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Hydro geochemistry Evaluation of Ground Water using Multivariate Factor Analysis in Srikakulam Costal Region of Andhra Pradesh, India

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ABSTRACT

The present research study, is an attempt to evaluate the quality of ground water in Srikakulam region of Andhra Pradesh by characterizing ground water samples collected from nearby Kalingapatnam creek stream joining the sea in Srikakulam district during pre monsoon and post monsoon seasons. 12 parameters viz., pH, EC, TDS, Na, K, Ca^{+2}, Mg^{+2}, Cl^{-}, HCO_3^{-}, NO_3^{-}, SO_4^{-2}, PO_4^{-3} were determined. The multivariate factor analysis is performed for pre and post monsoon chemical data set. It provides an insight into the source of parameters which are mainly responsible for the water quality variations that occur in the area including the sea water intrusion. The present research study elucidates the effectiveness of factor analysis in evaluating the hydro geochemistry of ground water quality in this coastal region which is dominated by natural and anthropogenic activities.

Keywords: Ground Water, Quality, Factor analysis, Coastal region, Monsoon.

INTRODUCTION

Ground Water is a significant natural resource for human life and its quality depends on geological environment, natural movement, utility and its recovery. The studies of Bear et al., revealed that coastal aquifers have site specific characteristics and differ from other aquifers in characteristic parameters, local industrial unit establishments on and around the coastal aquifers impact these aquifers in various magnitudes positively or negatively[1]. Hence understanding the changes in coastal ground water quality in the present context of contamination problems has become significant. Multivariate analysis is highly useful due to its relative significance in evaluating the combination of large chemical variable data set as a helpful statistical technique to reduce and organize large hydro geochemical data sets into particular groups with similar characteristics. The rotated factor analysis can be widely applied as a statistical tool in hydro-geo chemistry. The analysis is highly helpful to interpret the ground water quality data and to relate them to specific changes in hydro-geological processes. The factor analysis has been successfully applied to the sort out of hydro-geo chemical processes from the collected ground water quality data [2-6].

The main purpose of such analysis for the study of the hydro geo-chemistry of an aquifer is to find a set of factors and among them few can explain a large amount of the variance of the analytical data. The present

study with the application of factor analysis has great potential to demonstrate its usefulness as a technique for the estimation of salt water intrusion or salinity problems in Srikakulam coastal aquifers system in Andhra Pradesh. The study Area is located is Kalingapatnam of Srikakulam district, Andhra Pradesh, India having coordinates 18° 20' 6.9720" N 84° 7' 24.7548" E and the study area map is presented in figure 1.

