Evaluation of Groundwater Quality for Irrigation during the PreMonsoon Period in the Selected Area of Thrissur District, Kerala

Athira .K .R[1], C. Unnikrishnan Warrier[2]

[1,2]Isotope Hydrology Division, Centre for Water Resources Development and Management, Kunnamangalam, Kerala, India

Abstract: ***The irrigation quality of groundwater from a selected study area from Thrissur district, Kerala have been studied in pre monsoon season to evaluate its suitability in relation to agricultural uses. Groundwater samples were collected from fifty seven open wells and were analyzed for various physico-chemical attributes like temperature, pH, electrical conductivity(EC), Na^+, K^+, Ca^{2+},Mg^{2+}, alkalinity, hardness, chloride, salinity, Total Dissolved Solids (TDS) and sulphates (SO_4^{2-}). All these parameters satisfies their corresponding desirable limits. Various determinants such as Permeability Index (PI), Residual Sodium Carbonate (RSC), Sodium Absorption Ratio (SAR) revealed that all the samples are good for irrigation. Moreover that, suitability of water for irrigation was evaluated based on the Total Salt Concentration, Magnesium Ratio (MR), Kelley's Ratio (KR), Sodium Percent (Na %), Wilcox and USSL diagrams.***

Keywords: Groundwater Quality, Irrigation, Pre monsoon, Thrissur

1. Introduction

Water, the elixir of life has played the most critical and vital role throughout the history of mankind. And it continue to be an essential factor in modern times too. Groundwater is one of the most important and indispensable water resource available to humanity worldwide. Quality of groundwater is as important as its quantity. Groundwater is precious only when its quality is suitable for a variety of needs and is an essential and vital component of any life support system. It is not only the basic need for human existence but also a vital input for all development activities [1]. In Indian Scenario, it is estimated that nearly 70-80% of the irrigated food production is from groundwater [2]. Poor groundwater quality adversely affects the plant growth and thus will reduce the crop yield. So the impact of groundwater quality for irrigational purpose has an immense control over output of the agricultural sector. In Kerala Groundwater is one of the primary sources of water for human consumption, agriculture and industrial uses. Determination of physical, chemical and bacteriological quality of water is essential for assessing its suitability for various purposes like drinking, domestic, agricultural and industrial uses [3]. Quality of groundwater in coastal and non-coastal aquifers is constrained by several factors, both natural and anthropogenic. A proper understanding of the quality aspects of groundwater regime has a vital role in scientific management of groundwater resources [4].

The present study aims to evaluate the quality of groundwater for irrigation during the premonsoon season along a selected area of Thrissur District, Kerala.

2. Study Area

The present study covers an area of about 1025 km^{2}in Thrissur district in Central Kerala. The study area lies between longitudes 76˚06ˡ to 76˚30ˡ E and latitudes 10˚17ˡ to 10˚47ˡ N in the Survey of India Toposheet No.58B (58B/2, B/3, B/4, B/7, B/8). Study area is having 41 km long coast which is stretching from Vadanappally beach in the north to the Azhikode coast in the south with an approximate width of 25 km. It accounts nearly 33% of the total area of Thrissur district and is bounded on the south by the administrative boundary of Ernakulam district and Arabian Sea on the west. The western lowlands (coastal plains) and the central midlands regions are the two geomorphologic units embracing majority of the study area. Karuvannur river and Chalakudy river are the main rivers drained in the study area. And the Periyar river flow a small distance through the study area which almost demarcates the southern boundary of the study area.

Study area enjoys a tropical climate with an average annual rainfall of about 3198 mm.The maximum rainfall occurs during the south-west monsoon and nearly 71% of the total rainfall is received during this season whereas 16% of the total rainfall is received during North East monsoon, and the rainfall is received during January to May contributed the rest.

There are found four distinct types of soils in the study area such as Coastal alluvium, acid saline, alluvium, and laterite soil. The study area includes the land use categories namely Water bodies, Kole land, Residential, Agriculture, Plantation, Residential/Agriculture Mix, other Built up land use and Others.

