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Chemometric analysis of drinking water quality parameters of Sagar city, Madhya Pradesh, India

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Abstract. The present study uses numerous chemometric techniques to evaluate and interpret a water quality data obtained from the drinking water resources namely municipal water (supplied by Rajghat dam on Bewas River), bore well, ground water of Sagar city, a divisional headquarter of Madhya Pradesh, India. Data was collected from May 2018 to June 2019 for 10 parameters used to assess the status of the water quality. Water quality was monitored at 15 sampling stations along the entire district. The data were analyzed using chemometric analysis such as principal component analysis, correlation matrix, multivariate linear regression analysis and hierarchical cluster analysis that reduced the data dimensions for better interpretation. Results of statistical analysis expressed that slightly higher value of BOD in some areas due to sewage contamination, need of chlorination treatment required at those places. This study also presents the value of diverse statistical methods for assessment and analysis of drinking water quality data for the reason of monitoring the effectiveness of water resource management. The study indicated that the maximum quality parameters of drinking water is in permissible limits of WHO and IS: 10500 guidelines on entire study places.

Keywords: chemometric analysis; correlation matrix; principal component analysis; multivariate linear regression.

1. Introduction

Water quality is important for the safety of all community. Drinking water resources are suffering the impacts of urban, industrial and agricultural runoff, as well as a reduction in water quantity and quality [1].

The water quality contaminants that badly affected the physicochemical properties of ground and still water is likely to begin from a diversity of sources, including agricultural fertilizers, pesticides, herbicides, fungicides and inorganic wastes, sewage tanks, and infiltration of industrial effluents, this has impacted the healthiness and financial status of the populations [2]. Rajan M. R. *et al.* [3], Shyamla R. *et al.* [4], Karunakaran K. *et al.* [5] are the groups of well-known scientists prominently contribute to evaluate the quality of drinking water.

Rapid industrialization, deforestation, urbanization, and modern agricultural activities during the last few decades have deteriorate the groundwater quality and surface water of Sagar city, Madhya Pradesh [6-14].

In this study, quality parameters such as pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), alkalinity, chloride, Total Dissolved Solids (TDS), conductivity, Total Hardness (TH), Ca and Mg content in drinking water samples were determined by using standard analytical methods [15].

Chemometric analysis is applied to explain equally descriptive and predictive problems in experimental chemistry [16]. In descriptive applications, properties of chemical systems are modeled with the aim of learning the basic interrelationships and constitution of the system [17].

The main purpose of this study is to estimate the amount of correlation among the variables along with the other statistical parameters. The large number of data can lead to difficulties in the interpretation and illustration of the results [18, 19].

The obtained water quality data was subjected to statistical investigations to assess homogeneity and heterogeneity between sampling stations and to distinguish quality variables for temporal variations [20].

2. Experimental

2.1. Study area and collection of water samples

The objective of the study is to analyze the 10 quality parameters of water along 15 sampling stations of Sagar city for monsoon, post-monsoon and pre-monsoon, during May 2018 to June 2019.

Drinking water samples were collected from in and around Sagar city. Each water sample was taken every month. The samples were instantly analyzed in the chemistry lab to minimize physicochemical changes. Chemical analysis results compared with standard guideline produced by WHO [21] / IS: 10500 [22].

Table 1. Sampling locations and corresponding habitats

Station code - Sampling locations	Collection place (Village/Urban)	Sample source
S1- I. Gandhi Engineering College, Baheria Village	Office Area	Bore well
S2 - Gambhiria village	Village Residential Area	Dug well
S3 - Prabhakar Nagar	Residential Area	Bore well
S4 - Makronia	Residential Area	Municipal

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Station code - Sampling locations	Collection place (Village/Urban)	Sample source
chouraha		Water Supply
S5 - Raja Khedi Village	Residential Area	Bore well
S6 - Civil line	Residential Area	Municipal Water Supply
S7 - Bhainsa Naka area	Village Residential Area	Dug well
S8 - Tili hospital	Hospital Area	Dug well
S9 - Tili Chouraha	Residential Area	Hand pump
S10 - Parkota	Residential Area	Hand pump
S11 - Bada bazaar	Residential Area	Dug well
S12 - Katra bazaar	Residential Area	Dug well
S13 - Sadar bazaar	Residential Area	Dug well
S14 - Moti nagar	Residential Area	Bore well
S15 - Railway station, Sagar	Railway platform drinking water	Railway Water Supply

2.2. Materials and methods

All the chemicals used were of analytical reagents grade. Each sample was analysis using procedures as suggested in APHA guidelines [15].

