Application of GIS and Factor Analysis in Investigation of Hydrogeochemical Characteristics of Ground Water in Kandukuru Vagu Basin , Nalgonda District ,A.P. India

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Abstract

The analysis of hydrochemical data plays an important role in understanding the contamination, migration and designing the remedial measures . Kandukuru Vagu basin – a sub basin of Aler river forms a part of Nalgonda (Dt) A.P , India , is mainly occupied by granites and gneisses of Archean age intruded by dolerite dykes and quartz veins . In the area the groundwater quality being threatened by the increase in area and intensity of agriculture , urban and the agro based industrial wastes . As a result greater attention is being drawn to ground water resources evaluation and better understanding of hydrogeochemistry of ground water in Kandukuru Vagu basin .To know the spatial and temporal variation of concentration of elements in the ground water , water samples were collected during pre and post monsoon periods i.e. for one hydrological cycle in the year 2007 , and analyzed for 38 elements as per the standard procedures given in (APHA ,1995) .The factor analysis were carried out by XLSTAT software and the resulting factor scores were spatially analyzed using ArcGIS V.9.2 software . The results of factor analysis for geochemical parameters of ground water samples for pre and post monsoon are given in the form of factors loading values , biplot diagrams and the spatial distribution maps of the factor scores . The possible explanation of high correlation of elements of different water types my be due to the difference in chemical composition of bed rocks and soil . Further , the variation in the concentration of elements between different water types suggest that the hydrological controls such as , flow path length , recharge from different areas , duration of contact or resident time with the different rock types and influence of infiltration of fertilizer from the agricultural fields , has over all implication on the observed variation in the hydrochemical facies of the ground water .

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Key words : Kandukuru Vagu basin , Factor analysis , GIS , Factor scores , Factor loading , hydrogeochemical characteristics , ground water .

Introduction .

The Study of hydrogeochemical analysis plays an important role in ground water studies in characterizing the natural systems , understanding the contamination , migration and designing remedial measures . Many factors including the composition of precipitation , geological structures and mineralogy of watershed and aquifers , the geochemical processes within the aquifer , permeability and discharge rate , flow path and resident time of water within the aquifer, infiltration versus upward leaking from the neighboring aquifers, and ground water circulation/salt accumulation balance, affects the chemical composition of the ground water . The interaction of all factors combined with the prevailing climatic conditions and pH leads to various water facies (Suresh , 1994 ; Olobaniyi and Owoyemi , 2006; Agrawala , 2007 ; Ismael , 2007) .The interpretation of hydrochemical facies useful for determining the flow patterns , origins , and chemical history of ground water masses . (Dalton and Upchurch , 1978)

The basin of kandukuru Vagu , a sub basin of Aler river basin Nalgonda (dist.), A.P. India , covering an area of 212 sq.kms (Fig. 1) , is bounded by longitudes 78^{o} 46' and 79^{o} 04' and latitudes 17^{o} 35' and 17^{o} 41' . Most of the ground water in the basin occurs under unconfined and semi confined conditions . Therefore , the possibility of infiltration of chemical elements resulted from the use of fertilizer chemicals in the crops field activities and probability of the occurrence of harmful dissolvable elements in rocks , always causes pollution of ground water continuously in the Kandukuru Vagu basin .The occurrence in the increase , in salinity of ground water due to leaching of salts , build up in agricultural area under intense irrigation is reported Thus the ground water quality is being increasingly threatened by agricultural , urban and agro industrial wastes in the area of investigation . With the increase in stress on ground water resources and reducing fresh water availability , greater attention is being drawn to ground water resources evaluation and better understanding of hydrogeochemistry of ground water .

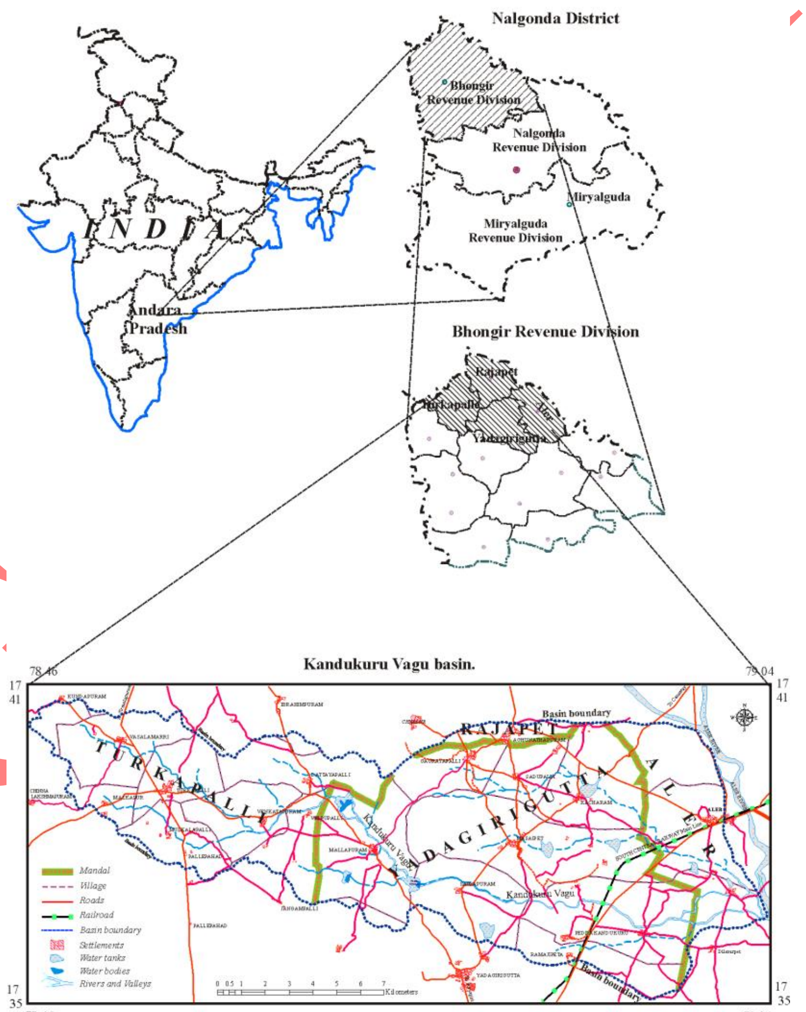
The objective of the present study is to apply the multivariate analysis and GIS tools to evaluate the spatial and temporal variations in chemical characteristics of ground water and to determine the flow direction of ground water in Kandukuru Vagu basin .