2.1 Geology

The study area can be divided into three geological units namely Quaternaries of the coastal tract, Gneissic belt and the Charnockite belt. The Quarternaries of coastal tract is consisting of geological formations like Kadappuram, Guruvayur, Periyar and Viyyam formations. Unconsolidated Quaternary sediments overlie the basement rocks unconformably. Gneissic belt represented by biotite gneiss of Migmatite complex is the major rock of the study area. This is mainly extending from Thrissur in the north to

Kottapuram in the south. Charnockite is generally massive but when foliated has a gneissic look, so the term charnockite/charnockite gneiss is used. Small lenticular bodies of biotite gneiss are seen within the charnockite terrain of Archean age. Dolerite and gabbro dykes are seen cutting across these older rocks and are generally aligned in NNW-SSE trend. Both are basic intrusives with palaeogene age of origin. Pegmatites and quartz veins occur within the charnockite and gneisses, mostly as fracture fillings. They are of small dimension and show no concentration in specific locality.

2.2 Hydrogeology

The study area can be mainly divided into two provinces based on the groundwater resource and its quality; (1) In the coastal plain the yield of water is high with shallow aquifer but in places the water is brackish and (2) In the midland area with laterite cover dug wells are more promising for domestic needs. The aquifer system can be broadly divided into hard rock aquifers, laterite aquifers and sedimentary aquifers. The sedimentary aquifers are seen along the coast and river courses while the hard rock and laterite aquifers constitute the remaining portion of the aquifer system. The main groundwater extraction structure in the study area are open wells. The diameter of the observational wells ranges from 0.85 to 3.77 m and depth ranges from 2.15 to 14.6 m. The depth to water level ranges from 1.1 to 11.85 m (bgl) during the study period.

3. Methodology

Groundwater samples were collected from 57 open wells (AGW1-AGW2) spaced ~ 4-5 km apart, covering the selected study area for pre monsoon (April, 2016) period (Fig 1:).

The selected wells are mainly used for domestic purposes. The physiochemical parameters like pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Salinity and Temperature were measured from the field itself using a hand held multi-parameter instrument. The samples were collected in cleaned fresh one litre polyethylene bottles for chemical analysis. These bottles were rinsed with sample itself prior to fill them with corresponding samples. The bottles were labeled properly and fetched to the laboratory for hydrochemical analysis. Chemical analysis of the collected groundwater samples from the study area were carried out for the major and minor ion concentration using the standard procedures as per APHA. Other Parameters like Total Alkalinity (TA), Total Hardness (TH), Calcium, Magnesium, Chloride, Fluoride, Sulphate, Phosphate, Nitrate, Sodium, Potassium and iron were analyzed in the laboratory by following standard methods [5]. Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Chloride (Cl^-) and Bicarbonate (HCO_3^-) concentration were determined by volumetric titration methods. Sodium (Na^+) and Potassium (K^+) are determined using Flame Photometer. Nephlo-turbidity meter was used to detect the concentration of Sulphate (SO_4^{2-}). Determination of Phosphate (PO_4^{3-}), Iron (Fe^{2+}), and Nitrate (NO_3^-) were done using Spectrophotometer.

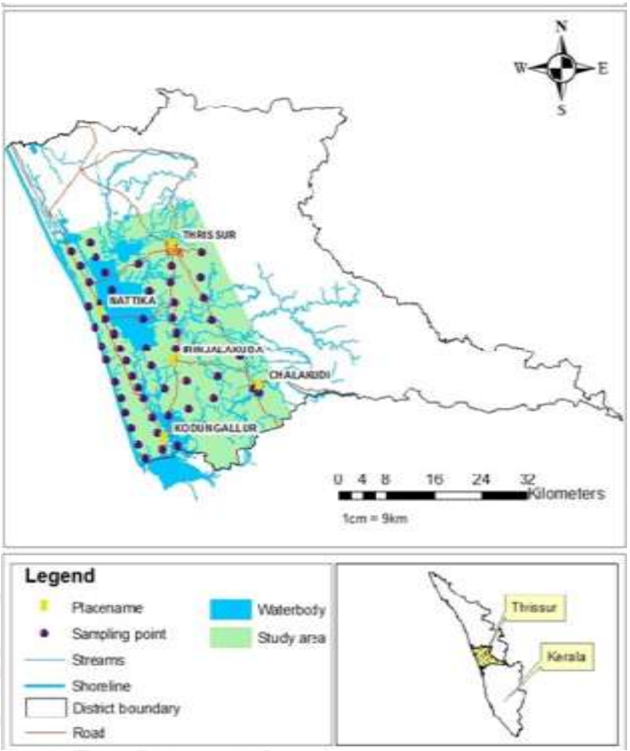

Figure 1: Location map of the study area with sampling points

In order to evaluate the groundwater quality for agricultural purposes certain irrigation determinants such as Percent Sodium (Na %), Kelly's ratio (KR) and Magnesium Ratio (MR), Permeability Index (PI), Residual Sodium Carbonate (RSC) and Sodium Absorption Ratio (SAR) were calculated.

