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APPLICATION OF CLUSTER ANALYSIS TO PHYSICO-CHEMICAL PARAMETERS OF MUNJ SAGAR TALAB, DHAR (MADHYA PRADESH, INDIA)

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Abstract

Clustering technique has received attention in many areas including engineering, medicine, biology and data mining. The purpose of clustering is to group together data points, which are close to one another. In the present study, cluster analysis is applied to physico-chemical parameters of Munj Sagar Talab (water body in Dhar, M.P, and India).

Cluster Analysis (CA) was used for analyzing physico-chemical data obtained from Munj Sagar Talab. Seventeen parameters (Water Temperature, pH, Dissolved Oxygen, Free Carbon Dioxide, Calcium, Magnesium, Total Hardness, Nitrates, Chloride, Alkinity, Bicarbonate Carbonate Alkalinity, Phosphate, Silicates, BOD, Depth, Transparency and Conductivity.) were measured. Samples were collected from three sampling locations. This paper illustrates the usefulness of using statistical techniques in analyzing environmental data for better understanding of the behavior of different parameters.

Keywords: Physico-chemical parameters, Cluster Analysis (CA), Dendrogram, Hierarchical Cluster, Cophenetic correlation coefficient

Introduction

Cluster analysis is a data analysis tool used to group data having similar characteristics. It has been used in data mining tasks such as unsupervised classification and data summation, as well as segmentation of large heterogeneous data sets into smaller homogeneous subsets that can be easily managed, separately modeled and analyzed. The basic objective of cluster analysis is to discover natural grouping of objects. The cluster analysis techniques have been used in many areas such as manufacturing, Medicine, nuclear science, radar scanning and research and development planning. According to Geetha et al. (1999) the cluster analysis is multivariable statistical technique applied to analyze the correlation between the physico-chemical and biological parameters and grouping them into cluster. Cluster analysis with dendrogram was reported by Mruthunjaya & Hosmani (2004), Rana & Bhat (2005), Praveena *et al*. (2007) and Abbas *et al.* (2008)

Materials and Methods

The water samples from three site of Munj sagar Talab were collected. The physico- chemical analysis of these water samples was performed as per the procedures describe in (APHA, 1985). Parameters selected for analysis were temperature, pH, dissolved oxygen, free carbon dioxide, calcium, magnesium, total hardness, nitrates, chloride, carbonate alkalinity, bicarbonate alkalinity, phosphate, silicates, BOD, depth, transparency and conductivity.

The two year data (Nov 2006-Oct 2008) of the physico- chemical parameters were subject to statistical analysis of Hierarchical cluster analysis.

Steps to conduct a Cluster Analysis

A common approach to conduct a cluster analysis is to create a table of relative similarities between all objects and to use this information to combines the objects into groups.

The table of relative similarities is called a distance matrix. The method of combining objects into groups is called a clustering strategy. The focus is to combine objects that are similar to one another.

Data matrix

Cluster analysis starts with a data matrix, where objects are rows, and observations are columns. The table constructed thereof gives a measure of similarities or differences between the observations.

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$$\begin{bmatrix} x_{11} & \cdots & x_{1f} & \cdots & x_{1p} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ x_{i1} & \cdots & x_{if} & \cdots & x_{ip} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ x_{n1} & \cdots & x_{nf} & \cdots & x_{np} \end{bmatrix}$$

Data matrix

$$\begin{bmatrix} 0 & & & & \\ d(2,1) & 0 & & & \\ d(3,1) & d(3,2) & 0 & & \\ \vdots & \vdots & \vdots & & \\ d(n,1) & d(n,2) & \cdots & \cdots & 0 \end{bmatrix}$$

Distance matrix

Distances are normally used to measure the similarity or dissimilarity between two data objects

$$d(i,j) = \sqrt[q]{(|x_{i1} - x_{j1}|^q + |x_{i2} - x_{j2}|^q + \ldots + |x_{ip} - x_{jp}|^q)}$$

Where, d(i,j) indicated distance between 'i'th and 'j'th parameter having data values as 'x'_i and 'x'_j and 'q' denoting the exponent.

Hierarchical Clustering methods

Hierarchical clustering methods do not necessarily require preset knowledge of the number of groups. Two general methods of hierarchical clustering methods are available namely *divisive* and *agglomerative*.

The divisive techniques start by assuming a single group, partitioning that group into subgroups, partitioning these subgroups further into subgroups and so on until each object forms its own subgroup.

The agglomerative techniques start with each object describing a subgroup, and then combine like subgroups into more inclusive subgroups until only one group remains.

Clustering Strategy (Unweighted Pair-Group Average)

In this method, groups once formed are represented by their mean values for each variable, that is, their mean vector, and inter-group distance is now defined in terms of distance between two such mean vectors. In the average group linkage method, the two clusters r and s are merged such that, after merger the average pair wise distance within the newly formed cluster is minimum. Suppose we label the new cluster formed by merging clusters r and s, as t. Then D (r,s), the distance between clusters r and s is computed as

D(r,s) = Average [d(i,j)] where observations i and j are in cluster t, the cluster formed by merging clusters r and s.

