



**GOVERNMENT OF KERALA  
GROUNDWATER DEPARTMENT**

**NATIONAL HYDROLOGY PROJECT**



**GROUNDWATER QUALITY MONITORING REPORT  
2019**

## **Water Quality Status of Hard Rock Terrain of Kerala, 2019**

The Analytical laboratory at Thiruvananthapuram monitors the water quality of the observation wells of the department in the districts of Trivandrum, Kollam, Kottayam, Pathanamthitta and Alappuzha

The Analytical laboratory at Ernakulam monitors the water quality of the observation wells of the department in the districts of Ernakulam, Idukki, Thrissur, Palakkad and Malappuram.

The Analytical laboratory at Kozhikode monitors the water quality of the observation wells of the department in the districts of Kozhikode, Wayanad, Kannur and Kazargode.

The samples were analysed for pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sodium (Na), Potassium (K), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Total Alkalinity (TA), Carbonate (CO<sub>3</sub>), Bicarbonate (HCO<sub>3</sub>), Sulphate (SO<sub>4</sub>), Chloride (Cl), Nitrate Nitrogen (NO<sub>3</sub>-N), Iron (Fe) and Fluoride (F).

<b><i>Drinking water specification (IS 10500:2012)</i></b>			
	<b>Parameter</b>	<b>Requirement ( Acceptable Limit) (mg/L)</b>	<b>Permissible Limit in the Absence of Alternate Source (mg/L)</b>
1	pH	6.5 - 8.5	No relaxation
2	Electrical conductivity/TDS	500	2000
3	Turbidity(NTU)	1	5
4	Total Hardness(mg CaCo <sub>3</sub> /l)	200	600
5	Calcium (mg/L)	75	200
6	Magnesium(mg/L)	30	100
7	Sodium(mg/L)	—	—
8	Potassium (mg/L)	—	—

9	Total Alkalinity(mg CaCo <sub>3</sub> /L)	200	600
10	Carbonate(Mg/L)	–	–
11	Sulphate(mg/L)	200	400
12	Chloride(mg/L)	250	1000
13	Fluoride(mg/L)	1	1.5
14	Iron(mg/L)	0.3	No relaxation
15	Nitrate-N (mg/L)	10	No relaxation
16	Total Coliform(MPN/100ml)	Nil	Nil
17	Faecal Coliform(MPN/100ml)	Nil	Nil

Results of the wells from hardrock terrain as classified by the Nodal Officer were interpreted for water quality status. The physico-chemical parameters of the samples showed the following deviation (**in percentage**) with respect to Drinking Water Standards BIS (**IS 10500: 2012**)

District	Total no of samples	pH>8.5	pH<6.5	EC>500 $\mu$ S/cm	NO <sub>3</sub> -N>10 mg/L	Fe>0.3 mg/L
Trivandrum	58	Nil	8	8	16	22
Kollam	30	Nil	9	9	18	6
Kottayam	49	Nil	Nil	2	Nil	71
Pathanamthitta	38	Nil	5	5	3	Nil
Ernakulam	28	Nil	1	Nil	3	32
Idukki	46	Nil	25	Nil	Nil	75
Thrissur	37	20	Nil	Nil	3	73
Palakkad	65	Nil	Nil	6	2	87
Malappuram	31	Nil	Nil	Nil	7	65
Kozhikode	32	Nil	9	6	3	43
Kannur	35	Nil	13	5	5	55

Kasaragod	37	Nil	4	Nil	Nil	97
Wayanad	26	Nil	3	Nil	Nil	7

### **Thiruvananthapuram District**

The departmental samples of Trivandrum District collected from various hard rock terrain areas were analysed for pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sodium (Na), Potassium (K), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Total Alkalinity (TA), Carbonate (CO<sub>3</sub>), Bicarbonate (HCO<sub>3</sub>), Sulphate (SO<sub>4</sub>), Chloride (Cl), Nitrate Nitrogen (NO<sub>3</sub>-N), Iron (Fe) and Fluoride (F).

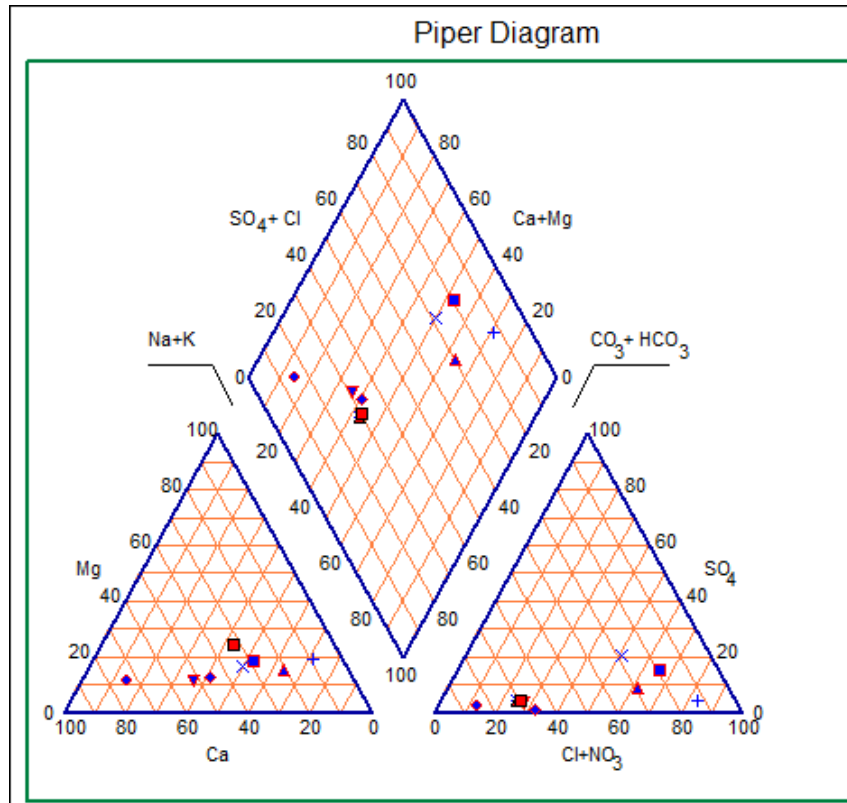
The results of the physico-chemical parameters of the above samples showed that most of the samples for majority of parameters lie under the acceptable limits set by BIS (2012)

#### **Statistical summary of physicochemical parameters and its comparison with BIS (2012) standards**

Variables	Minimum	Maximum	Mean	BIS (2012)	
				Acceptable limit	Permissible limit
pH	3.7	8.5	7.52	6.5-8.5	
EC ( $\mu$ S/cm)	190.53	224.44	206.63	-	
TDS (mg/l)	114.28	134.69	123.98	500	2000
Na (mg/l)	16.93	19.35	18.09	-	
K (mg/l)	2.39	4.87	3.84	-	
TH (mg/l of CaCO <sub>3</sub> )	71.06	78.94	74.53	200	600
Ca (mg/l)	13.58	17.54	15.12	75	200
Mg (mg/l)	2.97	5.53	3.91	30	100
TA (mg/l of CaCO <sub>3</sub> )	45.26	53.26	48.69	200	600
CO <sub>3</sub> (mg/l)	2.55	3.50	2.93	-	-
HCO <sub>3</sub> (mg/l)	48.75	56.59	52.20	-	-
SO <sub>4</sub> (mg/l)	7.42	7.42	7.42	200	400
Cl (mg/l)	25.44	29.21	27.14	250	1000
Fe (mg/l)	0	9.6	1.70	0.3	NR
F (mg/l)	0.10	0.10	0.10	1	1.5
NO <sub>3</sub> -N (mg/L)	0	19.2	3.22	10	NR

### Hydrochemical Facies and Water type

From the piper trilinear diagram it is depicted that the major hydrogeochemical facies are Na-Cl water type followed by mixed CaHCO<sub>3</sub>, Mixed Ca-Mg-Cl and mixed Ca- Na- HCO<sub>3</sub>.



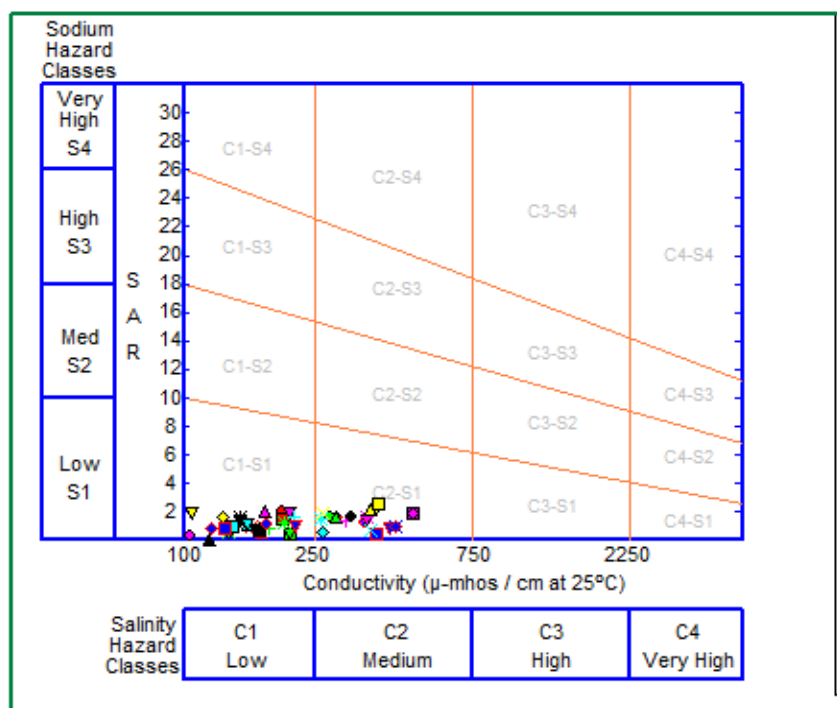
**Piper diagram showing the relationship between dissolved ions in the water samples**

### Irrigation Suitability

Majority of the water samples of the study area cluster around the good water quality field C1S1 and C2S1 zones, indicating low to medium salinity water and are suitable for irrigation.

#### **Irrigation water quality of samples**

## US Salinity Diagram



## **Kollam District**

The departmental samples of Kollam District collected were analysed for pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sodium (Na), Potassium (K), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Total Alkalinity (TA), Carbonate (CO<sub>3</sub>), Bicarbonate (HCO<sub>3</sub>), Sulphate (SO<sub>4</sub>), Chloride (Cl), Nitrate Nitrogen (NO<sub>3</sub>-N), Iron (Fe) and Fluoride (F).

The results of the physico-chemical parameters of the above samples showed that most of the samples for majority of parameters lie under the acceptable limits set by BIS (2012).

### **Statistical summary of physicochemical parameters and its comparison with BIS (2012) standards**

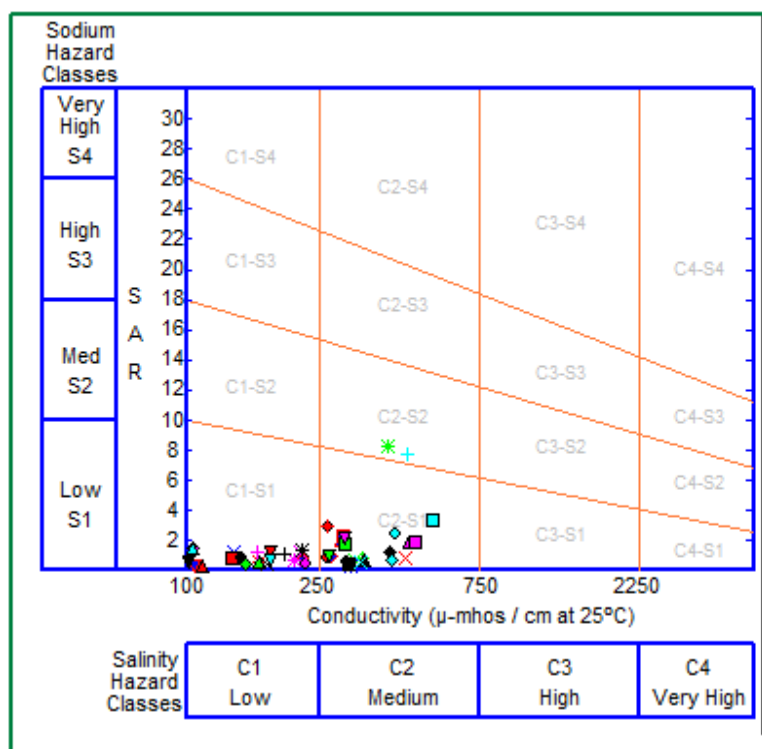
Variables	Minimum	Maximum	Mean	BIS (2012)	
				Acceptable limit	Permissible limit
pH	7.23	7.64	7.43	6.5-8.5	
EC (µS/cm)	173.95	274.97	217.72	-	
TDS (mg/l)	104.43	164.96	130.65	500	2000
Na (mg/l)	13.92	33.46	21.34	-	
K (mg/l)	2.40	4.16	3.17	-	
TH (mg/l)	41.78	69.57	54.99	200	600
Ca (mg/l)	11.44	18.74	15	75	200
Mg (mg/l)	2.80	6.99	4.77	30	100
TA (mg/l)	30.22	53.19	40.43	200	600
CO <sub>3</sub> (mg/l)	1.10	3.70	2.15	-	-
HCO <sub>3</sub> (mg/l)	36.10	58.78	46.72	-	-
SO <sub>4</sub> (mg/l)	10.02	11.69	10.86	200	400
Cl (mg/l)	23.35	45.46	31.73	250	1000
Fe (mg/l)	0.05	0.23	0.12	0.3	NR
F (mg/l)	0.27	0.31	0.29	1	1.5
NO <sub>3</sub> -N (mg/L)	3.48	3.95	3.71	10	NR

### **Irrigation Suitability**

Majority of the water samples of the study area cluster around the good water quality field C1S1 and C2S1 zones, indicating low to medium salinity water and are suitable for irrigation.

