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RESEARCH ARTICLE

ASSESSMENT OF SALT WATER INTRUSION AND IRRIGATION SUITABILITY OF GROUNDWATER IN THE KOLLAM COAST, SOUTH INDIA

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ABSTRACT

The Kollam coast in South India is a thickly populated area where the possibility of exploitation groundwater sources and contamination is high. The quality of groundwater is very important for various purposes. For the analysis of groundwater, fourteen dug wells in the seven coastal wards of Kollam Corporation were selected randomly and water samples were collected for the physico-chemical analysis. It was found that all physico-chemical parameters in the well water except total alkalinity, total hardness and, calcium are under permissible limits according to BIS (2012) drinking water quality. Based on the hardness values obtained, 42.9% of the wells are with moderately hard water and 35.7% of the wells in the coastal area are with hard water. Saltwater intrusion in groundwater sources was calculated using Base Exchange Index (BEX) and results show that 42% of wells are having saltwater intrusion. Irrigation suitability of the groundwater samples was measured by calculating magnesium hazard, sodium percent, and sodium adsorption ratio. Magnesium hazards of all well water are below 50%. Based on the sodium percent values obtained, 7% of the well water samples in the study area are under excellent class, 78% of the samples are under good class and 14% of the samples are under permissible class. The values of the Sodium adsorption ratio of all well water samples studied are under excellent class. It indicates that the groundwaters in the dug wells of the coastal area are suitable for irrigation purposes. The study shows that well water in the Kollam coastal area can be consumed after purification. Water purifiers with reverse a osmosis systems can be used to remove hardness and coliforms from the groundwater.

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INTRODUCTION

India has an active coastline of about 7500 km length, including the mainland coastline of about 5400 km. About 25% of the total population of India lives in the coastal tracts of the country. Coastal aquifers are the major sources of fresh water in many countries and particularly because almost 70 % of the world population lives in coastal areas (Kim *et al*., 2019). Aquifers along the coastal tracts of India can be divided into porous sedimentary formations and in fissured hard rock formations. The sedimentary tracts occur along the east coast and the coastal plains of Kerala (CGWB, 2013). The density of open wells in the coastal tract is about 200 per sq.km. In general, the dug wells are approximately 10m depth (Udayakumar, 2012). In the coastal area the quality of groundwater affected by the seawater, which contains a number of chemical constituents in very high concentrations as compared to groundwater. Salinity in coastal aquifers is mostly due to the seawater getting entrapped in aquifer zones during marine transgressions or through deposition of sediments from marine environments. In the coastal area of Kerala, salinity in the groundwater occurs in both shallow and deeper aquifers (CGWB, 2013). The suitability of groundwater for irrigation purposes depends upon the effect of mineral constituents of water on both plants and soils (Ramesh and Elango *et al*., 2012).

Study Area: Kollam is in the south-west part of Kerala state and extends from Lakshadweep Sea to the Western Ghats. It is bordered by Thiruvananthapuram district in the south, Alappuzha and Pathanamthitta districts in the north, and Tirunelveli district of Tamilnadu state in the west. Kollam, is an old boatyard on the Arabian Coast. Kollam beach also known as Mahatma Gandhi beach. It is located in Thamarakulam, Kollam, India with coordinates $8^0$52'26''N $76^0$35'33''E (District Industrial Potential Survey Report Kollam, 2017).Seven coastal wards were selected for the collection of groundwater which include Sakthikulangara (SK_1,SK_2), Maruthadi

(MD_1,MD_2), Kannimel (KL_1,KL_2), Thirumullavaram (TM_1,TM_2), Thangassery (TG_1,TG_2), Kaikulangara (KI_1,KI_2) and Mundackal west (ML_1,ML_2). Location map of the study area is shown in figure 1 and details of sampling stations given in Table 1.

METHODOLOGY

The physico-chemical analysis of groundwater was carried out following the procedures in APHA (2012). Irrigation suitability of groundwater samples was determined by calculating the Magnesium Hazard, Sodium percent and Sodium adsorption ratio.

Magnesium Hazard: Szaboles and Darab (1964) introduce magnesium hazard in relation to the alkaline earths for irrigation. The concentrations are reported in $meqL^{-1}$

$$MH = \frac{Mg^{2+}}{Ca^{2+}+Mg^{2+}} \times 100 \quad (1)$$

MH>50 not recommended for irrigation (Khodapanah *et al*., 2009).

