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Assessment of Lake Water Quality in Gudiyattam Region using Multivariate Statistical Techniques

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Abstract

Nowadays, the quality of water is adversely affected by both natural as well as anthropogenic activities taking place in the surrounding area of the water resources. The present study deals with the assessment of lake water quality in the Gudiyattam region, Vellore district, Tamilnadu, India. Which, the eight significant lakes in this region were selected and monitored for their quality from May-2018 to Apil-2019. The water samples were analyzed for various significant parameters and the mean value was considered for the water quality assessment purpose during the Pre-Monsoon, Monsoon, and Post-Monsoon season. Finally, the results were interpreted as variables using Multivariate statistical techniques – Principal Component Analysis (PCA) /Factor Analysis and Cluster Analysis (CA). The results indicated the existence of a lot of industrial as well as agricultural activity near Site 2 (Nellorepet) and Site 3 (Eripattrai). Especially, Site 2 revealed the highest mean value for Chromium, Lead, Copper, and Zinc compared to other sites in all three seasons owing to the agricultural runoff, dumping of leather finishing waste, and discharge of effluent from Leather processing industries, in that region. Through PCA, the complex data obtained from pre-monsoon, monsoon, and post-monsoon seasons were converted into 8,8, and 5 components. Based on the PCA score, CA has been performed to group the parameters based on the similarity of a cluster. Accordingly, the data were grouped into five, six, and four clusters respectively, for pre-monsoon, monsoon, and post-monsoon. Overall, the results acquired from the study recognized the possible pollution source of the lakes.

Keywords: Lake water Quality, PCA, CA, Gudiyattam, Heavy metals

1 Introduction

Water quality is viewed as a vital supporter of both wellbeing and condition of illness for people [1]. The declination of lake water quality is brought about by natural as well as human factors, including domestic sewage, industrial wastewater, agricultural runoff, and atmospheric deposition [2]. In India, water resources chiefly, lakes are having a significant contribution to the drinking water supply. However, the quality of water being supplied to the public was sub-stranded due to the poor management of resources and industrial activities. So far, numerous quality assessment studies was carried out in lakes such as Bellandur lake, Karnataka[3], Shahpura lake, Bhopal [4], Bhalswa lake, Newdelhi [5], lake Neel Tal, Himalaya [6], Kukarahalli lake, Mysore [7], Surha lake, Uttarpradesh [8], Dalvoy lake, Mysore[9], Rajsamand lake, Rajasthan [10], Ambattur lake, Chennai [11], wular lake, Kashmir [12], and lakes in Hyderabad [13]. Among the different industrial sectors, India occupies 4th place in leather products and 12 % of total world production. In which the major contribution is made by Tamilnadu, India. Based on the study 37% is produced from the Vellore district of Tamilnadu [14, 15]. For the processing of skins/hide into leather, the leather industries use a huge quantity of water along with various organic and inorganic compounds like sodium chloride, ammonium chloride, fats, and chromium [14]. In a year one tannery unit eliminates 40,000 tones of basic chemicals and 15,000 tones of chromium sulfate in their effluents and affects the environment if discharged untreated in the nearby water bodies [16, 17, 18]. Considering this issue, various investigations have been made for monitoring the lake water quality in the Vellore district and the outcomes revealed the presence of a high concentration of heavy metals such as Co, Zn, Fe, Ni, Mn, Cr in the surface water around Ranipet (pulliyakannu and pulliyanthangal lake), Vellore district by tannery effluent discharge [19-21]. Vellore district consists of various major towns such as Tiruppatur, Vaniyambadi, Ambur, Gudiyattam, Vellore, Katpadi, Walajah, Arcot, Arakkonam, etc., The town Ambur is the 2nd most affected area by tannery ventures in this region and it covers more than 100 tannery industries. The place Pernambattu has more than 35 tanneries most of the buffalo leathers and soul leathers are made for local supplies [20]. In Gudiyattam town, numerous industries are operating with the finished leather and exporting Leather footwear and its components.

The export volume of finished leather from the Gudiyattam cluster has increased from 2698 square feet in 2007-08 to 63435 square feet in 2016-17. Whereas the export of footwear components from the Gudiyattam cluster has increased from 48973 pairs in 2007-08 to 250250 pairs in 2016-17 [22]. Due to these increased export activities, there is a chance of lake water pollution in the Gudiyattam region with the discharge of effluent from tannery industries, agricultural runoff, and

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dumping of tannery waste in agricultural land. Further, monitoring the lake water quality will produce a tremendous and perplexing information framework which is complex to interpret a conclusion. Diverse water quality parameters in a single sampling location may lead to uncertainty in the quality sharpness of the sampling site [23].

Thus, nowadays multivariate statistical techniques such as Principal Component Analysis (PCA), Cluster Analysis (CA), Factor Analysis (FA), and Discriminate Analysis (DA) are used to pinpoint the feasible source responsible for the water pollution and thereby helps to manage the quality of water resource[24, 25]. Also, these techniques are used to categorize water quality data and find likeness among the samples or variables [26-34]. So far no water quality assessment studies were conducted in Gudiyattam lake. Therefore, the present study aims to assess the water quality of the lakes present in the Gudiyattam region and to evaluate both similarities and differences in the quality parameters among the lakes using multivariate statistical techniques analysis such as PCA and CA with help of SPSS Software V.22.

2 Materials and Methods

2.1 Study Area

Vellore district is the northern part of the state of Tamilnadu in India. The present study Gudiyattam town comes under the Vellore district and it is about 31km distance from Vellore city. Gudiyattam's geographical coordinates lie (Longitude 78.8644^{0}E, Latitude 12.93972^{0}N) is located in the Palar river basin with a total average area of 30.08 km^2. Our study lakes area in the Gudiyattam region are Thattaparai (S_1), Nellorepet (S_2), Yeripattrai (S_3), Thattankuttai (S_4), Valathur (S_5), Pakkam (S_6), Parasuramanpatti (S_7), Pallikonda (S_8). The monsoonal season for this location starts in October month and ends in the month of mid of January. Table 1 shows the Longitude and Latitude details of all the lakes in the Gudiyattam region.