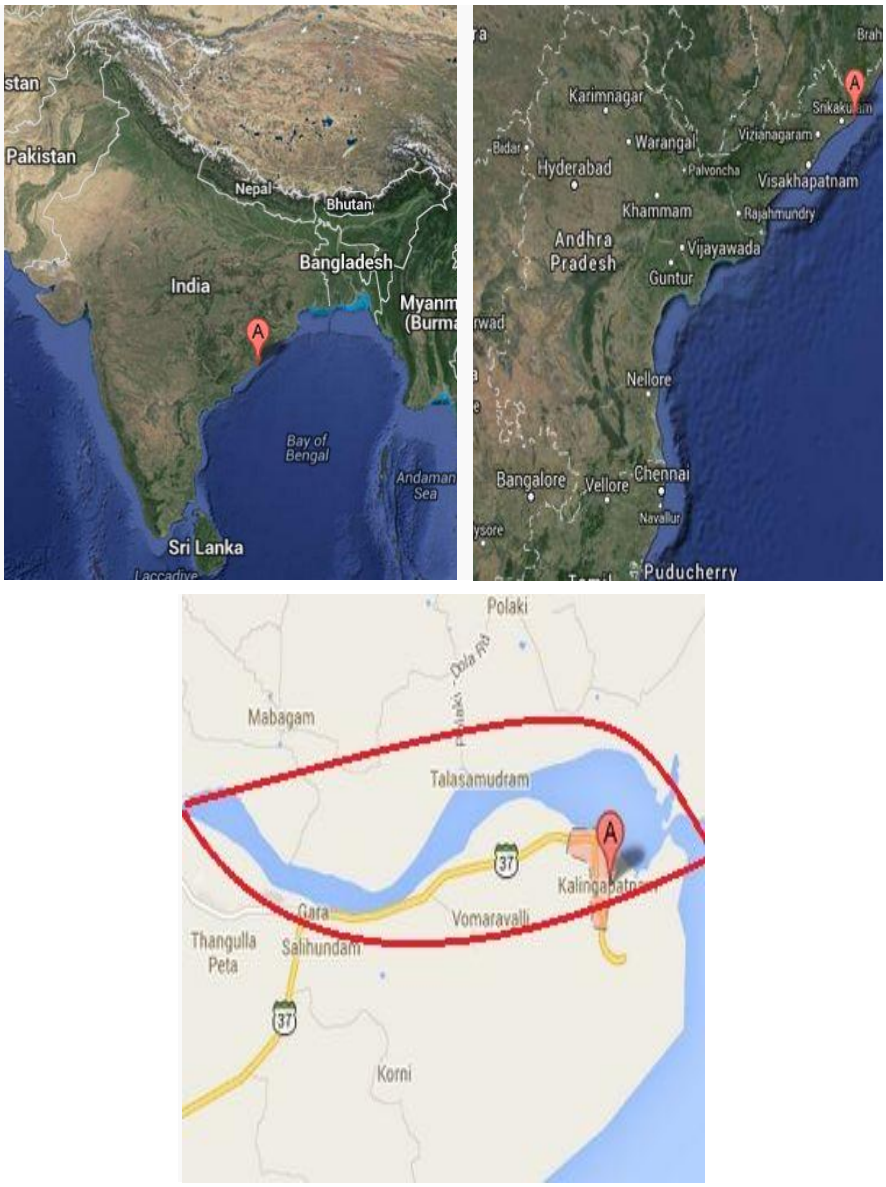

Fig 1. Study area map

MATERIALS AND METHODS

Ground water samples from 16 bore wells are collected during pre and post monsoon periods. The collected samples are characterized for physicochemical parameters viz., pH, EC, TDS, Na^{+}, K^{+}, Ca^{+2}, Mg^{+2}, Cl^{-}, HCO_3^{-}, NO_3^{-}, SO_4^{-2} and PO_4^{-3} by following standard procedures of APHA [7] and the analytical data is presented in tables-1 and 2 respectively.

Table 1. Physicochemical Characteristics of Ground water

Sample Code	pH		EC(µmhos cm^{-1})		TDS(mg L^{-1})		Ca^{+2} mg L^{-1}		Mg^{+2} mg L^{-1}		HCO_3^- mg L^{-1}	
	Pre- M	Post-M	Pre- M	Post-M	Pre- M	Post-M	Pre- M	Post-M	Pre- M	Post-M	Pre- M	Post-M
W-1	7.85	8.57	8160	1570	5222	1005	104	280	171	24.4	73	300
W-2	7.74	8.6	616	1060	394	678.4	24	240	34	48.8	73	400
W-3	7.9	8.3	2630	1750	1683	1120	24	200	83	97.6	73	400
W-4	7.13	7.28	2830	2330	1811	1491	136	160	127	48.8	73	400
W-5	7.54	7.32	2030	3270	1299	2093	56	200	54	BDL	73	400
W-6	7.42	7.83	5100	2920	3264	1869	136	240	176	73.2	98	300
W-7	7.77	8.53	4160	1630	2662	1043	96	120	68	73.2	37	200
W-8	7.21	8.32	3750	1270	2400	812.8	168	120	93	73.2	122	400
W-9	7.38	7.99	3310	1840	2118	1178	72	80	102	73.2	73	400
W-10	7.7	7.83	3870	1950	2477	1248	144	160	107	24.4	98	200
W-11	7.26	7.39	3840	580	2458	371.2	88	120	93	24.4	98	200
W-12	767	6.83	2660	1160	1702	742.4	88	80	39	73.2	49	300
W-13	7.09	8.11	779	1060	498	678.4	80	120	49	24.4	24	300
W-14	7.21	8.3	3240	810	2074	518.4	146	0	102	97.6	73	400
W-15	7.3	7.91	3430	1040	2195	665.6	72	80	78	73.2	73	300
W-16	6.89	8.58	3780	770	2419	492.8	120	80	58	48.8	98	500