At each stage of hierarchical clustering, the clusters r and s, for which D(r,s) is minimum, are merged. In this case, the two clusters are merged such that the newly formed cluster, on an average, will have minimum pair wise distances between the points in it.

Dendrogram

Hierarchical clustering is represented by a two dimensional diagram known as dendrogram.

Cophenetic Correlation

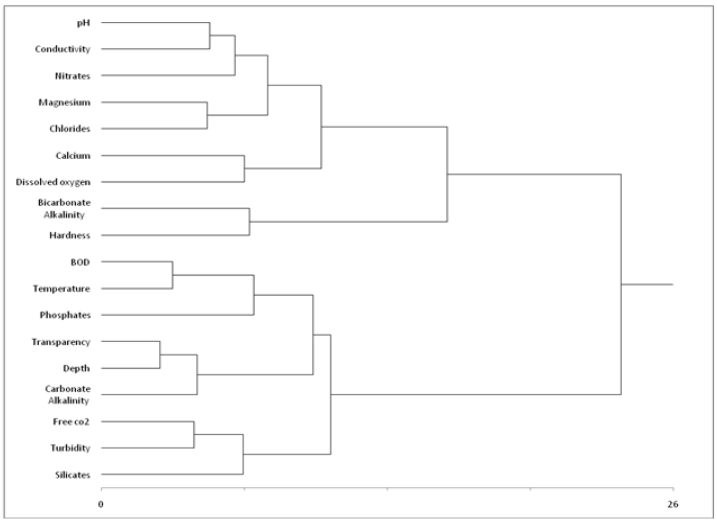
Cophenetic correlation (more precisely, the Cophenetic correlation coefficient) is a measure of degree of accuracy by which a dendrogram preserves the pair wise distances between the original non-modeled data points.

Cophenetic correlation lies between -1.0 to 1.0. Dendrogram is not necessarily exactly like the data matrix it represents. We need to know how well the tree represents the data matrix. The cophenetic correlation coefficient "c" provides with a partial answer. It measures how well the dendrogram and resemblance matrix match.

Result and Discussion

Varies et al.(1989) has reported that the application of multivariable analysis in combination with modeled or even descriptive knowledge of the dynamic system provides an effective tool in the elevation of statistical relationship in process studied by extracting the correlation structure of numerous cross concluded variable it allows them to be expressed in very condensed form. In the present study the monthly variations in physico-chemical parameters for three stations are presented in tables 1 to 3. Distance Matrix (Euclidean Distance) among the parameters for the station S1, S2 and S3 are reported in tables 4 to 6 respectively. Clustering strategy for S1, S2 and S3 are reported in tables 7 to 9. Cophenetic correlations are reported in table 10. The results are illustrated in dendrogram on Hierarchical Cluster analysis (figs. 1 to 3).

Figure 1: Showing dendogram for station S1



Dendogram of S1 shows following four clusters:

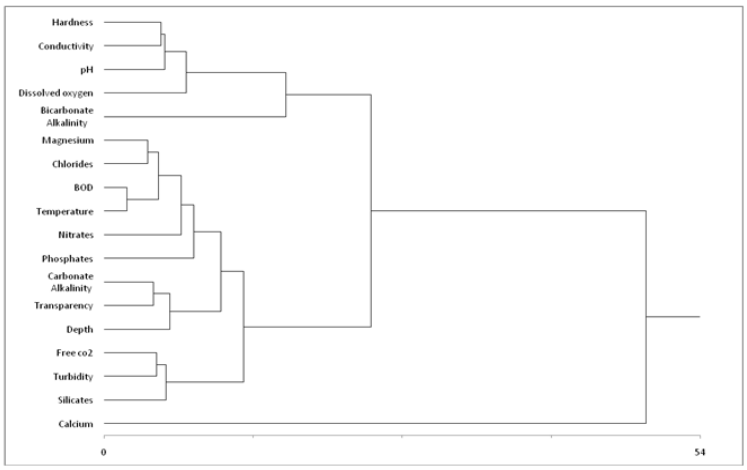
Cluster 1: pH, Conductivity, Nitrates, Magnesium, Chlorides, Calcium and Dissolved oxygen

Cluster 2: Bicarbonate alkalinity and Total Hardness

Cluster 3: BOD, Water temperature, Phosphate, Transparency, Depth and Carbonate alkalinity

Cluster 4: Free carbon dioxide, Turbidity and Silicates.

