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ASSESSMENT OF SALT WATER INTRUSION INTO THE COASTAL AQUIFERS OF KERALA

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Abstract - *As the world's population continues to grow at an alarming rate, fresh water supplies are constantly being depleted, bringing with it issues such as saltwater intrusion and increasing the importance of groundwater monitoring, management, and conservation. The migration of salt water into freshwater aquifers under the influence of groundwater development is known as salt water intrusion. Salt water intrusion is typically detrimental to an environment. Salt water can also contaminate drinking water in coastal communities. A case study was conducted at Kadappuram panchayat in Chavakkad municipality. The raw or treated water can be checked and analysed for creating a correlation between selected parameters and plotting a salt water intrusion profile.*

Key Words: aquifer, saltwater intrusion, correlation, saltwater intrusion profile.

1. INTRODUCTION

Ground water is the largest source of fresh water on the planet. It has been utilized to a great extent to meet the needs of agricultural, industrial and municipal water supply schemes. It may get contaminated due to the presence of salinity. Saltwater intrusion is the migration of saltwater into fresh water aquifers under the influence of ground water development. Saltwater encroachment is the major hazard to the public in all coastal zones. The coastal aquifers of Kerala experience severe degradation of water quality due to various anthropogenic activities. Kerala, the southernmost state of India has unique hydro geological characteristics with wide variation in the rainfall pattern. Both qualitatively and quantitatively, the coastal zones of Kerala in recent years witnessed serious ground water problems. Owing to the high demand of ground water to cater a large population in the coastal zones of Kerala, mitigation of the deterioration in the quality of ground water in shallow coastal aquifers was initiated through ground water recharge. The $Cl/(CO_3+HCO_3)$ ratio is one of the important criterions to evaluate saltwater intrusion.

The Objectives of the present study was, to plot the salt water intrusion profile for the analysed data of water samples collected from the coastal plain of Kadappuram panchayat and to study the correlation coefficient of analysed parameters using SPSS Software.

2. STUDY AREA

The selected area for investigation of saltwater intrusion into coastal aquifers was Kadappuram panchayat in Thrissur district, in the state of Kerala, India. It is located geographically 10°32′30″in north latitude and 76°1′37″ in east longitude. It covers an area of 9.63km^2.It is situated to the west of canola canal. Kadappuram panchayat can be called a half island since three sides of this panchayat is covered by water.

3. MATERIALS AND METHODS

Ground Water collected from selected area is achieved through eleven wells covering an area of two and half kilometers in the coastal plain. Samples were collected in plastic bottles of 1 Littre capacity during post and pre monsoon seasons. Water quality parameters like pH, alkalinity and chloride were analyzed in the laboratory, following standard analytical procedures (APHA 1995).

To delineate the seawater intrusion in the study area, $Cl/(CO_3 +HCO_3)$, ratio were used. Normally this ratio is less than 0.05 for fresh groundwater, 0.05 - 1.30 for slightly contaminated groundwater, 1.30 - 2.80 for moderately contaminated ground water, and greater than 2.8 for injuriously contaminated groundwater.

Measured data were statistically analysed by using SPSS software, to find out most significant parameters among

the quality variables. Correlation and regression analysis were conducted.

3. RESULTS AND DISCUSSION

The results of the chemical analyses and the general statistics are provided in Tables 1 and Table 2 of post monsoon season and pre monsoon season respectively. The permissible limit of chloride content is 250 mg/l. The desirable limit for alkalinity is 200 mg/l. For public water supplies, the desirable level of pH value is 6.5-8.5. The desirable limits of $Cl/(CO_3 + HCO_3)$ ratio is mentioned above. Fig. 1 and Fig. 2 show the saltwater intrusion profile drawn during post monsoon season and pre monsoon season respectively.

Table 1: Results of water quality analysis of ground water in post monsoon season

Sample ID	Distance from shore (m)	Chloride (mg/L)	Alkalinity (mg/L)	pH	$Cl/(CO_3+HCO_3)$	Remarks
Post Monsoon						
1	221.5	699.98	144	7.55	4.86	Injuriously contaminated
2	271	599.98	180	7.39	3.33	Injuriously contaminated
3	322	499.98	200	7.65	2.49	Moderately contaminated
4	370	349.98	142	7.74	2.46	Moderately contaminated
5	460.45	249.99	168	7.34	1.48	Moderately contaminated
6	694.45	200.99	174	7.79	1.15	Slightly contaminated
7	727.45	160.00	155	7.70	1.03	Slightly contaminated
8	790.45	649.981	282	7.82	2.30	Moderately contaminated
9	875.95	599.98	364	8.32	1.64	Moderately contaminated
10	1100.95	449.98	290	7.05	1.55	Moderately contaminated
11	1629.95	410.99	270	6.92	1.52	Moderately contaminated

