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Quality Assessment of Groundwater in the Vicinity of Coir Retting Areas of Kadinamkulam Estuary, South India

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Authors' contributions

This work was carried out in collaboration between both authors. Author SS contributed the sample collection, sample analysis and drafted the manuscript. Author DSJ guided all the analysis part and also helped with the drafting the manuscript and approved final manuscript.

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ABSTRACT

The present study was conducted in the selected groundwater bodies of the coastal gramapanchayath near Kadinamkulam estuary during the pre-monsoon, monsoon, and post-monsoon seasons. Kadinamkulam estuary is one of the major coir-retting areas in Kerala. The major objective of the study is to assess the physico- chemical characteristics and hydrogen sulfide pollution of groundwater in the residential areas of Azhoor Gramapanchayath in Thiruvananthapuram district. Surface water samples from selected stations were also collected from the Kadinamkulam estuary. The physico-chemical characteristics of water were analyzed following the standard procedures in APHA (2012). The results show that the recorded values for color, pH, phosphate, calcium, magnesium and hydrogen sulfide were above the permissible limits of drinking water quality standards (Bureau of Indian Standards, 1991; WHO, 1993, 1996). This may be due leaching of effluents from the coir retting activity in the Kadinamkulam estuary and due to the disposal of solid wastes. The study also revealed that the hydrogen sulfide content was high in lake water samples which affect the primary productivity of the water body. The correlation and principal component analysis shows that color is an important parameter and from cluster, analysis it was

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found that phosphate and hydrogen sulfide content significantly affect the groundwater quality. The study concludes that the groundwater sources in the study area are getting contaminated due to the leaching of pollutants from Kadinamkulam estuary and anthropogenic activities in the nearby residential areas.

Keywords: Coir retting; colour; hydrogen sulphide; Kadinamkulam lake; physical characteristics.

1. INTRODUCTION

Groundwater is precious because it provides fresh water for domestic, agricultural, industrial and environmental purposes. Groundwater is used for agricultural, industrial and domestic purposes. It accounts for about 50% of livestock and irrigation usage and just under 40% of water supplies, while in rural areas, 98% of domestic water use is from groundwater [1]. Water is an essential requisite for all living organisms. Studies show that no water body is free from pollution [2]. Any changes in the water body it may be physical, chemical or biological properties that hurts living things is termed as water pollution [3]. Among the common pollutants that degrade water quality, industrial effluents play a leading role. The chemical composition of groundwater is controlled by several factors that include the composition of precipitation, anthropogenic activities, geological structure and mineralogy of the watersheds, aquifers, and geological processes within the aquifer [4].

The retting of coconut husk has resulted in the formation of a curious and complex ecosystem of anaerobic and microaerobic properties in the extensive lake systems. Retting is brought about by the pectinolytic activity of micro-organisms, especially bacteria and fungi, liberating large quantities of organic substances like pectin, pentose, fat and tannin into the water. Polyphenols get constantly leached out. The oxidation of phenol produces diffusible melanin like pigment, which is also released into the medium during coir fermentation. Hydrogen sulfide is formed by sulfur and sulfate reducing bacteria that can occur naturally in water. These anaerobic bacteria use sulfate and sulfur compounds found in decaying plant material rock or soil to convert organic compounds into energy. Under these anaerobic condition hydrogen sulfideis formed as abyproduct. Hydrogensulfide occurs in deep and shallow wells and also can enter surface water through springs. Markedly offensive odour resembling those of hydrogen sulphide is produced from retting zones during the decomposition of pectin [5]. Studies reported that a high (>1 mg/L) concentration of H_2S is produced associated with retting process of coconut husk [6]. Due to the coir retting activity large quantities of organic substance is liberated into the surrounding medium especially hydrogen sulfide [7,8]. Shallow poorly constructed wells or those located close to sewer lines or septic system and surface water can become contaminated with sewage and develop problems with hydrogen sulfide [9]. Review of literature show that no detailed study was conducted to assess the groundwater quality in the coastal tract of Kadinamkulam estuary where coir retting activity is carried out. The people living in the coastal gramapanchayath (Azhoor) of Kadinamkulam estuary depends on groundwater sources for their drinking and domestic activities. The major objective of the present study was to assess the groundwater quality in the Azhoor Gramapanchayath near Kadinamkulam estuary in Kerala, South India.

2. MATERIALS AND METHODS

2.1 Study Area

Azhoor (8.648 N°76.8277 E°) is a coastal village in Thiruvananthapuram district in the state of Kerala, India. It is one of the “A” grade Panchayth in Thiruvananthapuram District, Kerala. As of 2011 Indian census, the village with an area of 12.52 sqk.m has a total population of 28831 with 13176 males and 15655 females. The population consists of middle class farmers, agricultural labourers, small coir industrialists, expatriates, coir workers and government employees. Perunguzhi railway station is in the Thiruvananthapuram-Kollam rail/route, and Thiruvananthapuram airport is the nearest Air Port. This gramapanchayath falls under the category of ‘Coastal Sandy Zone’ as the centers are classified into 13 agro-climatic zones of Kerala on the basis of average above sea level, rainfall, and topography. The panchayath experiences a tropical humid climate with extreme heat and subsequent monsoons. The two major monsoon seasons in the panchayath are the south-west monsoon (June and August) and the north-east monsoon (September and November). The average rainfall of this

panchayath is 1943 mm but most of the areas experience severe shortage of drinking water. The location map of the study area is given in Fig. 1. The Azhoor Gramapanchayath is situated in the coastal tract of Kadinamkulam Lake in the Thiruvananthapuram district, one of the major retting zones in the coastal belt of Kerala. For the study, a detailed field survey was conducted in Azhoor gramapanchayath and 18 open dug wells were selected for the study.