Sodium Percentage

Suitability of groundwater for irrigation was evaluated by sodium percentage. It was calculated by the following equation (Wilcox, 1948).

$$Na\ \% = \frac{\text{soluble sodium concentration}}{[Ca^{2+}+Mg^{2+}+Na^{+}+K^{+}]} \times 100 \quad (2)$$

The concentration of ions in $meqL^{-1}$.

The most suitable irrigation water is with sodium percentage less than 20%. Based on the Na%, water is classified into excellent (< 20%) good (20-40%) permissible (40-60%) doubtful (60-80%) unsuitable (>80%) (Khodapanah *et al*., 2009).

Sodium Adsorption Ratio: Sodium adsorption ratio (SAR) is also a parameter used for identifying the irrigation suitability (Rawat *et al*., 2018) The Sodium absorption ratio is

$$SAR = \frac{Na^{+}}{\sqrt{\frac{(Ca^{2+}+Mg^{2+})}{2}}} \quad (3)$$

Na^{+}, Mg^{2+} and Ca^{2+} are expressed in $meqL^{-1}$. Richard (1954) classifies the samples based on the sodium absorption ratio into excellent (< 10), good (10-18), fair (18-26) and poor (>26).

Salt water intrusion: The BEX index has been calculated to investigate if well water samples are affected by seawater intrusion. According to Stuyfzand (2008), using the relation between sodium, potassium, and magnesium to chloride, the process of salinization and freshening of groundwater can be identified with the help of a positive or negative value of the BEX.

$$BEX = Na + K + Mg - 1.0716 \times Cl\ (meqL^{-1}) \quad (4)$$

The BEX represents the trend of groundwater salinization or freshening: a positive value represents freshening, a negative value indicates salinization, and a value equal zero represents no base exchange (Sappa *et al*., 2019).

RESULTS AND DISCUSSION

From the analysis data obtained, it was found that all physico-chemical parameters in the well water except total alkalinity, total hardness and calcium are under permissible limits according to BIS (2012) drinking water quality [Fig 2-5]. From the study it was also found that 42.9% of the wells are with moderately hard water and 35.7% of the wells in the coastal area are with hard water.

Table 1. Description of sampling stations and wells

Sampling Station	Well No.	Depth of well (cm)	Latitude	Longitude
Sakthikulangara	W_1	213	08°55'44.90''	076°32'24.92''
(SK_1, SK_2)	W_2	182	08°55'43.50"	076°32'28.98''
Maruthadi	W_3	274	08°55'02.06''	076°32'36.21''
(MD_1, MD_2)	W_4	335	08°54'54.89''	076°32'36.93"
Kannimel	W_5	426	08°54'05.94''	076°32'58.02''
(KL_1, KL_2)	W_6	91	08°54'07.53''	076°33'05.96''
Thirumullavaram	W_7	335	08°53'49.67''	076°33'25.21''
(TM_1, TM_2)	W_8	274	08°53'42.40''	076°33'37.62''
Thangassery	W_9	396	08°53'01.14''	076°34'11.32''
(TG_1, TG_2)	W_{10}	487	08°53'07.32''	076°34'02.35''
Kaikulangara	W_{11}	365	08°53'03.42''	076°34'20.93''
(KI_1, KI_2)	W_{12}	365	08°53'06.13''	076°34'30.08''
Mundakkal west	W_{13}	548	08°52'15.98"	076°35'49.21''
(ML_1, ML_2)	W_{14}	518	08°52'08.98''	076°36'11.72''

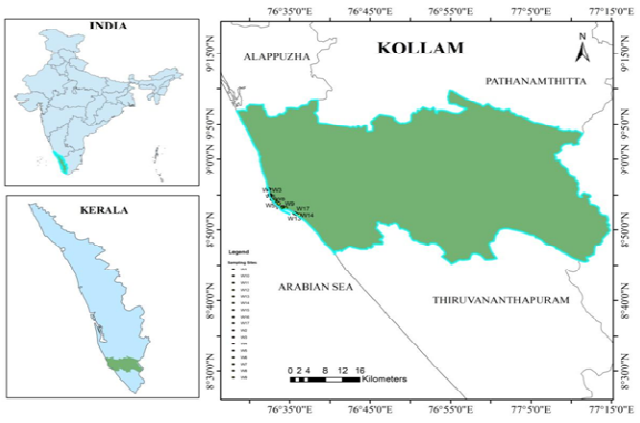


Figure 1.Location map of the Study area

The results show that the concentration of cations in the groundwater samples is in the order: Ca^{2+}>Na^{+}> K^{+}> Mg^{2+}. The average value of hardness was 163.1 mg/L as $CaCO_3$. Based on the hardness values, the samples can be divided into soft (0-75), moderately hard (75-150), hard (150-300) and very hard (over 300) (Sawyer *et al*., 1994). According to this, in the present study 21.4% of groundwater samples (W_5, W_6, W_{14}) are in the soft water

category. The 42.9 % samples (W_7, W_8, W_9, W_{10}, W_{11}, W_{12}) are under moderate category.