Table 2: Results of water quality analysis of ground water in pre monsoon season

Sample ID	Distance from shore (m)	Chloride (mg/L)	Alkalinity (mg/L)	pH	$Cl/(CO_3+HCO_3)$	Remarks
Pre Monsoon						
1	221.5	849.97	166	6.55	5.12	Injuriously contaminated
2	271	599.98	120	6.88	4.99	Injuriously contaminated
3	322	899.976	182	6.99	4.94	Injuriously contaminated
4	370	749.97	180	7.33	4.17	Injuriously contaminated
5	460.45	599.98	172	6.95	3.48	Injuriously contaminated
6	694.45	599.98	200	7.01	2.99	Injuriously contaminated
7	727.45	449.98	220	7.28	2.04	Moderately contaminated
8	790.45	949.97	260	7.19	3.65	Injuriously contaminated
9	875.95	749.97	254	7.77	2.95	Injuriously contaminated
10	1100.95	899.97	312	7.45	2.88	Injuriously contaminated
11	1629.95	949.97	350	6.84	2.71	Moderately contaminated

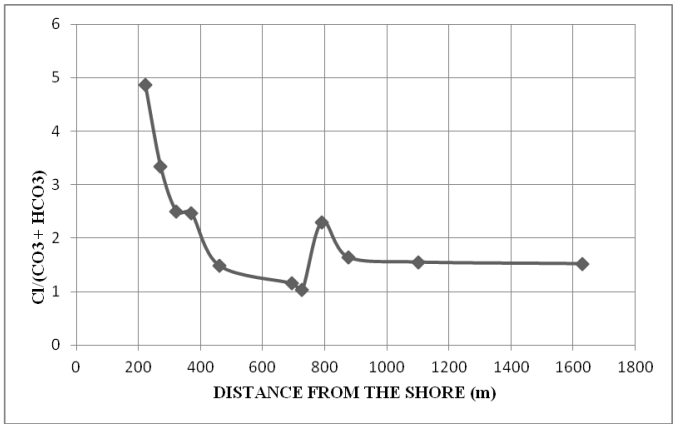

Fig.1: Salt Water Intrusion Profile of post monsoon season

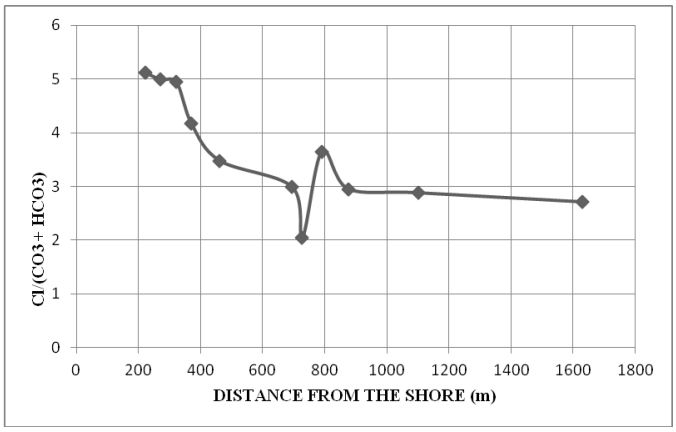

Fig. 2: Salt Water Intrusion Profile of pre monsoon season

In post monsoon season the salt water intrusion rate is high only at the first two sampling points. The water quality results in the pre monsoon season shows that the salt water intrusion rate is high in all sampling station except sampling point 7 and 11.

3.4. MATHEMATICAL MODELLING OF DATA

Using SPSS software correlation between various parameters was studied. The correlation is checked for the results of water quality analysis of ground water in post monsoon season (Table 1.)

Correlation is the operation through which the linear relation between two variables (parameters) can be studied. Correlation gives the values of bivariate correlation coefficient *r*, which measures the strength and direction of linear relationships between pairs of continuous variables, using correlation tests (here, Pearson's *r* test) and states if the relation between the variables is statistically significant or not. Each row of the table corresponds to one of the variables and each column also corresponds to one of the variables.

Table 2: Correlation between selected parameters

	DISTANCE	$Cl/(CO_3+HCO_3)$	pH	ALKALINITY	CHLORIDE
DISTANCE	1				
$Cl/(CO_3+HCO_3)$	-.588	1			
pH	-.367	-.005	1		
ALKALINITY	.648*	-.321	.146	1	
CHLORIDE	-.155	.728*	.133	.393	1

Again using the SPSS software, regression was studied. Since $Cl/(CO_3+HCO_3)$ ratio (as mentioned earlier) is the most important parameter to evaluate salt water intrusion, it is chosen here as the parameter for regression analysis. The regression analysis is carried out on the results of water quality analysis of ground water in post monsoon season.

