GROUNDWATER QUALITY AND CONTAMINATION SOURCE ASSESSMENT OF JAIPUR DISTRICT USING MULTIVARIATE STATISTICAL TECHNIQUES

HANSA RAJPUT, ROHIT GOYAL

Abstract: Jaipur district is facing water scarcity along with continuously deteriorating groundwater quality. In Jaipur district fluoride concentration varies in the range of 0.16 – 16.4 mg/liter, against the maximum permissible limit of 1.5 mg/liter and nitrate (NO_3) concentration varies in the range of 0.68 – 716 mg/liter, against maximum permissible limit of 45 mg/liter. The objective of the paper is to assess the groundwater quality of Jaipur district, using multivariate statistical techniques such as Correlation Analysis and PCA (Principal Component Analysis) along with GIS frame work. Water quality data was analysed for 13 physico-chemical parameters Total Dissolved Solids (TDS),Chloride (Cl), Fluoride (F),Nitrate and Iron(Fe) etc.The Correlation analysis showed strong relationship between TDS and Chloride, Sulfate,Sodium, Mg and Ca, indicating high salinity of groundwater. High fluoride concentrations in groundwater due to geogenic processes, high Nitrate due to excessive use of fertilizers and domestic sewage discharge, high Chloride to due organic waste and high bicarbonates resulting in to high alkalinity and pH were also observed during the data analysis. PCA of the water quality data resulted in 6 important PCs which explained 90.5% of the total variance in the data. The PCA assisted to extract and recognize the factors responsible for water quality variations. Integration of PCA factor scores with GIS resulted in maps, clearly explaining the variability at different sampling location.Thus multivariate statistical techniques offer a valuable tool for the evaluation and interpretation of complex water quality datasets which can assist the decision makers in identifying priorities to improve water quality that has deteriorated due to pollution from various anthropogenic activities.

Keywords: Correlation Analysis, Geographical Information System (GIS), Groundwater quality, Multivariate statistical techniques, Principal component analysis (PCA).

Introduction: Groundwater is one of the most vital natural resource for the survival of human life.Despite the enormous importance of this resource, it has been taken for granted and given very little protection. Continuous increase in population, rapid urbanization and industrialization has lead to increase in water demand,as a result of which groundwater resources are depleting rapidly. Increasing evidence of groundwater contamination in recent years, coupled with concern about human health and ecological effects of contaminants such as nitrate, pesticides etc. have been reported worldwide.In dry regions groundwater is the most important resource as most of the water demands are met by groundwater supplies.Groundwater quality in semi-arid and arid regions area is greatly controlled by the natural processes (e.g., geology, groundwater movement, recharge water quality, and soil/rock interactions with water), anthropogenic activities (e.g., agricultural production, industrial growth, urbanization with increasing exploitation of water resources) and atmospheric input [1].

Groundwater resources are important in Indian sub-continent because of most of the villages arenot connected with surface water supply system. The importance of groundwater resources increases many fold for arid tracts like Rajasthan.One of the most prominent geogenic groundwater contaminant in Rajasthan is fluoride. Almost all the districts of the state are affected by it. Apart from geogenic sources, the groundwater in the state is also affected by various anthropogenic activities, mainly industrial, agricultural and sewage discharge. Intensive use of chemical fertilizers in agriculture has resulted into leaching of the residual nitrate, causing high nitrate concentrations in groundwater. Pollution of groundwater due to industrial effluents and municipal waste in water bodies is another major concern. Bhaduri et al.,[2], carried out a detailed study of ground water of Sanganer block in Jaipur district to assess the effect of textile effluent on groundwater quality and level of contamination using mathematical model. The resultant total pollution load in Sanganer comprises of enormous higher load of Na+ and Cl- ions due to use of common salt (NaCl) for fixation of dyes. The study revealed that all observation points were severely affected with the TDS concentration values exceeding the permissible limits prescribed for drinking water quality. In Jaipur district (study area) fluoride concentration varies in the range of 0.16 – 16.4 mg/liter, against the maximum permissible limit of 1.5 mg/liter and nitrate (NO3) concentration varies in the range of 0.68 – 716 mg/liter, against maximum permissible limit of 45 mg/liter (CGWB, 2015 data). Hence, assessment of groundwater quality at both spatial and temporal scales is imperative for managing this vital resource, especially in water-scarce regions.

Many conventional tools/techniques are available for the graphical and statistical interpretation of groundwater.The multivariate statistical technique such as Co-correlation Analysis, PCA (Principal Component Analysis) coupled with GIS offer a valuable tool for the evaluation of spatio-temporal variations and interpretation of complex water quality datasets [3].Geographical Information System (GIS) is a very efficient tool for spatial data management and analysis.Its versatility in spatial interpolation can be utilized to interpolate the 2-D solutions at each section to get a 3-D solution and then to map the area under study [4]-[5].

Study Area: Jaipur district, as shown in figure 1, covering geographical area of 11,061.44 sq. km and extendingbetween north latitudes 26° 25' and 27° 51' and east longitudes 74° 55' and 76° 15'forms east-central part of the Rajasthan State.

Source:www.mapsofindia.com

Figure1: District Map of Rajasthan State

The district covers about 3.23% of total area of the State. The semi-arid district receives normal annual rainfall of 527mm (2001 to 2010).Groundwater in the district occurs both in unconsolidated Quaternary formations and consolidated formations of Bhilwara and Delhi Super Groups and also Post DelhiGranites. In greater part of the district, alluvial deposits comprising of mainly finesand and silt serve as potential aquifers in addition to gravel zones[6]. The scope of the present study is to determine:

- Effect of Physico-chemical parameters in the assessment of water quality during the year 2015 using Correlation Analysis.
- (ii). Order of influence of parameters or variables affecting the water quality using PrincipalComponent Analysis.
- (iii). GIS-based geo- statistical modeling (using Inverse Distance Weighted Interpolation) of the factor scores of PCA for better interpretation of variability in groundwater quality parameters with respect to sampling location.

