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Vulnerability Assessment of Seawater Intrusion in Ramanadhapuram Coastal Region, Tamil Nadu, India

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ABSTRACT

An Indicator based model is described to assess and quantify the significance of vulnerability to seawater intrusion due to excessive ground withdrawals in coastal areas. The study area map was prepared using Geographical Information System (GIS). Based on GLADIT index and Chloride content the vulnerability index was carried out. Further, the vulnerable areas are found to provide artificial recharge.

INTRODUCTION

Freshwater is most important resources for human life. Water exists in three forms: liquid (Oceans, sea, rivers, ponds and groundwater), Solid (ice and snow cover) and water vapour. Huge amounts of water are bound up in the composition of different minerals of the earth's crust, mantle and core. The distribution of water is shown in the table 1. Only 0.7% of total water can directly use for human needs. Demand is estimated to have risen six to seven times from 1900 to 1995, more than double the rate of population growth. It is a rise that seems likely to accelerate into the future, since the world population is expected to reach 8.3 billion by the year 2025 and 10 to 12 billion by 2050. Of today's estimated global demand for water, some 4000 cubic kilometer a year, agriculture probably takes more than 80 per cent, mostly for irrigation. In 1995 some 20 per cent of the global population of 5.7 billion people still lacked a safe and reliable water supply, while more than 50 per cent were without adequate sanitation (Agarwadkar, 2005).

Table.1.Global water distribution

	Volume (1000000 km^3)	%
Oceans	1370	97.25
Ice Caps and Glaciers	29	2.05
Groundwater	9.5	0.68
Lakes	0.125	0.01
Soil Moisture	0.065	0.005
Atmosphere	0.013	0.001
Streams and Rivers	0.0017	0.0001
Biosphere	0.0006	0.00004

(*Source: IRS*)

At the junction of groundwater aquifers with the coastline, a natural gradient exists towards the coast, and groundwater discharges into the sea. Seawater is 1.025 times heavier than fresh water; it intrudes into groundwater aquifer in coastal areas forming a saline wedge below the freshwater. The interface between aquifer and seawater is in a state of dynamic equilibrium, moving with the seasonal variations of the water table and daily tidal fluctuations.Theoretically, the interface occurs at a depth below sea level, Y, which is 40 times the height of freshwaterabove sea level, X, as per Ghyben-Herzberg relation (figure 1).

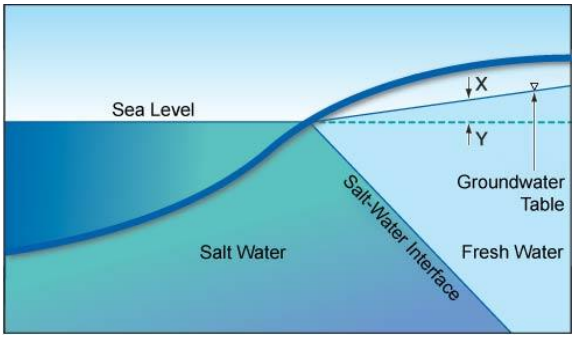

Figure.1.Seawater Intrusions

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Study Area: Ramanadhapuram lying N 78º 27´20´´ and E 09 º 17´ 30´´ on East coast of India . The coast receives moderate rainfall during North East monsoon (Oct-Nov). Ramanathapuram district is divided into 7 taluks. The taluks are further divided into 11 blocks, which further divided into 400 villages. The district is a part of East flowing river basin, Between Gundar and Veigai. Virusuliaru, Kottakkarai, andRameswaram Island are the important Sub-basins/Watershads. The study area map shown in fig 2.

Coastal Geomorphology: Ramanathapuram district has a long coastline of around 260 km. The coastal areas are flanked by Beach ridge complex-sand dunes, swales, swamps and backwater. Other features are the shallow pediment plain of Kamdhi, parts of Paramakudi and Tiruvadanai taluks with thin veneer of soil cover over weathered hornblende gneiss, laterite and the buried pediments.

Figure.2.Location of Study Area

Rainfall and Climate: The district receives the rain under the influence of both south-west and north-east monsoons. The northeast monsoon chiefly contributes to the rainfall in the district. Most of the precipitation occurs in the form of cyclonic stoms caused due to the depressions in Bay of Bengal. The southwest monsoon rainfall is highly erratic and summer rains are negligible.

Drainage: The major part of Ramanathapuram district falls in Gundar-Vaigai river basin. Vaigai and Gundar are the important rivers and in addition, Virusuli, Kottakariyar&Uppar are the other rivers draining the district. The drainage pattern, in general, is dendritic. All the rivers are seasonal and carry substantial flows during monsoon period.

Soils: Soils in the area have been classified into i) Black Clayey soil, ii) Sandy soil and iii) Red –ferruginous soil.In the Ramanathapuram district, majority of the area is covered by Black Clayey soil type. These soils are mostly black or black to brownish in colour and are found in parts of Ramanathapuram, Paramakudi, Kamuthi, Tiruvadanai and Mudukulathur blocks.

Hydrogeology: The district is underlain by both porous and fissured formations. . The important aquifer systems in the district are constituted by i) unconsolidated &semiconsolidatedformations and ii) weathered and fractured crystalline rocks The porous formations can be grouped into three aquifer groups, viz., Cretaceous sediments, Tertiary Sediments and Quaternary Sediments. The cretaceous aquifer is semi confined to confine in nature and consists of two zones. The top unit comprises fossiliferous sandstone red in color and compact in nature, while the bottom ispinkish or grayish sandstone intercalated with shales. The aquifers are characterized by freshwater and occurs at the depth range of 116-407 and 205-777 m bgl and has thickness in the range of 68 to 535 m. The aquifer is made up of compact sandstone and the potential is limited. The wells may yield a discharge of 5-10 lps and can sustain a pumping of 10-15 hours a day. The depth to water level in district varied between 3.3- 14.10m during pre-monsoon (2013) and 3.1-11.5 m during post monsoon depth to water level (2014).

