

Cluster analysis of water quality parameters of water samples from Colachel to Melmidalam in Kanyakumari district

MV Reena ¹, A Amalraj ^{2,*}, R Ajitha ³ and C Nirmala Louis ⁴

¹ Research Centre of Chemistry, Women's Christian College, Nagercoil, Kanyakumari District, Affiliated to Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli 627 012, Tamil Nadu, India.

² Department of Chemistry, St. Jerome's College Anandhanadarkudy-629 201, Kanyakumari District, Affiliated to Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli 627 012, Tamil Nadu, India.

³ Department of Chemistry, Women's Christian College, Nagercoil-629 001, Kanyakumari District, Affiliated to Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli 627 012, Tamil Nadu, India.

⁴ Department of Physics, Holy Cross College (Autonomous) Nagercoil-629 004, Kanyakumari District, Affiliated to Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli 627 012, Tamil Nadu, India.

Abstract

A methodical study has been carried out to explore physico-chemical parameters of drinking water from well and bore hole in and around the villages from Colachel to Melmidalam of Kanyakumari District. Water samples from well and bore hole in four sites namely Colachel, Kurumbanai, Midalam, Melmidalam were collected in pre monsoon and post monsoon seasons during 2019 and 2020 and analyzed for temperature, sodium, potassium and oxidation & reduction potential, pH, turbidity, alkalinity, hardness, salinity, fluoride, chloride, total dissolved solids, dissolved oxygen, BOD, electrical conductivity, total nitrogen, nitrate, sulphate, ammonia, phosphate, total phosphorus. The physico-chemical parameters were analyzed and the results were compared with water quality standards described by WHO. Statistical techniques, calculation of basic statistics, Correlation matrix, and Hierarchical Cluster analysis were simultaneously applied to the physico-chemical parameters of water samples taken from in different sites. The above study will be useful to know the water quality and their fitness for drinking purposes at various stations undertaken. Overall water quality was found satisfactory for drinking purpose without prior treatment.

Keywords: Bore hole; well water; Colachel; Kurumbanai; Midalam; Melmidalam; Physico-chemical parameters; Basic statistics; Pearson Correlation matrix; Dendrogram

1. Introduction

Drinking water or potable water is defined as that having acceptable quality in terms of its physical, chemical, bacteriological and acceptability parameters so that it can be safely used for drinking and cooking ^[1]. Surface waters are primary and limited water resources to meet agricultural industrial and domestic water needs of human and living beings. Polluted waters contain significant levels of pollutants, usually at levels above WHO certified drinking water quality standards and these are able to cause significant problems when ingested by humans ^[2]. According to Buchholz^[3], point sources are those that come from industrial facilities and municipal sewage systems. The natural cleansing ability of oxygen contained in the water is compromised and the water can no longer breakdown organic pollutants^[3]. Thus, they can be said to be pollution that can be traced to a particular source. Cairncross and Cliff^[4] have shown that soakage pits and pit latrines can extend their influence on ground-water quality up to 10m or more as

* Corresponding author: Amalraj A

St. Jerome's College Anandhanadarkudy-629 201, Kanyakumari District, Tamil Nadu, India.

groundwater flow is either lateral or vertical. Additionally, filtration does not occur during lateral flow and could carry faecal pollution for much longer distances possibly resulting in contamination of well water with pathogens [5,6]. Pye and Patric^[7] have shown that land disposal of sewage sludge, illegal dumping of septic tank pumpage, improper toxic waste disposal and run off from agricultural operations all contributed to surface and ground water contamination with chemicals and microorganisms.

2. Material and methods

2.1. Physico-Chemical Analysis

Samples collected from all the stations were analyzed for physico-chemical analysis using standard methods [8]. The following physico-chemical parameters such as temperature, pH, turbidity, alkalinity, hardness, salinity, fluoride, chloride, total dissolved solids, dissolved oxygen, BOD, electrical conductivity, total nitrogen, nitrate, sulphate, ammonia, phosphate, total phosphorus, sodium, potassium and oxidation & reduction potential have been analyzed. The temperature of the water samples was measured by mercury thermometer. The pH measurement of the water samples was carried out using digital pH meter (Elico pH-13 model). A conductivity meter was used to measure EC. Volumetric method using sulfuric acid as titrant and phenolphthalein and methyl orange as indicators was used to determine alkalinity. EDTA (complexometric) method was used to determine calcium, magnesium and total hardness titrimetrically. Flame photometer was used to identify sodium and potassium. Mohr's method was used to measure chloride by titration with silver nitrate. UV-Vis Spectrophotometer was used to analyze nitrate. Salinity was estimated by Argentometric titration method. The dissolved oxygen was estimated by Winkler's method. The findings of the present investigation were summarized and compared with standards [9, 10].

2.2. Statistical Analysis

The correlation between various physico-chemical parameters of water samples analyzed statistically conducting basic statistics (mean, standard deviation (SD), median, minimum, maximum, variance (V), Kurtosis (K), Skewness (S), Hierarchical cluster analysis, Pearson correlation analysis with the help of SPSS (Statistics Package for the Social Sciences) software (Windows version 19).

2.3. Descriptive statistics

In the forms of mean, SD, median, minimum, maximum, variance (V), Kurtosis (K), Skewness (S), standard error of kurtosis (SEK), standard error of skewness (SES) were calculated and summarized in Tabular forms in Tables 2, 5, for well water and Table 8, 11 for bore hole water samples respectively.

2.4. Dendrogram studies

Cluster analysis (CA) [11, 12] was used for multivariate modeling of the input data. The main goal of the Hierarchical Agglomerative cluster analysis is to spontaneously classify data into groups of similarity (cluster) searching objects in the n-dimensional space located in closest neighbourhood and to separate a stable cluster from other clusters. In figure 1 to 8, the hierarchical dendrogram for the clustering of determined physical and chemical parameters for all the studied stations is plotted (Ward's method of linkage, squared Euclidean distance as similarity measure, standardization of the input data). For clustering altogether 22 physical and chemical parameters were chosen. It could be concluded that the one big cluster and three small clusters are formed additionally sub clusters are also formed. Statistical Analysis of Ground water quality parameters in Erode District, Tamilnadu was studied by M. Jamuna et al [13]. Spatial and Temporal changes in water quality at Asi River using Multivariate Statistical Techniques was studied by Ece et al [14]. Statistical assessment of water quality parameters for pollution source identification in Bektas Pond was extended by Aydin et al [15].