Figure 2: Showing Dendogram for station S2



Dendogram of S2 shows following five clusters:

Cluster 1: pH, Dissolved oxygen, Conductivity and Total Hardness and

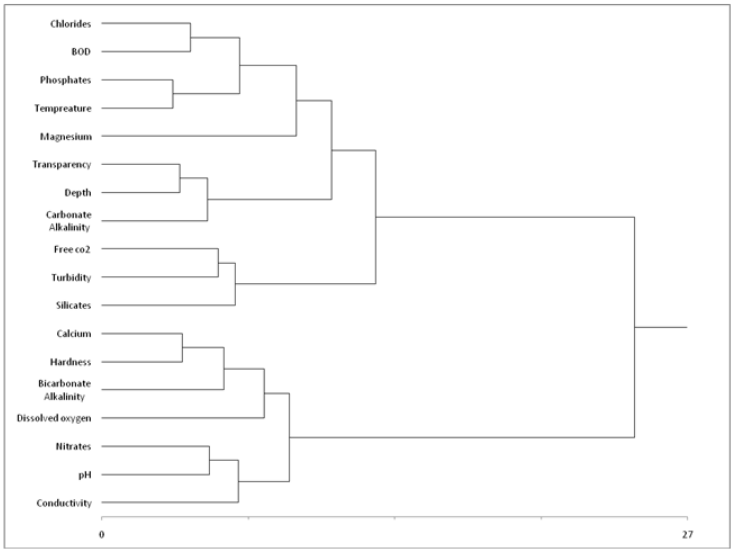
Cluster 2: Bicarbonate alkalinity

Cluster 3: BOD, Water temperature, Magnesium, Chlorides, and Nitrates and Phosphate,

Cluster 4: Free carbon dioxide, Turbidity, Silicates and Calcium.

Cluster 5: Transparency, Depth and Carbonate alkalinity

Figure 3: Showing dendogram for station S3



Dendogram of S3 shows following four clusters:

Cluster 1: Calcium, Dissolved oxygen, Bicarbonate alkalinity, Total Hardness, pH, Conductivity and Nitrates,

Cluster 2: Transparency, Depth and Carbonate alkalinity

Cluster 3: BOD, Chlorides, Phosphate, Water temperature and Magnesium

Cluster 4:, Free carbon dioxide, Turbidity and Silicates,

Table 1 – Showing the monthly variation in physico-chemical parameters at station S1

		Depth	Temp	Tran.	Tur.	Con.	pH	DO	F.co2	BOD	Cl	Har.	B. Alk.	Calk.	Sil.	Nit.	Phos.	Ca	Mg
2006-2007	NOVEMBER	252.30	22.40	47.10	11.00	234.00	7.71	7.50	1.00	10.40	41.90	26.59	110.75	7.60	12.80	0.17	0.11	17.39	9.20
	DECEMBER	240.30	16.50	50.50	9.00	220.00	7.91	8.70	0.60	7.80	38.90	28.76	114.25	11.20	7.80	0.18	0.13	18.81	9.95
	JANUARY	215.60	18.60	48.10	15.00	226.00	7.85	8.90	0.30	8.20	37.55	25.89	123.25	13.40	7.80	0.18	0.14	17.20	8.69
	FEBRUARY	199.60	21.70	38.50	22.00	245.00	7.87	8.80	0.83	8.60	37.50	28.89	121.75	8.40	8.50	0.18	0.12	18.30	10.59
	MARCH	185.40	23.70	33.10	28.00	230.00	7.93	8.20	1.40	9.80	34.50	29.48	127.75	6.50	8.83	0.18	0.13	18.30	11.18
	APRIL	160.40	24.80	30.10	32.00	248.00	7.98	7.90	1.40	10.10	44.52	31.58	137.50	6.50	9.60	0.17	0.18	19.70	11.88
	MAY	140.20	30.90	28.40	38.00	275.00	8.01	7.40	1.50	10.40	47.12	32.98	142.50	6.10	11.50	0.24	0.23	20.00	12.98
	JUNE	101.30	33.70	24.10	40.00	294.00	8.02	7.30	1.00	12.10	47.78	35.32	152.25	7.20	14.40	0.24	0.27	24.00	11.32
