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Research paper

Factor analysis and spatial distribution of water quality parameters of Aurangabad District, India.

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ABSTRACT:

In statistical analytical methods, the factor analysis is a key tool for extracting inter-relationship between water quality parameters and environmental system. For the study, 117 number of samples were collected within Aurangabad district for pre and post monsoon season. In-situ water quality parameters were analyzed on-site with the help of portable multi-parameter water analysis kit. Uranium concentration and rest of parameters were analyzed in the departmental laboratory. To analyze and extract number of sets of inter-corelated variables (i.e. factors), principle component analysis is used for 18 variables, out of which 6 factors were extracted in post and pre-monsoon. Extracted factor based on eigen value (>1) which contribute 72.87% and 72.46% variations in respective seasons. Out of which, the first factor is contribute 32.48% in post and 28.34% variance in pre-monsoon. The second factor was contributed 10.05% and 13.01% variance in post and pre-monsoon seasons respectively. The third, fourth, fifth and sixth factors are contributing 9.6%, 8.25%, 6.88% and 5.60% in post monsoon, where as 9.74%, 7.39%, 7.12% and 6.81% variance in pre-monsoon respectively. For spatial distribution of water quality parameters in study area, maps were created using the ArcGIS 10.3 software.

1. Introduction

In study area, the main source for availability of water for regular activity and agricultural purpose is groundwater. Though 90% of groundwater is used for irrigation purpose, near about three quarters of total groundwater is consumed for agricultural purpose in the study area (Rashid et al., 2015). For understanding the factors and processes which control and affect the water quality, the hydrological study is the key concern (Arslan, 2009). The analysis and clarification of data sets, water quality assessment, source identification of pollution and understanding spatio-temporal dissimilarities in water quality for effective water quality management, the multivariate statistical techniques is useful (Shrestha and Kazama, 2007). The hydro-chemical characteristics is useful for protection of aquifer, prediction of fluctuations, reducing the effects of salinization and pollution load in agricultural, hydro-chemical characteristics is operative (Hamzah et al., 2017). To evaluate hydro-chemistry and groundwater pollution, the multivariate statistical analysis method i.e. principal component analysis (PCA) is useful (Yang et al., 2015). The principal component analysis is useful tool which indicates that geogenic and anthropogenic sources are responsible for variation in physio-chemical parameters in the groundwater (Islam et al., 2017). In the earlier study, the processes that are observed which is responsible for this hydro-chemistry i.e. silicate minerals weathering, chloride salts dissolution, ion exchange between sodium, potassium and calcium, magnesium during the infiltration of reclaimed water, carbonate precipitation and anthropogenic activities (Nagaraju et al., 2016). Geographic Information System (GIS) is a key tool for management of groundwater resource with respect to prediction for spatial variation/distribution; groundwater quality and location of sources of pollution. Geographical Information System (GIS) is essential information tool for understand past, present and future impacts of environmental changes and management practices (Kura et al., 2014; Singh and Shashtri, 2011; Swarna Latha and Nageswara Rao, 2012). The outcome of GIS application is pictographic representation of groundwater quality for its suitability for various purposes (Anbazhagan and Nair, 2004; Huchhe and Bandela, 2016; Tikle et al., 2012).

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2. Experimental

2.1. Description of study area

Aurangabad is the regional capital of Marathwada, is situated central part of Maharashtra Fig. 1. The Aurangabad city was instituted by Malik Ambar in 1610, the city known as "Khidki" which is renamed as Fatehpur. In 1953, city again renamed as Aurangabad when Aurangzeb took over the Deccan kingdom and made it the capital to overpower the expanding his power against Maratha empire Chatrapati Shivaji Maharaj. It is bordered by the districts of Nashik to the west, Jalgaon to the north, Jalna to the east, and Ahmednagar to the south. The highest area is covered with Godavari river basin and partly in the Tapi River Basin. District's total area is 10,100 km^2 out of which 141.1 km^2 is urban area and 99,587 km^2 is rural area. Total forest covered area of district is 135.75 km^2. The district is located between 19° and 20° north longitude, and 74° and 76° east latitude. According to the 2011 census, population of district is 3,695,928 (Census of India, 2011). The district is a part of the Deccan plateau, in general the slopes in the district are towards south and southeast. Deccan traps is basaltic flow which horizontally disposed and speciously relatively uniform in composition (Aher and Deshpande, 2011; CGWB, 2013).

2.2. Sampling design and collection

The One hundred-seventeen groundwater and surfaces water samples were collected from study area with making the 6 × 6 km grid map on the basis of population density for uniformity of sampling. One sample is collected from each grid and sampling were carried out during the period Dec 2018 (Post-monsoon) and May 2019 (Pre-monsoon) in the study area. The in-situ parameters (pH, temperature, TDS, EC, salinity, ORP and dissolved oxygen) were analyzed on sampling spot. The water samples are collected using pre-cleaned and acid washed polypropylene bottle, stored in ice box and brought to the departmental laboratory for analysis of ex-situ parameters (alkalinity, nitrate, sulphate, phosphate, chloride, fluoride and uranium).

2.3. Experimental setup

The in-situ parameters (pH, temperature, TDS, EC, salinity, ORP and dissolved oxygen) were analyzed at sampling site, as per standard protocols and procedure of portable multi parameter water analysis kit (Orion Star A326). Whereas ex-situ parameters were analyzed in the departmental laboratory according to the standard methods of APHA (APHA, 1998). The uranium concentration was assessed according to the BRNS guidelines using LED Fluorimeter LF-2a (Quantalas India Pvt. Ltd). Chloride concentration is estimated by Mohr's method. nitrate, sulphate and phosphate were assessed by single beam spectrophotometer (Bio Era Life Sciences Make).

3. Results

3.1. Water quality parameters

The complied data of water quality analysis were shown in table no1 for both seasons (n = 117) along with univariate statistic results as box plot which is shown in Fig. 2a and b (post-monsoon and pre-monsoon) respectively.