### **Irrigation water quality of samples**

## US Salinity Diagram



## Kottayam District

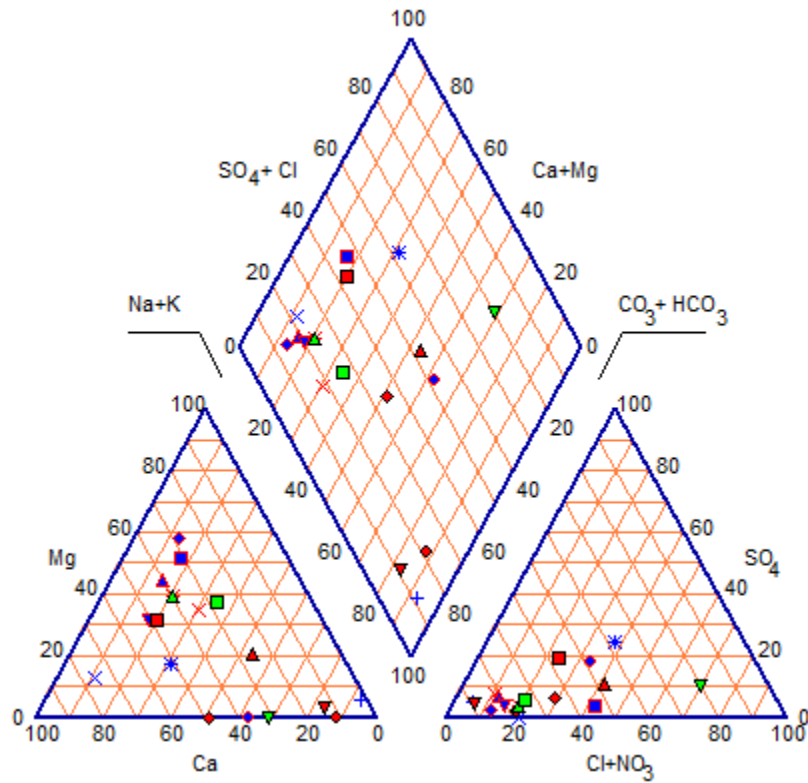
The departmental samples of Kottayam District collected from various hard rock terrain areas were analysed for pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sodium (Na), Potassium (K), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Total Alkalinity (TA), Carbonate ( $\text{CO}_3$ ), Bicarbonate ( $\text{HCO}_3$ ), Sulphate ( $\text{SO}_4$ ), Chloride (Cl), Nitrate Nitrogen ( $\text{NO}_3\text{-N}$ ), Iron (Fe) and Fluoride (F).

The results of the physico-chemical parameters of the above samples showed that pH value is mainly towards the alkaline side. BW 10 (Uzhavoor) and BW 19 (Eratupetta) are showing higher sodium values. Calcium bicarbonate hardness is found in some of the wells. (KTM OW 13 and BW3).



### Hydrochemical Facies and Water type

From the piper trilinear diagram it is inferred that the water type is generally mixed  $\text{CaHCO}_3$ . Mixed Ca-Mg-Cl type and  $\text{NaHCO}_3$  type and NaCl type are also seen.

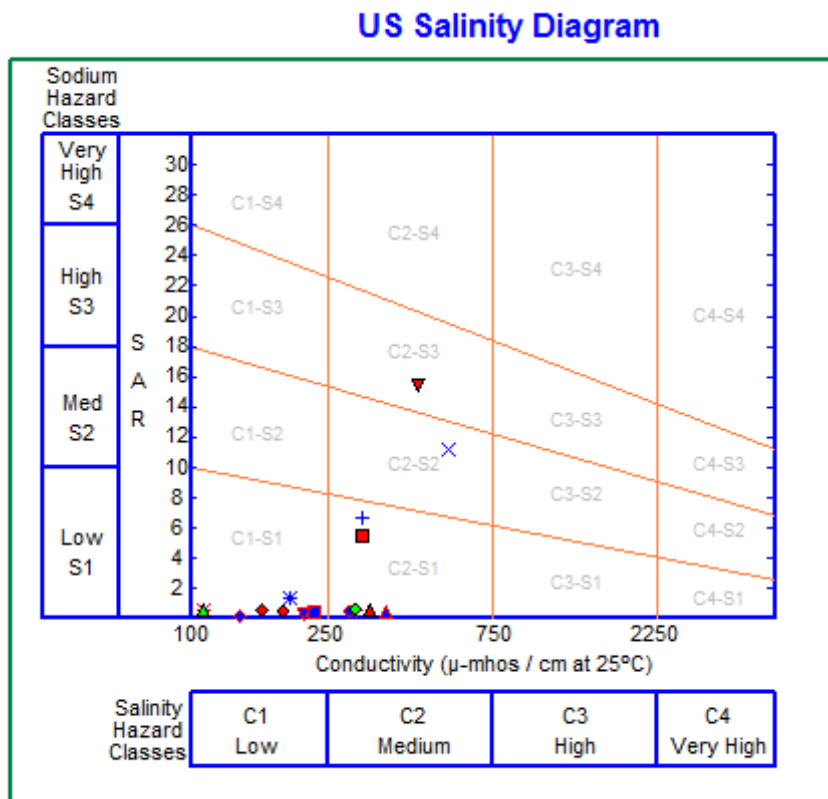


**Piper diagram showing the relationship between dissolved ions in the water samples**

## Irrigation Suitability

Majority of the water samples of the study area cluster around the good water quality field C1S1 and C2S1 zones, indicating low to medium salinity water and are suitable for irrigation. Above two wells BW 10 and BW 19 are C2S# and C2S2 region showing poor irrigation suitability.

### Irrigation water quality of samples



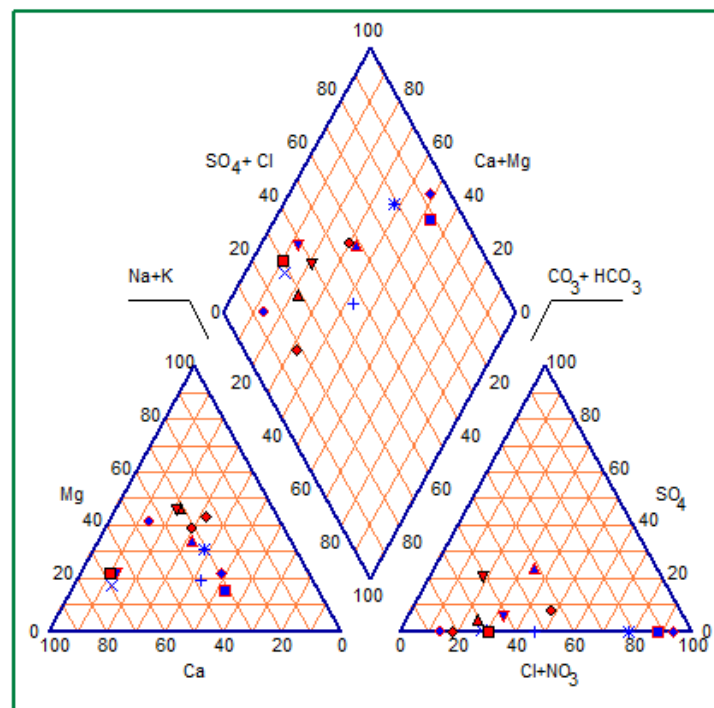
## Pathanamthitta District

The departmental samples of Pathanamthitta District collected from various hard rock terrain areas were analysed for pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sodium (Na), Potassium (K), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Total Alkalinity (TA), Carbonate ( $\text{CO}_3$ ), Bicarbonate ( $\text{HCO}_3$ ), Sulphate ( $\text{SO}_4$ ), Chloride (Cl), Nitrate Nitrogen ( $\text{NO}_3\text{-N}$ ), Iron (Fe) and Fluoride (F).

The results of the physico-chemical parameters of the above samples showed that most of the samples for majority of parameters lie under the acceptable limits set by BIS (2012). The pH value is mainly between 6.5 to 8.5. Nitrate within below 10 mg/L except for PTA 23 (Angadikal) Iron values are also found to be within limit for most of the wells. Electircal conductivity values are below 500  $\mu\text{S/cm}$  and total hardness is also below 200 mg/L of  $\text{CaCO}_3$ . Iron values above BIS can be seen only in 17% of wells.

### HydrochemicalFacies and Water type

From the piper trilinear diagram it is inferred that the water type is generally mixed  $\text{CaHCO}_3$ . Mixed Ca-Mg-Cl type and  $\text{NaHCO}_3$  type and NaCl type are also seen.

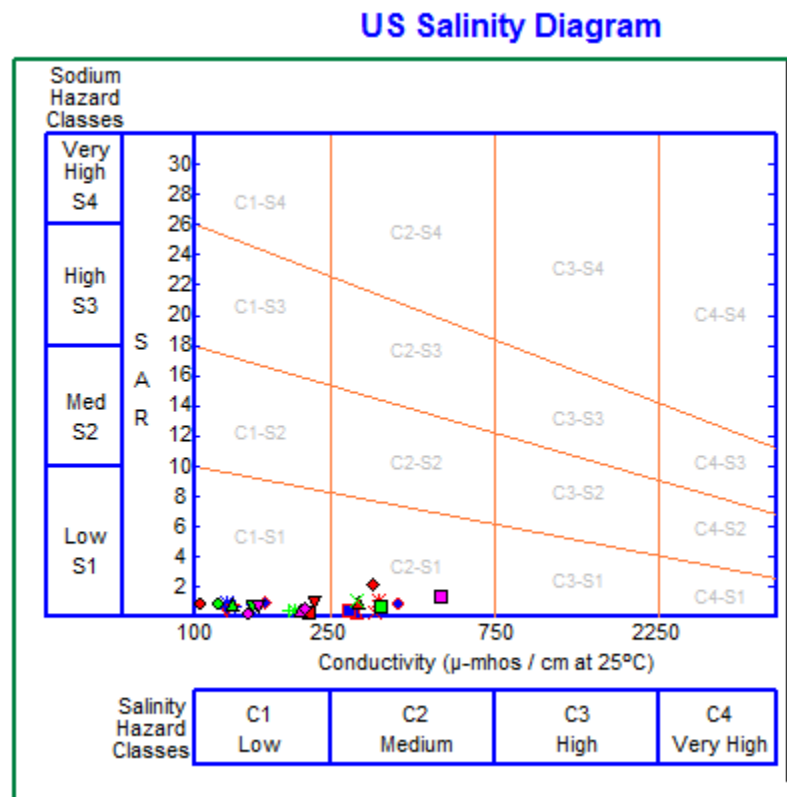


**Piper diagram showing the relationship between dissolved ions in the water samples**

### Irrigation Suitability

Majority of the water samples of the study area cluster around the good water quality field C1S1 and C2S1 zones, indicating low to medium salinity water and are suitable for irrigation.

#### **Irrigation water quality of samples**



## Ernakulam District

Charnikite and Gneiss are the major crystalline rocks found in the Ernakulam district. 24 wells are in Charnikite region and 4 wells in Gneissic region.

The pH varies from 3.2 to 8.5 with an average of 7.7. Except three open wells (GWE 01- kizhakkambalam, GWE 02- Rayamangalam and GWE 03- Kunnathunadu South) pH is within the desirable range of drinking water. Among these three wells GWE 01 the well water is highly acidic (less than 4) due to pollution.

Total dissolved solids are found to be within the desirable limit of 500 mg/L in the hard rock region. It varies from 25mg/L to 400 mg/L with an average of 115 mg/L.

Groundwater in the area is found to be soft to moderately hard with value vary from 15 mgCaCO<sub>3</sub>/L to 205 mgCaCO<sub>3</sub>/L with an average of 60 mgCaCO<sub>3</sub>/L. Moderately hard water is seen in BW 102, BW103, BW104, BW107, BW110.

The minimum, maximum and average values of the major ions in the hard rock region of the district is shown in the table.

Ion	Ca <sup>2+</sup>	Mg	Na	K	HCO <sub>3</sub>	Cl	SO <sub>4</sub>
Min	3.7	0	2.3	0.7	0	6	0
Max	66	24	96	14	260	77	35
Average	14	6.6	15	3.5	72	17	3.3

NO<sub>3</sub>-N is found to be above 10 mg/L in GWE01. The low pH value, high NO<sub>3</sub>-N and NaCl type water clearly indicates that there is a pollution source nearby. Iron value varies from trace to 9 mg/L with an average of 1. Very high values are observed in BW100, BW105, BW106, BW112, BW117 and BW123.

Seasonal variation in water quality is observed due to the fluctuation in water level.

The major water types found in the area are CaHCO<sub>3</sub> and mixed type (no dominant anion or cation). Waters draining igneous and metamorphic rocks are relatively dilute and have bicarbonate as the major anion and sodium and calcium as the major cations. The other types seen in the area are NaCl (GWE 01) and NaHCO<sub>3</sub> (BW101) types

The irrigation suitability shows that the C1S1, C2S1 and C2S2.

## **Thrissur District**

Charnikite and Gneiss are the major crystalline rocks found in the Thrissur district. 24 wells are in Charnikite region and 13 wells in Gneissic region.

The pH varies from 6.8 to 9.8 with an average of 8.2. pH is found to be slightly alkaline. Total dissolved solids are found to be within the desirable limit of 500 mg/L in the hard rock region. It varies from 27 mg/L to 426 mg/L with an average of 144 mg/L. Total dissolved solids are found to be below 100 mg/L in TSR 142, TSR 138, TSR 145 and TSR 146.

Groundwater in the area is found to be soft to hard with values vary from 10 mgCaCO<sub>3</sub>/L to 335 mgCaCO<sub>3</sub>/L with an average of 90 mgCaCO<sub>3</sub>/L. Hard water is seen in Karumathra TSR 143, Karussery TSR 112, Vadama TSR 116, Mattathur TSR 113 and Nellore TSR 114 and hardness is of temporary nature.

The minimum, maximum and average values of the major ions in the hard rock region of the district are shown in the table.

Ion	Ca <sup>2+</sup>	Mg	Na	K	HCO <sub>3</sub>	Cl	SO <sub>4</sub>
Min	2	0	2.1	0.2	0	8	0
Max	68	20	123	11	217	118	93
Average	19	10.7	16.3	3.4	72	27	15

Sodium is found to be above 100 mg/L in Nellore TSR 114 and NO<sub>3</sub>-N is found to be above 5 mg/L in TSR 129. Iron value varies from trace to 9 mg/L with an average of 0.7 mg/L. High values are observed in TSR 122, TSR 123, TSR 124, TSR 126, TSR 130, TSR 133 and TSR 137.

The major water types found in the area are CaHCO<sub>3</sub> and mixed type (no dominant anion or cation). Waters draining igneous and metamorphic rocks are relatively dilute and have bicarbonate as the major anion and sodium and calcium as the major cations. The irrigation suitability shows that the C1S1, C2S1 and C2S2.

## **PALAKKAD DISTRICT**

Charnikite, Gneiss and Hornblend Schist are the major crystalline rocks found in the Palakkad district. 15 wells are in Charnikite region, 50 wells in Gnessic region and one well is in Hornblend Schist.

The pH varies from 6.1 to 8.9 with an average of 8.3. pH is found to be slightly alkaline. Total dissolved solids are found to be above the desirable limit of 500 mg/L in the hard rock region. It varies from 59 mg/L to 1000 mg/L with an average of 275 mg/L. Total dissolved solids is found to be above 500 mg/L in Chittur 126, Pattambi 136, Ozhalapathy 141 and Nalleppilly 150.