	JULY	143.60	30.40	27.20	35.00	320.00	7.86	7.50	0.80	13.50	55.15	26.02	140.25	8.50	16.54	0.24	0.24	14.50	11.52
	AUGUST	185.20	31.50	30.10	31.00	305.00	7.76	6.40	1.00	13.60	40.52	26.34	135.20	7.40	20.40	0.17	0.20	16.70	9.64
	SEPTEMBER	240.20	29.50	34.40	22.00	284.00	7.83	6.50	1.10	12.40	41.62	27.18	132.52	7.60	26.40	0.18	0.19	17.30	9.88
	OCTOBER	260.40	28.50	38.40	20.00	256.00	7.89	7.50	0.80	11.40	37.50	25.23	125.50	8.90	29.40	0.19	0.14	17.40	7.83
2007-2008	NOVEMBER	267.20	20.40	46.70	15.00	240.00	7.99	8.00	0.63	10.40	38.45	25.45	115.25	10.80	12.80	0.17	0.12	18.40	7.05
	DECEMBER	254.20	19.40	48.60	12.00	215.00	7.91	8.59	0.82	8.20	38.20	27.38	110.50	8.70	10.40	0.18	0.13	17.60	9.78
	JANUARY	215.30	17.60	46.20	15.00	224.00	8.05	8.85	0.31	8.40	38.20	27.23	126.75	10.80	10.40	0.18	0.15	18.10	9.13
	FEBRUARY	200.30	19.80	37.40	18.00	242.00	7.95	8.69	1.10	8.90	37.80	28.50	130.75	6.40	11.20	0.18	0.17	16.50	12.00
	MARCH	186.20	23.70	31.40	33.00	225.00	7.98	8.13	1.60	10.10	35.40	30.01	137.75	5.40	12.30	0.18	0.17	18.30	11.71
	APRIL	158.20	25.70	29.70	33.00	240.00	7.88	7.70	1.50	10.50	48.47	28.97	150.50	5.50	12.10	0.15	0.18	16.40	12.57
	MAY	130.30	27.80	25.60	38.00	270.00	8.02	7.20	1.60	10.90	51.40	32.11	144.75	5.10	12.40	0.21	0.24	19.50	12.61
	JUNE	100.10	33.90	21.40	41.00	290.00	8.01	7.40	1.30	11.70	51.76	34.23	140.25	6.10	13.50	0.23	0.25	21.30	12.93
	JULY	130.20	31.50	24.40	37.00	315.00	7.69	6.80	0.94	14.40	57.25	26.10	135.75	7.80	15.50	0.15	0.24	13.40	12.70
	AUGUST	174.20	30.50	32.40	30.00	301.00	7.77	6.00	1.50	15.20	44.10	27.20	130.75	6.10	19.40	0.17	0.20	17.20	10.00
	SEPTEMBER	220.40	32.40	36.40	24.00	280.00	7.79	6.40	1.40	14.10	45.20	27.39	128.75	6.00	23.40	0.18	0.18	16.80	10.59
	OCTOBER	238.20	27.50	38.40	18.00	250.00	7.75	7.10	1.10	11.10	41.30	26.74	122.75	7.10	21.40	0.19	0.15	18.10	8.64