Table 1: Longitude and Latitude details of lakes in the Gudiyattam region

S. No	*Place*	*Latitude*	*Longitude*
Thattaparai	$Site_1$	12.97421	78.83825
Nellorepet	$Site_2$	12.94221	78.85074
Yeripattrai	$Site_3$	12.96081	78.82622
Thattankuttai	$Site_4$	12.91633	78.8663
Valathur	$Site_5$	12.87958	78.82626
Pakkam	$Site_6$	12.9782	78.8759
Parasuramanpatti	$Site_7$	12.93206	78.91543
Pallikonda	$Site_8$	12.8997	78.92846

2.2. Sample Collection and Experimental Procedure

Water samples were collected at 0.5m depth for 8 lakes every month from May 2018 to April 2019. The water samples collected from lakes were kept in 1L sterile polyethylene bottles. Then all the samples were soaked in 10% nitric acid for 24 hours for preservation. All the samples were taken to the laboratory on the same day of sample collection and stored in the refrigerator at 4^{0}C for further analysis as per standard methods prescribed in (APHA). The samples were analyzed for the following parameters such as pH, Turbidity, Electric conductivity (EC), Total Dissolved Solids (TDS), Total Alkalinity (TA), Total Hardness (TH), Ca^{2+}, Mg^{2+}, Chloride, Sulphate, Phosphate, Fluoride, Ammonical Nitrogen (NH_4-N), Sodium(Na), Potassium(K), Biochemical oxygen demand (BOD), chemical oxygen demand (COD) and elemental analysis such as Chromium(Cr), Lead (Pb), Zinc (Zn), Nickel (Ni), Manganese (Mn), Copper (Cu), Cobalt (Co), Iron (Fe) and Cadmium (Cd). All the parameters are determined by the standard procedure recommended by the APHA [47]. Among the different water quality parameters, pH and EC were evaluated onsite, using a water quality Analysis Kit (Model No-PC650, Eutech Instrument). Total alkalinity, total hardness, calcium ion, magnesium ion, chloride experiments were carried out by the titrimetric method. Turbidity and Sulphate experiments were carried out by the Nephelometry method. TDS was performed by drying the sample from 103^{0}C to 105^{0}C. Phosphate and Fluoride experiments were carried out by stannous chloride and spectrophotometric method. BOD and COD experiments were carried out by Winkler's and closed reflux methods. All the heavy metals experiments were carried out by using the instrument ICP-OES.

2.3 Multivariate Statistical Analysis

All mathematical and statistical computations performed with the water quality dataset in this study were done using SPSS Software V.22. In which, PCA techniques were used to infer the variance within a huge set of intercorrelated variables by transforming them into a smaller set of independent variables [24].

It gives information about the significant parameter used to express the entire data set, overall constitutes present in water with lesser loss of original data, and also helps in deduce the complex data [35, 37]. Cluster analysis classifies unique objects into sets where the number of groups as well as their forms is unknown [38]. In this hierarchical agglomerative clustering is the general approach and it gives natural behavior between any of one sample and entire data and is represented by dendrogram (tree diagram). This provides a clear view of the group and their closeness between each other and the dimensionality of the original data is greatly reduced [35]. In this study, PCA was applied to summarize the statistical relationship among lake water quality parameters. Further CA was performed with normalized data using Ward's method, where Squared Euclidean distances were used as a measure of similarity [36].

3 Result and Discussion

3.1 Physico-chemical Characteristics of the lakes

The lake water quality parameters were compared with the IS:(10500-2012), WHO, and USEPA standards [48, 49, 50]. The mean value of the following parameters was considered for Pre-Monsoon, Monsoon, and Post-Monsoon seasons.

pH: The mean pH results obtained for lake water samples collected from different sites were ranged from 6.63 to 9.59. Amongst the seasons, pre-monsoon lake water samples revealed the highest pH value 9.59 at Site 3 which is above the IS:(10500-2012) standards recommended for drinking water quality, and the lowest mean results (pH 6.68) was obtained during monsoon and the post-monsoon season at site 1. The lowest pH attained during the monsoon season was because of the dilution of alkaline substances in the monsoon season. Change in pH of lake water is mainly due to the saltwater solution of the weak acid and strong alkali, and vice versa. It is affected by dissolved gases such as CO_2, H_2S, NH_3, etc., [7]. The mean pH results obtained at different sites at various seasons are representation in Figure 1(i).

Turbidity: The turbidity variations at different sites at various seasons are presented in Figure.1(ii). The mean Turbidity value obtained was ranged from 11.4 to 272, which is higher than the IS:(10500-2012) standards recommended for drinking water quality. Among the season, Pre-monsoon has shown maximum turbidity of 360 NTU and the lowest value of 4.775 NTU was obtained in the monsoon season. As the most elevated turbidity is a significant restricting component for the biological productivity of the water bodies [39], due contemplations are necessary to handle this issue. The major factors contributing to the higher turbidity levels in the water bodies are the presence of suspended particulate matter, clay, silt, organic matter, and surface runoff.

Conductivity: Figure 1(iii). depicted the conductivity results of lake water obtained at different sites studied. The outcomes have shown a higher value of 761.05 (µs/cm) at site 2 in the monsoon season, which was above the WHO Standards. Any variation in EC specifies the change in ionic concentration [40]. The reason behind the higher conductivity was mainly due to the high concentrations of dissolved inorganic components such as Cl, SO_4, PO_4, Na, Mg, Fe, and aluminum ions by monsoon rain and sewage contamination. Precipitation and other biodiversity changes are chiefly liable for the difference in ionic composition.

TDS: As shown in Figure 1(iv), the mean total dissolved solids in the lake samples were ranged from 298 mg/L to 8345 mg/L and the values attained were higher than the IS:(10500-2012) standards. Among the sites, due to the dense human population and their town discharge, the highest mean value was obtained at site 7 in the post-monsoon season.

Alkalinity: Figure 1(v) depicted the concentration of alkalinity for three seasons. The alkalinity values were ranged from 70 mg/L to 1418.3 mg/L and the mean values obtained were higher than the IS:(10500-2012) standards. Amongst the sites, site 7 revealed a greater value of 1418 mg/L in the post-monsoon season and it would be due to the evaporation and photosynthetic process taking place in the water bodies in the post-monsoon season. It resulted in an increased concentration of carbonate and bicarbonate in water bodies.

Total Hardness, calcium, and magnesium: The concentration of Total Hardness were ranged from 90 mg/L to 800 mg/L. Between the sites, site 5 revealed the highest mean value for total hardness and the results obtained were higher than the IS:(10500-2012) standards in the pre-monsoon season. In which, Calcium existed as Ca^{2+} ions and its concentration was ranged from 24mg/L to 115mg/L and the highest Ca^{2+} concentration obtained at site 7 was 115mg/L in pre-monsoon season. For magnesium (mg^{2+}) ions the concentration was lies between 9.72 mg/L to 124.37 mg/L and the highest concentration was monitored in site 5 in the pre-monsoon season. This may be due to the trophic status of the lake during the different monsoonal seasons and also by human activities [42]. The results obtained for total hardness, Ca^{2+}, mg^{2+}ions were depicted in Figure 1(vi), Figure 1(vii), Figure 1(viii).