4. Results and Discussion

A summary of the physico-chemical analysis of the groundwater samples is presented in Table1.

The pH of most samples show a narrow range (7.24-8.6; avg = 8.04) and all the samples showing a pH value greater than 7 thus fall in alkaline category. The EC ranges from 30.7 to 738 µS/cm and two samples (AGW17 and AGW23) show relatively higher values among the observation wells. The average value of TH is 68 mg/L and the quality of water varies from soft to hard. Based on salinity values (27.2-490 mg/l) all the samples of good quality and categorized as fresh. The collected samples indicates calcium hardness is more prominent than magnesium hardness in the study area. The concentration of sodium and potassium ranges from 5.2-220 mg/l and 0.4-32.8 mg/l respectively. The concentration of bicarbonate varies from 12.2 to 236.7 mg/l whereas sulphate shows a range from 0.6-81.7 mg/l with an average value of 14.4 mg/l. The dominance of the cations and anions showed the following order: $Na^+ > Ca^{2+} > K^+ > Mg^{2+}$ and $HCO_3^- > Cl^- > SO^{4-}$. Except iron values of 10 samples all other chemical parameters are coming under desirable limits as per Bureau of Indian Standards for domestic uses [6], [7]. The higher iron concentration may be attributed to the laterite and lateritic soils.

Table 1: Descriptive statistics of groundwater samples during April, 2016.

Parameters	Min	Max	Mean
Temperature	26.9	29	27.6
pH	7.24	8.68	8.04
EC	30.7	738	187.9
TH	8	210	68
Ca^{2+}	1.6	64.8	16.6
Mg^{2+}	0.48	45.6	6.3
Cl^-	2.1	238.9	26.6
HCO_3^-	12.2	236.7	67.2
TA	10	194	55.1
Na^+	5.2	220	25.3
K^+	0.4	32.8	5.7
SO_4^{2-}	0.6	81.7	14.4
TDS	21.8	520	164.2
Salinity	27.2	490	129.9

All units are expressed in mg/L except pH, EC(µS/cm);TH-Total Hardness as $CaCO_3$; TA-Total Alkalinity;TDS-Total Dissolved Solids

4.1 Evaluation of groundwater quality for irrigation

The suitability of groundwater for irrigation is depending on the effects of the mineral constituents of water. Water for irrigation should satisfy the needs of soil and crop. EC and Na^+ play a vital role in the suitability of water for irrigation. The high salt content in irrigation water affects the plant growth, soil structure, permeability and aeration [8]. Various water quality determinants such as Kelley's Ratio, Magnesium Ratio, Percent Sodium, Permeability Index, Residual Sodium Carbonate and Sodium Absorption Ratio are used to determine the suitability of water for irrigation. A summary of computed values of irrigational water quality indices of the groundwater samples in the study area is given in the Table 2.

Table 2: summary of computed values of irrigational water quality indices of the groundwater samples in the study area

Parameters	*Min*	*Max*	*Average*
SAR	0.30	7.25	1.45
Na%	10.46	81.61	49.37
RSC	-2.45	0.61	-0.04
PI	56.29	190.05	102.94
KR	0.11	4.10	1.16
MR	5.13	90.48	33.30

4.1.1. Total Salt Concentration

For the determination of irrigation water quality total salt concentration is an important factor and it is expressed as electrical conductivity. There is a four-fold classification for irrigation water in terms of hazardous effect of total salt concentration (EC). Thus the irrigation water classified into four classes such as with low hazard effect (<1500µS/cm), medium hazard effect (1500-3000µS/cm), high hazard effect (3000-6000µS/cm) and very high hazard effect (>6000µS/cm) [6]. Based on this simple parameter all the collected groundwater samples were characterized as irrigation water with low hazardous effect.

4.1.2 Percent Sodium (Na%)

The sodium in irrigation waters is usually denoted as percent sodium. In all natural waters Na% is a common parameter to assess its suitability for irrigational purposes [9]. This irrigational determinant was obtained by using the following equation:

$$\text{Na }\% = \frac{(Na^+ + K^+)}{(Ca^{2+} + Mg^{2+} + Na^+ + K^+)} \times 100$$

,where all ionic concentrations are expressed in meq/l. The details of the categories based on the sodium percent is presented in the Table 3.