Methodology: The groundwater quality data for year 2015 was taken from CGWB. Data of total 24 samples (Fig. 2) from different sampling location of the Jaipur district were collected. Water quality parameters such as pH, Total Dissolved Solids (TDS), Bicarbonate (HCO_3), Calcium (Ca), Magnesium(Mg), Chloride (Cl), Sodium (Na), Fluoride (F),Sulfate (SO_4),Potassium (K),Nitrateand Iron(Fe) were considered for assessment of ground water quality usingstatistical techniques.

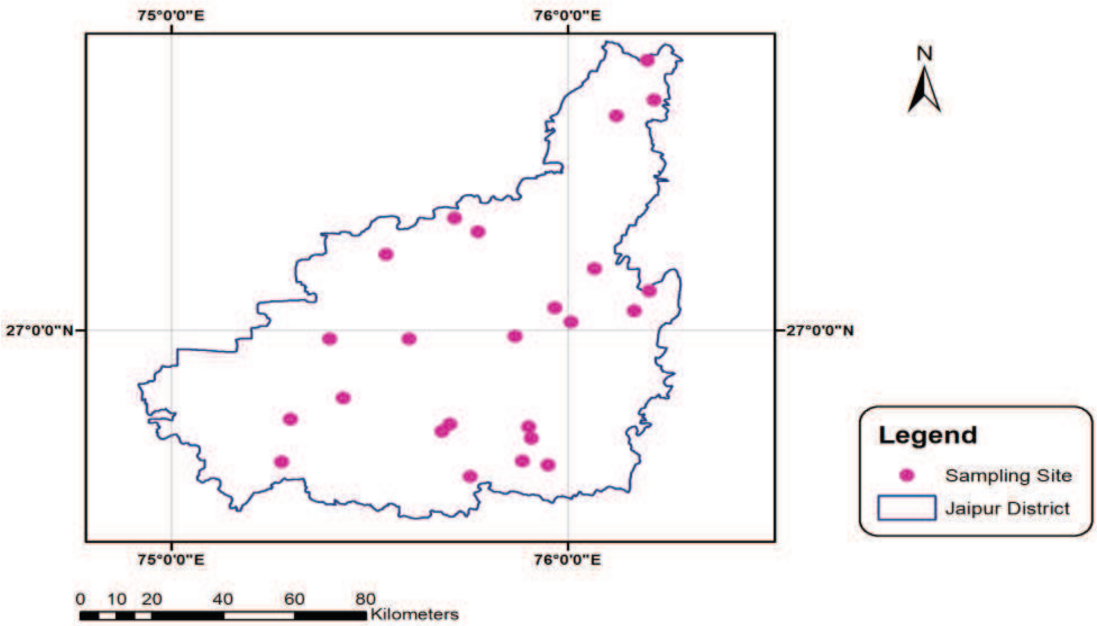

Figure 2: Map of the study area with groundwater sampling location

Results and Discussions: The statistical software XLSTAT2014 was used for the correlation coefficient and multivariate statistical analysis of the data. Correlation Coefficient is a measure of linear association between two variables. The correlation coefficient 'r' ranges from -1 to 1 where -1 describes a very strong negative relationship where an increase in one variable is accompanied by a predictable and consistent decrease in the other, 0 describes a random or non-existent relationship and +1 describes a very strong positive relationship where an increase in one variable is accompanied by a predictable and consistent increase in the other. Correlation values of -1 or 1 imply an exact linear relationship. Also, a low correlation value does not mean that no relationship exists; merely that no linear relationship exists [7].

Principal Component Analysis: Principal component analysis (PCA) is one of the most important statistical methods for the interpretation of groundwater chemistry [8]. PCA provides information on the most meaningful parameters which describe the interpretation of whole data set, leads to data reduction and summarizes the statistical correlation among constituents in the water with minimal loss of original information [1]-[9]. The purpose of applying PCA isto reduce the analytical data of each sampling site, which are inter-correlated to a smaller set of 'Principal Components' (PC) that are then interpretable.The starting point of PCA is to generate a new group of groundwater quality variables from the initial dataset (called PCs) that are a linear combination of original variables. The PCA starts by extracting eigenvalues and eigenvectors of the correlation matrix and then discarding the less important of these [10].Thereafter, eigenvectors are transformed to PCs of the dataset. First PC thus obtained explains the biggest part of variance, while following PCs explain repeatedly smaller parts of the variance. PC loadings show how the PCs characterize strong relationships (positive or negative) between groundwater quality variable and PC describing the variable. An eigenvalue gives a measure of the significance of the factor and factors with the highest eigenvalues are the most significant. Eigenvalues of 1.0 or greater are considered significant [11]. Classification of principal components is thus "strong", "moderate" and "weak", corresponding to absolute loading values of >0.75, 0.75 - 0.50 and 0.50 - 0.30, respectively [12].

The descriptive statistics of the physico-chemical parameters of groundwater of study area are presented in Table 1 while Table 2 shows the correlation coefficient matrix.

BIS has not included standards for Bicarbonate, Phosphate, Sodium and Potassium in drinking water. TDS varies in the range of 377 to 7150 mg/l with a mean value of 2053.8 mg/l. There is very strong positive correlation at $p < 0.05$ between TDS and Chloride (r=0.98), Sulfate (0.90), Sodium(0.97) and moderate positive correlation between TDS and Mg (0.76),Ca (0.72). This also indicates high salinity of groundwater.The origin belongs to dissolved salts from the aquifer matrix due to long residence time of ground water, evaporite deposits in sedimentary sequence etc. Water logging and over-irrigation causes the water table to rise and so causes the water to go saline due to contact with sources of salts, as well as due to a much greater rate of evaporation near the surface. Water logging of fields causes higher salination of ground water in arid or semi-arid areas where the rate of evaporation is quite high [13].