For the analysis, eighteen groundwater samples were collected from Azhoor Gramapanchayath. The sample collection were done during the premonsoon, monsoon and post monsoon seasons of the year 2016-2017. Estuary water samples in the coir retting areas were also collected from six selected stations 2 km apart upto 8 kms. Water samples were collected in clean polythene bottles and transported to the laboratory with proper care and analysed the pH, turbidity, colour, odour, total dissolved solids, phosphates, calcium, magnesium and hydrogen sulfide. The sampling, preservation, transport and analysis were performed according to the standard procedures [10]. Odour of water samples were noted by sniffing. pH and TDS of water were measured in the study stations itself using Digital Portable Water Analyser (Systronics, India). Calcium and magnesium content were determined by EDTA titration method. Phosphate content was determined by UV spectrophotometry and turbidity by nephelometric method. The concentration of hydrogen sulfide was determined by iodometry.

2.2 Statistical Analysis

SPSS statistical package software (version 20.0) was used for the statistical analysis [Principal component analysis (PCA) and Pearson's correlation analysis] of water quality parameters. Primer 6 was used for the cluster analysis (CA). Multivariate analysis was carried out in the groundwater parameters to understand the influence of parameters on the groundwater quality in the study area. The importance of cluster analysis is to categorize objects (cases) into classes (clusters), where objects places within a class are similar to each other, but differ

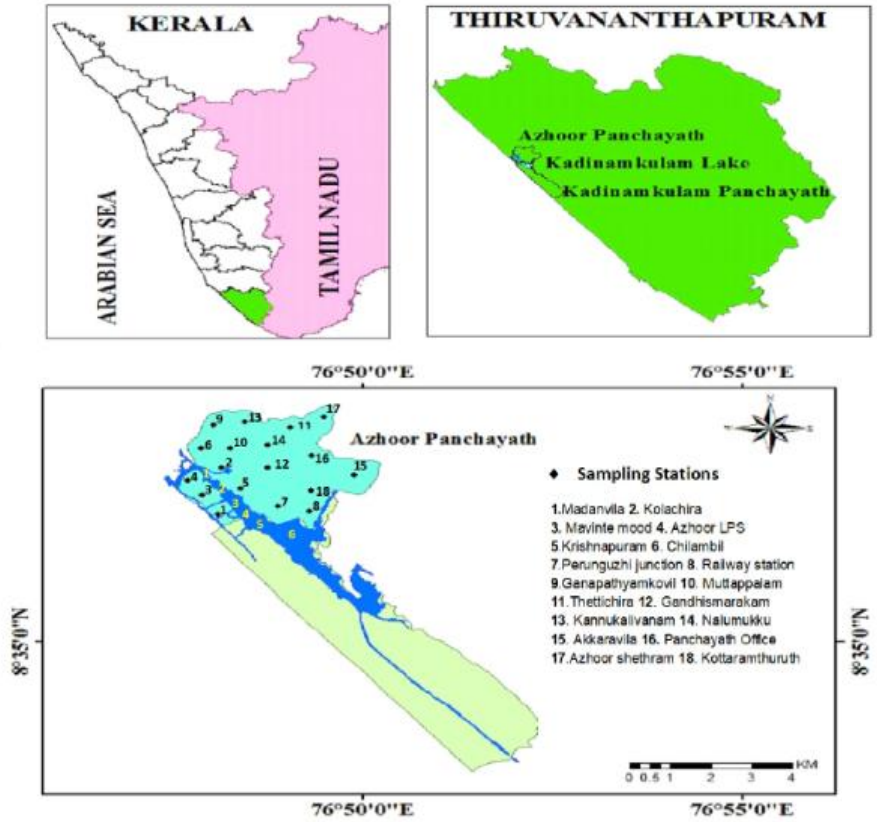

Fig. 1. Location map of the study area

from those others. Cluster analysis allows the grouping of water samples on the basis of their similarities. PCA technique is used for the periodic trends in sampling data and identify the temporal variation in water quality. The correlation analysis can be applied to understand the geological process in the groundwater samples.

