen. The depth to water level in this aquifer varies from 2 to 16 m.bgl and the yield of the well ranged between 2 to 10 m^3 per day. Exploratory drilling carried out by Central Ground Water Board in the State in the crystalline formations has indicated that the potential fractures are encountered at depths ranging between 60 to 175 m.bgl with yield varying from less than 1 to as much as 35 liters per second (lps). In Charnockites, more than 40% of the wells have yielded more than 10 lps or above indicating that in Kerala, Charnockite suite of rocks are better aquifers compared to Khondalite group.

b. Tertiary Aquifers

Groundwater occurs under phreatic condition in the shallow zone and under semi-confined to confined conditions in the deeper aquifers. The Tertiary formation of Kerala coast is divided into four distinct beds viz. Alleppey, Vaikom, Quilon and Warkali. These formations except the Alleppey beds are seen as outcrops and they are lateralized wherever they are exposed. The maximum thickness of Tertiary sediments is found between Karunagapally and Kattoor and all the four beds are found in this area. Groundwater is commonly developed through dug wells tapping the sandy zones at shallow depth in the Tertiary sediments. The depth to water level in this shallow zone ranges from 3.0 to 27 m.bgl and the yield of the wells range from 500 lpd to 10 m3 per day. The Vaikom and Warkali beds form the most potential aquifers in the Tertiary group. The Alleppey bed has been encountered at deeper levels in the bore holes drilled in the coastal tract of Alappuzha district and the formation water is found to be saline and hence, no tube well has been constructed tapping this formation. In the Vaikom aquifers, the piezometric level is between 2 and 20 m above msl. The yield of the tube wells constructed in this formation ranges from 1 to 57 lps. This bed forms auto flow zones along the coast between Karunagapally in Kollam district and Nattika and Kaipamangalam in Thrissur district. The water is generally fresh south of Karuvatta in Alappuzha district. Recent exploration by CGWB proved that good quality groundwater pockets are in existence in this formation in and around Cochin. Warkali aquifers are the most developed aquifer system among the Tertiary group. The urban and rural water supply in the coastal area between Kollam and Cherthala is mostly dependent on this. The piezometric head is about 3 m. above msl along the eastern part of the sedimentary basin whereas it is 10 m. below msl in and around Alappuzha. The yield of the wells tapping this formation ranges from 3 to 14 lps. The hydrogeological information on Quilon beds is very limited. The formation is considered to be a poor aquifer compared to Vaikom and Warkali beds.

c. Laterites

Laterites are the most widely distributed lithological unit in the State and the thickness of this formation varies from a few meters to about 30 m. The depth to water level in the formation ranges from less than a meter to 25 m.bgl. Laterite forms potential aquifers along topographic lows and valleys. The depth to water level in this formation ranges from 2 to 18 m.bgl and the yield ranges from 0.5 to 6 m3 per day. The occurrence and movement of groundwater in the laterites are mainly controlled by the topography. Laterite is a highly porous rock formation, which can form potential aquifers along topographic lows. However, due to the porosity, groundwater is drained from elevated places and slopes at shortest duration after monsoon and hence water scarcity is experienced in the elevated places and slopes.

d. Alluvium

The alluvium forms potential aquifer along the coastal plains and groundwater occurs under phreatic and semi-confined conditions in this aquifer. The thickness of this formation varies from few meters to above 100 m and the depth to water level ranges from less than a meter to 6 m.bgl. Filter point wells are feasible wherever the saturated thickness exceeds 5m. This potential aquifer is extensively developed by dug wells and filter point wells throughout the State and the yield ranges from 5 to 35 m^3 per day.

3.0 HYDROCHEMISTRY

Hydrochemistry is an interdisciplinary science that deals with the chemistry of water in the natural environment. Professional fields such as chemical hydrology, aqueous chemistry, hydrochemistry, water chemistry and hydro-geochemistry are all more or less synonyms. The classical use of chemical characteristics in chemical hydrology is to provide information about the regional distribution of water qualities. At the same time, hydrochemistry has a potential use for tracing the origin and history of water. The hydrochemistry can also be of immense help in yielding information about the environment through which water has circulated. Hydrochemistry can be helpful in knowing about residence times, flow paths and aquifer characteristics as the chemical reactions are time and space dependent. It is essential to study the entire system like atmospheric water (rainwater), surface water and ground water simultaneously in evaluating their hydrochemistry and pollution effect

3.1 CHEMISTRY OF RAINWATER

The atmosphere is composed of water vapors, dust particles and various gaseous components such as N_2, O_2, CO_2, CH_4, CO, SO_4, NO_3 etc. Pollutants in the atmosphere can be transported long distances by the wind. These pollutants are mostly washed down by precipitation and partly as dry fall out. Composition of rainwater is determined by the source of water vapors and by the ion, which are taken up during transport through the atmosphere. In general, chemical composition of rainwater shows that rainwater is only slightly mineralized with specific electrical conductance (EC) generally below 50 μS/cm, chloride below 5 mg/l and HCO_3 below 10 mg/l. Among the cations, concentration of Ca, Mg, Na & K vary considerably but the total cations content is generally below 15 mg/l except in samples contaminated with dust. The concentration of sulphates and nitrates in rainwater may be high in areas near industrial hubs.

3.2 CHEMISTRY OF SURFACE WATER

Surface water is found extremely variable in its chemical composition due to variations in relative contributions of ground water and surface water sources. The mineral content in river water usually bears an inverse relationship to discharge. The mineral content of river water tends to increase from source to mouth, although the increase may not be continuous or uniform. Other factors like discharge of city wastewater, industrial waste and mixing of waters can also affect the nature and concentration of minerals in surface water. Among anions, bicarbonates are the most important and constitute over 50% of the total anions in terms of milli equivalent per liter (meq/l). In case of cations, alkaline earths or normally calcium predominates but with increasing salinity the hydrochemical facies tend to change to mixed cations or even to Na-HCO_3 type.

3.3 CHEMISTRY OF GROUND WATER

The downward percolating water is not inactive, and it is enriched in CO_2. It can also act as a strong weathering agent apart from general solution effect. Consequently, the chemical composition of ground water will vary depending upon several factors like frequency of rain, which will leach out the salts, time of stay of rain water in the root-zone and intermediate zone, presence of organic matter etc. It may also be pointed out that the water front does not move in a uniform manner as the soil strata are generally quite heterogeneous. The movement of percolating water through larger pores is much more rapid than through the finer pores. The overall effect of all these factors is that the composition of ground water varies from time to time and from place to place.

Before reaching the saturated zone, percolating water is charged with oxygen and carbondioxide and is most aggressive in the initial stages. This water gradually loses itsaggressiveness, as free CO_2 associated with the percolating water gets gradually exhaustedthrough interaction of water with minerals.

$$CO_2 + H_2O \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$$

$$H^+ + \text{Feldspar} + H_2O \longrightarrow \text{Clay} + H_4SiO_4 + \text{Cation}$$

The oxygen present in this water is used for the oxidation of organic matter that subsequently generates CO_2 to form H_2CO_3. This process goes on until oxygen is fully consumed.

$CH_2O + O_2 \quad = \quad CO_2 + H_2O$
(Organic matter)

Apart from these reactions, there are several other reactions including microbiological mediated reactions, which tend to alter the chemical composition of the percolating water. For example, the bicarbonate present in most waters is derived mostly from CO_2 that has been extracted from the air and liberated in the soil through biochemical activity. Some rocks serve as sources of chloride and sulphate through direct solution. The circulation of Sulphur, however, may be greatly influenced by biologically mediated oxidation and reduction reactions. Chloride circulation may be a significant factor influencing the anion content in natural water.

4.0 WATER QUALITY CRITERIA

The available quality of groundwater is the resultant of all the processes and reactions, which taken place since the condensation of water in the atmosphere to the time it is retrieved in the form of groundwater from its source. The water has excellent capability to accumulate substances in soluble form as it moves over and into the land resource, from the biological processes and from human activities. Urbanization, agricultural development and discharges of municipal and industrial residues significantly alter characteristics of groundwater resource. The prevailing climatic conditions, topography, geological formations and use and abuse of this vital resource have significant effect on the characteristics of the water, because of which its quality varies with locations. The definition of criteria and standards for water quality vary with the type of use. The characteristic of water required for human consumption, livestock, irrigation, industries etc., have different water quality requirements. The term water quality criteria may be defined as the “Scientific data evaluated to derive recommendations for characteristics of water for specific use’. The term standard applies to any definite rule, principle or measure established by any statutory Authority. The distinction between criteria and standards is important, as the two are neither interchangeable nor they become synonyms for the objective or goal. Realistic standards are dependent on criteria, designated uses and implementation as well as identification and monitoring procedure. The changes in all these factors may provide a basis for alteration in standards. In formulation of water quality criteria, the selection of water quality parameters depends on its use. Sayers, et. al. (1976 as quoted in CGWB & CPCB 2000) identified the key water quality parameters according to its various uses (Table 4.0).

Table 4.0: Water quality criteria parameters for various uses (Sayers et.al., 1976)

Public Watersupply	Industrial Watersupply	Agricultural watersupply	Aquaticlife& wild life watersupply	RecreationandAesthetics
ColiformbacteriaTurbiditycolour,Taste, OdourTDS,CI,F,SO_4NO_3, CN,TraceMetals,Trace OrganicsRadioactivesubstances	**Processing** pH, TurbidityColour,Alkalinity,Acidity, TDS,Suspendedsolids, Tracemetals, TraceOrganics **Cooling** PH, Temp,Silica,AI,Fe,Mg, Totalhardness, Alkalinity /AcidityS uspended solids,Salinity	Farmstead Same as forpublicsupply Live-stock Same as forpublicsupply Irrigation TDS,EC,Na,Ca, Mg,K,B,CIandTracemetals	Temp, DO, pH,Alkalinity, Acidity, TDS Salinity, pH, DCOs, TurbidityColour,Settleablematerials,Toxicsubstances, Nutrients,Floatingmaterials	RecreationsTem, Turbidity,Colour,Odour,FloatingMaterials,SettableMaterialsNutrients,Coliforms AestheticsSame as forRecreation andSubstances adverselyaffecting wildlife

4.1 WATER QUALITY CRITERIA FOR DRINKING PURPOSE

With the objective of safeguarding water from degradation and to establish a basis for improvement inwater quality, standards / guide lines / regulations have been laid down by various national andinternational organizations such as; Bureau of Indian Standards (BIS), World Health Organization(WHO), European Economic Community (EEC), Environmental Protection Agency (EPA), UnitedStates, and Inland Waters Directorate, Canada. The Bureau of Indian Standards (BIS) earlier knownas Indian Standards Institutions (ISI) has laid down the standard specification for drinking waterduring 1983, which have been revised and updated from time to time. In order to enable the users, toexercise their discretion towards water quality criteria, the maximum permissible limit has beenprescribed especially where no alternative sources are available. The national water quality standardsdescribe essential and desirable characteristics required to be evaluated to assess suitability of waterfor drinking purposes. The important water quality characteristics as laid down in BIS standard (IS10500: 2012) are summarized in Table - 4.1

Table 4.1: Drinking WaterCharacteristics (IS 10500: 2012)

S.No.	Parameters	DesirableLimits(mg/L)	Permissiblelimits(mg/L)
EssentialCharacteristics			
1	ColourHazenUnit	5	15
2	Odour	Unobjectionable	-
3	Taste	Agreeable	-
4	Turbidity(NTU)	1	5
5	pH	6.5-8.5	Norelaxation
6	TotalHardness,$CaCO_3$	200	600
7	Iron(Fe)	1.0	Norelaxation
8	Chloride(Cl)	250	1000
9	ResidualFreeChlorine	0.2	1
10	Fluoride(F)	1.0	1.5
DesirableCharacteristics			
11	DissolvedSolids	500	2000
12	Calcium(Ca)	75	200
13	Magnesium(Mg)	30	100
14	Copper(Cu)	0.05	1.5
15	Manganese(Mn)	0.1	0.3
16	Sulphate(SO_4)	200	400
17	Nitrate(NO_3)	45	Norelaxation
18	PhenolicCompounds	0.001	0.002
19	Mercury(Hg)	0.001	Norelaxation
20	Cadmium(Cd)	0.003	Norelaxation
21	Selenium(Se)	0.01	Norelaxation
22	Arsenic(As)	0.01	Norelaxation
23	Cyanide(CN)	0.05	Norelaxation
24	Lead(Pb)	0.01	Norelaxation
25	Zinc(Zn)	5.0	15
26	HexavalentChromium	0.05	Norelaxation
27	Alkalinity	200	600
28	Aluminum(Al)	0.03	0.2
29	Boron(B)	0.5	2.4
30	Pesticides	Absent	0.001
31	Uranium	0.03	Norelaxation

NTU-Nephelometric TurbidityUnit.

N.B. The fluoride limits vary with average annual temperature of the areas. Similarly,the limits for magnesium are based on sulphatecontents of water. When sulphatecontent is 250 mg/L or above, the magnesium should be between 30 and 50 mg/L but ifsulphateis lower, highercontent ofmagnesium is permissible.

4.2 WATER QUALITY CRITERIA FOR IRRIGATION PURPOSE

Water quality plays a significant role in irrigated agriculture. Many problems originate due to inefficient management of water for agriculture use, especially when it carries high salt loads. The effect of total dissolved salts in irrigation water (measured in terms of electrical conductance) on crop growth is extremely important. Soil water passes in to the plant through the root zone due to osmotic pressure and the plants root able to assimilate water and nutrients. Thus, the dissolved solid contents of the residual water in the root zone also have to be maintained within limits by proper leaching. These effects are visible in plants by their stunted growth, low yield, discoloration and even leaf burns at margin or top. The safe limits of electrical conductivity for crops of different degrees of salt tolerances under varying soil textures and drainage conditions are presented in Table - 4.2.

Table 4.2: Safe Limits for electrical conductivity for irrigation water (IS:11624-1986)

S. No.	Natureof soil	CropGrowth	Upper permissible safelimit of electricalconductivityinwater µs/cmat 25°C
1	Deepblacksoilandalluvialsoilshavingclay contentmorethan30%;soilsthatarefairlytomoderatelywell Drained	Semi-tolerant	1500
		Tolerant	2000
2	Textured soils having clay contents of20-30%; soils thatarewelldrainedinternallyandhavegoodsurfacedrainagesystem	Semi-tolerant	2000
		Tolerant	4000
3	Mediumtexturedsoilshavingclay10-20%;internallyverywelldrainedand havinggoodsurfacedrainagesystem	Semi-tolerant	4000
		Tolerant	6000
4	Lighttexturedsoilshavingclaylessthan10%;soilsthat haveexcellent internalandsurfacedrainagesystem.	Semi-tolerant	6000
		Tolerant	8000

In addition to problems caused by total amount of salts, some of the specific ions likesodium,boronandtraceelements,ifpresentinwaterinexcess,alsorenderitunsuitableforagricultural use.

4.2.1 SODIUM ADSORPTION RATIO (SAR) & RESIDUAL SODIUM CARBONATE (RSC)

The clay minerals in the soil adsorb divalent cations like calcium and magnesium ions from irrigation water. Whenever the exchange sites in clay are filled by divalent cations, the soil texture is conducive for plant growth. Sodium reacts with soil to reduce its permeability. In case the irrigation water is sodium dominant, the clay lattice is filled with sodium ions due to ion exchange. Such soils become impermeable and sticky and as such the cultivation becomes difficult to support plant growth. However, the cation exchange process is reversible and can be controlled either by adjusting the composition of water or by soil amendment by application of gypsum, which releases cations (Calcium) to occupy the exchange position. The tendency of water to replace adsorbed calcium and magnesium with sodium can be expressed by the Sodium Adsorption Ratio (SAR), where all the ion concentrations are in milli-equivalents per litre (meq/L).

$$\mathbf{SAR} = \frac{\mathbf{Na}}{\sqrt{}(\mathbf{Ca} + \mathbf{Mg})/\mathbf{2}}$$

When, water having high bicarbonates and low calcium and magnesium is used for irrigation purpose, precipitation of calcium and magnesium as carbonate takes place, changing the residual water to high sodium water with sodium bicarbonate in solution. It is termed as Residual Sodium Carbonate (RSC) which is expressed as;

$$\mathbf{RSC} = (\mathbf{HCO3} + \mathbf{CO3}) - (\mathbf{Ca} + \mathbf{Mg})$$

(Wherealltheions'concentrationsareinmilliequivalents/litre).

Percentage sodium (%Na):

Percentage sodium (%Na) is an indication of the soluble sodium content of the groundwater and also used to evaluate Na hazard. In all natural waters, %Na is a common parameter to assess its suitability for irrigation purposes since sodium reacts with the soil to reduce permeability.

$$\%\mathbf{Na} = \frac{(\mathbf{Na} + \mathbf{K})}{(\mathbf{Ca} + \mathbf{Mg} + \mathbf{Na} + \mathbf{K})} \times \mathbf{100}$$

The quality of water is commonly expressed by classes of relative suitability for irrigation with reference to salinity levels. The recommended classification with respect to Electrical Conductivity, Sodium content, Sodium Adsorption Ratio, and Residual Sodium Carbonate, under customary irrigation conditions has been depicted in **Table - 4.2.1.**

Table 4.2.1: Guidelines for evaluation of quality of irrigation water

WaterClass	**Alkalinityhazards**		
	SAR **IS:11624-1986**	**RSC(meq/L)** **IS:11624-1986**	**%Na** **Wilcox**
Low	<10	<1.5	< 20
Medium	>10– 18	1.5– 3	20 - 60
High	>18– 26	3 - 6	> 60
Very High	>26	> 6	

4.3 EFFECTS OF WATER QUALITY PARAMETERS ON HUMAN HEALTH AND DISTRIBUTION FORVARIOUS USERS

It is essential to ensure that various constituents are within prescribed limits in drinking water supplies to avoid impact on human health **(Table – 4.3)**. Man, life forms and domestic animals are affected by alteration in water quality due to natural or anthropogenic reasons. The effect of these substances depends on the quantity of water consumed per day and their concentration in water.

Table 4.3: Effects of water quality parameters on human health when used fordrinkingPurpose

S. No.	**Parameters**	**Prescribedlimits IS:10500,2012**		**ProbableEffects**
		Desirable Limit	**Permissible Limit**	
1	Colour (Hazenunit)	5	15	Makes water aesthetically undesirable
2	Odour	Essentiallyfreefromobjectionableodour		Makes water aesthetically undesirable
3	Taste	Agreeable		Makes water aesthetically undesirable
4	Turbidity (NTU)	1	5	High turbidity indicates contamination/Pollution.
5	pH	6.5	8.5	Indicativeofacidicoralkalinewaters,affectstaste,corrosivity andthe water supplysystem
6	Hardnessas $CaCO_3$ (mg/L)	200	600	Affectswatersupplysystem(Scaling),Excessivesoapconsumption, and calcificationof arteries.Thereisnoconclusiveproofbutitmaycauseurinary concretions,diseasesofkidneyor bladderandstomachdisorder.
7	Iron(mg/L)	1.0	Norelaxation	Gives bitter sweet astringenttaste,causesstainingoflaundry andporcelain.Intracesitisessentialfornutrition.

S. No.	Parameters	Prescribedlimits IS:10500,2012		ProbableEffects
		Desirable Limit	Permissible Limit	
8	Chloride (mg/L)	250	1000	May be injurious to some peoplesufferingfromdiseasesofheartorkidneys.Taste,indigestion, corrosionandpalatabilityareaffected.
9	ResidualChlorine(mg/L) Onlywhenwateris Chlorinated	0.20	-	Excessivechlorinationofdrinking water may cause asthma,colitisandeczema.
10	TotalDissolvedSolids-TDS(mg/L)	500	2000	Palatabilitydecreasesandmaycause gastro intestinal irritation inhuman, may have laxative effectparticularlyupontransitsandcorrosion,maydamagewater system.
11	Calcium (Ca)(mg/L)	75	200	Causesencrustationinwatersupplysystem.Whileinsufficiencycausesaseveretypeofrickets,excesscausesconcretions in the body such askidneyorbladderstonesand irritationinurinarypassages.
12	Magnesium(mg)(mg/L)	30	100	Itssaltsarecatharticsanddiuretic. High concentration mayhavelaxativeeffectparticularlyonnewusers.Magnesiumdeficiencyisassociatedwithstructural and functional changes.Itisessentialasanactivatorof manyenzymesystems.
13	Copper(Cu)(mg/L)	0.5	1.50	Astringent taste but essential andbeneficialelementinhumanmetabolism. Deficiency results innutritionalanemiaininfants.Large amount may result in liverdamage,causecentralnervoussystemirritationanddepression. Inwatersupplyitenhancecorrosion of aluminum in particular
14	Sulphate(SO_4)(mg/L)	200	400	Causes gastro intestinal irritationalong with Mg or Na, can have acatharticeffectonusers,concentrationmorethan750mg/Lmayhavelaxativeeffect alongwithMagnesium.
15	Nitrate (NO_3)(mg/L)	45	Norelaxation	Cause infant methaemoglobinaemia(bluebabies)atveryhigh concentration,causesgastriccancer and affects adversely centralnervoussystemandcardiovascularsystem.
16	Fluoride(F)(mg/L)	1.0	1.50	Reducedentalcarries,very high concentration may cause cripplingskeletalfluorosis.

S. No.	Parameters	Prescribedlimits IS:10500,2012		ProbableEffects
		Desirable Limit	Permissible Limit	
17	Cadmium(Cd)(mg/L)	0.003	Norelaxation	Acute toxicity may be associatedwith renal, arterial hypertension,itai-itai disease, (a bone disease).Cadmiumsaltcausescramps, nausea,vomitinganddiarrhea.
18	Lead(Pb)(mg/L)	0.01	Norelaxation	Toxic in both acute and chronicexposures. Burning in the mouth,severeinflammationofthegastro-intestinaltractwithvomitinganddiarrhoea,chronictoxicity producesnausea,severeabdominal pain, paralysis, mentalconfusion,visualdisturbances, anaemiaetc.
19	Zinc(Zn) (mg/L)	5	15	Anessentialandbeneficialelementinhumanmetabolism.Taste threshold for Zn occurs atabout5mg/Limpartsastringent tastetowater.
20	Chromium(Cr^6)(mg/L)	0.05	Norelaxation	HexavalentstateofChromiumproduceslungtumorscanproducecutaneousandnasalmucousmembraneulcersand dermatitis.
21	Boron(B)(mg/L)	0.5	2.4	Affectscentralnervoussystemitssaltmaycause nausea,cramps, convulsions,comaetc.
22	Alkalinity (mg/L) as$CaCO_3$	200	600	Impartdistinctlyunpleasanttaste may be deleterious to human beinginpresenceofhighpH, hardness and total dissolved solids.
23	Pesticides: (mg/l)	Absent	0.001	Imparts toxicity and accumulatedindifferentorgansofhumanbodyaffectingimmuneandnervoussystemsmaybe carcinogenic.
24	Phosphate(PO_4)(mg/L)	Noguideline		Highconcentrationmaycausevomitinganddiarrhea,stimulate secondaryhyperthyroidismandboneloss
25	Sodium (Na)(mg/L)	Noguidelines		Harmful to persons suffering From cardiac, renal andcirculatorydiseases.
26	Potassium (K)(mg/L)	Noguidelines		Anessentialnutritionalelementbut its excessive amounts is cathartic
27	Silica(SiO_2) (mg/L)	Noguidelines		-
28	Nickel(Ni)(mg/L)	0.02		Non-toxicelementbutmaybecarcinogenicinanimals,canreact withDNAresultinginDNAdamagein animals.

S. No.	Parameters	Prescribedlimits IS:10500,2012		ProbableEffects
		Desirable Limit	Permissible Limit	
29	Pathogens(a) Totalcoliform (per100ml) (b) FaecalColiform(per100ml)	nil		Cause water borne diseaseslikecoliformJaundice,Typhoid,Cholera etc.produceinfectionsinvolving skin mucous membraneofeyes, ears and throat.
30	Arsenic	0.01	**No relaxation**	Various skin diseases, Carcinogenic
31	Uranium	0.03	**No relaxation**	Kidney disease, Carcinogenic

5.0 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 Programme, 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 programme 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 India has been categorized as desirable, permissible and 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 country 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.

5.1 DATA VALIDATION / DATA QUALITY CONTROL

Groundwater quality data validation is an essential step in ensuring the reliability and accuracy of the data. Here are some of the main steps for groundwater quality data validation.

a. Checking of Data Consistency: Checking of the data for consistency by comparing the measurements of a particular parameter over time. This will help identify any changes in the groundwater quality due to measurement methodology or equipment
b. Checking the correlation between EC and TDS:
    a. The relationship between the two parameters is often described by a constant (commonly between 0.55 and 0.95 for freshwaters).
    b. Thus: TDS (mg/l) ~ (0.55 to 0.95) x EC (mS/cm).
    c. The value of the constant varies according to the chemical composition of the water. For freshwaters, the normal range of TDS can be calculated from the following relationship:
    d. 0.55 conductivity (mS/cm) < TDS (mg/l) < 0.95 conductivity (mS/cm).
    e. Typically the constant is high for chloride rich waters and low for sulphate rich waters.

c. Checking the cation-anion balance

When a water quality sample has been analysed for the major ionic species, one of the most important validation tests can be conducted: the cation-anion balance.

Sum of cations = sum of anions

where:
cations = positively charged species in solution (meq/l)
anions = negatively charged species in solution (meq/l)

The Electronic charge balance is expressed as follows:

$$\text{Electronic Charge Balance (ECB \%)} = \frac{[\sum \text{cations} - \sum \text{anions}]}{[\sum \text{cations} + \sum \text{anions}]} \times 100$$

All concentrations should be in epm. Error charge balance has been computed for the chemical results of 2022-23 and analysis showing more than 10% ECB has not been accepted as it indicates that there has been an error made in at least one of the major cation/anion analyses.

6.0 GROUND WATER QUALITY SCENARIO IN INDIA

Thequality ofgroundwaterin Keralahasbeenevaluatedbysampling and analysis of water samples collected from Groundwater Monitoring wells.About **295** Groundwater Monitoring wells were considered for water quality duringApril 2022representingpre-monsoonwaterquality.The district-wisechemicalanalysis data of the samples are given in the Annexure - VII. The summarized results ofgroundwaterqualityranges aregiven in**Table - 6.1.**

Table- 6.1. Summarizedresults of groundwaterquality ranges, (April 2022)

S. No	Parameters	Quality	Range	No. of sample	Percentage
1	Electrical Conductivity	Fresh	< 750	281	95.25
		Moderate	750- 2250	13	4.41

S. No	Parameters	Quality	Range	No. of sample	Percentage
	µs/cm at 25°c	Slightly mineralized	2251- 3000	1	0.34
		Highly mineralized	> 3000	0	0
2	Chloride mg/L	Desirable limit	< 250	294	99.66
		Permissible limit	251-1000	1	0.34
		Beyond permissible limit	> 1000	0	0
3	Fluoride mg/L	Desirable limit	< 1.0	293	99.32
		Permissible limit	1.0 - 1.5	1	0.34
		Beyond permissible limit	>1.5	1	0.34
4	Nitrate mg/L	Permissible limit	< 45	267	90.51
		Beyond permissible limit	> 45	28	9.49

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 have been observed in some pockets in the districts of the state.

7.0 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 statehave been prepared depicting five 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. Chloride (> 1000 mg/L)
III. Fluoride (>1.5 mg/L)
IV. Nitrate (>45mg/L)
V. Uranium (>0.03 mg/L)
VI. Total Hardness (>600 mg/L)

7.1 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 7.1.1, 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 in the districst of Idukki, Kannur, Kasaragod, Kollam, Kottayam and Malappurametc., of the State.

Groundwater with EC ranging between 750 and 3000µS/cm at 25^0C falling under 'permissible' range are confined mainly to parts ofAlappuzha, Ernakulam, Kozhikode, Palakkad, Pathanamthitta, Thrissur, Trivandrum and Wayanad. The highest value of EC in the state was found in Ernakulam district with a value of 2500 µS/cm, no relatively high values of EC greater than 3000 S/cm are observed elsewhere in the state.Table 7.1.1 shows the list of districts with high EC water (750 to 2500µS/cm)and there are no areas in the state that can be identified as water quality hotspots from salinity point of view.

District-wise percentage of wells having EC in between 750 to 2500 µS/cm is shown as a bar diagram in Fig 7.1.1 and the occurrences of Electrical Conductivity in ground water have been shown on the contour map as Fig 7.1.2, the percentage groundwater samples in various EC range is also illustrated in Fig 7.1.3. Locations details are given in Annexure-I.

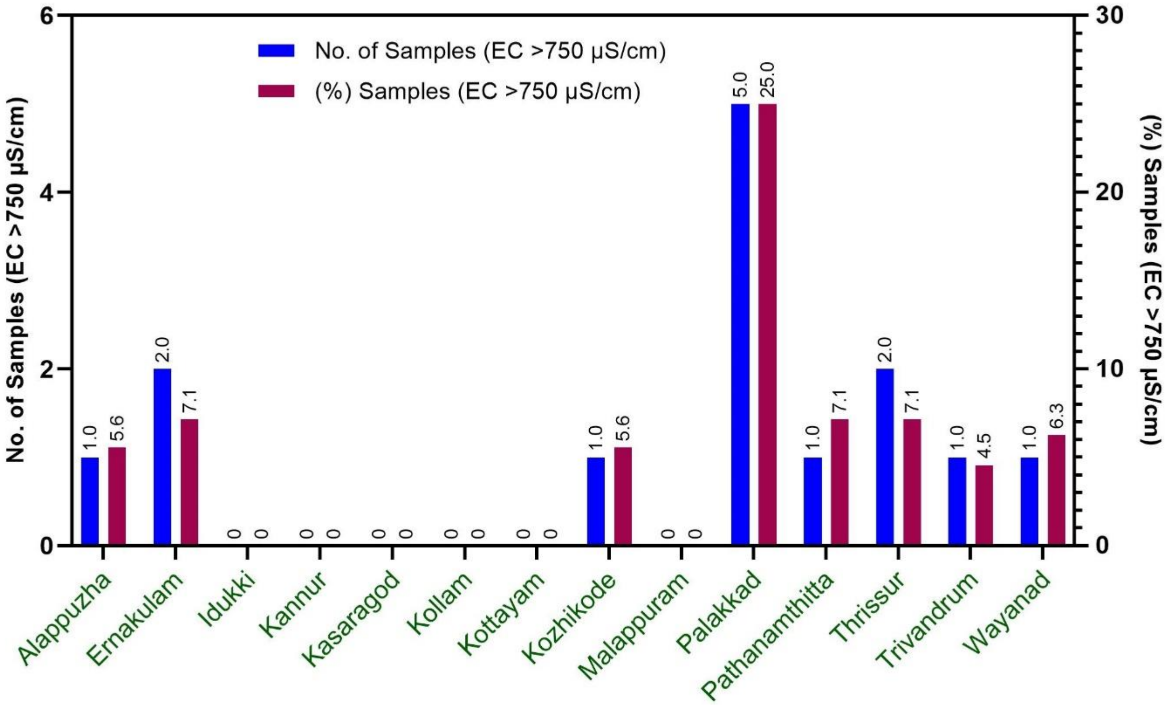


Fig 7.1.1 District-wise percentage of wells having EC >750 µS/cm.

Table 7.1.1 District-wise percentage of samples having EC >750 µS/cm

Sr.No	District	No. of Samples collected	No. of Samples (EC >750	(%) Samples (EC	No. of Samples (EC	(%) Samples (EC

		(NHS 2022-23)	µS/cm)	>750 µS/cm)	>3000 µS/cm)	>3000 µS/cm)
1	Alappuzha	18	1	5.6	0	0
2	Ernakulum	28	2	7.1	0	0
3	Idukki	20	0	0.0	0	0
4	Kannur	18	0	0.0	0	0
5	Kasaragod	22	0	0.0	0	0
6	Kollam	18	0	0.0	0	0
7	Kottayam	25	0	0.0	0	0
8	Kozhikode	18	1	5.6	0	0
9	Malappuram	28	0	0.0	0	0
10	Palakkad	20	5	25.0	0	0
11	Pathanamthitta	14	1	7.1	0	0
12	Thrissur	28	2	7.1	0	0
13	Trivandrum	22	1	4.5	0	0
14	Wayanad	16	1	6.3	0	0
	Total	295	14	4.7	0	0

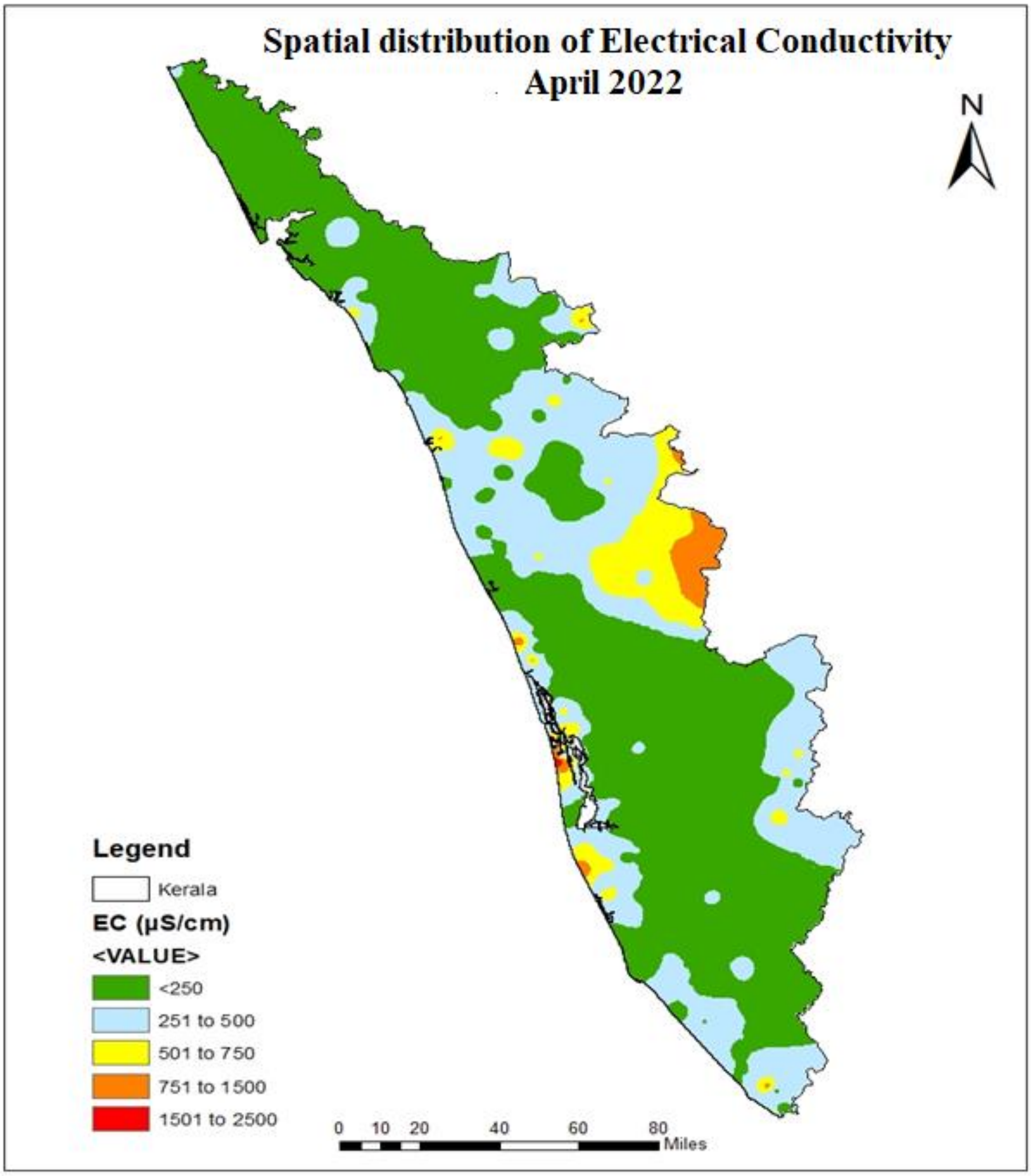


Fig 7.1.2 Spatial distribution of Electrical Conductivity during April 2022

Table 7.1.2: Locationswith EC > 750 µS/cm in Groundwater in Different District of Kerala.