Table 2 – Showing the monthly variation in physico-chemical parameters at station S2

	s2	Depth	Temp	Tran.	Tur.	Con.	pH	DO	F.co2	BOD	Cl	Har.	B. Alk.	C.alk.	Sil.	Nit.	Phos.	Ca	Mg
2006-2007	NOVEMBER	218.0	23.1	45.4	10.4	230.0	7.3	6.5	1.0	9.8	39.5	24.0	105.7	7.5	11.5	0.2	0.2	16.8	7.2
	DECEMBER	210.0	16.7	48.2	10.2	218.0	8.1	8.1	0.8	8.2	35.2	26.2	109.7	10.8	7.9	0.2	0.2	18.3	7.9
	JANUARY	200.0	19.1	44.7	17.4	224.0	8.0	8.4	0.4	8.8	33.2	26.2	118.2	12.5	7.8	0.2	0.3	16.2	10.0
	FEBRUARY	190.0	21.8	40.1	24.2	240.0	8.1	8.2	1.1	9.2	37.8	28.0	119.7	7.6	8.9	0.2	0.2	17.6	10.4
	MARCH	170.0	24.1	31.5	30.4	235.0	8.3	7.6	1.6	10.2	36.8	28.5	121.2	7.1	8.6	0.2	0.2	17.9	10.6
	APRIL	140.0	25.1	28.7	34.4	250.0	8.2	7.1	1.7	11.1	40.2	27.7	130.2	6.4	9.5	0.2	0.3	16.1	11.6
	MAY	120.0	31.1	27.4	37.4	265.0	8.4	6.6	1.9	12.4	43.5	29.0	135.7	5.8	12.5	0.3	0.3	16.9	12.1
	JUNE	90.0	33.9	22.1	39.4	287.0	8.5	7.1	1.3	13.4	44.2	30.7	142.4	7.4	15.4	0.3	0.3	20.1	10.6
	JULY	100.0	30.6	28.7	37.6	315.0	7.9	7.2	1.4	14.4	50.5	23.3	135.5	8.4	17.6	0.2	0.3	12.5	10.8
	AUGUST	165.0	31.8	29.2	33.2	301.0	7.8	6.2	1.4	14.5	43.1	25.5	128.5	7.1	21.3	0.2	0.2	15.3	10.2
	SEPTEMBER	219.0	29.7	33.4	21.2	278.0	7.9	6.0	1.8	13.2	40.6	28.0	124.7	7.2	23.4	0.2	0.2	18.3	9.7
	OCTOBER	250.0	29.1	36.7	17.4	245.0	7.9	7.0	1.5	11.4	38.2	27.0	121.4	7.9	24.4	0.2	0.2	19.6	7.4
2007-2008	NOVEMBER	259.0	20.7	44.7	12.2	236.0	8.0	7.4	0.9	10.1	39.5	25.5	110.3	10.8	12.4	0.2	0.2	17.8	7.7
	DECEMBER	245.0	19.7	46.2	11.2	213.0	8.0	8.1	0.9	8.5	35.5	26.6	116.5	8.4	11.2	0.2	0.2	18.2	8.4
	JANUARY	201.0	18.1	42.2	13.2	219.0	8.2	8.6	0.4	9.1	33.5	27.5	120.5	9.4	11.9	0.2	0.2	17.2	10.3
	FEBRUARY	194.0	20.1	39.5	17.4	235.0	8.0	7.7	1.0	9.4	38.1	28.6	129.7	5.9	12.4	0.2	0.2	18.2	10.4
	MARCH	178.0	24.1	29.4	31.2	238.0	8.0	7.7	1.5	10.5	37.1	29.2	131.8	5.2	13.4	0.2	0.2	18.2	11.0
	APRIL	148.0	25.8	30.5	36.8	245.0	8.3	6.4	1.7	11.3	53.1	31.9	125.8	5.0	14.1	0.1	0.3	18.8	13.1
	MAY	118.0	27.9	32.4	39.2	260.0	8.6	6.2	1.8	12.7	56.7	35.1	146.8	5.8	13.2	0.2	0.3	20.4	14.7
	JUNE	94.0	34.1	21.1	41.4	280.0	8.5	6.3	2.1	14.1	57.2	36.7	142.7	6.5	15.4	0.2	0.3	23.2	13.5
	JULY	114.0	31.6	28.7	39.2	309.0	8.2	6.3	1.1	15.2	62.2	29.7	140.5	7.9	18.1	0.1	0.2	15.1	14.6
	AUGUST	155.0	31.1	31.4	33.4	298.0	7.4	6.3	1.8	16.1	43.1	24.3	132.7	6.3	21.0	0.1	0.2	14.5	9.8
	SEPTEMBER	200.0	33.4	34.6	24.4	270.0	7.6	6.2	1.9	14.2	40.6	26.5	126.5	6.7	22.4	0.2	0.2	16.5	10.0
	OCTOBER	210.0	28.1	37.4	19.2	238.0	7.3	6.5	1.7	12.1	38.2	26.0	119.8	7.8	23.9	0.2	0.2	18.4	7.6

Table 3 – Showing the monthly variation in physico-chemical parameters at station S3