The Pearson correlation analysis was performed for measured parameters to determine the relation between these variables and given in Tables 3, 6, 9, 12. A correlation analysis is a bivariate method applied to describe the degree of relation between two hydro chemical parameters. A high correlation coefficient (near 1 or -1) means a good relationship between two variables and its value around zero means no relationship between them at a significant level of <0.05. More precisely it can be said that parameters showing coefficient >0.7 are considered to be strongly correlated whereas coefficient between 0.5 and 0.7 shows moderate correlation.

3. Results and discussion

For our research studies, the name of the villages are abbreviated, Colachel as CO, Kurumbanai as Ku, Midalam as MI, Melmidalam as MM. The water samples drawn during the period 2019 in pre monsoon season are abbreviated as PRA19CO, PRA19KU, PRA19MI and PRA19MM. The water samples drawn from well are abbreviated as WPRA19PO, WPRA19KU, WPRA19MI and WPRA19MM. The water samples drawn during the period 2020 in pre monsoon season are abbreviated as PRA20CO, PRA20KU, PRA20MI and PRA20MM. The water samples drawn from well are abbreviated as WPRA20CO, WPRA20KU, WPRA20MI and WPRA20MM.

Table 1 Comparison of water quality parameters of well water in Pre monsoon and Post monsoon season during 2019

S.No	Parameters	Sample code							
		WPRA19CO	WPRA19KU	WPRA19MI	WPRA19ME	WPON19CO	WPON19KU	WPON19MI	WPON19ME
1	pH	7.8	7.9	7.8	7.9	7.8	7.6	7.0	6.8
2	Turbidity (NTU)	6.8	8.2	8.2	8.9	6	8	7.3	7.3
3	Dissolved oxygen (DO) (ppm)	8	8	8	9	7.7	8	7	4.9
4	Biological Oxygen Demand (BOD) (ppm)	7	6.6	7	6	4.9	7.6	9	9
5	Hardness Mg (mg/L)	42	76	40	42	42	12	3	4.9
6	Sulphate (mg/L)	7	8	8	8	0.1	6.6	7	5.7
7	Total Nitrogen (mg/L)	4.6	4.8	4.8	4.5	0.4	3.9	3.8	4.9
8	Nitrate (mg/L)	0.3	0.6	0.9	0.5	8	0.4	0.4	0.9
9	Ammonia (mg/L)	0.8	0.7	0.7	0.1	0.9	0.9	0.5	0.6
10	Phosphate (mg/L)	0.5	0.9	0.8	0.4	0.8	0.8	0.5	0.9
11	Total Phosphorous (mg/L)	0.9	0.8	0.3	0.8	0.8	0.3	0.8	0.9
12	Fluoride (ppm)	0.1	0.4	7.6	0.4	3.4	0.5	0.2	0.5
13	Chloride (ppm)	260	830	250	360	470	211	230	290
14	Total dissolved solids (TDS) (ppm)	415	460	390	392	419	421	530	480
15	Electrical conductivity (Mics/cm)	472	560	570	460	570	472	510	510
16	Oxidation-Reduction Potential (mV)	560	581	582	571	562	581	691	671
17	Temperature (°C)	28	28	27	27	30	30	29	29
18	Sodium (mg/L)	32.1	33.5	33.4	33.8	33.2	16.8	21.5	21.6
19	Potassium (mg/L)	12.4	13.4	13.3	13.1	13.1	16.1	13.9	13.9
20	Alkalinity (mg/L)	168	180	231	231	231	181	180	180
21	Hardness Ca (mg/L)	61	70	56	54	56	34	65	66
22	Salinity (ppm)	94	91	41	74	74	86	90	91

The water samples drawn during the period 2019 in post monsoon season are abbreviated as PON19CO, PON19KU, PON19MI and PON19MM. The water samples drawn from well are abbreviated as WPON19CO, WPON19KU, WPON19MI and WPON19MM. The water samples drawn during the period 2020 in pre monsoon season are abbreviated as PON20CO, PON20KU, PON20MI and PON20MM. The water samples drawn from well are abbreviated as WPON20CO, WPON20KU, WPON20MI and WPON20MM.

The water samples drawn from bore hole are abbreviated as BPRA19CO, BPRA19KU, BPRA19MI and BPRA19MM. The water samples drawn during the period 2020 in pre monsoon season are abbreviated as PRA20CO, PRA20KU, PRA20MI

and PRA20MM. The water samples drawn from bore hole are abbreviated as BPRA20CO, BPRA20KU, BPRA20MI and BPRA20MM.

The water samples drawn during the period 2019 in post monsoon season are abbreviated as PON19CO, PON19KU, PON19MI and PON19MM. The water samples drawn from bore hole are abbreviated as BPON19CO, BPON19KU, BPON19MI and BPON19MM. The water samples drawn during the period 2020 in pre monsoon season are abbreviated as PON20CO, PON20KU, PON20MI and PON20MM. The water samples drawn from bore hole are abbreviated as BPON20CO, BPON20KU, BPON20MI and BPON20MM.