Table1: Physico-Chemical Parameters of Ground Water inthe Study Area

Sr.No.	Water Quality Parameter	Min	Max	Mean	Drinking Water StandardsBIS : 10500 - 1991
1	Bicarbonate (mg/l)	171.0	1500.0	567.6	-
2	Chloride (mg/l)	28.0	3018.0	594.4	250-1000
3	Sulfate (mg/l)	10.0	545.0	197.3	200-400
4	Nitrate (mg/l)	1.0	820.0	75.5	45
5	Fluoride (mg/l)	0.1	18.0	3.4	1-1.5
6	Phosphate(mg/l)	0.1	0.8	0.1	-
7	Ca (mg/l)	8.0	240.0	58.0	75-200
8	Na (mg/l)	36.0	2210.0	536.6	-
9	K (mg/l)	0.2	213.5	14.5	-
10	Mg (mg/l)	4.9	267.7	65.3	30-100
11	Fe (mg/l)	0.0	12.2	0.7	0.3-1
12	pH	7.6	8.7	8.1	6.5 to 8.5
13	TDS (mg/l)	377.0	7150.0	2053.8	500-2000

Bicarbonate (mg/l) varies in the range of 171 – 1500 mg/l with a mean value of 567.6 mg/l. Presence bicarbonates is one of the main cause of alkalinity in water .Chloride varies in the range of 28 – 3018 mg/l with a mean value of 594.4 mg/l. These unusual concentrations may indicate pollution by organic waste There is very strong positive correlation at $p < 0.05$ between Sulfate (r=0.85), Sodium(0.94) and moderate positive correlation with Ca (0.75) and Mg (0.75). Sulfate varies in the range of 10 – 545 mg/l with a mean value of 197.3 mg/l and has positive correlation at $p < 0.05$ with Na (0.85),and Mg (0.74). Ca varies in the range of 8 – 240 mg/l with a mean value of 58 mg/l.There is a positive correlation at $p < 0.05$ between Ca and Mg (0.90). It may be due to the presence of high amounts of calcium salts in ground water.Na varies in the range of 36 – 2210 mg/l with a mean value of 536.6 mg/l also there is a strong positive correlation at $p < 0.05$ with Sulfate (0.85).Thus chloride (Cl^-), sodium (Na^+), calcium (Ca^{+2}), magnesium (Mg^{+2}), and sulfate (SO_4^{-2}) contributes to the TDS and hence to salinity of groundwater.TDS in water originate from natural sources, sewage, urban runoff and industrial wastewater [14]. Concentration of TDS in water varies considerably in different geological regionsowing to differences in the solubility of minerals.

Table2:Correlation Coefficients of the Physico-Chemical Parameters of Ground Water

Parameters	Bicarbonate	Chloride	Sulphate	Nitrate	Fluoride	Phosphate	Ca	Na	K	Mg	Fe	pH	TDS
Bicarbonate	1												
Chloride	0.28	1											
Sulphate	0.48	**0.85**	1										
Nitrate	0.05	0.17	0.22	1									
Fluoride	0.27	0.29	0.24	0.02	1								
Phosphate	0.28	0.33	0.16	0.00	-0.07	1							
Ca	0.09	**0.75**	0.68	0.14	-0.08	0.41	1						
Na	0.51	**0.94**	**0.85**	0.24	0.40	0.28	0.56	1					
K	0.05	-0.03	0.23	-0.01	-0.09	-0.10	-0.11	-0.04	1				
Mg	0.14	**0.75**	**0.74**	0.31	0.02	0.34	**0.90**	0.60	0.06	1			
Fe	-0.05	0.42	0.43	-0.11	-0.03	-0.10	0.63	0.23	-0.08	0.68	1		
pH	-0.19	-0.37	-0.39	-0.10	-0.02	-0.36	-0.44	-0.30	0.17	-0.52	-0.25	1	
TDS	0.45	**0.98**	**0.90**	0.26	0.30	0.33	**0.72**	**0.97**	0.00	**0.76**	0.37	-0.38	1

Correlation is significant at the 0.05 level

Principal Component Analysis (PCA) of the water quality parametersare shown in Table 3 below which includes the factor loadings, eigenvalues of each PCs, total variance as well as the cumulative variance. It showed six PCs which explained 90.5% of the total variance. The first PC explained 45.26% of the total variance and was best represented by Chloride, Sulfate, Ca, Na, Mg, ,TDS with strong positive loading, Fe with moderate positive loading and pH with moderate negative loading a. PC2 was dominated by moderate positive loading of Bicarbonate, Fluoride, moderate negative loading for Fe and accounted for 13.17% of the total variance. PC 3 explained 10% of the total variance with strong positive loading for

Phosphate and moderate negative loading for Potassium (K).PC 4 was primarily represented by moderate negative loading for Fluoride and strong positive loading for Potassium (K), accounting for 8.7% while additional, 7.95% of the total variance was explained in PC 5 which was contributed by strong positive loading for Nitrate. PC 6 was responsible for 5.37% of the total variance and was best represented by strong positive loading for pH.