Table 2. List of water quality parameters and their test methods

S.N.	Parameters	Unit	Test methods
1	pH	-	pH meter
2	Dissolved oxygen	mg/L	Winkler method
3	Biochemical oxygen demand	mg/L	Incubation and titration
4	Conductivity	ms/cm	Conductivity meter
5	Alkalinity	mg/L	Titration
6	Total dissolved solids	mg/L	Digital conductivity meter
7	Chloride	mg/L	Argentometric titration
8	Total hardness as $CaCO_3$	mg/L	Complexometric titration
9	Ca	mg/L	Complexometric titration and calculation
10	Mg	mg/L	Complexometric titration and calculation

Results obtained were subjected to multivariate statistical analysis using WINKS/SPSS Statistical Software. The chemometric analysis has been performed using standard methods.

3. Results and discussion

Descriptive statistics of each data set of chemical parameters is given in Tables 3, 4 and 5. Mean values were taken into concern as typical values to see the differences during different seasons. The average values of BOD recorded highest in monsoon compare to post-monsoon and pre-monsoon which could be due to acidification of water by elevated microbial degradation of organic debris and concentrated dissolved solids in monsoon period showed a clear cut temporal effect.

As an important role of DO in water quality of drinking water, the average concentration of DO was maximum in post monsoon period and lowest in monsoon due to increase in phytoplankton and microbial activity. DO value to some extent more at pre-monsoon, it might be due to expansion of phytoplankton with less water flow, disturbance and uprooting leading to increased generation of O_2 by photosynthetic activities.

Value of total hardness was recorded comparatively slightly highest in pre-monsoon and monsoon and lowest in post-monsoon (beyond desirable limit prescribed by IS: 10500). Total alkalinity values are well within the desirable limit but exhibited higher values in monsoon and lowest in pre-monsoon. Anthropogenic sources, chemical fertilizers, agricultural field run off, domestic and industrial waste leaching and sewage contamination in municipal water supply lines and other many causes can be responsible for deteriorate drinking water quality.

The range of chloride in the samples was 36.3 to 62.6 mg/L at throughout the sampling periods. The concentrations of the mostly parameters were all below the WHO permissible limits.

Chemometric analysis of the experimentally estimated water quality parameters on water samples yielded the range of the variation, mean, standard deviation and co-efficient of variation.

Table 3. Descriptive statistics of drinking water quality parameters of Sagar city at monsoon*

	pH	DO	BOD	Conduc-tivity	Alka-linity	TDS	Chloride	Total hardness	Ca	Mg
N	15	15	15	15	15	15	15	15	15	15
Min	6.59	4.05	2.74	0.431	96	297.97	30.4	153.34	113.16	16.48
Max	8.54	7.82	7.56	0.684	286	452.85	84.9	295.56	226.45	69.11
Sum	115.1	93.73	85.34	7.785	2756	5305.8	864.41	3094.98	2311.87	675.39
Mean	7.674	6.2486	5.6893	0.519	183.733	353.72	57.62733	206.332	154.124	45.026
Std. error	0.172	0.3077	0.3455	0.016484	13.2044	13.713	3.917446	10.40815	9.12443	3.8586
Variance	0.446	1.4203	1.7906	0.004076	2615.352	2820.9	230.1958	1624.944	1248.82	223.34
Stand. dev	0.668	1.1917	1.3381	0.063844	51.14052	53.112	15.1722	40.3106	35.3387	14.944
Median	7.63	6.81	5.75	0.5	196	337.23	58.8	196.31	140.56	41.32
25 %s	7.22	5.2	5.26	0.484	141	308.58	45.1	182.38	130.5	36.98
75 %s	8.35	7.08	6.75	0.558	221	393.98	69.5	213.46	171.64	62.29
Skewness	-0.262	-0.5556	-1.0358	1.262081	0.18500	0.7796	-0.14821	1.410624	1.06189	0.0460
Kurtosis	-1.203	-0.9191	0.7397	2.101716	-0.51853	-0.7186	-0.40406	1.428594	0.53021	-0.330
Geom. mean	7.647	6.1327	5.5063	0.515586	176.8575	350.19	55.58947	203.0808	150.6946	42.41
Coeff. var	8.705	19.072	23.520	12.30126	27.8341	15.015	26.32814	19.53677	22.9287	33.191