District	Locations
Alappuzha	Purakkad
Ernakulam	Kumbalangi, Chellanum
Kozhikode	Ramanattukara
Palakkad	Palakkad, Agali, Gopalapuram, Kozhinjampara, Kozhippara.
Pathanamthitta	Enathu
Thrissur	Kodungalloor, Perinjanam
Trivandrum	Balaramapuram
Wayanad	Muthanga (R1)

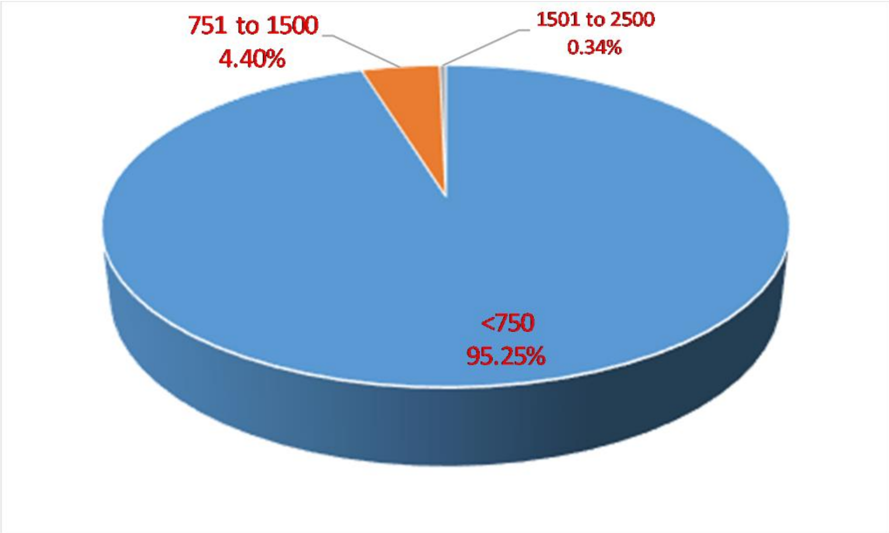


Fig 7.1.3 Percentage groundwater samples in various EC range (Kerala).

Table 7.1.3: Comparative change in number of Locations having EC > 750 µS/cm in various district.

Sr. No	District	2017	2022	Increase/Decrease
1	Alappuzha	0	1	1
2	Ernakulum	1	2	1
3	Idukki	0	0	0
4	Kannur	0	0	0
5	Kasaragod	0	0	0
6	Kollam	0	0	0
7	Kottayam	0	0	0
8	Kozhikode	1	1	0
9	Malappuram	4	0	-4
10	Palakkad	10	5	-5
11	Pathanamthitta	0	1	1
12	Thrissur	1	2	1
13	Trivandrum	2	1	-1
14	Wayanad	0	1	1
	Total	**19**	**14**	**-5**

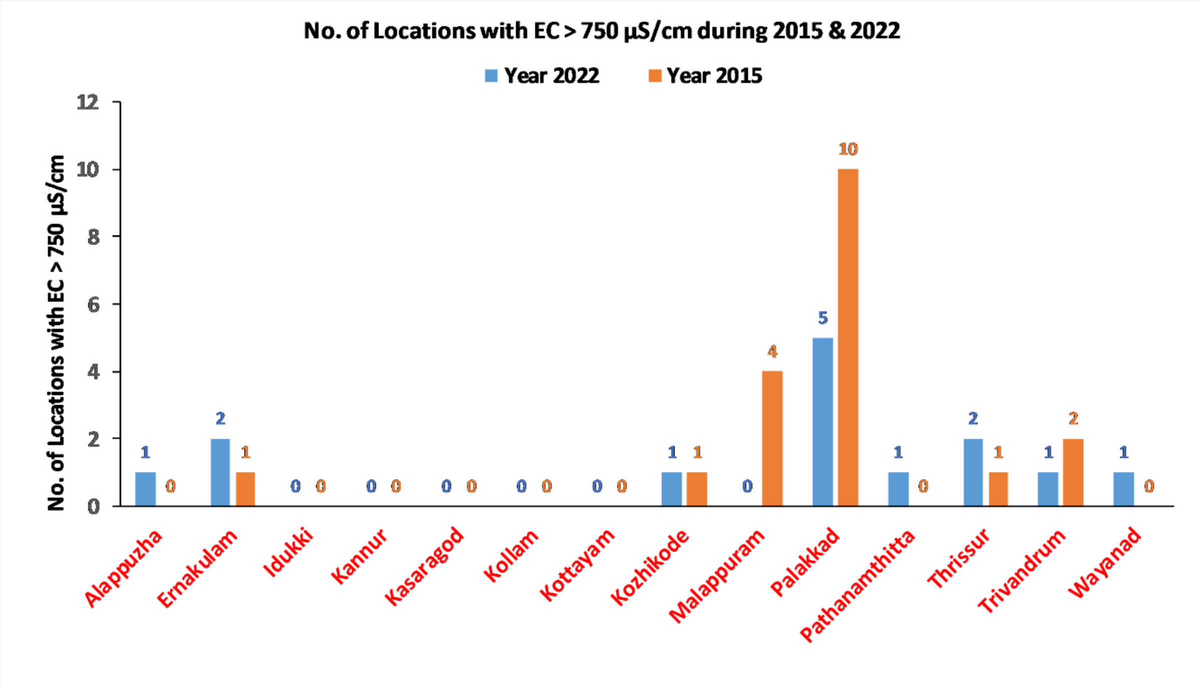


Fig. 7.1.4 Comparison on No. of Locations exceed EC >750 µS/cm during 2017 and 2022

In comparison to 2017(Table 7.1.3), it has been observed that the no. of locations having EC more than 750µS/cm in various district has decreased in 2022 by 5 number of locations (26.3 %). In Alappuzha, Ernakulum, Thrissur and Wayanad district the increase in the no. of locations is a matter of concern. However, in some district mainly Malappuram and Palakkad it has decreased also, which may be because of dilution in that particular area.

7.1.1 TREND ON ELECTRICAL CONDUCTIVITY

Trend analysis determines whether the measured values of the water quality variables increase or decrease during a time period. The Electrical Conductivity (EC) of groundwater is contributed by all the dissolved ionic constituents. Therefore, it is a measure of the total ionic content of the water. It could be used as a source of inorganic pollution indicator as most of the inorganic compounds are present as ions in water. Hence, EC was taken to assess the trend of ground water quality in India. No wells were monitored in the year 2020 due to the COVID pandemic situation. The percentage of well having electrical conductivity more than 750 µS/cm for the period of 2017 to 2022 were compared and presented in the Table7.1.4 and no significant trend was noticed. Trend on water quality for Electrical conductivity (EC) prepared for the district of Palakkad is showing a slightly decreasing trend (Fig. 7.1.5 & 7.1.5a).

Trend on Electrical Conductivity in a location, Chellanum of Ernakulam shows (Fig 7.1.6) a decreasing trend as a dilution factor due to heavy rain in a particular year. Trend on Electrical Conductivity in a location, Attingal of Trivandrum shows (Fig. 7.1.7) a linear trend due to unchanged external factors.

Table 7.1.4: Percentage of wells Exceed EC> 750 µS/cm during the period of 2017-2022

Year	Total Number of samples analysed	No. of Districts with EC >750	No. of Locations with EC >750	% of locations with EC >750
2017	442	11	38	8.60
2018	515	7	29	5.63
2019	351	7	27	7.69
2020	0	0	0	0.00
2021	351	9	20	5.70
2022	294	8	14	4.76

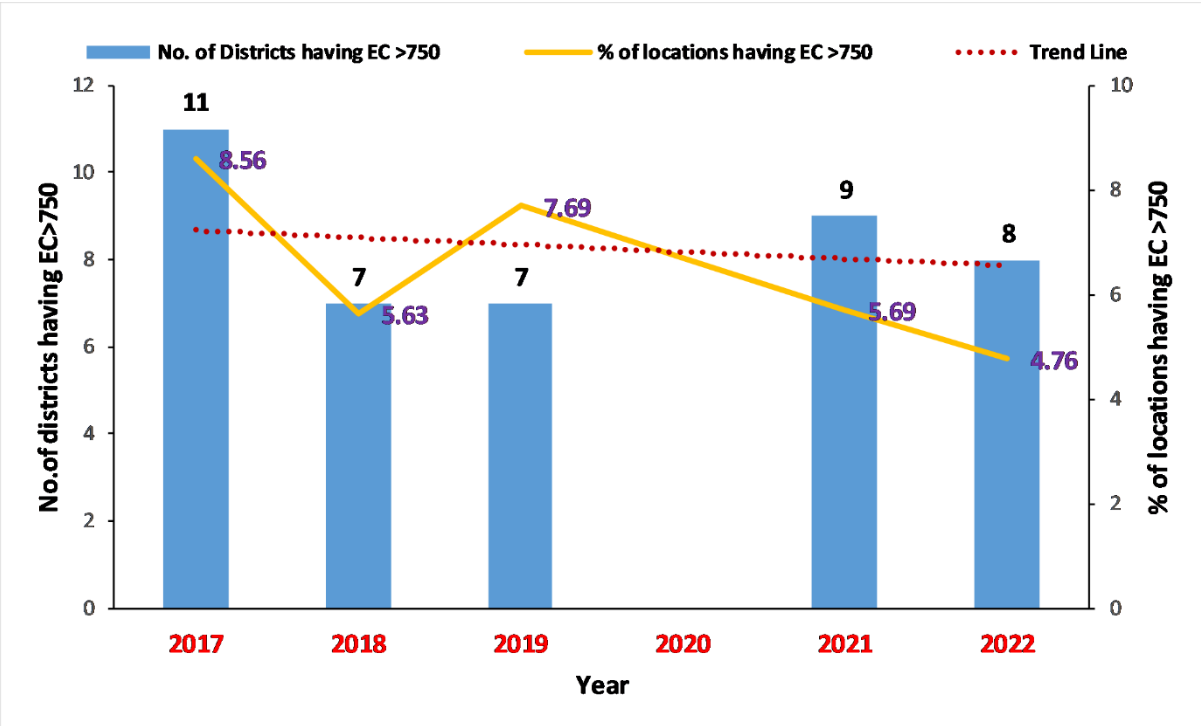


Fig. 7.1.5 Trend of Electrical Conductivity in Kerala

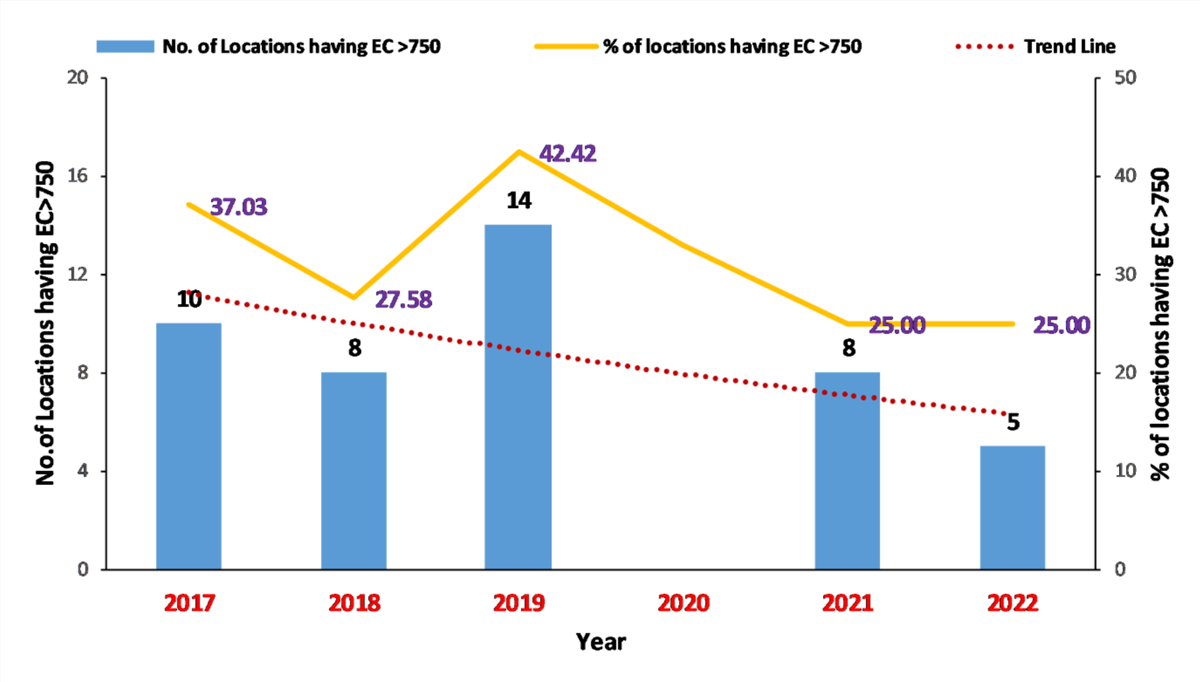


Fig. 7.1.5a Trend of Electrical Conductivity in Palakkad district

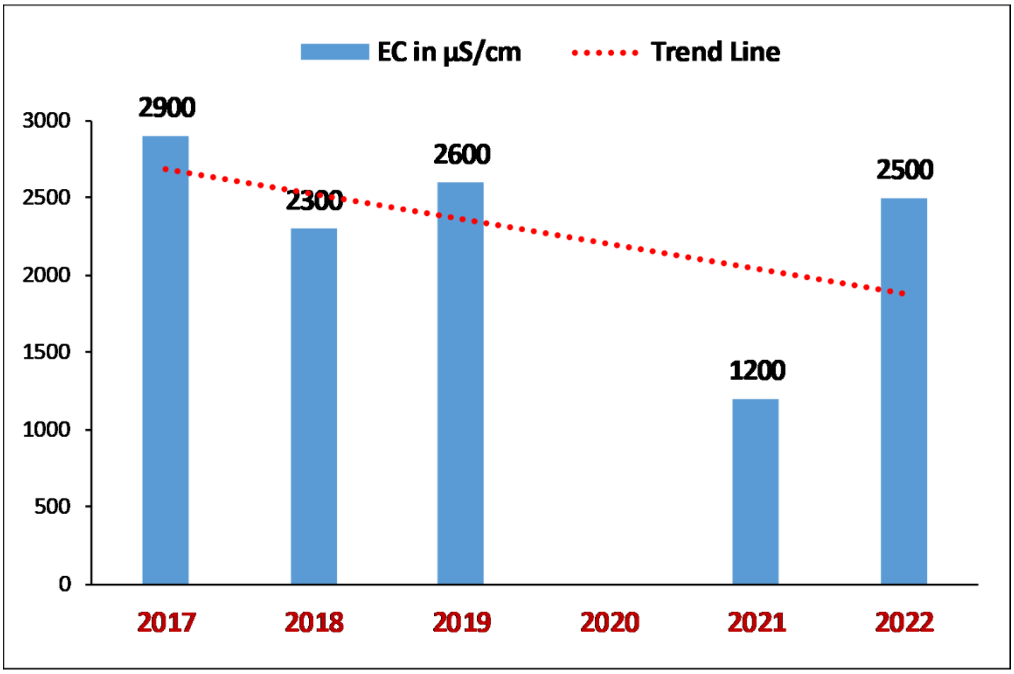


Fig. 7.1.6Trend on Electrical Conductivity in a location Chellanum (Ernakulum) for the period of 2017-2022

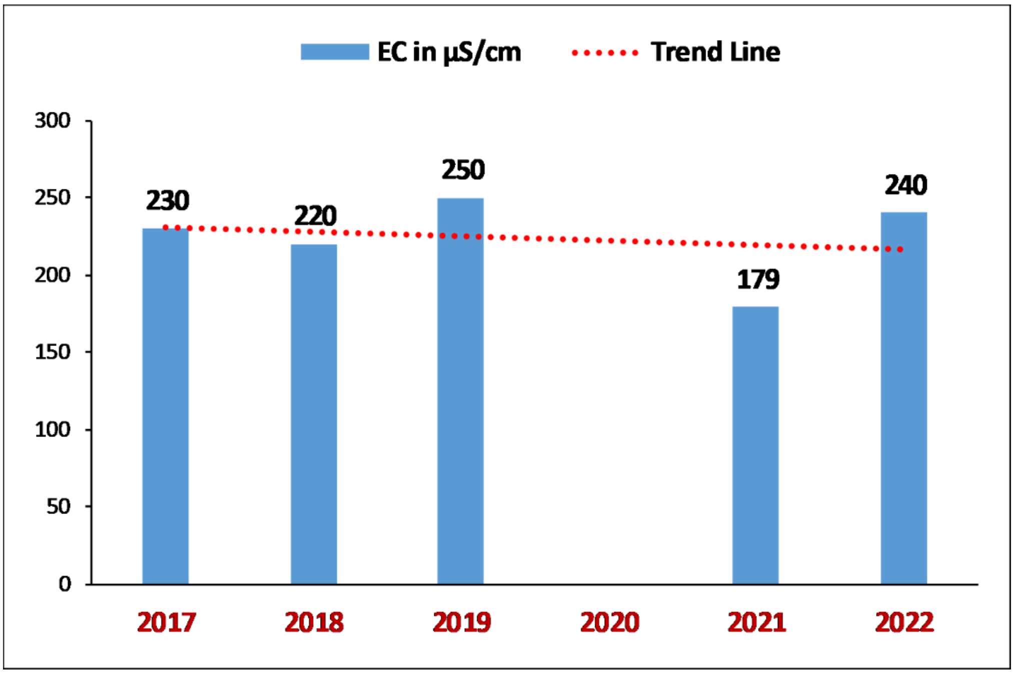


Fig. 7.1.7 Trend on Electrical Conductivity in a locationAttingal (Trivandrum) for theperiod of 2017-2022

7.2 CHLORIDE

Chloride is present in all-natural waters, mostly at low concentrations. It is highly soluble in water and moves freely with water through soil and rock. In ground water the chloride content is mostly below 250 mg/L except in cases where inland salinity is prevalent and in coastal areas. BIS (Bureau of Indian Standard) have recommended a desirable limit of 250 mg /L of chloride in drinking water; this concentration limit can be extended to 1000 mg/L of chloride in case no alternative source of water with desirable concentration is available. However, ground water having concentration of chloride more than 1000 mg /L are not suitable for drinking purposes.In Fig 7.2.1, the concentration of chloride (in mg/L) in ground water from observation wells have been used to show distribution patterns of chloride in different ranges of suitability. It is apparent from the map that all of the samples having chloride values less than 250 mg/L are found in all districts except in one location, Chellanum (Ernakulam) have the chloride concentration 724 mg/L (Annexure-II).

Table 7.2.1 District-wise percentage of samples having Chloride >250 mg/L&>1000 mg/L

Sr. No	District	No. of Samples collected (NHS 2022-23)	No. of Samples (Chloride >250 mg/L)	(%) Samples (Chloride >250 mg/L)	No. of Samples (Chloride >1000 mg/L)	(%) Samples (Chloride >1000 mg/L)
1	Alappuzha	18	0	0.0	0	0
2	Ernakulum	28	1	3.6	0	0
3	Idukki	20	0	0.0	0	0
4	Kannur	18	0	0.0	0	0
5	Kasaragod	22	0	0.0	0	0
6	Kollam	18	0	0.0	0	0
7	Kottayam	25	0	0.0	0	0
8	Kozhikode	18	0	0.0	0	0
9	Malappuram	28	0	0.0	0	0
10	Palakkad	20	0	0.0	0	0
11	Pathanamthitta	14	0	0.0	0	0
12	Thrissur	28	0	0.0	0	0
13	Trivandrum	22	0	0.0	0	0
14	Wayanad	16	0	0.0	0	0
	Total	**295**	**1**	**0.34**	**0**	**0**

Table-7.2.2: Location having Chloride concentration (more than 250mg/L) in Groundwater in Kerala (NHS 2022-23)

Sr. No	District	Locations of district having Chloride > 250 mg/L
1.	Ernakulam	Chellanum

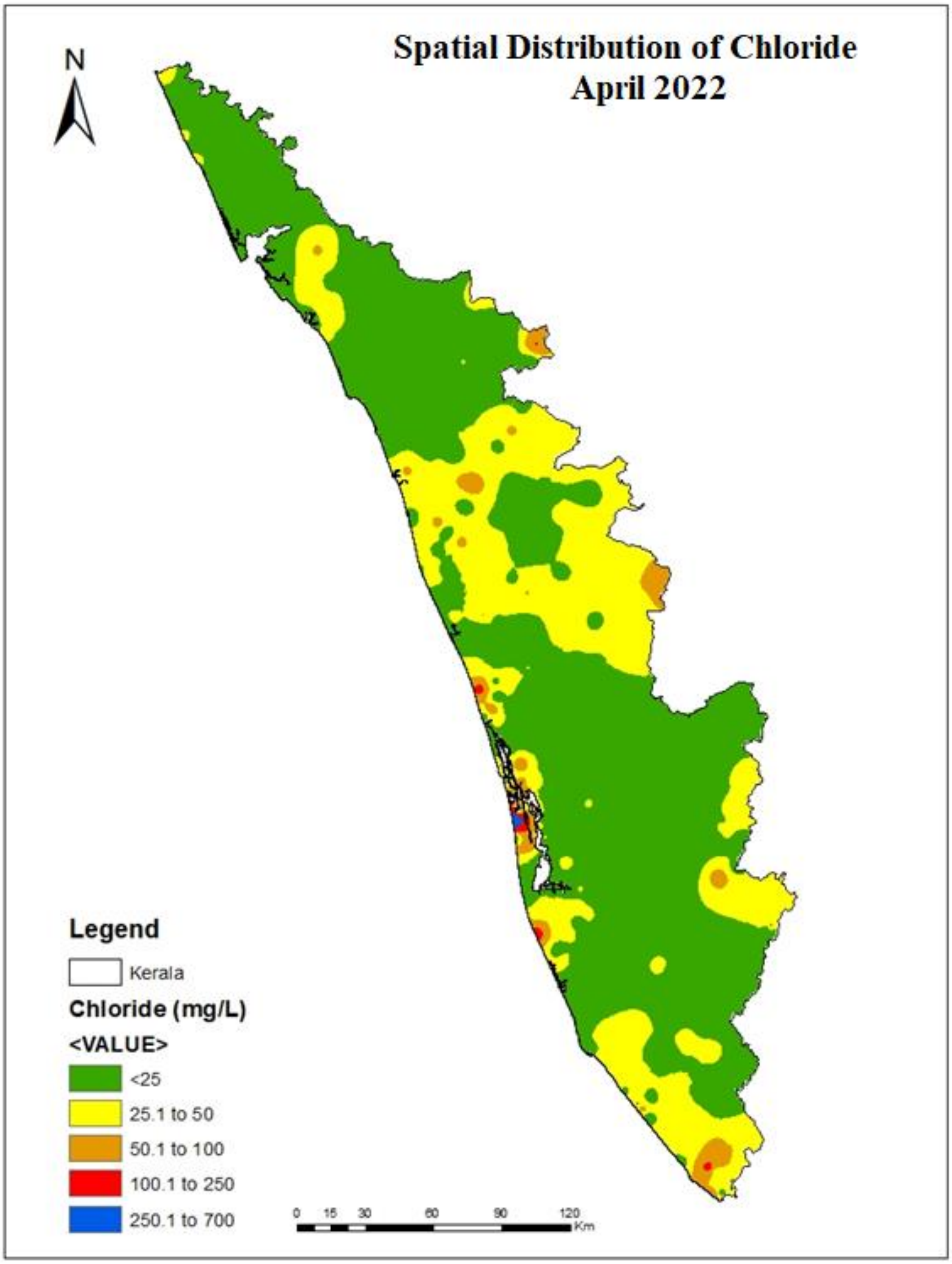


Fig 7.2.1 Spatial Distribution of Chloride during April 2022

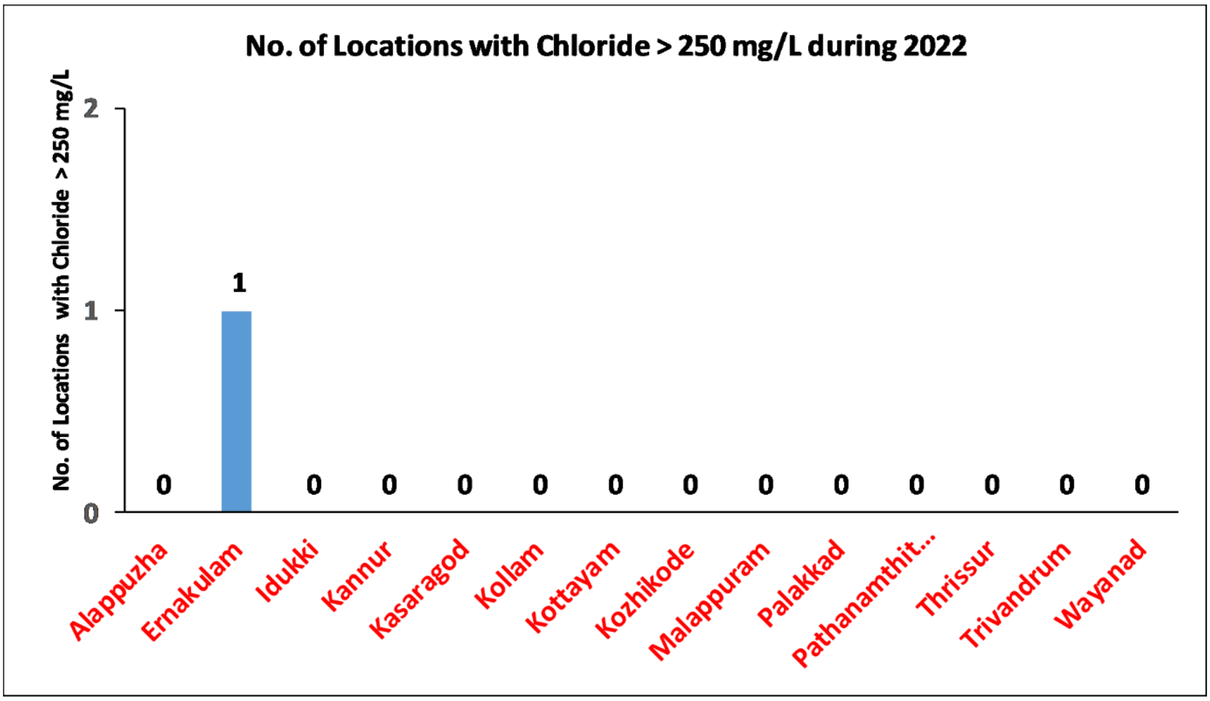


Fig 7.2.2 District-wise locations of wells having Chloride > 250 mg/L.

Table-7.2.3: Comparative Change in number of locations having Cl > 250 mg/L in Various district

Sr. No	District	2015	2022	Increase/Decrease
1	Alappuzha	0	0	0
2	Ernakulum	0	1	+1
3	Idukki	0	0	0
4	Kannur	0	0	0
5	Kasaragod	0	0	0
6	Kollam	0	0	0
7	Kottayam	0	0	0
8	Kozhikode	0	0	0
9	Malappuram	1	0	-1
10	Palakkad	0	0	0
11	Pathanamthitta	0	0	0
12	Thrissur	0	0	0
13	Trivandrum	0	0	0
14	Wayanad	0	0	0
	Total	**1**	**1**	**0**

In comparison to 2015, it has been observed that the no. of locations having chloride more than 250 mg/L in various district has not changed in 2022, but there have been changes in the specific locations and districts where this abnormality was observed (Table 7.2.3 & Fig.7.2.3).This phenomena may cause by dilution in the area where high levels of chloride were found in 2017, but salt-bearing geological formations in that area are the cause of high levels of chloride recorded in 2022. This occurrence is caused by dilution at the site where high chloride levels were found in 2015, but high chloride levels were observed in 2022, possibly owing to salt-bearing geological formations in that sample location.

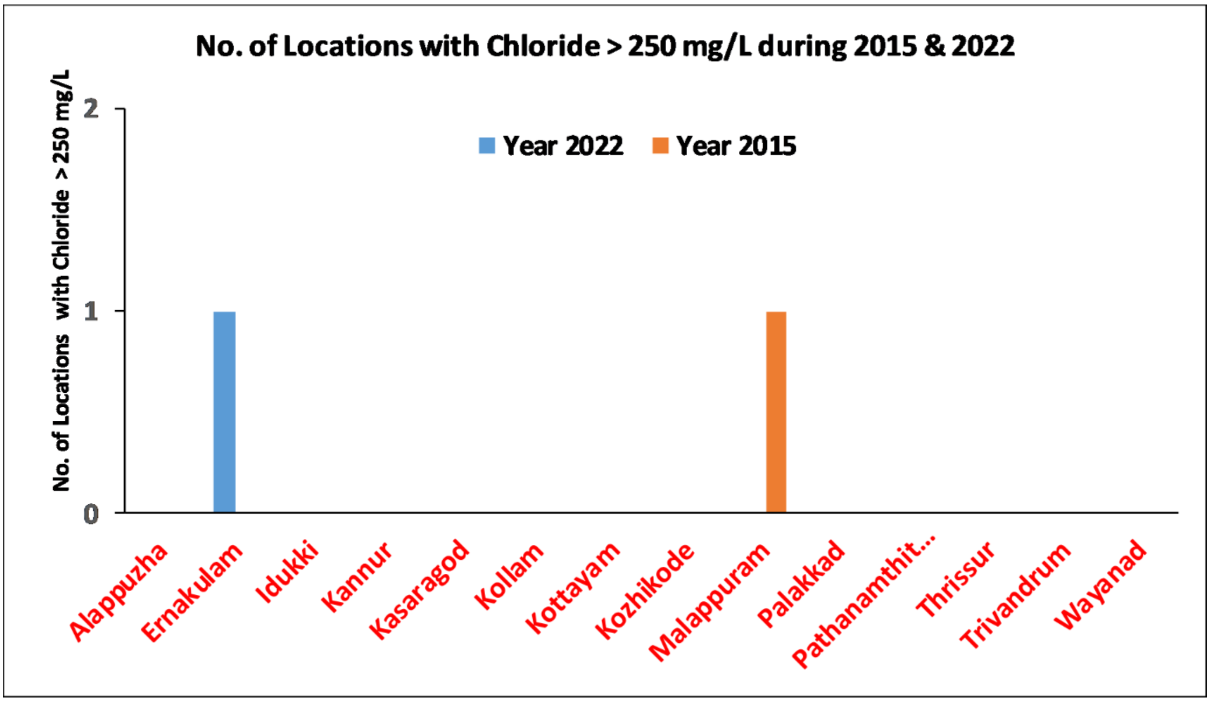


Fig. 7.2.3 Comparison on No of districts exceed Chloride >250 mg/L during 2015 and 2022.

Techniques Available for Removal of Salinity

Traditionally, distillation has been the method used for desalting water for human consumption or other use. Membrane methods have emerged through the last 50 years and now predominate among the desalination practices. The following describes each of the various methods used for water desalination treatment.

Distillation Methods

There are several variations in distillation technology used in desalination. They are all based on the vapourization of liquid water when brought to its boiling point. The nearly pure water vapour produced is condensed and collected for use, while dissolved salts remain behind in the remaining liquid feed water. Some of the methods by which distillation is practiced are as follows:

- Multi-stage flash;
- Multiple effect;
- Vapour compression;
- Membrane distillation; and
- Solar humidification.

Membrane Technologies

Membrane processes involve passing of impaired feed water through a semi-permeable material which can filter out unwanted dissolved or undissolved constituents, depending on the size and treatment of the openings. Membrane technologies identified include:

• Reverse Osmosis;

• Microfiltration/Ultrafiltration/Nanofiltration;

• Electrodialysis Reversal; and

• Forward Osmosis.

Hybrid Technology: A method of reducing overall costs of desalination can be the use of hybrid systems using both RO and distillation processes. Such a system could provide a more suitable match between power and water development needs.

7.3 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. 7.3.1. It is observed that only two locations have fluoride concentrations greater than 1 mg/L i.e.Kumily (Idukki) and Manjeri (Malappuram), with concentrations of 1.31 mg/L and 2.09 mg/L, respectively (Annexure-III).

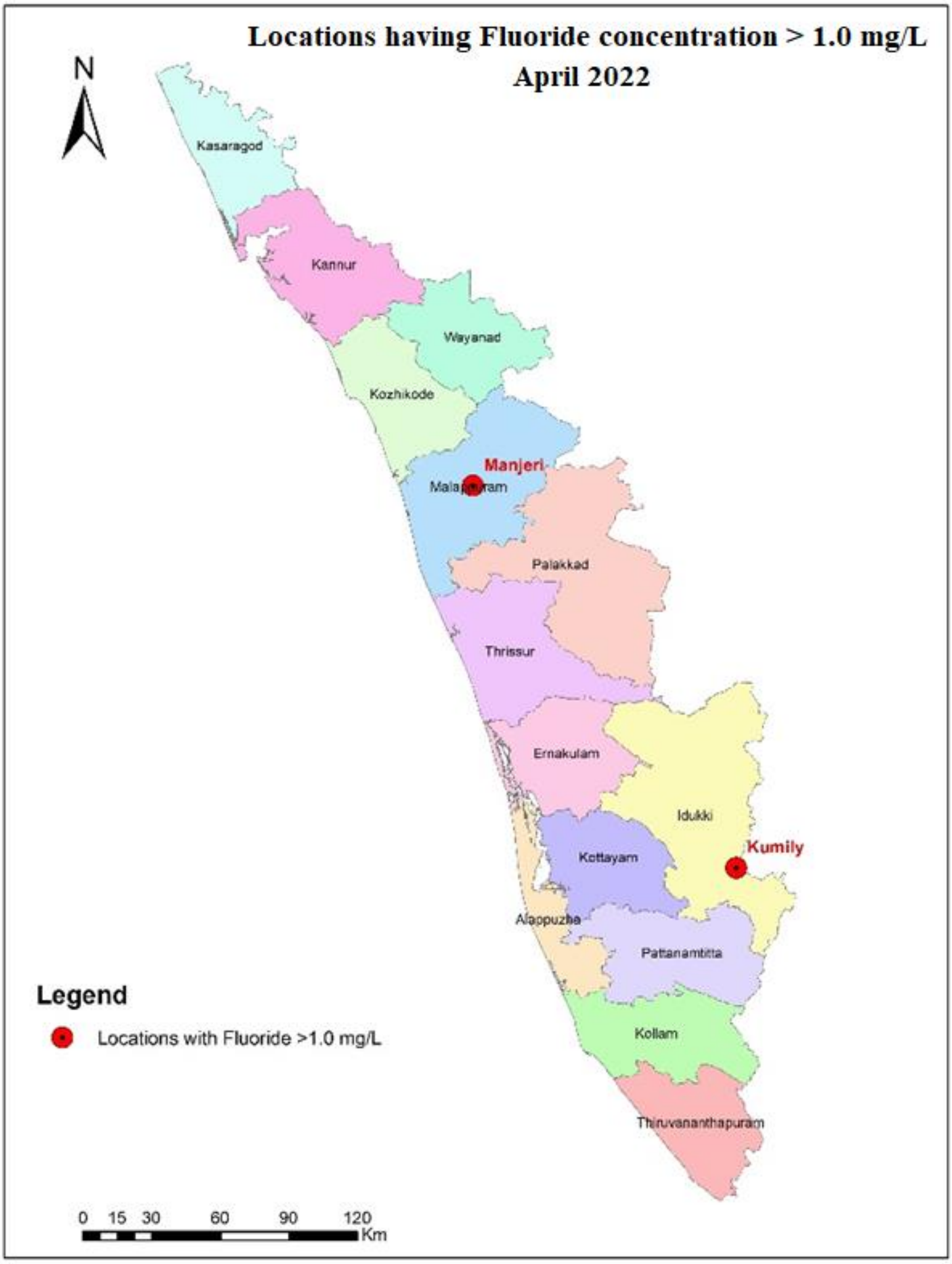


Fig 7.3.1 Locations having Fluoride concentration > 1.0 mg/L during April 2022.