Table 3: PCA of Water Quality Parameters of Jaipur District 2015

Physio-chemical Parameters	PC1	PC2	PC3	PC4	PC5	PC6
Bicarbonate	0.415	0.607	0.212	0.088	-0.281	-0.289
Chloride	0.943	0.066	-0.068	-0.087	0.012	0.223
Sulfate	0.908	0.148	-0.250	0.112	-0.090	-0.099
Nitrate	0.249	0.104	-0.025	0.414	0.845	-0.108
Fluoride	0.239	0.625	-0.126	-0.525	0.092	-0.084

Phosphate	0.388	-0.011	0.739	0.276	-0.229	0.276
Ca	0.833	-0.445	0.050	0.017	-0.018	0.153
Na	0.889	0.365	-0.037	-0.070	0.048	0.152
K	-0.012	0.154	-0.541	0.671	-0.378	-0.093
Mg	0.881	-0.369	-0.073	0.115	0.068	-0.059
Fe	0.513	-0.584	-0.352	-0.333	-0.144	-0.151
pH	-0.521	0.228	-0.445	0.014	0.013	0.603
TDS	0.966	0.178	-0.052	-0.009	0.032	0.123
Eigenvalue	5.884	1.712	1.301	1.132	1.033	0.698
Variability (%)	45.264	13.172	10.006	8.707	7.950	5.370
Cumulative %	45.264	58.436	68.442	77.149	85.099	90.469

Table 4 given below summaries the factor scores at all the sampling locations of the study area.45.26% of the total variance in the data explained by PC1 (Table 3) is mainly represented at sampling location 1,13 and 23.Similarly 13.172% of the total variance explained by PC2 is represented at sampling location 13,14 and 23. 10% of the total variance explained by PC3 is represented at sampling location 1, 13, 16 and 23. 8.7 % of the total variance explained by PC4 is represented at sampling location 16, 17, 19 and 23. 7.95% of the total variance explained by PC5 is represented at sampling location 16 and 17. 5.37% of the total variance explained by PC5 is represented at sampling location 1, 9 and 21. Thus maximum variability in the physico-chemical parameters of the groundwater is observed at eight sampling locations, mainly 1, 13, 14, 16,17,19,21 and 23.

Geostatistical Modeling of PCA Factors Scores: PCA factor score (Table 4) with respect to each sampling location were combined with GIS-based geo-statistical modeling for better understanding of the variability of groundwater quality parameters.GIS-based geostatistical modeling approach(Inverse Distance Weightedspatial interpolationtechnique) was adopted.As shown below in Figure 3, the classification of the factor scores in the maps is done as Positive (>1.2),Weak (-1.2 to 1.2), and Negative (<-1.2).The white area in the map represents positive variability of the physiochemical parameters at that particular location, whereasgreen area represents negative variability of the physico-chemical parameter at that particular location. The light brown area indicates very weak variability of the physico-chemical parameter. Both, positive and negative factor scores of the sampling locations indicate their contribution to the variabilityof the data. Only high positive and high negative factor scores are considered as they result in maximum variability, indicating which parameter is more or less significant at particular sampling location. Thus reducing the number of samples and quality parameters to be considered for analysis.

Table4: PCA factor scores of the sampling points.

Sr.No.	Sampling Location	PC1	PC2	PC3	PC4	PC5	PC6
1	Majhi Renwal	5.307	-0.108	3.44	1.375	-0.829	1.52
2	Raghunathpura	-2.038	-0.938	-0.136	-0.091	0.254	0.787
3	Khejroli	-1.885	-0.044	0.47	-0.083	-0.123	0.49
4	Gonera1	-2.092	-0.644	-0.428	-0.279	0.218	0.607
5	Datal Gurjran	-2.161	-0.995	0.361	0.058	-0.032	0.943
6	Kotputli1	-1.36	-0.961	1.174	0.018	-0.064	-0.835
7	Tilawala	-1.47	1.015	0.128	-0.504	-0.384	-0.196
8	Kalwad	-1.633	0.015	0.698	0.024	-0.300	0.03
9	Bhanpur Kalan	-1.988	-0.203	-0.761	-0.263	0.433	1.381
10	Tigaria	-1.633	-0.223	0.299	-0.192	0.018	-0.427
11	Rasala	-0.065	-0.965	0.905	0.653	-0.044	-1.255
12	Andhi	-1.052	0.218	0.401	-0.063	-0.185	-0.502
13	Hastal Ka Bas	5.261	-4.085	-1.58	-1.263	-0.757	-0.891
14	Goner	0.283	2.665	0.592	-0.178	-1.141	-0.907

15	Thalli	-1.002	1.102	0.375	-0.393	-0.396	-0.675
16	Dawach	-0.116	0.949	-2.816	3.293	-2.036	-0.395
17	Shivdaspura	2.868	0.879	-0.129	1.568	3.896	-1.100
18	Chaksu	3.237	0.459	-0.07	0.002	-0.517	0.106
19	Pallukhurd	-1.359	1.289	-0.288	-2.088	0.354	-0.432
20	Mangarwara	1.684	-0.027	-0.082	-0.544	-0.086	-0.208
21	Amber	-1.07	-0.746	-1.238	1.117	1.265	1.492
22	Jobner	-1.099	-0.704	0.423	0.096	0.35	-0.718
23	Nasnota	4.983	2.452	-1.594	-1.776	0.202	1.115
24	Hastera	-1.599	-0.399	-0.147	-0.486	-0.097	0.071

Conclusions: The pH of groundwateris slightly alkaline in nature at all the sampling locations. Nitrate varies in the range of 1 – 820 mg/l with a mean value of 75.5 mg/l which is much beyond the maximum permissible limit of 45 mg/l.This indicatesextensive use of fertilizers, pesticides in agriculture and domestic sewage discharge. Fluoride is the geogenic groundwater contaminant in the study area also affecting almost all the districts of Rajasthan.The Correlationanalysis clearly showed strong relationship between TDS,Chloride, Sulfate and Sodiumand moderate positive correlation between TDS and Mg and Ca.This also indicates high salinity of groundwater. Unusually high chloride concentrations may indicate pollution by organic waste and presence of high bicarbonate concentration indicates high alkalinity of water.