3. RESULTS AND DISCUSSION

The results of the physico-chemical characteristics of groundwater and surface water samples are shown in Tables 1 and 2. The colour of drinking-water is usually due to the presence of organic matter (primarily humic and fulvic acids) associated with the humus fraction of soil or the presence of iron and other metals, either as natural impurities or as corrosion products [11]. The average value of colour in groundwater samples recorded was 1.91 HU, 1 HU and 1.3HU during the pre monsoon, monsoon and post monsoon seasons respectively. During pre monsoon season instation 1 (Madanvila) and station 18 (Kottaramthuruthu) the colour value was above the permissible limit of WHO drinking water standard [12]. These wells (S1 and S8)are situated in the coastal tract of Kadinamkulam estuary, so the leaching of coir retting effluent containing water from the Kadinamkulam estuary may impart colour to the well water samples. The colour of the surface water samples analysed show 5 HU to 25 HU, 3 HU to 10 and 5 HU to 10 HU during the pre monsoon, monsoon and post monsoon seasons.

In this study, the odour of the sample detected by sniffing and the well water samples collected from the study area showed unobjectionable odour during the pre-monsoon, monsoon and post monsoon seasons. The lake water samples collected during the pre monsoon, monsoon and post monsoon showed smell of rotten egg except the water from the control station. It may be due to the release of hydrogen sulfide due to the coconut husk retting in the estuary. The presence of inorganic or organic contaminants in estuary water may also cause the odour. Related to taste, a strong odour from water for consumption will obviously cause revulsion or rejection on the part of the consumer [11].

Table 1. Physico-chemical characteristics of well water

Parameter	Pre monsoon		Monsoon		Post monsoon	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Colour (HU)	0.5	6	0.5	5.5	0.5	3
Odour	UO	UO	UO	UO	UO	UO
Temperature (°C)	28	30	27	29	27	29
pH	4.55	6.98	5.88	7.16	4.94	7.3
TDS(mg/L)	30.43	222.2	24.9	346	20.7	398
Turbidity(NTU)	2	15	0.8	2.9	1.2	11.1
Calcium (mg/L as $CaCO_3$)	12.61	69.79	11.08	103.02	13.02	38.21
Magnesium(mg/L as $CaCO_3$)	11.65	35.12	10.08	32.12	10.16	30.12
Phosphate(mg/L)	0	0.08	0.10	0.26	0	0.3
Hydrogen sulfide(mg/L)	0	0.03	0	0.11	0	0.03

UO= Unobjectionable

Table 2. Physico-chemical characteristics of Surface water

Parameter	Pre monsoon		Monsoon		Post monsoon	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Colour (HU)	5	25	3	10	5	10
Odour	UO	Rotten egg	UO	Rotten egg	UO	Rotten egg
Temperature (°C)	28.5	30	28	29	28	30
pH	7.02	7.48	6.90	7.80	7.15	7.81
TDS(mg/L)	20100	27700	19818	26117	2027	25134
Turbidity (NTU)	6.2	30.5	8	26.4	7.5	22.6
Calcium (mg/L as $CaCO_3$)	19.19	28.28	20.69	30.13	20.12	28.13
Magnesium (mg/L as $CaCO_3$)	15.28	19.12	14.32	19.26	14.62	16.75
Phosphate (mg/L)	0.2	0.41	0.21	0.32	0.2	0.32
Hydrogen sulfide(mg/L)	5.58	12.58	6.58	11.98	5.98	12.98

UO= Unobjectionable

In this study, seasonal average of well water temperature in pre monsoon season is 28.88°C and the values ranged from 28°C to 30°C. During the monsoon season, seasonal average is 26.55°C and the values ranged from 27°C to 29°C.In post-monsoon season, seasonal average is 27.66°C and values ranged from 27°C to 29°C. The variation in the water temperature may be due to different timings of sample collection and influence of season [13]. The lake water samples, temperature varied from 28.5°C to 30°C, 28°C to 29°C and 28°C to 30°C during the pre monsoon, monsoon and post monsoon season. This variation may be due to the release of organic substance during the retting process. Previous studies [5] also show the release of pectin by decomposition of organic matter that causes a high heat budget in the retting zones.

The pH in water samples serves as an index to denote the extent of pollution by acidic or basic waste. pH is a term used universally to express the intensity of the acid or alkaline condition of a solution [12]. The study shows that seasonal average of pH during the pre monsoon shows 5.59 and values ranged from 4.63 to 6.89. During monsoon, the seasonal average was 6.49 and values ranged from 5.88 to 7.16. In post monsoon average pH was 5.86 and values ranged from 5.15 to 7.16. The study reveals that the majority of the well water samples from the Azhoor gramapanchayath show acidic nature. During the pre monsoon season 97.44% wells, during the monsoon season 50% and post monsoon season 88.88% wells are outside the recommended pH range, being acidic in nature. In general, low pH in natural water may be due to the presence of CO_2, SO_2 and H_2S. Similar study conducted in Tamil Nadu in coconut husk retting area [14] shows that pH range in groundwater samples in all seasons is below the permissible limit of WHO. In lake water samples, the pH value ranged from 7.02 to 7.48 and in monsoon the pH varied from 6.90 to 7.80, and in post monsoon the pH values varied from 7.15 to 7.81. Studies [7] also show that retting zones shows a wide fluctuation in pH values (4.2 to 8.9).