Early studies on the characteristics of ground water facies and chemical evaluationary history , utilized the graphical representations of major ionic composition of ground water (Olobaniyi and Owoyemi, 2006) . Recently , applications of GIS and factor analysis has been used as a modern tool in the study of hypothesis of (a). geochemical evaluation of ground water (b). recharge and discharge areas and (c) ground water flow paths .

Factor analysis is widely used statistical method in the geochemistry of ground water (Temple ,1978 ; Tripathi , 1979).The effectiveness of this method in ground water chemistry discriminations over the traditional methods , come from its ability to reveal hidden inter – variables relationships and allows the use of virtually limitless number of variables . Thus trace elements and physical parameters can be part of classification parameters.

Factor analysis is a technique that summarizes the matrix of data to a number of factors , which represent the original variables with a minimum losses of information (Grande , 1996 ; Hardle and Simar , 2003 ; Agrawala , 2007) , More importantly the factor analysis can be applied to identify the main source of variance within geochemical data sets and link them to geochemical processes (Helvoort, 2005) . Furthermore , factor analysis aim to explain observed relation between numerous variables in terms of simpler relation . It is also a way of classifying manifestation of variables (Kumar et al , 2006). The advantage of factor analysis in hydrogeochemical interpretation come from that , it is independent of the number or type of variable used and uses the raw data instead of percentage data which is used in the case of graphical diagrams . (Dalton and Upchurch, 1978)

Fig. 1 : Location map of Kandukuru Vagu basin



Factor analysis Involve finding the eigenvalues of correlation matrix , and related the factors to the largest eigenvalue one by one and explain , which attribute and samples location are associated with the largest amount of spatial variability for each factor (Ritz et al. , 1993; Hardle and Simar , 2003) .The factor extraction is performed with a minimum acceptable eigenvalue equal to 1 (Caputo , 2005) and the Kaiser-Guttman rule suggests that only those factors which are associated with eigenvalues strictly greater than 1 should be kept (Addinsoft, 2008) . In factor analysis varimax rotation was used to terminal factor solutions . This method maximize the variance of the loadings on factor to simplify the columns of the factor matrix and hence adjusts factor loading to be either near ± 1 or near zero (Grande , 1996 ;Caputo ,2005 ; Olobaniyi and Owoyemi , 2006) . The rotated factor matrix allows the grouping of variables or factors and estimation of the influence on particular samples as a factor scores (Caputo , 2005).

Factor scores are computed for each sample by a matrix multiplication of the factor score coefficient with standardized data .The value of each score represent the importance of a given factor at the sample site . A factor score greater than “1” indicate intense influence by the chemical process , while negative value less than “-1” means area un effected by that factor and near zero values reflect that the area is affected to an average degree by the chemical process .(Lawrence and Upchurch , 1982 ; Locsey and Malcolm , 2003) .

Factor scores have usually been plotted as geochemical contour maps for each factor to identify anomalies and which give an indication about the mineralization process and contamination sources (Helvoort , 2005)

Water Sampling and Chemical Analysis .

Water samples were collected during pre and post monsoon periods of one hydrological cycle in the year 2007 in two litre polythine water bottles based on the rock and soil types , hydrogeomorphology , landuse/landcover ground water samples were collected at selected locations spreading throughout the basin. To know the spatial and temporal variation of chemical constituents of the ground water . All the water samples are located using Global Positioning System (GPS) . During the pre monsoon 33 ground water samples were collected from bore wells between 20^{th} and 25^{th} of May 2007 . During the post monsoon , 30 samples of ground water from bore wells collected between 14^{th} and 27^{th} of November 2007 .