Groundwater in the area is found to be soft to very hard with value vary from 35 mgCaCO<sub>3</sub>/L to 420 mgCaCO<sub>3</sub>/L with an average of 150 mgCaCO<sub>3</sub>/L. Hard water is seen in Thathamangalam 150, Ozhalapathy 141, Kuzhalmannam PKD S3, Kollengode 148, Nattukal 139, Pattambi 136, Vadakkancherri 121 PKD, Marutharode 160 PKD 10, Nellore 137 and Pudukode 144. Permanent hardness is found in certain locations.

The minimum, maximum and average values of the major ions in the hard rock region of the district are shown in the table.

Ion	Ca <sup>2+</sup>	Mg	Na	K	HCO <sub>3</sub>	Cl	SO <sub>4</sub>
Min	4	0	3.8	0.4	0	6	0
Max	80	85	175	71	350	325	109
Average	30	19	40	8.6	119	62	22

Sodium is found to be above 100 mg/L in Kuzhalmannam and Kozhinjampara. NO<sub>3</sub>-N is found to be above 10 mg/L in Mannarkkad. Iron value varies from trace to 7.9 mg/L with an average of 0.9 mg/L. Fluoride content varies from 0 to 1.85 mg/L with an average of 0.4 mg/L. High fluoride content is seen in Palakkad, Kuzhalmannam, Elavancherry, Nattukal, Pattambi and Thathamangalam.

The major water types found in the area are CaHCO<sub>3</sub> and mixed type (no dominant anion or cation). Waters draining igneous and metamorphic rocks are relatively dilute and have bicarbonate as the major anion and sodium and calcium as the major cations. The other types seen in the area are NaCl and CaCl<sub>2</sub> types. The irrigation suitability shows that the C1S1, C2S1 and C3S1.

### **Malappuram District**

Charnikite, Gneiss and Hornblend Schist are the major crystalline rocks found in the Malappuram district. 14wells are in Charnikite region, 15 wells in Gnessic region and 2 wells in HornblendSchist . The pH varies from 6.2to 8.9 with an average of 7.9. pH is found to be slightly alkaline.Total dissolved solids are found to be within the desirable limit of 500 mg/L. It varies from 47 mg/L to 360mg/L with an average of 180mg/L.

Groundwater in the area is found to be soft to hard with value vary from 25 mgCaCO<sub>3</sub>/L to 320 mgCaCO<sub>3</sub>/L with an average of 112 mgCaCO<sub>3</sub>/L. Hard water is seen in Pookkottoor and Perinthalmanna area. Hardness is of Permanent type.

The minimum, maximum and average values of the major ions in the hard rock region of the district are shown in the table.

Ion	Ca <sup>2+</sup>	Mg	Na	K	HCO <sub>3</sub>	Cl	SO <sub>4</sub>
Min	4	2.4	5	1.5	0	5	0
Max	76	46	62	62	342	157	106
Average	22	14	18	18	85	33	13

Comparatively high chloride content is found in Kottakkal and sulphate in Perinthalmanna. Iron value varies from trace to 7.8mg/L with an average of 1.6 mg/L.

The major water types found in the area are CaHCO<sub>3</sub> and mixed type (no dominant anion or cation). Waters draining igneous and metamorphic rocks are relatively dilute and have bicarbonate as the major anion and sodium and calcium as the major cations. The other types seen in the area are CaCl<sub>2</sub>type.The irrigation suitability shows that the C1S1, C2S1and C3S1.

### **IDUKKI**

Charnikite, Gneiss and Granite are the major crystalline rocks found in the Idukki district. 22wells are in Charnikite region, 18wells in Gnessic region and 6 wells in Granite.

The pH varies from 6.2 4.6to 8.7 with an average of 6.7. pH is found to be slightly acidic.Total dissolved solids varies from 10 mg/L to546/L with an average of 124mg/L. Total dissolved solids of Kalkoonthal is above desirable limit.

Groundwater in the area is found to be soft to hard with value vary from 15 mgCaCO<sub>3</sub>/L to 250 mgCaCO<sub>3</sub>/L with an average of 66 mgCaCO<sub>3</sub>/L. Hard water is seen in Pooppara well.

The minimum, maximum and average values of the major ions in the hard rock region of the district are shown in the table.

Ion	Ca <sup>2+</sup>	Mg	Na	K	HCO <sub>3</sub>	Cl	SO <sub>4</sub>
Min	4	0	0.5	0.3	0	3	0
Max	38	39	154	16.5	237	192	76



Average	15	6.9	17	3.7	50	26	8.7
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Comparatively high sodium and chloride content is found in Ayyappancoil Iron value varies from trace to 9.7 mg/L with an average of 1.1 mg/L.

The major water types found in the area are  $\text{CaHCO}_3$  and mixed type (no dominant anion or cation). The irrigation suitability shows that the C1S1 and C2S1.

### **KOZHICODE**

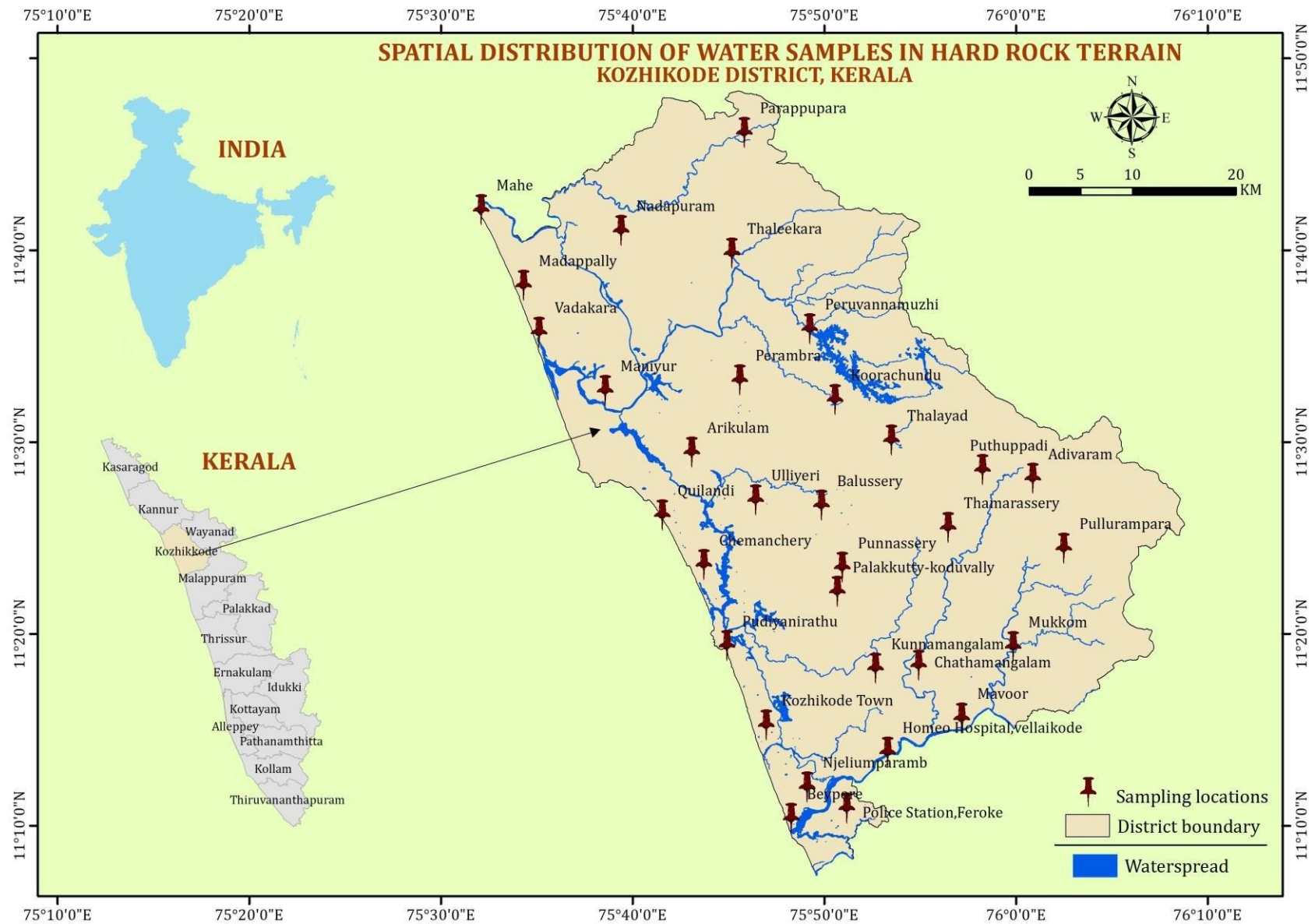
The department samples of Kozhikode district collected from various hard rock terrain were analyzed for pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sodium (Na), potassium (K), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Total Alkalinity (TA), Carbonate ( $\text{CO}_3$ ), Bicarbonate ( $\text{HCO}_3$ ), Sulphate ( $\text{SO}_4$ ), Chloride (Cl), Nitrate-Nitrogen ( $\text{NO}_3\text{-N}$ ), and Iron (Fe). Fig 1 illustrates the spatial distribution of water quality samples of hard rock terrain in Kozhikodedistrict.

The results of the physico-chemical parameters (Table 1) of the above samples show that most of the samples for majority of parameters lie within the acceptable limits set by BIS (2012).

**Table 1. Statistical summary of physicochemical parameters and its comparison with BIS (2012) standards**

Variables	Minimum	Maximum	Mean	BIS (2012)	
				Acceptable limit	Permissible limit
pH	3.7	8.3	7	6.5-8.5	
EC ( $\mu\text{S}/\text{cm}$ )	40	2303	286	-	
TDS (mg/l)	24	1382	171.6	500	2000
Na (mg/l)	3.6	356	26.44	-	
K (mg/l)	0	49.35	6.28	-	
TH (mg/l of $\text{CaCO}_3$ )	0	298	68.43	200	600
Ca (mg/l)	2.1	70	19.1	75	200
Mg (mg/l)	1	46.5	5.13	30	100

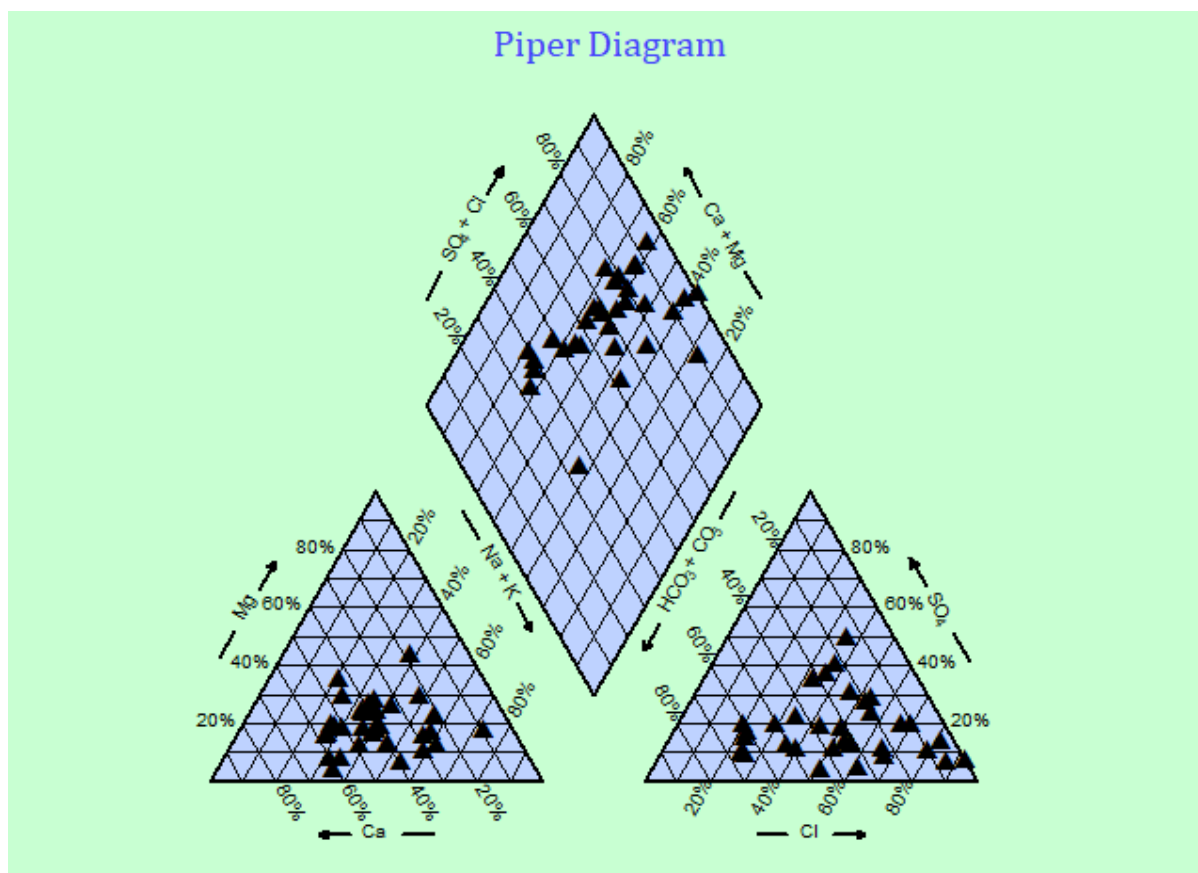
TA (mg/l of CaCO <sub>3</sub> )	0	145.3	34.49	200	600
CO <sub>3</sub> (mg/l)	0	18.2	0.57	-	-
HCO <sub>3</sub> (mg/l)	0	148	43.61	-	-
SO <sub>4</sub> (mg/l)	1	213	25.7	200	400
Cl (mg/l)	9.5	589	44.61	250	1000
Fe (mg/l)	0	8.76	1.25	0.3	NR
NO <sub>3</sub> -N (mg/L)	0	16	3.73	10	NR



**Fig 1. Spatial distribution of sampling locations**

## Hydrochemical Facies and Water type

From the piper trilinear diagram (Fig. 2) it is depicted that the major hydrogeochemical facies are Na-Cl water type followed by mixed Ca-Mg-Cl type.



**Fig. 2 Piper (1953) diagram showing the relationship between dissolved ions in the water samples**

## Water Quality Index

The Water Quality Index (WQI) is calculated following (Tiwari and Mishra 1985; Singh 1992; Rao 1997; Mishra and Patel 2001; Gebrehiwot et al. 2011; Hema et al 2018). The groundwater quality issues of aquifers are generally location specific and time variant. The composition of different litho-units, permeability of soils, intensity and the kind of weathering, etc. are some of the natural factors determining the fate and dispersal of hydrochemical signals (especially cations and anions) in well waters. The quality of well water is the outcome of many natural and man-made processes. Water quality classification ranges and types of water based on WQI values is shown in Table 2.