Regression analysis is used when we want to predict the value of a variable based on the value of another variable. Here, the two variables chosen are distance and $Cl/(CO_3+HCO_3)$ ratio. The variable we want to predict is called the dependent variable ($Cl/(CO_3+HCO_3)$ ratio) and the variable we are using to predict the other variable's value is called the independent variable (distance).

Table 3: Model Summary

Dependent Variable: $Cl/(CO_3+HCO_3)$ ratio	
Equation	Model Summary
	R Square
Linear	.346
Quadratic	.624
Cubic	.830

The R^2 value (the "**R Square**" column of table 3) indicates how much of the total variation in the dependent variable, $Cl/(CO_3 + HCO_3)$ ratio, can be explained by the independent variable, distance. In this case, by linear equation 34%, by quadratic equation 62% and by cubic equation 83% can be explained.

The **Coefficients** table (table 4) provides us with the necessary information to predict $Cl/(CO_3+HCO_3)$ ratio from distance, as shown below:

Table 4: Parameter Estimates (Coefficients)

Dependent Variable: $Cl/(CO_3 + HCO_3)$ ratio				
Equation	Parameter Estimates			
	Constant	b1	b2	b3
Linear	3.229	-.002		
Quadratic	4.927	-.007	3.011E-6	
Cubic	8.787	-.027	2.922E-5	-9.627E-9

Regression equations can be presented as:

Linear equation: $Cl/(CO_3 + HCO_3) = 3.229 - 0.002 \times Distance$

Quadratic equation: $Cl/(CO_3 + HCO_3) = 4.927 - 0.007 \times Distance - 3.011 \times 10^{-6} \times (Distance)^2$

Cubic equation : $Cl/(CO_3 + HCO_3) = 8.787 - 0.027 \times Distance + 2.922 \times 10^{-5} \times (Distance)^2 - 9.627 \times 10^{-9} \times (Distance)^3$

Form the above cubic equation, which is the most significant equation a mathematical model in MS Excel is created which helps in predicting the approximate value of $Cl/(CO_3 + HCO_3)$ ratio at a particular distance from the shore within 1629 m from the shore.

From regression analysis between the $Cl/(CO_3 + HCO_3)$ ratio and Distance (from the shore), a curve fit estimation is done to obtain the best fit curve. Taking distance i.e. the independent variable on the x-axis and $Cl/(CO_3 + HCO_3)$ ratio i.e. independent variable on the y-axis three curves (linear, quadratic and cubic) are plotted using SPSS software.

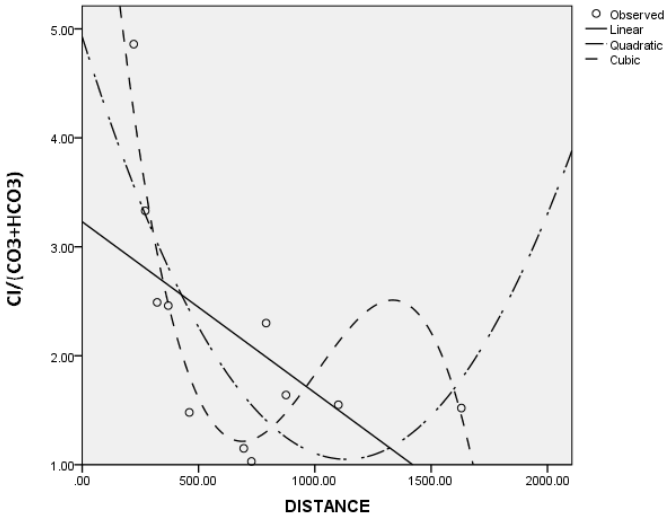

Fig. 3: Curve fit estimation between $Cl/(CO_3 + HCO_3)$ ratio and distance from the shore

4. CONCLUSION

It can be concluded that, there is salt water intrusion, as most people use bore wells and municipal water the $Cl/(CO_3+HCO_3)$ ratio shows that most of the samples are injuriously contaminated. From salt water intrusion profile it shows that as summer nears the intrusion severity increases. We could conclude that there is salt water intrusion in a distance of 1800m and it is clear that tendency of curve is further decreasing. The control measures are: Control of pumping pattern, artificial recharge, maintenance of freshwater ridges, forming subsurface barriers, installing tide control gates, ADR technique.

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