* The values, except pH and conductivity ($mho \cdot cm^{-1}$), are in mg/L

Table 4. Descriptive statistics of drinking water quality parameters of Sagar city at post-monsoon.*

Parameters	pH	DO	BOD	Conduc-tivity	Alka-linity	TDS	Chloride	Total hardness	Ca	Mg
N	15	15	15	15	15	15	15	15	15	15
Min	7.16	6.7	3.2	0.325	96	304.3	24.61	146.68	115.19	18.74
Max	8.34	8.8	5.8	0.537	286	452.8	55.85	259.37	168.26	119.14
Sum	117.9	116.8	70.8	6.407	2643	5224.	544.58	2653.24	1965.69	687.55
Mean	7.86	7.786	4.72	0.427133	176.2	348.2	36.3053	176.882	131.046	45.836
Std. error	0.082	0.177	0.218	0.017144	12.739	11.46	2.34701	7.79998	3.73559	6.4592
Variance	0.101	0.474	0.718	0.004408	2434.3	1970.	82.6268	912.595	209.32	625.82
Stand. dev	0.318	0.688	0.847	0.066400	49.338	44.38	9.08993	30.2091	14.4679	25.016
Median	7.95	8	4.46	0.433	154	334.8	35.6	169.76	128.63	42.43
25 %	7.63	7.2	4.26	0.364	138	310.1	26.3	156.38	121.83	30.51
75 %	8.14	8.4	5.46	0.483	212	389.7	45.61	178.63	130.78	55.3
Skewness	-0.57	-0.34	-0.48	-0.01066	0.5374	1.181	0.57744	1.79151	1.67567	1.8419
Kurtosis	-.002	-1.16	-0.75	-1.28921	0.0983	0.635	-0.0695	3.26272	2.64111	4.8460
Geom. mean	7.853	7.757	4.643	0.422244	169.86	345.8	35.2774	174.791	130.366	40.723

* The values, except pH and conductivity (mho·cm^{-1}), are in mg/L

Table 5. Descriptive statistics of drinking water quality parameters of Sagar city at pre-monsoon.*

	pH	DO	BOD	Conduc-tivity	Alka-linity	TDS	Chloride	Total hardness	Ca	Mg
N	15	15	15	15	15	15	15	15	15	15
Min	6.55	3.94	2.85	0.311	118	198.6	38.97	153.34	93.2	15.66
Max	8.52	7.32	9.76	0.520	216	328.1	89.97	278.35	211.87	61.98
Sum	105.0	94.52	83.93	7.661	2279	3763.	939.53	3075.0	2423.7	651.3
Mean	7.672	6.301	5.595	0.51073	151.9	250.8	62.635	205.00	161.58	43.42
Std. error	0.147	0.314	0.472	0.01563	7.964	9.946	3.8923	10.583	9.3884	4.001
Variance	0.3245	1.4817	3.3551	0.003665	951.4952	1483.9	227.2572	1680.122	1322.149	240.178
Stand. dev	0.5696	1.2172	1.8316	0.06054	30.84632	38.522	15.07505	40.9893	36.36137	15.4976
Median	7.83	6.91	5.74	0.49	138	239.1	59.97	185.12	143.16	40.18
25 %	7.34	5.2	4.46	0.469	131	222.6	49.97	181.53	138.72	36.98
75 %	8.15	7.1	6.43	0.526	182	287.6	72.97	213.46	173.14	46.89
Skewness	-0.42	-0.62	0.755	1.71305	0.926	0.715	0.1969	1.4230	0.7589	0.680
Kurtosis	-0.55	-0.96	2.302	4.2380	-0.50	-0.42	-0.666	1.360	-0.424	0.542