Table 7.3.1 District-wise percentage of wells with fluoride in between 1.0 to 1.5 mg/L &>1.5mg/L

Sr.No	District	No. of Samples collected (NHS 2022-23)	No. of Samples (Fluoride 1.0 to 1.5 mg/L)	(%) Samples (Fluoride 1.0 to 1.5 mg/L)	No. of Samples (Fluoride >1.5 mg/L)	(%) Samples (Fluoride >1.5 mg/L)
1	Alappuzha	18	0	0.0	0	0
2	Ernakulam	28	0	0.0	0	0
3	Idukki	20	1	5.0	0	0
4	Kannur	18	0	0.0	0	0
5	Kasaragod	22	0	0.0	0	0
6	Kollam	18	0	0.0	0	0
7	Kottayam	25	0	0.0	0	0
8	Kozhikode	18	0	0.0	0	0
9	Malappuram	28	0	0.0	1	3.6
10	Palakkad	20	0	0.0	0	0
11	Pathanamthitta	14	0	0.0	0	0
12	Thrissur	28	0	0.0	0	0
13	Trivandrum	22	0	0.0	0	0
14	Wayanad	16	0	0.0	0	0
	Total	**295**	**1**	**0.34**	**1**	**0.34**

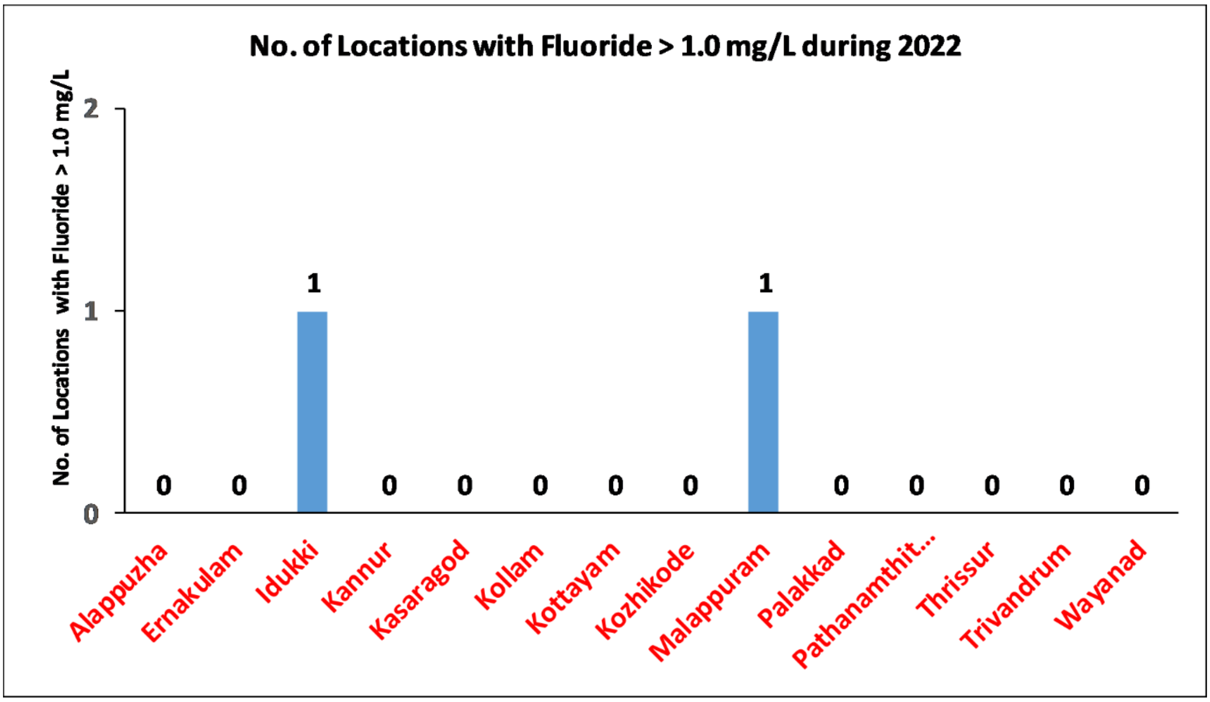


Fig 7.3.2 District-wise locations of wells having fluoride >1.0 mg/L

Table 7.3.2 Districts showing localized occurrence of Fluoride (>1.0 mg/L) in Groundwater in Kerala

Sl. No	District	Locations having F > 1.0 mg/L
1.	**Idukki**	Kumily
2.	**Malappuram**	Manjeri

Table-7.3.3: Comparative Change in number of locations having F > 1.0 mg/L in various district.

Sr. No	District	2015	2022	Increase/Decrease
1	Alappuzha	0	0	0
2	Ernakulum	0	0	0
3	Idukki	0	1	+1
4	Kannur	0	0	0
5	Kasaragod	0	0	0
6	Kollam	0	0	0
7	Kottayam	0	0	0
8	Kozhikode	0	0	0
9	Malappuram	0	1	+1
10	Palakkad	4	0	-4
11	Pathanamthitta	0	0	0
12	Thrissur	0	0	0
13	Trivandrum	0	0	0
14	Wayanad	0	0	0
	Total	**4**	**2**	**-2**

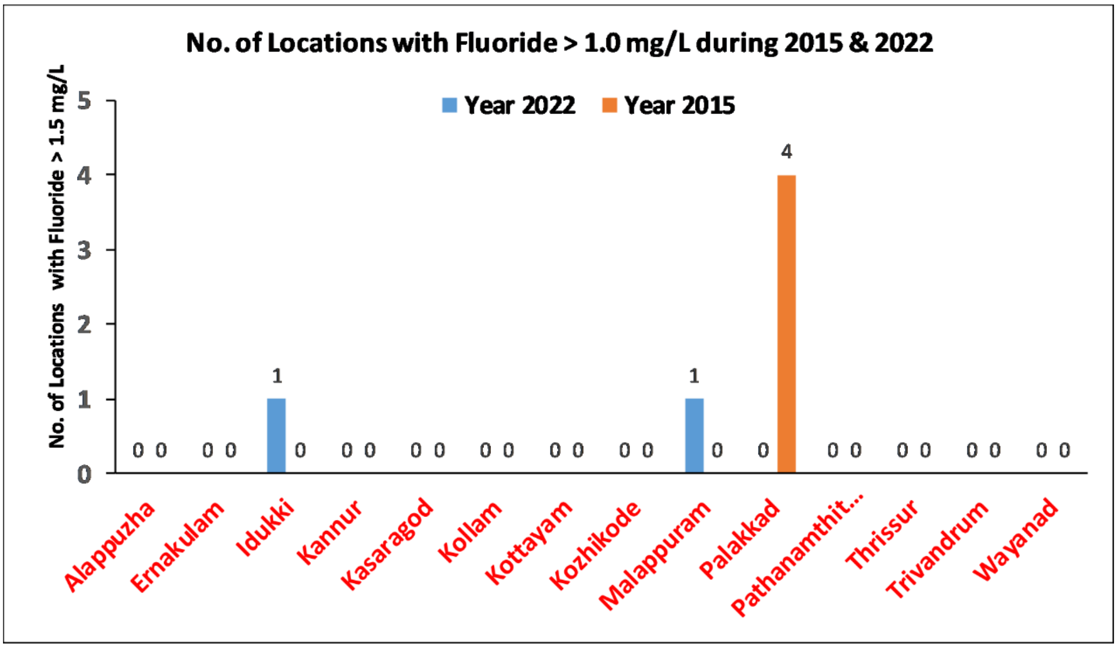


Fig 7.3.3 Comparison on No of locations exceed Fluoride >1.0 during 2015 and 2022

It has been observed (Table 7.3.3) that total number of locations affected by high fluoride in different districts has decreased by 50.00 % in 2022 as compared to the data available in 2015. The number of locations in Palakkad district has decreased, but there has been an increase in one sample location within the districts of Idukki and Malappuram.

7.3.1 TREND ON FLUORIDE

The occurrence of fluoride in groundwater is mainly due to weathering and leaching of fluoride bearing minerals from rocks and sediments. To assess the trend of ground water pollution due to geogenic activity, the percentage of well exceeds the acceptable limit of 1.0 mg/L for the period of 2017 to 2022 were compared and presented in the Table 7.3.4 and Fig 7.3.4 and observed that the percentage of samples exceed the permissible limit of fluoride 1.0 mg/L were ranging between 0.58 to 1.71 % and no significant trend was noticed. The no of wells monitored in the year 2020 due to COVID pandemic situation. Trend on water quality for fluoride was prepared for the district of Palakkad is showing a similar pattern (Fig 7.3.5). Trend on fluoride for Palakkad (Urban City) shows (Fig 7.3.6) an decreasing trend and shows Edapally (Ernakulum) (Fig 7.3.7) an increasing trend depends on the rain fall pattern and geogenic conditions

Table 7.3.4: Percentage of wells Exceed fluoride >1.0 mg/L during the period of2017-2022

Year	Total Number of samples analysed	No. of Districts with Fluoride > 1.0 mg/L	No. of Locations with Fluoride > 1.0 mg/L	% of locations with Fluoride > 1.0 mg/L
2017	442	2	4	0.90
2018	515	2	3	0.58
2019	351	1	2	0.57
2020	0	0	0	0.00
2021	351	1	6	1.71
2022	294	2	2	0.68

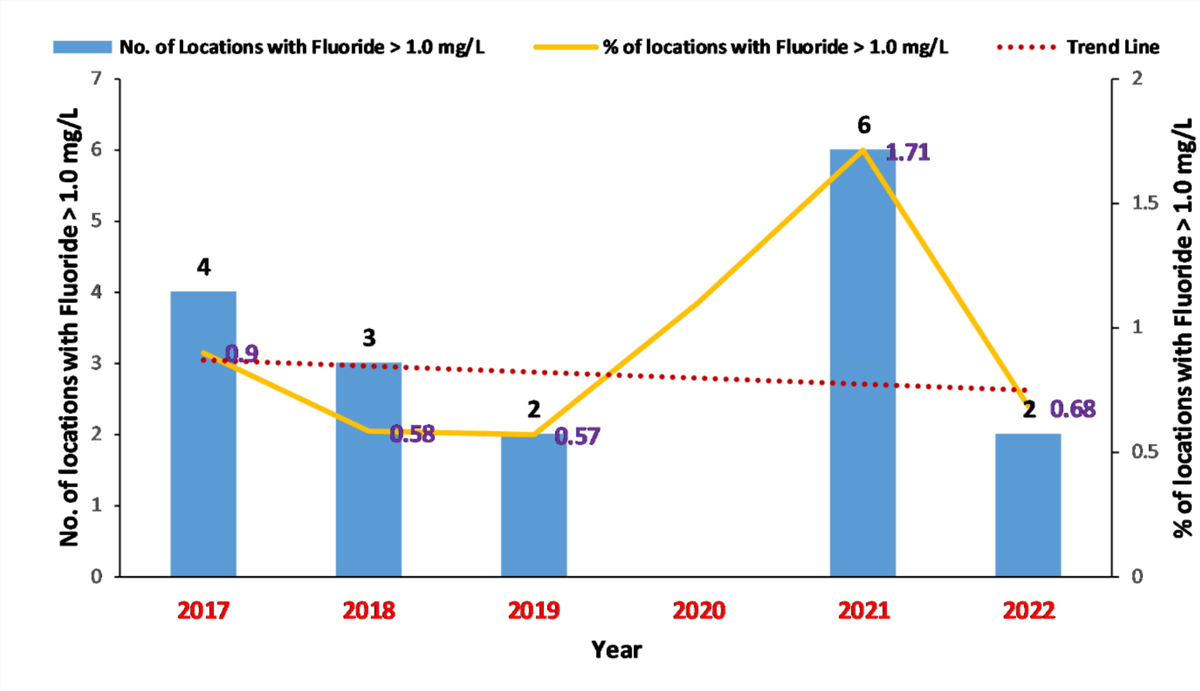


Fig. 7.3.4 Trend of Fluoride occurrence in Kerala

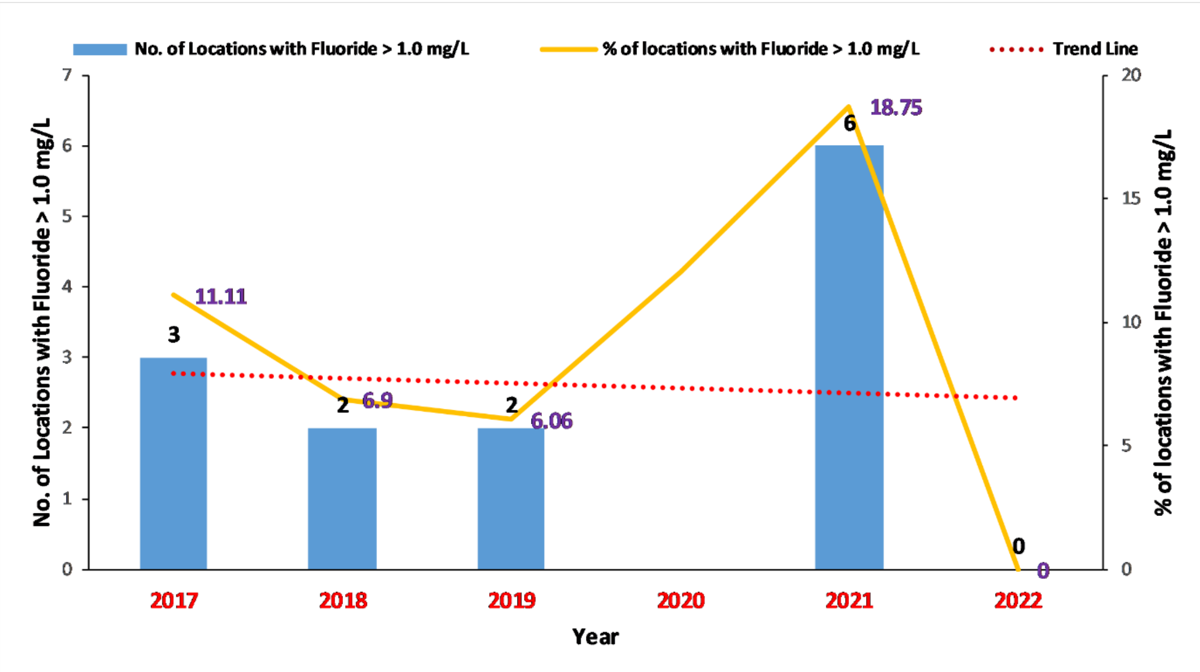


Fig. 7.3.5 Trend of Fluoride occurrence in Palakkad district.

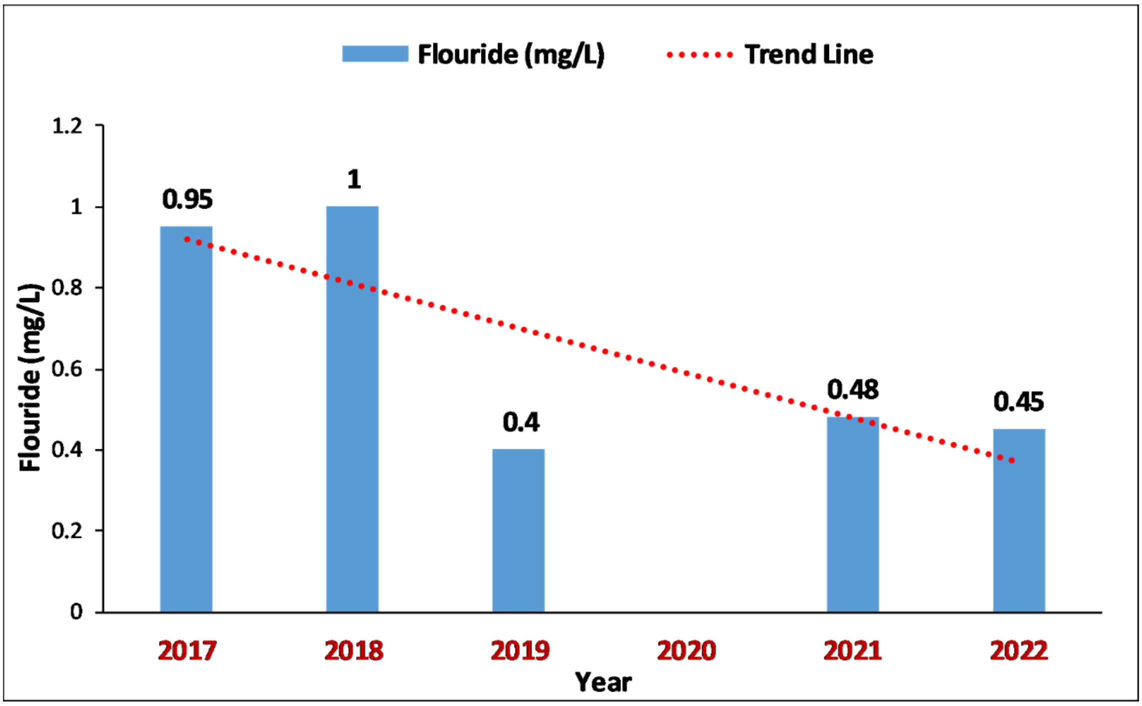


Fig 7.3.6 Trend on Fluoride at Palakkad (Urban City) for the period of 2017-2022

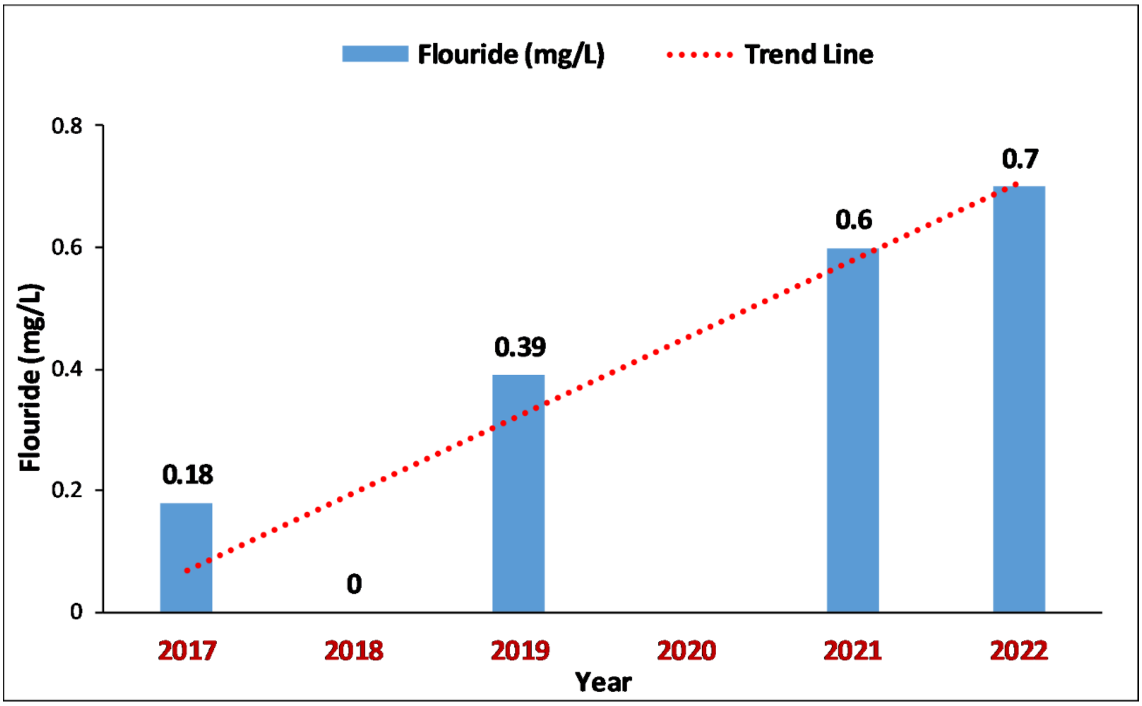


Fig 7.3.7 Trend on Fluoride at Edapally (Ernakulum) for the period of 2017-2022

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.

7.4 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.

Table 7.4.1: District-wise percentage of wells having Nitrate > 45 mg/L

Sr.No	District	No. of Samples collected (NHS 2022-23)	No. of Samples (Nitrate > 45 mg/L)	(%) Samples (Nitrate > 45 mg/L)
1	Alappuzha	18	1	5.6
2	Ernakulam	28	1	3.6
3	Idukki	20	5	25.0
4	Kannur	18	2	11.1
5	Kasaragod	22	1	4.5
6	Kollam	18	1	5.6
7	Kottayam	25	1	4.0
8	Kozhikode	18	0	0.0
9	Malappuram	28	5	17.9
10	Palakkad	20	2	10.0
11	Pathanamthitta	14	2	14.3
12	Thrissur	28	2	7.1
13	Trivandrum	22	5	22.7
14	Wayanad	16	0	0.0
	Total	**295**	**28**	**9.5**

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 7.4.1 and also given in Annexure-IV. Table-7.4.1 shows the districts where nitrate has been found in excess of 45 mg/L in groundwater.

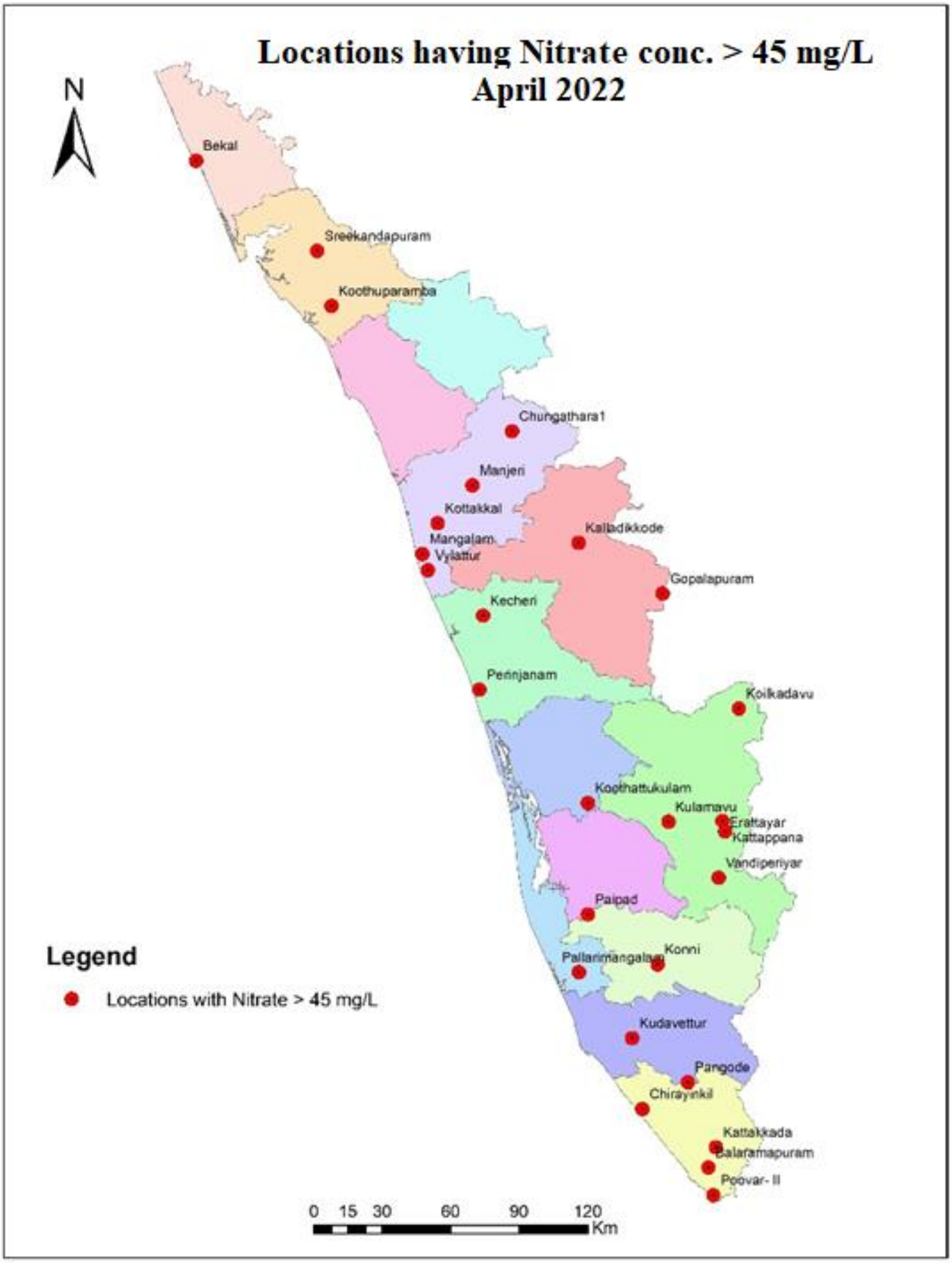


Fig 7.4.1 Locations having Nitrate concentration > 45 mg/L during 2022

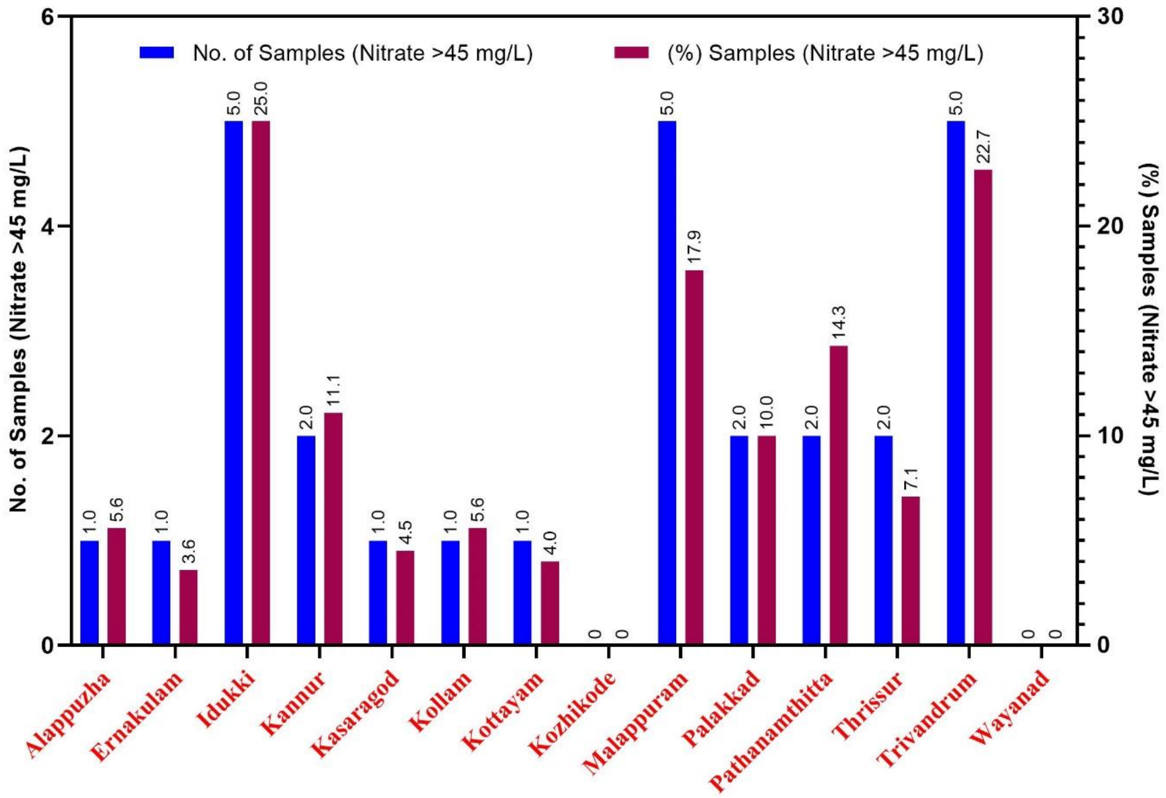


Fig 7.4.2 District-wise samples exceed Nitrate 45 mg/L (NHS 2022-23)

Table 7.4.2: List of locations Showing Occurrence of Nitrate (>45 mg/L) in Ground Water in Different Districts of Kerala.

Sl. No.	District	Parts of Districts having Nitrate > 45 mg/L
1	Alappuzha	Pallarimangalam
2	Ernakulam	Koothattukulam
3	Idukki	Kulamavu, Koilkadavu, Erattayar, Vandiperiyar, Kattappana
4	Kannur	Koothuparamba, Sreekandapuram
5	Kasaragod	Bekal
6	Kollam	Kudavettur
7	Kottayam	Paipad
8	Malappuram	Kottakkal, Chungathara, Mangalam, Manjeri, Vylattur
9	Palakkad	Kalladikkode, Gopalapuram
10	Pathanamthitta	Konni, Enathu
11	Thrissur	Kecheri, Perinjanam
12	Trivandrum	Chirayinkil, Pangode, Kattakkada, Poovar- II, Balaramapuram

Table-7.4.3: Comparative Change in number of locations having Nitrate > 45 mg/L in various districts

Sl. No.	District	2015	2022	Increase/ Decrease
1	Alappuzha	0	1	1
2	Ernakulam	1	1	0
3	Idukki	2	5	3
4	Kannur	3	2	-1
5	Kasaragod	1	1	0
6	Kollam	3	1	-2
7	Kottayam	1	1	0
8	Kozhikode	4	0	-4
9	Malappuram	4	5	1
10	Palakkad	5	2	-3
11	Pathanamthitta	1	2	1
12	Thrissur	3	2	-1
13	Trivandrum	5	5	0
14	Wayanad	0	0	0
	Total	**33**	**28**	**-5**

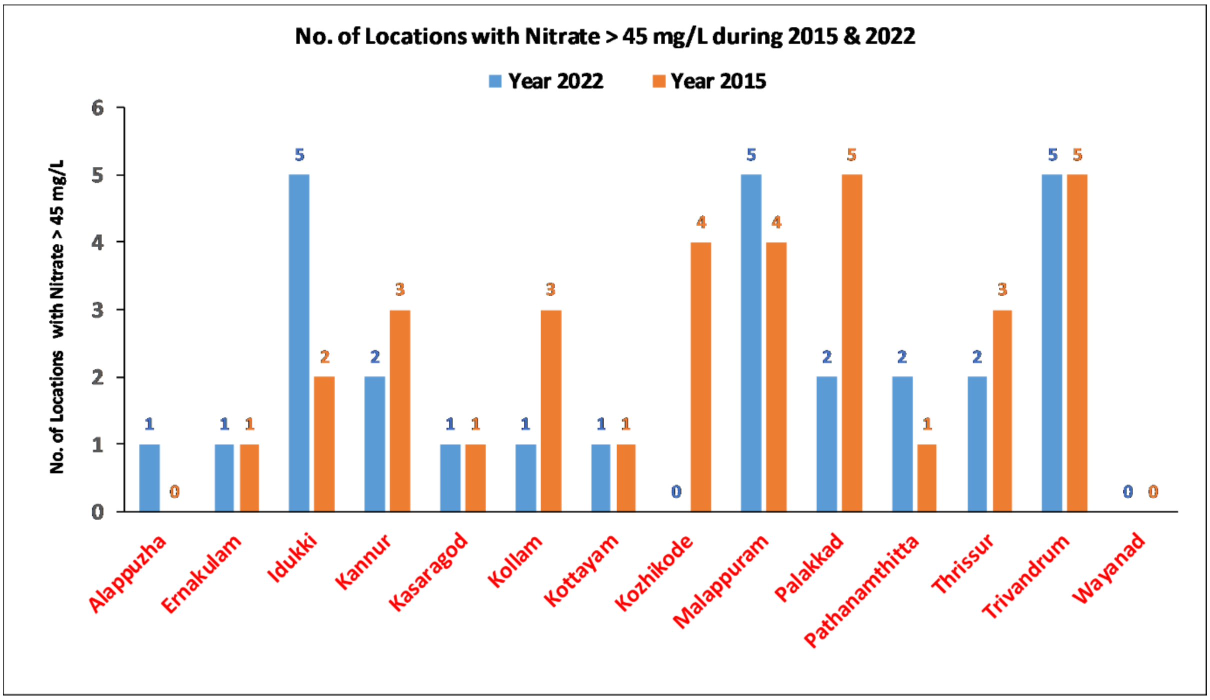


Fig. 7.4.3 Bar diagram comparing no. of Nitrate contaminated (45 mg/L) locations in various districts during year 2015 and 2022

It has been observed (Table 7.4.3) that No. of locations in various districts having high Nitrate (more than 45 mg/l) content in ground water has decreased by 15.15% in year 2022 as compared to the data available in year 2015.

7.4.1 TREND ON NITRATE

Trend analysis determines whether the measured values of the water quality variables increase or decrease during a time period. Nitrate is one of the major indicators of anthropogenic sources of pollution. Nitrate is the ultimate oxidized product of all nitrogen containing matter and its occurrence in groundwater can be fairly attributed to infiltration of water through soil containing domestic waste, animal waste, fertilizer and industrial pollution. As the lithogenic sources of nitrogen are very rare, its presence in ground water is almost due to anthropogenic activity. Hence, nitrate was taken to assess the trend of ground water quality in India due to anthropogenic activity. The percentage of well exceeds the permissible limit of 45mg/L for the period of 2017 to 2022 were compared and presented in the Table 7.4.4 and Fig 7.4.4 and observed that the percentage of samples exceed the permissible limit of nitrate (> 45 mg/L) were ranging between 8 - 10 % and decreasing trend was noticed. The no of wells monitored in the year 2020 due to COVID pandemic situation. The percentage of wells affected by nitrate was comparatively less (15%) in the year 2020. It is also observed that the type of waste generated is important in causing the nitrate pollution and also indicates that domestic waste leads to more nitrate problem. This could be due to the leaching of nitrate from the open sewerage lines. Trend on water quality for Nitrate prepared for the district of Trivandrum is showing a similar pattern (Fig 7.4.4).