	s3	Depth	Temp	Tran.	Tur.	Con.	pH	DO	F.co2	BOD	Cl	Har.	B. Alk.	C.alk.	Sil.	Nit.	Phos.	Ca	Mg
2006-2007	NOVEMBER	240.30	23.30	49.70	9.40	237.00	7.15	7.78	0.91	9.30	37.90	23.48	108.40	7.50	14.70	0.18	0.15	16.70	6.78
	DECEMBER	225.60	16.90	49.50	9.20	219.00	7.92	8.71	0.61	8.10	36.10	26.45	110.80	10.90	7.70	0.18	0.13	18.50	7.95
	JANUARY	210.40	19.30	46.40	16.10	227.00	7.82	8.92	0.41	8.70	34.20	26.19	120.70	11.50	7.50	0.18	0.14	16.50	9.69
	FEBRUARY	195.80	22.10	42.10	22.40	234.00	7.89	8.81	0.89	9.10	37.40	28.84	115.80	8.20	8.40	0.18	0.12	18.10	10.74
	MARCH	180.30	24.40	32.10	29.50	234.00	7.99	8.19	1.14	9.80	36.40	28.42	123.50	6.90	9.10	0.18	0.13	18.10	10.32
	APRIL	150.60	26.10	29.40	32.40	248.00	7.98	7.81	1.48	10.40	45.60	29.52	125.50	6.50	10.10	0.20	0.17	17.30	12.22
	MAY	130.60	31.50	27.10	37.60	267.00	8.07	7.38	1.61	11.40	47.80	32.21	132.20	6.10	13.50	0.21	0.22	18.30	13.91
	JUNE	92.90	34.10	24.10	37.50	278.00	8.06	7.29	1.58	12.40	47.40	34.32	138.70	7.50	14.40	0.21	0.26	22.10	12.22
	JULY	129.60	31.10	26.40	38.40	314.00	7.84	7.51	0.81	13.40	55.40	25.82	124.70	8.40	18.40	0.19	0.23	14.30	11.52
	AUGUST	173.30	32.10	32.10	31.60	304.00	7.76	6.42	1.21	13.40	42.10	24.74	130.10	7.10	20.40	0.16	0.19	14.30	10.44
	SEPTEMBER	225.60	29.80	35.10	22.80	280.00	7.81	6.51	1.48	12.40	39.20	26.99	127.70	7.60	26.40	0.19	0.20	17.40	9.59
	OCTOBER	255.60	29.30	37.10	16.40	248.00	7.82	7.48	1.59	11.40	37.10	26.43	124.50	7.70	27.10	0.18	0.18	18.70	7.73
2007-2008	NOVEMBER	260.30	20.90	48.40	13.20	234.00	7.99	8.01	1.12	9.40	37.90	23.76	112.70	10.90	14.30	0.18	0.14	17.10	6.66
	DECEMBER	250.90	20.10	47.50	10.20	216.00	7.91	8.81	0.87	8.30	36.10	26.29	112.80	8.40	10.20	0.18	0.15	17.80	8.49
	JANUARY	210.30	18.40	44.60	15.40	220.00	8.15	8.41	0.41	8.70	34.10	27.23	124.70	9.80	12.10	0.19	0.14	17.40	9.83
	FEBRUARY	200.60	20.30	40.60	17.60	234.00	7.89	8.31	1.12	9.10	37.10	29.15	130.50	6.00	12.10	0.20	0.17	18.10	11.05
	MARCH	180.60	24.40	30.50	31.40	240.00	7.81	7.75	1.35	9.70	35.90	28.54	133.50	5.10	12.50	0.19	0.17	18.10	10.44
	APRIL	154.40	26.10	29.40	36.20	240.00	8.01	7.21	1.62	10.50	48.60	29.70	156.20	5.00	13.10	0.22	0.19	17.50	12.20
	MAY	125.30	28.10	30.40	31.40	265.00	8.11	6.78	1.52	11.40	51.90	32.28	148.70	5.80	13.40	0.24	0.21	18.10	14.18
	JUNE	110.60	34.10	22.40	38.60	275.00	8.04	7.41	1.78	12.40	50.20	33.39	145.70	6.50	14.20	0.26	0.27	20.90	12.49
	JULY	125.50	31.60	29.40	37.20	305.00	7.81	6.89	0.78	13.70	59.60	27.38	150.70	7.90	17.60	0.22	0.19	15.40	11.98
	AUGUST	160.40	32.20	33.10	31.50	302.00	7.77	6.12	1.61	14.40	42.10	24.74	145.50	6.30	21.10	0.16	0.19	14.30	10.44
	SEPTEMBER	220.30	33.50	37.40	22.40	282.00	7.54	6.38	1.38	13.10	39.20	26.84	126.70	6.70	25.40	0.19	0.20	17.20	9.64
	OCTOBER	226.30	29.10	39.40	16.30	250.00	7.71	7.12	1.32	10.80	37.10	25.60	115.70	7.80	26.40	0.18	0.17	17.60	8.00

Table 4: Showing Distance Matrix (Euclidean Distance) for station S1

	Depth	Temp.	Trans.	Tur.	Con.	pH	DO	F. co2	BOD	Cl	Hard.	B.Alk.	C.Alk.	Sili.	Nit	Phos.	Cal.
Depth																	
Temperature	9.79																
Transparency	2.73	9.79															
Turbidity	11.22	11.36	12.06														
Conductivity	22.35	16.09	21.34	27.07													
pH	20.70	16.12	19.45	26.65	5.00												
Dissolved oxygen	25.89	22.45	24.38	32.42	10.14	6.86											
Free co2	9.58	10.80	10.72	4.28	26.29	25.52	31.31										
BOD	10.39	3.29	10.20	13.68	14.09	14.27	20.72	12.89									
Chlorides	17.23	10.76	16.12	21.24	6.83	7.23	13.37	20.55	9.10								
Hardness	32.36	26.73	31.07	37.37	11.38	11.95	9.31	36.56	24.94	16.61							
Bicarbonate Alkalinity	37.84	32.21	36.63	42.89	16.67	17.24	13.95	41.92	30.39	22.35	6.83						
Carbonate Alkalinity	4.83	10.00	4.02	10.39	22.55	21.13	26.12	10.47	10.86	17.15	32.40	38.13					
Silicates	8.94	12.11	10.81	6.54	27.64	27.15	33.03	6.53	13.88	22.27	38.31	43.76	9.64				
Nitrates	18.67	13.06	17.44	23.43	6.69	5.67	10.97	22.66	11.93	5.79	15.05	20.62	18.67	24.28			
Phosphates	9.27	5.90	9.39	6.38	21.12	20.89	26.82	7.05	8.20	15.30	31.50	37.05	8.23	8.80	17.57		
Calcium	24.64	19.74	23.31	30.15	7.74	5.57	6.62	29.05	18.32	11.19	10.16	14.55	24.95	30.92	8.11	24.43	
Magnesium	15.41	9.28	14.28	18.81	9.96	9.04	14.70	17.83	8.40	4.90	19.11	24.58	15.54	20.47	7.16	13.21	12.76

