

Assessment of Groundwater Quality for Irrigation in the Southern Coastal Area of Kannur District, Kerala

Shyni M¹, C. Unnikrishnan Warri²

^{1,2}Isotope Hydrology Division, Centre for Water Resources Development and Management, Kunnamangalam, Kerala, India

Abstract: This study aims to investigate the groundwater quality for irrigation in the southern coastal area of Kannur district, Kerala. Fifty five samples were collected in premonsoon season (May 2016) and analysed for various physico chemical parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), sodium (Na⁺), potassium (K⁺), calcium (Ca²⁺), magnesium (Mg²⁺), bicarbonate (HCO₃⁻), chloride (Cl⁻) and sulphate (SO₄²⁻). From the hydrochemical analyses suitability of water for irrigation was evaluated based on Sodium Adsorption Ratio (SAR), Sodium Percent (Na%), Permeability Index (PI), Residual Sodium Carbonate (RSC), Kelly's Ratio (KR), Magnesium Ratio (MR) and USSL diagram. Results of physico chemical analyses revealed majority of samples show an acidic pH with a mean value of 5.64, TDS of 85.33mg/l, EC of 157.63µS/cm, Ca of 10.39mg/l, Mg of 3.05mg/l and Na of 12.16mg/l. SAR and RSC show that the groundwater of the study area is suitable for irrigation. USSL diagram showed that samples fall under C₁S₁ (low alkali and low salinity hazard), C₂S₁ (low alkali and medium salinity hazard) and C₃S₁ (low alkali and high salinity hazard) categories. Thus most of the groundwater samples are acceptable for irrigation purpose.

Keywords: Groundwater, Irrigation, Hydrochemistry, Kannur

1. Introduction

Groundwater is an important source of water for drinking and irrigation. The quality of water determines its suitability for a specific purpose. Use of poor quality water adversely affects the human health and growth of plants [1], [2]. Water with high salt concentration can generate physiological drought which affects the plant growth and reduce crop yield [3]. It has been estimated that 70-80% in India and 40% of the world's irrigated food production is from groundwater. Geochemical assessment reveals the quality of groundwater for various uses such as drinking, irrigation and industrial purposes. A numbers of studies on quality of groundwater with respect to drinking and irrigation purposes have been carried out in the different parts of the country [4], [5], [6], [7], [8].

The present study aims to find out the quality of groundwater for irrigation along southern coastal area of Kannur District, Kerala.

2. Study Area

The study has been carried out in Thalassery and Edakkad blocks and Thalassery municipality in Kannur district of Northern Kerala. The study area lies between latitudes 11° 41' to 11° 56' North and longitudes 75° 28' to 75° 36' East. Study area is having 22 km long coast with a maximum width of 14 km and is enriched with three rivers namely Anjarakady, Dharmadam and Mahe.

The geology of the area show that the Tertiary and coastal alluvium ranging in age from Archean to Recent underlain by hornblende biotite gneiss and schist. The Archaean crystallized rocks and the Tertiary sedimentary rocks are extensively lateritised. Minor laterite cliffs of various heights from 50-60m above Mean Sea Level are the characteristics of the study area.

The average annual rainfall in the study area is around 3030mm. The southwest monsoon contributed about 70% of the rainfall where as the northeast monsoon and premonsoon rain together contributed the rest.

Open wells are the main groundwater extraction structure in the study area. The diameter of the open wells ranges from 2 to 3.5 m and depth ranges from 2 to 18 m. The depth to water level ranges from 1.2 to 17.2 m (bgl) during the study period.

3. Methodology

Groundwater samples were collected from 55 open wells during Premonsoon (May 2016) season (Fig 1:).

Samples were collected in white poly ethylene bottles of 1 litre capacity. Before the collection of samples these bottles were rinsed with sample. After the sample collection the bottles were labeled properly and carried to the laboratory for hydrochemical analysis. pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Temperature, Dissolved Oxygen (DO) and salinity were measured insitu. Samples were analyzed in the laboratory for major cations such as sodium (Na⁺), potassium (K⁺), calcium (Ca²⁺), magnesium (Mg²⁺) and anions such as bicarbonate (HCO₃⁻), chloride (Cl⁻) and sulphate (SO₄²⁻). Standard procedures were followed for the analysis [9]. Total Hardness (TH), calcium, magnesium, chloride and bicarbonate were analyzed by volumetric titration. Sodium and potassium were measured by flame photometry. Sulphate is determined by Nephelo turbidity method. In order to determine the quality of water for irrigation Sodium Adsorption Ratio (SAR), Percent Sodium (Na %), Permeability Index (PI), Residual Sodium Carbonate (RSC), Kelly's ratio (KR) and Magnesium Ratio (MR) were calculated.