Table 7.4.4: Percentage of wells Exceed Nitrate >45 mg/L during the period of 2017-2022

Year	Total Number of samples analysed	No. of Districts with Nitrate > 45 mg/L	No. of Locations with Nitrate > 45 mg/L	% of locations with Nitrate > 45 mg/L
2017	442	11	42	9.50
2018	515	7	39	7.57
2019	351	7	32	9.12
2020	0	0	0	0
2021	351	9	29	8.26
2022	294	8	28	9.52

The trend on nitrate in two locations, Beypore (Kozhikode) and Kottakkal (Malappuram), is shown (Fig 7.4.6 and 7.4.7), and it is observed that the decrease in trend may be attributed to the dissolution of water samples resulting from uneven annual rainfall or lowered anthropological release of pollutants. On the other hand, the increasing trend suggests a higher discharge of nitrate pollutants originating from domestic waste.

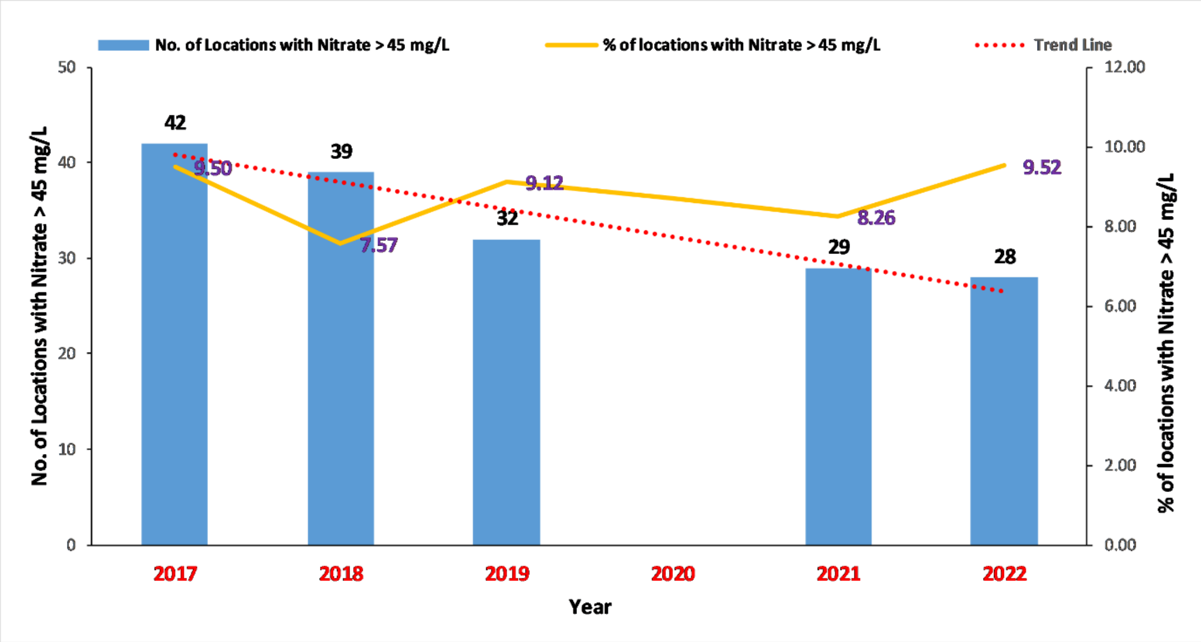


Fig. 7.4.4 Trend of Nitrate occurrence in Kerala

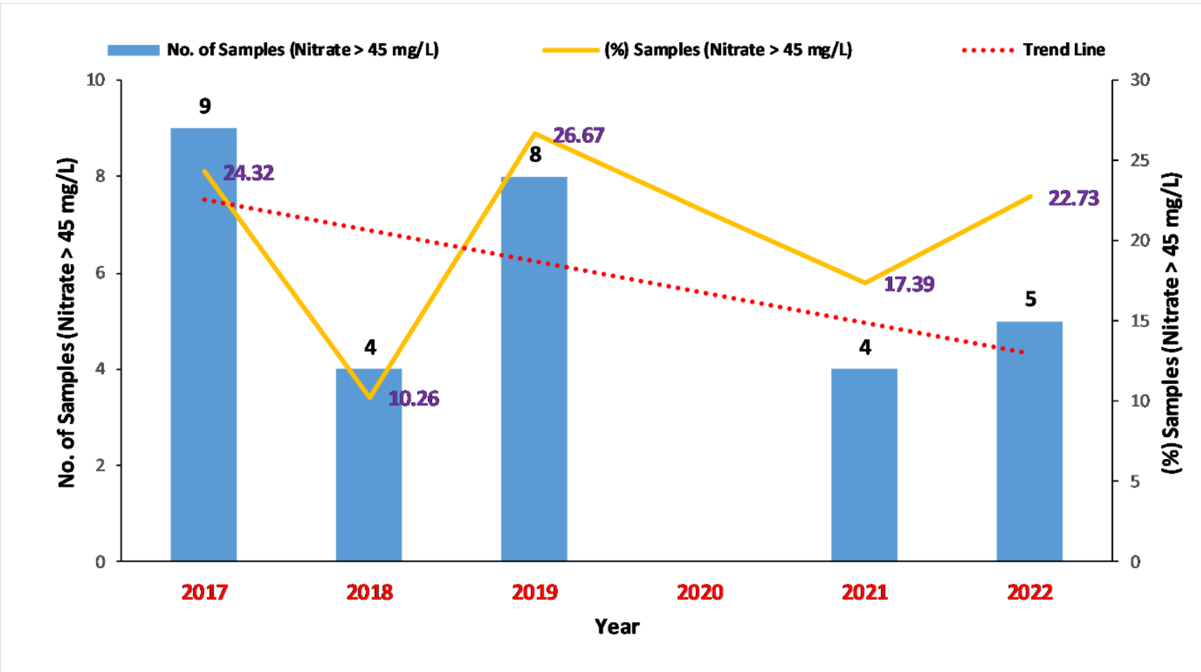


Fig. 7.4.5 Trend of Nitrate occurrence in Trivandrum District

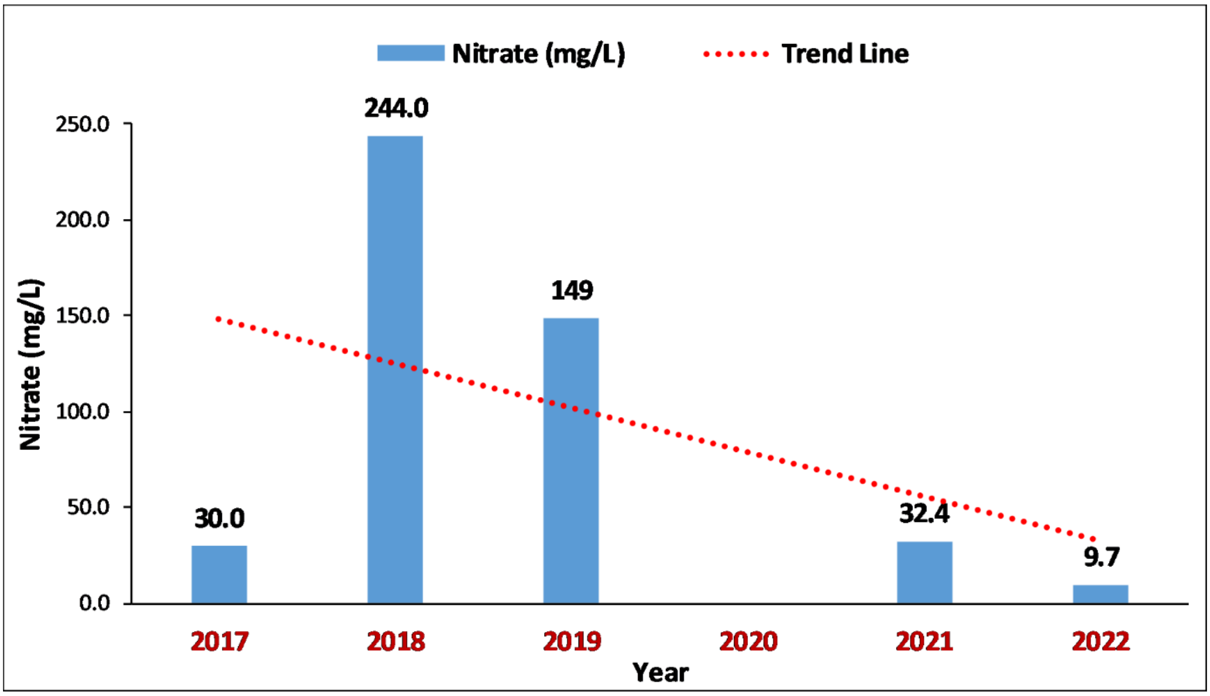


Fig 7.4.6 **Trend on Nitrate in Beypore (Kozhikode) for the period of 2017-2022**

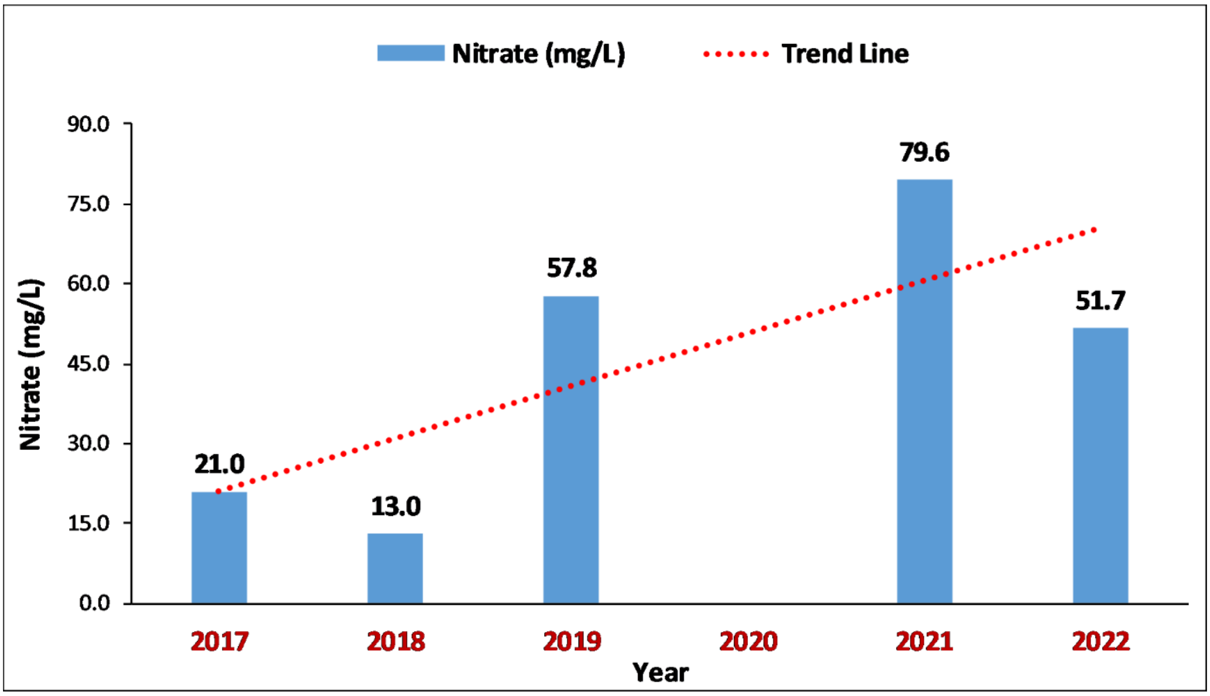


Fig 7.4.7 Trend on Nitrate in Kottakkal (Malappuram) for the period of 2017-2022

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 suchaschemicalcoagulation, lime softening and filtration which are commonly used forremovingmostofthe 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 ofcontaminated 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.

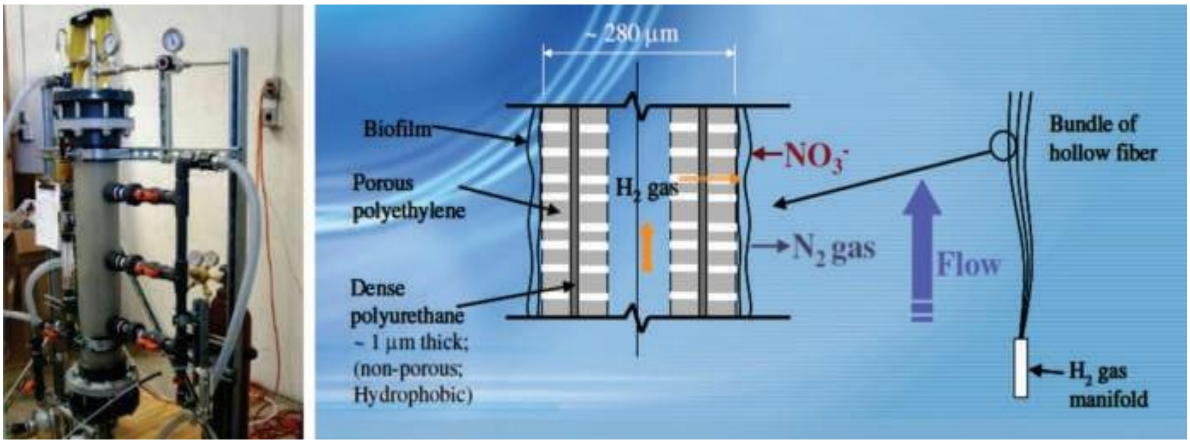


Fig. 7.4.8 Advanced Nitrate Reduction Hollow Fiber Membrane Reactor (Source: Hand Book for Drinking Water Treatment, JJM, Ministry of Jal Shakti, Gov. of India)

7.5 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 7.5.1, Annexure-V). It is based on the chemical analysis of water samples mostly collected from the groundwater observation wells on April 2021. The details of the sampling sources are given in Annexure-VI. The iron point value map indicates central part of Kerala having more iron content in groundwater compare to others part. The most iron affected districts are Thrissur, Alappuzha, Ernakulum andKottayam.

The summary list of districts in which iron in ground water is found to exceed the permissible limits for drinking water in localized areas is shown in table 7.5.1.

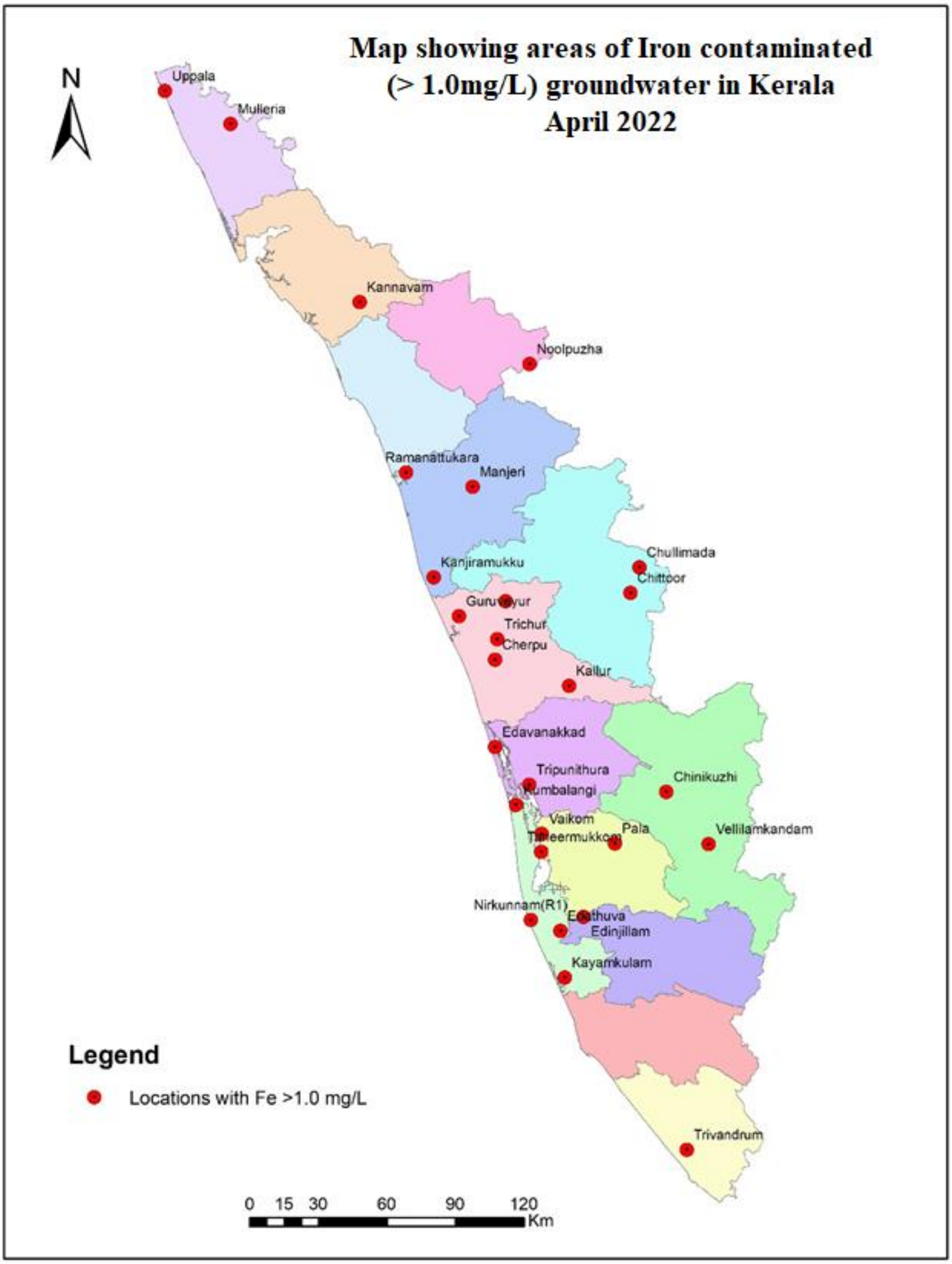


Fig. 7.5.1 Map showing areas of Iron contaminated (> 1.0mg/L) groundwater in Kerala,2022

Table 7.5.1 Districts Having Localized Occurrence of Iron (>1.0 mg/L) in GroundWater in Kerala

Sl. No	District	Locations of Districts Having Fe > 1.0 mg/L
1	Alappuzha	Edathuva, Kayamkulam, Nirkunnam(R1), Taneermukkom
2	Ernakulum	Edavanakkad, Kumbalangi, Tripunithura
3	Idukki	Chinikuzhi, Vellilamkandam
4	Kannur	Kannavam
5	Kasaragod	Mulleria, Uppala
6	Kottayam	Edinjillam, Pala, Vaikom
7	Kozhikode	Kozhikode Corporation
8	Malappuram	Kanjiramukku, Manjeri
9	Palakkad	Chittoor, Chullimada
10	Thrissur	Cherpu, Guruvayur, Kallur, Trichur, Wadakkancherry
11	Trivandrum	Trivandrum
12	Wayanad	Noolpuzha

Table-7.5.2: Comparative Change in number of Districts having Fe > 1.0 mg/L in various districts.

Sr.No	District	2016	2021	Increase/Decrease
1	Alappuzha	6	4	-2
2	Ernakulam	1	3	2
3	Idukki	2	2	0
4	Kannur	2	1	-1
5	Kasaragod	2	2	0
6	Kollam	2	0	-2
7	Kottayam	3	3	0
8	Kozhikode	2	1	-1
9	Malappuram	2	2	0
10	Palakkad	3	2	-1
11	Pathanamthitta	0	0	0
12	Thrissur	6	5	-1
13	Trivandrum	0	1	1
14	Wayanad	2	1	-1
	Total	**33**	**27**	**-6**

As compared to the data available in year 2016, the number of locations having Iron more than 1.0 mg/L in ground water samples has decreased (Table 7.5.2) by 18.2 % during the year 2021.

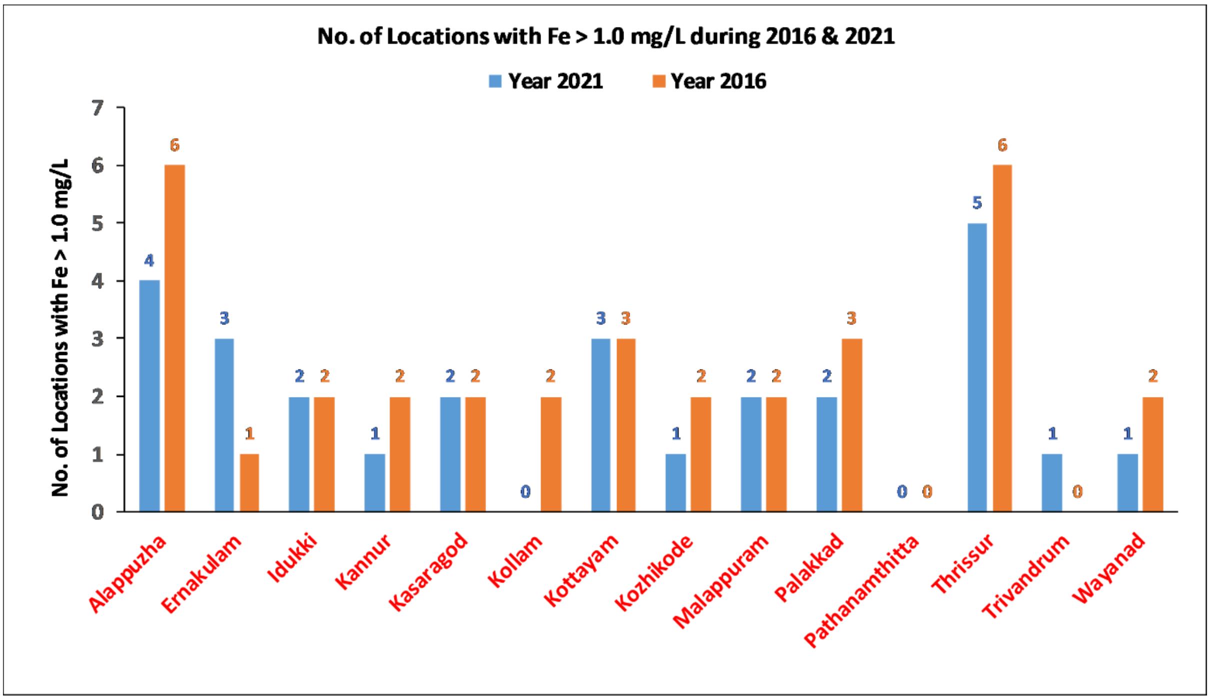


Fig. 7.5.2 Comparison on No of districts exceed Iron >1.0 mg/L during 2016 and 2021.

Remedial Measures for Iron/Manganese

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

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

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

Oxidation and Filtration Method for Fe and Mn Removal from Ground Water In general, manganese oxidation is more difficult than iron because the reaction rate is slower. A longer detention time (10 to

30 minutes) following chemical addition is needed prior to filtration to allow the reaction to take place. Manganese greensand is by far the most common medium in use for removal of iron and manganese through pressure filtration. Greensand is a processed material consisting of nodular grains of the zeolite mineral glauconite. The material is coated with manganese oxide. The ion exchange properties of the glauconite facilitates the bonding of the coating. This treatment gives the media a catalytic effect in the chemical oxidation reduction reactions necessary for iron and manganese removal. This coating is maintained through either continuous or intermittent feed of potassium permanganate.

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

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

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

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 and manganese as an electrolytic solution. A limited quantity of sodium chloride salt is added to enhance the electric conductivity through the solution. A comparison between different methods was undertaken to evaluate the applied conditions and the efficiency of Fe and Mn removal at different times and initial concentrations. The results revealed that CPE method was the best choice for the simultaneous removal of both iron and manganese in a short time < 10 min.

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

7.6 ARSENIC

Arsenic is a naturally occurring trace element found in rocks, soils and the water in contact with them. Arsenic has been recognized as a toxic element and is considered a human health hazard. The occurrence of Arsenic in ground water was first reported in 1980 in West Bengal in India. The occurrence of Arsenic in ground water is mainly in the aquifers upto 100 m depth. The deeper aquifers are free from Arsenic contamination. No arsenic levels higher than the BIS permissible limit of 0.01mg/L (10 ppb) reported from shallow aquifer wells in Kerala

7.7 URANIUM

Uranium occurs naturally in groundwater and surface water. Being a radioactive mineral, high uranium concentration can cause impact on water, soil and health. Uranium has both natural and anthropogenic source that could lead to the aquifer. These sources include leaching from natural deposits, release in mill tailings, and emissions from the nuclear industry, combustion of coal and other fuels and the use of phosphate fertilizers that contains uranium and contribute to ground water pollution. Uranium enters in human tissues mainly through drinking water, food, air and other occupational and accidental exposures. Intake of uranium through air and water is normally low, but in circumstances in which uranium is present in a drinking water source, the majority of intake can be through drinking water. Water with uranium concentration above the recommended maximum permissible concentration of 30 ppb (BIS,10500:2012) is not safe for drinking purposes as it can cause damage to internal organs, on continuous intake. Elevated uranium concentrations in drinking water have been associated with many epidemiological studies such as urinary track cancer as well as kidney toxicity. A recent study, found a strong correlation between uranium concentration in drinking water and uranium in bone, suggesting that bones are good indicators of uranium exposed via ingestion of drinking water. Therefore, such studies trigger further assessment of uranium's adverse health effects on humans and/or the environment for countries where elevated uranium concentration in drinking water has been observed. Hence, it becomes important to study the level of uranium in drinking water for health risk assessment.

Uranium concentration in the shallow ground water varies primarily due to recharge and discharge, which would have dissolved or leached the uranium from the weathered soil to groundwater zone. High uranium concentrations observed in groundwater may be due to local geology, anthropogenic activities, urbanization and use of phosphate fertilizers in huge quantity for agriculture purpose. Studies have shown that phosphate fertilizer possess uranium concentration ranging from 1 mg/kg to 68.5 mg/kg (Brindha K et al., 2011). Hence, the phosphate fertilizers manufactured from phosphate rocks may also contribute uranium to ground water in agriculture region. In ores, uranium is found as uranite (UO_2^{2+}) and pitchblende ($U_3O_8^{2+}$) or in the form of secondary minerals (complex oxides, silicates, phosphates, vanadates).

Table 7.7.1 Summary of uranium concentrations in different types of rocks

Rocks	Range(mg/kg)
Granite	3.4
Limestone/dolomite	2.2
Argillaceous shale	3.7
Sediments	1.4-53
Phosphates	30-100

Table 7.7.2 Standards and guidelines for uranium in drinking water in various countries.

Sl. No	Country / agency	guideline value (µg/L)	Reference
1	Australia	GV 17	NHMRC, Australia (2011)
2	Bulgaria	ML 60	European Food Safety Authority (2009)
3	Canada	MAC 20	Health Canada (2019)
4	Finland	RV 100	European Food Safety Authority (2009)
5	India	RBL 60	AERB, India (2004)
6	India	PL 30	BIS,2012
7	Malaysia	MAV 2	Ministry of Health Malaysia (2004)
8	USA	MCL 30	USEPA (2011)
9	WHO	PGV 30	WHO 2011

GV, Guideline value; ML, Maximum limit; MAC, Most acceptable concentration; RV, Recommended value; RBL, Radiological based limit; PL, Permissible Limit; MAV, Maximum acceptable value; MCL, Maximum contaminant level; PGV, Provisional guideline value

To assess the Uranium concentration and distribution in the ground water, Central Ground Water Board (CGWB) had decided to carry out Uranium sampling of its National Hydrograph Network Stations (NHNS) in the entire country during Pre-monsoon monitoring (May,2019).The sample collection and storage were done according to the standard protocols prescribed by APHA (2017). The groundwater samples were collected in plastic bottles after having been filtered through 0.45-µm filter paper. For the cations and uranium analyses, groundwater samples were immediately acidified below pH 2 by adding nitric acid to prevent precipitation and adsorption to the container walls. Uranium (U) was detected using Inductively Coupled Plasma Mass-spectrometry. To ensure quality control, duplicate and standard checks were performed on every ten samples. In addition, a trace element standard reference material was examined. In Kerala state, there are no sample locations where the uranium in groundwater exceeds the permissible limit (30 ppb).

7.8 TOTAL HARDNESS

Total hardness is predominantly caused by cations such as calcium and magnesium and anion such as bicarbonate and sulphate. Total hardness is defined as the sum of calcium and magnesium both expressed as $CaCO_3$ in mg/L. Hardness represents the soap-consuming capacity of water. Species that form insoluble compounds with soap Ca, Mg, Organic compounds etc.Total hardness is sum of Ca and Mg and expresses as CaC03 mg/l. EDTA titration. The two kind of hardness observed in water.

- Temporary hardness is due to Carbonate.
- Permanent hardness is due to Sulphate, Chloride or Nitrate.
-

The hardness in water is derived largely from contact with the soil and rock formations. Rain water as it falls upon the earth is in capable of dissolving the tremendous amount of solids found in many natural waters. People with kidney and bladder stones should avoid high content of calcium and magnesium in water (K. R. Karanth, 1997). The BIS acceptable limit is 200 mg/L whereas, permissible limit of hardness is 300 – 600 mg/L. The total hardness in groundwater was observed in a many part of the state. It is observed that there are several locations in the district of Alappuzha, Ernakulum, Kannur, Kollam, Kottayam, Malappuram, Palakkad, Thrissur and Wayanadwhere the total hardness in ground water exceeds 200 mg/L. There are no sample locations where the total hardness in groundwater exceeds the permissible limit (600 mg/L).The details of locations where total hardness concentration more than 200 mg/l is given in table 7.8.1.

Table – 7.8.1 Number of location having total hardness > 200 mg/L in districts of Kerala

Sr. No	District	No. of Samples (TH > 200 mg/L)	No. of Samples (TH > 600 mg/L)
1	Alappuzha	2	0
2	Ernakulam	4	0
3	Idukki	0	0
4	Kannur	1	0
5	Kasaragod	0	0

6	Kollam	1	0
7	Kottayam	1	0
8	Kozhikode	0	0
9	Malappuram	2	0
10	Palakkad	7	0
11	Pathanamthitta	0	0
12	Thrissur	3	0
13	Trivandrum	0	0
14	Wayanad	1	0
	Total	**22**	**0**

Table 7.8.2 locations having total hardness > 600 mg/L in Groundwater in Different Districts of Kerala

Sl. No	District	No. of locations having TH> 200 mg/L	Locations having TH> 200 mg/L
1	Alappuzha	2	Thakazhi, Purakkad
2	Ernakulum	4	Aluva, Tripunithura, Kumbalangi, Chellanum
3	Kannur	1	Mahe
4	Kollam	1	Needakara
5	Kottayam	1	Kumarakom
6	Malappuram	2	Chungathara, Kadalundi
7	Palakkad	7	Agali, Gopalapuram, Vadakkanchery, Alathur, Palakkad, Kozhinjampara, Kozhippara
8	Thrissur	3	Kundannur, Perinjanam, Kodungalloor
9	Wayanad	1	Muthanga

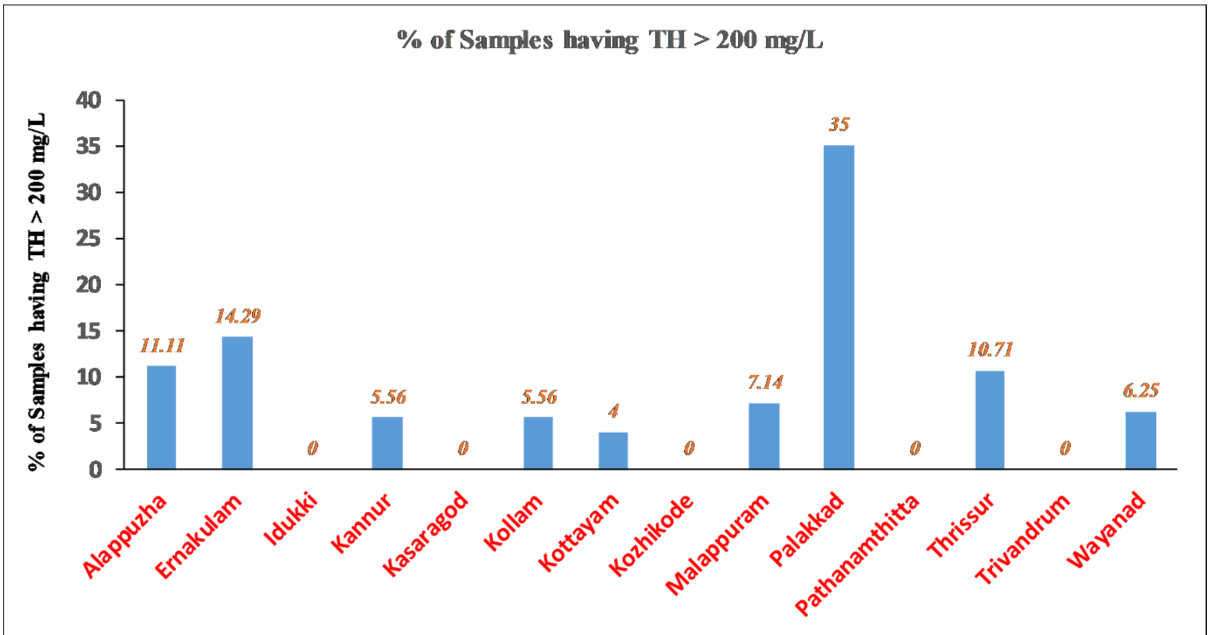


Fig 7.8.1 Bar diagram District-wise percentage of wells having Total hardness > 200 mg/L

Removal of total hardness

A few methods to remove hardness from water are,

- Chemical Process of Boiling Hard Water.
- Adding Slaked Lime (Clark's Process)
- Adding Washing Soda.
- Calgon Process.
- Ion Exchange Process.
- Using Ion Exchange Resins.

CARBONATE (TEMPORARY) HARDNESS also known as Ca Bicarbonate
$Ca(HCO_3)_2$ + Mg Bicarbonate $Mg(HCO_3)_2$. Removal by Boiling or adding Lime

NON-CARBONATE (PERMANENT) HARDNESS
Calcium Sulfate $CaSO_4$ + Magnesium Sulfate $MgSO_4$ & Calcium Chloride $CaCl_2$ + Magnesium Chloride $MgCl_2$
Removal by Lime-soda, Zeolite or Demineralization Processes

Table 7.8.4 District-wise percentage of samples having Total hardness >200 mg/L

Sr. No	District	No. of Samples collected (NHS 2022-23)	No. of Samples (TH > 200 mg/L)	(%) Samples (TH > 200 mg/L)	No. of Samples (TH > 600 mg/L)	(%) Samples (TH > 600 mg/L)
1	Alappuzha	18	2	11.1	0	0
2	Ernakulam	28	4	14.3	0	0
3	Idukki	20	0	0.0	0	0
4	Kannur	18	1	5.6	0	0
5	Kasaragod	22	0	0.0	0	0
6	Kollam	18	1	5.6	0	0
7	Kottayam	25	1	4.0	0	0
8	Kozhikode	18	0	0.0	0	0
9	Malappuram	28	2	7.1	0	0
10	Palakkad	20	7	35.0	0	0
11	Pathanamthitta	14	0	0.0	0	0
12	Thrissur	28	3	10.7	0	0
13	Trivandrum	22	0	0.0	0	0
14	Wayanad	16	1	6.3	0	0

8.0 SUITABILITY OF GROUNDWATER FOR IRRIGATION PURPOSE

The chemical quality of water is an important factor to be considered in evaluating its usefulness for irrigation purposes. Plants grown by irrigation absorb and transpire water but leave nearly all the salts behind in the soil, where they accumulate and eventually prevent plant growth. Excessive concentrations of solute interfere with the osmotic process by which plant root membranes are able to assimilate water and nutrients. In areas where natural drainage is inadequate, the irrigation water infiltrating the root zone will cause water table to rise excessively. In addition to problems caused by excessive concentration of dissolved solids, certain constituents in irrigation water are especially undesirable and some may be damaging even when present in small concentrations. Irrigation indices viz. Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) have been evaluated to assess the suitability of ground water for irrigation purposes.

