ECO CHRONICLE
ISSN: 0973-4155
Vol. 12, No. 2, June, 2017
PP: 35 - 38

VULNERABILITY OF COAST TO SALT WATER INTRUSION IN AND AROUND THE PROPOSED INTERNATIONAL SEA PORT, THIRUVANANTHAPURAM DISTRICT, SOUTH KERALA, INDIA.

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ABSTRACT

Saline water intrusion along coastal stretches is a serious issue in developing and developed countries. The present study is confined to the southern coastal region of Thiruvananthapuram District of Kerala state, for a distance of 15 km which covers the proposed Vizhinjham International Sea Port. A detailed studyhas been carried out to assess the vulnerability of the coast to salinewater intrusion and the GALDIT model has been used for this purpose. Twenty seven open wells were monitored and groundwater samples were collected during the pre-monsoon period. The GALDIT parameters such as groundwater occurrence, aquifer hydraulic conductivity, depth to groundwater level above mean sea level, distance from the shore, impact of existing status of sea water intrusion in the area and thickness of aquifer were derived from field work, primarydat as well as secondary data. The study reveals that the entire coast is under serious stress. The proposed port area is less vulnerable for salt water intrusion due to the presence of hard rock aquifers in the underground. But in due course, owing to the huge exploitation of groundwater resources in future, the port area may suffer from saltwater intrusion in future.

Keywords: Coastal aquifer, GALDIT method, salt water intrusion

INTRODUCTION

The coastal aquifers of Kerala state of India experience severe degradation of water quality due to various anthropogenic activities. Kerala, the southern most state of India has unique hydrogeological characteristics with wide variation in the rainfall pattern. The coastal zones of Kerala in recent years witnessed serious ground water problems, both qualitatively and quantitatively. High population pressure, intense human activities, inappropriate resource use and absence of proper management practices lead into this situation. In the present paper, it is intended to evaluate the coastal stretch of southern portion of the Thiruvananthapuram district in order to assess its vulnerability to sea water intrusion by using the GALDIT model.

The present study area extends along the coastal region of Trivandrum District of Kerala state, for a distance of 15 km, extending from Kovalam in the North to Poovar in the South (Figure.1). The proposed Vizhinjham International Sea Port falls entirely in this coastal stretch. Lithologically the area is comprised of sedimentaries composed mainly of sand, silt and clay belonging to the Quaternary and Tertiary periods and Precambrian crystallines comprising fractured and weathered charnockites and khondalites. Both the sedimentaries and crystallines are lateritisedto a considerable extent in the top portions with some exceptions. The groundwater occurs under unconfined condition in the area.

Materials and Methods

The study has been carried out by monitoring 27 open wells in the coastal stretch ensuring an average spatial separation of approximately 1 km. The wells were located on the map by GPS survey. The elevation of the locations, depth to water table (later reduced to mean sea level) and distance of the well from the shore were measured in the field. Water samples were collected from each well during pre-monsoon period (May 2014) and later subjected to chemical analysis by following standard procedures (APHA, 1995; Trivedi and Goel, 1986).

As per the GALDIT model (Chachadi and Lobo-Ferreira, 2001), the most importantfactors which control the intensity of sea water intrusion along the coastal regions are Groundwater Occurrence, Aquifer hydraulic conductivity, Depth to Groundwater Level above mean sea level, Distance from the shore, Impact of existing status of sea water intrusion in the area and Thickness of aquifer being mapped.In 2005, they revised the model by some modifications in the weight and ranks given to the parameters. Based on the GALDIT index arrived from the ranks and weights given to each parameter (Table 1)any coastal stretch can be categorized in the increasing order of vulnerability such as low vulnerability, moderate vulnerability and high vulnerability. Each of the six indicators has a pre-determined, fixed weight that shows its relative susceptibility to sea water intrusion. The GALDIT index is then obtained by computing the individual scores and summing them. The details of the parameters considered in the present study are described below and shown in the table.

Groundwater occurrence

The nature and extent of sea water intrusion is dependent on the basic nature of groundwater occurrence. In the present study area, the water table is found in unconfined conditions and hence the rating given for the parameter is '7.5'.