Table 5: Showing Distance Matrix (Euclidean Distance) for station S2

	Depth	Temp.	Trans.	Tur.	Con.	pH	DO	F. co2	BOD	Cl	Hard.	B.Alk.	C.Alk.	Sili.	Nit	Phos.	Cal.
Depth																	
Temperature	10.83																
Transparency	5.87	9.27															
Turbidity	10.71	12.29	13.95														
Conductivity	25.74	17.77	21.06	29.57													
pH	23.02	16.43	18.04	27.73	5.39												
Dissolved oxygen	25.93	20.83	20.69	31.62	8.81	5.76											
Free co2	8.54	10.01	11.91	4.75	27.45	25.56	29.56										
BOD	11.38	2.06	9.26	13.17	16.79	15.65	20.04	11.08									
Chlorides	12.93	5.00	9.64	14.92	15.32	13.61	18.18	13.21	4.33								
Hardness	27.39	20.00	22.49	31.35	5.20	5.66	7.80	29.34	19.10	16.82							
Bicarbonate Alkalinity	41.11	33.65	36.12	45.27	16.29	18.29	16.82	43.13	32.78	30.90	14.60						
Carbonate Alkalinity	6.04	8.98	4.48	12.00	22.36	19.74	22.56	10.81	9.13	10.10	23.97	37.77					
Silicates	7.49	10.62	11.55	6.44	27.89	26.23	30.00	4.80	11.42	14.00	30.01	43.78	10.08				
Nitrates	11.02	6.69	7.83	14.63	17.55	14.97	18.38	12.89	7.21	7.42	19.43	32.63	8.10	13.53			
Phosphates	16.88	9.02	12.63	19.60	11.40	9.00	13.46	17.82	8.62	6.67	12.71	26.18	13.23	18.92	8.25		
Calcium	60.21	53.60	55.08	65.34	36.13	37.79	35.00	63.01	52.74	50.86	34.40	20.52	56.96	63.52	52.24	46.15	
Magnesium	11.52	5.31	8.95	12.57	17.85	15.66	19.85	11.34	5.18	3.96	19.21	33.12	9.08	12.61	6.81	8.07	53.16

Table 6: Showing Distance Matrix (Euclidean Distance) for station S3

	Depth	Temp.	Trans.	Tur.	Con.	pH	DO	F.co2	BOD	Cl	Hard.	B.Alk.	C.Alk.	Sili.	Nit	Phos.	Cal.
Depth																	
Tempreature	10.16																
Transparency	3.58	9.54															
Turbidity	11.33	12.41	13.01														
Conductivity	25.17	18.32	22.87	30.27													
pH	20.91	15.52	18.42	26.95	6.10												
Dissolved oxygen	27.21	23.05	24.51	34.04	9.60	7.96											
Free co2	8.79	10.05	10.78	5.33	27.98	24.47	31.64										
BOD	12.81	4.52	11.33	16.46	14.08	11.69	19.38	14.25									
Chlorides	13.82	6.37	11.87	17.02	13.81	10.90	18.24	15.24	4.07								
Hardness	29.76	23.55	27.27	35.01	8.09	9.22	7.12	32.54	19.82	18.73							
Bicarbonate Alkalinity	30.30	23.84	27.88	35.43	7.06	9.83	8.82	33.05	19.77	18.95	4.56						
Carbonate Alkalinity	5.73	8.77	3.96	12.63	22.18	17.97	24.17	11.19	10.47	10.85	26.75	27.41					
Silicates	8.64	12.21	11.32	6.60	30.00	26.74	33.86	5.61	16.13	17.59	35.24	35.51	11.63				
Nitrates	23.92	17.68	21.47	29.01	6.43	4.91	8.45	26.61	14.07	12.57	6.87	7.83	20.93	29.21			
Phosphates	9.65	3.24	9.19	10.79	20.20	17.07	24.41	8.62	6.81	7.54	24.97	25.46	8.28	11.17	18.94		
Calcium	30.09	24.63	27.61	36.18	9.69	10.04	6.34	33.43	21.01	20.12	3.68	6.64	27.22	35.99	8.39	26.04	
Magnesium	10.87	8.51	9.99	13.52	20.28	16.72	23.42	12.19	9.39	9.00	24.72	24.89	10.25	14.33	18.69	8.71	26.14

Table 7: Showing cluster strategy for station S1

Cluster	1st Item	2nd Item	Distance
1	Transparency	Depth	2.725
2	BOD	Temperature	3.289
3	Free co2	Turbidity	4.282
4	Cluster 1	Carbonate Alkalinity	4.423
5	Magnesium	Chlorides	4.899
6	pH	Conductivity	5.005
7	Cluster 6	Nitrates	6.183
8	Cluster 3	Silicates	6.533
9	Calcium	Dissolved oxygen	6.620
10	Bicarbonate Alkalinity	Hardness	6.825
11	Cluster 2	Phosphates	7.052
12	Cluster 7	Cluster 5	7.668
13	Cluster 11	Cluster 4	9.770
14	Cluster 12	Cluster 9	10.141
15	Cluster 13	Cluster 8	10.598
16	Cluster 14	Cluster 10	15.968
17	Cluster 16	Cluster 15	23.973