The chemical analysis of ground water samples was carried out by volumetric , gravimetric, colorometric and potentiometric methods using different instruments and analysis techniques .as per the test procedures given in the standard textbooks (APHA, 1995) .

Factor Analysis and Spatial Distribution .

XLSTAT statistical software was used to carry out the factor analysis . The principal factor method applied iteratively to generate several factors, enhanced by selecting of varimax rotation to facilitate the interpretation of the results.

The most important of the factor analysis outputs , are the factor loading tables related with weighted distribution of different geochemical elements on the resulted factors . Using ArcGIS 3D analyst spatially distributed factors as iso-score maps prepared , for both pre and post monsoon water samples , to know the location of recharge and discharge , direction of groundwater flow path , contamination and evaluation of ground water in the basin .

Results and Discussion .

The results of factor analysis for hydrogeochemical parameters of ground water samples collected during pre and post monsoon are given in the form of factors loading values (Tables 2 ,4) , biplot diagrams (Fig. 2a,b,c and 3a,b,c) , factor scores (Table 3, 5) and iso-scores maps (Fig. 4a,b,c,d,e,f and 5a,b,c,d,e,f).

Table no. 2 shows the correlation of variables and factors of bore well water samples collected during pre monsoon , are represented by six factors explaining with eigenvalues greater than 1 , explain about 82% of the total chemical parameters . Each pair of factors are plotted on biplot diagrams (Fig. 2a,b,c) , which explain the positive and negative loading of the parameters on each factor . It is clear from the diagrams that , most of the elements have positive loading on factors 1 and factor 2 (Fig. 2a) .The scores of each factor observed for water samples are given in table no. 3 . The spatial distribution of factor scores (Figs. 4a,b,c,d,e,f) are prepared using 3D analyst ArcGIS V.9.2 software .

Factor -1, cover 24.7% of the total parameters , including highly positive loaded parameters i.e. TDS , Salinity , Cl, SO4, NO3, Mg, TH , Ca, Sr, Ba and HCO3 . The spatial distribution of factor 1 parameters , presented as iso- scores map (Fig. 4a) shows that , near 8b, 27B, and 6B sample locations , the domination of positively loaded parameters of factor 1 indicates that most of the water is fresh and not saline because strontium (Sr^{+2}) is a good indicator for fresh ground water . The location of these samples are in the recharge area of ground water and the increase of TDS is due to the increase in solubility of chemical elements by the chemical process during infiltration of CO_3 and HCO_3 waters through the soil and rock fractures . Further , the high concentration of Nitrate (NO_3) and Sulfate(SO_4) may be derived from the continuous uses of fertilizer chemicals used in the agricultural fields . Ca , Mg and minor elements like Sr , Ba probably are derived from the rock types and accessory minerals present in the composition of granite and dolerite rocks . Geologically this area is occupied by the alkali feldspar granite rocks intruded by dolerite dykes .

Factor -2 represent 23.9% of the total parameters , explaining the highly loaded elements of Cr, Co, Al, Fe ,Li, B, Si, Pb, Mo and Mn . The factor scores of these elements when presented spatially on the map of iso- score (Fig. 4b) , shows that the highly weighted scores appear at 15B, 32A, 27B and 9B sample locations. The highly loaded of these elements are derived by the chemical reactions between the water and rocks of pink and gray alkali feldspars with high percentage of biotite , hornblende and albite minerals and other accessory minerals rich in chemical compounds of these elements .

Factor -3 explain 12.8% of the total parameters with highly loaded parameters of Co3 , pH, Na and F . The spatial distribution of highly loaded elements presented on iso- score map (Fig. 4c) , show that , the sample nos. 20A,15B, 3B, 7B and 13B are located in the down stream side of kandukuru Vagu basin . The rise in the alkalinity and pH of the ground water is due to more dissolution of chemicals and ion exchange process taking between soils , rocks and ground water .

Factor -4 cover 8.2% of the total parameters , explaining the highly loaded elements of . Rb, Zn and K at sample locations of X3, X4 and 15B (Fig.4d). These samples are located in the area covered by the granites with high potassium feldspar and accessory minerals rich in Rb and Zn .

Factor 5 explain 7.1 % of the total parameters , with highly loaded elements of Be, As, Ag and Pb . The spatial distribution of the highly loaded elements presented on iso-score map (Fig.4e) show that , these minor elements are highly concentrated at sample number 4A , located in the extreme upstream area of kandukuru vagu basin . Geologically this area is occupied by pegmatite granite rocks with some accessory minerals composed of complex sulfides .

Factor -6 represent 5.4% of the total parameters, explaining highly loaded elements of Mn , Sb and Ni in bore well water samples of 8B, 5B and 20A , located at the eastern part of the basin(Fig.4f) . This area is generally dominant in gray alkali granite with accessory minerals containing Antimony (Sb) and Nickel(Ni) .