Chloride: The concentration graph for chlorides is shown in Figure 1(ix). As shown in Figure 1(ix), site 5 revealed a higher concentration of 119.8mg/L in the pre-monsoon season, and the lowest concentration of 81.3 mg/L was monitored in monsoon. The source for chlorides in water bodies is natural or anthropogenic sources like surface runoff, agricultural activities, industrial effluents, and waste disposal [43]. The lowest concentration was due to the dilution effect of rainwater.

Sulfate: The results obtained for sulfate analysis in lake water samples were shown in Figure 1(x) and values obtained were ranged from 18.47mg/L to 2000mg/L, which was above the IS:(10500-2012) standards recommended for drinking water. Among the samples, Site 5 showed a higher concentration of Sulphate in the post-monsoon season. Higher sulfate concentration may be due to dilution and utilization of Sulphate by aquatic plants.

Phosphate: As shown in Figure 2(i), site 3 revealed the highest concentration of 4.9 mg/L in the post-monsoon season, due to the agricultural runoff, runoff from the cropland, etc. Also, the results obtained at site 3 were higher than the USEPA Standards.

Fluoride: In Figure 2(ii), the concentration of fluoride is presented for all three seasons. Among the sites, the lowest mean concentration value was obtained at Site 7 and the highest was monitored at Site 5 in Pre-monsoon. The results obtained were ranged from 0.4 mg/L to 3.95 mg/L and it was higher than the IS:(10500-2012) standards.

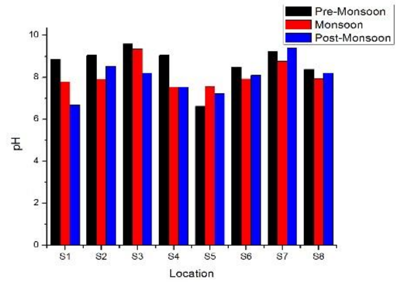
Ammonical nitrogen: The concentration of Ammonical nitrogen is illustrated in Figure 2(iii). The mean concentrations were ranged from 0.1 mg/L to 5.1 mg/L and it was higher than the IS:(10500-2012) standards. Amongst the sites, the highest concentration was monitored at Site 5 in the pre-monsoon season and the lowest was monitored at Site 1 in the monsoon season. Higher ammonia is may be due to the generation of heterotrophic bacteria as a primary end product of the decomposition of organic matter, plants, and debris [44].

Sodium and Potassium: The mean concentration of sodium and potassium are presented in Figure 2(iv) and Figure 2(v). At site 5, the highest mean sodium concentration of 5234 mg/L was observed during the pre-monsoon season and the lower concentration was monitored at site 4 during the post-monsoon season. The results obtained for sodium were above the WHO Standards. For potassium, the highest concentration was observed at site 7 in the pre-monsoon season and the lowest was monitored at site 6 during monsoon season. There are no specific standards are available for Pottasium. This increased concentration of potassium and sodium in freshwater may be by domestic sewage [45].

BOD: The BOD analysis results observed for lake samples at various sites are depicted in Figure 2(vi). As shown in the figure, the highest concentration of 26 mg/L was observed at site 6 in the pre-monsoon season and a lower concentration of 2.25 mg/L at site 2 was observed during monsoon season. The reason behind the biological demand in lake water was due to agricultural runoff, nutrient waste from fertilizers, leaves, etc.

COD: COD results monitored at different sites are presented in Figure 2(vii). The highest mean concentration of 568 mg/L was obtained at site 5 and the lowest concentration of 80 mg/L was monitored at site 2 during the post-monsoon season. The higher concentration may be due to industrial activities, agricultural runoff, and domestic waste discharge [46].

Heavy metals: The mean concentration values monitored from the metal analysis are presented in Figure. Figure 3(i), 3(ii), 3(iii) ,3(iv), 3(v), 3(vi), 3(vii), 3(viii), 3(ix) for Cr, Pb, Ni, Co, Cd, Fe, Zn, Mn, Cu. The heavy metal chromium has the higher concentration at site 2 as 0.67 mg/L in the pre-monsoon season and the lowest concentration at the same site 2 as 0.002mg/L in the monsoon season. For lead, the highest concentration of 0.765 mg/L was monitored at site 2 in pre-monsoon and the lowest concentration of 0.05 mg/L was monitored at site 6 in post-monsoon. For a nickel, the highest concentration of 0.1165 mg/L was observed at site 3 and the lowest concentration of 0.02 mg/L was observed at site 1 during pre-monsoon season. For cobalt, a higher concentration of 0.118 mg/L was observed at site 2 and a lower concentration of 0.07 mg/L was observed at site 4 in pre-monsoon. For cadmium, the higher concentration of 0.019 mg/L in pre-monsoon, and the lowest concentration of 0.019 mg/L were observed at site 2. In monsoon and post-monsoon seasons, the metal concentrations were undetectable.



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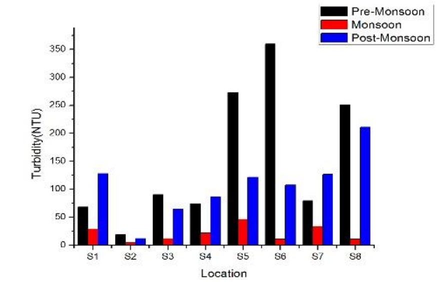

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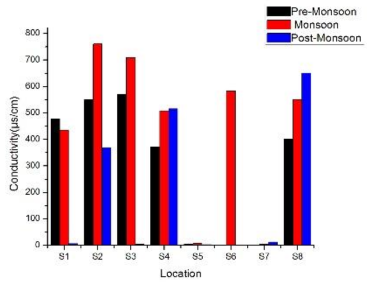

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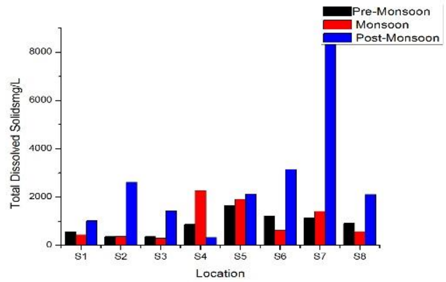

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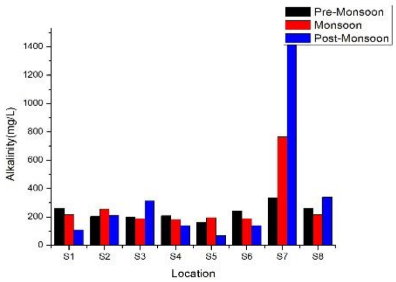