Alkali Hazard

In the irrigation water, it is characterized by absolute and relative concentrations of cations. If the sodium concentrations are high, the alkali hazard is high and if the calcium & magnesium levels are high, this hazard is low. The alkali soils are formed by the accumulation of exchangeable sodium and are characterized by poor tilt and low permeability. The U.S. Salinity laboratory has recommended the use of sodium adsorption ratio (SAR) as it is closely related to adsorption of sodium by the soil.

SAR is derived by the following equation:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} Mg^{2+}}{2}}}$$

The water with regard to SAR is classified into four categories

- **S_1 – Low Sodium Water** (SAR <10)

Such waters can be used on practically all kinds of soils without any risk or increase in exchangeable sodium.

- **S_2 – Medium Sodium Water** (SAR 10-18)

Such waters may produce an appreciable sodium hazard in fine textured soil having high cation exchange capacity under low leaching.

- **S_3 – High Sodium Water** (SAR >18-26)

Such waters indicate harmful concentrations of exchangeable sodium in most of the soil and would require special management, good drainage, high leaching and addition of organic matter to the soil. If such waters are used on gypsiferrous soils the exchangeable sodium could not produce harmful effects.

➢ **S_4 – Very High Sodium Waters** (SAR >26)

Generally, such waters are unsatisfactory for irrigation purposes except at low or perhaps at medium salinity where the solution of calcium from the soil or addition of gypsum or other amendments makes the use of such waters feasible.

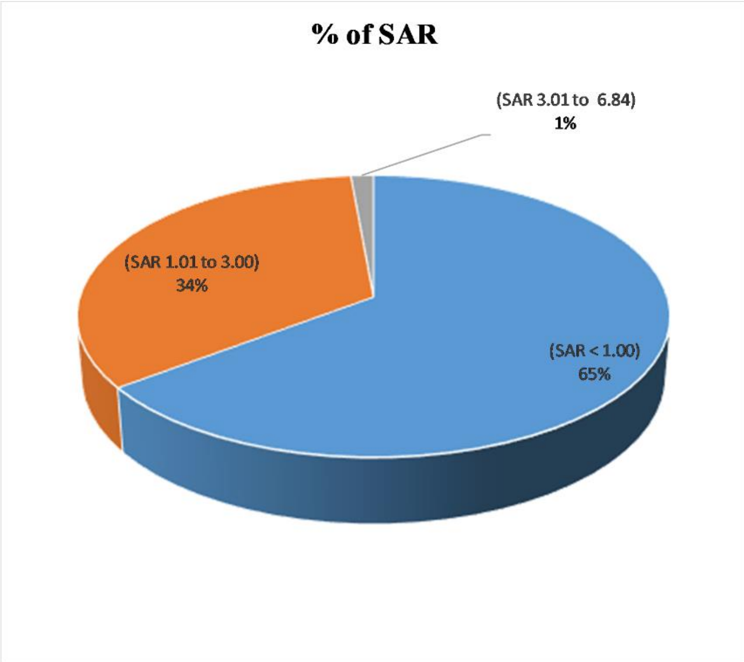


Figure 8.1: Percentage of groundwater samples according to SAR (n=295).

The computed SAR values ranges from 0.17 to 6.84. The maximum SAR value has been found at Chellanum of Ernakulum district. It is apparent from Fig. 8.1 that 100 % samples belong to excellent category (S_1) and all samples are suitable for irrigation.

Table 8.1: Summary of irrigation quality of the groundwater samples in various district based on SAR calculation.

Sr.No	District	No. of Samples collected (NHS 2022-23)	No. of Samples (SAR 2.00 to 6.84)	(%) Samples (SAR 2.00 to 6.84)	No. of Samples (SAR > 10)	(%) Samples (SAR > 10)
1	Alappuzha	18	0	0.0	0	0
2	Ernakulam	28	1	3.6	0	0
3	Idukki	20	2	10.0	0	0
4	Kannur	18	1	5.6	0	0
5	Kasaragod	22	0	0.0	0	0
6	Kollam	18	1	5.6	0	0

7	Kottayam	25	0	0.0	0	0
8	Kozhikode	18	1	5.6	0	0
9	Malappuram	28	2	7.1	0	0
10	Palakkad	20	1	5.0	0	0
11	Pathanamthitta	14	0	0.0	0	0
12	Thrissur	28	2	7.1	0	0
13	Trivandrum	22	7	31.8	0	0
14	Wayanad	16	0	0.0	0	0

According to SAR calculation, the number of samples and percentage SAR >2.00 and >10 are shown in Table No. 8.1. It was found that in Trivandrum district highest percent of SAR (< 2.00) observed (Fig. 8.2).

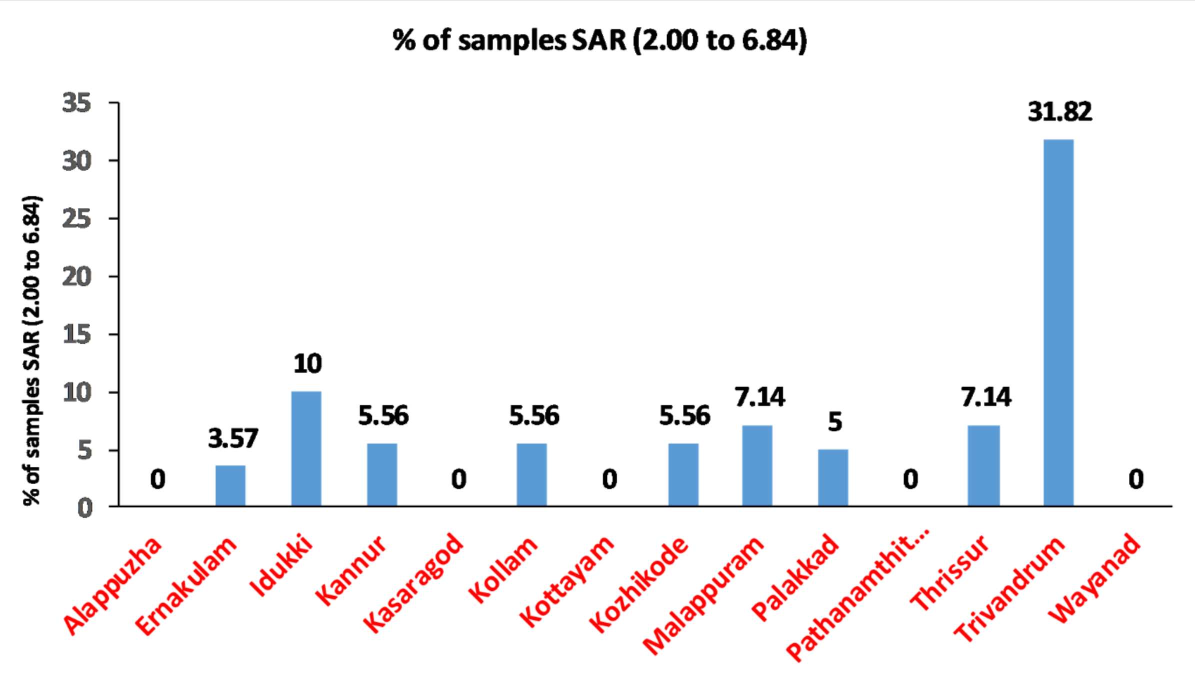


Figure 8.2: Percentage of samples with respect to SAR values (2.00 to 6.84)

In Kerala state, there are no sample locations that are unsuitable for irrigation based on SAR (>10).

Residual Sodium Carbonate (RSC)

If the enriched carbonate (residual) concentration becomes relatively high, carbonates get together with calcium and magnesium to form precipitates. The relative abundance of sodium in comparison to alkaline earths and the quantity of bicarbonate and carbonate in excess of alkaline earths also influences the suitability of water for irrigation. This excess is represented in terms of "Residual Sodium Carbonate" (RSC). The highly soluble sodium carbonate known as residual sodium carbonate (RSC) is defined as;

$$RSC = (HCO_3^- + CO_3^-) - (Ca^{2+} + Mg^{2+})$$

Waters with high RSC produces harmful effects on plant development and is not suitable for irrigation. Waters associated with RSC < 1.25 are of excellent irrigation quality and can be safely applied for irrigation for almost all crops without the risks associated with residual sodium carbonate (Wilcox et al.,1954).

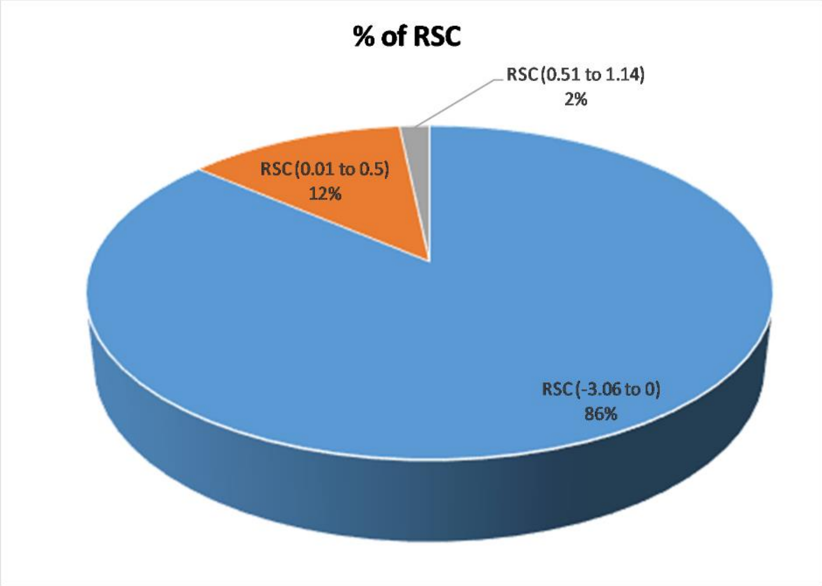


Figure 8.3: Percentage of groundwater samples in various categories according to RSC calculation (n= 295)

If the RSC values lie between 1.25 and 2.5, the water is of an acceptable quality for irrigation. Waters associated with RSC values higher than 2.5 are not acceptable for irrigation. In fig. it can be seen that in Kerala 100% collected water samples are associated with RSC values less than 1.25 and are safe for use in irrigation practices. The highest value of RSC (1.14) is observed at Kozhippara of Palakkad district. Table 8.4summarizes the irrigation quality of the groundwater samples in various district based on RSC values.

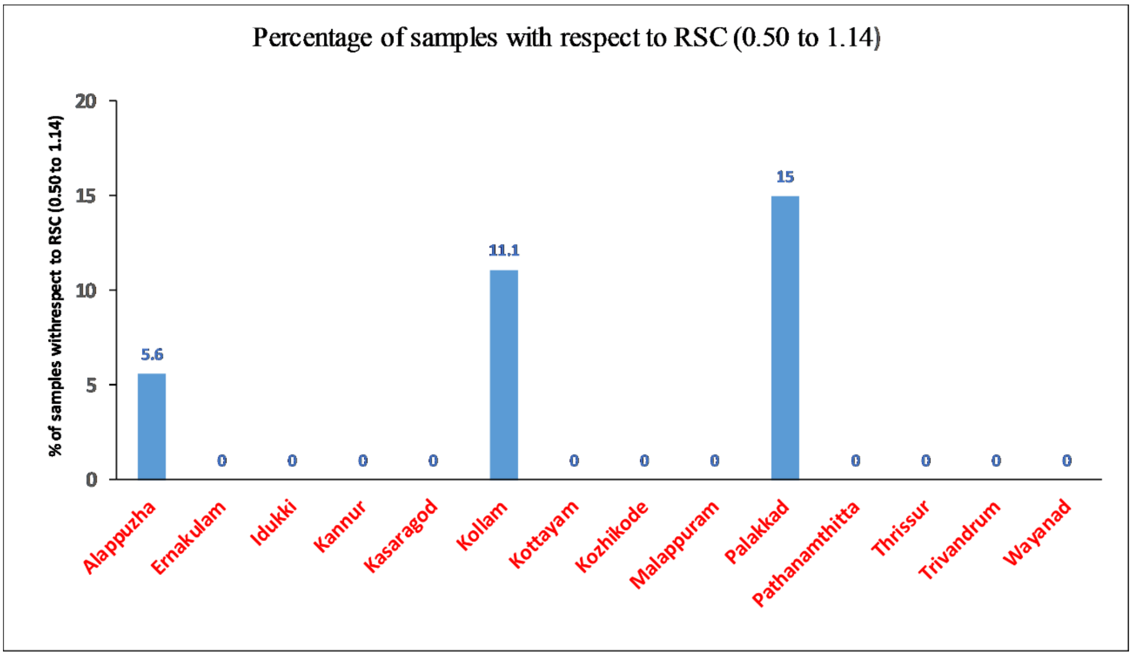


Figure 8.4: Percentage of samples with respect to RSC values (0.50 to 1.14)

According to RSC classification 100% of water samples in Kerala fall in very safe category with RSC values less than 1.25.

Table 8.2: Summary of irrigation quality of the groundwater samples in various district based on RSC values.

District	%. of samples in various RSC range		
	<1.25 (Very safe)	1.25-2.5 (marginally safe)	>2.5 Unsuitable
Alappuzha	100	0	0
Ernakulam	100	0	0
Idukki	100	0	0
Kannur	100	0	0
Kasaragod	100	0	0
Kollam	100	0	0
Kottayam	100	0	0
Kozhikode	100	0	0
Malappuram	100	0	0
Palakkad	100	0	0
Pathanamthitta	100	0	0
Thrissur	100	0	0
Trivandrum	100	0	0
Wayanad	100	0	0

9.0 WILCOX DIAGRAM

EC and sodium concentration are very important in classifying irrigation water. The Wilcox diagram (Wilcox 1948) relating EC and %Na shows (fig. 9.0) that all the samples are plotted in excellent to good categories and most all of the water samples indicating their suitability for irrigation. Wilcox diagram of some of the districts of Kerala is presented as Fig. 9.0 a to 9.0f.

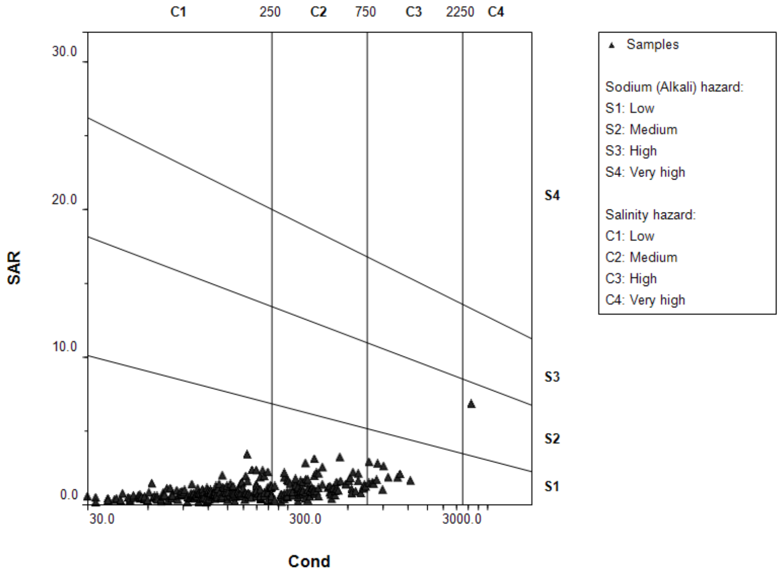


Fig.9.0 : Plots of sodium percent verses electrical conductivity (after Wilcox 1955) in groundwater samples of Kerala.

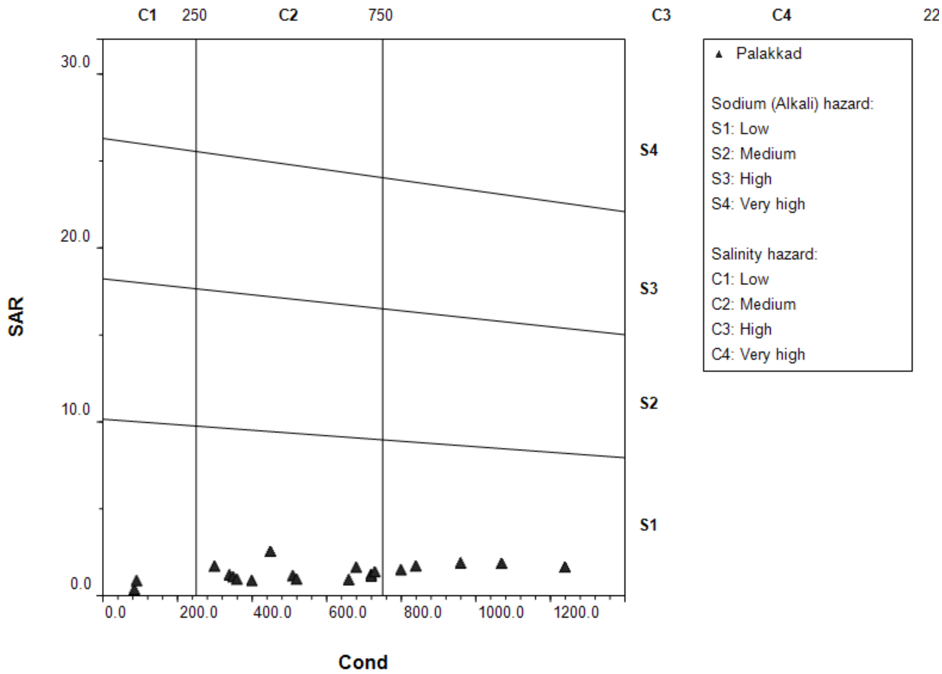


Fig.9.0a : Plots of sodium percent verses electrical conductivity (after Wilcox 1955) in groundwater samples in Palakkad district.

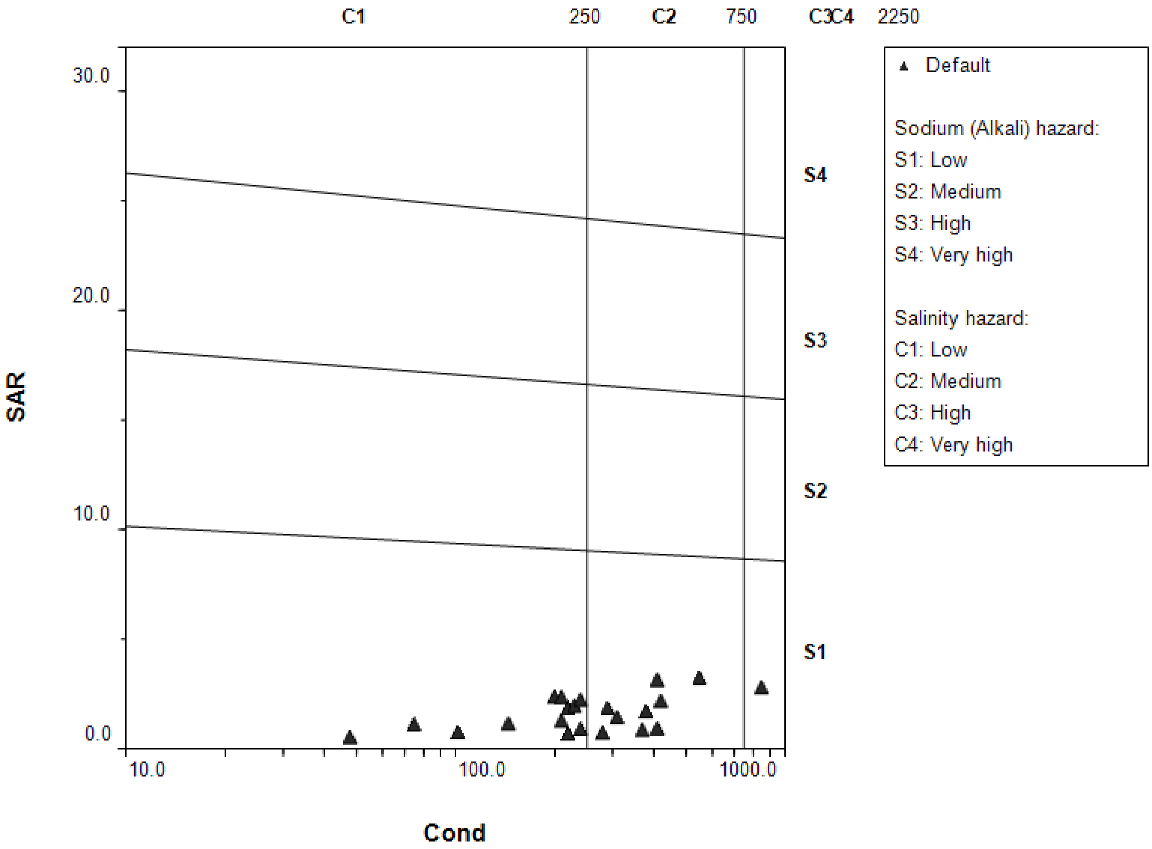


Fig.9.0b : Plots of sodium percent verses electrical conductivity (after Wilcox 1955) in groundwater samples in Trivandrum district.

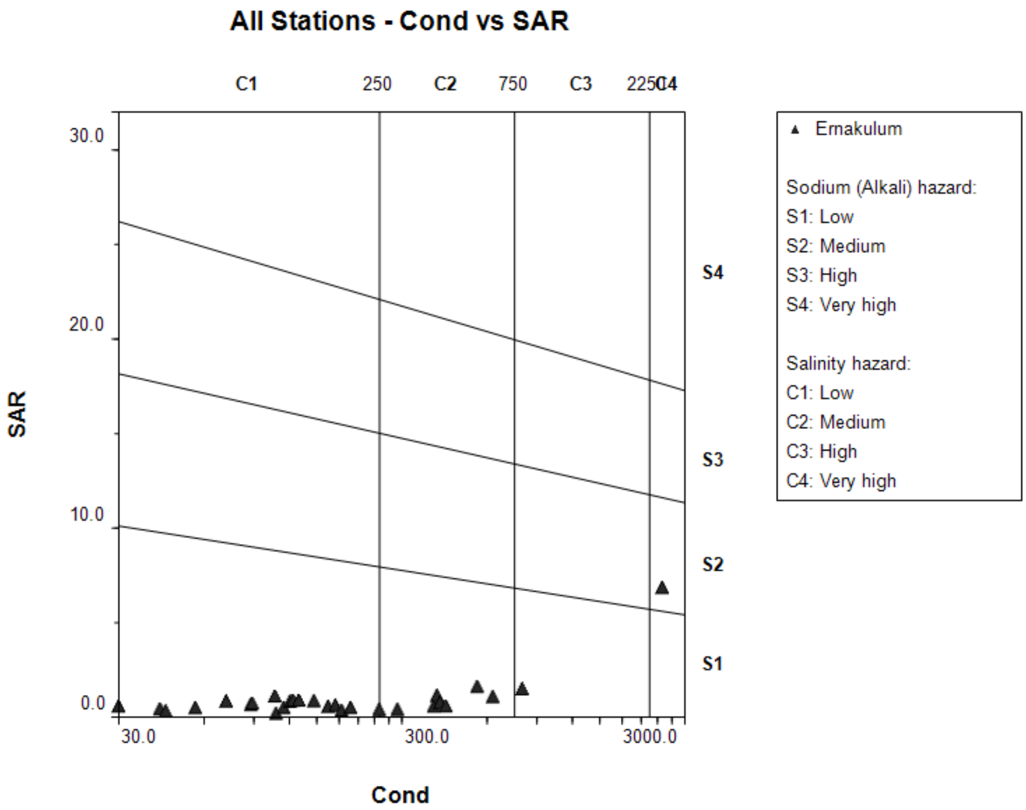


Fig.9.0c : Plots of sodium percent verses electrical conductivity (after Wilcox 1955) in groundwater samples in Ernakulum district.

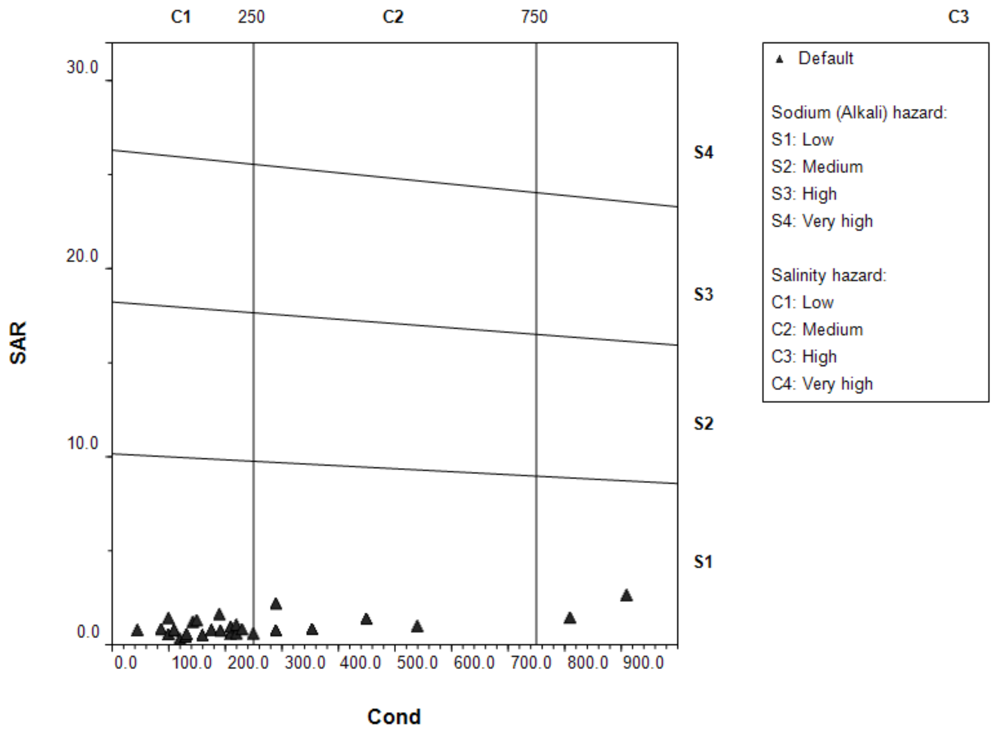


Fig.9.0d : Plots of sodium percent verses electrical conductivity (after Wilcox 1955) in groundwater samples in Thrissur district.

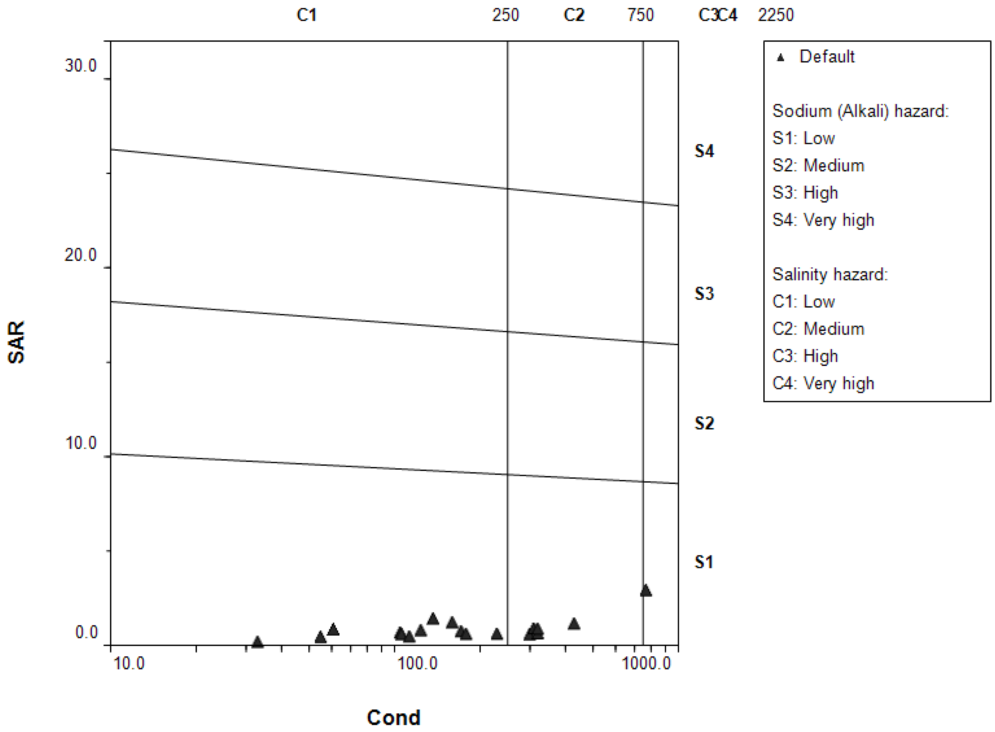


Fig.9.0e : Plots of sodium percent verses electrical conductivity (after Wilcox 1955) in groundwater samples in Kozhikode district.

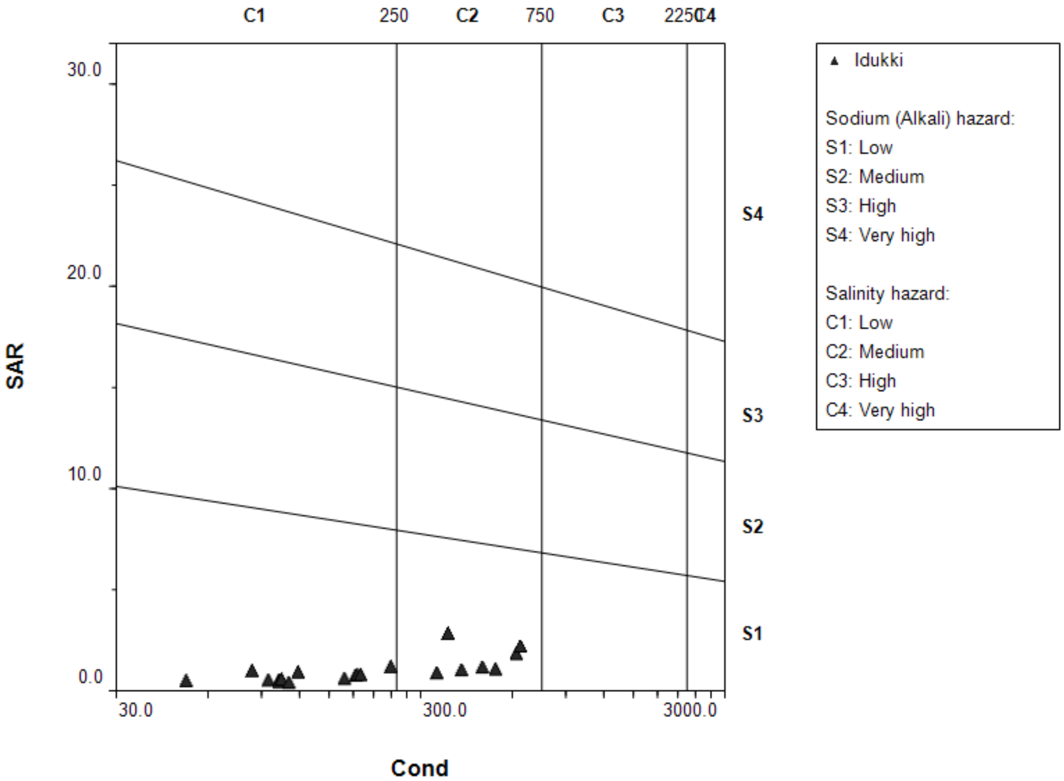


Fig.9.0f : Plots of sodium percent verses electrical conductivity (after Wilcox 1955) in groundwater samples in Idukki district.

9.1 Piper Diagram:

Piper diagram (Piper 1944) describes the process responsible for the evolution of hydrogeochemical parameter in groundwater. Based on the major cation and major anion content in the water samples and plotting them in the trilinear diagram, hydrochemical facies could be identified. Hydro-chemical facies are very useful in investigating diagnostic chemical character of water in hydrologic systems. Different types of facies within the same group formations are due to characteristic ground water flow through the aquifer system and effect of local recharge. The types of facies are inter-linked with the geology of the area and distribution of facies with the hydrogeological controls. Hydrochemical facies are delineated by plotting percentage reacting value of major ions on tri-linear diagrams know as Piper Diagram.

In Kerala, cation chemistry is dominated by calcium is followed by sodium and Potassium. In anion side bicarbonate is dominating anion followed by chloride.

The facies mapping shows (Fig.9.1) that Ca-HCO_3 is the dominant hydrogeochemical facies followed by mixed chemical character of hydrogeochemical facies.

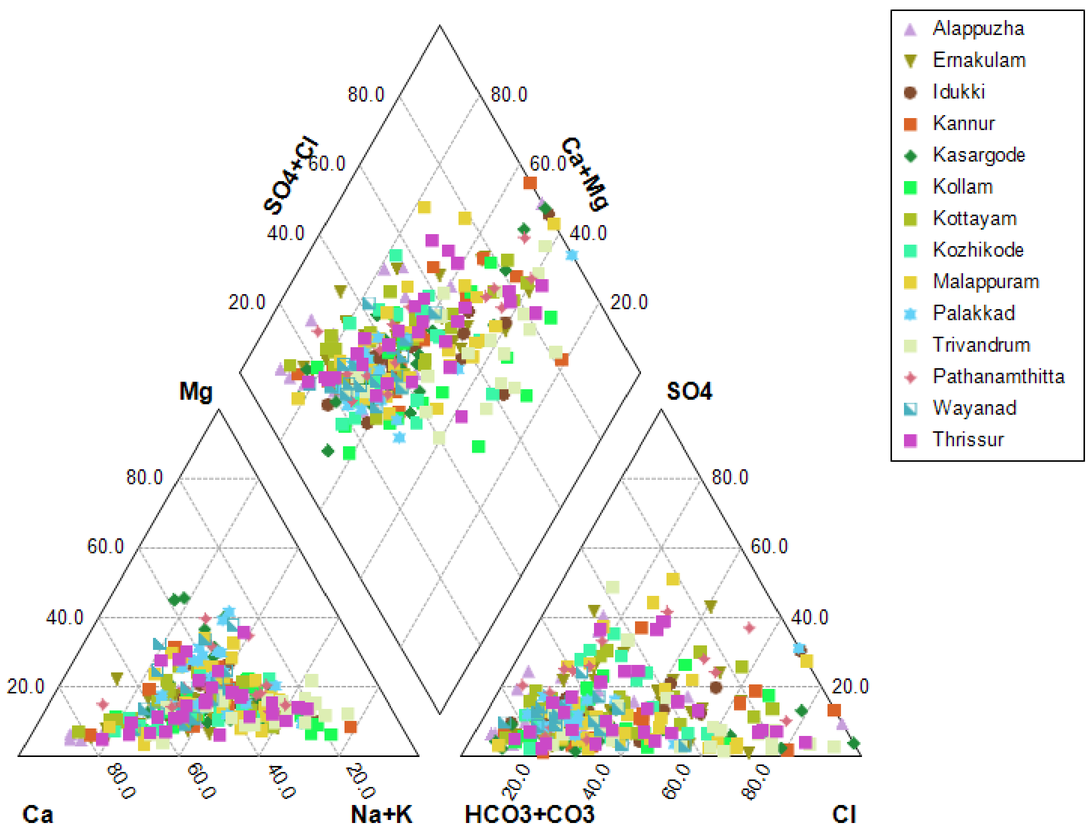


Fig- 9.1 Piper diagram of groundwater of Kerala.

The Piper Plot showing hydrochemical species in Palakkad, Ernakulum, Trivandrum, Idukki and Thrissur are displayed in Fig.9.1 a to 9.1 e.