3.2. Factor analysis

The data is obtained from the water quality analysis including the uranium concentration for both seasons is organized in a matrix with variables columns and for 117 samples in the form rows. The statistical

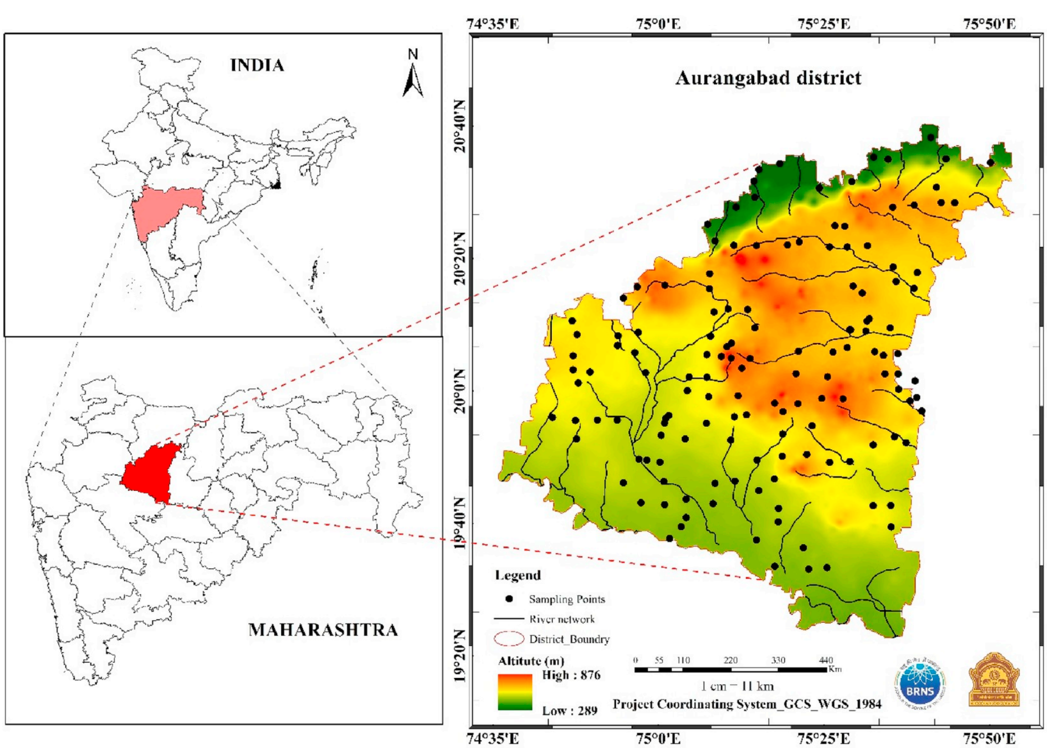

Fig. 1. Illustrate the Aurangabad District (study area) along sampling spots.

Table 1
Descriptive statistics of study area.

Parameters	Post Monsoon					Pre-monsoon				
	Mean	Standard Error	Median	Mode	Standard Deviation	Mean	Standard Error	Median	Mode	Standard Deviation
pH	7.41	0.04	7.37	7.17	0.42	7.90	0.04	7.82	7.59	0.45
TDS (mg L^{-1})	826	61	649	705	668	958	61	792	448	664
EC (μS^{-cm})	1685	125	1323	–	1362	1952	125	1611	–	1354
ORP (mV)	167	2	167	156	18	165	2	165	153	18
Temp. (°C)	27.19	0.18	27.50	26.00	1.94	29	0	29	30	2
Salinity (mg L^{-1})	872	70	649	366	762	966	62	800	452	671
DO (mg L^{-1})	6.29	0.10	6.29	5.98	1.07	3.8	0.1	3.9	3.0	1.3
F^- (mg L^{-1})	0.51	0.03	0.42	0.35	0.37	0.60	0.03	0.51	0.31	0.37
Cl^- (mg L^{-1})	319	35	163	950	379	251	8	232	284	87
NO_3^- (mg L^{-1})	106	8	85	32	86	112	8	91	35	86
SO_4^{-2} (mg L^{-1})	247	8	228	310	87	251	8	232	284	88
PO_4^{-3} (mg L^{-1})	15.70	0.54	15.95	21.00	5.91	18	1	18	23	6
U (μg L^{-1})	2.61	0.30	1.31	0.10	3.27	2.93	0.32	1.58	0.10	3.44
TH (mg L^{-1})	476	22	418	240	240	508	22	452	364	238
CaH (mg L^{-1})	190	9	167	96	96	159	7	141	114	74
MH (mg L^{-1})	285	13	251	144	144	174	7	160	266	71
HCO_3^- (mg L^{-1})	552	21	502	850	225	557	21	513	850	227