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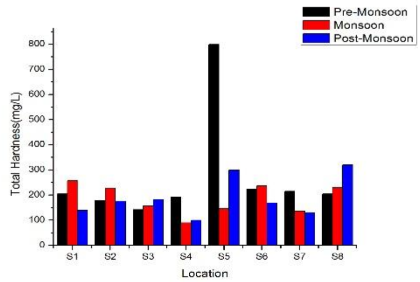

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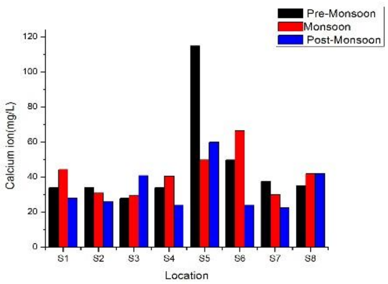

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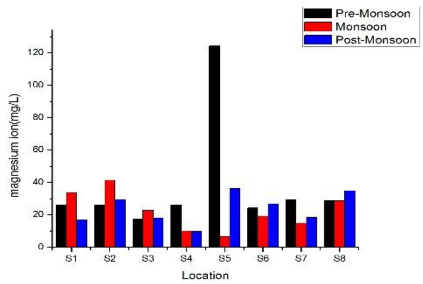

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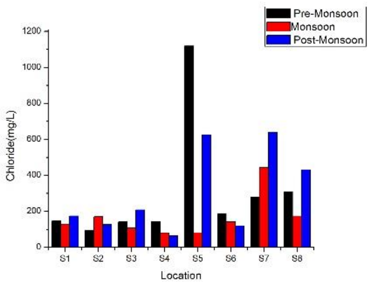

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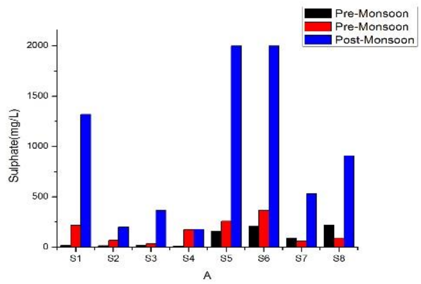

(x)

Figure 1: Physico-chemical parameter(vi)rs of lake water samples. (i) pH, (ii) Turbidity, (iii) conductivity, (iv) TDS, (v) Alkalinity, (vi) Total Hardness, (vii) Calcium, (viii) Magnesium, (ix) Chloride, (x) Sulphate.

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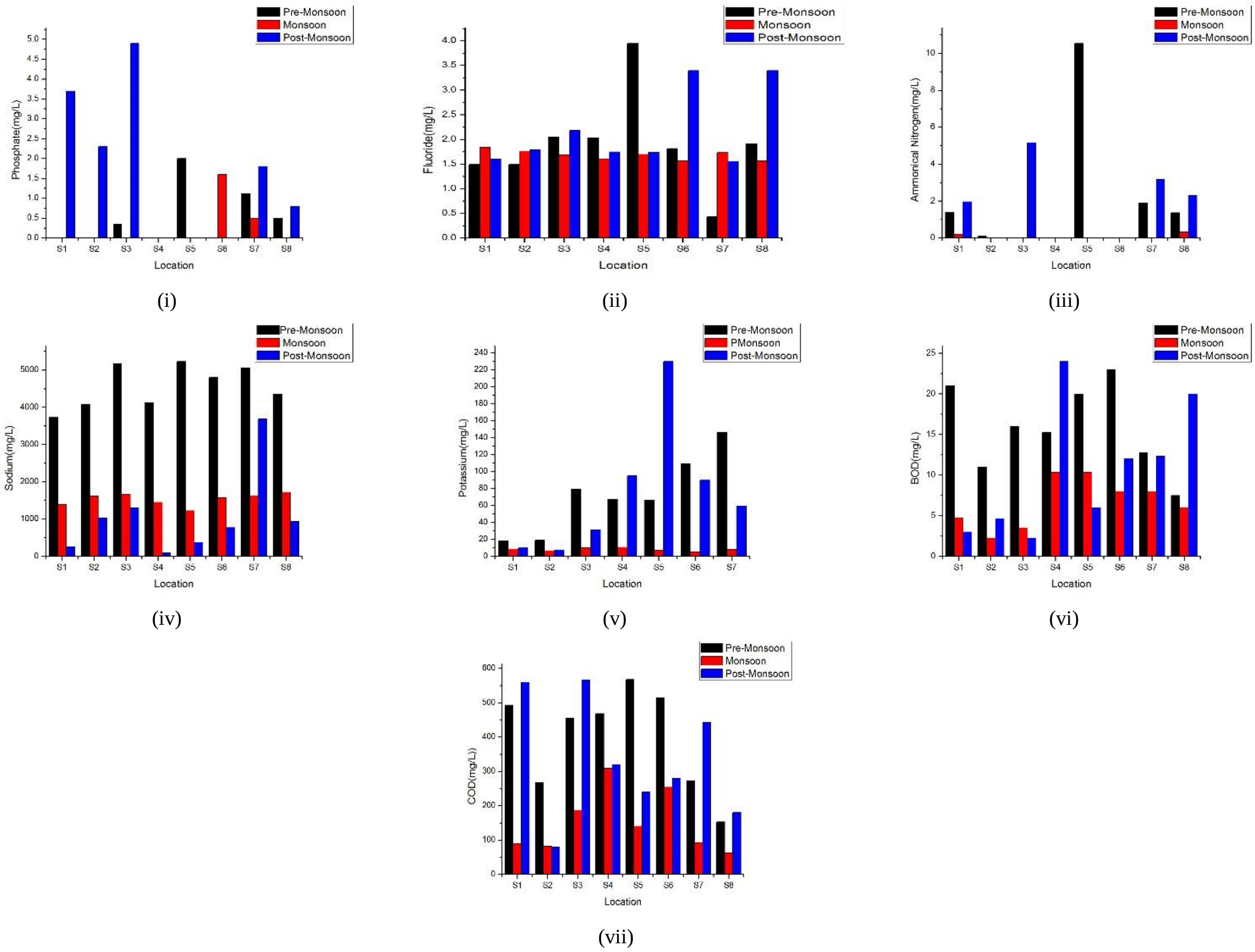


Figure 2: Physico-chemical parameters of lake water samples. (i) Phosphate, (ii) Fluoride, (iii) Ammonical nitrogen, (iv) Sodium, (v) Potassium, (vi) BOD, (vii) COD

Fe has a higher concentration of 6.6183 mg/L at site 5 in the pre-monsoon season and the lowest level of 0.0024 mg/L at site 4 in the post-monsoon season. For zinc (Zn), a higher concentration of 8.1097 mg/L was observed at site 2 in pre-monsoon and a lower concentration of 0.0205 mg/L was observed at site 1 during monsoon. For Manganese, the higher concentration of 0.3922 mg/L was observed at site 1 in monsoon and a lower concentration of 0.009 mg/L was observed at site 7 during monsoon and for copper, a higher concentration of 0.15275 mg/L was observed at site 2 in pre-monsoon and a lower concentration of 0.006 mg/L was observed at site 7 during monsoon.