**Table 2. Classification ranges and type of water based on WQI (Krishnakumar et al 2014)**

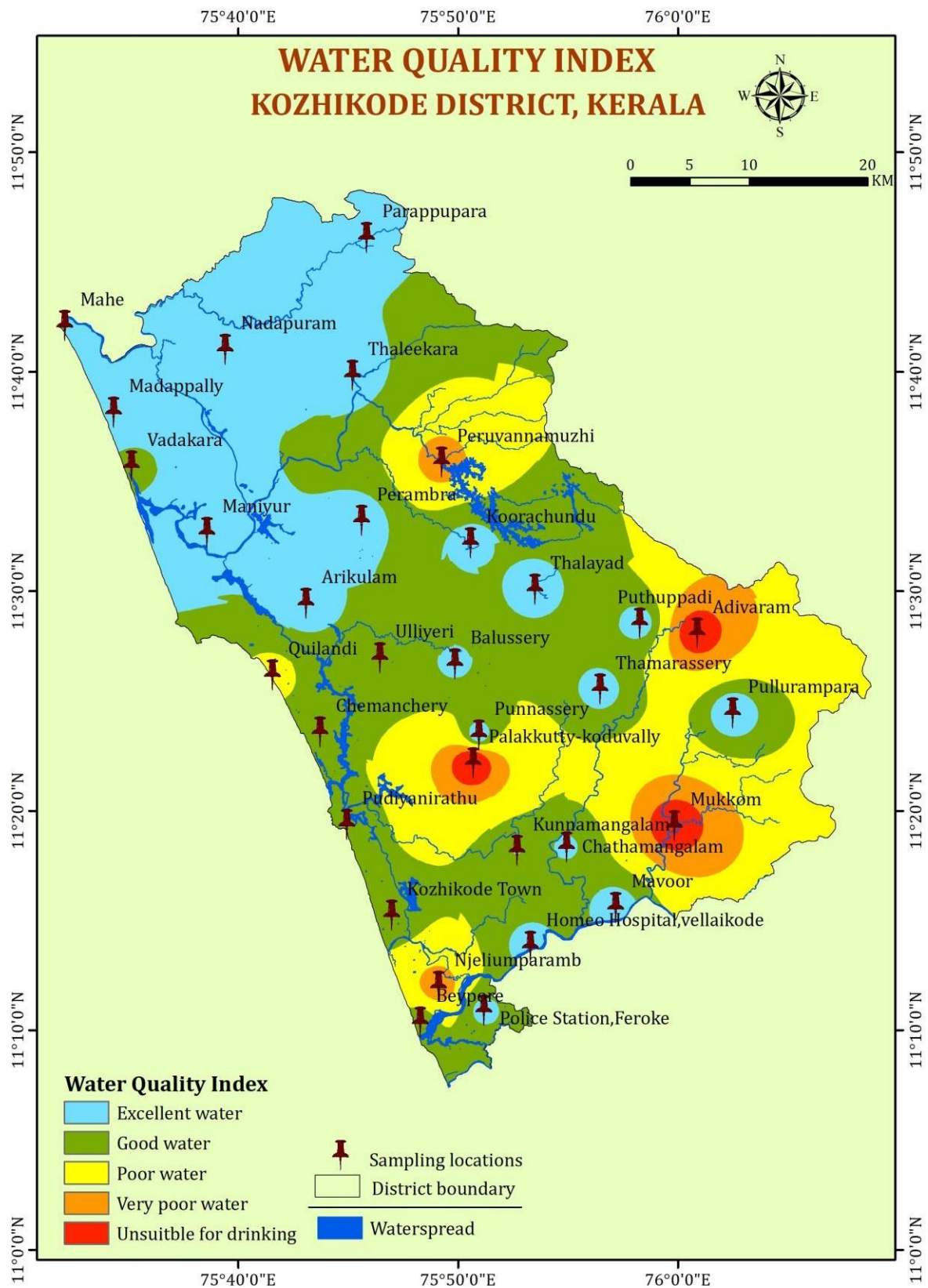
Range	Type of Water
<50	Excellent water
50–100	Good water
100–200	Poor water
200–300	Very poor water
>300	Water unsuitable for drinking purposes

Based on the groundwater quality index, 60 % of the samples falls under excellent and 22% of samples falls in good category, 10% of samples accounts to poor and very poor category and 8% of samples are unsuitable for drinking (Table 3). Spatial distribution of water quality indices is given in Fig3.

**Table 3. Water quality index (WQI) classification for individual samples**

S. No	Well No	Block	Location	WQI	Classification type
1	KKDOW 012	Koduvally	Pullurampara	17.59	Excellent Water
2	KKDOW 013	Koduvally	Adivaram	372.63	Unsuitable for drinking
3	KKDOW 014	Balusseri	Thalayad	30.27	Excellent Water
4	KKDOW 016	Perambra	Peruvannamuzhi	244.47	Very poor water
5	KKDOW 017	Kunnummal	Thaleekara	30.62	Excellent Water
6	KKDOW 018	Kozhikode	Pudiyaniirathu	71.37	Good Water
7	KKDOW 020	Thuneri	Parappupara	42.74	Excellent Water
8	KKDOW 156	Kozhikode	Beypore	66.40	Good Water
9	KKDOW 157	Kunnamangalam	Mavoor	26.84	Excellent Water
10	KKDOW 158	Kunnamangalam	Chathamangalam	43.30	Excellent Water
11	KKDOW 159	Kunnamangalam	Mukkom	372.23	Unsuitable for drinking
12	KKDOW 160	Koduvally	Thamarassery	30.59	Excellent Water
13	KKDOW 174	Panthalayani	Quilandi	117.10	Poor Water
14	KKDOW 175	Perambra	Perambra	31.98	Excellent Water

S. No	Well No	Block	Location	WQI	Classification type
15	KKDOW 176	Vadakara	Vadakara	54.16	Good Water
16	KKDOW 177	Thuneri	Mahe	50.02	Good Water
17	KKDOW 161	Koduvally	Puthuppadi	25.16	Excellent Water
18	QKKD048	Kozhikode	Kozhikode Town	61.42	Good Water
19	QKKD049	Kozhikode	Njeliumparamb	261.58	Very poor water
20	QKKD050	Kozhikode	Police Station,Feroke	36.03	Excellent Water
21	QKKD051	Kunnamangalam	Homeo Hospital,vellaikode	29.48	Excellent Water
22	QKKD052	Kunnamangalam	Kunnamangalam	49.21	Excellent Water
23	QKKD053	Koduvally	Palakkutty-koduvally	434.72	Unsuitable for drinking
24	QKKD054	Chelannur	Punnassery	12.67	Excellent Water
25	QKKD055	Balusserly	Balusserly	41.94	Excellent Water
26	QKKD056	Balusserly	Koorachundu	35.84	Excellent Water
27	QKKD057	Balusserly	Ulliyeri	53.37	Good Water
28	QKKD058	Kunnummal	Nadapuram	33.04	Excellent Water
29	QKKD059	Panthalayani	Arikulam	20.50	Excellent Water
30	QKKD060	Thodannur	Maniyur	24.29	Excellent Water
31	QKKD061	Badagaru	Madappally	31.42	Excellent Water
32	QKKD062	Panthalayani	Chemanchery	81.41	Good Water

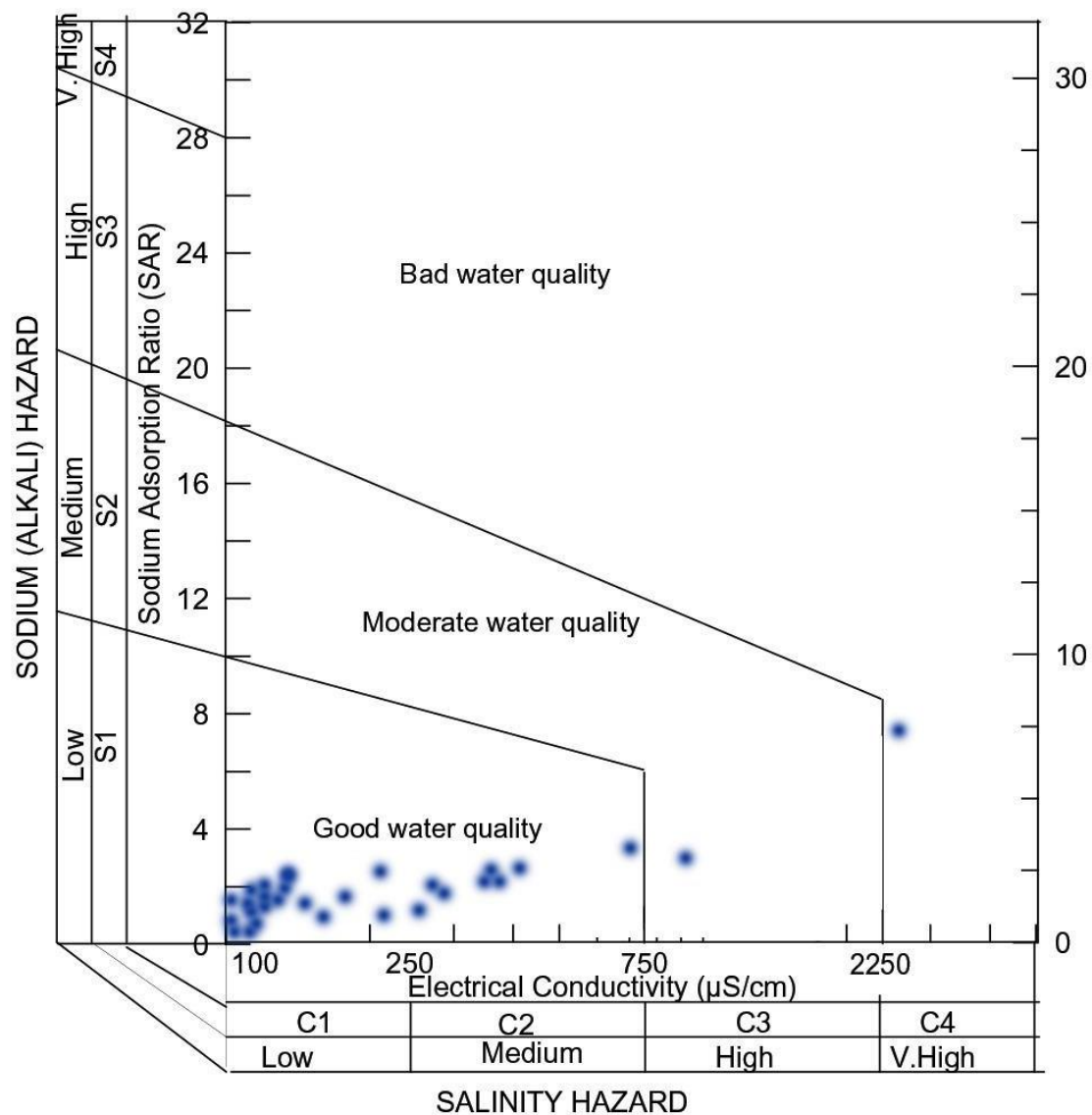


**Fig 3. Spatial distribution of water quality indices worked out for the study area**



### Assessment of irrigation water suitability

US salinity diagram: The US salinity lab's diagram (Richards 1954) is used for rating irrigation waters, where SAR is plotted against EC (Fig 3). Majority of the water samples of the study area cluster around the good water quality field C1S1 and C2S1 zones, indicating low to medium salinity water and are suitable for irrigation.



**Fig. 3 Irrigation water quality (Richards 1954)**



## WATER QUALITY STATUS OF HARD ROCK TERRAIN

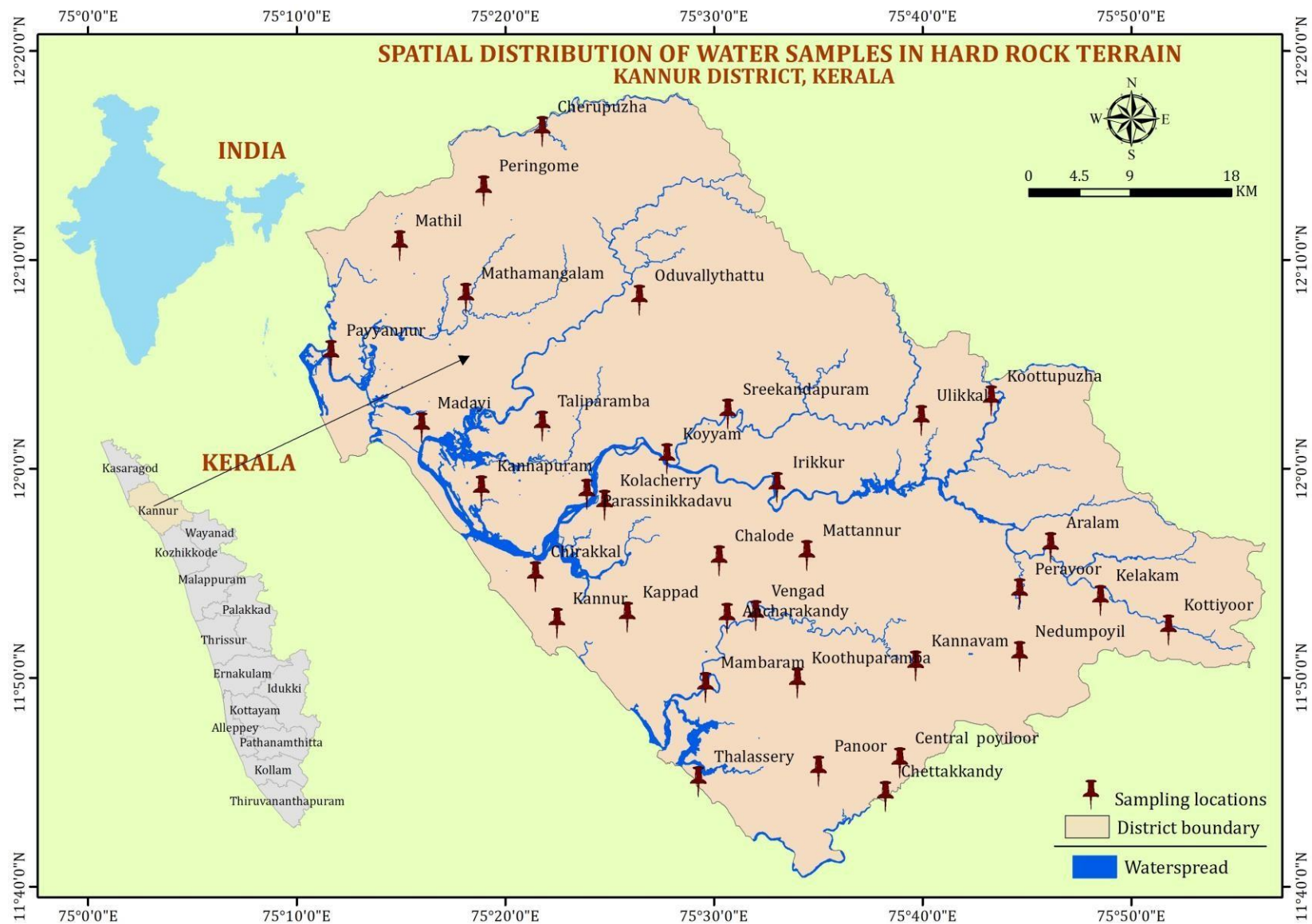
### KANNUR DISTRICT, KERALA

The department samples of Kannur district collected from various hard rock terrain were analyzed for pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sodium (Na), potassium (K), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Total Alkalinity (TA), Carbonate (CO<sub>3</sub>), Bicarbonate (HCO<sub>3</sub>), Sulphate (SO<sub>4</sub>), Chloride (Cl), Nitrate-Nitrogen (NO<sub>3</sub>-N), and Iron (Fe). Fig 1 illustrates the spatial distribution of water quality samples of hard rock terrain in Kannur district.