Table 2. Physicochemical Characteristics of Ground water

Sample Code	Cl^- mg L^{-1}		Na mg L^{-1}		K mg L^{-1}		Phosphate(mg L^{-1})		Sulphate(mg Lv)		Nitrate(mg L^{-1})	
	Pre- M	Post-M	Pre- M	Post-M	Pre- M	Post-M	Pre- M	Post-M	Pre- M	Post-M	Pre- M	Post-M
W-1	567	815.35	7.13	35.8	23.07	4.93	BDL	BDL	164	197.3	5.6	8.4
W-2	121	283.6	6.93	17.38	22.27	3.93	BDL	BDL	62	76.8	7.2	9.6
W-3	64	354.5	41.59	35.58	27.48	8.94	BDL	BDL	156.4	179.5	14.8	16.2
W-4	64	194.98	28.89	33.71	39.05	11.43	BDL	BDL	110.8	121.6	16.6	15.8
W-5	14	17.73	29.37	61.52	32.23	14.96	BDL	BDL	280.5	338.5	14.2	16.3
W-6	213	35.45	61.62	48.7	46.45	12.66	BDL	BDL	230.2	237.4	8.6	9.2
W-7	121	88.63	57.87	3.36	53.09	6.89	BDL	BDL	110.8	122.5	5.4	6.8
W-8	128	35.45	40.55	24.2	46.21	5.63	BDL	BDL	111.2	117.5	14.3	17.6
W-9	113	17.73	52.23	42.34	22.32	4.42	BDL	BDL	120.6	132.3	12.6	14.8
W-10	206	124.08	62.52	47.58	31.81	1.83	BDL	BDL	64.5	88.9	11.4	14.4
W-11	177	88.63	59.85	7.55	29.22	1.42	BDL	BDL	23.6	30.8	8.8	9.8
W-12	85	17.73	39.61	20.71	26.53	7.38	BDL	BDL	44.2	65.3	10.40	12.6
W-13	64	17.73	9.81	23.74	29.34	1.79	0.60	0.7	48.5	64.3	16.20	18.4
W-14	85	35	44.14	18.93	24.43	1.23	1.22	1.4	22.6	28.2	14.12	15.6
W-15	99	35	51.38	16.7	31.38	1.24	1.54	1.8	46.4	50.1	18.21	17.6
W-16	156	88.63	59.94	17.89	30.09	1.26	BDL	BDL	171.6	197.3	15.30	14.3

Processing of Data: The analytical data is used as variable inputs for factor analysis was performed employing SPSS package described by Nie, the data is standardized according to criteria[8] .This procedure renders a new rotated factor varimax (Tables 3,4) in which each factor is described in terms of only those variables and affords greater ease for interpretation. Factor loading is an indicator of the degree of closeness between the variables and the factor analysis provides several positive features that allow interpretation of the data set.