TDS is an indicator of the saline behavior of groundwater [11]. TDS of groundwater is mainly due to vegetable decay, evaporation, disposal of effluent and chemical weathering of rocks. TDS value should be below than 500 mg/L for drinking water according to WHO [12]. The present study reveals that in the groundwater samples from Azhoor gramapanchayath seasonal average of TDS values were 132.47 ppm, 155.55 ppm, 142.51 ppm during the pre monsoon, monsoon and post monsoon seasons. In the surface water samples during the pre monsoon season the TDS value ranged from 20100 ppm to 27700, in monsoon 19818 ppm to 26117 ppm, and in post monsoon season value varied from 20127 ppm to 25134 ppm. In freshwater ecosystem, dissolved solids originate from natural sources and depend upon the location, geological structure of the water body drainage, rain fall, bottom deposits and inflowing water [15].

Turbidity is the measurement of the cloudiness of water. Water cloudiness is caused by material suspended in water [16]. The study reveals the seasonal average of turbidity in the wells of Azhoor gramapanchayath shows 4.16 NTU, 1.65 NTU and 3.13 NTU during the pre monsoon, monsoon and post monsoon seasons. The study reveals that turbidity values of all the well water samples collected from the study area are within the permissible limit of WHO. In estuary water samples, turbidity value varied from 6.2NTU to 30.5NTU, 8NTU to 26.4 NTU and 7.5NTU to 22.6 NTU during pre monsoon, monsoon and post monsoon seasons respectively.

In this study during the monsoon season, 6 wells (Station1,4,6,713 and 18) show hydrogen sulfide content above the permissible limit of WHO drinking water standard [17]. Shallow poorly constructed wells or those located close to sewer lines or septic system and surface water can become contaminated with sewage and develop problems with hydrogen sulfide [9]. The concentration of hydrogen sulfide in surface water samples varied from 5.58 mg/L to 12.58 mg/L, 6.58 mg/L to 11.98 mg/L and 5.98 mg/L to 12.98 mg/L during the premonsoon, monsoon and post monsoon seasons. Studies reported that high H_2S (>1 mg/L) concentration is an important feature associated with sewage created from the retting process of coconut husk [6]. The concentration of hydrogen sulfide observed exceeded the permissible limit of EPA surface water quality standard [18]. The study reveals the dangerous situation existing in the estuary and this may cause destruction of organisms in the water body.

In the present study the calcium content in groundwater samples ranged from 12.61 mg/L to 69.79 mg/L as $CaCO_3$, 11.08 mg/L to 103.02 mg/L as $CaCO_3$, 13.02 mg/L to 38.21 mg/L as $CaCO_3$ during the pre monsoon, monsoon and post monsoon seasons respectively. The value of calcium content in well water samples are within the desirable limit of BIS drinking water standards during the pre monsoon and post

monsoon seasons. In this study during the monsoon season 4 wells (station 2, 4, 8 and 16) show calcium content above the BIS drinking water standard. Calcium is the second major constituent, after bicarbonate, present in most natural waters, within the concentration range between 10 and 100 mg/as $CaCO_3$.It is a primary constituent of water hardness, and the calcium level between 40 and 100mg/L as $CaCO_3$ are generally considered as hard to very hard [19]. According to WHO standards [12] the desirable amount of calcium in drinking water is 75 mg/Las $CaCO_3$. Excess calcium in our body can cause gallstones, kidney stones, bone and joint calcification, arthritis, and hardening and blocking our arteries [12]. In lake water samples calcium values varied from 19.19 mg/L to 28.28 mg/L as $CaCO_3$ with an average of 23 mg/L, 20.69 mg/L to 30.13 mg/L as $CaCO_3$ with an average of 24.32 mg/L, 20.12 mg/L to 28.13 mg/L as $CaCO_3$ with an average of 24.10 mg/L as $CaCO_3$ during the pre monsoon, monsoon and post monsoon seasons respectively. Magnesium salts are more soluble than calcium, but they are less abundant in geological formations. In this study, the magnesium content in the water samples collected from different sampling stations ranged from 11.65 mg/L to 35.12 mg/L as $CaCO_3$ with an average of 23.62 as $CaCO_3$, 10.08 mg/L to 32.12 mg/L as $CaCO_3$ with an average of 20.45 mg/L, 10.16 mg/L to 30.12 mg/Las $CaCO_3$ with an average of 20.59 mg/L as $CaCO_3$ during the pre monsoon, monsoon and post monsoon seasons. The desirable limit of magnesium in drinking water is 30 mg/Las $CaCO_3$ [18]. It was found that the magnesium level in groundwater samples in the study area were above the desire limits of drinking water quality during the pre monsoon (6 wells), monsoon (3 wells) and post monsoon (1 well) seasons. Magnesium values recorded in surface water samples are 15.28 mg/L to 19.21 mg/Las $CaCO_3$, 14.32 mg/L to 19.26 mg/Las $CaCO_3$, 14.62 mg/L to 16.75 mg/Las $CaCO_3$ during the premonsoon, monsoon and post monsoon seasons respectively. The study reveals that during the monsoon season 4 wells in stations 3,8,14 and 18, and in post monsoon season 1 well (station 5) showed the phosphate value above the limit (0.3 mg/L) of drinking water standard [20]. It may be due to the leaching of effluents containing phosphates from the coir retting stations and domestic wastewater into the groundwater. Higher concentration of phosphate is indicative of pollution and the major source of anthropogenic phosphorus is sewage, detergents, agricultural effluents and fertilizers [21]. In lake water samples, average value of phosphate shows 0.29 mg/L,0.25 mg/L, 0.25 mg/L during the pre monsoon, monsoon and post monsoon seasons respectively. The study shows that majority of the groundwater samples in the coastal tract of Kadinamkulam estuary are contaminated. It may be due to the leaching of polluted water into the groundwater sources. The sandy aquifer in the study area may facilitate the mobility of contaminants to the groundwater. Previous study [22] also shows that the sandy aquifers increase the possibility of interaction between groundwater and polluted surface water.