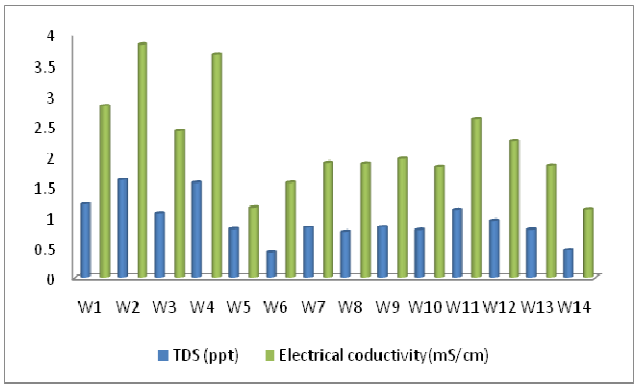


Fig.2 TDS and EC of well water samples

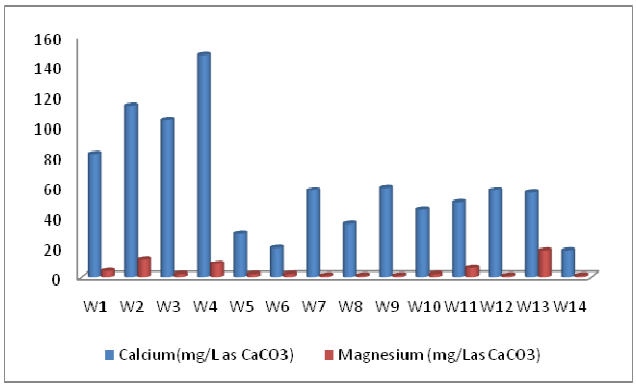
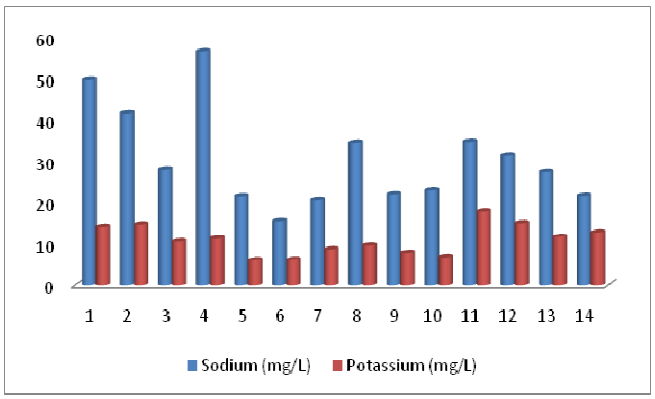


Fig.3.Ca and Mg Hardness of well water samples



\Fig.4. .Na+ and K+ content of well water samples

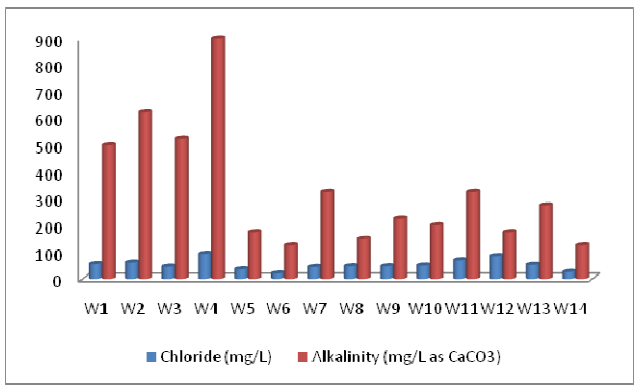


Fig.5. Chloride content and Alkalinity of well water samples

The 21.4 % samples (W_1, W_3, W_{13}) are under the hard water category. The samples 14.3 % of samples (W_2, W_4) are under the very hard water category

Table 2. Classification of Well Water Based on Total Hardness

Hardness (mg/L as $CaCO_3$)	Water class	Sample name
0-75	Soft	W_5
		W_6
		W_{14}
75-150	Moderately Hard	W_7
		W_8
		W_9
		W_{10}
		W_{11}
		W_{12}
150-300	Hard	W_1
		W_3
		W_{13}
Over 300	Very hard	W_2
		W_4

[Source : Sawyer *et al*., 1994]

Excess amounts of magnesium ions in water cause soil damage which leads to agricultural loss (Ramesh and Elango, 2012). There are two classes of water based on the magnesium hazard value. That is MH<50 suitable for irrigation and MH>50 unsuitable for irrigation. In the present study Magnesium Hazard values of ground water samples varied from 2.63% to 34%. This value indicates that the samples are suitable for irrigation.