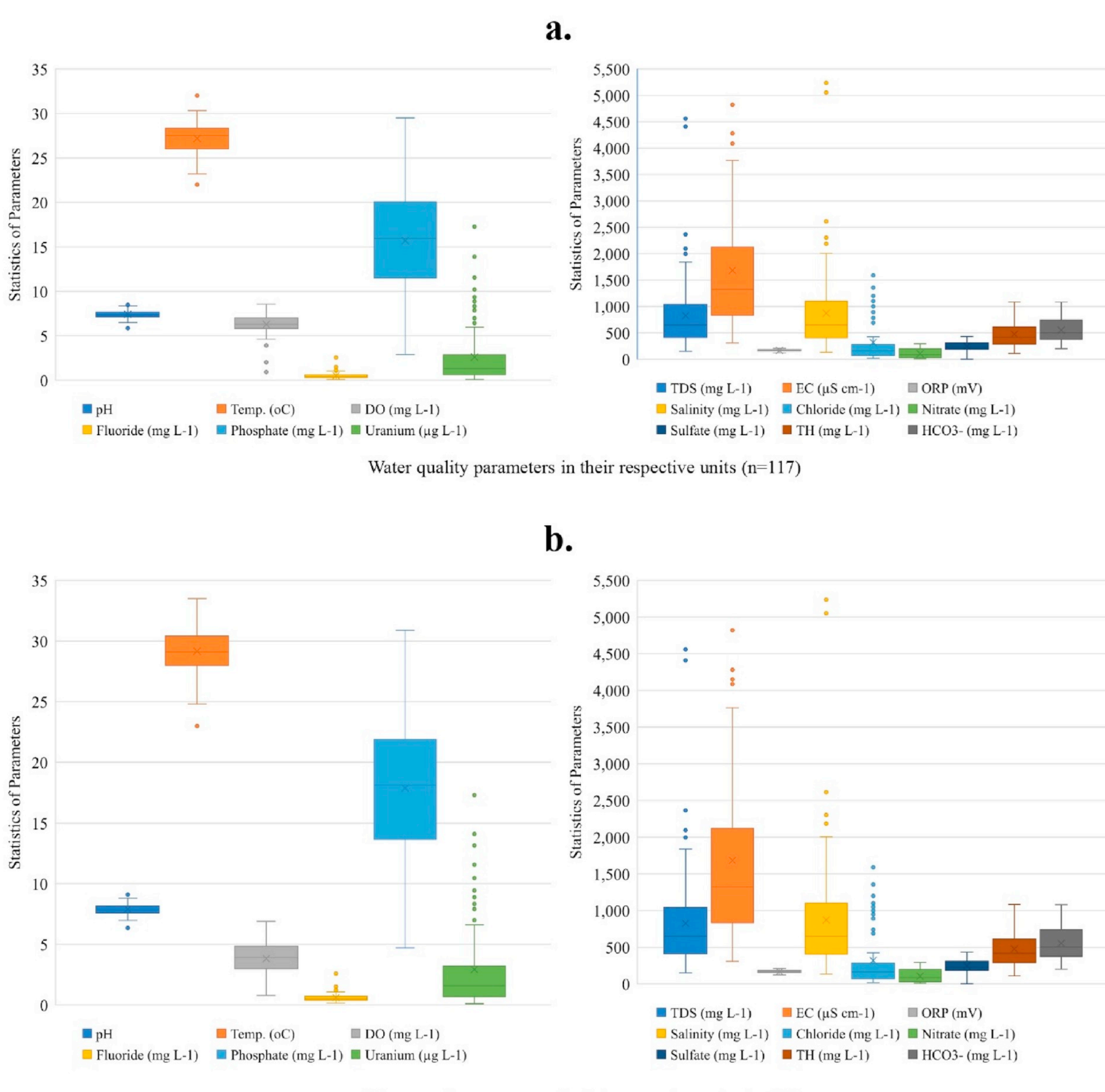

Fig. 2. Box plot of water quality parameters of study area (**a.** post-monsoon period (2018). **b.** pre-monsoon period. (2019)).

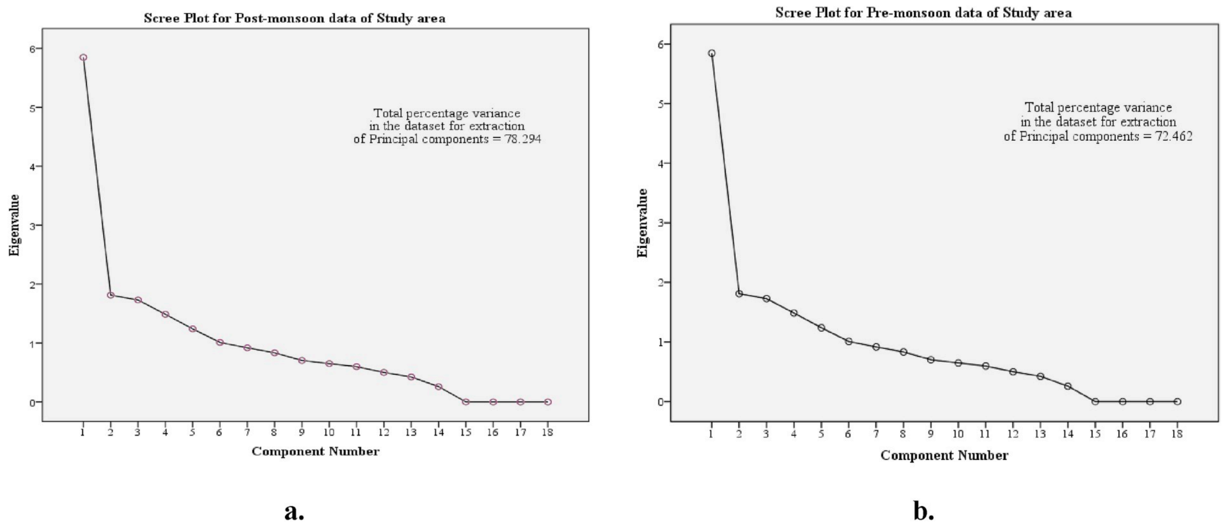

Fig. 3. Scree plot of water quality data (**a.** post monsoon, 2018 **b.** pre-monsoon, 2019).

software (SPSS version 23) was used for carrying out statistical analysis of data. The non-confirmatory principal component analysis was done for the factor extraction. Entire output data of study area were shown in the form descriptive statistics, correlation matrix, total variance explained, scree plot, component matrix (rotated and unrotated) and factor score etc. The extracted scree plots are shown in Fig. 3 a and b for both seasons. The scree plots include percentage variances are explained by each component and it gives an idea on how the different principal component was extracted.

The eigenvalues for different factors, percentage variance accounted, cumulative percentage variance and component loadings (unrotated and rotated) are represented in table no 2a and 2b.

For the extraction of each component in factor analysis, the eigen value is taken 1 as criterion value which required for explaining the source of variance in the data. Based on the descriptive statistics it is observed that, there is high standard deviation from certain water quality parameters. According to earlier study it is due to discharge of untreated waste dump into the water bodies and that water is unfit for domestic uses (Ravi Shankar and Mohan, 2005), probable sources of pollution are municipal sewage, man-made activities without proper treatment on un-lined surface (Shinde et al., 2016) excessive use fertilizer in agriculture sector is contributing the higher concentration of ions in aquifer (Aher and Deshpande, 2011). The principal components (Varimax rotation and after rotation) are shown in table no 2 a and b (for both seasons) which reflects the eigenvalues and variance percentage. To secure the increasing the principal components of chemical as well as environmental significance the varimax rotation was achieved. The PCA was made on the basis of correlation coefficient between the different parameters tracked by varimax rotation. The factor analysis is carried out on 18 parameters from 117 sampling sites is observed that, cumulative extraction of squared loadings is 72.87% and 72.46% in post and pre-monsoon respectively which is showing in Table 3a and b.