* The values, except pH and conductivity (mho·cm^{-1}), are in mg/L

From abovementioned Tables 3 to 5, drinking water in a most part of the study area has large amount of dissolved solids, all areas having conductivity within permissible limits. During monsoon, there were higher values of conductivity at entire collection point due to the heavy rain consequence presence of high TDS in water sources. Conductivity values were in the range of 0.431 mho/cm to 0.684 mho/cm. High EC values were observed for two sampling points S2 and S7 (open well) indicating the presence of high amount of dissolved inorganic substances in ionized form.

Total dissolved solids values are higher (but well within the desirable limit) in all seasons at sample points S2, S5, S7, S8 and S13. The important reason of that is the location of about all of the above sampling points nearly highly populated area mixing of agriculture/urban run-off into the water sources. TDS values are higher at monsoon. It may be due to raining. Rainwater dissolved many solids, nutrients from soil and mixed with water sources.

The alkalinity values are within normal acceptable limits at all sampling places.

The pH values of water samples varied from 6.55 to 8.54 and were found within the limit prescribed by IS/WHO. Ground water sample in the Sagar city is slightly alkaline in nature at maximum collection point in and slightly acidic at few sampling points.

Total hardness, Ca and Mg content of all sampling point at all season are within the desirable limit prescribed by the standard IS-10500: 1991. The high value of TH in water samples may be due to dissolution of Ca and Mg ions. Calcium is the predominant cations in the selected sampling sources.

Value of dissolved oxygen is satisfactory all collection place at entire analysis period, it means water quality is satisfactory. DO concentration is high at post monsoon. It is due to the winter season (inversely proportional relationship with temperature).

Low values of BOD/COD mean water quality is satisfactory at all collection places. Low value of BOD in drinking water indicated the low pollution load produce by waste matter. Then the value of DO is available in sufficient quantity in drinking water.

The high chloride concentrations at all season found in sampling point S7 can occur due to irrigation drains. The chloride concentration in all investigating area is below 250 mg/L at all the locations (sampling point), at all season are within the desirable limit prescribed by the IS10500:1991 standard.

3.1. Pearson correlation

Pearson correlation coefficient value is determined using correlation matrix to identify the highly correlated and interrelated water quality parameters. Tables 6, 7, and 8 represent the relationship between different parameters.

Table 6. Matrix of Pearson correlation for different parameters in the water samples at monsoon. *

Parameters	pH	DO	BOD	Conductivity	Alkalinity	TDS	Chloride	TH	Ca	Mg
pH	1	0.035	0.126	0.68096	0.047568	0.845	0.56371	0.225	0.017936	0.39955
DO	0.5444	1	0.066	0.41839	0.00579	0.706	0.07482	0.178	0.002098	0.78153
BOD	0.4125	0.486	1	0.82396	0.067214	0.902	0.09880	0.017	0.000563	0.70743
Conductivity	-0.115	0.225	-0.06	1	0.42	0.512	0.07640	0.386	0.95863	0.062759
Alkalinity	0.5187	0.674	0.484	-0.22505	1	0.860	0.2841	0.148	0.000997	0.020525
TDS	0.0548	0.106	0.034	0.18372	-0.04971	1	0.36679	0.110	0.55926	0.76553
Chloride	0.1621	0.473	0.442	0.47095	0.29599	0.251	1	0.211	0.06495	0.8716
TH	-0.333	-0.366	-0.60	0.24103	-0.39191	-0.428	-0.34221	1	0.046486	0.71901
Ca	-0.600	-0.727	-0.78	0.014666	-0.76047	-0.163	-0.48803	0.520	1	0.20565
Mg	0.2348	0.078	0.105	-0.49154	0.59029	0.084	-0.04567	-0.10	-0.3466	1