The higher concentration of metals in the lake samples was due to the disposal or discharge of tannery industry waste or wastewater around the lakes through direct dumping or surface runoff to the lakes. The metals that lie at lower concentrations were owing to the precipitation-mediated dilution. In monsoon and post-monsoon season, the metal was undetectable level. The Higher Concentration of metals may be due to the elimination of tannery industries present around the lakes and also the dumping of tannery waste into the land and generate as surface runoff to the lakes. The metals that lie at lower concentrations may be because dilution takes place in rainy seasons.

Fe has a higher concentration at site 5 as 6.6183 mg/L in the pre-monsoon season and the lowest level at site 4 as 0024 mg/L in the post-monsoon season. For zinc (Zn) higher concentration at site 2 as8.1097 mg/L in pre-monsoon and lower at site 1 as 0.0205 mg/L in monsoon. For Manganese higher concentration site 1 as 0.3922 mg/L in monsoon and a lower concentration at site 7 as 0.009 mg/L in monsoon and for copper higher concentration attained at site 2 as 0.15275 mg/L in pre-monsoon and a lower concentration at site 7 as 0.006 mg/L in monsoon. The mean concentration graph for the metals Cr, Pb, Ni, Co, Cd, Fe, Zn, Mn, Cu were clearly shown in Figures 3(a), 3(b), 3(c).

3.2 PCA Analysis

PCA analysis was carried out to examine 26 parameters analyzed for lake water samples and the correlation among those parameters was arrived [27]. The measured parameters were taken as independent variables and sampling sites were considered as the dependent variables. The result of PCA analysis for Pre-monsoon, Monsoon, and Post-Monsoon is shown in Table 2, Table 3, Table 4. In the Pre-monsoon season, eight components of PCA analysis showed 85% as variance in the data set, the PCA analysis classified 26 parameters into eight groups. The first component (PC1) included Ammonical Nitrogen, Sulphate, Chloride, and Ca^{2+} which showed 22.4% of the total variance in the data set.

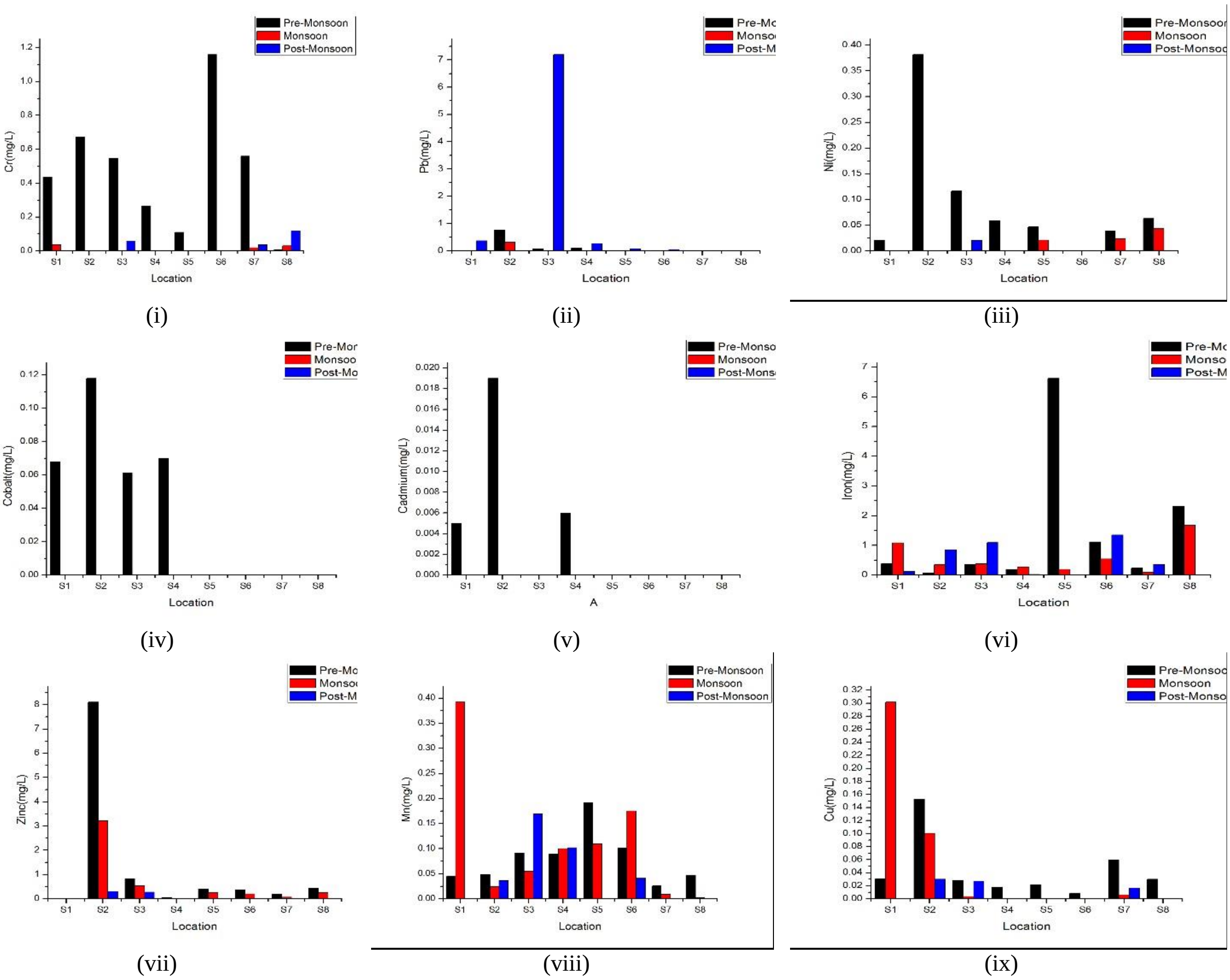


Figure 3: Heavy metals concentration of lake water samples. (i) Chromium, (ii) Lead, (iii) Nickel, (iv) Cobalt, (v) cadmium, (vi) Iron, (vii) Zinc, (viii) Manganese, (ix) Copper