Table 3. Irrigational suitability of well water

Well No.	Magnesium Hazard (%)	Sodium Percent (%)	Sodium Adsorption Ratio(SAR)
W_1	7.2	31.29	1.46
W_2	14.4	20.5	0.99
W_3	3.05	17.73	0.74
W_4	9	22.72	1.23
W_5	10	34.74	1.045
W_6	14.2	34.5	0.97
W_7	2.63	21.93	0.73
W_8	4.40	41.77	1.56
W_9	2.69	22.74	0.77
W_{10}	6.63	27.85	0.91
W_{11}	16.2	30.57	1.23
W_{12}	2.63	29	1.12
W_{13}	34.0	20.78	0.82
W_{14}	8.34	42.20	1.36

Based on the sodium percent the irrigation water can be divided into excellent (<20%), good (20-40%), permissible (40-60%), doubtful (60-80%) and unsuitable (>80%) (Khodapanah *et al*., 2009). In the present study, among the groundwater samples 7 % of sample (W_3) included in the excellent category, 78% of samples are under good class (W_1,W_2,W_4,W_5, W_6,W_7, W_9,W_{10}, W_{11},W_{12},W_{13}). 14% samples are under permissible category (W_8, W_{14}). Low amount of sodium is essential for the plants but a high amount of sodium is toxic to plants. If the irrigation water has more sodium it damages the soil quality and affects the growth of the plant (Wilcox, 1948). According to the sodium percent values obtained for the water samples it didn't show any sodium hazard. This is probably due to the presence of Na salts, which cause osmotic effects in soil plant system. Hence, air and water circulation is restricted during wet conditions and such soils are usually hard when dry (Saleh *et al*., 1999). The Sodium Adsorption

Ratio of ground water samples lies in the excellent class (<10) and it indicates that there is no hazard. Therefore, the results of sodium adsorption ratio in the well waters shows that the groundwater samples in the study area are suitable for irrigation. The higher the SAR values in the water, the greater the risk of Na^+ which leads to the development of an alkaline soil (Todd, 1980). Base Exchange Index (BEX) was used to assess the intrusion of seawater to the well water samples of coastal areas. Positive value of BEX indicates freshening and negative value indicates salinization. Base exchange index 'zero' represents no base exchange (Seppa *et al*., 2019). In the present study, 42% samples W_1, W_2 (Sakthikulangara) W_7 (Thirumullavaram), W_9, W_{10} (Thangassery), W_{12} (Kaikulangara) shows the negative value indicating salt water intrusionin these wells.

Table 2. Base Exchange Index of Well water

Well No.	BEX
W_1	-56.5
W_2	-65.4
W_3	0.28
W_4	0.65
W_5	0.18
W_6	0.39
W_7	-0.18
W_8	0.47
W_9	-0.18
W_{10}	-0.18
W_{11}	0.34
W_{12}	-0.75
W_{13}	1.35
W_{14}	0.57

The other samples show positive values. Salinity mainly is due to inundation of seawater into the coastal wells or it is induced by the heavy groundwater drawing. Other reasons may be industrial waste disposal or clayey soil in this area. This study is in agreement with the study by Omprakash and Gadikar (2018) on salt water intrusion and water scarcity issues of coastal Community in Thane District, Maharashtra.

CONCLUSION AND RECOMMENDATION

BEX results obtained in the present study shows that 42% of coastal wells are having salt water intrusion. It was found that the concentration of cations in the groundwater samples are in the order: $Ca^{2+}>Na^+>K^+>Mg^{2+}$ and it is also an indication of salt water intrusion. The irrigation suitability of water samples based on Sodium percent, Magnesium Hazardand Sodium Adsorption ratio shows that the samples are suitable for irrigation. The wellwaterin the Kollam coastal area can be consumed after purification and disinfection. Water purifiers with reverse osmosis system canbe used to remove hardness and coliforms from the groundwater. The study suggests annual monitoring and evaluation of groundwater quality is essential in Kollam coast. Also recommended to conduct awareness programmes on "Health and Sanitation" among the coastal community to reduce domestic waste disposal in the study area.

GLOSSARY OF ABBREVIATIONS

MH - Magnesium Hazard
Na % - Sodium Percentage
SAR - Sodium Adsorption Ratio
BEX- Base exchange

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