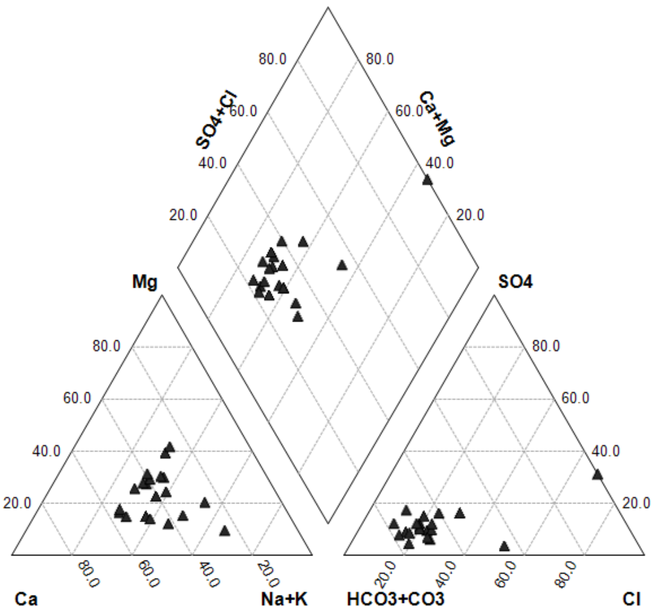


Fig- 9.1a Piper diagram of groundwater of Palakkad district.

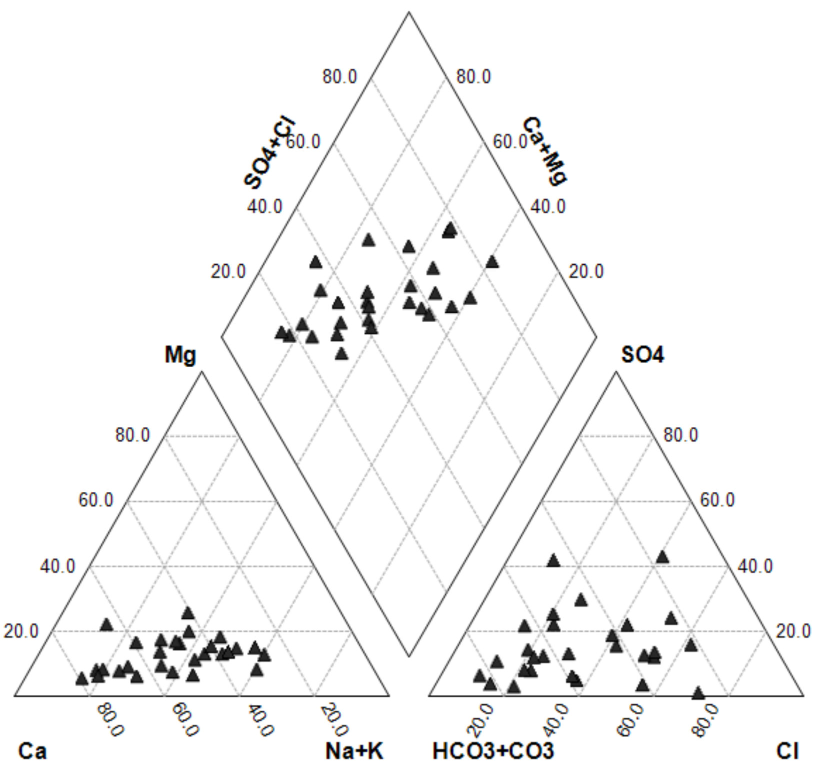
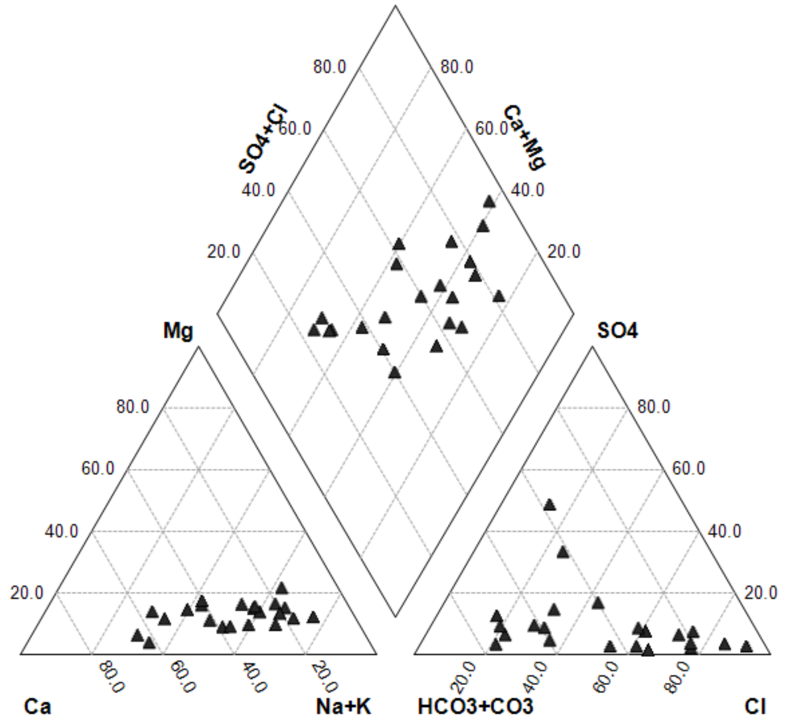
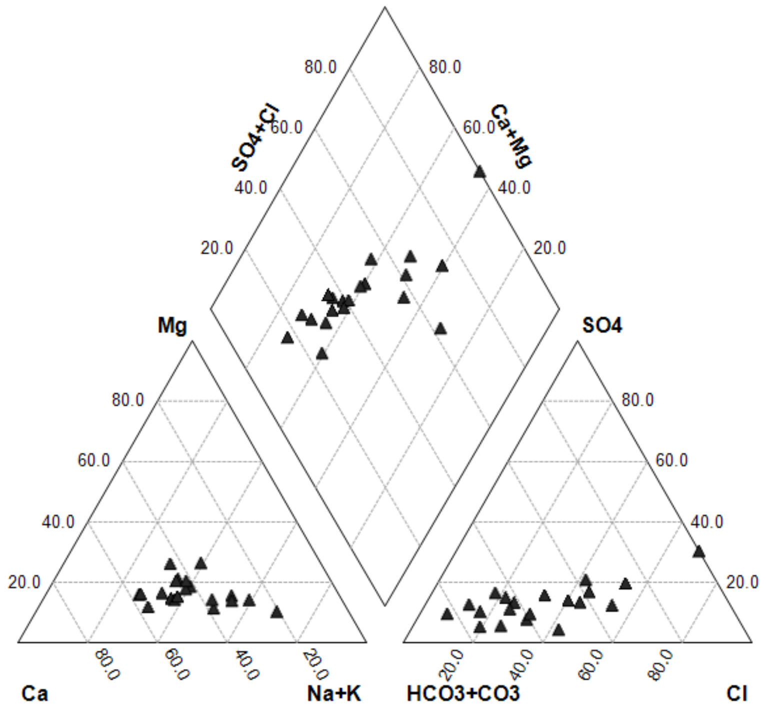


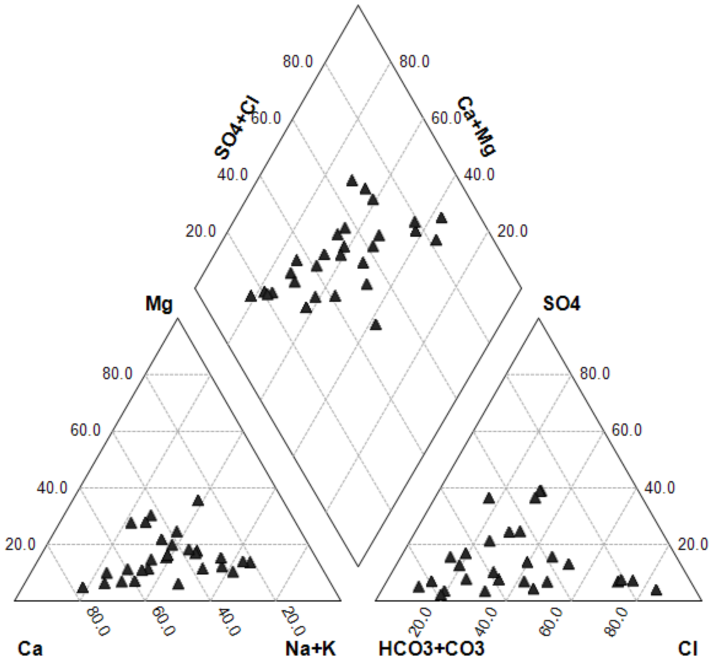
Fig- 9.1 b Piper diagram of groundwater of Ernakulum district.



9.1 c Piper diagram of groundwater of Trivandrum district.



9.1 d Piper diagram of groundwater of Idukki district.



9.1 e Piper diagram of groundwater of Thrissur district.

The piper plots of the Palakkaddistrict is exhibited that the groundwater is mostly Ca-HCO3 type in nature. In Ernakulum district ground water is mix to Ca-HCO3 in nature. In Trivandrum district it is Mix to Na-Cl type in nature. In Idukki district it is Ca-HCO3 in nature and in Thrissur district majority of groundwater is Ca-HCO3 in nature, where as in few locations it is Na-Cl in nature.

9.2 X-Y Plot:

If halite dissolution is responsible for the sodium, the Na+/Cl- ratio is approximately one, whereas a ratio greater than one, it is typically interpretated as Na+ released from Silicate weathering reaction. In the water samples of the shallow aquifers of India, 5.4 % of the samples fall along the equilibrium in the Na+/Cl- plot, indicating common source of halite for both the ions (Fig.9.2). In the water samples of the shallow aquifers of India, 87.7 % of the samples have molar ratio greater than one indicating ion exchange is the major process. It is where Na montmorillonite clay reacts with calcium and magnesium and releases sodium (sometimes called natural softening).

$$2Na^{+} – clay + Ca^{2+} = Ca^{2+} – clay + Na^{+}$$

The observed $Na^{+}/Cl^{-} < 1$, may be attributed to groundwater interaction with connate seawater in coastal areas and Cl^{-} enrichment from anthropogenic sources such asirrigation return flows or domestic waste disposal in another areas. Bivariant plot of Ernakulum, and Palakkad is shown in Fig.9.2a & 9.2b.

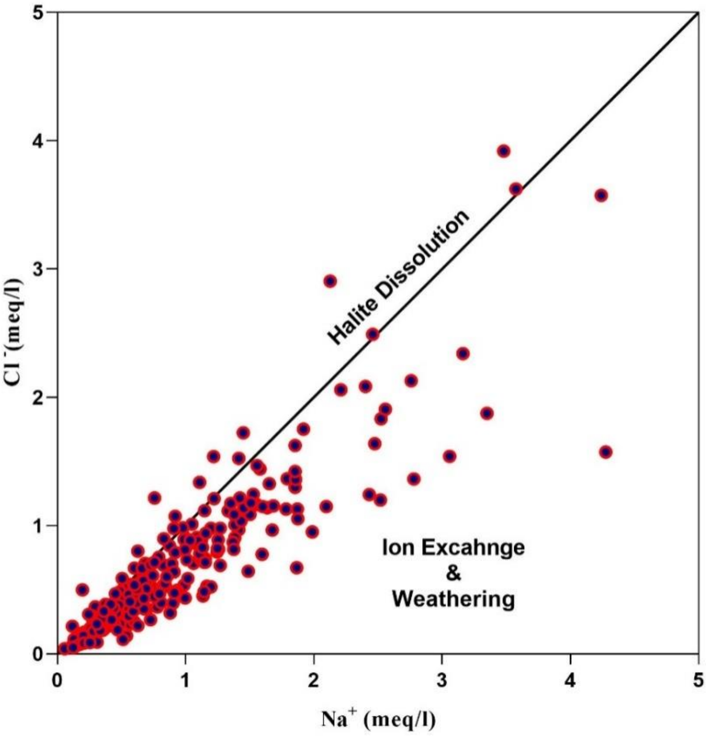


Fig. 9.2: The plot for Na versus Cl in groundwater samples of Kerala

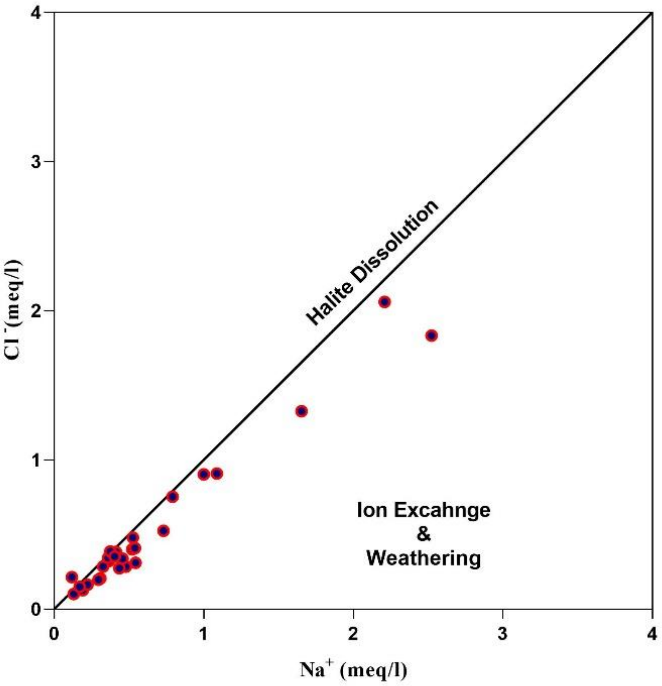


Fig.9.2a: The plot for Na versus Cl in groundwater samples of Ernakulum District

In Ernakulum district sodium and chloride enriched in groundwater by halide dissolution followed by ion exchange and silicate weathering processes.

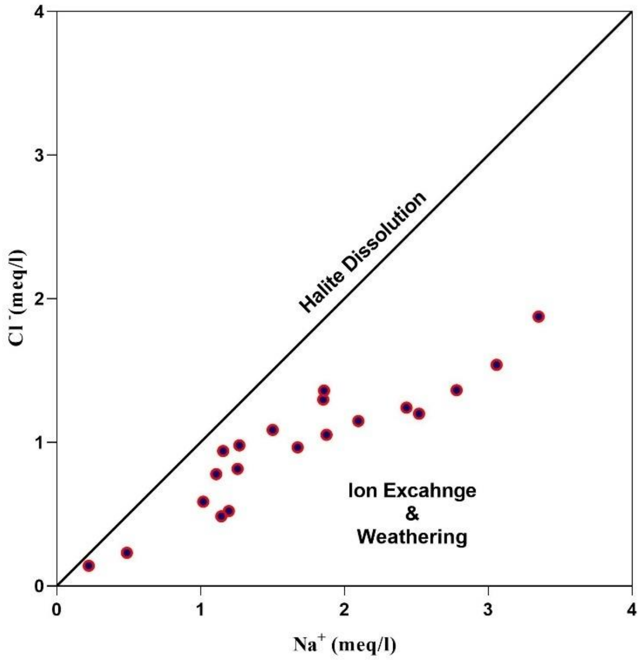


Fig. 9.2b: The plot for Na versus Cl in groundwater samples of Palakkad district

In Palakkad district silicate weathering is main mechanism for sodium and chloride enrichment in groundwater.

10.0 Bibliography

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Annexure-I

Location details of wells having Electrical Conductivity (District wise)						
Sl. No	**Sate**	**District**	**Location**	**Longitude**	**Latitude**	**EC (µS/cm) at 25 C**
1	Kerala	Alappuzha	Purakkad1	76.370	9.350	1100
2	Kerala	Ernakulam	Kumbalangi	76.291	9.863	800
3	Kerala	Ernakulam	Chellanum	76.285	9.807	2500
4	Kerala	Kozhikode	Ramanattukara	75.859	11.177	770
5	Kerala	Palakkad	Palakkad	76.772	10.661	800
6	Kerala	Palakkad	Agali	76.746	11.118	840
7	Kerala	Palakkad	Gopalapuram	76.870	10.693	960
8	Kerala	Palakkad	Kozhinjampara	76.841	10.744	1070
9	Kerala	Palakkad	Kozhippara	76.869	10.686	1240
10	Kerala	Pathanamthitta	Enathu	76.75	9.08	900
11	Kerala	Thrissur	Kodungalloor	76.195	10.234	810
12	Kerala	Thrissur	Perinjanam	76.148	10.315	910
13	Kerala	Trivandrum	Balaramapuram	77.050	8.430	850
14	Kerala	Wayanad	Muthanga (R1)	76.371	11.677	770

Annexure-II

Locations having Chloride > 250 mg/L						
Sr. No	**State**	**District**	**Location**	**Longitude**	**Latitude**	**Chloride (mg/L)**
1	Kerala	Ernakulam	Chellanum	76.2847	9.8069	724

Annexure-III

Locations having Fluoride >1 mg/L						
Sl.no	**State**	**District**	**Location**	**Longitude**	**Latitude**	**Fluoride (mg/L)**
1	Kerala	Idukki	Kumily	77.15711389	9.612086111	1.315
2	Kerala	Malappuram	Manjeri	76.1201	11.1201	2.092

Annexure-IV

Locations having Nitrate >45 mg/L in Kerala State

Sr. No	State	District	Location	Longitude	Latitude	Nitrate (mg/L)
1	Kerala	Alappuzha	Pallarimangalam	76.540	9.200	125
2	Kerala	Ernakulam	Koothattukulam	76.575	9.867	104
3	Kerala	Idukki	Kulamavu	76.893	9.793	50.5
4	Kerala	Idukki	Koilkadavu	77.170	10.240	54.5
5	Kerala	Idukki	Erattayar	77.105	9.798	56
6	Kerala	Idukki	Vandiperiyar	77.090	9.572	59.4
7	Kerala	Idukki	Kattappana	77.116	9.755	92.7
8	Kerala	Kannur	Koothuparamba	75.565	11.828	69.6
9	Kerala	Kannur	Sreekandapuram	75.508	12.045	83.2
10	Kerala	Kasargode	Bekal	75.031	12.400	45.6
11	Kerala	Kollam	Kudavettur	76.750	8.940	63.2
12	Kerala	Kottayam	Paipad	76.575	9.428	64.9
13	Kerala	Malappuram	Kottakkal	75.983	10.971	51.7
14	Kerala	Malappuram	Chungathara1	76.276	11.334	52
15	Kerala	Malappuram	Mangalam	75.922	10.849	61.6
16	Kerala	Malappuram	Manjeri	76.120	11.120	66
17	Kerala	Malappuram	Vylattur	75.944	10.786	105.4
18	Kerala	Palakkad	Kalladikkode	76.539	10.894	47.6
19	Kerala	Palakkad	Gopalapuram	76.870	10.693	88.1
20	Kerala	Pathanamthitta	Konni	76.850	9.230	58.8
21	Kerala	Pathanamthitta	Enathu	76.75	9.08	91.6
22	Kerala	Thrissur	Kecheri	76.162	10.607	68.5
23	Kerala	Thrissur	Perinjanam	76.148	10.315	157.5
24	Kerala	Trivandrum	Chirayinkil	76.790	8.660	46.5
25	Kerala	Trivandrum	Pangode	76.969	8.765	54.7
26	Kerala	Trivandrum	Kattakkada	77.080	8.510	77.5
27	Kerala	Trivandrum	Poovar- II	77.070	8.320	86.4
28	Kerala	Trivandrum	Balaramapuram	77.050	8.430	147.5

Annexure-V

Locations having Iron >1.0 mg/L in Kerala State

Sr.No	State	District	Location	Longitude	Latitude	Iron (mg/L)
1	Kerala	Alappuzha	Edathuva	76.466	9.367	10.5
2	Kerala	Alappuzha	Kayamkulam	76.483	9.183	1.9
3	Kerala	Alappuzha	Nirkunnam(R1)	76.350	9.410	1.04
4	Kerala	Alappuzha	Taneermukkom	76.390	9.678	20.5
5	Kerala	Ernakulam	Edavanakkad	76.208	10.092	3.21
6	Kerala	Ernakulam	Kumbalangi	76.291	9.863	1.78
7	Kerala	Ernakulam	Tripunithura	76.343	9.943	1.406
8	Kerala	Idukki	Chinikuzhi	76.883	9.915	1.765
9	Kerala	Idukki	Vellilamkandam	77.050	9.708	2
10	Kerala	Kannur	Kannavam	75.675	11.847	1.03
11	Kerala	Kasargod	Mulleria	75.167	12.550	2.05
12	Kerala	Kasargod	Uppala	74.907	12.680	11.13
13	Kerala	Kottayam	Edinjillam	76.558	9.423	6.42
14	Kerala	Kottayam	Pala	76.681	9.711	9.025
15	Kerala	Kottayam	Vaikom	76.393	9.750	1.11
16	Kerala	Kozhikode	Ramanattukara	75.858	11.175	2.582
17	Kerala	Malappuram	Kanjiramukku	75.967	10.761	4.17
18	Kerala	Malappuram	Manjeri	76.121	11.118	5.5
19	Kerala	Palakkad	Chittoor	76.742	10.700	9
20	Kerala	Palakkad	Chullimada	76.777	10.801	1.16
21	Kerala	Thrissur	Cherpu	76.208	10.436	10.5
22	Kerala	Thrissur	Guruvayur	76.067	10.608	1.9
23	Kerala	Thrissur	Kallur	76.500	10.333	1.04
24	Kerala	Thrissur	Trichur	76.217	10.517	20.5
25	Kerala	Thrissur	Wadakkancherry	76.250	10.667	1.04
26	Kerala	Trivandrum	Trivandrum	76.964	8.503	6
27	Kerala	Wayanad	Noolpuzha	76.345	11.603	2.825

Annexure-VI

Locations showing details of sampling sources for Iron in Kerala State

Sr. No	District	Block	Location	Longitude	Latitude	Fe (mg/L)
1	Alappuzha	Aryad	Alleppey	76.326	9.492	0.29
2	Alappuzha	Mavelikara	Aranootimangalam	76.580	9.230	0.29
3	Alappuzha	Thykattussery	Arukutti	76.320	9.850	0.398
4	Alappuzha	Pattanakkad	Chandirur	76.304	9.774	0
5	Alappuzha	Mavelikara	Chettikulangara	76.518	9.250	0.29
6	Alappuzha	Veliyanad	Edathuva	76.466	9.367	10.5
7	Alappuzha	Haripad	Haripad	76.464	9.288	0.724
8	Alappuzha	CHENGANNUR MUNIC.	Kallissery	76.617	9.333	0.398
9	Alappuzha	Bharanikavu	Kattanam	76.567	9.175	0
10	Alappuzha	Aryad	Kattoor	76.320	9.556	0.505
11	Alappuzha	KAYAMKULAM MUNIC.	Kayamkulam	76.483	9.183	1.9
12	Alappuzha	Bharanikavu	Kudasanad	76.670	9.190	0.505
13	Alappuzha	Champakulam	Nedumudi (pupalli)	76.383	9.433	0.075
14	Alappuzha	Ambalapuzha	Nirkunnam(R1)	76.350	9.410	1.04
15	Alappuzha	Muthukulam	Oachira1	76.514	9.146	0.183
16	Alappuzha	Mavelikara	Pallarimangalam	76.536	9.204	0.073
17	Alappuzha	Chengannur	Parumala	76.545	9.319	0.29
18	Alappuzha	Muthukulam	Pathiyur	76.483	9.217	0.505
19	Alappuzha	Pattanakkad	Pattanakad	76.292	9.733	0.183
20	Alappuzha	AMBALAPUZHA	Purakkad	76.367	9.347	0.29
21	Alappuzha	VELIYANAD	Ramankari	76.485	9.418	0.183
22	Alappuzha	Kanjikuzhi	Sherthalai	76.350	9.700	0.29
23	Alappuzha	Chengannur	Taneermukkom	76.390	9.678	20.5
24	Alappuzha	THAIKKATUSSERY	Thaikattusseri-R1	76.342	9.783	0.398

Sr. No	District	Block	Location	Longitude	Latitude	Fe (mg/L)
25	Alappuzha	Champakulam	Thakazhi	76.400	9.380	0.29
26	Alappuzha	Kanjikuzhi	Valavanad	76.333	9.600	0.398
27	Alappuzha	CHENGANNUR	Venmani	76.616	9.247	0.398
28	Ernakulam	PAMPAKKUDA	Anchalpetty	76.500	9.914	0.429
29	Ernakulam	ANGAMALI MUNIC.	Angamali	76.388	10.190	0.729
30	Ernakulam	PALLURUTHY	Chellanum	76.285	9.807	0.729
31	Ernakulam	PARAKKADAVU	Chengamanad	76.339	10.153	0.278
32	Ernakulam	ANGAMALY	Chulli	76.471	10.249	0.429
33	Ernakulam	KOCHI CORPORATION	Edapally	76.308	10.022	0.353
34	Ernakulam	VYPIN	Edavanakkad	76.208	10.092	3.21
35	Ernakulam	KOCHI CORPORATION	Fort Cochin	76.246	9.950	0.353
36	Ernakulam	ANGAMALY	Karukutty	76.550	9.883	0.353
37	Ernakulam	PAMPAKKUDA	Koothattukulam	76.575	9.867	0.053
38	Ernakulam	MUVATTUPUZHA	Kothamangalam	76.628	10.067	0.278
39	Ernakulam	KOTHAMANGALAM	Kottapadi	76.599	10.131	0.128
40	Ernakulam	ALANGAD	Kottapuram	76.300	10.128	0.203
41	Ernakulam	PALLURUTHY	Kumbalangi	76.291	9.863	1.78
42	Ernakulam	KOOVAPPADY	Malayattur	76.533	10.183	0.353
43	Ernakulam	VYPIN	Malipuram	76.225	10.022	0.429
44	Ernakulam	MULAMTHURUTHY	Mulanthuruthi	76.392	9.892	0.353
45	Ernakulam	VYPIN	Munambam	76.172	10.172	0.654
46	Ernakulam	MUVATTUPUZHA MUNIC.	Muvattupuzha	76.579	9.985	0.203
47	Ernakulam	KOTHAMANGALAM	Neriyamangalam	76.774	10.056	0.203
48	Ernakulam	PARAVUR	North Paravur	76.217	10.183	0.88
49	Ernakulam	PAMPAKKUDA	Perumbadavam	76.508	9.942	0.429
50	Ernakulam	KOTHAMANGALAM	Pothanikad	76.708	10.006	0.053

Sr. No	District	Block	Location	Longitude	Latitude	Fe (mg/L)
51	Ernakulam	THRIPPUNITHARA MUNIC.	Tripunithura	76.343	9.943	1.406
52	Ernakulam	ALANGAD	Varapuzha	76.256	10.077	0.278
53	Ernakulam	ANGAMALY	Vazhakulam North	76.400	10.131	0.504
54	Idukki	ADIMALI	Adimali	76.955	10.013	0
55	Idukki	ELAMDESOM	Chinikuzhi	76.883	9.915	1.765
56	Idukki	THODUPUZHA	Chittur	76.676	9.910	0.369
57	Idukki	AZUTHA	Elapara	76.981	9.633	0.201
58	Idukki	KATTAPPANA	Erattayar	77.105	9.798	0.089
59	Idukki	IDUKKI	Idukki	76.978	9.842	0.034
60	Idukki	ELAMDESOM	Kaliyar	76.782	9.975	0.034
61	Idukki	THODUPUZHA	Karimkunnam	76.688	9.854	0.034
62	Idukki	KATTAPPANA	Kattappana	77.088	9.733	0.089
63	Idukki	Nedumkandam	Koilkadavu	77.170	10.240	0.034
64	Idukki	Idukki	Kulamavu	76.880	9.800	0.313
65	Idukki	THODUPUZHA	Kumaramangalam	76.708	9.936	0.034
66	Idukki	AZUTHA	Kuttikkanam1	76.967	9.558	0.157
67	Idukki	IDUKKI	Molamattam	76.845	9.799	0.089
68	Idukki	DEVIKULAM	Munnar	77.067	10.088	0
69	Idukki	NEDUMKANDAM	Nedumkandam	77.161	9.838	0.034
70	Idukki	Devikulam	NirmalaCity	77.073	9.783	0.201
71	Idukki	NEDUMKANDAM	Poopara	77.154	9.983	0.034
72	Idukki	KATTAPPANA	Vandanmedu	77.157	9.715	0.145
73	Idukki	AZUTHA	Vandiperiyar	77.100	9.567	0.089
74	Idukki	KATTAPPANA	Vellilamkandam	77.050	9.708	2
75	Kannur	TALIPARAMBA	Alacode	75.465	12.194	0.531
76	Kannur	EDAKKAD	Chakkarakkal	75.475	11.883	0.25

Sr. No	District	Block	Location	Longitude	Latitude	Fe (mg/L)
77	Kannur	TALIPARAMBA	Chapparapadavu	75.414	12.125	0.475
78	Kannur	THALASSERY MUNIC.	Dharmadam	75.481	11.783	0.924
79	Kannur	TALIPARAMBA	Kanapuram	75.308	11.978	0.278
80	Kannur	PERAVOOR	Kannavam	75.675	11.847	1.03
81	Kannur	PERAVOOR	Kottiyur	75.861	11.861	0.278
82	Kannur	PAYYANNUR	Kozhichal	75.451	12.289	0
83	Kannur	THALASSERY MUNIC.	Mahe	75.542	11.711	0.306
84	Kannur	MATTANNUR MUNIC.	Mattannur	75.571	11.917	0.39
85	Kannur	KOOTHUPARAMBA	Mokeri	75.579	11.777	0.306
86	Kannur	IRITTY	Muzhakkunnu	75.683	11.933	0.699
87	Kannur	PAYYANNUR	Payyanaur	75.219	12.111	0.334
88	Kannur	PAYYANNUR	Peringome	75.413	12.292	0.334
89	Kannur	PAYYANNUR	Ramanthali	75.183	12.067	0.615
90	Kannur	IRIKKUR	Sreekandapuram	75.508	12.042	0.503
91	Kannur	THALIPARAMBA MUNIC.	Taliparamba	75.365	12.033	0.362
92	Kannur	THALASSERY MUNIC..	Thalasserry	75.488	11.749	0.278
93	Kannur	IRIKKUR	Ulikkal	75.665	12.033	0.334
94	Kannur	TALIPARAMBA	Valapattanam	75.358	11.925	0.306
95	Kasargod	MANJESHWAR	Anadimegar	75.083	12.647	0.256
96	Kasargod	KASARAGOD	Bandadka	75.247	12.483	0.179
97	Kasargod	KANHANGAD	Bekal	75.039	12.400	0.205
98	Kasargod	NILESHWAR	Chayangode	75.192	12.292	0.438
99	Kasargod	NILESHWAR	Chittarikkal	75.354	12.317	0.464
100	Kasargod	KANHANGAD	Kanhangad Town	75.078	12.326	0.127
101	Kasargod	MANJESHWAR	Kumbala	74.946	12.589	0.153
102	Kasargod	MANJESHWAR	Manjeshwar	74.893	12.724	0.697
103	Kasargod	KASARAGOD	Mulleria	75.167	12.550	2.05

Sr. No	District	Block	Location	Longitude	Latitude	Fe (mg/L)
104	Kasargod	NILESHWAR	Neeleswaram	75.133	12.250	0.593
105	Kasargod	KANHANGAD	Odayanchal	75.211	12.399	0.127
106	Kasargod	KANHANGAD	Panathur	75.311	12.454	0.179
107	Kasargod	KASARAGOD	Parappa N	75.276	12.572	0.308
108	Kasargod	MANJESHWAR	Perla	75.109	12.645	0.049
109	Kasargod	KASARAGOD	Poinachi	75.058	12.467	0.231
110	Kasargod	KASARAGOD	Povval	75.080	12.510	0.127
111	Kasargod	NILESHWAR	Thrikkarippur	75.167	12.147	0.436
112	Kasargod	MANJESHWAR	Uppala	74.907	12.680	11.13
113	Kollam	ANCHAL	AchanKovil	77.125	9.083	0.106
114	Kollam	CHADAYAMANGALAM	Akkal	76.824	8.863	0.52
115	Kollam	ANCHALUMMOOD	Anchalummoodu	76.603	8.928	0.244
116	Kollam	ANCHAL	Ariyankavu	77.147	8.967	0.429
117	Kollam	PATHANAPURAM	Avaneeswaram	76.853	9.036	0.613
118	Kollam	ANCHAL	Ayoor	76.864	8.889	0.382
119	Kollam	KOTTARAKKARA	Chenkulam	76.750	8.875	0.29
120	Kollam	KOLLAM CORPORATION	Iravipuram	76.618	8.856	0.106
121	Kollam	KOLLAM CORPORATION	Kollam	76.635	8.891	0.198
122	Kollam	KOTTARAKKARA	Kottarakara	76.780	9.000	0.198
123	Kollam	KOTTARAKKARA	Kudavettur	76.750	8.940	0.475
124	Kollam	ANCHAL	Kulathupuza	77.056	8.908	0.198
125	Kollam	PATHANAPURAM	Kunnada	76.806	9.103	0.106
126	Kollam	CHADAYAMANGALAM	Madathara	77.008	8.832	0.198
127	Kollam	CHAVARA	Needakara	76.692	8.928	0.382
128	Kollam	ITHIKKARA	Paripalli	76.761	8.810	0.336
129	Kollam	CHITTUMALA	Perinad	76.638	8.947	0.198
Sr.	**District**	**Block**	**Location**	**Longitude**	**Latitude**	**Fe**

Sr. No	District	Block	Location	Longitude	Latitude	Fe (mg/L)
130	Kollam	PARAVOOR MUNICIPALITY	Pozhikara	76.657	8.812	0.613
131	Kollam	PUNALUR MUNICIPALITY	Punalur	76.926	9.017	0.198
132	Kollam	MUKHATHALA	Quilon	76.583	8.890	0.198
133	Kollam	SASTHAMKOTTA	Sasthamkotta	76.619	9.044	0.198
134	Kollam	SASTHAMKOTTA	Sooranadu	76.621	9.100	0.106
135	Kollam	ANCHAL	Thenmala	77.069	8.964	0.152
136	Kollam	OACHIRA	Vallikavu	76.496	9.090	0.198
137	Kollam	ANCHAL	Yeroor	76.957	8.932	0.2
138	Kottayam	KADUTHURUTHY	Aranootimangalam	76.498	9.800	0.127
139	Kottayam	CHANGANASSERY MUNIC.	Changanacherry	76.529	9.445	0.127
140	Kottayam	VAIKOM	Chempu	76.396	9.810	0.705
141	Kottayam	PAMPADY	Cheruthikara	76.608	9.604	0.185
142	Kottayam	MADAPPALLY	Edinjillam	76.558	9.423	6.42
143	Kottayam	KANJIRAPPALLY	Erumelly	76.849	9.481	0.127
144	Kottayam	ETTUMANOOR	Ettumanur	76.572	9.670	0.185
145	Kottayam	KADUTHURUTHY	Kaduthuruthi	76.492	9.761	0.185
146	Kottayam	KANJIRAPPALLY	Kanjirapally	76.762	9.558	0.185
147	Kottayam	KOTTAYAM MUNIC.	Kottayam	76.524	9.593	0.127
148	Kottayam	UZHAVOOR	Kozha	76.567	9.768	0.185
149	Kottayam	PALLOM	Kumarakom	76.438	9.587	0
150	Kottayam	UZHAVOOR	Kuruvilangad	76.553	9.757	0.127
151	Kottayam	ERATTUPETTA	Naranganam	76.739	9.730	0.069
152	Kottayam	ETTUMANOOR	Neendur	76.505	9.687	0.169
153	Kottayam	MADAPPALLY	Paipad	76.575	9.428	0.358
154	Kottayam	PALA MUNIC.	Pala	76.681	9.711	9.025