Table 2 Descriptive Statistics of water quality parameters of well water in Pre monsoon and Post monsoon season during 2019

Descriptive Statistics										
	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance	Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error
Temp	8	3	27	30	28.50	.423	1.195	1.429	-1.456	1.481
pH	8	1.1	6.8	7.9	7.575	.1521	.4301	.185	.110	1.481
Turbidity	8	2.9	6.0	8.9	7.588	.3259	.9219	.850	-.140	1.481
Alkalinity	8	63	168	231	197.75	9.845	27.845	775.357	-2.147	1.481
HardnessCa	8	36	34	70	57.75	3.931	11.119	123.643	2.914	1.481
HardnessMg	8	73.0	3.0	76.0	32.738	8.7332	24.7012	610.151	-.207	1.481
Salinity	8	53	41	94	80.13	6.220	17.594	309.554	3.765	1.481
Fluoride	8	7.5	.1	7.6	1.638	.9329	2.6387	6.963	4.234	1.481
Chloride	8	619	211	830	362.63	73.076	206.690	42720.839	4.303	1.481
TDS	8	140	390	530	432.88	16.956	47.960	2300.125	1.602	1.481
DO	8	4.1	4.9	9.0	7.575	.4279	1.2104	1.465	3.977	1.481
BOD	8	4.1	4.9	9.0	7.138	.4960	1.4030	1.968	-.393	1.481
EC	8	110	460	570	515.50	16.282	46.053	2120.857	-1.987	1.481
TotNitrogen	8	4.5	.4	4.9	3.963	.5295	1.4976	2.243	6.217	1.481
Nitrate	8	.6	.3	.9	.600	.0845	.2390	.057	-1.834	1.481
Sulphate	8	7.9	.1	8.0	6.300	.9310	2.6333	6.934	5.819	1.481
Ammonia	8	.8	.1	.9	.650	.0926	.2619	.069	2.417	1.481
Phosphate	8	.5	.4	.9	.700	.0707	.2000	.040	-1.729	1.481
Totphosphorus	8	.6	.3	.9	.775	.0701	.1982	.039	6.572	1.481
Sodium	8	17.0	16.8	33.8	28.238	2.4824	7.0214	49.300	-1.461	1.481
Potassium	8	3.7	12.4	16.1	13.650	.3891	1.1006	1.211	4.137	1.481
ORP	8	131	560	691	599.88	18.054	51.064	2607.554	.152	1.481
Valid N (listwise)	8									

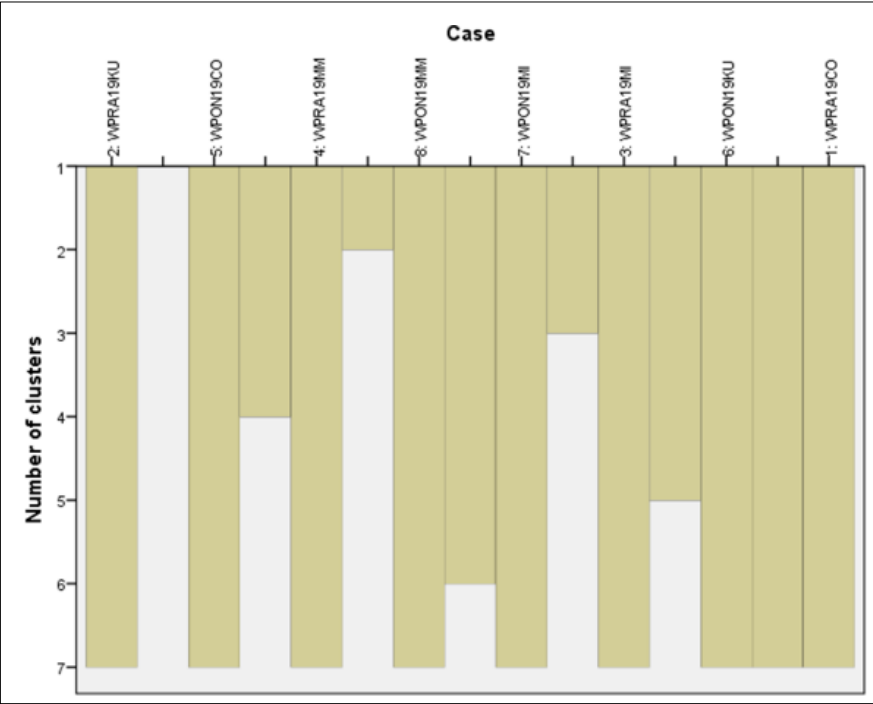


Figure 1 Cluster Diagram of water quality parameters of well water in Pre monsoon and Post monsoon season during 2019

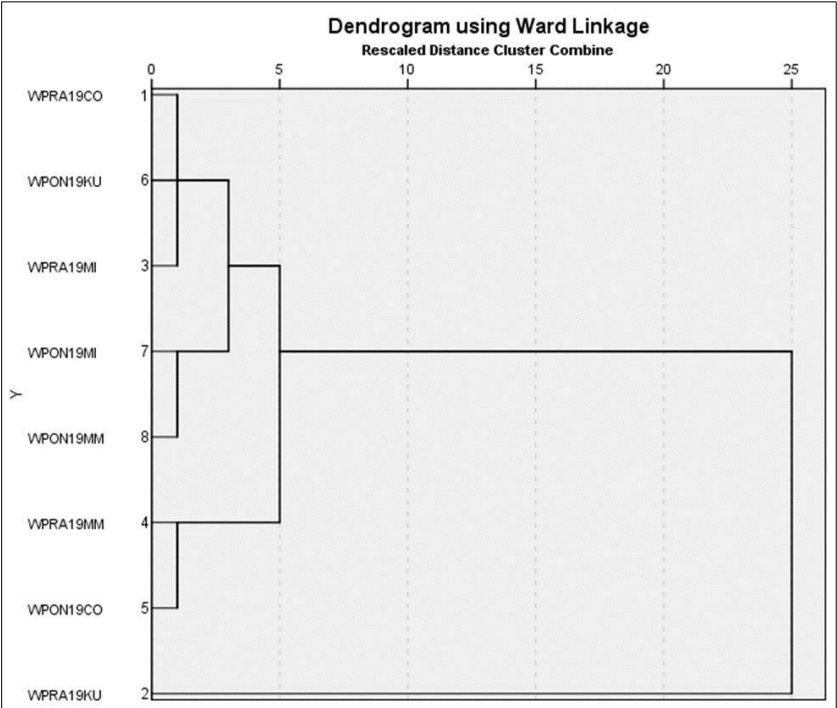


Figure 2 Dendrogram of water quality parameters of well water in Pre monsoon and Post monsoon season during 2019

Table 3 Pearson Correlation Coefficient (r) of water quality parameters of well water in Pre monsoon and Post monsoon season during 2019