Aquifer hydraulic conductivity

The magnitude of seawater front movement towards land is influenced by the hydraulic conductivity of the aquifer. Higher the conductivity, higher the inland flow of the sea water fronts. A geologic cross section was constructed based on direct field observations, bore hole data obtained from Central Ground Water Board, Thiruvananthapuram and resistivity survey data from Kerala State Ground Water Department which depicted various geologic formations underneath. It is noted from the cross section that most of the sampling wells are situated in sandy aquifers as well as in crystallines. The hydraulic conductivity values vary with respect to change in lithology and the ratings were given accordingly. Hard rock aquifers in the study area has a hydraulic conductivity of 10m/day and that of sandy aquifer is found as 60m/day.

Ground water Level above mean sea level

The level of groundwater with respect to mean sea level is an important factor in the evaluation of the extent of sea water intrusion because it determines the hydraulic pressure availability to push back the sea water front. The parameter required for the present study is obtained by

Location map of the study area

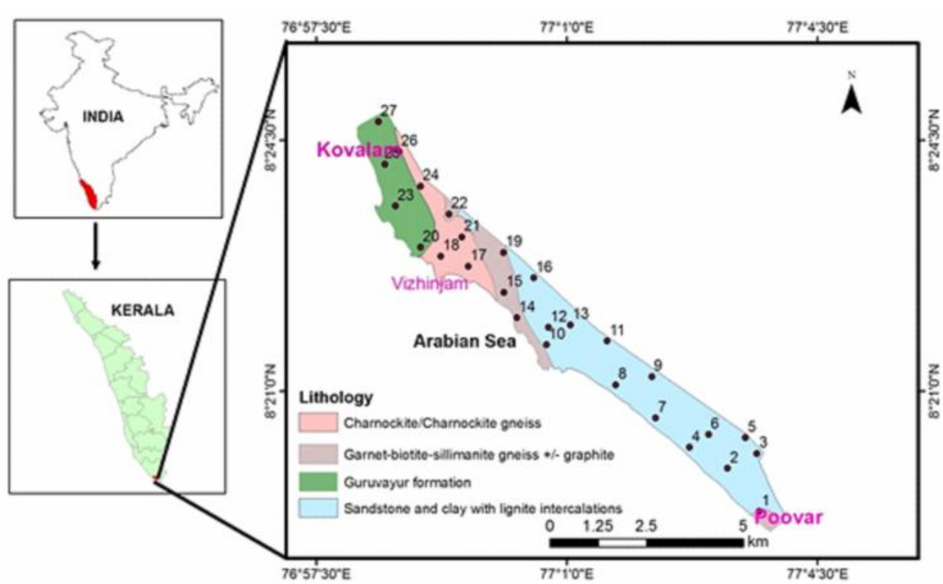


Table 1. GALDIT scores and weights

Parameters	Ground water occurrence	Aquifer conductivity	Height of the ground water level	Distance from the shore	Impact of existing status	Aquifer thickness
Weight / Rates	1	3	4	4	1	2
2.5	Bounded aquifer	Very low < 5m	Very low > 2m	>1000 m	<1	<5
5	Leaky confined aquifer	Low 5 -10 m	Low 1.5 – 2m	750 – 1000	1 – 1.5	5 – 7.5
7.5	Unconfined aquifer	Medium 10 – 40 m	Medium 10 – 40 m	500 – 750	1.5 – 2	7.5 – 10
10	Confined aquifer	High > 40 m	High > 40 m	<500	>2	>10

reducing the water level with respect to mean sea level. The obtained height of water table above mean sea level in the study area ranges from 0.9m to 53.6m.

Distance from the Shore

The impact of sea water intrusion generally decreases away from the shore so the maximum rating of 10 can be assigned for a distance less than 500m from the coast. In the present study, the wells are located upto a distance of 1400m from the shore line.

Impact of existing status of saline water intrusion

If the present study area is already under stress by saline water intrusion, then it might have already modified the natural hydraulic balance between sea water and fresh groundwater. Chachadi and Lobo Ferreira (2001) recommended the ratio of Cl/ (CO_3^{2-} +HCO_3^-) as an effective indicator to study the impact of existing stress on groundwater. The Cl /(CO_3^{2-} +HCO_3^-) ratio of the water samples in the study area ranges from 0.79 to 45.16. This ratio will be greater than 1.5 in those areas where salt water intrusion has already occurred. An evaluation of the Cl /(CO_3^{2-} +HCO_3^-) ratio of the present study reveals that many parts of the present study area experiences saltwater intrusion now. Also the ratio greater than two indicates high vulnerability of the coast to salt water intrusion. It can be noted that most of the locations are characterised with a value of greater than two.