Six factors with eignvalue greater than 1 were extracted from the hydrogeochemical data of bore well water samples collected during post monsoon period -2007 . The results of factor analysis are presented in the form of tables (Tables no.4,5) , biplot diagrams (Fig.3a,b and c) and spatial distribution of iso-score maps (Fig.5a,b,c,d,e and f) .The factor loads presented on biplot diagrams (Fig 3a,b and c) shows positive and negative loading of elements at each factor . It is clear from the diagrams that , most of the elements have positive loading on factors 1 and factor 2 (Fig. 3a) , while the figure no. 3b shows most of the positively loaded elements are from factor 4 .

Factor-1 , describe 27.8% of the total parameters , explaining the positive loaded elements of TDS, Salinity , HCO_3, Cl, Th, Mg, Sr, K, Na , ,Na, Li, Ba, SO_4, NO_3 and Se . The factor scores have high weight at sample locations CH1 and 21B where the dominant rocks types are alkali feldspar granites . The spatial distribution of highly loaded elements presented on iso score map (Fig 5a) shows that they are located in the recharge area .

Factor -2 , cover 20% of the total parameters explaining the highly loaded minor elements of Pb, Cu, Ni, Zn, Co, Mn, Fe, Al, and Be at sample locations. D1 and 8B .The spatial distribution of the highly loaded elements on iso score map (Fig.5b) shows that the samples are located geologically in the area of granites and gneisses intruded by dolerite dykes with a mineral composition of plagioclase , labrodorite , augite and other accessory minerals .

Factor -3 describe 8.9% of total parameters with highly loaded elements of F, pH and CO3, at sample location of 15B and 7B(Fig.5c) , located in the down stream area with high alkalinity and pH .

Factor-4 cover 11.9% of total parameters with highly loaded minor and toxic elements of Cr, Si, V, Fe, As, Se, and Sb , at sample locations of 9B and J1 located in the downstream side of the Kandukuru Vagu basin (Fig.5d) . The area is covered by gray alkali feldspar granite .

Factor -5 describe 7% of the total parameters , explaining highly loaded elements of B, Ag and Al near 8B and 21B sample locations (Fig.5e) . The dominant rocks types near these sample locations are alkali feldspar granite intruded by dolerite dykes .

Factor - 6 describe 5.8% of parameters with moderately loaded elements of Rb , SO4, As, Be and Sb . The high factor scores are shown near X2 and T1 sample locations , located in the upstream side of the basin (Fig.5f) covered by pegmatite and granite gneiss intruded by dolerite dykes .

Conclusions.

The modern tools of geographical information systems (GIS) and multivariate statistical analysis are fast and better tools to extract information about the a). hydrogeochemical evaluation of ground water , b). recharge and discharge areas and c). ground water flow paths in the basin . Thus from the results and discussions the hypothesis one i.e. the hydrogeochemical evolution of ground water can be fully accepted . However, as the number of samples collected in the recharge and discharge areas are not sufficient , the other two hypothesis i.e. flow direction , recharge and discharge area are partially revealed . In the majority data sets of pre and post monsoon water samples , the highly loaded elements are appears in the first three factors i.e. factors 1, 2 and 3 .

Table 2 : Correlations between variables and factors of bore wells water samples - pre monsoon .

Parameter	F1	F2	F3	F4	F5	F6	Communality
EC	0.953	0.006	0.258	0.025	-0.042	-0.009	0.975
TDS	0.949	0.005	0.268	0.025	-0.043	-0.015	0.974
SALINITY	0.950	0.003	0.267	0.023	-0.048	-0.014	0.975
Ph	-0.257	-0.096	0.851	-0.258	-0.023	-0.023	0.855
TH	0.892	0.049	-0.395	0.003	0.003	0.162	0.977
CO3	0.017	0.029	0.947	0.051	-0.087	-0.053	0.885
HCO3	0.528	0.609	0.340	0.316	-0.022	0.094	0.877
CL	0.944	0.106	-0.067	-0.035	0.009	0.166	0.928
SO4	0.902	-0.174	0.067	-0.064	-0.095	0.037	0.854
NO3	0.842	0.077	-0.440	-0.063	-0.051	0.181	0.940
F	-0.167	0.054	0.763	0.102	-0.090	-0.192	0.644
Li	-0.053	0.688	-0.056	-0.282	-0.239	-0.392	0.770
Na	0.404	0.361	0.785	0.022	-0.017	0.036	0.900
K	0.303	0.039	-0.165	0.787	-0.084	0.229	0.787
Mg	0.870	0.323	-0.282	0.000	-0.042	0.032	0.945
Ca	0.756	0.282	-0.403	0.207	-0.013	0.251	0.906
Sr	0.648	0.445	-0.415	-0.031	-0.004	-0.268	0.851
Mn	0.400	0.537	-0.090	0.320	-0.008	0.588	0.881
Fe	0.284	0.830	-0.181	0.104	0.014	0.388	0.972
Rb	-0.062	0.295	0.063	0.900	0.059	-0.069	0.967
Ba	0.594	0.466	-0.489	0.229	-0.014	0.155	0.882
Zn	-0.102	-0.139	-0.013	0.843	-0.008	-0.090	0.749
Ni	0.106	0.471	0.041	-0.128	0.405	0.521	0.659
Be	-0.297	0.060	0.160	0.380	0.531	-0.121	0.547