The second component (PC2) which contains Lead, Copper, and Zinc were having 11.75 as total variance and in that metals are having similar patterns, and are responsible for metal pollution in lakes. In PC3 the parameters COD, Sodium, and Manganese were having higher similarity and showed 10% as the total variance and is due to anthropogenic pollutants through the discharge of domestic waste and industrial effluents. In (PC4), the parameters, Total Hardness, $Mg^{2+,}$ and Iron were having more similarity and showed 9.8% as total variance, In PC5 the parameters pH and alkalinity had more similarities and revealed 9.2% as the total variance. In PC6 the parameters, Fluoride, and heavy metal Chromium were having more unique patterns and showed 7.9 % as total variance and pollution load is caused by the tanning industrial discharge into the lakes. In (PC 7) the parameters Nickel and Cobalt were having an identical pattern and revealed 7.5% as the total variance. In (PC8) the parameters cadmium, conductivity and potassium were having higher identical trends with 6.3% as the total variance.

In the monsoon season, all the parameters were converted into eight components. In (PC1) pH, Fluoride, Sodium, and Potassium were having higher similar trends with 20% total variance. In (PC2) the parameters of chromium, cobalt, and cadmium were having higher similarities with 11.4% as a total variance. In (PC3) the parameters sulfate and manganese were having more similar patterns with a total variance of 11%. In (PC4) the parameter Turbidity and TDS were having higher unique patterns with 10.6% as the total variance due to surface runoff. In (PC5) the parameters Lead and Zinc were having a more unique trend with a total variance of 10.6%. In (PC6) Alkalinity and Chloride were correlated with a total variance of 10%. In (PC 7) Ammonical nitrogen, Nickel and Iron have a correlation with a total variance of 8.7% and in (PC8) phosphate and COD have more correlation and have 6.5% as the total variance due to the discharge of industrial effluents and domestic sewage.

In the Post-monsoon season, all the parameters were having a total variance of 79.9%. In which, all the parameters were converted into 5 components. In (PC 1) pH, Total Hardness, $Ca^{2+,}$ and Fluoride showed more similarity with a total variance of 5.5%. In (PC2) Zinc, Copper, Manganese, and Sodium showed more similarities with a total variance of 4.7%. In (PC3) Lead and phosphate were having higher similarities with a total variance of 4.5%. In (PC4) TDS and COD were having unique patterns with a total variance of 3.9%. In (PC5) Cobalt and Cadmium were having similar trends with a total variance of 2%. Overall, the pollution load was due to the discharge of industrial effluents and domestic sewage.

3.3 Comparison of PCA Analysis Output

By comparing the variance value obtained from various seasons, the Monsoon season variance value was below the Pre-Monsoon and Post Monsoon values. It was due to the dilution of lake water through surface runoff and precipitation during the monsoon. In the Pre-Monsoon season, the parameter

Ammonical Nitrogen, Sulphate, Chloride, and Ca^{2+} were having 22.4% as total variance in their data set, and in the monsoon season the parameters pH, fluoride, sodium, and potassium were having higher similar trends with 20% total variance. In the Post-Monsoon season the parameters pH, total hardness, Ca^{2+}, and fluoride attained more similarity and have 5.5% as a total variance. In all three seasons, the Physico-chemical parameter was having a vital role in lake water quality.

Table 2: PCA Analysis for Pre-Monsoon

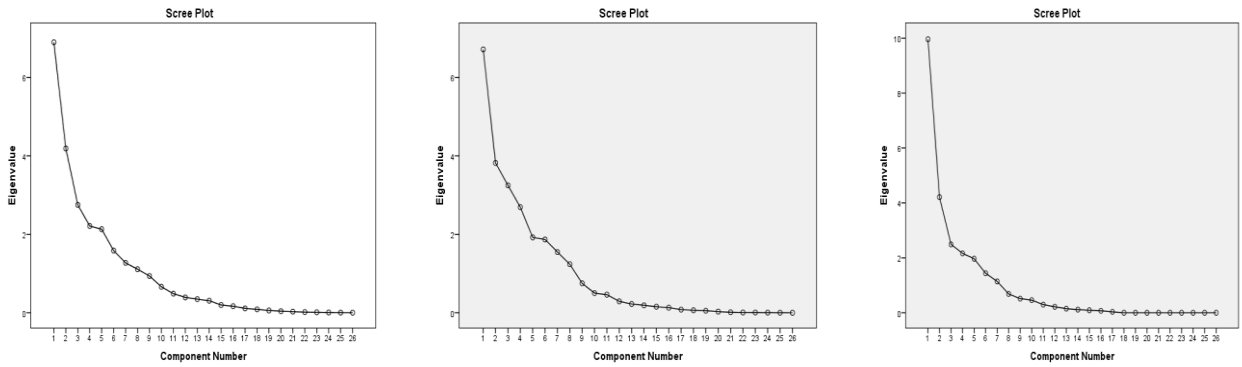
Parameters	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
pH	-.039	.128	.312	-.041	.850	.075	.212	-.137
Conductivity	-.177	.224	.188	-.321	.023	.269	.473	-.544
Turbidity	.446	-.222	.258	-.064	.241	.156	-.210	.417
TDS	.615	-.072	-.225	-.048	.288	.268	-.120	.338
Alkalinity	-.032	.076	-.084	.069	.860	-.013	-.049	-.037
TotalHardness	.695	-.006	.265	.637	.103	-.059	-.006	.018
Ca^{2+}	.864	.042	.318	.179	.161	-.042	-.092	.013
Mg^{2+}	.502	.052	.173	.815	.054	-.055	.049	.013
Chloride	.833	-.044	.114	.485	.036	-.079	-.045	.057
Sulphate	.904	-.048	-.005	.165	-.146	.267	-.058	.022
Phosphate	.878	-.004	-.227	.009	.076	-.052	-.089	.127
BOD	.317	-.141	-.023	-.029	.515	.488	.057	.005
COD	-.123	.040	.834	.268	.117	-.150	-.193	.056
Fluoride	.321	-.127	-.078	-.154	-.085	.799	.011	-.232
Ammonical Nitrogen	.958	-.028	-.070	-.099	-.095	.102	-.031	-.010
Sodium	.007	.288	.754	.260	-.016	-.313	-.167	.092
Potassium	.202	-.112	-.435	-.082	.595	.000	-.129	.440
Chromium	-.129	-.080	-.237	.075	.137	.847	-.081	.148
Lead	-.037	.967	.073	-.058	-.007	.003	.012	-.036
Nickel	-.079	-.024	-.039	.084	.009	-.195	.890	.090
Cobalt	-.095	-.036	-.113	-.066	.055	.103	.824	-.088
Copper	-.028	.933	-.080	.051	.138	-.179	.021	.050
Cadmium	-.067	-.106	-.165	-.050	.121	.013	-.084	-.834
Iron	-.010	-.035	.250	.921	-.066	.006	-.036	.069
Zinc	-.025	.967	.155	-.005	-.028	-.057	-.063	-.014
Manganese	.500	-.110	.662	.140	-.114	.003	.209	.107
Eigenvalue	5.841	3.042	2.621	2.554	2.394	2.073	1.975	1.639
Variability %	22.465	11.700	10.082	9.824	9.209	7.974	7.596	6.303
Cumulative %	22.465	34.165	44.247	54.071	63.280	71.254	78.849	85.152