3.2.1. *Factor 1*

First factor is highly loaded (factor score >0.50) with major ions like TDS, EC salinity, chloride, hardness (calcium and magnesium) and bicarbonate are accounts for 23.78% in post-monsoon, 19.17% in pre-monsoon. The first factor has shown positive correlation between salinity, chloride, hardness and bicarbonates is accounts 23.75% in post monsoon and 19.17% in pre monsoon respectively. In the present investigation shows that due to increasing in the salt concentration or excess use of fertilizers and over-exploitation of groundwater may be the reason. Many researchers were also reported the same findings (CGWB, 2013).

3.2.2. *Factor 2*

Second factor is also positively loaded with fluoride, nitrate and uranium in the seasons along with chloride and sulphate in addition, whereas fluoride and uranium were escaped from study due to correlation matrix.

3.2.3. *Factor 3*

The third factor were extracted with 9.42% in post monsoon and 11.67% of variance respectively. In the post monsoon the temperature is only parameter, which is significantly loaded. In pre-monsoon ORP is negatively, whereas fluoride and uranium are positively loaded. This factor may be termed as heavy-metal removal factor. An increase in the oxygen reduction potential of water will disturb the contact between metals ions from the solution by the above-mentioned process. Some earlier workers are in opinion that ORP monitoring data would be used for track conditions and seasonal variations of metallic pollution of groundwater and could provide feedback for more efficient metal removal process from the drinking ground water (Bose and Sharma,

Table 2a
Extracted values of various factor analysis parameters for study area in post-monsoon.

Total Variance Explained in Post-monsoon						
Component	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Initial Eigenvalue	% of Variance	Cumulative %	Eigenvalue	% of Variance	Cumulative %
1	5.846	32.477	32.477	4.280	23.779	23.779
2	1.810	10.057	42.535	3.086	17.144	40.922
3	1.728	9.600	52.135	1.697	9.425	50.347
4	1.486	8.255	60.390	1.466	8.145	58.493
5	1.238	6.880	67.270	1.362	7.564	66.057
6	1.008	5.602	72.872	1.227	6.815	72.872

Extraction Method: Principal Component Analysis.

Table 2b
Extracted values of various factor analysis parameters for study area in.pre-monsoon.

Total Variance Explained Pre-monsoon						
Component	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Initial Eigenvalue	% of Variance	Cumulative %	Eigenvalue	% of Variance	Cumulative %
1	5.101	28.340	28.340	3.451	19.171	19.171
2	2.342	13.012	41.352	2.827	15.707	34.878
3	1.761	9.784	51.136	2.100	11.668	46.545
4	1.330	7.388	58.524	1.664	9.246	55.791
5	1.282	7.123	65.647	1.502	8.343	64.135
6	1.227	6.815	72.462	1.499	8.327	72.462

Extraction Method: Principal Component Analysis.

Table 3a
Component matrix in (post-monsoon, 2018).

Variables	Factors					
	1	2	3	4	5	6
Depth of water level (feet)	.283	.395	.055	-.028	**.505**	-.052
pH	**-.590**	-.058	-.118	.455	-.140	.039
TDS (mg L^{-1})	**.823**	.218	-.443	-.037	-.227	.097
EC (μS/cm)	**.823**	.218	-.443	-.037	-.227	.097
ORP (mV)	.112	-.244	.186	**-.676**	-.233	.173
Temp. (°C)	.103	.156	**-.530**	.083	**.600**	-.057
Salinity (mg L^{-1})	**.818**	.209	-.455	-.031	-.227	.097
DO (mg L^{-1})	.065	-.118	.042	**.521**	.123	.499
Fluoride (mg L^{-1})	-.064	**.581**	.267	.341	-.378	.123
Chloride (mg L^{-1})	**.750**	-.232	.081	.134	.182	-.038
Nitrate (mg L^{-1})	-.170	**.653**	.213	-.350	-.100	-.277
Sulphate (mg L^{-1})	-.123	.233	.338	-.251	.323	.432
Phosphate (mg L^{-1})	.354	-.036	.162	.315	-.008	**-.636**
Uranium (μg L^{-1})	.108	**.593**	.382	.275	-.048	.091
Total hardness (mg L^{-1})	**.882**	-.192	.355	.068	.001	.007
Calcium hardness (mg L^{-1})	**.882**	-.192	.355	.068	.001	.007
Magnesium hardness (mg L^{-1})	**.882**	-.192	.355	.068	.001	.007
Bicarbonate (mg L^{-1})	**.535**	.281	.084	-.174	.295	-.012

Bold values denote significant scores.
Extraction Method: Principal Component Analysis.
a. 6 components extracted.

Table 3b
Component matrix in (pre-monsoon, 2019).

Variables	Factors					
	1	2	3	4	5	6
Depth of water level (feet)	.303	.268	.156	-.046	.186	**-.405**
pH	**-.523**	-.197	.240	**.340**	.168	.138
TDS (mg L^{-1})	**.876**	-.158	.024	.303	-.309	-.001
EC (μS/cm)	**.876**	-.156	.023	.303	-.309	.000
ORP (mV)	.075	.011	**-.516**	-.383	**-.446**	.019
Temp. (°C)	.198	-.060	.188	.307	.202	**-.684**
Salinity (mg L^{-1})	**.876**	-.156	.023	.303	-.308	.000
DO (mg L^{-1})	-.017	-.134	-.140	**.352**	.372	.076
Fluoride (mg L^{-1})	-.059	.207	**.561**	.149	-.313	.374
Chloride (mg L^{-1})	-.157	**.819**	-.410	.328	-.003	.059
Nitrate (mg L^{-1})	-.118	**.522**	.390	-.300	-.372	-.125
Sulphate (mg L^{-1})	-.156	**.820**	-.409	.328	-.003	.059
Phosphate (mg L^{-1})	.283	-.039	.216	-.243	.304	.369
Uranium (μg L^{-1})	.050	.368	**.534**	.206	.102	.325
Total hardness (mg L^{-1})	**.797**	-.010	-.259	-.092	.274	.259
Calcium hardness (mg L^{-1})	**.797**	-.010	-.259	-.092	.274	.259
Magnesium hardness (mg L^{-1})	**.696**	.413	.209	-.252	.181	-.126
Bicarbonate (mg L^{-1})	**.696**	.413	.209	-.252	.181	-.126

Bold values denote significant scores.
Extraction Method: Principal Component Analysis.
a. 6 components extracted.

2002; Račys et al., 2010).