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Aquifer Parameter

Table.2.Aquifer parameter of Ramanadhapuram

Aquifer	Transmissivity(m^2/sec)	Storativity	Specific yield %
Weathered Crystallines	<1	-	<2
Fractured Crystallines	1-10	1.32 X 10^{-3} to 8.0X 10^{-3}	-
Cretaceous Aquifer	50-500	27 X 10^{-3} to 5.5 X 10^{-5}	2 - 5
Tertiary Aquifer	5-3000	2.5 X 10^{-3}	-
Quaternary Aquifer	5-50	-	6 - 10

(Source:Ministry of Water Resources, CGWB, CHENNAI)

METHODOLOGY

The GALDIT method is a weightage driven approach to assess the vulnerability of coastal aquifers using hydro-geological parameters. It is a tool for aquifer pollution vulnerability evaluation and ranking for estimation of vulnerability index, which is computed from hydro-geological, morphological and other aquifer characteristics (Chachadi, A. G et.al).

Parameters for GALDIT: Chachadi et al. (2003) has proposed a method for aquifer vulnerability mapping. The most important factors that control the seawater intrusion are

1. Groundwater occurrence (aquifer type: unconfined, confined and leaky confined)
2. Aquifer hydraulic conductivity
3. Depth of groundwater Level above sea
4. Distance from the shore (distance inland perpendicular from shoreline)
5. Impact of existing status of seawater intrusion in the area.

6 Thickness of the aquifer.

The GALDIT method was used for evaluating the vulnerability of the coastal Aquifer for Seawater intrusion problem along with chloride content values. According to the GALDIT method, each of the six parameters has a predetermined fixed relative weight that reflects its relative importance to vulnerability. The expression of GALDIT model is given below.

$$\mathbf{GALDIT = (W1*G) + (W2*A) + (W3*L) + (W4*D) + (W5*I) + (W6*T)} \quad (1)$$

Data used: Groundwater data from PWD, Tharamani, Chennai, Groundwater quality - Cl-, CO3--, HCO3-, TDS

Depth of the Well For pre-monsoon and post monsoon period of year 2013, 2014

Table.3.Groundwater data

Aquifer	Transmissivity (m^2/sec)	Storability	Specific yield %
Weathered Crystallines	<1	-	<2
Fractured Crystallines	1-10	1.32 X 10^{-3} to 8.0X 10^{-3}	-
Cretaceous Aquifer	50-50.0	27 X 10^{-3} to 5.5 X 10^{-5}	2 - 5
Tertiary Aquifer	5-3000	2.5 X 10^{-3}	-
Quaternary Aquifer	5-50	-	6 - 10

Calculation of GLADIT index:

- Groundwater type is unconfined throughout the area; hence , the rank for G is 9 for all wells.
- Aquifer conductivities were given values depending on the table 3 and is 5-10 m/day.
- Depth above mean sea level is 34 - 56m from the static water level in the wells.
- Distance from the coastal line was calculated using the satellite images was 3.2 - 8 km and the average perpendicular distance from the coastal line was calculated for all well locations.
- Impact of existing ground water intrution was calculated for two data sets(2013-2104) using the formula, $Cl^-/(CO_3^- + HCO_3)$ equation3.2
- Thicknesss of aquifer was taken depending on the depth of the well upto the full aquifer depth.

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Calculation of vulnerability using GLADIT score: The final GLADIT values are calculated using equation and are interpolated using Universal Krigging method. The GLADIT values were grouped into vulnerability classes as given in the table:

Table.4.Vulnerability values

Range of GLADIT values	Vulnerability Class
0 - 50	Non-Vulnerable
50 - 70	Less Vulnerable
70 - 90	Moderately Vulnerable
90 -130	Highly Vulnerable

Vulnerability depending on the chloride content: The standards given by potable water, population drinking more than 250ppm is considered as vulnerable population. The vulnerability class made depend on chloride content in drinking water is given in the table.

Table.5.Vulnerability depending on the chloride content

Chloride Content	Vulnerability Class
0 - 250	Non-Vulnerable
250 - 500	Less Vulnerable
500 - 1000	Moderately Vulnerable
1000 onwards	Highly Vulnerable

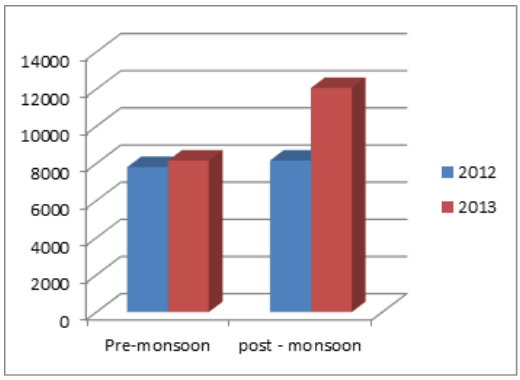

Figure.3.Chloride variation

CONCLUSION

The vulnerability in Ramanathapuram coastal area has been studied, to show the impact of the sea water intrusion along the coastal zone. This shows that the coastal region and the mouth of river vaigai were affected by sea water intrusion. This study has proven that the sea water intrusion will be minimized through the artificial recharge. This will helps in utilizing the underground water of the well throughout the year with low salinity. This artificial recharge is the best way to minimize/ prevent the sea water intrusion in this coastal area.

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