The results of the physico-chemical parameters (Table 1) of the above samples show that most of the samples for majority of parameters are within the acceptable limits set by BIS (2012).

**Table 1. Statistical summary of physicochemical parameters and its comparison with BIS (2012) standards**

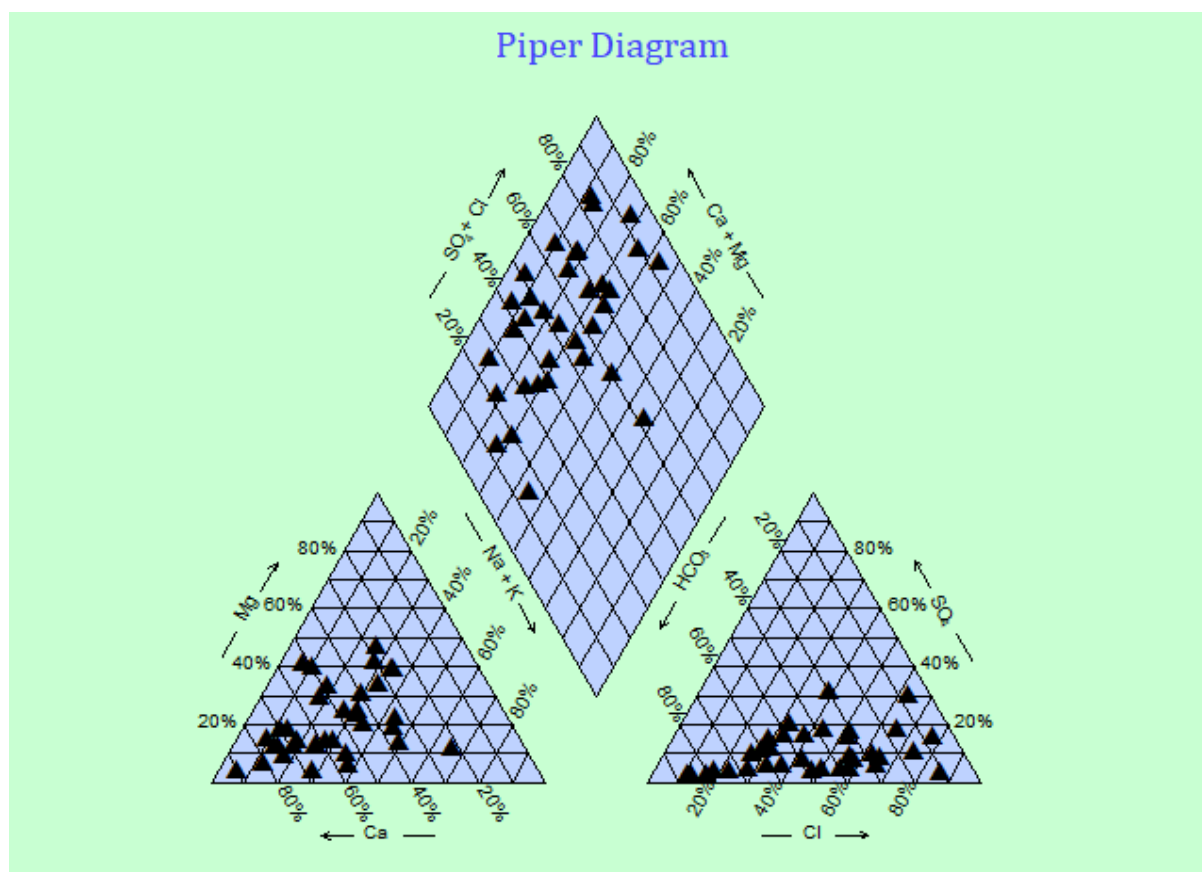
Variables	Minimum	Maximum	Mean	BIS (2012)	
				Acceptable limit	Permissible limit
pH	5.8	7.9	7.05	6.5-8.5	
EC (μS/cm)	53	715	193	-	
TDS (mg/l)	31.8	429	116	500	2000
Na (mg/l)	1.1	29.4	8.96	-	
K (mg/l)	0	17	2	-	
TH (mg/l of CaCO <sub>3</sub> )	16	192	64.5	200	600
Ca (mg/l)	4.3	75	20	75	200
Mg (mg/l)	1	16	3.9	30	100
TA (mg/l of CaCO <sub>3</sub> )	4.5	173	37.9	200	600
CO <sub>3</sub> (mg/l)	0	0	0	-	-
HCO <sub>3</sub> (mg/l)	5.5	211	46.28	-	-
SO <sub>4</sub> (mg/l)	1	53	8.43	200	400
Cl (mg/l)	7.6	112	23	250	1000
Fe (mg/l)	0.12	7.21	0.95	0.3	NR
NO <sub>3</sub> -N (mg/L)	0.1	20	3.87	10	NR



**Fig 1. Spatial distribution of sampling locations**

## Hydrochemical Facies and Water type

From the piper trilinear diagram (Fig. 2) it is depicted that the major hydrogeochemical facies are  $\text{CaHCO}_3$  water type followed by mixed Ca-Mg-Cl type.



**Fig. 2 Piper (1953) diagram showing the relationship between dissolved ions in the water samples**

## Water Quality Index

The Water Quality Index (WQI) is calculated following (Tiwari and Mishra 1985; Singh 1992; Rao 1997; Mishra and Patel 2001; Gebrehiwot et al. 2011; Hema et al 2018). The groundwater quality issues of aquifers are generally location specific and time variant. The composition of different litho-units, permeability of soils, intensity and the kind of weathering, etc. are some of the natural factors determining the fate and dispersal of hydrochemical signals (especially cations and anions) in well waters. The quality of well water is the outcome of many natural and man-made processes. Water

quality classification ranges and types of water based on WQI values is shown in Table 2.

**Table 2. Classification ranges and type of water based on WQI (Krishnakumar et al 2014)**

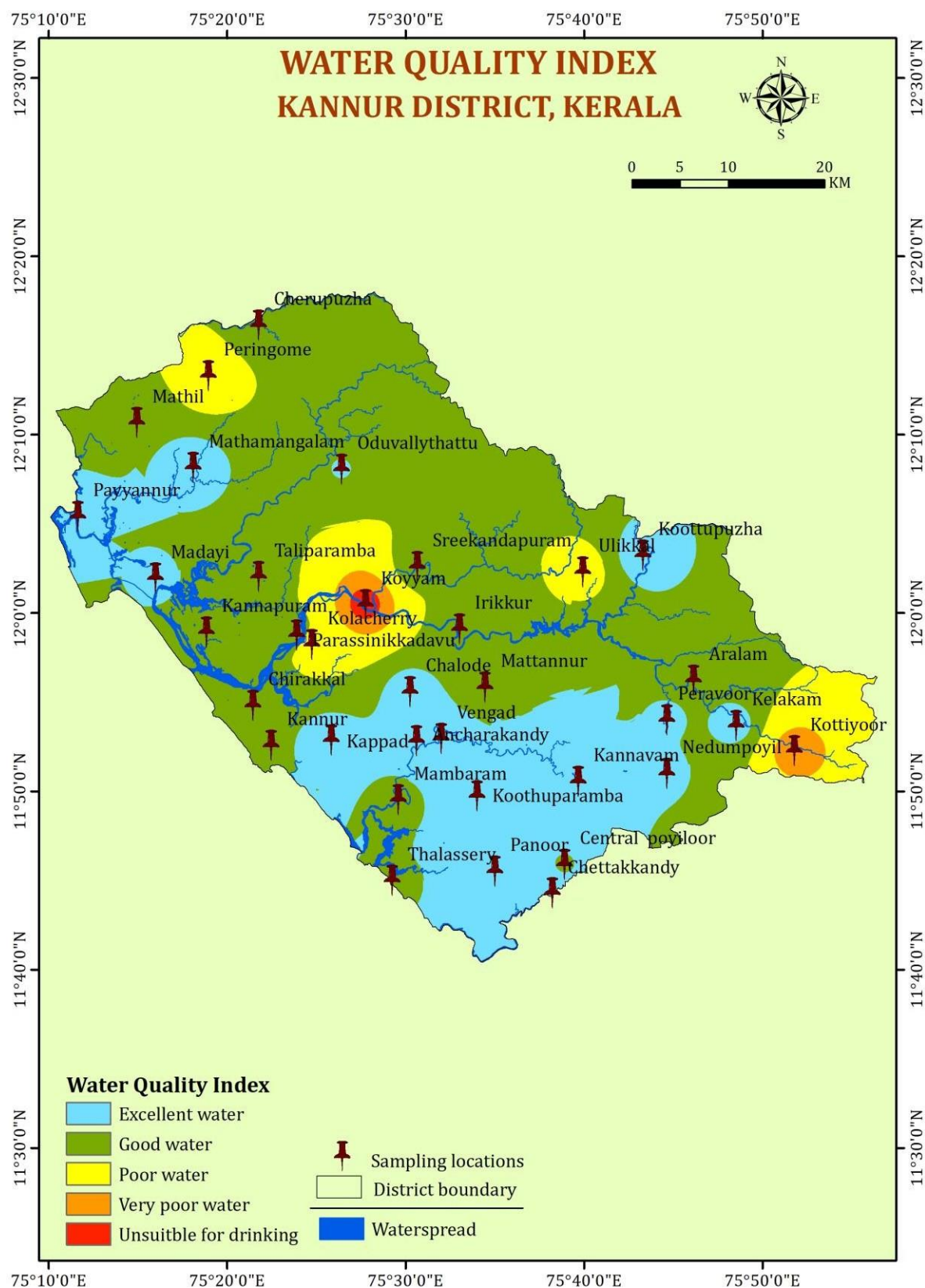
Range	Type of Water
<50	Excellent water
50–100	Good water
100–200	Poor water
200–300	Very poor water
>300	Water unsuitable for drinking purposes

Based on the groundwater quality index, 49 % of the samples falls under excellent and 38% of samples falls in good category, 10% of samples accounts to poor and very poor category and 3% of samples are unsuitable for drinking (Table 3). Spatial distribution of water quality indices is given in Fig3.

**Table 3. Water quality index (WQI) classification for individual samples**

S. No	Well No	Block	Location	WQI	Classification type
1	KNR-POW-C22	Edakkad	Ancharakandy	21.31	Excellent Water
2	KNR-POW-C25	Edakkad	Kappad	21.06	Excellent Water
3	KNR-POW-C1	Kannur	Chirakkal	51.34	Good Water
4	KNR-POW-C5	Taliparamba	Kannapuram	57.79	Good Water
5	KNR-MOW181	Kannur	Kannur	50.99	Good Water
6	KNR-MOW184	Payyannur	Madayi	40.78	Excellent Water
7	KNR-POW-C4	Taliparamba	Parassinikkadavu	45.62	Excellent Water
8	KNR-POW-C6	Payyannur	Mathil	54.13	Good Water
9	KNR-POW-C2	Irikkur	Kolacherry	164.04	Poor Water
10	KNR-POW-C8	Taliparamba	Oduvallythattu	47.80	Excellent Water
11	KNR-MOW187	Payyannur	Mathamangalam	15.57	Excellent Water
12	KNR-POW-C10	Irikkur	Koyyam	363.88	Unsuitable for drinking
13	KNR-MOW186	Payyannur	Payyannur	40.91	Excellent Water

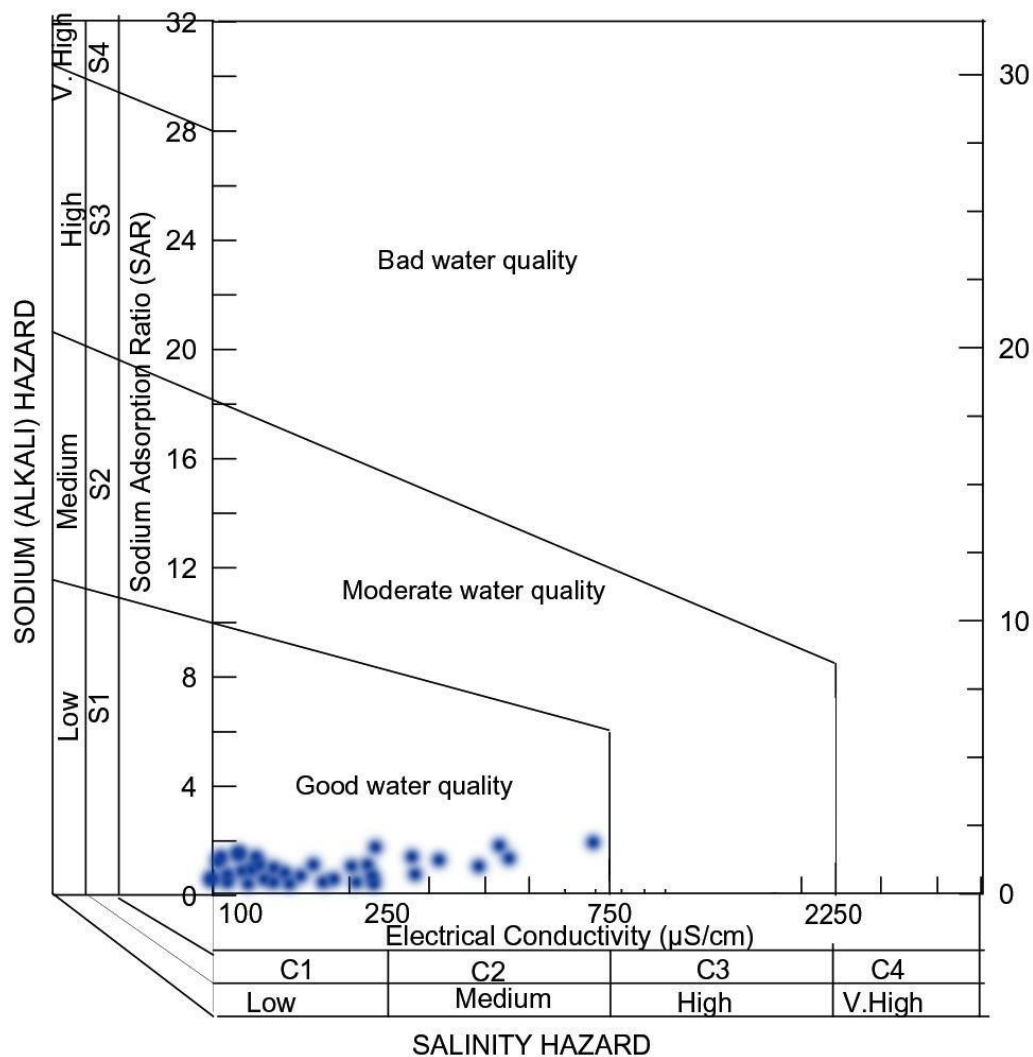
S. No	Well No	Block	Location	WQI	Classification type
14	KNR-MOW190	Payyannur	Peringome	167.16	Poor Water
15	KNR-MOW183	Irikkur	Sreekandapuram	53.35	Good Water
16	KNR-POW-C7	Taliparamba	Taliparamba	57.87	Good Water
17	KNR-MOW189	Payyannur	Cherupuzha	55.77	Good Water
18	KNR-POW-C12	Irikkur	Ulikkal	129.45	Poor Water
19	KNR-POW-C14	Iritty	Aralam	51.49	Good Water
20	KNR-POW-C21	Koothuparamba	Mambaram	66.53	Good Water
21	KNR-POW-C17	Peravoor	Kannavam	23.77	Excellent Water
22	KNR-POW-C15	Peravoor	Kelakam	33.02	Excellent Water
23	KNR-MOW173	Iritty	Mattannur	69.07	Good Water
24	KNR-POW-C18	Thalassery	Central poyiloor	51.33	Good Water
25	KNR-POW-C24	Iritty	Chalode	19.52	Excellent Water
26	KNR-MOW179	Koothuparamba	Koothuparamba	31.53	Excellent Water
27	KNR-POW-C16	Peravoor	Kottiyoor	248.91	Very poor water
28	KNR-MOW172	Peravoor	Peravoor	46.75	Excellent Water
29	KNR-POW-C23	Koothuparamba	Vengad	27.20	Excellent Water
30	KNR-MOW178	Koothuparamba	Panoor	44.44	Excellent Water
31	KNR-MOW182	Irikkur	Irikkur	66.34	Good Water
32	KNR-POW-C19	Thalassery	Chettakkandy	41.49	Excellent Water
33	KNR-MOW180	Thalassery	Thalassery	55.99	Good Water
34	KNR-MOW171	Peravoor	Nedumpoyil	44.07	Excellent Water
35	KNR-POW-C11	Iritty	Koottupuzha	23.12	Excellent Water