B	0.330	0.695	0.051	0.046	-0.106	-0.125	0.623
Al	-0.124	0.836	0.094	0.299	0.153	0.088	0.836
Si	-0.106	0.629	-0.504	0.047	-0.110	-0.073	0.660
V	0.111	0.623	0.408	0.015	0.109	0.163	0.598
Cr	0.010	0.942	-0.097	-0.122	-0.077	0.263	0.998
Co	0.110	0.882	-0.017	0.206	0.021	0.297	0.926
Cu	-0.247	0.491	0.076	-0.130	0.144	0.076	0.350
As	0.061	-0.102	-0.072	-0.073	0.946	0.103	0.948
Se	0.350	0.813	0.320	-0.136	-0.095	-0.055	0.932
Mo	0.142	0.632	0.231	0.208	-0.079	-0.209	0.562
Ag	-0.126	-0.008	-0.117	0.012	0.905	0.197	0.898
Cd	-0.077	-0.759	0.180	-0.065	-0.029	-0.181	0.653
Sb	0.135	0.237	-0.166	-0.076	0.232	0.759	0.670
Pb	-0.119	0.691	-0.196	-0.120	0.520	0.073	0.831
Eigenvalue	12.386	6.857	4.906	2.974	2.820	1.239	
Variability(%)	24.651	23.930	12.806	8.144	7.137	5.392	
Cumulative (%)	24.651	48.581	61.386	69.531	76.668	82.060	

Table 3 : Factor scores of bore well water samples -pre monsoon .

Sa.No.	F1	F2	F3	F4	F5	F6
8B	**2.504**	0.386	-0.467	0.500	-0.075	**2.751**
7B	0.494	-0.881	**1.333**	-0.869	-0.707	-0.410
25A	-0.347	-1.317	0.060	-0.034	-0.244	-0.382
6B	**2.217**	-1.240	-0.781	-0.252	0.367	0.544
1A	-0.670	-0.702	-0.526	-0.838	-0.722	0.352
5B	-0.700	0.910	-1.096	-0.315	-0.508	**1.631**
15A	-0.856	-1.114	-0.216	-0.009	-0.402	-0.170
32B	0.148	-0.976	0.892	0.091	0.745	-0.732
10A	0.128	-1.064	0.438	-0.323	-0.296	-0.474
3B	0.181	-0.542	**1.382**	-0.288	-0.018	-0.010
X4	-0.377	-0.529	-0.349	**2.410**	-0.244	-0.254
21B	-0.616	-0.415	-1.136	-0.616	-1.069	0.092
9B	-0.510	**1.275**	0.616	-0.315	-0.157	0.680
4A	-0.741	-0.595	-0.481	-0.324	**4.413**	0.351
13B	0.435	-0.661	**1.184**	-0.169	-0.341	-0.854
27B	**2.352**	**1.547**	-1.302	-0.453	0.073	-2.350
15B	-0.133	**1.771**	**1.856**	**1.835**	0.756	-0.537
20B	-0.909	0.796	-0.810	-0.033	-0.106	0.505
X3	-0.282	-0.429	-0.413	**3.166**	-0.348	-0.107
6A	-0.564	-0.936	-0.762	-0.110	-0.276	-0.391
X2	0.156	0.964	-1.042	-0.052	0.107	-1.053
8A	-0.978	0.546	-0.909	-0.608	-0.137	-0.269
32A	-1.097	**1.560**	-0.290	-0.835	-0.365	-0.092
20A	-0.081	0.880	**1.902**	-0.645	-0.115	**1.216**
28B	0.244	0.766	0.917	-0.914	-0.329	-0.035

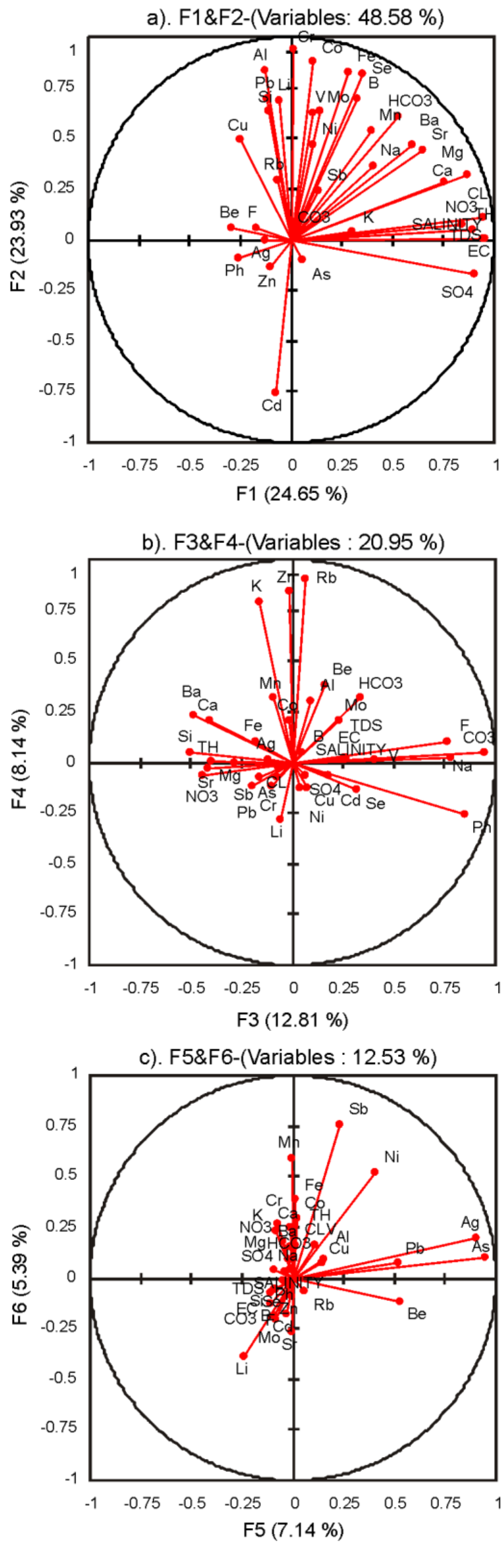
Table 4 : Correlations between variables and factors of bore well water samples -post monsoon .