3.2.4. Factor 4

Factor 4, explains 8.14% of variance and loaded with ORP and DO in the post-monsoon season. It may be due to the oxidation and reduction process. In pre-monsoon, pH and DO is loaded with 9.25% of variance. ORP and dissolved oxygen are two key parameters is widely used for controlling and monitoring of aeration methods, which are also essentially for oxidation–reduction processes (Bjugstad et al., 2016; Ndegwa et al., 2007).

3.2.5. Factor 5 and 6

In factor 5 and 6, percentage of variance in both seasons (7.56% in post-monsoon, 8.34% in pre-monsoon) and (6.81% in post-monsoon, 8.33% in pre-monsoon) were subsidized. In the 5th factor the depth of water and temperature are positively loaded in post-monsoon and are also found in the 6th factor in pre-monsoon. In the 6th factor form post monsoon the phosphate is negatively loaded.

3.3. Spatial distribution

For geographical distribution, the spatial analyst modelling tool

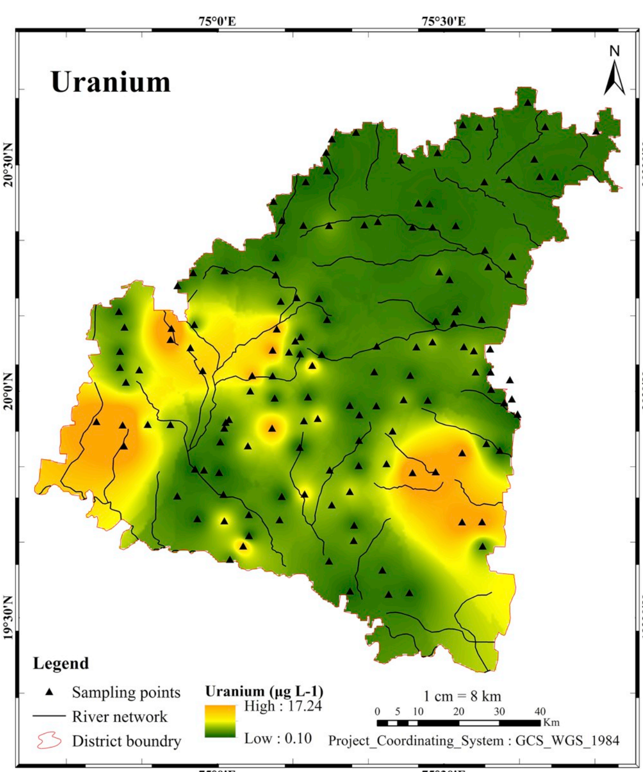

Fig. 4. Spatial distribution of TDS in Aurangabad district.

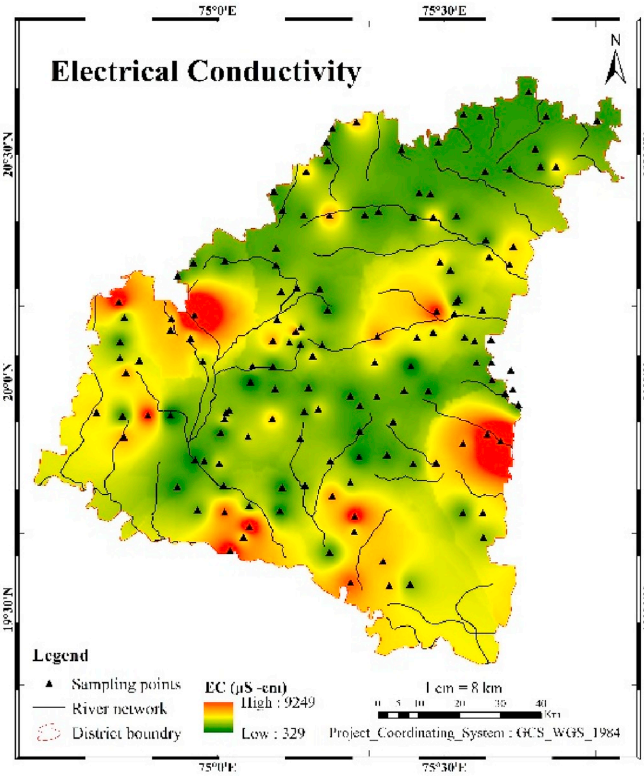

Fig. 5. Spatial distribution of EC in Aurangabad district.

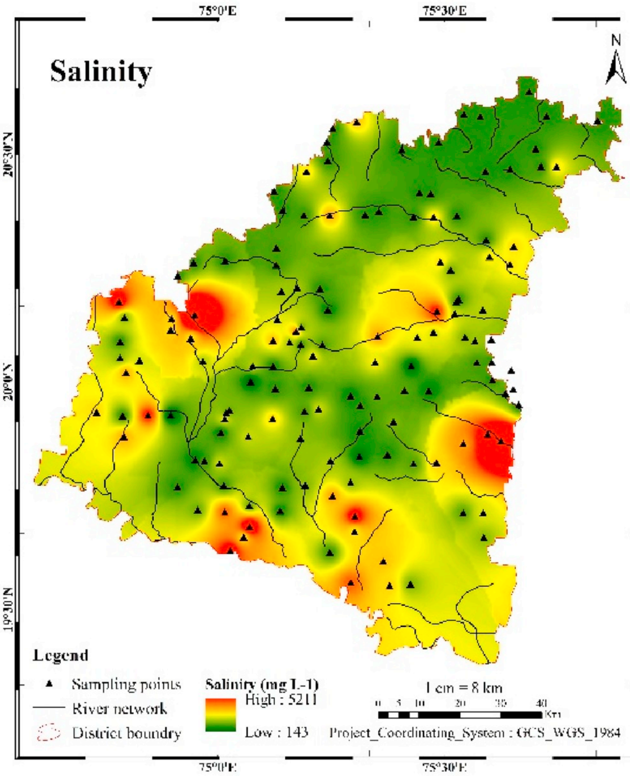

Fig. 7. Spatial distribution of salinity in Aurangabad district.