Table 8: Showing cluster strategy for station S2

Cluster	1st Item	2nd Item	Distance
1	BOD	Temperature	2.062
2	Magnesium	Chlorides	3.955
3	Carbonate Alkalinity	Transparency	4.480
4	Free co2	Turbidity	4.751
5	Cluster 2	Cluster 1	4.957
6	Hardness	Conductivity	5.201
7	Cluster 6	pH	5.527
8	Cluster 4	Silicates	5.620
9	Cluster 3	Depth	5.952
10	Cluster 5	Nitrates	7.031
11	Cluster 7	Dissolved oxygen	7.458
12	Cluster 10	Phosphates	8.125
13	Cluster 12	Cluster 9	10.598
14	Cluster 13	Cluster 8	12.655
15	Cluster 11	Bicarbonate Alkalinity	16.500
16	Cluster 15	Cluster 14	24.262
17	Cluster 16	Calcium	49.218

Table 9: Showing cluster strategy for station S3

Cluster	1st Item	2nd Item	Distance
1	Phosphates	Tempreature	3.239
2	Transparency	Depth	3.577
3	Calcium	Hardness	3.677
4	Chlorides	BOD	4.066
5	Cluster 2	Carbonate Alkalinity	4.845
6	Nitrates	pH	4.914
7	Free co2	Turbidity	5.332
8	Cluster 3	Bicarbonate Alkalinity	5.602
9	Cluster 7	Silicates	6.106
10	Cluster 6	Conductivity	6.262
11	Cluster 4	Cluster 1	6.311

12	Cluster 8	Dissolved oxygen	7.426
13	Cluster 12	Cluster 10	8.585
14	Cluster 11	Magnesium	8.902
15	Cluster 14	Cluster 5	10.523
16	Cluster 15	Cluster 9	12.553
17	Cluster 16	Cluster 13	24.401

Table 10: Showing Cophentic correlation at all three station

Station	Cophentic correlation
S1	0.761
S2	0.881
S3	0.86

Biggest cluster for S1 and S3 contains seven parameters while S2 has six parameters in its biggest cluster. Geetha et al. (1999) also reported three different cluster group while studding the physical and chemical parameters and described biggest cluster of seven parameters.

The values of Cophenetic correlation calculated for S1, S2 and S3 are 0.761, 0.881 and 0.860 respectively are on higher side.

Conclusion

Since higher values of cophenetic correlation indicates good similarity between data matrix of parameters and dendogram, the conducted cluster analysis stands justified.

The cluster analysis of station S1 and S3 indicates that they are alike on the basis of physico-chemical nature. However, station S3 showed slight variation from S1 and S2 in cluster forming showed that its physico-chemical properties are different from station S1 and S3. In authors opinion it may be due to the presence of anthropogenic activities which were absent in station 1 and 3.

References

Abbas F. M. Al-karkhi1, Md. Azmal Hossain1 and Norli, I.2008. Application of Cluster Analysis for Water Quality Parameters - Juru Estuary (MALAYSIA), International Conference on Environmental Research and Technology (ICERT 2008) pp-486-490

APHA .1985. Standard methods for the Examination of Water, Waterwest 16th edition, American Public Health Association, Washington DC, USA.

Geetha, P.; Shenthi, K.; Jaganathan, R. and Balasubramanian, S. 1999. Modeling seasonal fluctuation of aquatic fauna with reference to the environment factors in a high altitude lake of peninsular index (The Ootacamund Lake).In Limnological research in India (Ed.S.R.Mishra).Daya Publishing House, Delhi-110035, and pp 225-240.

Mruthunjaya, T.B and Hosmani, S.P. 2004. Application of cluster Analysis to evaluate pollution in Lingambudhi Lake in Mysore, Karnataka. Nature Environment and Pollution Technology, 3(4):463:466

Praveena, S. M., Ahmed A., Radojevic, M., Abdullah, M. H., Aris, A. Z. 2007. Factor-Cluster analysis and enrichment study of Mangrove Sediments and examples from Mengkabong sabah. The Malaysian Journal of Analytical Sciences, 11(2):421 – 430

Rana, M.K., Bhat, K.V. (2005). RAPD markers for genetic diversity Study among Indian cotton cultivators. Current Science, 88(12):1956-1961

Varies, O; Sirvo, H. & Kettunen, J.1989. Multivariate analysis of Lake Phytoplankton and environment factor. Arch. Hydrobiol, 117:163-175.