The Pearson correlation analysis was used to determine the relationship between the physico-chemical characteristics of groundwater samples during the pre monsoon, monsoon and post monsoon seasons. The Pearson correlation matrix for the groundwater samples was shown in Table 3A, 3B and 3C. During the pre monsoon season, the colour value showed strong positive correlation with turbidity and pH (0.755^{**} and 0.612^{**}). The calcium and magnesium values are also strongly positively correlated (0.845^{**}). The temperature and TDS show positive correlation (0.539^{*}). During the monsoon season the colour value showed significant positive correlation with pH (0.655^{**}) and strongly correlated with TDS (0.487^{*}). During the post monsoon season TDS and calcium (0.590^{**}), pH and H_2S (0.616^{**}) show strong significant positive correlation and also pH and colour (0.566^{*}) show strong positive correlation. The magnesium and phosphate show strong negative correlation (-534^{*}). On the basis of above values it may be concluded that colour of the well water is an important drinking water parameter as it is significantly correlated with pH and turbidity.

Principal Component Analysis (PCA) was carried in order to find out the environmental parameters, which accounted for the variation in the study area. The extracted factor values were used to group the primary associated factor loadings. The PCA values during the study period were shown in the Table 4 and Fig. 2.During the pre monsoon season, the first principal component (PC1) explained 28.75% of variance and negatively loaded by TDS and phosphate. The remaining parameters were positively loaded. The highest score on the first PC1 was colour, followed by pH and turbidity which explains the importance of groundwater quality. PC2 explained 22.86% of the variability and was positively contributed by TDS, temperature, turbidity calcium, magnesium and phosphate and the remaining variables were negatively loaded. The highest score on the PC2

was calcium (.865) followed by magnesium and phosphate. PC3 explained 19.78% of the variability and TDS, temperature, colour, turbidity and magnesium were positively loaded and the remaining parameters were negatively loaded (Table 4, Fig. 2A). During the monsoon season the first principal component (PC1) explained 26.26% of variance and negatively loaded by turbidity, only remaining all parameters are positively loaded. The highest score on the first PC1 was colour (.922) followed by pH (.741) and TDS (.664) which explains the importance of groundwater quality. In PC2 explained 22.08% of variance and 3 parameters were negatively loaded. The highest score was for Mg (.0788) followed by calcium (.727) and pH (.458). In PC 3explained, 15.63% of variance only 3 parameters were negatively loaded, remaining all parameters are positively loaded (Table 4, Fig. 2B). In the post monsoon season PC1 shows 26.45% of variance and TDS, turbidity and phosphate were negatively loaded and hydrogen sulfide were high positively loaded (.868). In PC 2 high positive loaded TDS (.868) followed by colour (.839). In PC 3 shows 18.90% of variance and TDS, temperature, phosphate and hydrogen sulfide were negatively loaded with high positively loaded magnesium (Table 4, Fig. 2C).

Table 3A. Pearson correlation matrix of the physico-chemical parameters in well water (pre monsoon)

	pH	TDS	Temp.	Colour	Turbidity	Calcium	Magnesium	Phosphate	H_2S
pH	1	-.202	.066	**.612****	.357	.350	.379	-.331	.132
TDS		1	**.539***	.344	.095	.064	.108	-.046	-.131
Temp.			1	.384	.165	.130	.315	-.261	-.135
Colour				1	**.755****	.193	.390	-.182	.170
Turbidity					1	.236	.298	.021	.040
Calcium						1	**.845****	.299	-.397
Magnesium							1	.082	-.292
Phosphate								1	-.178
H_2S									1

***. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed)*

Table 3B. Pearson correlation matrix of physico-chemical parameters in well water (Monsoon)

	pH	TDS	Temp.	Colour	Turbidity	Calcium	Magnesium	Phosphate	H_2S
pH	1	.422	-.075	**.655****	-.160	.347	.358	.445	-.188
TDS		1	-.164	**.487***	-.025	.005	-.010	.037	.190
Temp:			1	.106	.232	.235	.341	-.149	.165
Colour				1	-.036	.115	.337	.393	.358
Turbidity					1	-.307	.059	-.129	-.163
Calcium						1	.425	-.017	-.256
Magnesium							1	.197	-.420
Phosphate								1	.059
H_2S									1

***. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed)*

Table 3C. Pearson correlation matrix of the physico-chemical parameters in well water (Post monsoon)

	pH	TDS	Temp	Colour	Turbidity	Calcium	Magnesium	Phos	H_2S
pH	1	.145	-.070	**.566***	-.305	.278	.465	-.323	**.616****
TDS		1	.083	-.084	-.024	**.590****	.152	-.052	-.020
Temp.			1	.098	-.162	.065	-.030	.147	.164
Colour				1	-.094	.094	.272	-.125	**.598****
Turbidity					1	.020	-.266	.022	-.291
Calcium						1	.466	-.268	.188
Magnesium							1	**-.534***	.023
Phosphate								1	-.097
H_2S									1

**. Correlation is significant at the 0.05 level (2-tailed); **. Correlation is significant at the 0.01 level (2-tailed)*

Table 4. Extracted factor loading values, Eigen value, % variance and cumulative percentage value of the well water

Parameter	Premonsoon			Monsoon			Post monsoon		
	1	2	3	1	2	3	1	2	3
pH	.854	-.004	-.197	.741	.458	-.213	.761	.153	.406
TDS	-.039	.045	.883	.664	-.174	-.094	-.069	.868	-.044
Temperature	.210	.049	.834	.015	.199	.872	.288	.310	-.598
Colour	.859	-.073	.357	.922	.049	.177	.788	-.093	.152
Turbidity	.723	.063	.130	-.159	-.097	.582	-.492	-.080	.068
Calcium	.379	.865	-.002	.115	.727	.003	.120	.839	.256
Magnesium	.520	.721	.155	.233	.788	.311	.265	.382	.682
Phospate	-.292	.560	-.226	.529	.141	-.269	-.110	-.147	-.784
H_2S	.231	-.680	-.217	.388	-.726	.232	.868	.011	-.066
Total	**2.588**	**2.057**	**1.780**	**2.363**	**1.987**	**1.407**	**2.381**	**1.760**	**1.702**
% of Variance	**28.752**	**22.861**	**19.780**	**26.260**	**22.083**	**15.634**	**26.456**	**19.558**	**18.906**
Cumulative %	**28.752**	**51.613**	**71.392**	**26.260**	**48.343**	**63.977**	**26.456**	**46.013**	**64.919**

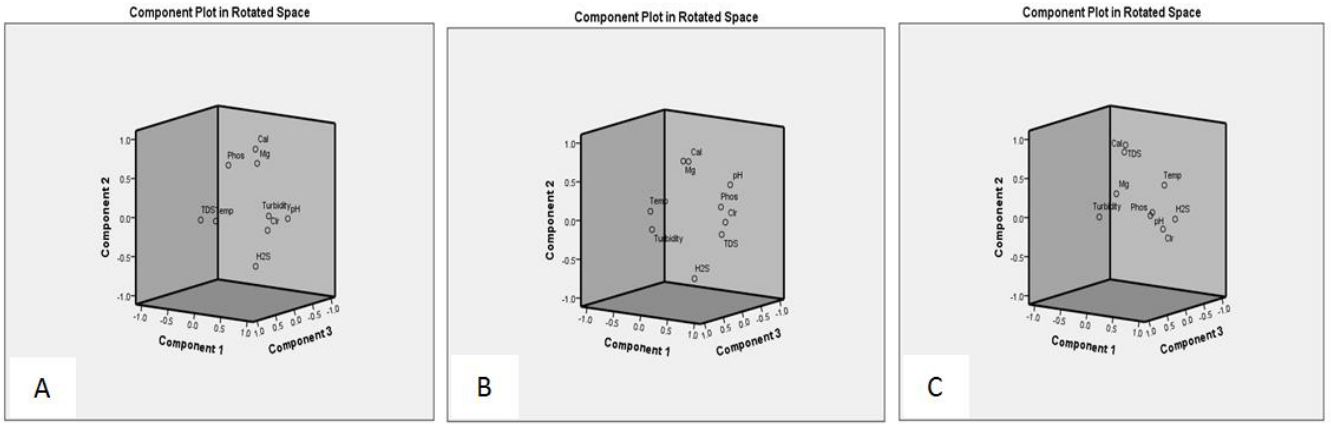

Fig. 2. Principal component plot of elements and other related parameters in well water samples pre monsoon, monsoon and post monsoon seasons

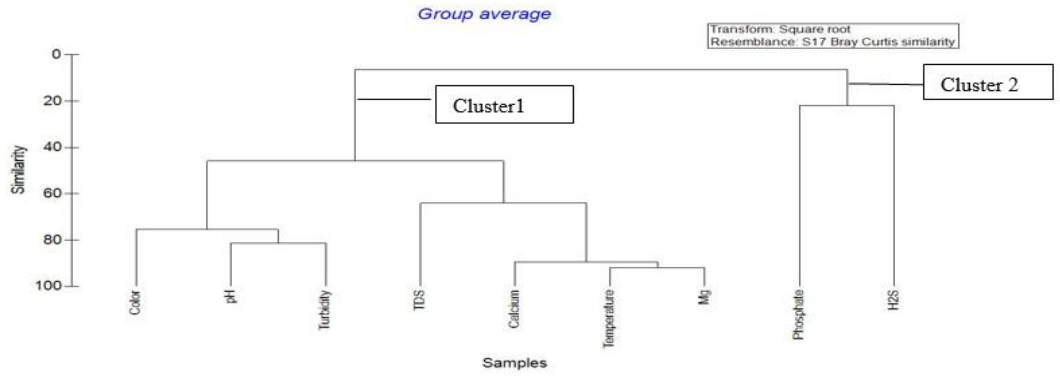

Fig. 3A. Dendrogram showing physico chemical characteristics of well water in pre monsoon season