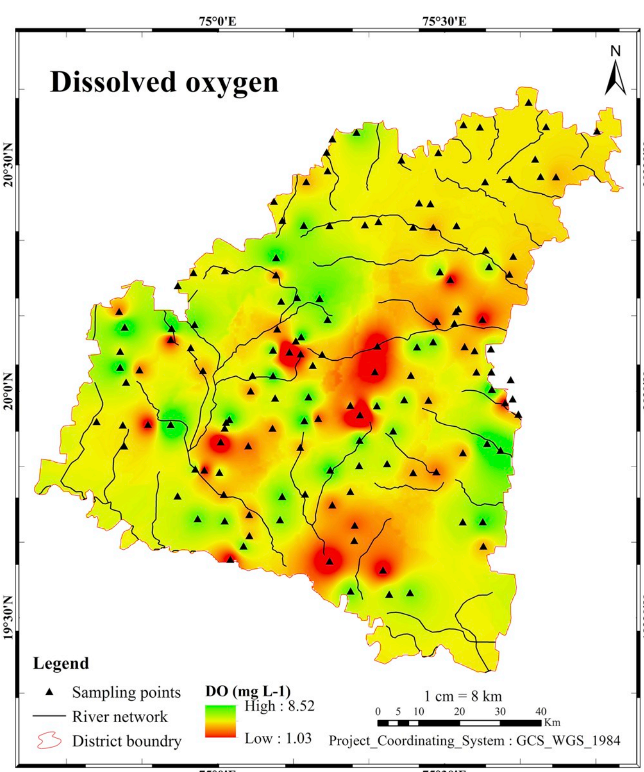

Fig. 6. Spatial distribution of DO in Aurangabad district.

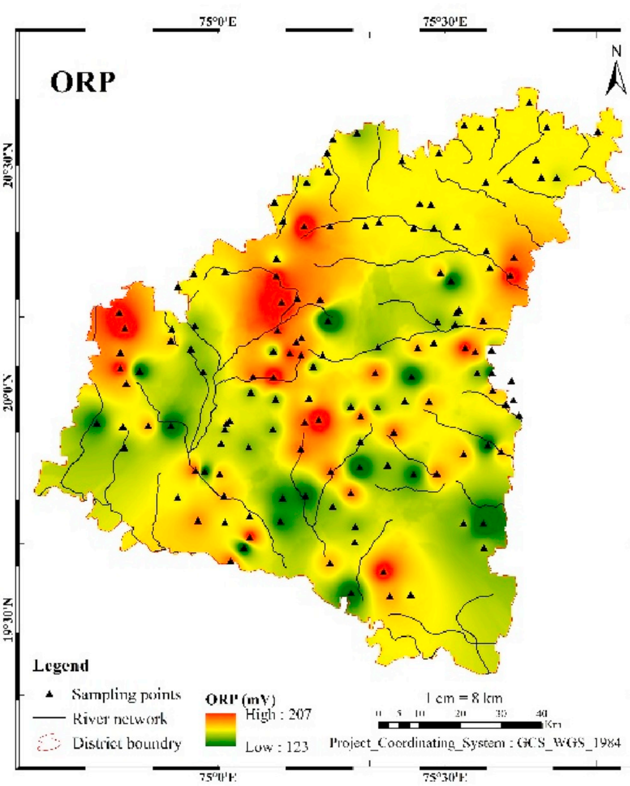

Fig. 8. Spatial distribution of ORP in Aurangabad district.

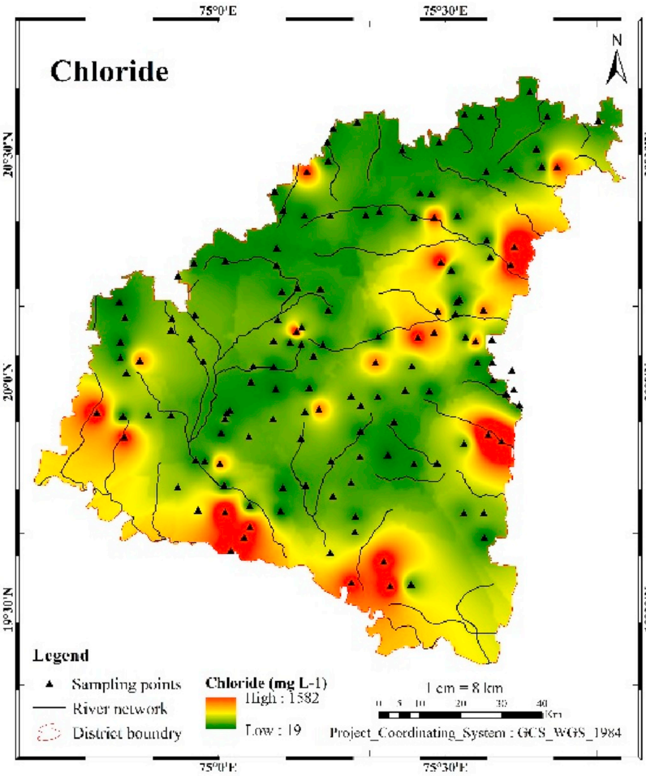

Fig. 9. Spatial distribution of chloride in Aurangabad district.

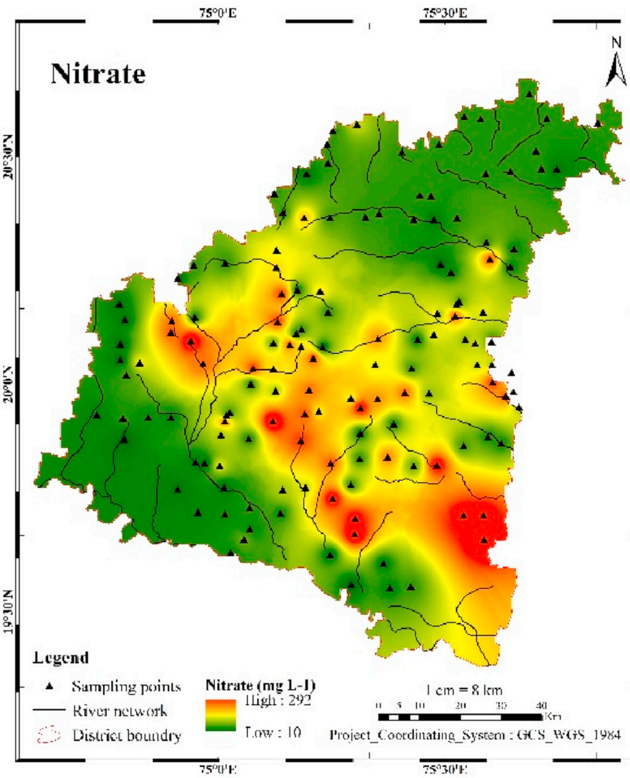

Fig. 11. Spatial distribution of nitrate in Aurangabad district.