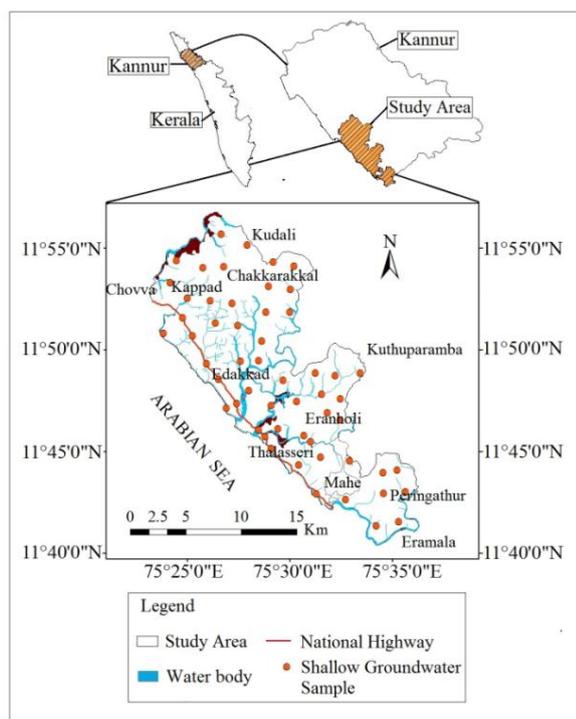


Figure 1: study area with sampling point

4. Results and Discussion

The summary of results of hydrochemical analysis is given below in Table 1. It illustrates that the groundwater in the study area is generally acidic in nature (93%). The acidic nature of the water may be attributed to the laterite and lateritic soils.

Table 1: Minimum, Maximum and Average of physicochemical composition of groundwater samples.

Parameters	Min	Max	Avg
pH	4.56	8.22	5.64
EC	25.60	1145.00	157.63
Ca ²⁺	1.60	100.80	10.39
Mg ²⁺	0.00	16.32	3.05
Na ⁺	1.90	42.30	12.16
K ⁺	0.30	30.00	4.63
HCO ₃ ⁻	4.88	363.56	35.09
Cl ⁻	4.25	154.56	18.64
SO ₄ ²⁻	3.17	22.37	6.61

All units are expressed in mg/l except pH, EC (µS/cm)

EC in the area ranges from 25.60- 1145µS/cm. The concentration of Na⁺, K⁺, Ca²⁺, Mg²⁺, HCO₃⁻ and SO₄²⁻ ranges from 1.90-42.30mg/l for Na⁺ and 0.3-30mg/l for K⁺, 1.6-100.8 for Ca²⁺, 0-16.32mg/l for Mg²⁺, 4.88-363.56mg/l for HCO₃⁻ and 3.17-22.37mg/l for SO₄²⁻ respectively. The dominance of the cations and anions showed the following order: Na⁺>Ca²⁺>K⁺>Mg²⁺ and HCO₃⁻>Cl⁻>SO₄²⁻.

4.1. Irrigation quality of water

Quality of groundwater used for irrigation plays a dominant role in plant growth as well as crop yield. If the concentration of salts in the soil solution is high then the osmotic pressure of the solution will increase. It physically affects the growth of plants by reducing the capacity to uptake water. Salts

concentration affects the soil structure, permeability and aeration which indirectly affect the growth of plants. In order to classify the quality of groundwater for irrigation various determinants such as Sodium Adsorption Ratio (SAR), Sodium Percent (Na%), Permeability Index (PI), Residual Sodium Carbonate (RSC), Kelly's Ratio (KR), Magnesium Ratio (MR) were calculated. Statistical representation of irrigational quality parameters of the groundwater samples is presented in Table 2:

Table 2: Minimum, maximum and average of irrigational quality indices of the groundwater samples

Parameters	Min	Max	Average
SAR	0.22	3.77	1.04
Na%	9.58	87.91	50.95
RSC	-4.00	0.20	-0.20
PI	22.32	196.39	112.75
KR	0.07	5.43	1.18
MR	0.00	83.33	41.90

All units are expressed in meq/l

4.1.1. Total salt concentration

Total salt concentration is an important factor that determines the irrigation water quality. It is expressed as electrical conductivity. In relation to hazardous effect of total salt concentration (EC), the irrigation water classified into four classes such as low (<1500µS/cm), medium (1500-3000µS/cm), high (3000-6000µS/cm) and very high (>6000µS/cm) [10]. All water samples were characterized by low hazardous effect and fall under good to permissible class for irrigation [11].