		Correlation ^a																												
		Temp	pH	Turbidity	Hardness	Chloride	Sulfate	Fluoride	Chloride	TDS	CO ₃	ED	EC	Total Hardness	Calc	Sulfate	Ammonia	Phosphate	Alkalinity	Sulfate	Phosphate	Calc	ED	EC	Total Hardness	Calc	Sulfate	Ammonia	Phosphate	
Temp	Pearson Correlation Sig. (2-tailed)	1																												
pH	Pearson Correlation Sig. (2-tailed)	-0.08	1																											
Turbidity	Pearson Correlation Sig. (2-tailed)	-0.05	0.06	1																										
Hardness	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	1																									
Chloride	Pearson Correlation Sig. (2-tailed)	-0.05	0.06	0.05	0.07	1																								
Sulfate	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	1																							
Fluoride	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	1																						
Chloride	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	1																					
TDS	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	1																				
CO ₃	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	1																			
ED	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1																		
EC	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1																	
Total Hardness	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1																
Calc	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1															
Sulfate	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1														
Ammonia	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1													
Phosphate	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1												
Alkalinity	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1											
Sulfate	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1										
Phosphate	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1									
Calc	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1								
ED	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1							
EC	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1						
Total Hardness	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1					
Calc	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1				
Sulfate	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1			
Ammonia	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1		
Phosphate	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1	
Alkalinity	Pearson Correlation Sig. (2-tailed)	-0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1

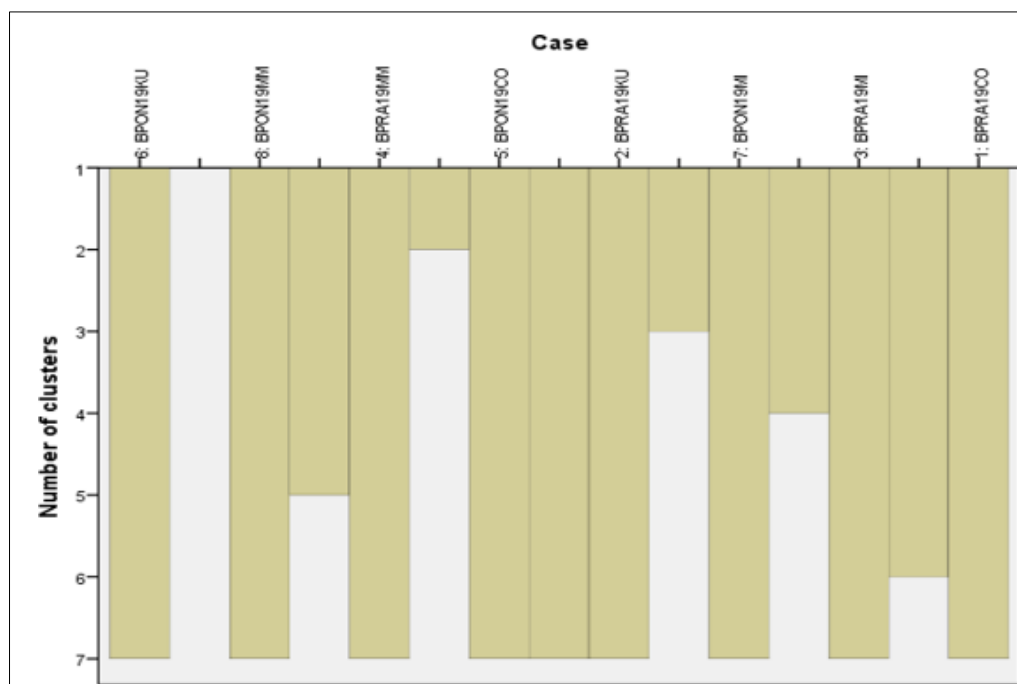
a. Listwise

Table 4 Comparison of water quality parameters of bore hole water in Pre monsoon and Post monsoon season during 2019

S.No	Parameters	Sample code							
		Pre moon Season				Post moon Season			
		BPRA19CO	BPRA19KU	BPRA19MI	BPRA19ME	BPON19CO	BPON19KU	BPON19MI	BPON19ME
1	pH	7.1	8.0	7.2	7.8	7.9	8	6.8	7
2	Turbidity (NTU)	6.0	7	8.2	6	8.9	7.4	6	6
3	Dissolved oxygen (DO) (ppm)	8	9	9	8	6.0	7	7	7
4	Biological Oxygen Demand (BOD) (ppm)	9	7	6.6	7.7	0.5	8.5	8	5.4
5	Hardness Mg (mg/L)	61	41	70	71	71	10	4.5	3
6	Sulphate (mg/L)	7.8	6.8	6.9	9	0.5	7.7	5.6	8.0
7	Total Nitrogen (mg/L)	4.7	4.2	4.2	4.9	0.9	2.1	4.3	3.9
8	Nitrate (mg/L)	0.5	0.9	0.9	4.9	9	0.3	0.3	0.4
9	Ammonia (mg/L)	1.4	1.5	1.5	0.5	1.5	0.4	0.4	0.9
10	Phosphate (mg/L)	0.6	0.3	1.1	1.5	0.9	0.6	0.8	0.5
11	Total Phosphorous (mg/L)	0.8	0.3	0.8	0.9	0.5	0.4	0.4	0.8
12	Fluoride (ppm)	0.8	0.3	0.1	0.4	3.6	0.4	0.4	0.2
13	Chloride (ppm)	230	390	240	340	392	180	280	240
14	Total dissolved solids (TDS)(ppm)	370	390	390	270	378	381	480	230
15	Electrical conductivity (Mics/cm)	500	490	570	570	460	521	510	640
16	Oxidation-Reduction Potential (mV)	632	630	631	681	640	672	721	721
17	Temperature (°C)	30	27	28	28	29	30	28	30
18	Sodium (mg/L)	33.1	26.3	26.8	32.8	32.8	17.8	18.3	18.9
19	Potassium (mg/L)	11.4	12.4	12.3	12.2	12.4	15	20.1	19
20	Alkalinity (mg/L)	221	231	180	180	180	176	178	171
21	Hardness Ca (mg/L)	54	56	70	71	71	26	60	65
22	Salinity (ppm)	76	76	70	92	92	381	85	91

Table 5 Descriptive Statistics of water quality parameters of bore hole water in Pre monsoon and Post monsoon season during 2019