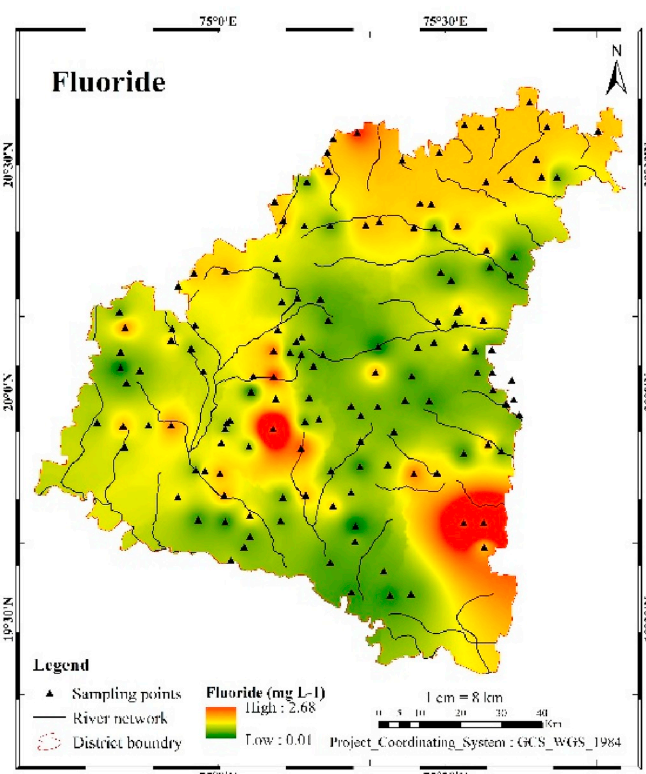

Fig. 10. Spatial distribution of fluoride in Aurangabad district.

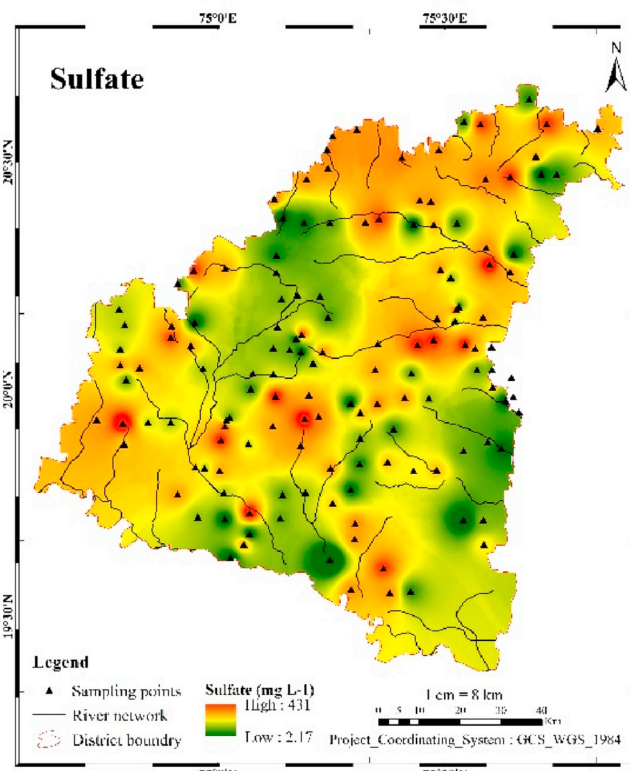

Fig. 12. Spatial distribution of sulphate in Aurangabad district.

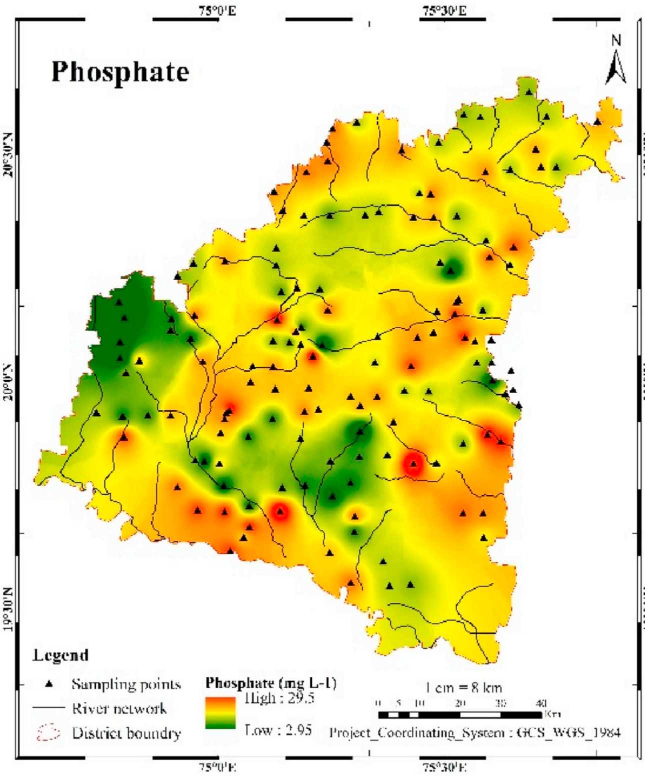

Fig. 13. Spatial distribution of phosphate in Aurangabad district.