* The values, except pH and conductivity (mho·cm^{-1}), are in mg/L

Table 7. Matrix of Pearson correlation for different parameters in the water samples at post-monsoon. *

	pH	DO	BOD	Conductivity	Alkalinity	TDS	Chloride	TH	Ca	Mg
pH	1	0.4	.07	0.4296	0.562	0.08	0.296	0.02	0.228	0.0578
DO	0.20	1	0.01	0.4275	0.631	0.43	0.083	0.33	0.601	0.3873
BOD	0.47	0.6	1	0.4425	0.122	0.52	0.128	0.02	0.089	0.1043
Conductivity	-0.2	-0.2	-0.21	1	0.972	0.085	0.655	0.79	0.306	0.3638
Alkalinity	0.16	0.1	0.416	0.0098	1	0.646	0.240	0.62	0.893	0.6043
TDS	0.46	0.2	0.176	-0.458	-0.128	1	0.037	0.33	0.279	0.5879
Chloride	0.28	0.4	0.410	-0.1257	0.322	0.540	1	0.36	0.907	0.3014
TH	-0.5	-0.2	-0.57	-0.073	0.138	-0.26	-0.252	1	0.027	0.61578
Ca	-0.3	-0.1	-0.45	0.282	0.038	-0.29	-0.032	0.56	1	0.7042
Mg	-0.4	-0.2	-0.43	-0.252	0.145	-0.15	-0.286	0.87	0.107	1

* The values, except pH and conductivity (mho·cm^{-1}), are in mg/L

Table 8. Matrix of Pearson correlation for different Parameters in the waters samples at pre-monsoon. *

	pH	DO	BOD	Conductivity	Alkalinity	TDS	Chloride	TH	Ca	Mg
pH	1	0.332	0.263	0.48601	0.74462	0.603	0.15518	0.485	0.89188	0.11247
DO	-0.269	1	0.222	0.90272	0.061803	0.109	0.06799	0.084	0.03252	0.77803
BOD	-0.308	0.335	1	0.47462	0.74881	0.972	0.55016	0.901	0.64643	0.14438
Conductivity	0.1950	-0.034	0.200	1	0.92591	0.259	0.2269	0.409	0.23512	0.57563
Alkalinity	-0.091	0.493	0.090	-0.02629	1	0.469	0.41646	0.104	0.041621	0.73759
TDS	-0.145	0.430	0.009	-0.3108	0.20223	1	0.67657	0.248	0.29356	0.57085
Chloride	0.3861	0.483	0.167	0.33185	0.22672	0.117	1	0.051	0.073516	0.39605
TH	-0.195	-0.460	0.035	0.23007	-0.43542	-0.317	-0.51086	1	6.96E-07	0.076511
Ca	-0.038	-0.552	-0.12	0.32638	-0.53112	-0.290	-0.47508	0.926	1	0.71086
Mg	-0.426	0.075	0.395	-0.15727	0.094516	-0.159	-0.23652	0.470	0.10452	1

* The values, except pH and conductivity (mho·cm^{-1}), are in mg/L

3.2. Factor analysis

Principal component analysis and multivariate linear regression analysis were performed on 10 variables for the 15 different sampling stations in pre-monsoon, monsoon and post-monsoon during May 2018 to June 2019, in order to identify effective chemical parameters. Principal axis has been used to analysis the data correlation matrix of the original data and their interrelationships.

The principal component analysis results along with Eigen values and percentage of variance for all collection places are presented in Figures 1, 2 and 3. These figures reported factor loading and thus classified as strong, moderate and weak. Two factors or PCs explained 83.05, 75.4 and 80.3 % of the total variance for monsoon to pre-monsoon respectively, which was ample to give a high-quality initiative of the data formation.

An eigen value gives a measure of the significance of the factor, factor with highest eigen values being the most significant.