Table 3: PCA Analysis for Monsoon

Parameters	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
pH	.902	-.099	.079	.147	.074	.247	.031	.005
Conductivity	.660	.283	-.006	-.569	-.086	-.185	-.065	.016
Turbidity	.243	.156	.265	.796	-.148	.068	-.020	-.137
TDS	.243	-.110	-.047	.707	-.179	.401	-.078	.008
Alkalinity	.158	.024	.013	.116	-.014	.959	-.065	-.066
TotalHardness	.715	.193	.439	-.219	.230	.045	.262	.163
Ca^{2+}	.669	-.075	.432	.202	-.086	-.180	.113	.299
Mg^{2+}	.582	.174	.256	-.463	.480	.155	.205	-.062
Chloride	.236	-.012	.012	.093	-.008	.909	.047	-.002
Sulphate	.217	-.040	.869	.103	-.120	.272	-.042	.149
Phosphate	.019	-.048	.187	-.159	-.076	.041	-.046	.913
BOD	.321	.050	-.070	.684	-.140	.027	.100	.403
COD	.105	-.020	-.115	.443	-.016	-.167	.064	.687
Fluoride	.908	.043	.208	.198	.144	.231	-.013	-.024
Ammonical Nitrogen	.104	.273	-.088	-.130	-.075	-.015	.897	-.044
Sodium	.858	.003	.136	.219	-.033	.065	.123	.143
Potassium	.742	.155	-.054	.244	.044	.314	-.032	-.120
Chromium	.091	.839	-.029	-.045	-.068	.231	.363	-.059
Lead	.093	-.041	-.147	-.176	.939	-.006	-.088	-.032
Nickel	-.010	-.041	-.074	.190	-.016	.001	.871	.055
Cobalt	.039	.986	-.022	.020	-.021	-.072	-.018	-.009
Copper	-.050	-.035	.578	.029	.750	.019	-.009	-.144
Cadmium	.039	.986	-.022	.020	-.021	-.072	-.018	-.009
Iron	.302	-.022	.557	-.231	-.035	-.079	.627	-.007
Zinc	.110	-.064	-.180	-.105	.946	-.060	-.036	-.005
Manganese	.219	-.039	.878	.031	-.061	-.164	-.111	-.003
Eigenvalue	5.203	2.966	2.882	2.804	2.777	2.426	2.287	1.699
Variability %	20.012	11.407	11.086	10.786	10.682	9.330	8.794	6.534
Cumulative %	20.012	31.419	42.505	53.291	63.974	73.304	82.098	88.632

Table 4: PCA Analysis for Post-Monsoon

Parameters	PC1	PC2	PC3	PC4	PC5
pH	.936	.001	-.130	-.129	.025
Conductivity	.409	.045	-.289	-.542	.098
Turbidity	.821	.429	.008	.196	.019
TDS	.546	.256	-.390	.542	-.069
Alkalinity	.554	.155	-.457	.469	-.067
TotalHardness	.933	.001	-.067	-.292	.065
Ca^{2+}	.944	-.042	.172	-.071	.038
Mg^{2+}	.832	-.010	-.231	-.419	.067
Chloride	.749	.316	-.336	.365	-.035
Sulphate	.494	.418	.129	-.034	.013
Phosphate	.356	.479	.652	-.061	-.026
BOD	.500	.376	-.044	-.232	.151
COD	.691	-.098	.270	.592	-.043
Fluoride	.907	.045	.093	-.036	.031
Ammonical Nitrogen	.421	.517	.601	-.122	.010
Sodium	.573	-.674	-.159	-.226	.023
Potassium	.642	.534	-.085	.006	.034
Chromium	.489	.180	-.470	-.143	.057
Lead	.271	.334	.698	.006	-.037
Nickel	.362	-.593	.306	.426	-.002
Cobalt	-.150	.002	.025	.139	.976
Copper	.526	-.663	.046	.304	-.011
Cadmium	-.150	.002	.025	.139	.976
Iron	.665	-.478	.158	-.259	.023
Zinc	.537	-.793	.116	-.137	.027
Manganese	.534	-.691	.257	.073	.019
Eigenvalue	5.57	4.753	4.541	3.909	2.018
Variability %	21.422	18.282	17.467	15.03	7.76
Cumulative %	21.422	39.704	57.171	72.2	79.96



(a) (b) (c)

Figure 4: Scree Plot Diagram

Scree Plot diagram for Pre-monsoon, Monsoon, and Post-Monsoon shown in Figure.4(a), 4(b), and 4(c). The scree plot shows the variation of eigenvalue with the number of components keeping cut off eigenvalue as 1. In the Pre-monsoon analysis, there were eight principal components, for the monsoon season it was grouped into eight components and for the Post-Monsoon season, it was split into five components based on the pollution load.

3.4 Cluster Analysis

The hierarchical cluster analysis yielded five major clusters. The first cluster has the majority of all the heavy metals. This cluster was seen for all three seasons. This cluster has the most parameter in the Pre-Monsoon season. For the Pre-Monsoon season, the first cluster is subdivided into four major sub-clusters. The first subcluster has the majority of heavy metals and ions in the study region. Two exceptions are TDS and total hardness**.** Alkalinity and BOD formed the next subcluster. Potassium and turbidity are the next subclusters. The second cluster comprises COD and Sodium. Fluoride, Conductivity, and pH are classified as a separate cluster. For the Monsoon season, Monsoon season all the parameters were totally grouped into 6 clusters. In that Co, Cd, Cr formed the first Cluster. The parameters ammonical nitrogen and heavy metals formed the second Cluster. Cluster 3 includes Ni, Phosphate, Pb, Cu, So_4, Alkalinity, COD. Cluster 4 was grouped by Iron and Mn. Cluster 5 includes the parameter TDS, BOD, and Turbidity. In cluster 6 Total Hardness, Calcium, Mg^{2+}, Ca^{2+}, K, and Conductivity were grouped. In the Post-monsoon season, the entire parameters were converted into 4 clusters based on the data set. In cluster 1 the parameter CO and Cd grouped. In cluster 2 Zn, Mn, Ni, Cu, PO_4, Ammonical nitrogen, Pb, TDS, Alkalinity, Chloride, K, Turbidity, and BOD. In cluster 3 sodium and Iron grouped. In cluster 4 Ca^{2+}, Mg^{2+}, Fluoride, pH, and conductivity were grouped. The hierarchical dendrogram for pre-monsoon, monsoon, and the post-monsoon season was illustrated in Figure.5, Figure.6, and Figure.7.