**Fig 3. Spatial distribution of water quality indices worked out for the study area**

### Assessment of irrigation water suitability

US salinity diagram: The US salinity lab's diagram (Richards 1954) is used for rating irrigation waters, where SAR is plotted against EC (Fig 3). All of the water samples of the study area cluster around the good water quality field C1S1 and C2S1 zones, indicating low to medium salinity water and are suitable for irrigation.



**Fig. 3 Irrigation water quality (Richards 1954)**



### **KASARAGOD**

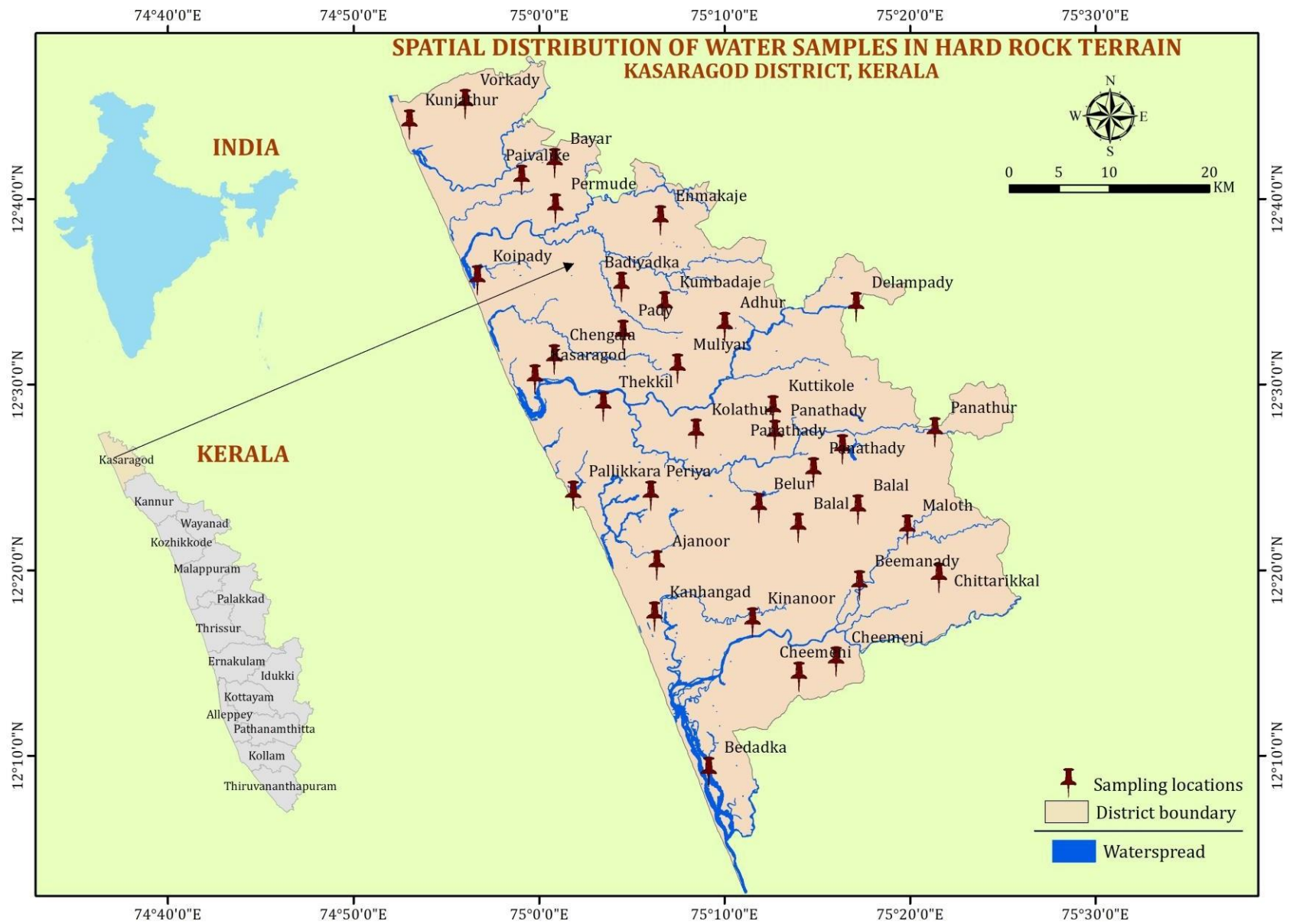
The department samples of Kasaragod district collected from various hard rock terrain were analyzed for pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sodium (Na), potassium (K), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Total Alkalinity (TA), Carbonate (CO<sub>3</sub>), Bicarbonate (HCO<sub>3</sub>), Sulphate (SO<sub>4</sub>), Chloride (Cl), Nitrate-Nitrogen (NO<sub>3</sub>-N), and Iron (Fe). Fig 1 illustrates the spatial distribution of water quality samples of hard rock terrain in Kasaragoddistrict.

The results of the physico-chemical parameters (Table 1) of the above samples showed that most of the samples for majority of parameters lie under the acceptable limits set by BIS (2012).

**Table 1. Statistical summary of physicochemical parameters and itscomparison with BIS (2012)standards**

Variables	Minimum	Maximum	Mean	BIS (2012)	
				Acceptable limit	Permissible limit
pH	4.2	7.9	6.9	6.5-8.5	
EC (μS/cm)	30	440	159.2	-	
TDS (mg/l)	18	264	95.5	500	2000
Na (mg/l)	2.4	33.1	9.17	-	
K (mg/l)	0.04	13.7	2	-	
TH (mg/l of CaCO <sub>3</sub> )	10.64	160	58.42	200	600
Ca (mg/l)	2.13	55.3	14.6	75	200
Mg (mg/l)	1.3	22	5.3	30	100
TA (mg/l of CaCO <sub>3</sub> )	0	161	41.04	200	600
CO <sub>3</sub> (mg/l)	0	0	0	-	-
HCO <sub>3</sub> (mg/l)	0	197	50.11	-	-
SO <sub>4</sub> (mg/l)	0	31	8.04	200	400
Cl (mg/l)	9	67.5	20.11	250	1000
Fe (mg/l)	0.12	9.5	3.4	0.3	NR
NO <sub>3</sub> -N (mg/L)	0	5	1.26	10	NR

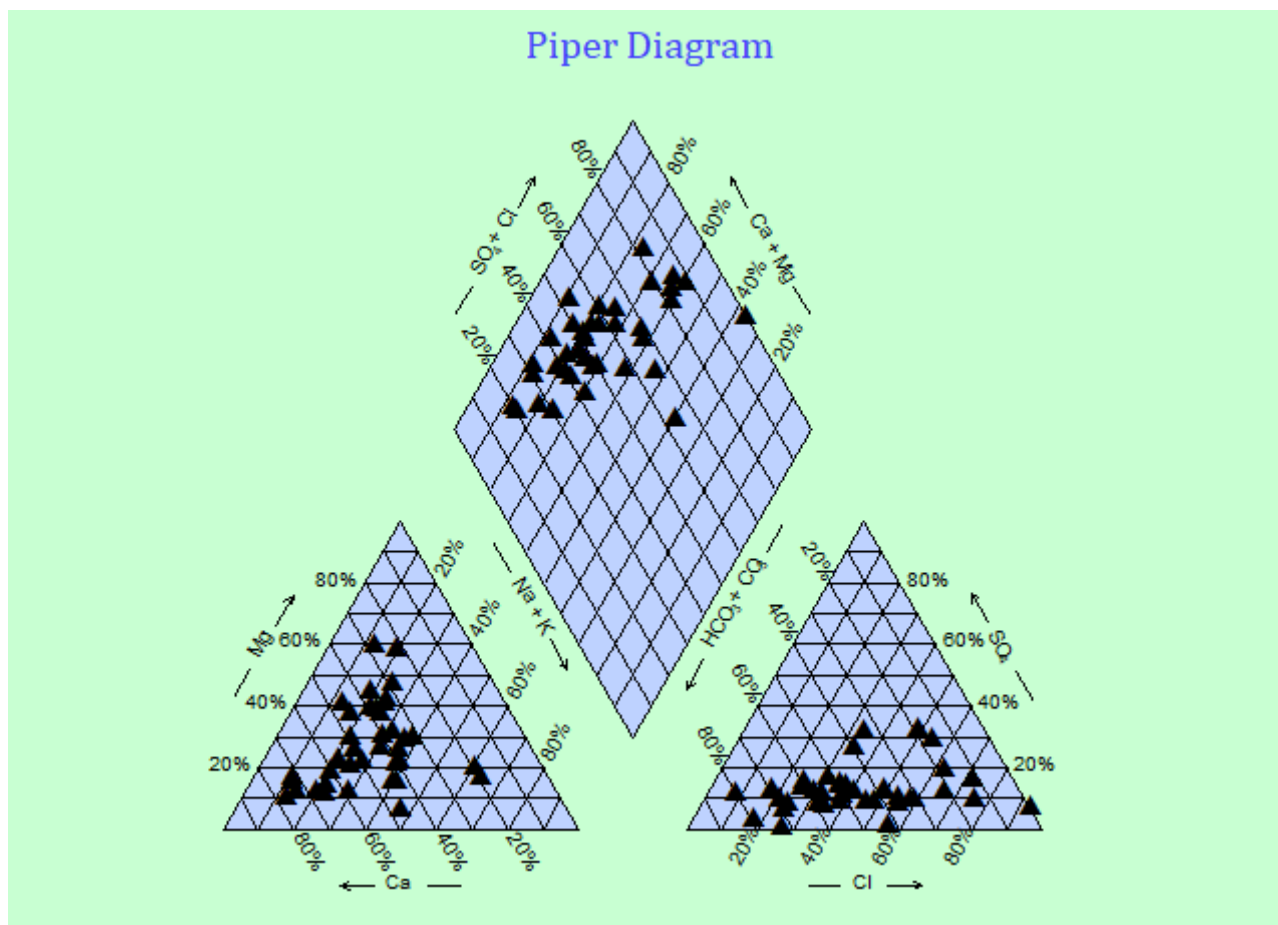




**Fig 1. Spatial distribution of sampling locations**

## Hydrochemical Facies and Water type

From the piper trilinear diagram (Fig. 2) it is depicted that the major hydrogeochemical facies are Ca-Mg-Cl and CaHCO<sub>3</sub> water type.



**Fig. 2 Piper (1953) diagram showing the relationship between dissolved ions in the water samples**

## Water Quality Index

The Water Quality Index (WQI) is calculated following (Tiwari and Mishra 1985; Singh 1992; Rao 1997; Mishra and Patel 2001; Gebrehiwot et al. 2011; Nair et al 2018). The groundwater quality issues of aquifers are generally location specific and time variant. The composition of different litho-units, permeability of soils, intensity and the kind of weathering, etc. are some of the natural factors determining the fate and dispersal of hydrochemical signals (especially cations and anions) in well waters. The quality of well water is the outcome of many natural and man-made processes. Water quality classification ranges and types of water based on WQI values is shown in Table 2.