PCA of the water quality dataresulted in 6 important PCs which explained 90.5% of the total variance in the data. The first PC explained 45.26% of the total variance and was best represented by Chloride, Sulfate, Ca, Na, Mg, Fe, pH and TDS. PC 2 was dominated by Bicarbonate, Fluoride, and Fe and accounted for 13.17% of the total variance. PC 3 explained 10% of the total variance and loaded heavily Phosphate and Potassium (K).PC 4 was loaded primarily by Fluoride and Potassium (K), accounting for 8.7 % while additional, 7.95% of the total variance was explained in PC 5 which was contributed Nitrate. PC 6 was responsible for 5.37% of the total variance and was best represented by pH.Also the analysis of Factor scores at sampling location revealed that maximum variability in the physico-chemical parameters of the groundwater is observed at eight sampling locations, mainly 1, 13, 14, 16,17,19,21 and 23. Integration of PCA factor scores with GIS resulted in maps, clearly explaining the variability at different sampling location.Thus Statistical techniques such as Co-relation Analysis and Multivariate statistical techniques including principal component analysis can successfully be used to derive information from the data set about the extent of correlation between different water quality parametersand possible influences of the environment on groundwater. The result of PCA helps in extraction and recognition of the factors/parameters responsible for water quality at different location. It also showed that a parameter that can be significant in contributing to water quality in one location may be less or not significant at another location. This result may be used to reduce the number of samples to be analyzed, without much loss of information. Further the integration of statistical analysis and GIS-based geo-statistical modeling aids in assessment of spatial as well as temporal variation of groundwater quality parameters. In addition, it could help provide a guideline to select possible preventive measures for the proper management of groundwater water by giving priority to minimizing the parameters identified as means of improving the water quality