Descriptive Statistics										
	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance	Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error
Temp	8	3	27	30	28.75	.412	1.165	1.357	-1.613	1.481
pH	8	1.2	6.8	8.0	7.475	.1760	.4979	.248	-2.223	1.481
Turbidity	8	2.9	6.0	8.9	6.938	.4049	1.1451	1.311	-.810	1.481
Alkalinity	8	60	171	231	189.63	8.064	22.809	520.268	.291	1.481
HardnessCa	8	22	54	76	65.38	2.815	7.963	63.411	-1.446	1.481
HardnessMg	8	68.0	3.0	71.0	41.438	11.0006	31.1143	968.103	-2.207	1.481
Salinity	8	311	70	381	120.38	37.351	105.645	11160.839	7.848	1.481
Fluoride	8	3.5	.1	3.6	.775	.4100	1.1597	1.345	7.252	1.481
Chloride	8	212	180	392	286.50	27.905	78.927	6229.429	-1.410	1.481
TDS	8	250	230	480	361.13	27.404	77.510	6007.839	.476	1.481
DO	8	3	6	9	7.63	.375	1.061	1.125	-.940	1.481
BOD	8	8.5	.5	9.0	6.588	.9576	2.7084	7.336	4.199	1.481
EC	8	180	460	640	532.63	20.321	57.478	3303.696	.420	1.481
TotNitrogen	8	4.0	.9	4.9	3.750	.4590	1.2984	1.686	3.453	1.481
Nitrate	8	8.7	.3	9.0	2.150	1.1199	3.1677	10.034	2.946	1.481
Sulphate	8	8.5	.5	9.0	6.538	.9323	2.6371	6.954	4.850	1.481
Ammonia	8	1.1	.4	1.5	1.013	.1837	.5194	.270	-2.345	1.481
Phosphate	8	1.2	.3	1.5	.788	.1342	.3796	.144	.601	1.481
Totphosphorus	8	.6	.3	.9	.613	.0833	.2357	.056	-2.197	1.481
Sodium	8	15.3	17.8	33.1	25.850	2.3919	6.7652	45.769	-2.083	1.481
Potassium	8	8.7	11.4	20.1	14.425	1.1800	3.3376	11.139	-.423	1.481
ORP	8	91	630	721	666.00	13.800	39.031	1523.429	-1.454	1.481
Valid N (listwise)	8									

**Figure 3** Cluster Diagram of water quality parameters of bore whole water in Pre monsoon and Post monsoon season during 2019

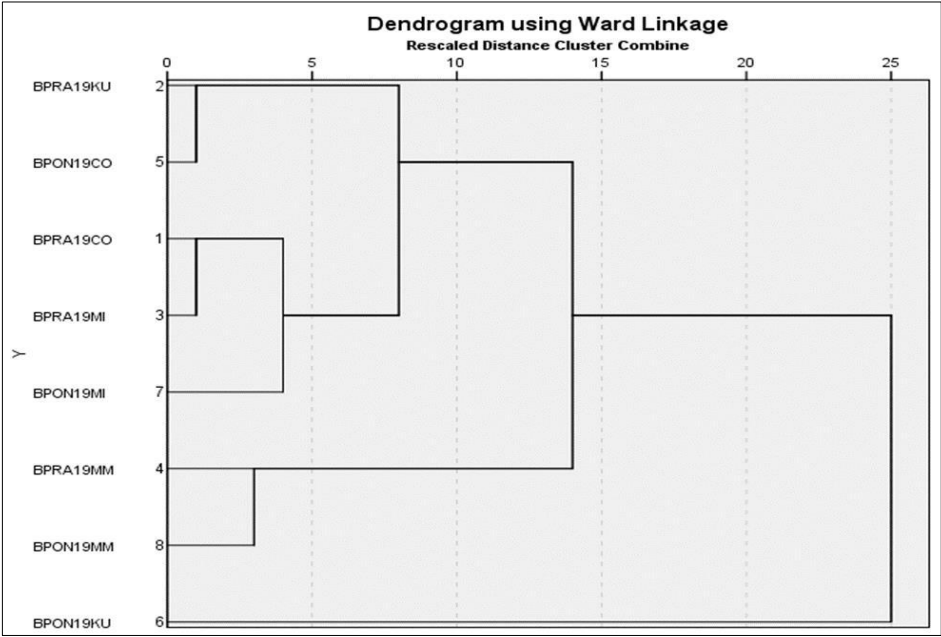


Figure 4 Dendrogram of water quality parameters of bore whole water in Pre monsoon and Post monsoon season during 2019

Table 7 Comparison of water quality parameters of well water in Pre monsoon and Post monsoon season during 2020

S.No	Parameters	Sample code							
		WPRA20CO	WPRA20KU	WPRA20MI	WPRA20ME	WPON20CO	WPON20KU	WPON20MI	WPON20ME
1	pH	7.5	8.1	6.5	7.3	7.8	7.9	7.8	7.8
2	Turbidity (NTU)	8.1	7.0	9.0	9.0	8.0	7.0	8.0	7.0
3	Dissolved oxygen (DO) (ppm)	8	8	7.5	7.0	8.1	9	8	8
4	Biological Oxygen Demand (BOD) (ppm)	9	9	8	8.1	7	8	7	7
5	Hardness Mg (mg/L)	4.5	4.5	20	7	104	90	77	70
6	Sulphate (mg/L)	5	5	2.5	0.9	7	7	7	6.9
7	Total Nitrogen (mg/L)	4.5	4.9	4.8	4.9	4.1	4.9	4.9	4.9
8	Nitrate (mg/L)	0.2	0.6	0.3	0.8	0.1	0.9	0.2	0.9
9	Ammonia (mg/L)	0.9	0.8	0.4	0.9	0.8	0.7	0.8	0.9
10	Phosphate (mg/L)	0.2	0.5	0.8	0.1	0.4	0.4	0.4	0.8
11	Total Phosphorous (mg/L)	0.5	1.5	0.5	0.5	0.9	0.3	0.3	0.9
12	Fluoride (ppm)	0.8	0.8	0.3	0.9	0.2	0.9	0.9	0.4
13	Chloride (ppm)	237	237	300	180	325	390	398	330
14	Total dissolved solids (TDS)(ppm)	582	592	190	580	480	480	472	490
15	Electrical conductivity (Mics/cm)	631	692	420	620	480	490	490	490
16	Oxidation-Reduction Potential (mV)	765	760	561	770	570	570	560	561
17	Temperature (°C)	30	30	30	28	27	28	25	29
18	Sodium (mg/L)	26.1	29.1	19.3	25.6	33.5	32.6	39.5	33.1
19	Potassium (mg/L)	19.6	16.1	11.3	16.3	12.4	12.5	12.4	14.1
20	Alkalinity (mg/L)	170	192	240	185	230	330	270	231
21	Hardness Ca (mg/L)	54	61	40	60	70	77	80	56
22	Salinity (ppm)	92	92	85	110	90	80	92	91