Comparison of Cluster Analysis Output: In all the three-season the heavy metals are grouped with any one of the Physico-chemical parameters of lake water quality. It seems that due to the tanning industrial activity the lake water quality is affected. The chemicals used in tanning industries are responsible for proportionality among the parameters.

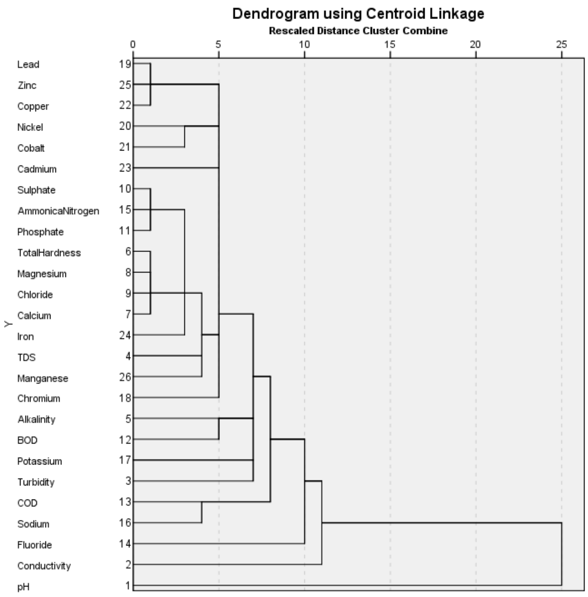


Figure 5: Hierarchical dendrogram representation for Pre-Monsoon season.

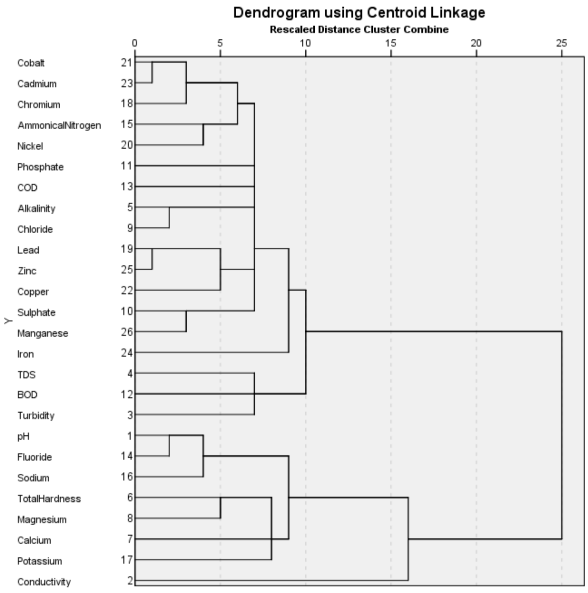


Figure 6: Hierarchical dendrogram representation for Monsoon season

4 Conclusion

In this study, a detailed analysis of various Physico-chemical and metal analyses was carried out at 8 lakes in different monsoons. The results revealed the presence of more contaminants in the Pre-monsoon season compared to monsoon and in the Post-Monsoon season. In each lake, contaminants levels exceeded beyond the standards level. Among all the lakes, specifically, site 2 (Nellorepet) and Site 3 (Eripattarai) are dominated highly in all the parameters for all three seasons. These results indicated that near to the two lakes lot of industrial activity and agricultural activity was existing a large scale. The heavy metals especially chromium, lead, Nickel are very high in Site 2 and Site 3 compared to all other lakes. It might be due to the discharge of tannery industrial sewage, surface runoff, agricultural runoff.

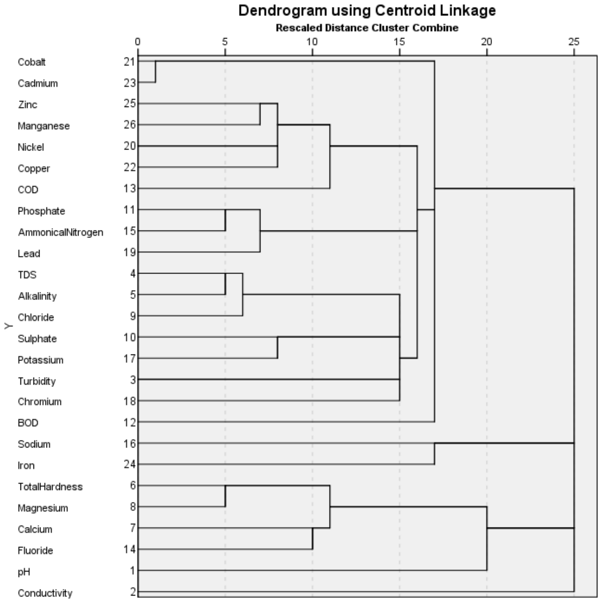


Figure 7: Hierarchical dendrogram representation for Post-Monsoon season

The outcome from PCA analysis given that major variation in lake water quality was by soluble salts, anthropogenic pollutants, and heavy metals by the tannery industries.CA analysis helped in the grouping of similarities among the various parameters as clusters. In pre-monsoon season the data was totally grouped into five clusters, for Monsoon grouped into six clusters and for Post-monsoon grouped into four clusters based on the similarities in the parameter. Here all the heavy metals had similarities in all three seasons. The overall studies helped for the identification of dominant pollutants in lake water. In the future there is a need to study the impact of pollutants on health aspects in humans, there is a need to reduce the contaminants in specific lakes in gudiyattam region, and also there is a necessity to find possible treatment technology to avoid the percolation of contaminant from lakes to open wells and closed well near to that region.

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Ethical Consideration

A plagiarism check was done thoroughly for the entire manuscript.

Competing Interest

True of our Knowledge we never copied and never submitted to other Journal for Publication Purpose.

Author Contribution

Both authors had equal contributions to this project.

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