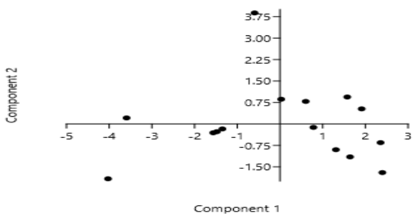

Figure 1. Scatter plot for principal components analysis at monsoon

3.2.1. Summary of important principal components axis

PC	Eigen value	% Variance
1	4240.85	48.371
2	3041.08	34.687
3	829.514	9.4615
4	394.122	4.4954
5	163.99	1.8705

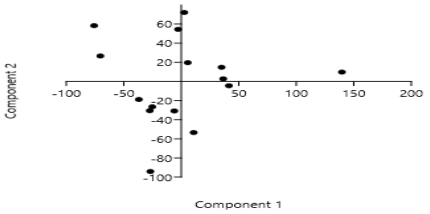

Figure 2. Scatter plot for principal components analysis at post-monsoon

3.2.2. Summary of important principal components axis

PC	Eigen value	% Variance
1	2725.16	43.698
2	1978.45	31.724
3	1243.58	19.941
4	252.009	4.0409
5	36.516	0.58553

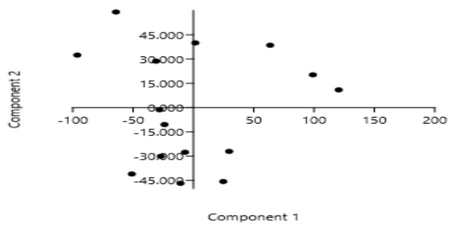

Figure 3. Scatter plot for principal components analysis at pre-monsoon

3.2.3. Summary of important principal components axis

PC	Eigen value	% Variance
1	3503.79	59.282
2	1246.52	21.091
3	724.122	12.252
4	269.662	4.5625
5	162.799	2.7545

3.3. Multiple regressions analysis

Multiple regressions are an extension of simple linear regression into several dimensions (several independent variables). In these experiments, the effect of independent variables on a single dependent variable (here pH) is determined on which we have performed the regression analysis. To test the significance of the pair of parameters *p*-value is carried out and in order to test the combined effects of numerous independent parameters. Multiple regressions fit an equation that predicts interrelationship between pH from two or more independent variables. WINK/SPSS software calculates and displays the coefficients and intercept of the regression line.

Table 9. Multivariate linear regression analysis at monsoon. Independent parameter = pH

Variable	Slope	Error	Intercept	Error	*r*	*p*
DO	0.97117	0.41501	-1.2047	3.1963	0.54442	0.035882
BOD	0.82635	0.50604	-0.65259	3.8974	0.41256	0.12645
Conductivity	-0.01107	0.026326	0.60397	0.20275	-0.11585	0.68096
Alkalinity	39.707	18.151	-121	139.79	0.51872	0.047568
TDS	4.3629	22.016	320.24	169.56	0.054879	0.84598
Chloride	3.6823	6.2152	29.367	47.868	0.16214	0.56371
TH	-20.099	15.779	360.59	121.52	-0.33312	0.22503
Ca	-31.762	11.731	397.89	90.351	-0.60047	0.017936
Mg	5.2527	6.0306	4.7132	46.447	0.23482	0.39955

Table 10. Multivariate linear regression analysis at post-monsoon. Independent parameter = pH

Variable	Slope	Error	Intercept	Error	*r*	*p*
DO	0.45243	0.58609	4.2305	4.6102	0.20936	0.45395
BOD	1.275	0.64774	-5.3019	5.0951	0.47919	0.070714
Conductivity	-0.04595	0.056378	0.78833	0.44347	-0.2205	0.42969
Alkalinity	25.183	42.377	-21.738	333.34	0.16262	0.56254
TDS	64.767	34.211	-160.77	269.11	0.46488	0.080811
Chloride	8.2435	7.5752	-28.489	59.587	0.28895	0.29626
TH	-54.247	21.568	603.26	169.65	-0.5721	0.025837
Ca	-15.007	11.887	249	93.5	-0.3304	0.22893
Mg	-39.24	18.862	354.26	148.37	-0.4997	0.057837

Table 11. Multivariate linear regression analysis at pre-monsoon. Independent parameter = pH