Table 8 Descriptive Statistics of water quality parameters of well water in Pre monsoon and Post monsoon season during 2020

Descriptive Statistics										
	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance	Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error
Temp	8	5	25	30	28.38	.625	1.768	3.125	.522	1.481
pH	8	1.6	6.5	8.1	7.588	.1777	.5027	.253	3.102	1.481
Turbidity	8	2.0	7.0	9.0	7.888	.2961	.8374	.701	-1.465	1.481
Alkalinity	8	160	170	330	231.00	18.304	51.771	2680.286	.780	1.481
HardnessCa	8	40	40	80	62.25	4.632	13.101	171.643	-.228	1.481
HardnessMg	8	99.5	4.5	104.0	47.125	14.9214	42.2042	1781.196	-2.236	1.481
Salinity	8	30	80	110	91.50	3.047	8.619	74.286	3.576	1.481
Fluoride	8	.7	.2	.9	.713	.0934	.2642	.070	.896	1.481
Chloride	8	218	180	398	299.63	27.244	77.058	5937.982	-1.038	1.481
TDS	8	402	190	592	483.25	45.734	129.354	16732.500	4.551	1.481
DO	8	2.0	7.0	9.0	7.950	.2000	.5657	.320	2.036	1.481
BOD	8	2.0	7.0	9.0	7.888	.2961	.8374	.701	-1.465	1.481
EC	8	272	420	692	539.13	33.615	95.078	9039.839	-1.161	1.481
TotNitrogen	8	.8	4.1	4.9	4.738	.1034	.2925	.086	3.153	1.481
Nitrate	8	.8	.1	.9	.500	.1195	.3381	.114	-2.202	1.481
Sulphate	8	6.1	.9	7.0	5.163	.8287	2.3440	5.494	-.088	1.481
Ammonia	8	.5	.4	.9	.775	.0590	.1669	.028	4.175	1.481
Phosphate	8	.7	.1	.8	.450	.0886	.2507	.063	-.652	1.481
Totphosphorus	8	1.2	.3	1.5	.675	.1436	.4062	.165	1.532	1.481
Sodium	8	20.2	19.3	39.5	29.850	2.1899	6.1940	38.366	.208	1.481
Potassium	8	8.3	11.3	19.6	14.338	.9894	2.7984	7.831	.222	1.481
ORP	8	210	560	770	639.63	36.744	103.927	10800.839	-2.227	1.481
Valid N (listwise)	8									

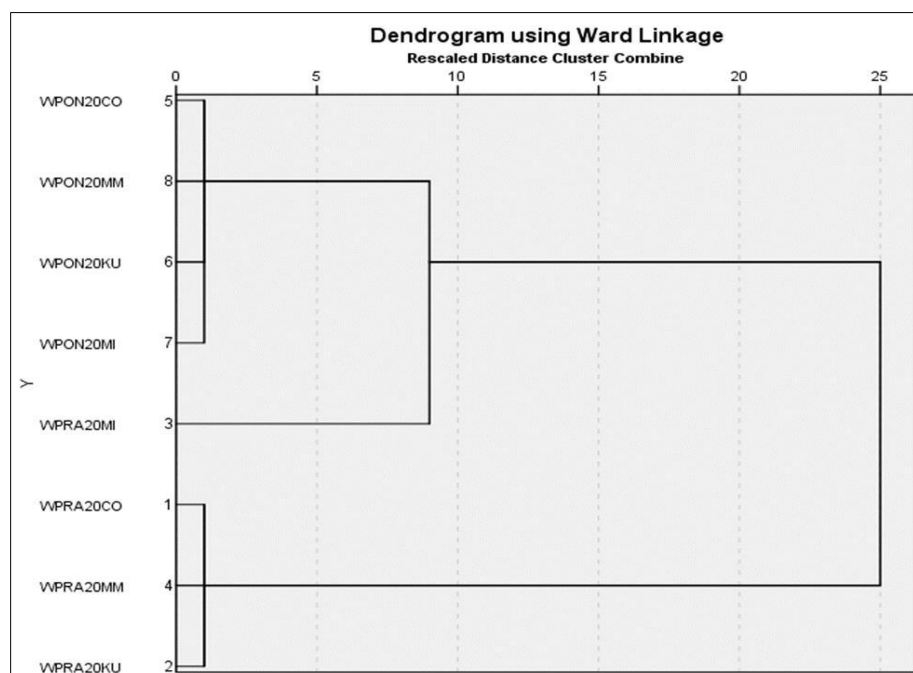
**Figure 6** Dendrogram of water quality parameters of well water in Pre monsoon and Post monsoon season during 2020

Table 10 Comparison of water quality parameters of bore hole water in Pre monsoon and Post monsoon season during 2020