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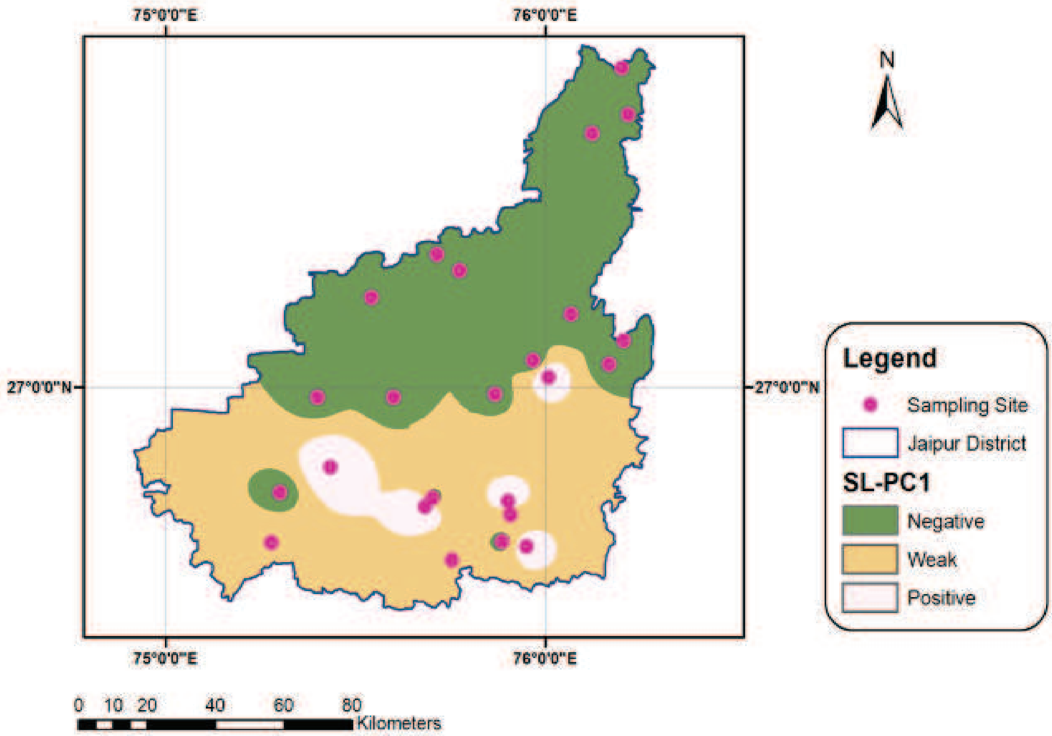
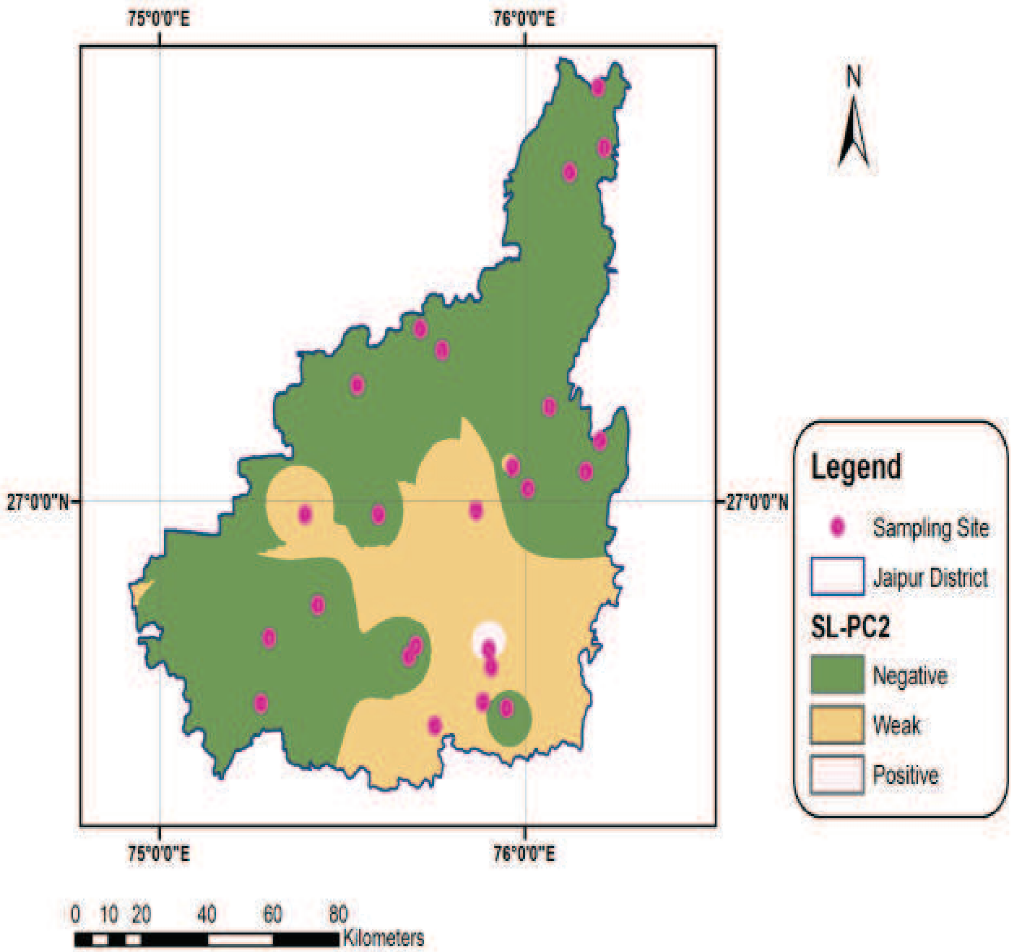
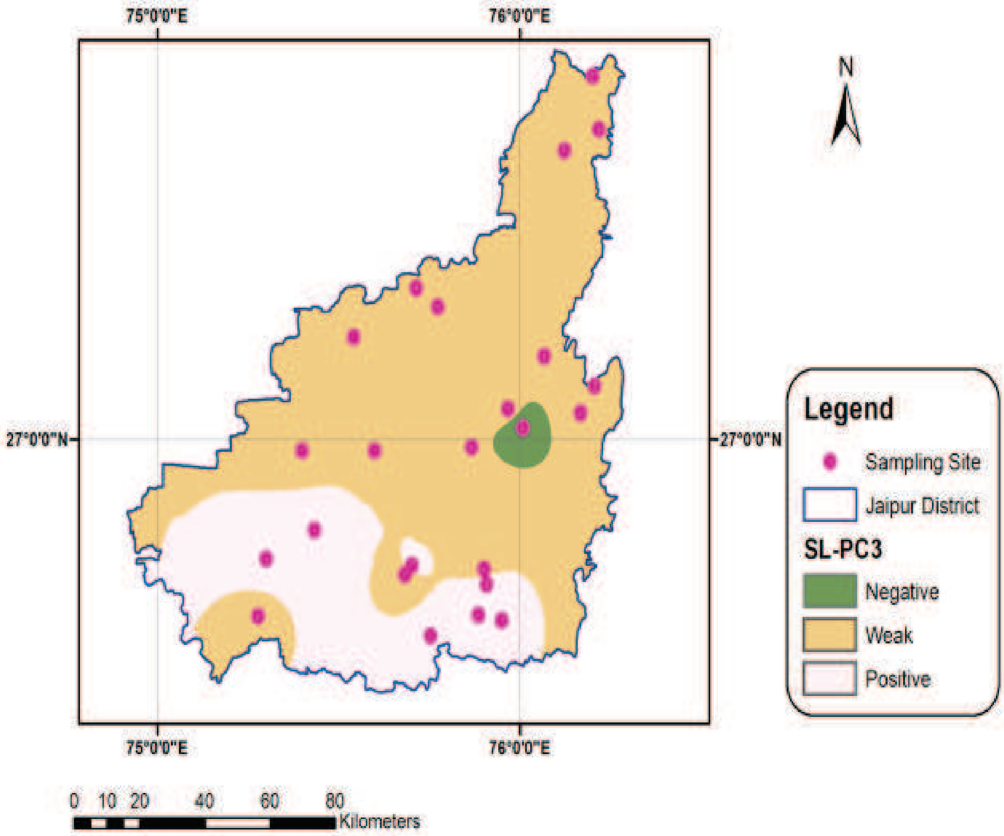