Thickness of the aquifer

Aquifer thickness is an important parameter which decides the extent and magnitude of sea water intrusion in coastal areas. Larger the aquifer thickness, greater will be the sea water intrusion (Chachadi and Lobo-Ferreira, 2005). The aquifer thickness of the study area is derived from the direct field observations, the bore hole data collected from Central Ground Water Board and resistivity survey data from Kerala State Ground Water Department. Most of the observation wells fall in the sedimentary aquifers where the thickness is very high and its exact values are not available, obviously they got a rating of 10. But in hard rock areas, it lies below 10m and the rates given are also varying. The rates were given based on the calculated aquifer thickness and shown in the table 2.

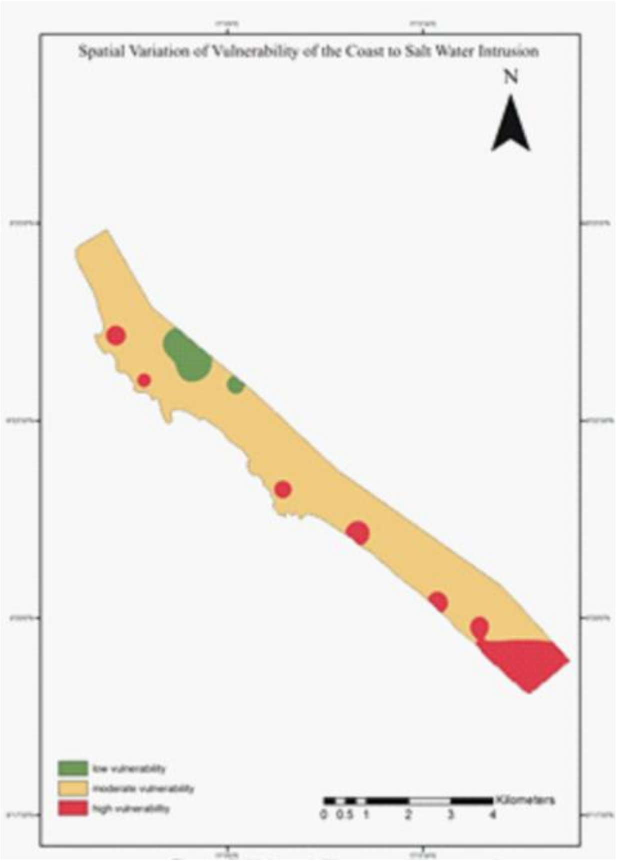
Table 2. Galdit parameters and their rates