S.No	Parameters	Sample code							
		Pre moon Season				Post moon Season			
		BPRA20CO	BPRA20KU	BPRA20MI	BPRA20ME	7BPON20CO	7BPON20KU	7BPON20MI	7BPON20ME
1	pH	7.2	7.3	7.4	7.9	7.2	7.5	7.9	7.2
2	Turbidity (NTU)	6	8.1	11	7.0	8.2	9.2	8.9	8.2
3	Dissolved oxygen (DO) (ppm)	7	6	6.5	8.1	8.0	8.0	9.0	9.0
4	Biological Oxygen Demand (BOD) (ppm)	6.2	9.1	6.3	6.3	6.6	6.9	6.9	6.6
5	Hardness Mg (mg/L)	6	6	40	7	60	40	48	41
6	Sulphate (mg/L)	7.2	7.8	4.8	7.4	6.5	6.5	6.9	0.6
7	Total Nitrogen (mg/L)	4	9	2.8	5	4.8	4.8	4.6	4.6
8	Nitrate (mg/L)	0.2	0.9	0.1	0.4	0.8	0.5	0.1	0.6
9	Ammonia (mg/L)	0.3	0.3	0.3	0.3	1.9	0.1	1.2	1.6
10	Phosphate (mg/L)	0.1	0.1	0.8	0.7	0.2	0.2	0.2	0.5
11	Total Phosphorous (mg/L)	0.6	6.1	0.9	0.9	0.5	0.7	0.7	0.6
12	Fluoride (ppm)	0.2	0.2	0.2	0.7	0.3	0.4	0.2	0.3
13	Chloride (ppm)	185	185	170	240	380	360	380	380
14	Total dissolved solids (TDS)(ppm)	691	691	380	580	390	390	380	390
15	Electrical conductivity (Mics/cm)	537	592	375	530	570	580	540	136
16	Oxidation-Reduction Potential (mV)	791	792	491	714	680	680	670	578
17	Temperature (°C)	29	29	29	29	29	29	27	30
18	Sodium (mg/L)	21.4	12.1	19.8	11.4	29.8	21.9	31.8	26.1
19	Potassium (mg/L)	18	19	12.8	19	11.6	11.8	11.9	13.1
20	Alkalinity (mg/L)	215	154	230	185	180	189	210	180
21	Hardness Ca (mg/L)	61	60	30	50	55	58	56	70
22	Salinity (ppm)	112	161	55	95	75	65	85	96

Table 11 Descriptive Statistics of water quality parameters of bore hole water in Pre monsoon and post monsoon season during 2020

Descriptive Statistics										
	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance	Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error
Temp	8	3	27	30	28.88	.295	.835	.696	4.970	1.481
pH	8	7	7.2	7.9	7.450	.1052	.2976	.089	-.781	1.481
Turbidity	8	5.0	6.0	11.0	8.325	.5260	1.4878	2.214	.992	1.481
Alkalinity	8	76	154	230	193.50	8.424	23.827	567.714	-.069	1.481
HardnessCa	8	40	30	70	55.00	4.110	11.625	135.143	3.433	1.481
HardnessMg	8	40	30	70	55.00	4.110	11.625	135.143	3.433	1.481
Salinity	8	106	55	161	95.50	11.055	31.268	977.714	2.765	1.481
Fluoride	8	5	.2	.7	.313	.0611	.1727	.030	4.062	1.481
Chloride	8	210	170	380	285.00	34.834	98.525	9707.143	-2.517	1.481
TDS	8	311	380	691	486.50	50.534	142.931	20429.143	-1.539	1.481
DO	8	3.0	6.0	9.0	7.700	.3905	1.1045	1.220	-1.118	1.481
BOD	8	2.9	6.2	9.1	6.863	.3332	.9425	.888	6.163	1.481
EC	8	456	136	592	482.50	54.984	155.519	24186.286	3.813	1.481
TotNitrogen	8	6.2	2.8	9.0	4.950	.6299	1.7817	3.174	5.010	1.481
Nitrate	8	.8	.1	.9	.450	.1086	.3071	.094	-1.412	1.481
Sulphate	8	7.2	.6	7.8	5.963	.8296	2.3464	5.506	4.689	1.481
Ammonia	8	1.8	.1	1.9	.750	.2493	.7051	.497	-1.218	1.481
Phosphate	8	.7	.1	.8	.350	.0982	.2777	.077	-1.106	1.481
Totphosphorus	8	5.6	.5	6.1	1.375	.6768	1.9144	3.665	7.869	1.481
Sodium	8	20.4	11.4	31.8	21.788	2.6353	7.4538	55.558	-1.014	1.481
Potassium	8	7.4	11.6	19.0	14.625	1.2001	3.3944	11.522	-2.092	1.481
ORP	8	301	491	792	674.50	35.858	101.421	10286.286	.277	1.481
Valid N (listwise)	8									

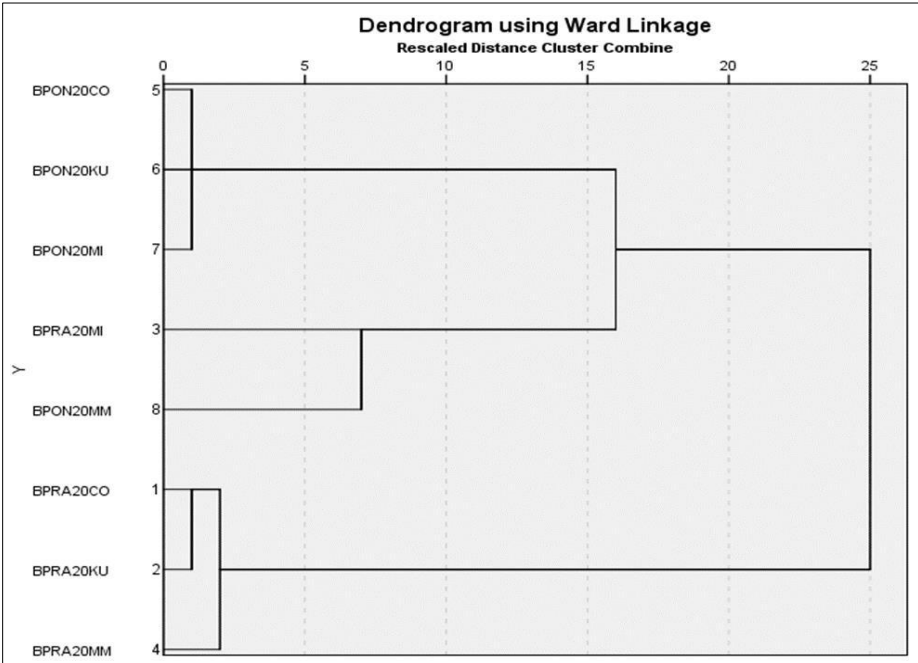


Figure 8 Dendrogram water quality parameters of bore hole water in Pre monsoon and Post monsoon season during 2020