**Table 2. Classification ranges and type of water based on WQI (Krishnakumar et al 2014)**

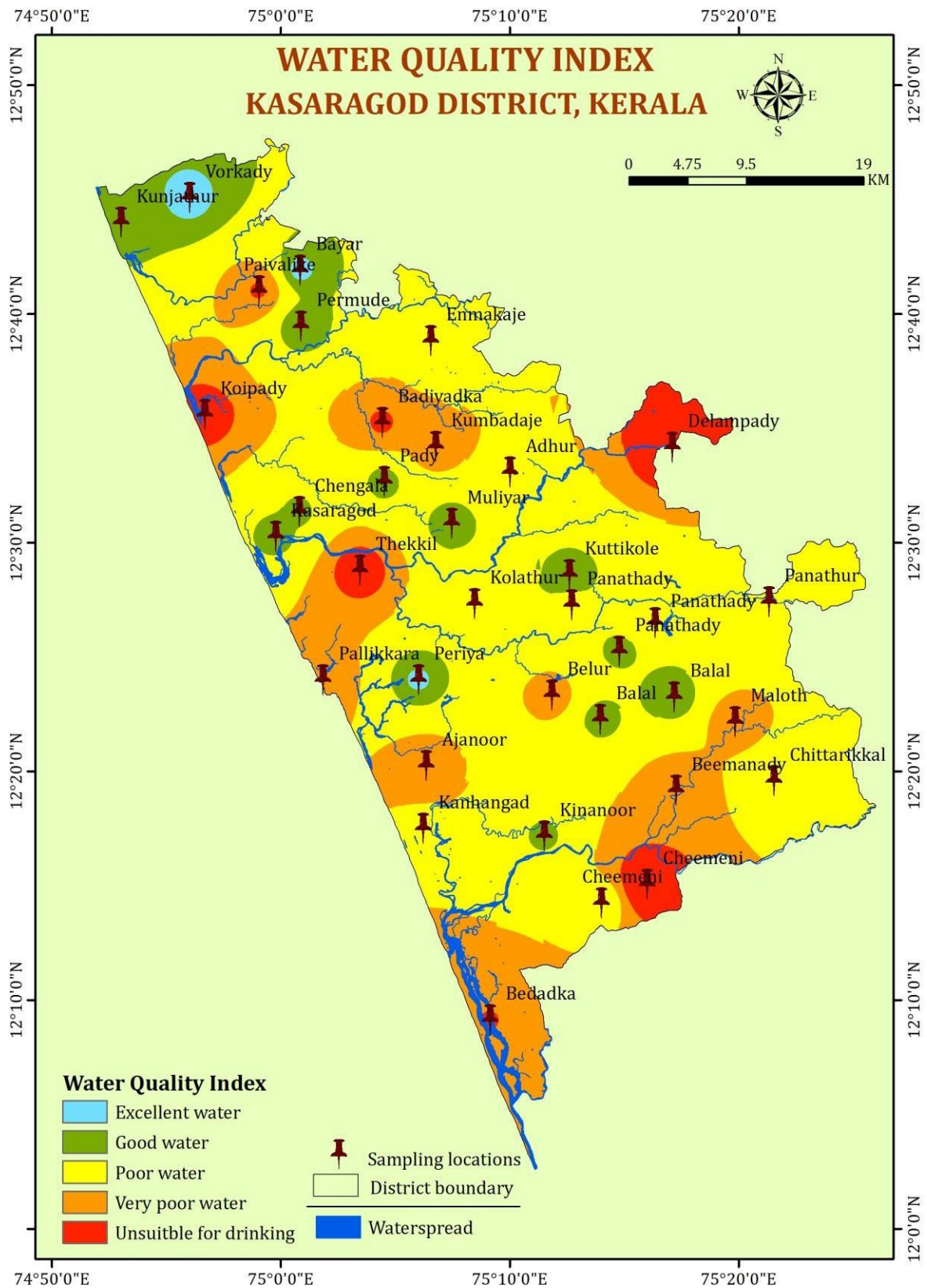
Range	Type of Water
<50	Excellent water
50–100	Good water
100–200	Poor water
200–300	Very poor water
>300	Water unsuitable for drinking purposes

Based on the groundwater quality index, 8 % of the samples falls under excellent and 30% of samples falls in good category, 44% of samples accounts to poor and very poor category and 18% of samples are unsuitable for drinking (Table 3). Spatial distribution of water quality indices is given in Fig 3.

**Table 3. Water quality index (WQI) classification for individual samples**

S. No	Well No	Block	Location	WQI	Classification type
1	192	Nileswaram	Cheemeni	111.05	Poor Water
2	193	Kanhangad	Pallikkara	265.54	Very poor water
3	195	Kanhangad	Ajanoor	261.85	Very poor water
4	196	Kanhangad	Belur	263.14	Very poor water
5	197	Kanhangad	Balal	48.40	Good Water
6	198	Nileswar	Beemanady	291.86	Very poor water
7	199	Kanhangad	Periya	38.44	Excellent Water
8	202	Kasaragod	Adhur	190.88	Poor Water
9	203	Manjeswar	Badiyadka	320.84	Unsuitable for drinking
10	204	Manjeswar	Mangalpady	161.93	Poor Water
11	207	Manjeswar	Enmakaje	104.81	Poor Water
12	208	Manjeswar	Vorkady	29.00	Excellent Water
13	209	Nileswaram	Kunjathur	111.05	Poor Water

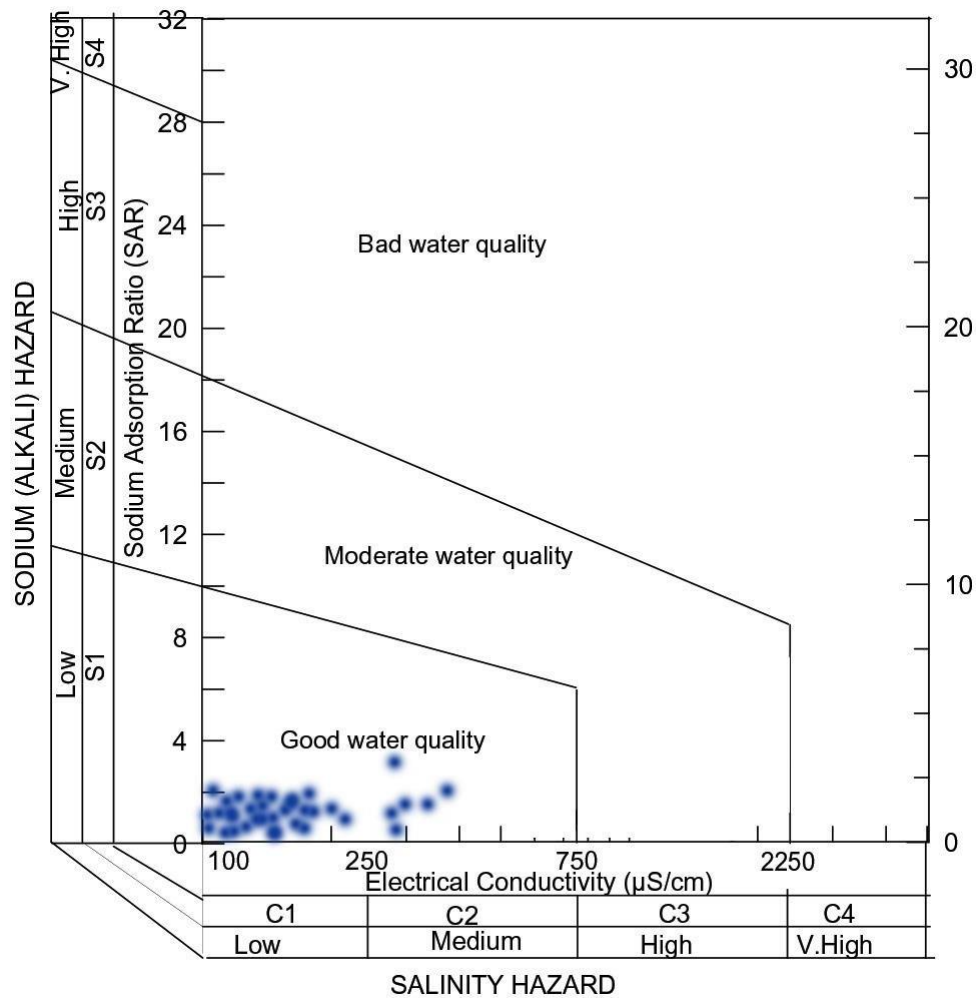
S. No	Well No	Block	Location	WQI	Classification type
14	210	Manjeswar	Bayar	71.75	Good Water
15	211	Kasaragod	Kumbadaje	32.39	Excellent Water
16	212	Manjeswar	Pady	259.25	Very poor water
17	213	Kasaragod	Delampady	67.35	Good Water
18	214	Kasaragod	Bedadka	437.28	Unsuitable for drinking
19	215	Kanhangad	Panathady	301.65	Unsuitable for drinking
20	216	Nileswar	Kanhangad	122.33	Poor Water
21	KSOW-01	Kasaragod	Kasaragod	179.86	Poor Water
22	KSOW-04	Manjeswar	Paivalike	76.90	Good Water
23	KSOW-05	Manjeswar	Permude	313.88	Unsuitable for drinking
24	KSOW-08	Kasaragod	Muliyar	51.97	Good Water
25	KSOW-09	Kasaragod	Thekkil	54.62	Good Water
26	KSOW-10	Kasaragod	Kolathur	399.63	Unsuitable for drinking
27	KSOW-11	Kasaragod	Kuttikole	125.68	Poor Water
28	KSOW-14	Nileswar	Cheemeni	71.19	Good Water
29	KSOW-16	Kanhangad	Panathady	469.91	Unsuitable for drinking
30	KSOW-17	Kanhangad	Panathady	88.48	Good Water
31	KSOW-18	Kanhangad	Panathur	110.63	Poor Water
32	KSOW-19	Kanhangad	Balal	154.60	Poor Water
33	KSOW-20	Kanhangad	Maloth	73.36	Good Water
34	KSOW-22	Nileswar	Chittarikkal	264.89	Very poor water
35	KSOW-24	Nileswar	Kinanoor	104.09	Poor Water
36	KSOW-25	Kasaragod	Chengala	86.54	Good Water
37	KSOW-02	Manjeswar	Koipady	87.15	Good Water



**Fig 3. Spatial distribution of water quality indices worked out for the study area**

### Assessment of irrigation water suitability

US salinity diagram: The US salinity lab's diagram (Richards 1954) is used for rating irrigation waters, where SAR is plotted against EC (Fig 3). All of the water samples of the study area cluster around the good water quality field C1S1 and C2S1 zones, indicating low to medium salinity water and are suitable for irrigation.



**Fig. 3 Irrigation water quality (Richards 1954)**

### **WAYANAD DISTRICT**

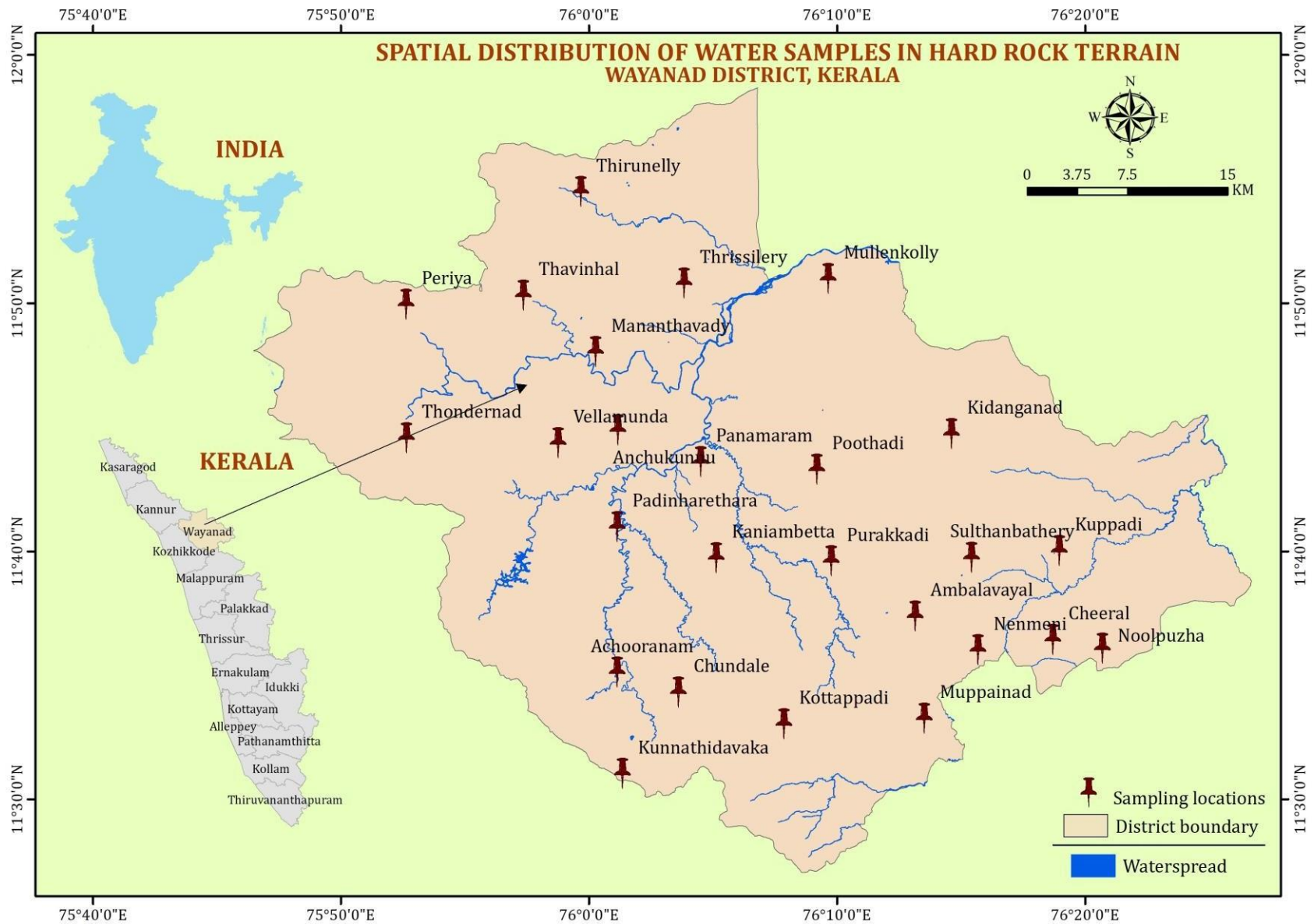
The department samples of Wayanad district collected from various hard rock terrain were analyzed for pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sodium (Na), potassium (K), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Total Alkalinity (TA), Carbonate (CO<sub>3</sub>), Bicarbonate (HCO<sub>3</sub>), Sulphate (SO<sub>4</sub>), Chloride (Cl), Nitrate-Nitrogen (NO<sub>3</sub>-N), and Iron (Fe). Fig 1 illustrates the spatial distribution of water quality samples of hard rock terrain in Wayanaddistrict.

The results of the physico-chemical parameters (Table 1) of the above samples showed that most of the samples for majority of parameters lie under the acceptable limits set by BIS (2012).