Variable	Slope	Error	Intercept	Error	*r*	*p*
DO	-0.57506	0.57078	10.713	4.3903	-0.26912	0.33208
BOD	-0.9914	0.84834	13.201	6.5252	-0.30833	0.26354
Conductivity	0.020731	0.028911	0.35168	0.22237	0.19506	0.48601
Alkalinity	-4.9762	14.954	190.11	115.03	-0.0919	0.74462
TDS	-9.8726	18.554	326.62	142.71	-0.14599	0.60364
Chloride	10.218	6.7704	-15.753	52.076	0.38611	0.15518
TH	-14.067	19.571	312.92	150.54	-0.1955	0.48501
Ca	-2.4521	17.69	180.39	136.07	-0.03842	0.89188
Mg	-11.615	6.8231	132.53	52.481	-0.42694	0.11247

3.4. Cluster analysis

The hierarchical tree diagram provides the analyst with an effective visual condensation of the clustering results and their numbers for spotting outliers. The aim of cluster analysis is to divide the observations into different clusters so that the members of any one cluster differ from one another as little as possible. Hierarchical cluster analysis grouped 10 stations into different clusters as per season with similar water quality features.

The affiliations among the stations were obtained through cluster analysis using Ward's method. This method tends to join clusters with a small number of observations and is biased towards producing clusters with roughly the same number of observations, with Euclidian distance as a similarity measure and was amalgamated into dendrogram plots (Figures 4, 5 and 6).

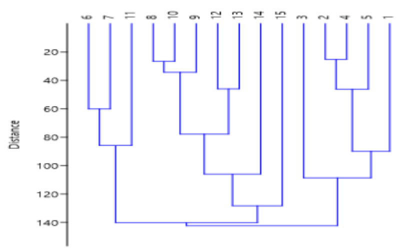

Figure 4. Hierarchical clustering at monsoon

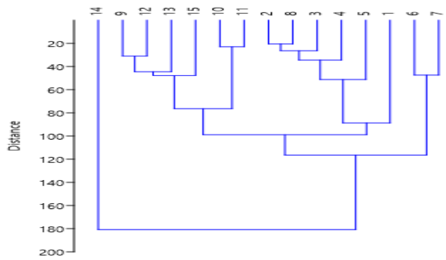

Figure 5. Hierarchical clustering at post-monsoon

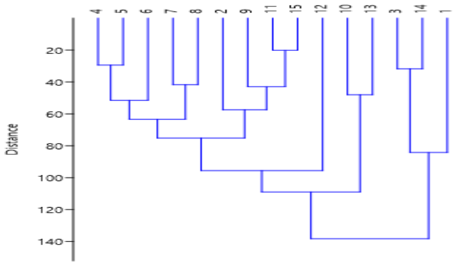

Figure 6. Hierarchical clustering at pre-monsoon

The cluster with a large number of collecting locations construed the spatial resemblance in their chemical composition amongst them, as influenced by urban run-off. Spatial variation in significant amount can be seen in the fourth and third cluster of the monsoon. The number of clustered groups obtained through dendrogram for monsoon, pre-monsoon and post-monsoon have a temporal impact on the drinking water quality.

By cluster analysis, group formed with highest Euclidian distance compared to other cluster groups reflects inflow of organic pollutants and extent of pollution and indicated the clear spatial variation among different sample locations. Hence, these water samples can be completely fit for drinking after disinfectants treatment.

Since the correlation matrix gives the interrelationship between the parameters, correlation coefficients were calculated. After regular monthly monitoring on results of multivariate analysis show that all applied water quality parameters are within the permissible limit set by WHO /IS: 10500.

4. Conclusions

On the basis of above discussion, it may be said that the drinking water of the Sagar city, Madhya Pradesh, India in general is found to be alkaline in nature. The TDS, TH, alkalinity and BOD in some sample collection places were found to be slightly high.

Drinking water analysis should be carried out regularly to monitor the place and type of contamination. It is need of human being to increase knowledge amongst the community to get the drinking water at their highest quality and purity levels. The current study is immediately necessary to draw the awareness towards this big region for taking essential steps to reduce the adverse effects likely to happen because of contaminated water.

Conflict of interest

The author declares that there is no conflict of interest regarding this research article.

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