Table 3. Percentage Variance explained by Factors for Pre Monsoon Ground Water samples

	Rotated Factor Pattern				Final
	Factor1	Factor2	Factor3	Factor4	Communalities
pH	-0.100	-0.014	-0.062	0.836	0.714
EC	0.955	0.188	-0.105	-0.048	0.960
TDS	0.955	0.188	-0.105	-0.048	0.960
Na	0.037	0.795	0.046	0.056	0.639
K	-0.034	0.720	-0.324	-0.088	0.632
Ca^{+2}	0.396	0.723	0.220	-0.026	0.728
Mg^{+2}	0.798	0.218	-0.027	-0.336	0.798
Cl^{-}	0.975	-0.050	-0.110	-0.006	0.966
HCO_3^{-}	0.270	0.516	-0.057	-0.409	0.510
Nitrate	-0.482	0.125	0.558	-0.410	0.728
Sulphate	0.113	0.035	-0.662	-0.547	0.752
Phosphate	-0.075	-0.073	0.889	-0.081	0.808
Eigen Values	4.51	1.90	1.53	1.26	
% Variance	42.46	22.64	18.90	15.99	

Table 4. Percentage Variance explained by Factors for Post Monsoon Ground water samples

	Rotated Factor Pattern				Final
	Factor1	Factor2	Factor3	Factor4	Communalities
pH	-0.269	0.786	0.116	0.251	0.767
EC	0.956	-0.135	-0.038	-0.102	0.944
TDS	0.956	-0.135	-0.038	-0.102	0.944
Na	0.816	-0.033	0.266	-0.322	0.842
K	0.925	-0.120	-0.127	0.128	0.902
Ca^{+2}	0.569	0.529	-0.361	-0.341	0.850
Mg^{+2}	-0.151	-0.042	0.084	0.925	0.888
Cl^{-}	0.033	0.807	-0.241	-0.241	0.768
HCO_3^{-}	0.222	0.338	0.732	0.314	0.799
Nitrate	-0.032	-0.311	0.881	-0.094	0.883
Sulphate	0.859	0.278	0.112	-0.090	0.836
Phosphate	-0.495	-0.272	0.441	0.117	0.527
Eigen Values	5.03	2.31	1.57	1.03	
% Variance	48.26	19.74	18.27	13.71	

By verifying the factor loadings, communalities and Eigen values the variables related to a specific chemical process can be identified and the importance of the major parameters can be evaluated in terms of the total data set and in terms of each factor. Communality is an indicator of the error term. The factor scores for each sample and reflect the importance of a given factor at that sample site, the factor scores can be counted for each factor and for evaluating the aerial importance of the chemical process represented by that factor. Factor scores can be related to intensity of the chemical process described by each factor[9]. Extreme negative numbers (<-1) reflect areas essentially unaffected by the process and positive scores (>+1) reflect areas mostly affected. Near zero scores approximate areas affected to an average degree by the chemical process of that particular factor.

RESULTS AND DISCUSSION

Pre Monsoon: For pre monsoon season, four factors show Eigen values >1, hence these four factors were considered. In the post monsoon period also four factors have Eigen values>1 and hence four factors were considered.

Factor-1 shows the affect of seawater intrusion in the studied aquifer. It is observed a strong positive correlation of TDS with EC, Mg^{+2} and Cl^{-}. Factor-1 explained for 42.46% of the total variance and characterized by very strong positive loading. The presence of cation Mg^{+2} and anion Cl^{-} in ground water results in the enhancement of EC and thereby the TDS. Besides this, TDS represented by abundant mineral elements in the ground water. Accordingly Factor-1 can be defined as the salanization factor Cl^{-} serves as an indicator of sea water intrusion then the studied aquifer. Kalingapatnam canal mouth is highly affected by the tides and due to river water seepage into aquifer system; the quality of ground water is depleted.

Factor-2 of pre monsoon samples include mainly Na, K, Ca and HCO_3^{-} as the shallow aquifers are intensively employed for agricultural purposes. Higher concentrations of Na and K indicate the leaching and dissolution of secondary salts in the pore spaces and the presence of Calcium is an indicator of sea water inundation and this factor accounts as22.64%

Factor-3 of pre monsoon sample is represented by NO_3^{-} and PO_3^{-} and this factor accounts for 18.9%. The higher contribution of Nitrate and Phosphate indicate the excessive interaction of water with aquifer due to the utilization of Fertilizers for crops in the surrounding areas.