4.1.2. Sodium Adsorption Ratio (SAR)

Sodium Adsorption Ratio is the most commonly used method to evaluate the effects of exchangeable sodium on the physical condition of the soil [12]. The excess sodium in water reacts with soil which changes the soil structure and reducing the soil permeability. Then the soil becomes compact and impervious. SAR is calculated from the ratio of sodium to calcium and magnesium and is defined as the following equation.

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

All concentrations were expressed in meq/l.

Richards [12] classified the irrigation water into four classes based on SAR as Excellent (0-10), Good (10-18), Doubtful (18-16), and Unsuitable (>26). The SAR value of water sample ranges from 0.22-3.77 with an average of 1.04 which indicates that all water samples in the study area belongs to excellent category.

As per the USSL classification (Fig2:) of irrigation water based on EC and SAR, 35% of the groundwater samples are having low alkali and low salinity hazard (C1S1) and 9% of samples belong to low alkali and medium salinity hazard (C2S1) whereas two samples show low alkali and high salinity hazard.

Low alkali and moderate salinity hazard water can be used for irrigation on all soil [13]. High sodium hazard water generates exchangeable sodium in a harmful level, so it needs regular leaching and special soil management for salinity control.

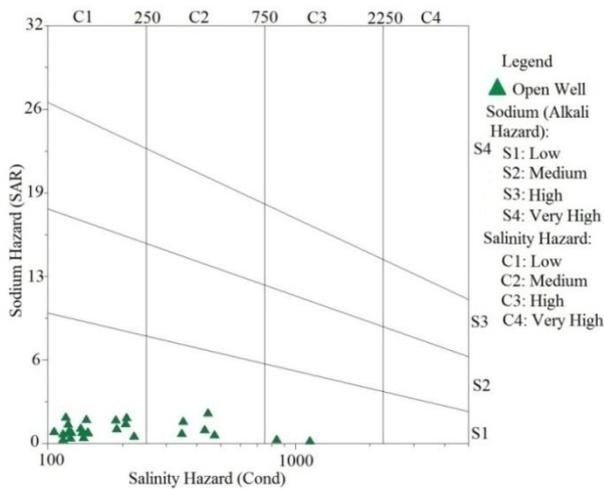


Figure 2: Suitability of groundwater for irrigation based on salinity and alkali hazard

4.1.3. Percent Sodium (Na%)

Another important parameter widely utilized for judging the degree of suitability of water for irrigation is Percent Sodium. It is computed with respect to relative proportion of cations present in water. Na% is calculated using the following formula.

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

All concentrations were expressed in meq/l.

The Na% in groundwater ranges from 9.58 to 87.91 meq/l. Based on this, 6% of the samples belongs to the unsuitable category and 22% was under doubtful category. Rest of the samples fall under excellent (4%), good (22%), and permissible (46%) categories (Fig 3:).

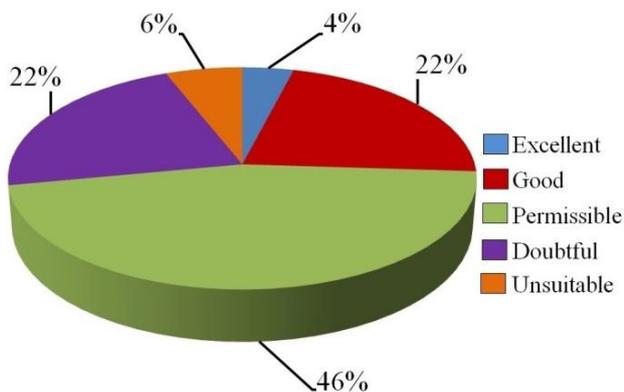


Figure3: Irrigation Water Quality based on Na%

4.1.4. Permeability Index (PI)

Doneen [14], evolved a groundwater classification for irrigation based on the Permeability Index. PI is calculated from the following equation and all concentrations were expressed in meq/l.

$$PI = \frac{Na^{+} + \sqrt{HCO_3^{-}}}{(Ca^{2+} + Mg^{2+} + Na^{+})} * 100$$

Based on PI water can be classified as Class I, II and III. Class I and II represent the good quality of water for irrigation with 75% or more of maximum permeability. Class III water have a maximum permeability of 25% and unsuitable for irrigation. In the study area 98% of the samples fall under class I and class II. One sample with Permeability Index 196.39 meq/l fall under class III (Fig 4:).