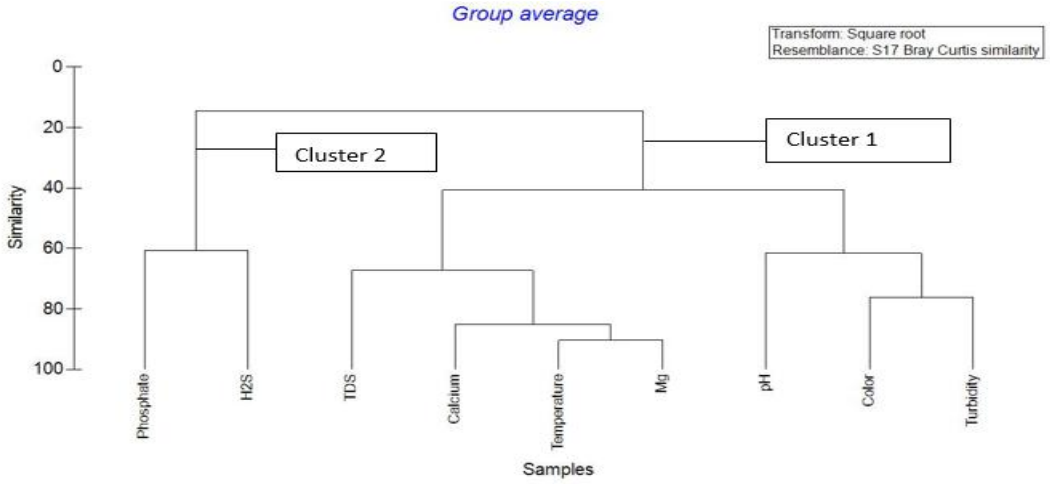

Fig. 3B. Dendrogram showing physico chemical characteristics of well water in monsoon season

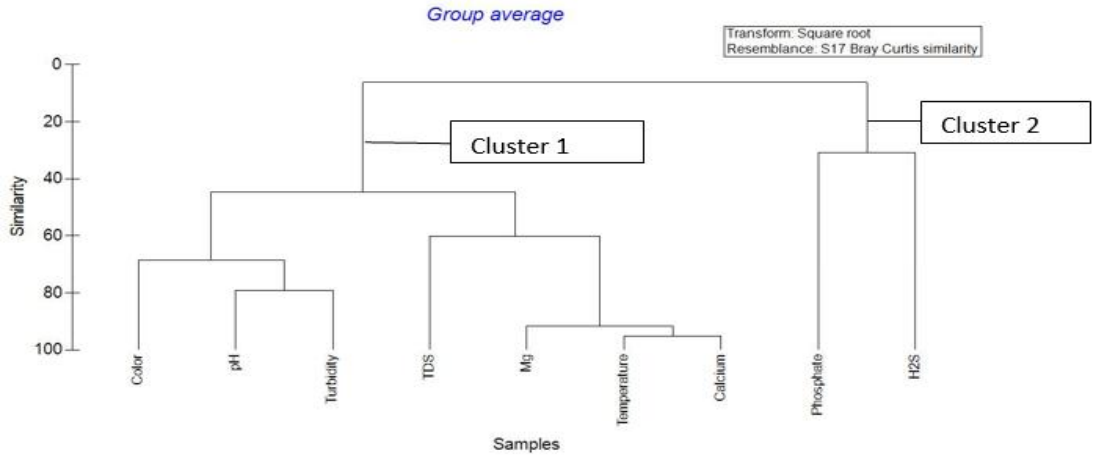

Fig. 3C. Dendrogram showing physico chemical characteristics of well water in monsoon season

Cluster analysis (CA) is to find subgroups within a large group and form a tree like structure form called dendrogram. Hierarchical agglomerative clustering is commonly used, which supplies with instinctive similarity relationships between any one sample and the entire data set [23]. The CA was performed for the 18 samples and 9 variables in pre monsoon, monsoon and post monsoon seasons (Fig. 3A, 3B and 3C).The cluster analysis employed in groundwater quality variables formed a two distinctive group of clusters formed during the pre monsoon, monsoon and post monsoon seasons (Cluster 1 and 2). The study also reveals that in all the seasons phosphate and hydrogen sulfide form a cluster (Cluster2) and remaining all parameters formed another cluster (Cluster 1). The existence of two clusters indicated that the groundwater quality under investigation is characterized by two different water quality parameters. Cluster 1 has highest number of parameters and cluster 2 only two parameters. This distinctive group (Cluster 2) invariably indicates that two factors are responsible for the groundwater quality in the study area. The phosphates and H_2S emanating from anthropogenic sources especially coir retting activity may be responsible for the deterioration of groundwater quality in the study area.