location number	Groundwater occurrence (G)	hydraulic conductivity (A)	amsl (L)	Distance (D)	Cl/HCO_3 (I)	Thickness (T)	GALDIT index	classification
1	Unconfined aquifer (7.5)	60 (10)	0.9 (10)	265 (10)	4.29(10)	(10)	9.83	high vulnerability
2	Unconfined aquifer (7.5)	60 (10)	1.7 (5)	500(7.5)	1.90(7.5)	(10)	7.67	high vulnerability
3	Unconfined aquifer (7.5)	60 (10)	28.15 (2.5)	1300(2.5)	3.32(10)	(10)	5.83	moderate vulnerability
4	Unconfined aquifer (7.5)	60 (10)	3.1 (2.5)	270(10)	1.84(7.5)	(10)	7.67	high vulnerability
5	Unconfined aquifer (7.5)	60 (10)	23.1 (2.5)	1300(2.5)	1.59(7.5)	(10)	5.67	moderate vulnerability
6	Unconfined aquifer (7.5)	60 (10)	21.6 (2.5)	800(5)	1.59(7.5)	(10)	7.00	moderate vulnerability
7	Unconfined aquifer (7.5)	60 (10)	8.4 (2.5)	300(10)	0.79(2.5)	(10)	7.33	moderate vulnerability
8	Unconfined aquifer (7.5)	60 (10)	5.5 (2.5)	300(10)	5.69(10)	(10)	7.83	high vulnerability
9	Unconfined aquifer (7.5)	60 (10)	7.12 (2.5)	1000(2.5)	2.66(10)	(10)	5.83	moderate vulnerability
10	Unconfined aquifer (7.5)	60 (10)	22.84 (2.5)	300(10)	6.20(10)	(10)	7.83	high vulnerability
11	Unconfined aquifer (7.5)	60 (10)	4.85 (2.5)	1200(2.5)	21.25(10)	(10)	5.83	moderate vulnerability
12	Unconfined aquifer (7.5)	60 (10)	22.9 (2.5)	500(7.5)	7.97(10)	(10)	7.17	moderate vulnerability
13	Unconfined aquifer (7.5)	60 (10)	18.86 (2.5)	1000(2.5)	2.21(10)	(10)	5.83	moderate vulnerability
14	Unconfined aquifer (7.5)	10 (5)	4.25 (2.5)	100(10)	1.39(5)	6 (5)	5.83	moderate vulnerability
15	Unconfined aquifer (7.5)	10 (5)	14.88 (2.5)	300(10)	3.98(10)	6 (5)	6.17	moderate vulnerability
16	Unconfined aquifer (7.5)	60 (10)	26.8 (2.5)	1000(2.5)	7.97(10)	(10)	5.83	moderate vulnerability
17	Unconfined aquifer (7.5)	10 (5)	13.2 (2.5)	350(10)	4.09(10)	4(2.5)	5.83	moderate vulnerability
18	Unconfined aquifer (7.5)	10 (5)	16.2 (2.5)	300(10)	1.88(7.5)	2.5(2.5)	5.67	moderate vulnerability
19	Unconfined aquifer (7.5)	10 (5)	27.3 (2.5)	1000(2.5)	45.16(10)	(10)	4.83	low vulnerability
20	Unconfined aquifer (7.5)	60 (10)	25.7 (2.5)	300(10)	12.84(10)	(10)	7.83	high vulnerability
21	Unconfined aquifer (7.5)	10 (5)	39.35 (2.5)	1000(2.5)	11.95(10)	6 (5)	4.17	low vulnerability
22	Unconfined aquifer (7.5)	10 (5)	42.75 (2.5)	1400(2.5)	3.98(10)	5 (5)	4.17	low vulnerability
23	Unconfined aquifer (7.5)	60 (10)	32.1 (2.5)	350(10)	5.76(10)	(10)	7.83	high vulnerability
24	Unconfined aquifer (7.5)	60 (10)	53.6 (2.5)	1000(2.5)	2.66(10)	(10)	5.83	moderate vulnerability
25	Unconfined aquifer (7.5)	60 (10)	8 (2.5)	350(10)	0.93(2.5)	(10)	7.33	moderate vulnerability
26	Unconfined aquifer (7.5)	60 (10)	28.2 (2.5)	750(7.5)	2.66(10)	(10)	7.17	moderate vulnerability
27	Unconfined aquifer (7.5)	60 (10)	21.5 (2.5)	700(7.5)	3.54(10)	(10)	7.17	moderate vulnerability

(rates are given in simple brackets)

Table 2. Galdit parameters and their rates

Figure 2. Vulnerability map of the coast



RESULTS AND DISCUSSION

Each of the six indicators has a pre-determined fixed weight that reflects its relative importance to seawater intrusion. The GALDIT Index is then obtained by computing the individual indicator scores and summing them as per the following expression:

$$\text{GALDIT-Index} = \sum_{i=1}^{6} \{(W_i)\, R_i\} / \sum_{i=1}^{6} W_i$$

Where Wi is the weight of the i^{th} indicator and Ri is the importance rating of the i^{th} indicator.

SUMMARY AND CONCLUSIONS

In the present study area, seven locations with a GALDIT score of more than 7.5 are grouped as high vulnerability areas and three locations with GALDIT score less than 5 are grouped as low vulnerability area, where as, the remaining seventeen locations having values in between 5 & 7.5 are grouped as moderate vulnerability areas.Figure 2 depicts the spatial variation of vulnerability of the coast to salt water intrusion. This study shows that the entire coast is under serious stress. The proposed port area falls in the category of moderate vulnerability to salt water intrusion owing to the presence of hard rock aquifers in the underground. But in future, due to the expected huge exploitation of groundwater resources, the port area may subject to saltwater intrusion.

ACKNOWLEDGEMENTS

The first author is grateful to the Kerala State Council for Science, Technology and Environment for the financial support. The facilities provided in the Department of Geology, University of Kerala through DST-FIST, UGC-SAP and KSCSTE-SARD is gratefully acknowledged. Authors are also thankful to Central Ground Water Board, Kerala region and Kerala State Ground Water Department for providing data.

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