**Table 1. Statistical summary of physicochemical parameters and its comparison with BIS (2012) standards**

Variables	Minimum	Maximum	Mean	BIS (2012)	
				Acceptable limit	Permissible limit
pH	6.3	8.2	7.42	6.5-8.5	
EC (μS/cm)	54	549	238	-	
TDS (mg/l)	32.4	329.4	142.78	500	2000
Na (mg/l)	1.5	42.1	14	-	
K (mg/l)	0.42	19.5	4.12	-	
TH (mg/l of CaCO <sub>3</sub> )	21	186	74.69	200	600
Ca (mg/l)	4.3	57.4	20.12	75	200
Mg (mg/l)	1.3	25.5	5.96	30	100
TA (mg/l of CaCO <sub>3</sub> )	5	186	51.65	200	600
CO <sub>3</sub> (mg/l)	0	13.8	0.53	-	-
HCO <sub>3</sub> (mg/l)	5.6	199	61.9	-	-
SO <sub>4</sub> (mg/l)	0.8	29	10.52	200	400
Cl (mg/l)	8	75	28.4	250	1000
Fe (mg/l)	0	0.93	0.18	0.3	NR
NO <sub>3</sub> -N (mg/L)	1	13	6.91	10	NR



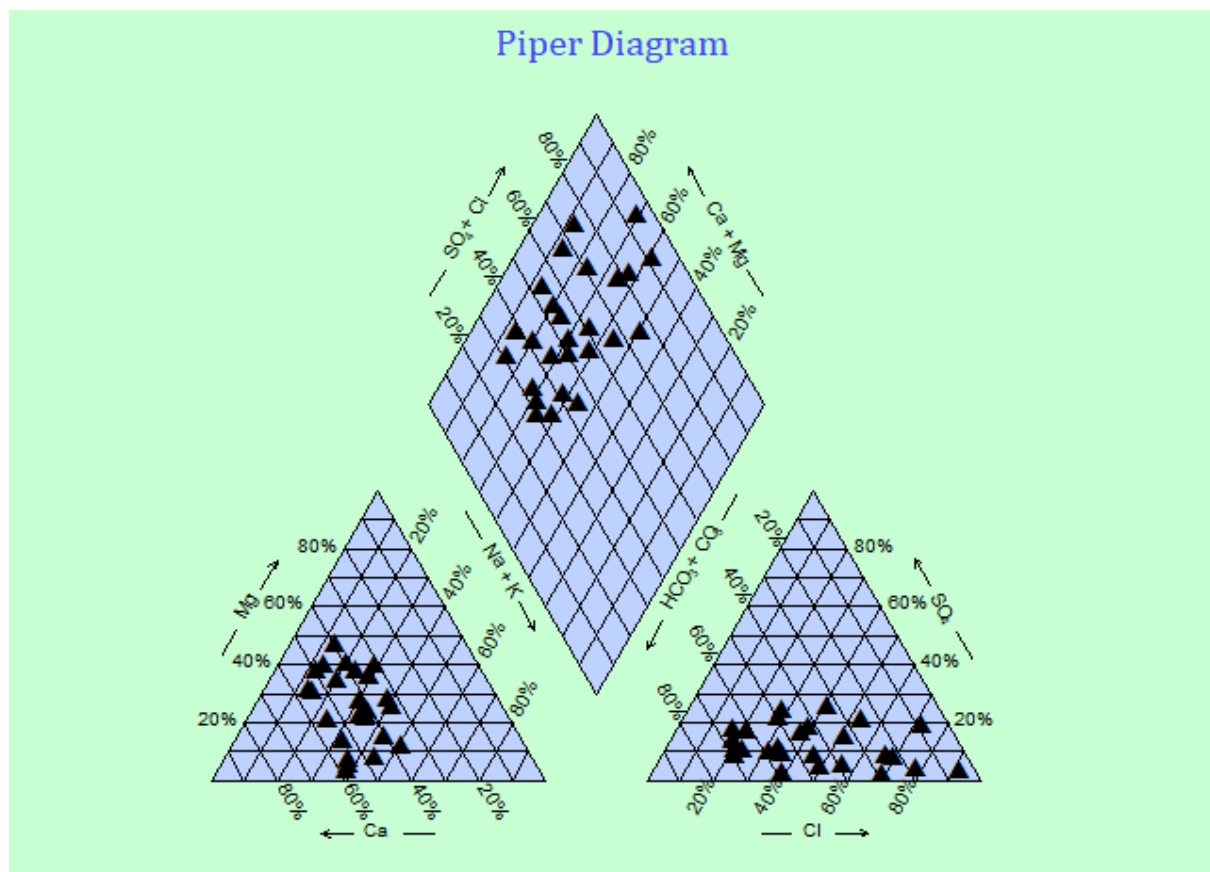


**Fig 1. Spatial distribution of sampling locations**



### Hydrochemical Facies and Water type

From the piper trilinear diagram (Fig. 2) it is depicted that the major hydrogeochemical facies are that majority of samples fall in non-dominant type followed by Ca-Mg-Cl type of water.



**Fig. 2 Piper (1953) diagram showing the relationship between dissolved ions in the water samples**

### Water Quality Index

The Water Quality Index (WQI) is calculated following (Tiwari and Mishra 1985; Singh 1992; Rao 1997; Mishra and Patel 2001; Gebrehiwot et al. 2011; Hema et al 2018). The groundwater quality issues of aquifers are generally location specific and time variant. The composition of different litho-units, permeability of soils, intensity and the kind of weathering, etc. are some of the natural factors determining the fate and dispersal of hydrochemical signals (especially cations and anions) in well waters. The

quality of well water is the outcome of many natural and man-made processes. Water quality classification ranges and types of water based on WQI values is shown in Table 2.

**Table 2. Classification ranges and type of water based on WQI (Krishnakumar et al 2014)**

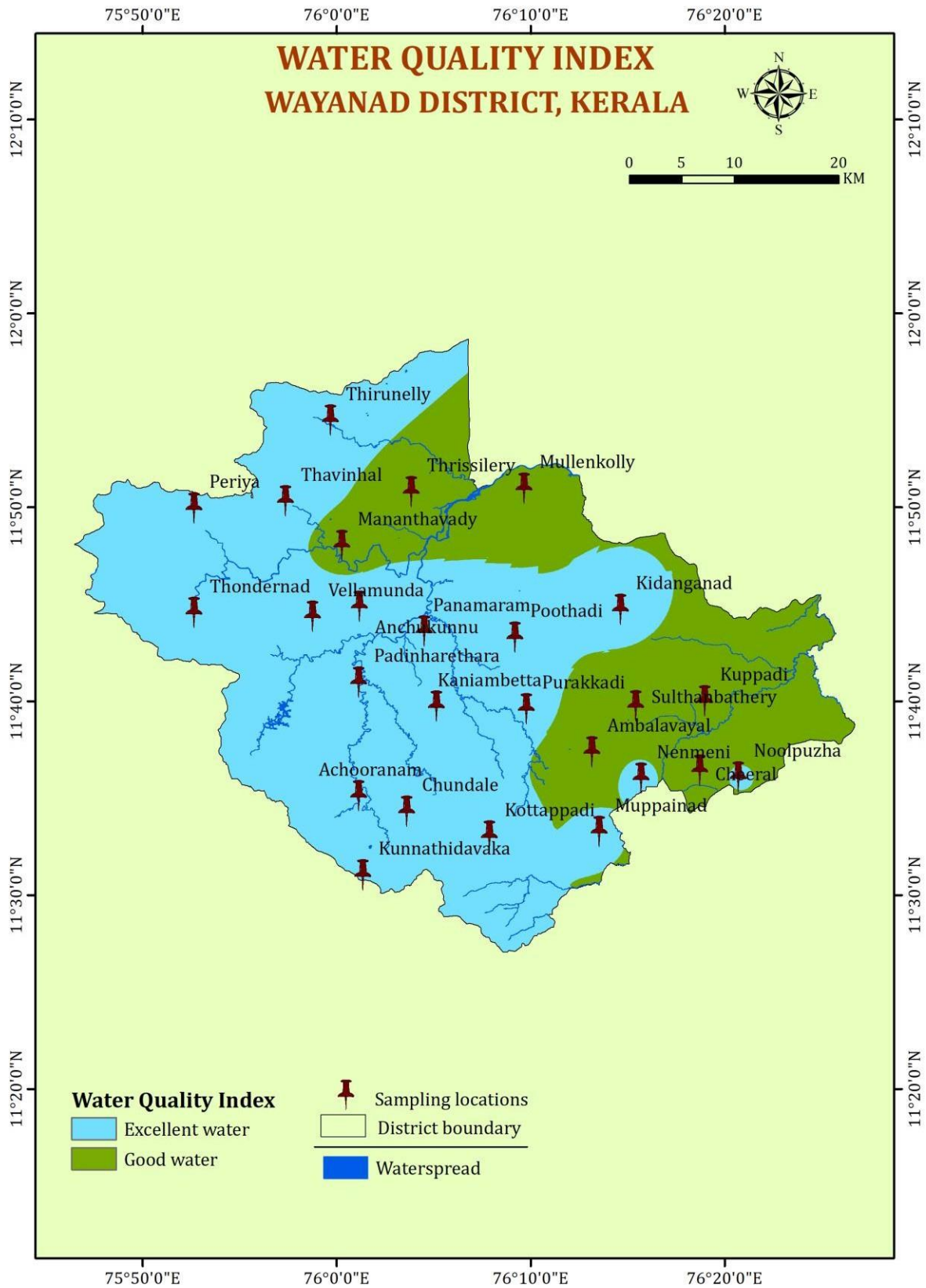
Range	Type of Water
<50	Excellent water
50–100	Good water
100–200	Poor water
200–300	Very poor water
>300	Water unsuitable for drinking purposes

Based on the groundwater quality index, 74 % of the samples falls under excellent and rest 26% of samples falls in good category (Table 3). Spatial distribution of water quality indices is given in Fig3.

**Table 3. Water quality index (WQI) classification for individual samples**

S. No	Well No	Block	Location	WQI	Classification type
1	167	Mananthavady	Anchukunnu	42.85	Excellent Water
2	SOW-11	Sulthanbathery	Mananthavady	58.72	Good Water
3	166	Mananthavady	Panamaram	31.60	Excellent Water
4	170	Sulthanbathery	Periya	33.75	Excellent Water
5	SOW-12	Sulthanbathery	Thavinhal	33.39	Excellent Water
6	SOW-14	Mananthavady	Thirunelly	14.94	Excellent Water
7	169	Kalpetta	Thondernad	34.07	Excellent Water
8	SOW-13	Sulthanbathery	Thrissilery	72.96	Good Water
9	168	Mananthavady	Vellamunda	30.62	Excellent Water
10	164	Sulthanbathery	Ambalavayal	60.29	Good Water
11	SOW-4	Sulthanbathery	Cheeral	79.90	Good Water
12	SOW-7	Sulthanbathery	Kidanganad	34.90	Excellent Water
13	SOW-6B	Sulthanbathery	Kuppadi	71.26	Good Water
14	SOW-9	Sulthanbathery	Mullenkolly	42.85	Excellent Water

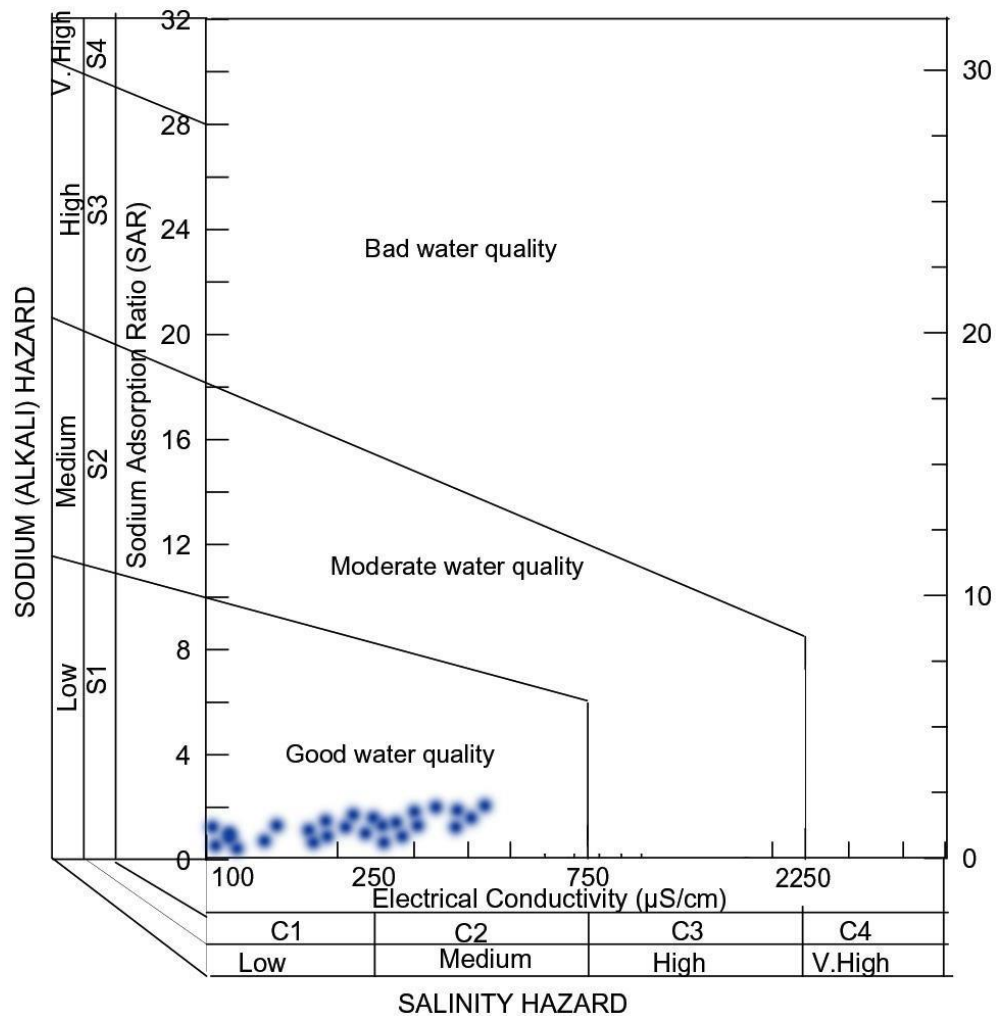
S. No	Well No	Block	Location	WQI	Classification type
15	SOW-3	Sulthanbathery	Nenmeni	62.66	Good Water
16	SOW-5	Sulthanbathery	Noolpuzha	39.00	Excellent Water
17	SOW-10	Sulthanbathery	Poothadi	42.89	Excellent Water
18	SOW-18	Kalpetta	Purakkadi	36.82	Excellent Water
19	165	Mananthavady	Sulthanbathery	40.67	Excellent Water
20	SOW-16	Mananthavady	Achooranam	59.33	Good Water
21	162	Kalpetta	Chundale	31.56	Excellent Water
22	SOW-17	Kalpetta	Kaniambetta	41.80	Excellent Water
23	163	Kalpetta	Kottappadi	38.80	Excellent Water
24	SOW-1	Sulthanbathery	Kunnathidavaka	42.11	Excellent Water
25	SOW-2	Sulthanbathery	Muppainad	27.78	Excellent Water
26	SOW-15	Mananthavady	Padinharethara	43.22	Excellent Water



**Fig 3. Spatial distribution of water quality indices worked out for the study area**

### Assessment of irrigation water suitability

US salinity diagram: The US salinity lab's diagram (Richards 1954) is used for rating irrigation waters, where SAR is plotted against EC (Fig 3). All of the water samples of the study area cluster around the good water quality field C1S1 and C2S1 zones, indicating low to medium salinity water and are suitable for irrigation.



**Fig. 3 Irrigation water quality (Richards 1954)**

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