Table 3: Classification of Irrigational water quality based on Na%

Classification Pattern	Categories	No. of samples	% of samples
Percent Sodium (Na%) (Wilcox, 1955)	Excellent (0-20)	1	1.5
	Good (20-40)	20	35
	Permissible (40-60)	17	30
	Doubtful (60-80)	17	30
	Unsuitable (>80)	2	3.5

Wilcox diagram is adopted for classification of irrigation, wherein the EC is plotted against Na% (Fig 2:). This diagram relating Na% and total concentration shows that only one sample falls within the permissible to doubtful category whereas all other samples belong to the excellent to good category.

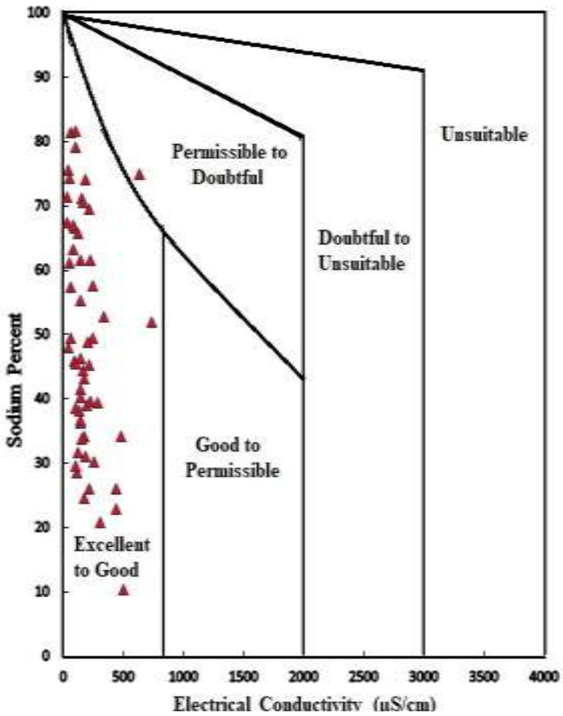

Figure 2: Classification of irrigation water quality, with respect to total salt concentration and sodium percent.

4.1.3 Kelley's Ratio (KR)

Irrigation water quality can be rated using the Kelley's Ratio (KR), which is defined as the level of Na^+ measured against Ca^{2+} and Mg^{2+} [10], [11]. The Kelley's Ratio was calculated by the following equation:

$$KR = \frac{Na^+}{(Ca^{2+} + Mg^{2+})}$$

The values of KR falls in the range of 0.11-4.10 in the study area. During the study period 63% of the collected samples showed KR<1 (suitable for irrigation) while 37% falls in the unsuitable category. The evaluation indicates that 37% of the samples are having excess concentration of sodium, thereby making the water unsuitable for irrigation.

4.1.4 Magnesium Ratio (MR)

Normally in most waters calcium and magnesium maintains a state of equilibrium. The MR is the excess amount of Mg^{2+} over Ca^{2+}. MR is otherwise called as magnesium hazard, the concept was developed by Paliwal [11]. The excess Mg^{2+} affect the quality of soil resulting in poor agricultural returns. MR value> 50 makes it unsuitable whereas MR value < 50 makes the water suitable for irrigation [12]. The MR was calculated using the following equation:

$$MR = \frac{Mg^{2+}}{(Ca^{2+} + Mg^{2+})} \times 100$$

In the study area the magnesium hazard value falls in the range of 5.12 to 90.47%. 46 samples(81%) exhibit magnesium ratio <50 thus indicating their suitability for irrigation. The evaluation illustrates that 11 samples ie., 19% of the samples falls in the unsuitable category can cause adverse effect on the yield of agriculture as the soil becomes more alkaline.

4.1.5 Permeability Index (PI)

The permeability index is effectively used to evaluate the suitability of water for irrigation. Doneen [13] classified irrigation water based on the Permeability Index into three classes, and PI is calculated using the formula given below:

$$PI = \frac{Na^{+} + \sqrt{HCO3^{-}}}{(Ca^{2+} + Mg^{2+} + Na^{+})} \times 100$$

Class I and II water are categorized as good for irrigation with 75% or more of maximum permeability. Class III water is suitable with 25% of maximum permeability [13]. Based on the PI values, 86% of the samples belong to Class I and the remaining 14% of the samples belong to Class II category. There is no sample with PI value less than 25%.