parameter	F1	F2	F3	F4	F5	F6	Communality
EC	0.965	-0.071	0.180	0.018	-0.078	-0.016	0.984
TDS	0.960	-0.068	0.193	0.019	-0.083	-0.015	0.975
SALINITY	0.962	-0.062	0.193	0.035	-0.076	-0.007	0.978
Ph	-0.038	-0.048	0.707	0.030	0.302	-0.121	0.560
TH	0.817	0.001	-0.138	0.028	0.039	0.142	0.692
CO3	0.251	-0.221	0.654	0.237	-0.175	-0.502	0.838
HCO3	0.650	0.187	0.339	0.452	-0.104	0.172	0.796
Cl	0.919	0.081	-0.013	0.139	0.292	0.175	0.993
SO4	0.744	-0.058	0.009	-0.125	-0.262	0.485	0.860
NO3	0.727	0.030	-0.272	-0.230	0.293	0.247	0.789
F	-0.116	0.041	0.932	-0.020	-0.047	0.043	0.842
Li	0.716	0.252	0.009	0.253	0.281	0.125	0.722
Na	0.532	-0.118	0.540	0.355	-0.280	-0.292	0.841
K	0.778	-0.047	-0.204	0.287	-0.109	0.295	0.821
Mg	0.915	0.061	0.017	0.125	0.191	-0.051	0.887
Ca	0.358	0.299	-0.305	0.124	0.411	0.639	0.866
Sr	0.832	0.262	-0.095	0.188	0.233	-0.228	0.908
Mn	0.377	0.770	-0.094	0.109	0.139	0.030	0.749
Fe	0.074	0.714	-0.169	0.565	0.158	0.219	0.922
Rb	0.356	0.500	-0.052	0.162	0.115	0.552	0.700
Ba	0.798	0.274	-0.228	0.258	0.086	-0.292	0.913
Zn	0.097	0.861	0.190	-0.123	0.095	0.034	0.784
Ni	0.007	0.922	-0.025	0.213	0.219	0.035	0.908
B	0.378	0.226	0.198	0.151	0.821	0.113	0.941
Be	-0.129	0.662	-0.058	0.025	0.259	0.358	0.628
Al	-0.066	0.701	0.028	0.325	0.424	0.094	0.758
Si	0.095	0.262	0.322	0.632	0.287	-0.211	0.661
V	0.154	0.461	0.568	0.611	0.147	-0.064	0.940
Cr	0.090	0.375	-0.016	0.867	0.205	-0.090	0.959
Co	0.166	0.849	-0.100	0.312	0.342	0.041	0.971
Cu	-0.016	0.949	0.046	-0.081	-0.213	-0.055	0.969
As	0.343	0.264	-0.105	0.577	-0.247	0.441	0.774
Se	0.579	0.334	0.203	0.564	0.062	-0.057	0.790
Mo	0.114	-0.173	0.476	0.299	-0.577	0.215	0.677
Ag	0.083	0.318	0.108	0.195	0.781	0.098	0.694
Cd	-0.101	0.157	-0.138	-0.847	-0.039	-0.095	0.707
Sb	0.076	0.358	-0.330	0.495	-0.103	0.316	0.545
Pb	-0.076	0.961	-0.109	0.187	0.003	0.027	0.974
Eigen value	13.365	7.652	4.326	2.418	2.082	1.473	
Variability (%)	27.764	20.100	8.888	11.927	7.886	5.846	
Cumulative %	27.764	47.864	56.753	68.679	76.565	82.411	

Table 5 : Factor scores of bore well water samples - post monsoon .