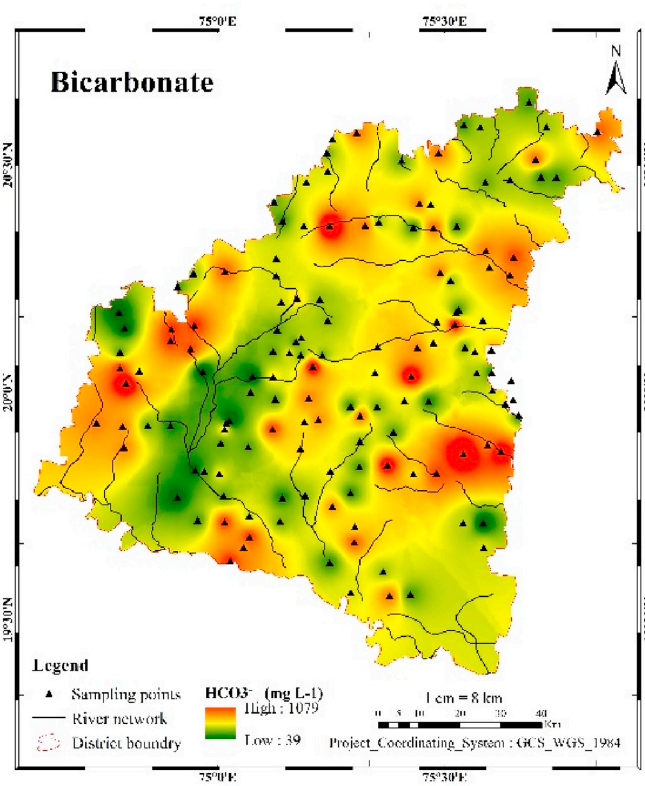

Fig. 14. Spatial distribution of bicarbonate in Aurangabad district.

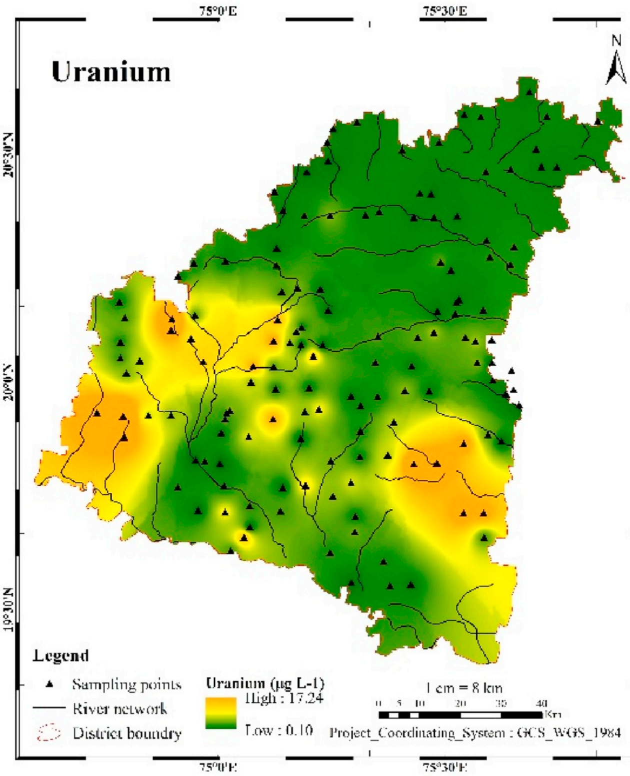

Fig. 15. Spatial Distribution of uranium in Aurangabad district.

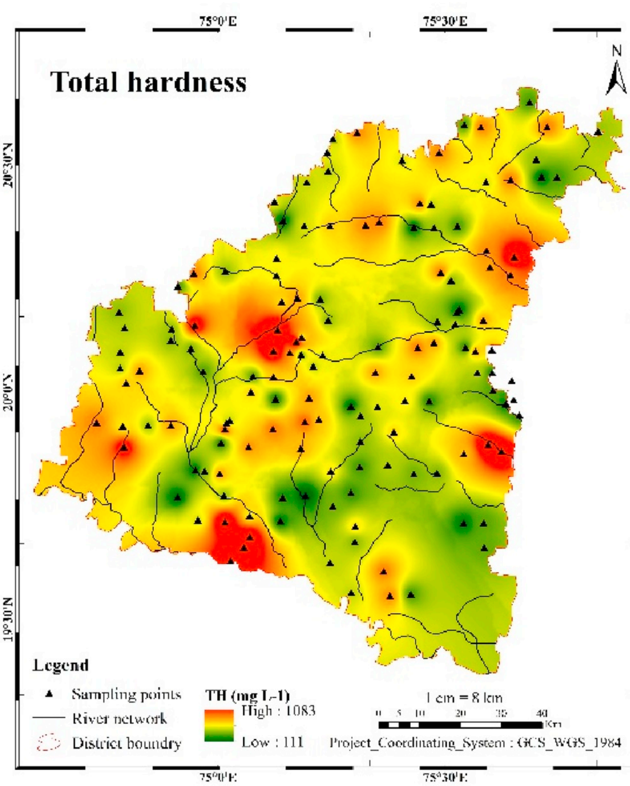

Fig. 16. Spatial distribution of hardness in Aurangabad district.

(ArcGIS 10.3) was used, to predict unknown concentration of water quality parameters from known sample spot for the geographical area based on interpolation (Inverse distance weighted) method. On the basis of distribution, it is easy to find that the value points which are close to sampling point were more likely to be similar than those farther apart on weighted distance. In the present investigation for predicting the correlation between the parameters and spatial distribution patterns, the interpolation method (Inverse distance weighted) is applied. The resulting maps were showed in Figs. 4–16 which is showing the spatial distribution of water quality parameters throughout study area. (All distribution maps are showing in the pdf below the conclusion. Please move it form below to in spatial distribution section).

4. Conclusion

The application of principal component analysis on chemical composition of groundwater reveals that major contaminants causes by anthropogenic activities for all parameters were done. The rotated component matrix shows that correlations between the observed variables and principal components. The first factor has shown positive correlation between salinity, chloride, hardness and bicarbonates which is showing that it may be happen due to increasing in the salt concentration, excess use of fertilizers and over exploitation of groundwater. Second factor is also positively loaded with fluoride, nitrate and uranium in the seasons along with chloride and sulphate in addition, whereas fluoride and uranium were escaped from study due to correlation matrix. Factor third may be termed as heavy-metal removal factor. An increase in the oxygen reduction potential for water will disturb the contact between metals ions from the solution. Factor 4 explained oxidation and reduction factor which is important method is widely used for control and monitor of aeration methods. Fifth and sixth factors were showing the significantly correlation in between the depth of water source and temperature. The spatial distribution maps were prepared and was showing the spatial variation in the study area. The extracted results from the statistical test i.e. principal component analysis indicates that parameters responsible for groundwater chemistry are due to the weathering of minerals from parent rock, dissolution of chloride salt, excessive use of chemical based fertilizers and anthropogenic activities.

Acknowledgement

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gsd.2020.100345.

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