Table 12 Pearson Correlation Coefficient (r) of water quality parameters of bore hole water in Pre monsoon and Post monsoon season during 2020

		Correlation ^a																										
		PH	Ca	Mg	Na+K	Cl	SO ₄	NO ₃	NO ₂	Fe	CO ₃	HCO ₃	CaCO ₃	Hardness	TH	EC	TD	DO	ORP	pH	Ca	Mg	Na+K	Cl	SO ₄	NO ₃	NO ₂	Fe
COLACHEL	Pre monsoon	1	-0.051	-0.047	-0.024	-0.024	-0.005	-0.011	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	Post monsoon	-0.051	1	-0.047	-0.024	-0.024	-0.005	-0.011	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
KURUMBANAI	Pre monsoon	-0.047	-0.051	1	-0.024	-0.024	-0.005	-0.011	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	Post monsoon	-0.047	-0.051	-0.024	1	-0.024	-0.005	-0.011	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
MIDALAM	Pre monsoon	-0.024	-0.024	-0.024	-0.024	1	-0.005	-0.011	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	Post monsoon	-0.024	-0.024	-0.024	-0.024	-0.005	1	-0.011	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
MELMIDALAM	Pre monsoon	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	1	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	Post monsoon	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.001	1	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
KURUMBANAI	Pre monsoon	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.001	-0.001	-0.005	1	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	Post monsoon	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.001	-0.001	-0.005	-0.001	1	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
MIDALAM	Pre monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	1	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	Post monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	1	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
MELMIDALAM	Pre monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	1	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	Post monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	1	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
KURUMBANAI	Pre monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	1	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	Post monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	1	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
MIDALAM	Pre monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	1	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	Post monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	1	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
MELMIDALAM	Pre monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	1	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	Post monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	1	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
KURUMBANAI	Pre monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	1	-0.001	-0.001	-0.001	-0.001	-0.001
	Post monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	1	-0.001	-0.001	-0.001	-0.001
MIDALAM	Pre monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	1	-0.001	-0.001	-0.001
	Post monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	1	-0.001	-0.001
MELMIDALAM	Pre monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	1	-0.001
	Post monsoon	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	1

4. Conclusion

The physico-chemical analysis of well and bore hole water samples in and around the villages from Colachel to Melmidalam of Kanyakumari District was done. Water samples from well and bore hole in four sites namely Colachel, Kurumbanai, Midalam, Melmidalam were collected in pre monsoon and post monsoon seasons during 2019 and 2020 were carried out. The statistical assessment is also carried out for the Physico-chemical parameters. Most of the parameters are well within the permissible limits. It is concluded that from the results of the present study, it may be said that the water from well and bore hole in and around the villages from Colachel to Melmidalam of Kanyakumari District collected in pre monsoon and post monsoon seasons during 2019 ad 2020 fits for domestic purpose. Statistical analysis results showed that the CA technique is useful in classification of water samples in the study region and the number of parameters. The application of cluster analysis proved that one major group of similarity between twenty two physicochemical parameters are formed in the water samples of well and bore hole in and around the villages namely Colachel, Kurumbanai, Midalam, Melmidalam.

Compliance with ethical standards

Acknowledgments

The authors thank the concerned authorities of Manonmaniam Sundaranar University, Tirunelveli.

Disclosure of conflict of interest

No conflict of interest.

Author's contribution

The first author is a research scholar. The second author is supervisor. The third author is joint supervisor. The fourth author is also encouraging and promoting the research carrier to the students.

References

- [1] WHO, (2004). Guidelines for Drinking Water quality (Addendum). Geneva.
- [2] Cunningham, S. (1999). Environmental Science; A Global concern, 5th edition, the McGraw-Hill Companies, USA, pp 439 - 440, 451.
- [3] Buchholz, A.,R. (1993). Principles of Environmental Management. 2nd edition. The greening of Business. Pp 179 - 187
- [4] Cairncross, S. and Cliff, J.L. (1987). Water use and health in Mireda, Mozambique. Trans. Royal [https://doi.org/10.1016/0035-9203\(87\)90280-X](https://doi.org/10.1016/0035-9203(87)90280-X) Soc. Trop. Med. Hyg. 81: 51 - 54
- [5] Zoetman, B.C.T. (1980). Sensory assessment of water quality. Pergamon Press, Oxford.
- [6] Crain, G.F. (1984). Health aspect of ground water pollution. In Ground water Pollution Microbiology ed. Bilton, G. and Gerba, C.P. Florida: Kneger Publishing Company pp: 135 - 179.
- [7] Pye VI and Patrick R (1983). Ground water contamination in the United States, Science 221: 713- 718 <https://doi.org/10.1126/science.6879171> PMID:6879171
- [8] American Public Health Association (APHA) 1998. Standard methods for the Examinations of water and waste water, 17th Edn; Washington, DC
- [9] WHO, 1984. Guideline for drinking water quality Geneva.
- [10] ISI, 1964. Indian standard specification for drinking water ISI 10500
- [11] M.K. Gupta, Anjani Gupta, G.S. Gupta, Rajesh Kr.Dubey, International Journal of Innovative Research in Science, Engineering and Technology. 3, 3, 2014, PP 10220-10229.
- [12] A papaioannu, K. KAkavas, P. Plageras, A. Minas, Z. Roupa, A.G. Paliatsos, P.T. Nastos and A. Minas, Multivariate Statistical Interpretation of Physical, Chemical and Microbiological Data of Potable water in the context of public Health. 14, 2007, PP 347-352.
- [13] M. Jamuna, Statistical Analysis of Ground water quality parameters in Erode District, Tamilnadu International Journal of Recent Technology and Engineering 2277-3878, 7, (4), 2018.
- [14] Ece Kilic,Nebil Yucel. Determination of Spatial and Temporal changes in water quality at AsiRiver using Multivariate Statistical Techniques. Trk. J. ish & Aquat.Sci.19), 727-737,2018.
- [15] Aydin Uncumusaoglu, Statistical assessment of water quality parameters for pollution source identification in Bektas Pond. Globel Nest.20 (1), 151-160, 2018.<https://doi.org/10.30955/gnj.002369>.