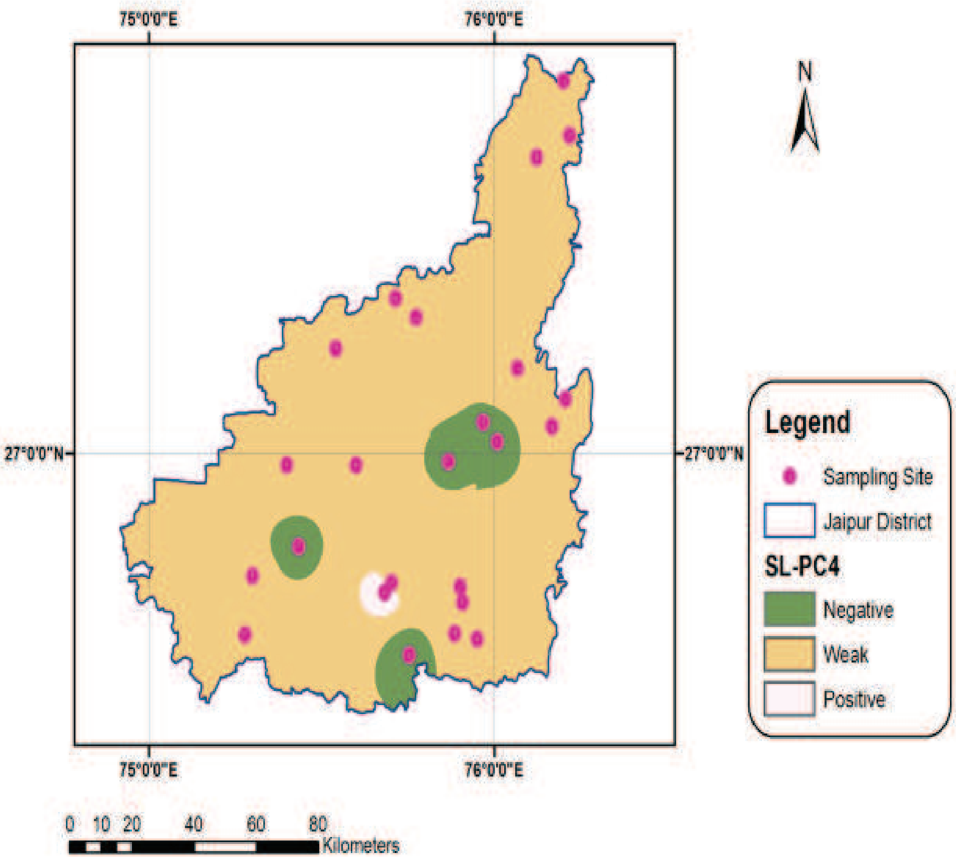
(a) PC1 Factor score



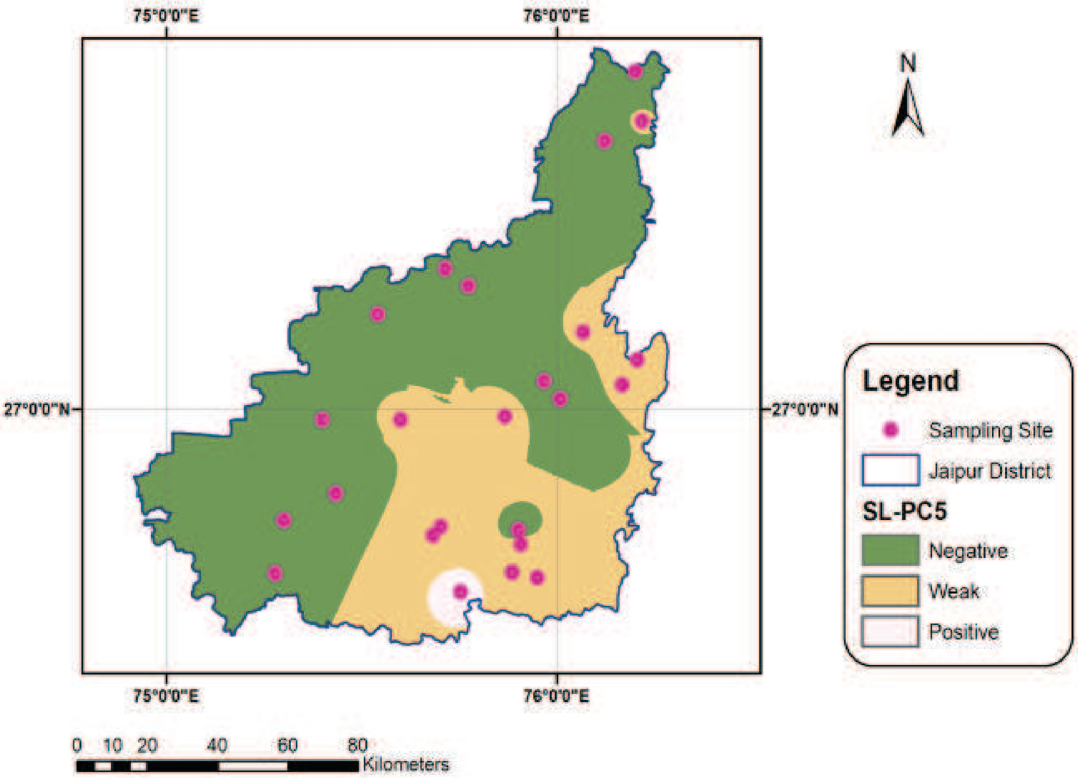
(b) PC2 Factor score



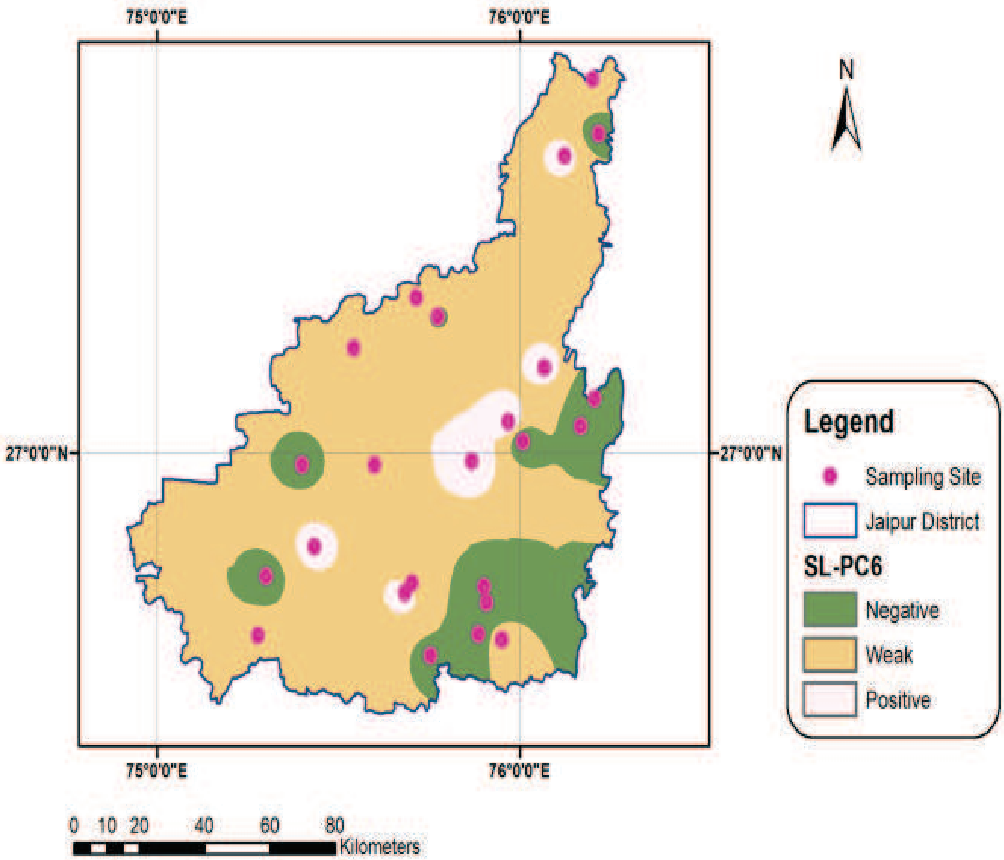
(c) PC3 Factor score



(d) PC4 Factor Score



(e) PC5 Factor Score



(e) PC5 Factor Score

Figure 3: Maps of Factor Score of the Principal Component in theStudy Area

References:

1 B. Helena, R. Pardo, M. Vega, E. Barrado, J. M. Fernandez and L. Fernandez, "Temporal Evaluation of Ground Water Composition in an Alluvial Aquifer (Pisuerga River, Spain) by Principal Component Analysis," *Water Research*, Vol. 34, No. 3, 2000, pp. 807-816. doi:10.1016/S0043-1354(99)00225-0

2 Bhaduri, M., Goyal, Rohit, Gupta, A.B. (2009), "Ground Water Quality in Sanganer Area of Rajasthan", *J. Hydraulic Eng.*, ISH, 15(3), Nov., 65-74.

3 MachiwalD,Jha M.K., "Identifying sourcesofgroundwater contamination inahard-rockaquifersystem using multivariate statistical analyses and GIS-based geostatistical modeling techniques", Journal of Hydrology: Regional Studies 4 (2015) 80–110. http://dx.doi.org/10.1016/j.ejrh.2014.11.005

4 Dhaneswar Kalita, Sub-Linear Dc Photoconductivity of thermally Evaporated Polycrystalline CDSE Thin Films; Engineering Sciences international Research Journal: ISSN 2320-4338 Volume 3 Issue 1 (2015), Pg 36-44

5 Kongre D.N and Goyal R," Prediction of Water Logging Using Analytical Solutions—A Case Study of Kalisindh Chambal River Linking Canal, Journal of Water Resource and Protection, 2013, 5, 624-632. doi:10.4236/jwarp.2013.56063

6 Singhal V and Goyal Rohit, (2014), "Groundwater model to predict the impact due to textile units at Pali", *Arabian Journal of Geosciences,* 7(12), pp 5185-5192.

7 Central Ground Water Board (CGWB), "Ground Water Information Jaipur District Rajasthan," Western Region, Jaipur, 2013.www.cgwb.gov.in

8 O.Ganeshbabu, M.C.Sashikkumar, M.Vijayaraj, K.Gokulakrishnan, N.Sakthieswaran, "Assessment of Groundwater Quality in the District of Erode, Tamil Nadu, India, International Journal of Advanced Engineering Technology,*Vol. VII/Issue II/April-June,2016/1248-1252*