4. CONCLUSION

The study shows that majority of the groundwater bodies in the vicinity of coir retting areas are polluted during the monsoon season. The colour value, pH, hydrogen sulfide, calcium, magnesium and phosphate content are above the permissible limits of drinking water standards prescribed by WHO/BIS. The degradation of the physico-chemical quality of groundwater in the study area may be due to the leaching of waste water from the coir retting activity and sewage wastes in the Kadinamkulam estuary. The correlation study shows colour is an important parameter in the groundwater quality as it is significantly correlated with pH and turbidity. The principle component analysis also reveals that colour is an important parameter. By the cluster analysis it was found that the concentration of phosphates and hydrogen sulfide significantly affect the groundwater quality in the study area. For the control of groundwater pollution in the study area, periodic cleaning and disinfection of wells with chlorine or potassium permanganate are recommended. The study shows that the concentration of hydrogen sulfide in the estuary water exceeded the standard limit by WHO. So the dangerous situation due to organic wastes affects all organisms in the estuary except the anaerobic bacteria in the ecosystem. It is also recommended to adopt the closed retting process, the green technology for controlling open coir retting related pollution problems in backwaters and its surrounding areas.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Todd K. Groundwater hydrology. John Wiley & Sons, New York, Chichester; 1980.
2. Ahluwalia VK, Sunitha M. In: Environmental science, Ane Books Pvt. Ltd., New Delhi. 2009;351.
3. WHO, Water Pollution Control - A Guide to the Use of Water Quality Management principles. Great Britain: WHO/UNEP; 1997.
4. Ander L, Franceschi M, Pouchan P, Atteia O. Using geochemical data and modeling to enhance the understanding of ground water flow in regional deep aquifer, Aquitain Basin, south west of France. Journal of Hydrology. 2005;305: 40-62.
5. Aziz A. Ph.D Thesis, University of Kerala. Ecology of retting grounds in the backwater systems of Kerala; 1978.
6. Kumari A, Ph D Thesis, University of Kerala, Ecology and community structure of estuarine meiofuna in the South West of India., Thiruvananthapuram; 1996.
7. Aziz A, Nair B. Proceedings of the symposium on coastal aquaculture, ecology of coconut husk retting ground of Kerala. 1986;4:1115-1130.
8. Nandan BS. Retting of coconut husk retting a unique case of water pollution on the South West Coast of India. International Journal of Environmental Studies.1997;52(1-4):335-355.

9. Mark L, Farland Mc,Provin TL. Hydrogen sulfide in drinking water causes and treatment alternatives. The Texas A&M University System, U.S. Department of Agriculture, and the County Commissioners Courts of Texas Cooperating; 1998.
10. American Public Health Association: Standard methods for the examination of water and wastewater, 22nd edition, APHA, AWWWA, WEF, Washington DC; 2012.
11. Bernard E, Ayeni N. Physico-chemical analysis of groundwater samples of Bichi Local Government Area of Kano of Nigeria. World Environment. 2012;2(6):116-119.
12. WHO, Guidelines for drinking water quality, Geneva, Switzerland. 13. World Health Organization (WHO), International Standards for drinking water, Geneva; 1984.
13. Jayaraman PR, Ganga Devi T, NayaVT. Water quality studies on Karamanariver, Thiruvanantpuram, District South Kerala, India, Poll. Res. 2003;32(1):89-100.
14. Jessymol I,Baskaran T. Evaluation of groundwater quality at coconut husk retting area. Applied Ecology and Environmental Research. 2017;5(14):1745-1765.
15. Gaval AR, Kumar MHC, Rathod ARD, Rajanna MD. Nutrient over loading of few selected lakes of Karnataka. J. Ecobiol. 2011;29(1):65-69.
16. Chandra S, Singh A, Tomar PK, Kumar A. Evaluation of physico chemical characteristics of various river water in India. E- Journal of Chemistry. 2011;8(4): 1546-1555.
17. WHO, Guidelines for drinking-water quality, 2nd Ed. Health criteria and other supporting information. World Health Organization, Geneva. 1996;2.
18. Environmental Protection Agency, Water quality standard for surface water, Adopted august 13. 2002;18.
19. WHO. Calcium and magnesium in drinking water: Public health significance, World Health Organization; 2009.
20. BIS, Drinking water specifications, Bureau of Indian Standards, IS 10500; 1991.
21. Gupta N, Pandey P, Hussain J. Effect of physicochemical and biological parameters on the quality of river water of Narmada, Madhya Pradesh, India. Water Science. 2017;31:11-23.
22. Kumar PJS, Delson PD, Babu PT. Appraisal of heavy metals in groundwater in Chennai City using a HPI model. Bull Environ Contam Toxicol. 2012;89:793–798.
23. Massart DL, Kaufman L. The interpretation of analytical data by the use of cluster analysis, John Wiley & Sons, New York; 1983.

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