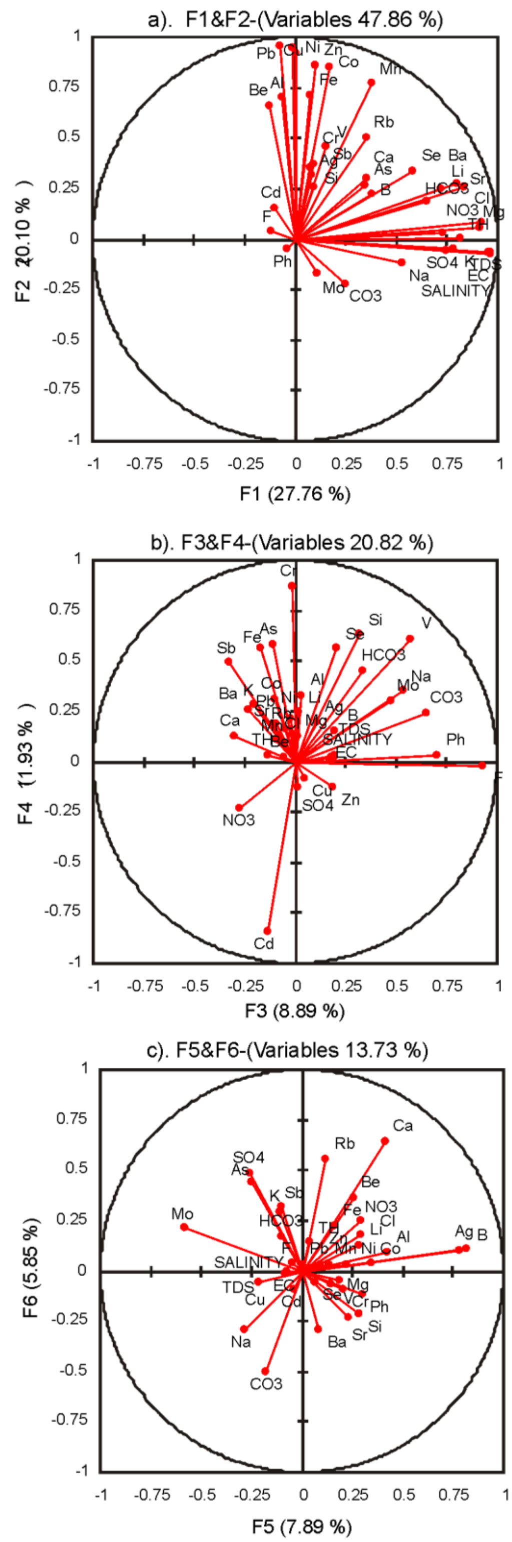
Sa.No.	F1	F2	F3	F4	F5	F6
8B	0.407	**1.192**	0.724	0.533	**3.380**	0.376
7B	-0.131	-0.352	**2.478**	0.284	-0.691	-0.163
25A	0.129	-0.800	0.327	-2.406	0.199	-0.314
15A	-1.078	-0.315	-0.785	0.267	0.422	-0.773
32B	-0.063	-0.376	0.343	0.280	-0.717	-0.711
10A	0.196	-0.501	-0.012	0.212	-0.404	-0.856
21B	**2.284**	0.066	0.263	-0.208	**1.002**	0.567
9B	-0.176	0.370	-1.163	**1.707**	-0.008	-1.510
15B	-0.429	0.103	**2.511**	0.201	-0.780	0.091
20B	-1.000	-0.460	-0.723	0.071	0.298	-0.592
6A	-0.683	-0.724	-0.755	-2.413	0.530	-0.016
X2	0.287	-0.261	-0.783	0.890	-1.085	**2.995**
8A	-0.711	-0.175	0.060	-0.279	-0.309	0.891
J1	-0.048	-0.445	0.282	**1.373**	0.411	-0.693
D1	-0.032	**3.875**	-0.377	-0.899	-1.170	-0.301
AL1	0.425	-0.106	0.001	0.021	-0.660	-1.108
K1	-1.228	-0.300	-0.571	0.480	0.263	0.362
KO1	0.261	-0.099	-0.874	-0.281	-0.252	0.876
T1	-0.711	0.290	-0.124	0.376	0.305	**1.115**
V1	-0.600	-0.306	-0.088	-0.222	-0.031	0.332
CH1	**2.902**	-0.676	-0.735	0.014	-0.702	-0.568

Fig. 2 :Biplot diagrams for water samples - pre monsoon :a). F1&F2 , b). F3&F4 and c). F5&F6 .