4.1.6 Residual Sodium Carbonate (RSC)

The Residual Sodium Carbonate also indicates whether groundwater is suitable for irrigation or not.
Groundwater with higher bicarbonate concentration will precipitate calcium and magnesium cations as carbonates. The excess sum of CO_3^{2-}+ HCO_3^- in groundwater over the sum of Ca^{2+} and Mg^{2+} also influences the suitability of the groundwater for irrigation that is evaluated based on Residual Sodium Cabonate [14].

RSC= $(CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$, where the concentrations are reported in meq/l. Based on RSC irrigation water can be classified as suitable (<1.25), marginal (1.25-2.5) and not suitable (>2.5) [12]. The RSC values of groundwater samples shows that 100% of the samples are suitable for irrigation having values <1.25. Agricultural usage of groundwater with RSC values greater than 2.5 will eventually leads to the degradation of physical condition of soil by hindering the air and water movement through void spaces because of the accumulation of salt.

4.1.7 Sodium Absorption Ratio

The assessment of Na^+ Concentration is essential for evaluating the irrigational suitability of groundwater. Excess sodium ions in water will produce undesirable effects such as alteration of soil properties and reducing soil permeability [10]. SAR indicates the degree to which irrigation water enters into cation exchange reactions in soil. The Na^+ replacing adsorbed Ca^{2+} and Mg^{2+} is a hazard as it causes damage to the soil structure, making it compact and impervious. SAR is expressed as an equation as follows:

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

where the concentrations were reported in meq/l.

Based on SAR irrigation water is classified [14] has indicated that all the groundwater samples belongs to the excellent category. USSL diagram (Fig 3:)is also used for rating irrigation water, wherein SAR is plotted against specific conductance .Sodium and salinity hazard are the two significant parameters that can suggest suitability of water for irrigation purposes. As per USSL diagram, it has been noted about 60% of the samples fall within C1S1 (low sodium hazard, low salinity hazard) category. While 18% of the pre-monsoon groundwater samples belong to C2S1 (low sodium hazard and medium salinity hazard). Water belongs to this two categories can be used for irrigation effectively in an all soil types. Water with high sodium hazard will generate exchangeable sodium in a harmful level, so this situation demands regular leaching and special soil management for salinity control.

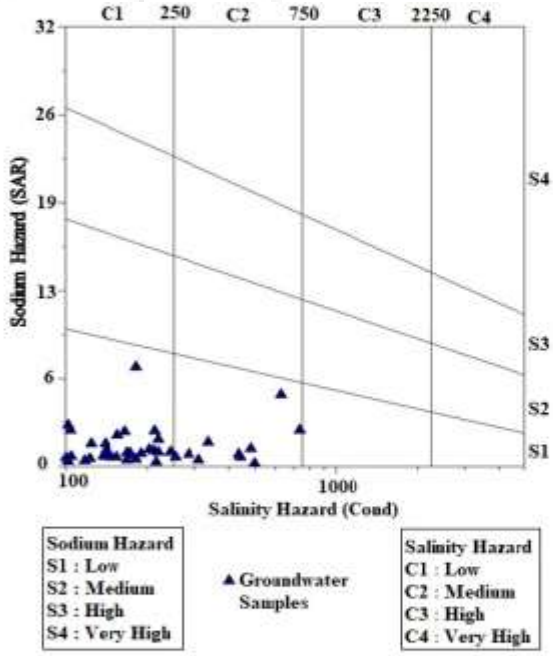

Figure 3: Suitability of groundwater for irrigation based on salinity and alkali hazard

5. Conclusion

The pH of all the samples showing alkaline in nature. It has been noted that cation and anion dominance is in the order of $Na^+ > Ca^{2+} > K^+ > Mg^{2+}$ and $HCO_3^- > Cl^- > SO_4^{2-}$ respectively. Total salt concentrations expressed as EC indicates that all water samples have low hazardous effect hence are suitable for irrigation purpose. The SAR and RSC of all samples fall under excellent and good category. Based on USSL diagram 35% of the groundwater samples were having low alkali and low salinity hazard (C_1S_1) and 9% of samples belong to low alkali and medium salinity hazard (C_2S_1) whereas two samples show low alkali and high salinity hazard (C_3S_1). Higher salinity has required regular leaching and special soil management to control salinity. Na% (66.5%), MR (81%) and KR (63%) indicated groundwater samples are suitable for irrigation. The study based on the hydrochemical analysis and using various statistical determinants concludes that overall evaluation of groundwater quality for irrigation was found to be satisfactorily good for its purpose during the study period from the selected study area of Thrissur District.