Factor-4 of pre monsoon ground water samples is associated with pH and this factor accounts for 15.99% and the higher value of pH indicates the alkaline nature of these ground waters due to the presence of alkali and alkaline earth metal ions is with more loading.

Post Monsoon

Factor-1of post monsoon season is represented by EC, TDS, Na, K, Ca and Sulphate it accounts for 48.26%. The presence of Na, K, Ca and Sulphate in ground water enhance TDS and thereby EC. The higher concentration of TDS is an indication of the presence of mineral elements in ground water in the study area. Factor-1 can be considered as a factor which can explain the salanization based on the higher loading of Total Dissolved Solids due to the presence of Na, K, Ca and Sulphate in which results in higher EC due to salanization of water which in turn is an indicator of salt water intrusion in the aquifer of the study area.

Factor-2 of post monsoon loaded largely by pH and Cl^{-} and accounts for 19.74% of variance. pH indicates the nature of water while the higher load of Cl^{-} will indicates the salt water inundation in the aquifer in the study area.

Factor-3 accounts for 18.27% of variance and represented by HCO_3^- and NO_3^-. Higher loading of HCO_3^- indicates the intensive utilization of ground water in the study area while higher loading of NO_3^- in ground water indicates the utilization of Nitrogenous fertilizers in the study area.

Factor-4 includes higher loading of Mg^{+2} and accounts for 13.71% of variance. Higher concentration of Magnesium may be due to the salt water intrusion and inundation during high tide in the Kalingapatnam coastal area which activates the sea water into ground water system through seepage.

APPLICATIONS

This numerical analysis can help to resolve ambiguities and provide unique hydro geochemical information. This technique can be extended to all coastal aquifer as a component to standard hydro geochemical methods.

CONCLUSIONS

The results of the factor analysis as applied to the chemical data set of ground water in Kalingapatnam of Srikakulam district coastal area provides an insight into the underlying factors controlling hydro geochemical processes in the region. These factors in pre monsoon including factor-1 (EC, TDS, Cl^-) factor-2 (Na, K, Ca, HCO_3^-), factor-3 (NO_3^-, PO_4^{-3}) and factor-4 (pH) extracted from the data set represent the proper signatures of salt water intrusion, interaction with the geological matrix and dissolution of secondary precipitates of connected compounds respectively in the ground water. Factor 2 and 3 represent the ions with dominant concentrations and are the main contributors to the ground water salinity.
The factors in post monsoon including factor-1 (EC, TDS, Na, K, Ca & SO_4^{-2}), factor-2 (pH, Cl^-), factor-3 (HCO_3^-, NO_3^-) and factor-4 (Mg^{+2}) resulted from the data set also indicate the signatures of salt water intrusion, interaction with the geological matrix and dissolution of secondary precipitates of related compounds in the ground water. Factor-1 represents the parameters with dominant concentration and ground water salinity. The present study demonstrated usefulness of factor analysis in interpreting the hydro geochemistry data and relating those data to salt water intrusion, percolation and leaching processes occurring in general in this coastal aquifer. In the present study the salt water intrusion into the ground water in these two periods under study (Pre Monsoon and Post Monsoon) are very well represented by the factors with the loading of EC, TDS, Cl^-, Na, K, Ca, Mg, HCO_3^-. The increase in Bicarbonate concentration during hot season may be attributed to the fact that the increase in temperature accelerates the organic content accessible to bacterial decomposition, where HCO_3^- is the final product of this decomposition[10]. The anthropogenic signatures are also well demarcated by nitrate and phosphate content. This technique can be extended to all coastal aquifer as a component to standard hydro geochemical methods. Further the numerical analysis can further help to resolve ambiguities and provide unique hydro geochemical information.

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