9 Dunteman, G.H., 1989. Principal Component Analysis. Sage, Thousand Oaks, CA

10 C B Gandigudi, L A Udachan, investigations on Characterization of Polystyrene and Polymethyle Mythcrylate Thin Films; Engineering Sciences international Research Journal: ISSN 2320-4338 Volume 3 Issue 1 (2015), Pg 45-47

11 D. A. Wunderlin, M. P. Diaz, M. V. Ame, S. F. Pesce, A. C. Hued and M. A. Bistoni, "Pattern Recognition Techniques for the Evaluation of Spatial and Temporal Variations in Water Quality. A Case Study: Suquia River Basin (Cordoba-Argentina)," *Water Research*, Vol. 35, No. 12, 2001, pp. 2881-2894. doi:10.1016/S0043-1354(00)00592-3

12 Davis, J.C., 2002. Statistics and Data Analysis in Geology. John Wiley & Sons, Singapore, pp. 526–540

13 S. Shrestha and F. Kazama, "Assessment of Surface Water Quality Using Multivariate Statistical Techniques: A Case Study of the Fuji River Basin," *Japan Environmental Model Software*, Vol. 22, No. 4, 2007, pp. 464-475. doi:10.1016/j.envsoft.2006.02.001

14 Dhaneswar Kalita, Effect of Deposition Temperature on Structural and Carrier Mobility of thermally Evaporated Nanocrystalline Cdse Thin Films; Engineering Sciences international Research Journal: ISSN 2320-4338 Volume 3 Issue 1 (2015), Pg 48-55

15 W. X. Liu, X. D. Li, Z. G. Shen, D. C. Wang, O. W. H. Wai and S. Y. Li, "Multivariate Statistical Study of Heavy Metal Enrichment in Sediments of the Pearl River Estuary," *Environmental Pollution*, Vol. 121, No. 3, 2003, pp. 377-388. doi:10.1016/S0269-7491(02)00234-8

16 Central Ground Water Board (CGWB), "Geogenic Contamination of Ground Water In India-With a special note on Nitrate", BujalBhawan, NH-IV, Faridabad, 2014 Haryana.www.cgwb.gov.in, mtt-cgwb@nic.in

17 WHO, "Nitrate and Nitrite in Drinking Water.Background Document for Preparation of WHO Guidelines for Drinking Water Quality," World Health Organization, Geneva, 2003.

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