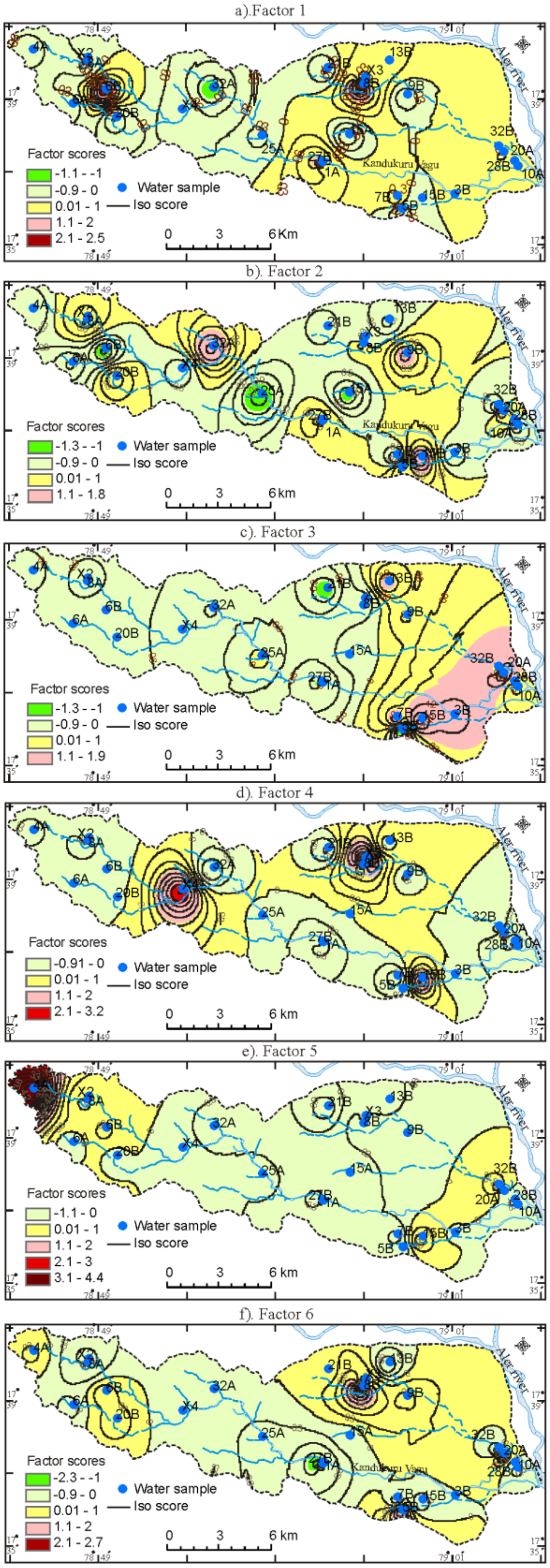
Source : Table no. 2.

Fig. 3 :Biplot diagrams for water samples - post monsoon :a). F1&F2 , b). F3&F4 and c). F5&F6 .



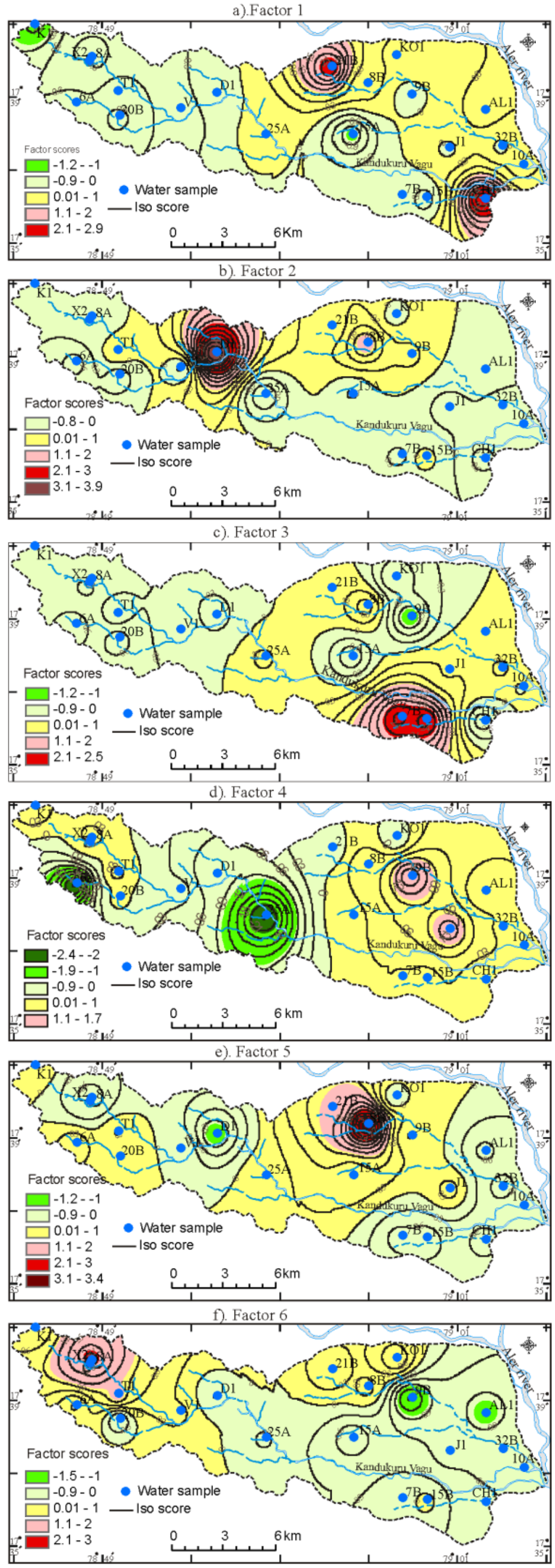
Source : Table no. 4.

Fig 4 : Factor score maps of pre monsoon water samples -Kandukuru Vagu basin.



Source : Table no. 3 .

Fig 5 : Factor score maps of post monsoon water samples -Kandukuru Vagu basin.



Source : Table no. 5 .

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