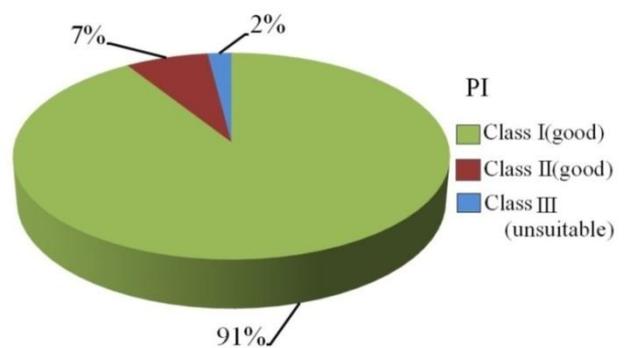


Figure4: Irrigation Water Quality based on PI

4.1.5. Kelley's Ratio (KR)

Kelley [15] and Paiwal [16] introduced a parameter for calculating irrigation water quality based on the level of Na⁺ measured against Ca²⁺ and Mg²⁺. If the concentration of Na⁺ exceeds the concentration of Ca²⁺ and Mg²⁺ then the water is unsuitable.

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

Water with Kelley's Ratio < 1 is suitable for irrigation and Kelley's Ratio > 1 is unsuitable. 53% of the samples record KR < 1 indicating that the good quality of water for irrigation purposes (Fig 5:).

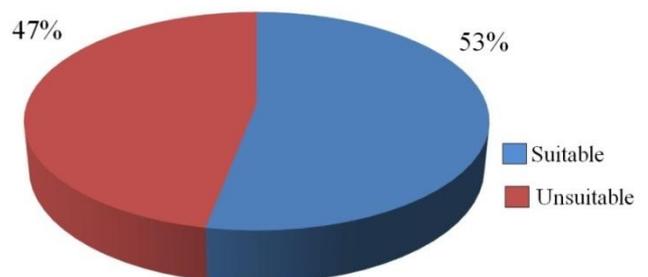


Figure 5: Irrigation Water Quality based on KR

4.1.6. Magnesium Ratio (MR)

The Magnesium Ratio is the excess amount of Mg^{2+} over Ca^{2+} . In common, Mg^{2+} concentration is in equilibrium with Ca^{2+} in most waters. Excess amount of Mg^{2+} changes the soil properties and reduce the plant growth. MR value < 50 is suitable for irrigation while MR value > 50 is unsuitable [13]. Majority of the samples (71%) during the study period is suitable for irrigation based on MR (Fig 6:).

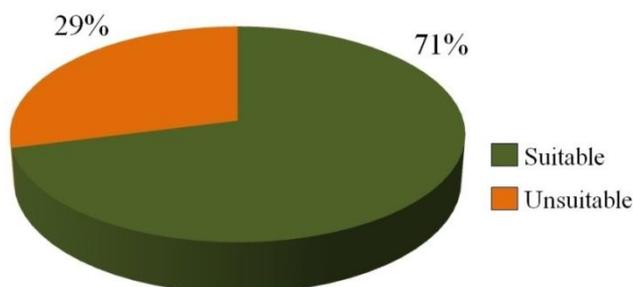


Figure 6: Irrigation Water Quality based on MR

4.1.7. Residual Sodium Carbonate (RSC)

Higher concentration of HCO_3^- in water results precipitation of Ca^{2+} and Mg^{2+} as CO_3^{2-} . If the $CO_3^{2-} + HCO_3^-$ concentration excess the concentration of $Ca^{2+} + Mg^{2+}$ will influence the suitability of water for irrigation. Continuous use of water having RSC more than 2.5 lead to salt build up which obstruct the air and water movement through soil pore space and lead to degradation of the physical condition of soil. Richard [12] evolved a formula for calculating the hazardous effect of CO_3^{2-} and HCO_3^- on the quality of water in terms of RSC.

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

All concentrations were expressed in meq/l.