Sr. No	District	Block	Location	Longitude	Latitude	Fe (mg/L)
155	Kottayam	VAIKOM	Palamkadavu	76.441	9.793	0.994
156	Kottayam	PAMPADY	Pallikathodu	76.684	9.601	0.185
157	Kottayam	PALLOM	Pallom(Nattagam)	76.510	9.531	0.416
158	Kottayam	PAMPADY	Pambadi	76.647	9.563	0.301
159	Kottayam	PALLOM	Paruthumpara	76.543	9.528	0.127
160	Kottayam	VAZHOOR	Plakkalpadi	76.739	9.513	0.069
161	Kottayam	ETTUMANOOR	Pulikuttisseri	76.493	9.626	0.243
162	Kottayam	KADUTHURUTHY	Talayolaparambu	76.437	9.783	0.127
163	Kottayam	MADAPPALLY	Tottakkad	76.606	9.529	0.532
164	Kottayam	VAIKOM MUNIC.	Vaikom	76.393	9.750	1.11
165	Kottayam	VAZHOOR	Vazhur	76.723	9.569	0.105
166	Kottayam	KADUTHURUTHY	Velloor II	76.450	9.830	0.243
167	Kozhikode	Badagara	Badagara	75.585	11.598	0
168	Kozhikode	Balusseri	Balusseri	75.830	11.447	0.095
169	Kozhikode	Kozhikode	Beypore	75.806	11.172	0.443
170	Kozhikode	Kozhikode	Chelavur	75.883	11.299	0
171	Kozhikode	Panthalayini	Chemencheri	75.728	11.408	0.144
172	Kozhikode	Kunnummal	Devarkoil	75.767	11.667	0.045
173	Kozhikode	Kozhikode	Elattur	75.744	11.338	0.095
174	Kozhikode	Balusseri	Kakkayam	75.897	11.550	0.194
175	Kozhikode	Thuneri	Kayapanachi	75.634	11.712	0.194
176	Kozhikode	Koduvalli	Koduvalli	75.893	11.358	0.841
177	Kozhikode	Perambra	Koothali	75.970	11.602	0.095
178	Kozhikode	Kozhikode	Kozhikode	75.792	11.250	0.045
179	Kozhikode	Kunnamangalam	Mavoor II	75.942	11.250	0.194
180	Kozhikode	VADAKARA	Mukkali	75.556	11.671	0.194
181	Kozhikode	THUNERI	Nadapuram	75.667	11.533	0.294

Sr. No	District	Block	Location	Longitude	Latitude	Fe (mg/L)
182	Kozhikode	Perambra	Perambra	75.942	11.438	0.294
183	Kozhikode	Thuneri	Pudukayam	75.731	11.744	0.144
184	Kozhikode	Koduvalli	Pudupadi	75.985	11.497	0.095
185	Kozhikode	Panthalayini	Quilandy	75.694	11.442	0.194
186	Kozhikode	Kozhikode Corporation	Ramanattukara	75.858	11.175	2.582
187	Kozhikode	Koduvally	Thamarasseri	75.941	11.415	0.443
188	Kozhikode	Thodannur	Thiruvallur	75.673	11.591	0.144
189	Kozhikode	Melady	Tikkodi	75.628	11.488	0.493
190	Malappuram	Kuttippuram	Amminikkad	76.017	10.933	0.149
191	Malappuram	AREEKODE	Arikode	76.042	11.233	0.609
192	Malappuram	NILAMBUR	Chokkad	76.333	11.233	0.264
193	Malappuram	Nilambur	Chungathara	76.275	11.333	0.149
194	Malappuram	Ponnani	Edappal	76.017	10.782	0.379
195	Malappuram	Wandoor	Edavanna	76.150	11.208	0.264
196	Malappuram	THIRUR	Iswaramangalam	75.917	10.808	0.609
197	Malappuram	AREEKODE	Kadalundi	76.083	11.138	0.494
198	Malappuram	NILAMBUR	Kalikavu	76.321	11.169	0.724
199	Malappuram	ANDATHODE	Kanjiramukku	75.967	10.761	4.17
200	Malappuram	Perinthalmana	Kariavattom	76.230	10.980	0.149
201	Malappuram	NILAMBUR	Karulai	76.328	11.283	0.034
202	Malappuram	KONDOTTY	Kondotty	75.963	11.147	0.264
203	Malappuram	TANUR	Kottakkal	75.983	10.971	0.264
204	Malappuram	MANKADA	Kuruva	76.110	10.976	0.494
205	Malappuram	KUTTIPPURAM	Kuttipuram	76.031	10.846	0.379
206	Malappuram	MANKADA	Malappuram	76.091	11.035	0.379
207	Malappuram	THIRUR	Mangalam	75.917	10.850	0.839
208	Malappuram	MANJERI MUNICI.	Manjeri	76.121	11.118	5.5

Sr. No	District	Block	Location	Longitude	Latitude	Fe (mg/L)
209	Malappuram	Nilambur	Maruda	76.325	11.417	0.724
210	Malappuram	PERINTHALMANNA	Melattur	76.267	11.033	0.034
211	Malappuram	Nilambur	Nilambur	76.223	11.276	0.264
212	Malappuram	TIRURANGADY	Parappanangadi	75.860	11.047	0
213	Malappuram	ANDATHODE	Perumpadappu	75.989	10.703	0.149
214	Malappuram	PonnaniMunic.	Ponnani	75.921	10.782	0.839
215	Malappuram	MANKADA	Pulamanthol	76.186	10.906	0.034
216	Malappuram	TANUR	Tanur	75.875	10.983	0.264
217	Malappuram	THIRUR	Thirunavaya	75.985	10.867	0.264
218	Malappuram	Wandoor	Thuvur	76.285	11.110	0.609
219	Malappuram	THIRUR MUNICI.	Tirur	75.921	10.910	0.264
220	Malappuram	Kuttippuram	Valancheri	76.074	10.895	0.149
221	Malappuram	Tanur	Vazhikadavu	76.349	11.389	0.494
222	Malappuram	PonnaniMunic.	Vylattur	75.944	10.786	0.379
223	Palakkad	Attapadi	Agali	76.746	11.118	0.733
224	Palakkad	ALATHUR	Alathur	76.542	10.650	0.76
225	Palakkad	ALATHUR	Athipetta	76.478	10.672	0.143
226	Palakkad	Attapadi	Chavadiyur	76.667	11.158	0.413
227	Palakkad	Sreekrishnapuram	Cherpulassery	76.325	10.875	0.413
228	Palakkad	THODUPUZHA	Chittoor	76.742	10.700	9
229	Palakkad	Malampuzha	Chullimada	76.777	10.801	1.16
230	Palakkad	Chittur	Gopalapuram	76.869	10.686	0.627
231	Palakkad	MANNARKKAD	Kalladikode	76.533	10.896	0.787
232	Palakkad	MALAMPUZHA	Kanjikode	76.750	10.794	0.44
233	Palakkad	SREEKRISHNAPURAM	Karimpuzha	76.400	10.904	0.573
234	Palakkad	Kollengode	Kollengode	76.640	10.670	0.52
235	Palakkad	Pattambi	Koppam	76.188	10.861	0.33

Sr. No	**District**	**Block**	**Location**	**Longitude**	**Latitude**	**Fe (mg/L)**
236	Palakkad	Chittur	Kozhinjampara	76.850	10.733	0.44
237	Palakkad	Kuzhalmannom	Kozhippara	76.869	10.686	0.413
238	Palakkad	OTTAPPALAM	Mankara	76.475	10.775	0.147
239	Palakkad	Mannarkkad	Mannarghat	76.489	10.994	0.413
240	Palakkad	CHITTUR	Meenakshipuram	76.863	10.638	0.413
241	Palakkad	KOLLENGODE	Meenkara	76.750	10.608	0.413
242	Palakkad	PALAKKAD	Mundur	76.581	10.836	0.44
243	Palakkad	Chittur	Nadupuni	76.877	10.729	0.627
244	Palakkad	Nemmara	Nenmara	76.600	10.594	0.6
245	Palakkad	OTTAPPALAM	Ottapalam	76.425	10.767	0.547
246	Palakkad	CHITTUR	Palghat	76.772	10.661	0.68
247	Palakkad	Attapadi	Tavalam	76.587	11.067	0.52
248	Palakkad	Thrithala	Trithala	76.133	10.800	0.387
249	Pathanamthita	Parakode	Angadikkal	76.800	9.217	0.786
250	Pathanamthita	Pandalam	Aranmula	76.840	9.330	0.786
251	Pathanamthita	Parakode	Enathu	76.75	9.08	0.786
252	Pathanamthita	Mallappally	Kaviyur	76.600	9.400	0.786
253	Pathanamthita	Konni	Konni	76.850	9.230	0.786
254	Pathanamthita	Mallappally	Mullapally	76.647	9.453	0.786
255	Pathanamthita	Pulikeezh	Muthoor	76.550	9.410	0.071
256	Pathanamthita	Konni	Naduvathumuzhi	76.920	9.200	0.071
257	Pathanamthita	Pandalam	Pandalam	76.707	9.238	0.071
258	Pathanamthita	Konni	Pathanamthitta	76.790	9.260	0.786
259	Pathanamthita	Pulikeezh	Peringara	76.533	9.400	0.07
260	Pathanamthita	Pulikeezh	Pulikeezh	76.550	9.350	0.786
261	Pathanamthita	Ranni	Ranni Peruned	76.856	9.367	0.07
262	Pathanamthita	Koipuram	Thelliyur	76.690	9.390	0.786

Sr. No	District	Block	Location	Longitude	Latitude	Fe (mg/L)
263	Pathanamthita	KULANADA	Ullannur	76.688	9.275	0.786
264	Pathanamthita	Ranni	Vadasserikkara	76.840	9.340	0.071
265	Thrissur	PUZHACKAL	Adatt	76.142	10.533	0.29
266	Thrissur	MALA	Annamanada	76.327	10.238	0.29
267	Thrissur	CHALAKUDY MUNIC.	Chalakudy	76.333	10.292	0.398
268	Thrissur	CHAVAKKAD MUNIC.	Chavakkad	76.024	10.583	0
269	Thrissur	Pazhayannur	Chelakkara	76.342	10.694	0.29
270	Thrissur	CHERPU	Cherpu	76.208	10.436	10.5
271	Thrissur	Pazhayannur	Cheruthuruthi	76.294	10.742	0.724
272	Thrissur	KODAKARA	Echipara	76.407	10.433	0.398
273	Thrissur	Thalikulam	Engandiyur	76.061	10.497	0
274	Thrissur	Kodungallur	Eriyad	76.165	10.206	0.505
275	Thrissur	CHOWWANNUR	Guruvayur	76.067	10.608	1.9
276	Thrissur	Vellangallur	Irinjalakkuda	76.192	10.333	0.505
277	Thrissur	CHOWWANNUR	Kallumpuram	76.099	10.708	0.075
278	Thrissur	CHALAKUDY	Kallur	76.500	10.333	1.04
279	Thrissur	Puzhackal	Kecheri	76.117	10.600	0.183
280	Thrissur	KodungallurMunic.	Kodungalloor	76.197	10.231	0.073
281	Thrissur	WADAKKANCHERY	Kundannur	76.203	10.678	0.29
282	Thrissur	MALA	Mala	76.264	10.242	0.505
283	Thrissur	THALIKULAM	Manalur	76.067	10.469	0.183
284	Thrissur	OLLUKKARA	Manamangalam	76.341	10.498	0.29
285	Thrissur	OLLUKKARA	Mulankunnathukavu	76.215	10.585	0.183
286	Thrissur	Irinjalakkuda	Muriyad	76.264	10.358	0.398
287	Thrissur	Ollukkara	Pattikkad	76.292	10.554	0.29
288	Thrissur	Mathilakam	Perinjanam	76.148	10.313	0.398
289	Thrissur	CHAVAKKAD	Punnayoor	75.992	10.675	0.398

No						**(mg/L)**
290	Thrissur	Vellangallur	Thekkumkara(Konathukunnu)	76.212	10.274	0.398
291	Thrissur	THRISSUR CORP.	Trichur	76.217	10.517	20.5
292	Thrissur	THALIKULAM	Triprayar	76.113	10.413	0.935
293	Thrissur	WADAKKANCHERY	Wadakkancherry	76.250	10.667	1.04
294	Trivandrum	ATTINGAL MUNIC.	Attingal	76.817	8.697	0.127
295	Trivandrum	NEYYATINKARA MUNIC.	Balaramapuram	77.046	8.423	0.205
296	Trivandrum	VAMANAPURAM	Chembur	76.876	8.683	0.282
297	Trivandrum	CHIRAYINKEEZHU	Chirayinkil	76.789	8.658	0.282
298	Trivandrum	ATHIYANNUR	Chittagode	77.075	8.369	0.153
299	Trivandrum	VARKALA	Edava	76.697	8.761	0.153
300	Trivandrum	CHIRAYINKEEZHU	Kadakkavur	76.771	8.679	0.231
301	Trivandrum	VAMANAPURAM	Kallar	77.131	8.708	0.256
302	Trivandrum	PERUMKADAVILA	Kallikkad	77.125	8.531	0.205
303	Trivandrum	VELLANAD	Kattakada	77.083	8.507	0.205
304	Trivandrum	KAZHAKKOOTTAM	Kazhakuttam	76.871	8.571	0.386
305	Trivandrum	ATHIYANNUR	Kulathur	77.108	8.319	0.386
306	Trivandrum	NEDUMANGAD	Mannanthala	76.950	8.569	0.231
307	Trivandrum	VELLANAD	Nedumangad	77.010	8.610	0.36
308	Trivandrum	NEYYATINKARA MUNIC.	Neyyattinkara	77.081	8.411	0.153
309	Trivandrum	VAMANAPURAM	Palode	77.032	8.721	0.179
310	Trivandrum	VAMANAPURAM	Pangode	76.969	8.765	0.412
311	Trivandrum	CHIRAYINKEEZHU	Perumkuzhi	76.813	8.629	0.231
312	Trivandrum	TVM CORPORATION	Trivandrum	76.964	8.503	6
313	Trivandrum	VAMANAPURAM	Vamanapuram	76.900	8.719	0.205
314	Trivandrum	VARKALA MUNIC.	Varkala	76.717	8.731	0.308
315	Trivandrum	PERUMKADAVILA	Vellarada1	77.200	8.440	0.308
316	Trivandrum	VELLANAD	Vidura	77.085	8.669	0.308
Sr.	**District**	**Block**	**Location**	**Longitude**	**Latitude**	**Fe**

No						(mg/L)
317	Wayanad	Sulthans' Bathery	Ambalavayal	76.213	11.618	0.2
318	Wayanad	Sulthans' Bathery	Chenad	76.244	11.735	0.152
319	Wayanad	Panamaram	Kamblakat	76.074	11.678	0.198
320	Wayanad	Mannanthody	Koroth	75.880	11.744	0.152
321	Wayanad	Sulthans' Bathery	Minangadi	76.163	11.660	0.198
322	Wayanad	Sulthans' Bathery	Noolpuzha	76.345	11.603	2.825
323	Wayanad	Panamaram	Perikallur	76.150	11.861	0.382
324	Wayanad	Panamaram	Pulpally	76.166	11.785	0.152
325	Wayanad	Kalpetta	Vaduvanchal	76.224	11.556	0
326	Wayanad	Mannanthody	Valatt	75.907	11.795	0.194

Annexure-VII

Summarized results of groundwater quality in Kerala State

#	Longitude	Latitude	District	Block	Location	pH	EC in micro Siemens at 25C	CO3	HCO3	Cl	F	SO4	NO3	Total Hardness	Ca	Mg	Na	K
								<……Values in mg/l……>										
1	76.3300	9.4900	Alappuzha	Aryad	Alleppey	7.78	280	0	162	4.8	0.2	9	1.1	125	46.8	2.1	5.3	1.9
2	76.5800	9.2300	Alappuzha	Mavelikara	Aranootimangalam	4.5	128	0	0	13.0	0.2	1.8	18.7	21	6.2	1.4	6.8	6
3	76.3200	9.8500	Alappuzha	Thykattussery	Arukutti	7.84	340	0	148.6	10.50	0.20	26.1	1.6	140	53	1.8	6.4	2.1
4	76.3000	9.8300	Alappuzha	Pattanakkad	Chandirur	8.04	260	0	123	9.5	0.10	3.7	1	101	36.4	2.4	7.4	4.8
5	76.5200	9.2500	Alappuzha	Mavelikara	Chettikulangara	7.98	280	0	58.1	12.0	0.10	41.7	1.7	90	31.6	2.8	11.5	4.8
6	76.4700	9.3700	Alappuzha	Veliyanad	Edathua1	8.02	590	0	168	40.4	0.30	37.2	8.6	137	39.1	9.7	37.6	8.4
7	76.4600	9.2900	Alappuzha	Haripad	Haripad	8.1	300	0	142	5.0	0.30	28	1.7	108	37.4	3.6	12.4	5.8
8	76.3200	9.5600	Alappuzha	Aryad	Kattoor1	7.9	118	0	58	2.10	0.10	3.30	0.6	47	17.8	0.6	2.6	1.3
9	76.6700	9.1900	Alappuzha	Bharanikavu	Kudasanad	7.89	115	0	25.8	6.7	0.0	6.8	7.6	27	7.6	1.9	8.3	2.6
10	76.3800	9.4300	Alappuzha	Champakulam	Nedumudi(pupalli)	8.22	590	0	233	40.0	0.2	8	2.6	165	42	14.6	41	4.9
11	76.5400	9.2000	Alappuzha	Mavelikara	Pallarimangalam	7.97	520	0	58	24.5	0.0	14.5	125	165	57	5.6	19	3
12	76.2900	9.7300	Alappuzha	Pattanakkad	Pattanakad	8.54	500	12	180	8.20	0.2	55	3	194	72	3.5	13	11.3
13	76.3700	9.3500	Alappuzha	Ambalapuzha	Purakkad1	8.35	1100	24	123	139.00	0.0	66	32.2	277	93	11	80	12
14	76.4800	9.4200	Alappuzha	Champakulam	Ramankari-R1	8.21	490	0	162	39.00	0.20	14.1	1.6	137	42	7.9	34	4.8
15	76.48333	9.25	Alappuzha	Champakulam	Thakazhi	8.34	740	24	149	40.00	0.20	117	1.6	228	66.5	15	43	6
16	76.5400	9.2300	Alappuzha	Haripad	Thevery	8.25	300	0	96.9	12.4	0.1	27.1	0.4	106	27	9.3	16.1	4.4
17	76.3300	9.6000	Alappuzha	Kanjikuzhi	Valavanad	7.93	220	0	64.6	15	0	12	4.7	65	20.2	3.5	12.7	6.5
18	76.38	9.66	Alappuzha	Chengannur	Thannirmukkom	8.36	410	18	130	14	0.1	16.1	2.9	143	50	4.5	20.7	5.4
19	76.4278	10.0153	Ernakulam	Vadavucode	Aikaranad	7.57	30	0	7.7	4.5	0.1	2.2	4.4	11.4	3.4	0.7	4.4	1.1
20	76.3561	10.1117	Ernakulam	Vazhakulam	Aluva	7.33	121	0	7.7	11.4	0	16.1	8.6	201	6.4	1	8.4	10
21	76.5	9.9139	Ernakulam	Pampakuda	Anchalpetty	7.28	88	0	18.2	10.1	0	6.4	8.2	25.6	8.3	1.2	7.5	2.2
22	76.3875	10.1903	Ernakulam	Angamali	Angamali	7.16	44	0	18.1	3.6	0.1	1.6	1.7	18.2	5.5	1.1	3	1.2
23	76.2847	9.8069	Ernakulam	Palluruthy	Chellanum	7.95	2500	0	480	724	0.2	11.8	24.6	542	148	42	366	25.4
24	76.3394	10.1528	Ernakulam	Parakadav	Chengamanad	8.16	72	0	15.6	12.2	0.1	1	8.2	19	5.3	1.4	8.3	2
25	76.4708	10.2486	Ernakulam	Angamali	Chulli	7.83	56	0	15.6	5.8	0.0	1	7.1	21.1	5.8	1.6	5.1	0.9

26	76.3075	10.0222	Ernakulam	Kochi Corporation	Edapally	7.85	555	0	208	73	0.7	16.9	4.4	190	67	5.5	50.8	7.1
27	76.2083	10.0917	Ernakulam	Vypin	Edavanakkad	7.91	250	0	130	13.6	0.1	4.6	3.1	116	42	2.7	9.5	3.8
28	76.2464	9.95	Ernakulam	Kochi Corporation	Fort Cochin	7.84	390	0	188	18.6	0.2	20.4	12	168	60.6	4.1	16.8	3.7
29	76.55	9.8833	Ernakulam	Angamali	Karukutty	8.07	124	0	15	14.2	0.1	4.8	20.1	36	9.5	2.9	12	3.3
30	76.575	9.8667	Ernakulam	Pampakuda	Koothattukulam	7.85	400	0	39	32.2	0.1	10.5	104	92	27	6.1	25	31
31	76.6281	10.0672	Ernakulam	Kothamangalam	Kothamangalam	7.83	175	0	45.4	10.1	0.0	16.6	24.3	62	19.9	3	11	4.3
32	76.5986	10.1306	Ernakulam	Kothamangalam	Kottapadi	7.85	108	0	33.7	7.6	0.2	5.1	9	44	13	2.7	2.7	0.8
33	76.3	10.1278	Ernakulam	Alangad	Kottapuram	7.71	147	0	32.5	11.0	0.6	17.0	7.1	42	12.1	2.8	12.5	5.4
34	76.2911	9.8631	Ernakulam	Palluruthy	Kumbalangi	7.88	800	0	363	65	0.1	31.8	21	291	100	10	58	22
35	76.5333	10.1833	Ernakulam	Angamali	Malayattur	7.99	115	0	31.1	7.3	0.0	9.6	7.7	41	10	3.8	7.1	4
36	76.225	10.0222	Ernakulam	Vypin	Malipuram	8.01	410	0	195	32	0.1	5.7	13	176	63.5	4.3	23	5
37	76.3917	9.8917	Ernakulam	Mulanthuruthi	Mulanthuruthi	8.18	130	0	10.4	17	0.0	5.8	19.5	36	12.7	1	12.1	1.9
38	76.1722	10.1722	Ernakulam	Vypin	Munambam	7.99	290	0	162	12	0.2	9.5	1	136	51.2	2.1	10.5	1.6
39	76.5792	9.9847	Ernakulam	Muvattupuzha	Muvattupuzha	6.24	184	0	44	7	0.0	31.5	11.1	72	22.6	3.8	6.8	6.6
40	76.7736	10.0556	Ernakulam	Kothamangalam	Neriamangalam	6.46	89	0	10.4	13.7	0.0	8.4	5.7	27	8.2	1.5	8.6	2
41	76.2167	10.1833	Ernakulam	Paravur	North Paravur	7.35	430	0	156	26.7	0.0	26.1	33.6	190	70.5	3.5	18.2	4.8
42	76.5083	9.9417	Ernakulam	Pampakuda	Perumbadavam	7.66	42	0	7.8	5.3	0.0	3.7	5.1	16	4.9	1	3.9	0.6
43	76.7083	10.0056	Ernakulam	Kothamangalam	Pothanikad	7.43	165	0	39	12.5	0.0	7.1	22.6	55	16.3	3.4	9.3	7
44	76.3431	9.9431	Ernakulam	Tripunithura	Tripunithura	7.9	630	0	240	47	0.1	33.7	34.4	243	89	5	38	15.8
45	76.45611	10.12028	Ernakulam	Koovapady	Vallom	8.25	107	0	15.6	14.5	0.0	4.3	9.8	24	6.3	2	12.4	3.6
46	76.2556	10.0772	Ernakulam	Alangad	Varapuzha	7.83	198	0	71.2	9.7	0.0	19	8	79	27.8	2.3	10	4.6
47	76.96	10.013	Idukki	Adimaly	Adimali	6.3	119	0	15.5	10.6	0.139	5.3	11.4	23.6	7.3	1.3	10.1	1.7
48	76.841336	9.892156	Idukki	Elamdesom	Chinikuzhy	7.13	111	0	56.9	3.2	0.024	5.1	2.9	40.1	12.6	2.1	5.8	1.7
49	76.676222	9.910075	Idukki	Thodupuzha	Chittur	7.1	51	0	20.6	3.10	0.106	1.1	15.2	18.0	4.1	1.9	4.7	1.2
50	76.979281	9.632397	Idukki	Azhutha	Elappara	6.95	169	0	20.6	10.6	0.027	4.9	23.7	40.0	12.4	2.2	8.6	4.5
51	77.104779	9.797752	Idukki	Kattappana	Erattayar	7.17	370	0	36.2	23.8	0.187	15.8	56	43.8	11.8	3.5	42.9	4.4
52	76.980969	9.847094	Idukki	Idukki	Idukki	7.14	95	0	31	6.6	0.173	1.9	3.6	29.2	7.9	2.3	6.4	1.7
53	76.781797	9.975083	Idukki	Elamdesom	Kaliyar	7.19	184	0	36.2	13.4	0.153	8.6	19.4	48.0	13.3	3.6	12	4.9

54	77.116339	9.755036	Idukki	Kattappana	Kattappana	3.14	620	0	0	40.90	0.143	23.9	92.7	85.8	24	6.3	38.7	14.8
55	77.17	10.24	Idukki	Nedumkandam	Koilkadavu	8.09	410	0	98.2	16.00	0.588	19.30	54.5	123.2	33.9	9.4	26.1	8.2
56	76.892556	9.793447	Idukki	Idukki	Kulamavu	7.65	186	0	31	14.4	0.26	1.9	50.5	51.0	14.5	3.6	12.9	4
57	76.708167	9.935989	Idukki	Thodupuzha	Kumaramangalam	7.5	103	0	31	6.3	0.179	5.7	11.6	35.6	10.8	2.1	7	2
58	77.157114	9.612086	Idukki	Azhutha	Kumily	8.35	340	5	129.3	19.0	1.315	15.2	5.8	128.2	32.1	11.7	22.7	6
59	76.970428	9.580075	Idukki	Azhutha	Kuttikkanam1	7.87	240	0	20.6	19.0	0.314	5.8	40.5	49.5	14.4	3.3	19	4.5
60	76.845264	9.798525	Idukki	Idukki	Molamattam	7.7	103	0	46.5	4.6	0.166	6.1	8.8	41.2	12.9	2.2	6.3	1.4
61	77.067183	10.08745	Idukki	Devikulam	Munnar	7.64	105	0	31	9.40	0.149	3	5.7	34.3	10.6	1.9	7.4	3
62	77.160594	9.836814	Idukki	Nedumkandam	Nedumkandam	8.4	530	10.1	129.3	34.30	0.979	20.1	34	180.5	60	7.5	32.5	9.9
63	77.198925	9.976856	Idukki	Devikulam	Pooppara	8.35	480	5	124.1	32.10	0.076	22.4	20.7	142.9	38.5	11.4	31.8	15
64	77.156617	9.719158	Idukki	Kattappana	Vandanmedu	8	191	0	51.7	16.20	0.248	6.4	21.6	57.1	17.3	3.4	13.5	4.8
65	77.090319	9.572497	Idukki	Azhutha	Vandiperiyar	7.79	640	0	62	73.90	0	36.1	59.4	119.5	31.4	10	55.2	43
66	77.050425	9.712858	Idukki	Kattappana	Vellilamkandam	7.66	84	0	20.6	12.4	0.046	5	10.5	27.3	7.3	2.2	11.7	4.8
67	75.3725	11.8764	Kannur	Kannur	Kannur DW	6.7	250	0	43.3	18.5	0.048	34.5	22.6	89.6	29.3	4	16.2	7.4
68	75.4703	11.8909	Kannur	Kannur	Chakkarakkal	6.2	178	0	16.2	35.8	0.089	13.9	15.2	48.3	14.9	2.7	24.1	6
69	75.4635	11.7776	Kannur	Thalassery	Dharmadom	6.3	131	0	48.7	15.7	0.029	5.4	0.9	49.7	17.1	1.7	14.1	1.4
70	75.3169	11.9794	Kannur	Taliparamba	Kannapuram	7.48	240	0	146.2	7.2	0.053	9.7	5.1	129.3	48.2	2.2	7.8	4.6
71	75.6597	11.8450	Kannur	Koothuparamba	Kannavam	6.1	54	0	21.6	6	0.023	0.7	3.7	15.8	4.2	1.3	5.7	0.7
72	75.5649	11.8279	Kannur	Koothuparamba	Koothuparamba	6.4	330	0	27	42.9	0.094	14	69.6	92.8	24	8	28.1	10.4
73	75.8587	11.8760	Kannur	Peravoor	KottiyurPhc	6.75	79	0	43.3	5	0.059	3.2	3.2	36.8	9.3	3.3	6	0.7
74	75.4501	12.2917	Kannur	Payyannur	kozhichal	6.64	60	0	37.9	5.6	0.083	0.35	0.29	31.2	7.4	3.1	3.9	0.9
75	75.54167	11.71111	Kannur	Thalassery	Mahe	8.38	630	10.1	217.2	26.3	0.073	22.1	1.7	220.4	66.4	13.3	26.5	7.5
76	75.57083	11.91667	Kannur	Mattannur	Mattannur	5.66	138	0	16.2	19.1	0.044	0.9	29.1	40.5	10.8	3.3	12.1	6.2
77	75.5791	11.7772	Kannur	Panur	Mokeri	4.24	189	0	10.3	27.5	0.062	0.7	43	21.9	5.3	2.1	36.7	1.1
78	75.7033	11.9453	Kannur	Peravoor	MuzhakkunnuDw	6.35	113	0	48.7	13.7	0.076	3.2	2.9	40.2	10.5	3.4	12.1	2.1
79	75.21944	12.11056	Kannur	Payyanur	Payyanur	6.4	101	0	21.6	10.2	0	4.2	21.6	34.4	10.5	2	9	2.2
80	75.4125	12.29167	Kannur	Payyannur	Peringome	6.3	160	0	32.4	15.4	0	5.4	32.2	52.2	15.3	3.4	13.8	5.4

81	75.5085	12.0452	Kannur	Irikkur	Sreekandapuram	3.38	380	0	0	54	0.046	11.1	83.2	94.9	28.3	5.9	32.5	6.5
82	75.4858	11.7520	Kannur	Thalasserry	Thalasserry	7.8	360	0	167.8	25	0.067	22.3	18.8	127.0	43	4.8	24.4	12.4
83	75.3598	12.0374	Kannur	Taliparamba	Taliparamba	7.55	172	0	37.9	17.3	0	6.4	30	60.2	20	2.5	12.9	6.5
84	75.6651	12.0376	Kannur	Irikkur	Ullikkal	7.43	56	0	27	5.8	0.024	0.9	6.3	21.1	5	2.1	5.4	0.6
85	75.08333	12.64722	Kasargode	Manjeshwar	Angadimogar	6.86	80	0	36.2	9.5	0.066	1.9	1	27.8	7.7	2.1	8	1
86	75.24722	12.48333	Kasargode	Kasaragod	Bandadka	7.82	220	0	134.5	7.7	0	11.7	1.8	122.2	22.6	16	9.5	2.7
87	75.0311	12.4004	Kasargode	Kanhangad	Bekal	3.78	210	0	0	34.8	0.05	1.8	45.6	49.7	11.5	5.1	22.5	5
88	75.1911	12.2867	Kasargode	Nileshwar	Choyankode	7.76	78	0	10.3	13	0.158	1.6	15.9	21.3	6.9	1	12	1.4
89	75.3568	12.3252	Kasargode	Nileshwar	Chittarikkal	6.88	58	0	31	3.7	0.114	1	5.6	25.9	5.1	3.2	4.4	0.5
90	75.07778	12.32583	Kasargode	Kanhangad	Kanhangad TOWN	7.45	149	0	10.3	25	0.065	1	35	35.1	9.3	2.9	15.7	2.7
91	74.9875	12.5010	Kasargode	Kanhangad	Kasaragod-DW	6.78	135	0	5.2	28.4	0.349	6.4	16.2	34.6	9.9	2.4	14.4	3
92	74.9450	12.5896	Kasargode	Manjeshwar	Kumbala-dw	7.5	196	0	108.6	14.9	0.196	5.9	4.6	97.6	27.9	6.8	15	3.3
93	74.8855	12.7250	Kasargode	Manjeshwar	Manjeswaram-DW	7.96	350	0	129.3	47.4	0.119	6.6	0.2	137.6	23	19.5	25.5	5.9
94	75.1000	12.5600	Kasargode		Mavinkatta	8.08	133	0	93	4	0.269	3.4	0.6	59.6	12.7	6.8	11.8	3.3
95	75.1651	12.5489	Kasargode	Kardka	Mulleria	6.67	72	0	15.5	9.2	0.008	2	12	24.5	6.7	1.9	6.4	3.1
96	75.1341	12.2471	Kasargode	Nileshwar	Neeleswaram	7.36	164	0	46.5	17.7	0.042	3.1	21.2	62.8	20.9	2.6	4.5	9.7
97	75.2050	12.4020	Kasargode	Kanhangad	Odayanchal	7.34	58	0	31	5.9	0.066	1.5	2.3	22.9	5.9	2	5.6	1
98	74.9843	12.6863	Kasargode	Manjeshwar	Paivalige	7.32	121	0	46.5	16	0.044	5.1	1.6	37.3	12	1.8	13.7	3.4
99	75.31111	12.45417	Kasargode	Kanhangad	Panathur-Panathady	8.3	220	10.1	129.3	9	0.157	2.9	0.6	122.8	21.7	16.7	11.4	2.5
100	75.2823	12.5715	Kasargode	Kasaragod	Parappa N	7.62	58	0	31	5.8	0.162	1.1	0.9	26.5	6	2.8	5.5	1.5
101	75.1088	12.6451	Kasargode	Manjeshwar	Perla	7.31	152	0	41.3	18.7	0.027	4	18.2	46.2	15.4	1.9	13.2	4.1
102	75.0587	12.4645	Kasargode	Kasaragod	Poinachi	7.36	86	0	31	9.7	0.022	3.7	9.5	32.3	10.3	1.6	8.3	2.4
103	75.0800	12.5098	Kasargode	Kasaragod	Povval	7.29	148	0	41.3	14.3	0.027	2.7	21.7	51.2	17.4	1.9	13.1	2.1
104	75.0952	12.3552	Kasargode	Kanhangad	Pullur	7.48	55	0	25.8	7.7	0.012	1.4	3.2	16.9	4.8	1.2	6.4	1.6
105	75.1777	12.1430	Kasargode	Nileshwar	Thrikkarippur	7.26	33	0	15.5	5.3	0.013	3	0.5	14.1	4	1	4.3	1
106	74.9046	12.6803	Kasargode	Manjeshwar	Uppala	7.46	172	0	77.5	17.8	0.096	1.2	7.8	65.6	21	3.2	13	2.6