6. Acknowledgement

This article is a part of thePh.Dprogramme of the corresponding author. The study also forms part of the CWRDM Plan funded project 'Stable Isotopic and Geochemical Characterization of Groundwater from Kodungallur Coast, Thrissur District'. The authors gratefully acknowledge the Kerala State Council for Science Technology and Environment (KSCSTE), for their financial assistance, whereas the Executive Director, CWRDM, Kozhikode acknowledgedfor the permission given to publish the article.

References

[1] S.V. Sarath Prasanth , N.S. Magesh, K.V. Jitheshlal, N. Chandrasekar, K.Gangadhar, 'Evaluation of groundwater quality and its suitability for drinking and agricultural use in the coastal stretch of Alappuzha District, Kerala, India," Appl Water Sci, (2), pp. 165-175, 2012.

[2] M. Shyni and C.Unnikrishnan Warrier, "Assessment of Groundwater Quality for Irrigation in the Southern Coastal Area of Kannur District, Kerala," International Journal of Science and Research, Vol.6 Issue 6, pp. 189-193, 2017.

[3] T.M. Manjusree, Sabu Joseph, Jobin Thomas, "Hydrogeochemistry and Groundwater Quality in the Coastal Sandy Clay Aquifers of Alappuzha District, Kerala," Journal Geological Society of India, Vol.74, pp. 459-468, 2009.

[4] CGWB, "Report On Status Of Ground Water Quality In Coastal Aquifers Of India,"Government of India, Ministry of Water Resources, Central Ground Water Board, Faridabad,Haryana, pp. 1-121, 2014.

[5] APHA, "Standard methods for the examination of water and waste water," 21stedition, American Public Health Association, Washington DC, 2005.

[6] Bureau of Indian Standards (BIS),"Guidelines for the Quality of Irrigation Water," IS 11624 (1986, Reaffirmed 2009), UDC 631. 671. 03: 626. 810 (026).

[7] WHO, "Guidelines for drinking water quality 4thedition, incorporating the 1st addendum," World Health Organization, Geneva, pp. 219-230, 2017.

[8] D.K. Todd, L.W.Mays,"Groundwater Hydrology." John Wiley & Sons, Inc second edition, pp.329-357, 2005.

[9] L.V. Wilcox, "Classification and use of irrigation water," Agric circ 969, USDA, Washington D.C., pp. 19,1955.

[10] W.P. Kelley, "Alkali Soil-Their Formation Properties and Reclamation," Reinold publication, New York, 1946.

[11] K.V. Paiwal, "Effect of Gypsum application on the quality of irrigation water," The Madras Agri. Jour (59), pp.646-647, 1967.

[12] J.W. Lloyd and J.A. Heathcoat, ''Natural Inorganic Hydrochemistry in relation to groundwater: An introduction," Claredon Press, Oxford, 1985.

[13] L.D. Doneen, "Notes on water quality in agriculture", Published as a Water Science and Engineering Paper 4001, Department of Water Science and Engineering University of California, 1964.

[14] L.A. Richard, "Diagnosis and improvement of saline and alkali soils," Handbook 60, USDA, Washington D.C., 1954.

Author Profile

Dr. C. Unnikrishnan Warrier (1968-2017) received M.Sc. and M. Phil. degree in Geology from University of Madras, Chennai in 1990 and 1991, respectively. He obtained his D.Sc. in Geology from Osaka City University, Japan in 1995. At the time of his sad demise, he was the principal Scientist and Head in Isotope Hydrology Division (IHD), Centre for Water Resources Development and Management (CWRDM), Calicut, Kerala,India.

Athira. K. R has completed her B.Sc degree in Geology from Christ College Irinjalakuda in the year 2012 under Calicut University. She received M.Sc. degree in Geology from Department of Geology, Kariavattom Campus, University of Kerala. She is now doing research in Hydrogeology at Centre for water Resources Development and Management (CWRDM), Calicut, Kerala, India with KSCSTE research Fellowship.