Water with RSC < 2.5 is suitable, 1.25-2.5 is marginal and > 2.5 is unsuitable [13]. The RSC values of all samples fall under good quality criteria for irrigation purpose.

5. Conclusion

Physicochemical analysis showed that the majority of the groundwater samples in the region are slightly acidic in nature. The 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% (72%), PI (98%), MR (71%) and KR (53%) indicated groundwater samples are good for irrigation. According to hydrochemical assessment, water found to be suitable for irrigation purpose.

Acknowledgement

This paper is a part of the Ph.D programme of the corresponding author. The study also forms part of the CWRDM Plan funded project 'Geochemical and Isotopic characterization of groundwater's from the coastal aquifers of Kannur district.' The authors gratefully acknowledge the Kerala State Council for Science Technology and Environment (KSCSTE), for their financial assistance. Executive Director, CWRDM, Kozhikode is acknowledged for permission to publish the paper.

Reference

- [1] WHO, "Guidelines for drinking water quality 4th edition," World Health Organization, Geneva, 2011.
- [2] D.K. Todd, Groundwater hydrology second edition, 2006.
- [3] G. Fipp, "Irrigation water quality standards and salinity management strategies" Texas Agricultural Extension Service, Texas A&M University System, College station, TX(USA).B-1667, 4-03, pp. 1-19.
- [4] N. SubbaRao, "Seasonal Variation of Groundwater Quality in a part of Guntur District, Andhra Pradesh, India," Environ Geol, (49) pp. 413-429, 2006.
- [5] T. Ramkumar, S. Vekatramanan, I. Anitha Mary, M. Tamilselvi, G. Ramesh, "Hydrogeochemical Quality of Groundwater in Vedaraniyam Town, Tamil Nadu, India," Research Journal of Environmental and Earth Science, 2(1), pp. 44-48, 2010.
- [6] K. Ramesh, L. Elango, "Groundwater Quality and its Suitability for Domestic and Agricultural use in Tondiar River basin, Tamil Nadu, India," Environ Monit Assess, DOI 10.1007/s10661-011-2231-3, 2011.
- [7] K. Brindha, K.V. NeenaVaman, K. Srinivasan, M. SathishBabu, L. Elango, "Identification of Surface Water- Groundwater Interaction by Hydrogeochemical Indicators and Assessing its Suitability for Drinking and Irrigational Purposes in Chennai, Southern India," Appl Water Sci, (4), pp. 159-174, 2014.
- [8] K.M. Nayak, H.K. Sahoo, "Hydrogeochemical Evaluation of Mahanga Block, Cuttack District, India," Journal of Geosciences and Geomatics, 2(5A), pp. 16-21, 2014.
- [9] APHA, "Standard methods for the examination of water and waste water, 21st edition," American Public Health Association, Washington DC, 2005.
- [10] Bureau of Indian Standards (BIS), "Guidelines for the Quality of Irrigation Water," IS 11624 (1986, Reaffirmed 2009), UDC 631. 671. 03 : 626. 810 (026).
- [11] L.V. Wilcox, "Classification and use of irrigation water," Agric circ 969, USDA, Washington D.C., pp. 19, 1955.
- [12] L.A. Richard, "Diagnosis and improvement of saline and alkali soils", Handbook 60, USDA, Washington D.C., 1954.
- [13] J.W. Lloyd and J.A. Heathcote, "Natural Inorganic Hydrochemistry in relation to groundwater: An introduction," Clarendon Press, Oxford, 1985.
- [14] 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.

- [15] W.P. Kelley, "Alkali Soil-Their Formation Properties and Reclamation," Reinold publication, New York, 1946.
- [16] K.V. Paiwal, "Effect of Gypsum application on the quality of irrigation water," The Madras Agri. Jour (59), pp.646-647, 1967.

Author Profile



Dr. C. Unnikrishnan Warriier received the M.Sc. and M. Phil. degree in Geology from University of Madras, Chennai in 1990 and 1991, respectively. He received his D.Sc. in Geology from Osaka City University, Japan in 1995. He is presently principal Scientist and Head in Isotope Hydrology Division (IHD), Centre for Water Resources Development and Management (CWRDM), Calicut, Kerala, India.



Shyni M received the B.Sc. and M.Sc. degree in Geology from Kannur University in 2010 and 2012, respectively. She is now doing research in Hydrology in Centre for water Resources Development and Management (CWRDM), Calicut, Kerala, India as KSCSTE research Fellow.