107	77.125	9.08333	Kollam	Anchal	Achenkovil	7.3	248	0	81.2	17.6	0.31	21.1	1.9	68.2	17.1	6.2	21.5	17.3
108	77.15	8.97	Kollam	Anchal	Ariyankavu	6.95	124	0	54.16	13.7	0.21	2.3	0.4	39.7	9.5	3.9	14.5	2.1
109	76.8528	9.0361	Kollam	Pathanapuram	Avaneeswaram	6.6	113	0	37.9	19.2	0.14	1.4	0.3	28.5	8.8	1.6	12.8	4.1
110	76.8639	8.8889	Kollam	Anchal	Ayur	6.86	64	0	43.3	3.5	0.068	1.6	0.5	23.5	7.6	1.1	5.4	2.6
111	76.6181	8.8556	Kollam	Kollam Corporation	Iravipuram	7.5	338	0	135.4	31.5	0.21	29	4.5	137.8	48.3	4.2	28.8	7.8
112	76.775	8.9972	Kollam	Kottarakkara Municipality	Kottarakkara	7.32	186	0	32.4	39.6	0.05	3	14.6	35.0	9.4	2.8	26.4	5.2
113	77.0556	8.9083	Kollam	Anchal	Kulathupuzha	7.23	226	0	81.21	39.5	0.032	8	0.8	32.8	9.2	2.4	30.6	9.1
114	76.8061	9.10306	Kollam	Pathanapuram	Kunnada	7.27	63	0	10.8	12.9	0.11	0.8	0.4	8.3	2.5	0.5	9.6	3.2
115	76.75	8.9403	Kollam	Kottarakkara	Kudavettur	6.87	248	0	16.2	31.4	0.2	4.1	63.2	71.9	18.1	6.5	25.8	5.9
116	76.69167	8.927778	Kollam	Chavara	Needakara	7.7	496	0	281	30.3	0.1	14.8	2.3	246.8	85.4	8.2	25	2.5
117	76.6375	8.9472	Kollam	Chittumala	Perinad	4.23	142	0	10.8	29.9	0.048	10.2	0.7	19.3	6.1	1	20.1	1.1
118	76.6569	8.8119	Kollam	ParavorrMunicipality	Pozhikkara	6.87	304	0	54.1	44.1	0.061	36.4	2.1	91.0	21.3	9.2	35.1	1.7
119	76.9056	9.0361	Kollam	Punalur Municipality	Punalur	7.43	206	0	124.5	11.3	0.13	7	2.3	96.7	31.5	4.4	20.2	5
120	76.5833	8.89	Kollam	Kollam Corporation	Quilon	7.32	108	0	43.3	17.2	0.022	4.8	0.8	45.6	14.8	2.1	11.2	1.8
121	77.0694	8.9639	Kollam	Anchal	Thenmala	6.25	66	0	32.4	6	0.089	1.8	0.5	24.6	7.4	1.5	4.8	1.6
122	76.54	9.01	Kollam		Vadakkumthalawest	7.17	126	0	43.3	11.5	0.032	14.7	1	50.2	16.5	2.2	8.8	1.9
123	76.4958	9.0903	Kollam	Ochira	Vallikavu	7.62	215	0	113.7	12.9	0.089	10	1.5	108.7	39.1	2.7	17.9	1.6
124	76.9569	8.9322	Kollam	Anchal	Yeroor	8.41	372	5	198.5	33.7	0.088	25.3	4.1	131.6	40.7	7.3	45.7	6.4
125	76.4981	9.80083	Kottayam	Kaduthuruthy	Aranootimangalam	5.8	65	0	15.5	7	0.043	1.5	9.2	18.0	4.4	1.7	5.8	1.8
126	76.5294	9.44528	Kottayam	Changanassery Municipality	Changanacherry	6.59	330	0	41.4	43.1	0.61	38.5	40.5	86.2	25.3	5.6	32.7	17
127	76.3961	9.81028	Kottayam	Vaikom	Chempu	7.43	151	0	87.9	6.7	0.15	18.1	2.2	86.5	30.2	2.7	7.1	2.6
128	76.6083	9.60417	Kottayam	Pampady	Cheruthikara	7.2	79	0	31	9.1	0.16	4.5	3	28.5	8.3	1.9	7.3	3.3
129	76.85	9.48	Kottayam	Kanjirapara	Erumelly	7.08	92	0	25.8	18.6	0.02	4.5	13.80	39.1	9.4	3.8	14.5	2
130	76.4922	9.76139	Kottayam	Kaduthuruthy	Kaduthuruthi	7.06	128	0	36.2	12.7	0.05	9.2	14.5	48.9	15.8	2.3	12.2	3.3
131	76.7617	9.55889	Kottayam	Kanjirappally	Kanjirapally	7.11	70	0	41.4	3.1	0.017	6.8	4.2	36.5	13	1	3.2	1
132	76.5236	9.59333	Kottayam	Kottayam Municipality	Kottayam	6.96	51	0	10.3	7	0.03	3.6	7.6	17.6	5.4	1	6	1
133	76.5667	9.76806	Kottayam	Uzhavoor	Kozha	6.79	73	0	20.6	7.7	0.1	4.7	14.4	23.8	6.4	1.9	7.1	2.9
134	76.4375	9.58694	Kottayam	Pallom	Kumarakom	8.3	380	15.2	232.7	15.2	0.1	12.2	2.2	232.7	86	4.4	11.4	4.7

135	76.88	9.57	Kottayam	Kanjirapara	Kuttikal	7.57	49	0	20.6	3.2	0.01	2.7	5.6	23.6	7.3	1.3	3.2	2.2
136	76.7389	9.72972	Kottayam	Erattupetta	Naranganam	7.03	38	0	20.6	3.8	0.11	1	4.4	14.8	4.3	1	3.9	1.4
137	76.505	9.68667	Kottayam	Ettumanoor	Neendur	6.68	119	0	10.3	19.2	0.04	4.3	14.8	26.9	7.8	1.8	13.6	6.1
138	76.575	9.42778	Kottayam	Madappally	Paipad	6.4	260	0	15.5	30.6	0.03	18.4	64.9	65.5	21.3	3	23.8	12.6
139	76.6806	9.71111	Kottayam	Pala Municipality	Pala	6.86	102	0	41.4	8.8	0.04	7.3	13.9	52.9	15.6	3.4	7.8	3
140	76.4411	9.7925	Kottayam	Vaikom	Palamkadavu	7.44	155	0	93	12.7	0.21	6.7	0.2	82.8	21.5	7.1	13.2	1.8
141	76.5097	9.53056	Kottayam	Pallom	Pallom(Nattagam)	7.22	133	0	36.2	9.4	0.032	17.8	8.2	48.1	16.3	1.8	10.8	3.3
142	76.6472	9.5625	Kottayam	Pampady	Pambadi	7.16	76	0	41.3	4.5	0.021	6.1	2.9	38.1	13.3	1.2	4	1
143	76.5431	9.52778	Kottayam	Pallom	Paruthumpara	6.65	176	0	10.3	28	0.031	7.2	30.5	40.4	12.9	2	21.1	9.9
144	76.4933	9.62556	Kottayam	Ettumanoor	Pulikuttisseri	8.37	350	30.5	155.1	38	0.083	10.6	0.6	186.3	65.6	5.5	21.1	2.6
145	76.4369	9.78333	Kottayam	Kaduthuruthy	Talayolaparambu	8.1	139	0	46.5	11	0.032	20.7	2.5	69.7	19.7	5	9.8	2.7
146	76.6056	9.52917	Kottayam	Madappally	Tottakkad	7.31	38	0	15.5	4	0.018	2.2	5.7	19.3	6.1	1	3	0.5
147	76.3931	9.74972	Kottayam	Vaikom Municipality	Vaikom	8.31	320	20.3	144.8	18.6	0.24	21.8	4.80	167.4	57.7	5.7	19.4	6.1
148	76.7231	9.56944	Kottayam	Vazhoor	Vazhur	8.15	49	0	20.6	5.2	0.03	1	4.8	23.2	6	2	4.6	1
149	76.4522	9.83	Kottayam	Kaduthuruthy	Velloor II	7.83	163	0	72.2	8.8	0.09	13.6	15.2	73.2	18.3	6.7	13.8	3.7
150	75.5848	11.5985	Kozhikode	Badagara	Badagara	6.85	310	0	52	24.9	0.00	23.2	37.3	101.2	33.5	4.30	20.5	10.2
151	75.8298	11.4468	Kozhikode	Balusseri	Balusseri	6.92	160	0	21	19.9	0.04	2.9	21.3	33.5	10.0	2.10	16	5.7
152	75.8062	11.1734	Kozhikode	Kozhikode	Beypore	7.26	430	0	109	35.6	0.03	53.9	9.7	147	47.5	7.10	31.8	13.3
153	75.7275	11.3946	Kozhikode	Panthalayini	Chemencheri	7.17	230	0	52	9.8	0.18	23.7	13.3	67	23.9	1.80	11.2	4.6
154	75.7409	11.3345	Kozhikode	Kozhikode	Elattur	7.1	320	0	78	12.90	0.03	29.9	11.9	100	35.3	2.90	14.3	3
155	75.8970	11.5499	Kozhikode	Balusseri	Kakkayam	7.07	55	0	36	2.8	0.03	4.3	3.3	22.1	6.9	1.20	4.6	1.7
156	75.8927	11.3340	Kozhikode	Koduvalli	Koduvalli	9.93	106	15.2	26	6.5	0.03	1.1	1.1	38	9.6	3.40	8.1	1
157	75.7913	11.2533	Kozhikode	Kozhikode	Kozhikode	8.2	300	0	114	20.6	0.00	19.5	8.2	137	50.1	3.00	15.2	1.9
158	75.9408	11.2514	Kozhikode	Kunnamangalam	Mavoor II	7.86	137	0	26	20.1	0.03	3.4	6.6	22.8	6.5	1.60	15.4	9.2
159	75.66667	11.53333	Kozhikode	Thuneri	Nadapuram	7.6	172	0	67	12.90	0.03	9.6	1.3	57	17.9	3.00	12.7	3
160	75.7553	11.5653	Kozhikode	Perambra	Perambra	7.79	179	0	57	10.60	0.03	8.1	15.5	62	22.4	1.50	10.6	3.1
161	75.7169	11.7436	Kozhikode	Thuneri	Pudukayam	7.87	61	0	26	8.80	0.04	1.8	5.4	22.8	6.5	1.60	9.1	1.4
162	75.98472	11.49722	Kozhikode	Koduvalli	Pudupadi	7.47	124	0	26	10.90	0.01	9.7	14.4	37.1	11.4	2.10	10.9	4.2

163	75.6935	11.4417	Kozhikode	Panthalayini	Quilandy	8.02	320	0	145	15.40	0.03	15.6	7.8	133	48.5	3.00	22.9	12
164	75.8594	11.1774	Kozhikode	Kozhikode	Ramanattukara	8.72	770	15.2	243	55.80	0.37	50.1	25.8	217	47.1	24.30	98.3	14
165	75.9406	11.4153	Kozhikode	Koduvalli	Thamarasseri	7.94	105	0	52	9.40	0.03	6.4	2.8	46.2	14.4	2.50	10.5	2
166	75.675	11.56667	Kozhikode	Thodannur	Thiruvallur	7.08	33	0	5	1.4	0.03	3.2	5.1	11.6	4.0	0.40	1.3	0.4
167	75.64694	11.48861	Kozhikode	Meladi	Tikkodi	7	113	0	21	10.9	0.01	5	5.7	28.8	9.4	1.30	5.6	8.8
168	76.01667	10.93333	Malappuram	Kuttippuram	Amminikad	7.41	72	0	36.2	6.6	0.073	2	7.4	32.9	7.9	3.2	7.4	1.6
169	76.0504	11.2345	Malappuram	Areekode	Arikode	7.22	161	0	41.3	16.3	0.043	7.3	19.3	54.7	16.8	3.1	12.8	2.4
170	76.3300	11.2258	Malappuram	Nilambur	Chokkad	8.57	330	20.3	87.9	36.7	0.091	7.7	13.5	119.9	30.6	10.6	32.9	3.3
171	76.2756	11.3337	Malappuram	Nilambur	Chungathara1	8.84	610	36	139.6	58.1	0.317	31.3	52	232.9	44.9	29.4	56.9	13
172	76.0100	10.7819	Malappuram	Ponnani	Edappal	7.55	99	0	25.8	13.4	0.038	2	17.8	39.1	8.4	4.4	11	1
173	76.0833	11.1375	Malappuram	Areekode	Kadalundi	8.3	700	5	98.2	54.5	1	125.3	1.13	233.9	65.4	17.2	28	5.3
174	75.9653	10.7617	Malappuram	Andathode	Kanjiramukku	8.03	330	0	72.4	41.2	0.097	9.9	3	78.1	26.2	3.1	35.8	4.8
175	76.225	10.98333	Malappuram	Perinthalmana	Kariavattam	7.8	132	0	15.5	16.6	0.047	1.4	19.5	28.4	7.1	2.6	15.6	3
176	76.3052	11.2889	Malappuram	Nilambur	Karulai	8.3	380	10.1	108.6	28.1	0.134	82.5	10	152.0	31.6	17.8	28.6	1.4
177	75.98333	10.97083	Malappuram	Tanur	Kottakkal	7.35	430	0	46.5	62.1	0.041	4.1	51.7	82.2	24.2	5.3	44.1	11.5
178	76.0321	10.8411	Malappuram	Kuttipuram	Kuttipuram	8.3	400	10.1	108.6	24.4	0.426	23.7	22.7	127.6	31.2	12.1	29.2	11.6
179	76.0889	11.0397	Malappuram	Mankada	Malappuram	7.46	128	0	41.3	10	0.107	2.6	14.1	41.8	10.5	3.8	10.9	3.5
180	75.9223	10.8490	Malappuram	Thirur	Mangalam	8.82	500	10.1	20.7	30.8	0.163	77	61.6	158.9	49.2	8.8	31.5	11.2
181	76.1201	11.1201	Malappuram	Manjeri	Manjeri	7.8	680	0	129.3	75.5	2.092	24.9	66	170.1	53	9.2	63.4	21.1
182	76.3219	11.4197	Malappuram	Nilambur	Maruda	7.75	210	0	67.2	18	0.029	1.58	21.1	77.3	18.8	7.4	15.9	1.7
183	76.2753	11.0596	Malappuram	Perinthalmana	Melattur	7.72	180	0	62	14.1	0.133	3.3	12.2	54.2	14.8	4.2	18.6	1
184	76.2231	11.2753	Malappuram	Nilambur	Nilambur	7.55	175	0	20.1	19.4	0.177	1	34.6	38.3	9.6	3.5	19.3	3.4
185	75.8587	11.0479	Malappuram	Tirurangady	Parappanangadi	7.92	490	0	129.3	26	0.081	49.6	29.3	178.4	64.9	4	25.7	11.5
186	75.9880	10.6990	Malappuram	Andathode	Perumpadappu	8.3	390	10.1	119	18.7	0.039	46.8	4.7	153.2	58.6	1.7	26.8	5.3
187	75.9180	10.7822	Malappuram	Ponnani	Ponnani1	8.35	370	20.3	160.3	10.5	0.08	5.3	6.4	169.0	60.8	4.2	12.8	8.5
188	76.1914	10.9020	Malappuram	Mankada	Pulamantol	7.6	350	0	98.2	38.5	0.116	9	37.7	71.9	19.9	5.4	31.7	13.9
189	75.8737	10.9910	Malappuram	Tanur	Tanur	7.5	161	0	25.9	15.8	0.19	9.8	15.8	35.9	10.6	2.3	17.4	6.3

190	75.9801	10.8636	Malappuram	Thirur	Thirunavaya	8	360	0	155.1	17.1	0.188	21.1	7.1	158.1	38.8	14.9	21.4	1.7
191	76.2841	11.1120	Malappuram	Wandoor	Thuvur	7.6	108	0	25.9	9.7	0.038	1.5	18.9	33.8	9.6	2.4	10.3	2.7
192	75.92083	10.90972	Malappuram	Tirur	Tirur	7.33	250	0	36.2	31.6	0.071	19.9	16.9	67.0	20.1	4.1	22.7	2.5
193	76.0748	10.8953	Malappuram	Kuttippuram	Valancheri	7.15	360	0	46.5	61.1	0.222	2.8	29.2	88.4	20.6	9	33.3	8.3
194	76.3432	11.3858	Malappuram	Nilambur	Vazhikadavu	8.3	420	10.1	129.3	34.7	0.097	17	13.8	171.7	43.1	15.6	27.5	3.6
195	75.94444	10.78611	Malappuram	Ponnani	Vylattur	2.8	410	0	0	48.4	0.026	24.4	105.4	83.6	27.9	3.4	41.2	17.5
196	76.746	11.118	Palakkad	Attapadi	Agali	8.3	840	15.2	248.2	42.5	0	37.8	31.8	221.4	67.8	12.7	57.9	4.7
197	76.54167	10.65	Palakkad	Alathur	Alathur	8.44	720	15.2	170.6	46	0.419	42	5.4	239.2	53.5	25.7	42.6	6.5
198	76.47778	10.67222	Palakkad	Alathur	Athipetta	8.3	660	10.1	134.4	33.3	0.214	17.7	5.5	166.2	40.4	15.9	26.6	10.6
199	76.3206	10.8861	Palakkad	Sreekrishnapuram	Cherpulassery	7.88	85	0	62	5	0.087	7.6	6.4	42.1	13.1	2.3	5.1	4
200	76.8700	10.6933	Palakkad	Chittur	Gopalapuram	8.31	960	5	222.3	48.3	0.761	17.6	88.1	224.4	69.5	12.4	63.9	4.5
201	76.5389	10.8939	Palakkad	Mannarkkad	Kalladikkode	3.05	450	0	0	48.2	0	29.3	47.6	53.5	15.5	3.6	42.7	9.7
202	76.7464	10.7967	Palakkad	Malampuzha	Kanjikkode	9.69	680	36	170.6	40.7	0.227	29.3	29.6	167.7	47.1	12.2	48.2	46.5
203	76.42	10.9175	Palakkad	Sreekrishnapuram	Karimpuzha	7.9	91	0	41.3	8.2	0.059	4.5	3.7	33.3	10.4	1.8	11.2	3.4
204	76.1892	10.8658	Palakkad	Pattambi	Koppam	7.52	300	0	51.7	34.7	0.085	3.1	19.6	57	12.8	6.1	29.2	3.3
205	76.8411	10.7444	Palakkad	Chittur	Kozhinjampara	8.35	1070	10.1	294.8	66.5	0.535	45.3	42.4	328.5	71.0	36.80	77	5.3
206	76.86944	10.68611	Palakkad	Kuzhalmannom	Kozhippara	8.3	1240	15.2	465.4	54.6	0.643	38.1	6.7	349.9	54.7	51.90	70.3	9
207	76.5939	10.7078	Palakkad	Kuzhalmannom	Kuzhalmannom	8.3	730	10.1	274.1	37.3	0.396	27.1	7.1	190	40.9	21.40	43.1	9.7
208	76.475	10.775	Palakkad	Palakkad	Mankara	8.05	340	0	113.7	18.5	0.182	15.7	6.5	104.2	25.1	10.10	27.5	6.1
209	76.4672	10.9933	Palakkad	Mannarkkad	Mannarkkad	8.31	520	5	160.3	28.9	0.151	19	21.6	180.2	56.9	9.30	28.9	13.7
210	76.5803	10.8369	Palakkad	Palakkad	Mundur	8.33	510	5	165.5	38.5	0.246	12	6.7	176.6	40.8	18.20	34.5	5.1
211	76.6003	10.5939	Palakkad	Nenmara	Nenmara	8.66	400	10.1	149.9	17.2	0.45	32.6	11.1	180.2	54.9	10.50	26.3	8.2
212	76.77222	10.66111	Palakkad	Palakkad Mun	Palakkad	8.74	800	15.2	284.4	44	0.451	27.9	11	273.3	46.9	38.00	55.9	3.9
213	76.1864	10.8044	Palakkad	Pattambi	Pattambi	7.99	350	0	82.7	27.6	0.262	19.6	11.1	107.4	27.7	9.30	25.5	5.6
214	76.5814	11.0847	Palakkad	Attapadi	Thavalam	8.36	360	5	129.3	20.8	0.203	6.2	11.1	119.4	28.9	11.50	23.4	2.7
215	76.4836	10.5922	Palakkad	Alathur	Vadakkanchery	8.66	720	10.1	181	34.2	0.181	35.7	39.9	231	59.8	19.90	38.5	5.9

216	76.82	8.70	Trivandrum	Attingalmuncipality	Attingal	7.55	240	0	91	16.6	0.12	6.2	15.3	79.4	30.0	1.10	18.3	1.4
217	77.05	8.43	Trivandrum	Nemom	Balaramapuram	6.27	850	0	13	128.50	0.18	4.9	147.5	163.7	41.4	14.70	82.2	38.8
218	76.79	8.66	Trivandrum	Chirayinkil	Chirayinkil	6.85	410	0	32	67.60	0.04	2.3	46.5	67.2	16.4	6.40	58.8	3.6
219	77.08	8.37	Trivandrum	Athiyannur	Chittagode	7	290	0	39	40.30	0.27	7.8	26.2	61.7	16.0	5.30	33.4	10.2
220	76.77	8.68	Trivandrum	Chirayinkil	Kadakkavur1	7.1	310	0	65	22.80	0.33	40.6	39.0	108.1	30.3	7.90	34.2	4.1
221	77.13	8.71	Trivandrum	Vamanapuram	Kallar	6.76	48	0	19	5.30	0.07	2.3	1.3	16.2	4.7	1.10	4.7	1.6
222	77.08	8.51	Trivandrum	Perumkadavila	Kattakkada	5.92	420	0	13	57.60	0.58	3	77.5	72.7	19.1	6.10	42.6	14.5
223	77.10	8.33	Trivandrum	Parasala	Kulathur	6.68	75	0	32	11.30	0.23	1.9	3.2	17.6	5.4	1.00	10.6	2.1
224	76.95	8.57	Trivandrum	Trivandrum corporation	Mannanthala	6.13	210	0	13	31.10	0.14	4.1	34.2	21.8	4.3	2.70	25.2	12
225	77.01	8.61	Trivandrum	Nedumangadmuncipality	Nedumangad	6.94	240	0	58	41.60	0.16	2.7	2.9	37.1	10.6	2.60	31.1	5.9
226	77.08	8.41	Trivandrum	NeyyattinkaraMuncipality	Neyyattinkara	6.8	200	0	26	29.10	0.54	0.8	34.9	27.8	6.7	2.70	28.7	4.3
227	77.03	8.72	Trivandrum	Vellanad	Palode	7.09	210	0	71	22.60	0.33	8.1	17.6	51.4	16.8	2.30	20.9	8.8
228	76.9694	8.76528	Trivandrum	Vamanapuram	Pangode	7	230	0	26	25.30	0.11	1.4	54.7	34.6	7.6	3.80	26.3	9.8
229	76.81	8.63	Trivandrum	Chirayinkil	Perumkuzhi	7.24	280	0	58	12.40	0.14	59.1	16.3	87.8	26.8	5.10	15.5	19
230	77.07	8.32	Trivandrum	Parasala	Poovar- II	7.28	550	0	39	83.00	0.08	5.2	86.4	96.4	16.4	13.50	72.7	3.1
231	76.94	8.45	Trivandrum	Trivandrum corporation	Poonthura	7.6	220	0	84.0	11.80	0.00	11.7	19.5	75	24.8	3.20	13.6	8.3
232	76.81	8.61	Trivandrum	Chirayinkil	Pudukurichi	8.3	410	20.3	116.3	25.3	0.06	15.7	35.7	162.6	52.3	7.80	26.5	10
233	76.96	8.50	Trivandrum	Trivandrum corporation	Trivandrum	7.82	220	0	25.8	29.4	0.05	4.8	34.4	36.9	8.2	4.00	26	6
234	76.90	8.72	Trivandrum	Vamanapuram	Vamanapuram	8.37	370	20.3	148.7	31.4	0.36	6.2	12.1	150.6	55.1	3.20	23.8	9.8
235	76.72	8.73	Trivandrum	Varkala	Varkala	7.68	145	0	12.9	23.7	0.11	2.8	20.8	28.1	7.3	2.40	13.8	2.5
236	77.20	8.44	Trivandrum	Perumkadavila	Vellarada1	7.77	380	0	64.6	40.7	0.30	21.2	42.0	88.4	28.5	4.20	36.8	20.3
237	77.08	8.67	Trivandrum	Vellanad	Vithura	7.58	102	0	25.8	9.0	0.06	5.5	16.0	25.6	8.1	1.30	8.7	3.5
238	76.8400	9.3300	Pathanamthitta	Pandalam	Aranmula	6.96	240	0	84.5	9.4	0.00	17.6	24.7	81	17.2	9.20	16.7	1.8
239	76.75	9.08	Pathanamthitta	Parakode	Enathu	7.73	900	0	208.0	28.90	0.00	12.1	91.6	182	52.5	12.40	31.6	13.8
240	76.8500	9.2300	Pathanamthitta	Konni	Konni	7.7	350	0	13.0	43.1	0.20	40.1	58.8	67	15.6	6.90	17.4	27.1

241	76.7300	9.4000	Pathanamthitta	Mallappally	Kottanadu	7.63	115	0	10.3	12.7	0.00	8	13.1	27	6.7	2.40	10.1	4.9
242	76.6500	9.4500	Pathanamthitta	Mallappally	Mullapally	7.55	89	0	7.7	8.3	0.00	6.7	15.0	17	4.8	1.20	8.7	2.2
243	76.9200	9.2000	Pathanamthitta	Konni	Naduvathumuzhi	7.41	41	0	13.0	2.0	0.00	4.2	3.9	16	4.4	1.20	3.1	2.2
244	77.0133	9.3883	Pathanamthitta	Ranni	Nilakkkal	7.3	156	0	7.7	25.0	0.00	4.5	11.1	27	7.0	2.40	17	2.4
245	76.6500	9.2300	Pathanamthitta	Pandalam	Pandalam	7.38	67	0	23.4	6.0	0.00	1.3	2.2	22	3.7	3.10	6.4	0.7
246	76.7900	9.2600	Pathanamthitta	Konni	Pathanamthitta	7.38	192	0	46.0	9.40	0.10	17	15.3	66	21.0	3.30	9.3	7.7
247	76.5300	9.4000	Pathanamthitta	Pulikeezh	Peringara	7.62	134	0	57.0	8.30	0.20	5	5.6	50	9.2	6.60	8.1	0.7
248	76.8600	9.3700	Pathanamthitta	Ranni	Ranni Peruned	7.58	67	0	20.7	2.60	0.00	6.6	4.3	25	7.1	1.70	4	2.2
249	76.6900	9.3900	Pathanamthitta	Koipuram	Thelliyur	7.38	98	0	20.7	4.70	0.00	11.2	6.0	33	10.4	1.80	5.9	2.9
250	76.6900	9.2800	Pathanamthitta	Pandalam	Ullannur	7.44	58	0	7.7	5.00	0.00	9.1	9.0	14	3.6	1.20	4.7	3.2
251	76.8400	9.3400	Pathanamthitta	Ranni	Vadaserikara	7.31	95	0	41.5	1.70	0.00	8.9	3.9	45	15.1	1.90	2.8	0.9
252	76.2131	11.6184	Wayanad	Sulthans' Bathery	Ambalavayal	7.41	130	0	28.5	10.1	0	5.7	9.4	40	13.8	1.40	9.6	2.2
253	76.2441	11.7351	Wayanad	Sulthans' Bathery	Chenad	7.51	118	0	46.7	4.9	0	3.1	9.7	49	17.7	1.20	6.5	1.9
254	76.0835	11.6071	Wayanad	Kalpetta	Kalpetta (R1)	7.75	390	0	97.4	26	0.1	22.8	16.5	115	38.2	4.90	23.2	17.3
255	76.0743	11.6784	Wayanad	Panamaram	Kamblakat	7.82	170	0	52	7.8	0	6.3	37.1	51	13.5	4.30	14.4	1.5
256	75.8795	11.7442	Wayanad	Mannanthody	Koroth	7.7	80	0	21	5.6	0	2.7	6.8	22	5.9	1.80	6.6	1.8
257	76.0032	11.8022	Wayanad	Mannanthody	Mannanthody	7.83	280	0	97.4	14.2	0	18	10.9	88	28.5	4.00	14.2	13.3
258	76.1626	11.6604	Wayanad	Sulthans' Bathery	Minangadi	7.85	141	0	54.5	8.3	0	7.5	2.2	59	19.3	2.50	7.7	4.9
259	76.3714	11.6767	Wayanad	Sulthans' Bathery	Muthanga (R1)	8.13	770	0	266	103	0	11.4	9.8	206	34.9	28.90	48.9	3.1
260	76.3449	11.6031	Wayanad	Sulthans' Bathery	Nool Puzha	8.23	122	0	75.3	3.2	0.1	6.8	0.5	3	17.5	7.10	7.1	1.6
261	75.9747	11.6797	Wayanad	Kalpetta	Padinjarattara(R1)	8.04	220	0	45	8.3	0	14.7	27.2	83	22.8	6.40	10.3	1.4
262	76.1501	11.8611	Wayanad	Panamaram	Perikallur	8.25	530	0	168.7	50.4	0.2	16	32.7	145	34.6	14.30	42.6	2.9
263	76.1664	11.7846	Wayanad	Panamaram	Pulpally	8.37	300	6	136	16.8	0.2	12.9	9.7	111	23.1	12.90	21	1.2
264	76.2574	11.6630	Wayanad	Sulthans' Bathery	Sulthans' Bathery	8.4	340	12	117	14.4	0	18.8	14.4	122	40.7	5.10	13	17.1
265	75.9920	11.9076	Wayanad	Mannanthody	Thirunelly (R1)	8.19	151	0	59.7	9.4	0.1	5.8	2.1	57	16.1	4.00	9.7	4.6
266	76.2238	11.5559	Wayanad	Kalpetta	Vaduvanchal	7.99	142	0	13	9.7	0	0.7	32.2	38	11.1	2.50	7.9	6.7
267	75.9066	11.7952	Wayanad	Mannanthody	Valad (R1)	7.89	70	0	28.5	3	0	4.3	7.1	34	11.3	1.50	4.8	0.8

268	76.1479	10.5454	Thrissur	Puzhakkal	Adatt	5.86	160	0	24.0	3.1	0.14	4.2	25.8	27	6.6	2.55	5.8	2.8
269	76.3268	10.2387	Thrissur	Mala	Annamanada	6.06	143	0	12.7	23.6	0.00	3.02	24.9	31	8.9	2.14	15.2	7.16
270	76.3329	10.3073	Thrissur	Chalakkudy Municipality	Chalakudi	6.31	87	0	15.2	13.64	0.04	4.52	15.0	27	7.1	2.15	9.55	2.38
271	76.0263	10.5909	Thrissur	Chavakkad	Chavakkad	6.65	192	0	63.4	16.7	0.00	19.37	0.7	73	24.6	2.90	14.4	4.78
272	76.3345	10.6948	Thrissur	Pazhayannur	Chelakkara	7.4	450	0	177.5	51.1	0.70	7.2	5.1	133	22.5	18.70	36.3	3.73
273	76.2101	10.4376	Thrissur	Cherpu	Cherpu	7.56	100	0	31.7	15.3	0.00	3.3	1.8	23	6.9	1.52	15.5	3.49
274	76.2754	10.7509	Thrissur	Pazhayannur	Cheruthuruthy	7.44	290	0	126.8	21.3	0.42	18.3	3.6	129	30.4	12.90	19.6	3.7
275	76.67	9.853	Thrissur	Azhutha	Echipara	7.47	110	0	31.7	6.6	0.10	19.3	5.2	41	11.2	3.20	10.8	1.8
276	77.09	9.733	Thrissur	Thalikulam	Engadiyur	7.36	220	0	95.1	14.0	0.00	3.3	16.8	99	36.4	1.95	13.1	3
277	76.1713	10.2133	Thrissur	Mathilakam	Eriyad	7.5	250	0	126.8	17.90	0.10	2.6	0.8	118	41.2	3.65	14.2	4.13
278	76.0369	10.5984	Thrissur	Guruvayur Municipality	Guruvayur	7.89	220	0	63.4	34.60	0.12	4.2	3.1	77	22.8	4.95	20.86	3.13
279	76.2086	10.3470	Thrissur	Irinjalakkuda	Irinjalakkuda	7.64	210	0	38.0	20.80	0.00	33.1	9.7	79	26.7	3.00	11.6	5.8
280	76.0756	10.7191	Thrissur	Chovvannur	Kallumpuram	9.61	230	18	31.7	24.60	0.08	27.9	18.2	81	21.8	6.50	16.7	4.81
281	76.2847	10.4530	Thrissur	Kodakara	Kallur	7.73	110	0	25.4	16.6	0.10	3	12.2	35	9.6	2.70	10.4	6.8
282	76.1617	10.6069	Thrissur	Puzhakkal	Kecheri	7.43	290	0	12.7	52.0	0.10	3.2	68.5	52	12.9	4.70	35.8	8.3
283	76.1947	10.2340	Thrissur	Kodungallur Municipality	Kodungalloor	7.82	810	0	285.0	88.3	0.13	38.2	42.1	298	106.9	7.51	56.5	21.2
284	76.2178	10.6769	Thrissur	Wadakkancherry	Kundannur	8.15	540	0	235.6	41.7	0.40	48.5	2.4	242	60.6	22.20	34.7	9.1
285	76.2632	10.2436	Thrissur	Mala	Mala	8.09	132	0	19.0	11.7	0.05	19.5	9.6	44	13.2	2.67	8.34	7.76
286	76.1031	10.4920	Thrissur	Anthikkad	Manalur	7.96	45	0	12.7	6.3	0.00	2.91	2.5	14	4.2	0.79	6.49	0.7
287	76.2149	10.5868	Thrissur	Puzhakkal	Mulangunnathukavu	7.5	210	0	63.4	21.60	0.12	6.34	24.6	64	17.2	5.03	17.1	10.8
288	76.3407	10.4010	Thrissur	Kodakara	Mupliam	7.7	150	0	12.7	25.3	0.00	3.5	31.4	35	9.2	2.90	17.4	4.78
289	76.2635	10.3608	Thrissur	Irinjalakkuda	Muriyad	7.41	190	0	12.7	31.8	0.00	4.02	8.4	27	6.6	2.57	19.1	7.7
290	76.3315	10.5580	Thrissur	Ollurkkara	Pattikkad	7.55	130	0	63.4	6.5	0.26	4.3	3.8	67	17.3	5.71	7.7	1.7
291	76.1476	10.3146	Thrissur	Mathilakam	Perinjanam	7.96	910	0	178.0	126.7	0.08	57	157.5	263	93.4	7.20	97.5	18.7
292	75.9937	10.6600	Thrissur	Chavakkad	Punnayur	7.76	120	0	63.4	4.8	0.00	2.9	1.5	59	22.1	0.82	4.95	2.1

293	76.2135	10.2836	Thrissur	Vellangallur	Thekkumkara(Konathukunnu)	7.56	100	0	19.0	8.2	0.00	8.43	4.2	32	10.5	1.34	7.06	1.6 3
294	76.2177	10.5302	Thrissur	Thrissur Corporation	Thrissur	7.66	176	0	31.7	19.00	0.00	31.9	6.4	62	19.2	3.32	13.8	2.1 6
295	76.1114	10.4142	Thrissur	Thalikkulam	Triprayar	7.86	354	0	140.0	28.80	0.04	12.2	0.9	147	53.2	3.40	22.9	9.3