SPATIAL AND TEMPORAL VARIATION OF LAKE WATER QUALITY PARAMETERS IN BANGALORE REGION

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ABSTRACT

The purpose of this study is to analyze the spatial & temporal variation of all the lake water quality parameters for the lakes in Bangalore region by generating maps & to recommend some long term sustainable eco-friendly suggestions. The data of parameters like pH, Conductivity, coliform, DO, BOD, COD, Turbidity, Total Hardness, Total Dissolved solids , Potassium , Sulphates , Chlorides & Fluorides have been obtained from monitoring stations, namely Nelamangala , Peenya , Mahadevpura , Bommanahalli , Yelankha , Dasarahalli , Anekal
, Sarjapura , Rajarajeshwari Nagara , Bangalore south , Bangalore east and Bangalore west. These lake water quality metrics' regional and temporal fluctuation is generated using Q-GIS platform. By the use of MINITAB software the variations of the above parameters are depicted a normality test, Box plot, Matrix plot & co- relation Analysis. The results shows that few lakes are highly polluted in different seasons due to the change in quality parameters. This is majorly due to the release of industrial effluents without proper treatment. This study can further be extended to find out the implications on healthcaused due to the variation in these parameters.

Keywords- Water quality, Lake parameters, Bangalore, MINITABS , Q-GIS, box plot, Matrix plot, Corelation Analysis.

INTRODUCTION

Water pollution indicates to the release ofharmful pollutants into the water bodies, causing several health effects to human beings, aquatic life and for the environment in total. Water quality is a measurement of how pure or filthy the water is with respect to its purpose of using such as Drinking, Irrigation, Industrial use, swimming etc and it's vital to keep track of it since contaminated water may be harmful to human health, aquatic life and for theenvironment. It is measured with an index called Water Quality Index (WQI). Few parameters, namely Turbidity, Total Solids, Temperature, pH, Conductivity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Nitrate, Total Phosphorus and Fecal Coliform acts as a major parameters in procuring the WQI for an area. Each parameter is weighted according to how much it affects the overall Water quality. Bengaluru, which was formerly referred to as the "garden city," has unfortunately suffered a decline in the quality of its water over time. Some of the major reasons include release of untreated sewage and industrial effluence, Oil leaks and spills, radioactive waste, Global warming, social and religious practices, etc. A Geographic Information System (GIS) is computer-based

software for assessing and mapping elements on the earth, whereas Remote Sensing (RS) is the science of collecting data regarding an entity without actually coming into physical contact with it. Using the new technology of RS and GIS, we can generate Spatial mapping, which has its own capabilities to generate a 3D map of an environment. It allows a gadget to interact with and learn about the actual environment. On comparing the water quality spatial and temporal maps of various Lake Water parameters of Bengaluru city during Pre-Monsoon, Monsoon and Post-Monsoon seasons we can identify the areas to improve for maintaining the lake water quality and work towards sustainability. India is a highly culturally varied nation, where several religious and cultural festivals are held. An idol is a representation of a deity that is worshipped. Following worship, these idols are submerged in bodies of water. When submerged, idols have a considerable impact on the water's quality since they are formed of materials like plaster of Paris, clay, fabric, little iron rods, and bamboo and painted with a range of colours, including varnish and water colours. Lead, mercury, cadmium, arsenic, zinc, and chromium are just a few examples of the heavy metals that are present in the paints used to colour these idols. Particularly high levels of lead, zinc oxide, chromium, and mercury are found in the hues red, blue, orange, and green. Two heavy elements, lead and chromium, are also introduced to the water bodies through the usage of sindoor, a conventional red-coloured cosmetic powder that married women generally wear and that is widely used during festivals. After decomposing, floating items released by decomposition in the river and lake cause eutrophication, a rise in acidity, and a concentration of heavy metals. As heavy metal pollution from idol immersion kills fish, harms plants, and obstructs the water's normal flow, it can cause stagnation and harm the ecosystem.

STUDY AREA

Bengaluru, the capital city of Karnataka state, is the fifth largest and among the fastest developing cities of India. It is known as the Silicon Valley of India as it has seen a massive growth in the Information Technology (IT) sector and also was called the Garden City of India, due to its abundant greenery and numerous gardens, but unfortunately has seen a decline over the years. The Bengaluru city is situated in the heart of the South Deccan plateau to the southern East

part of Karnataka state. The area lies between longitudes 77°24' to 77°48' E and Latitudes 12°46' to 13°11' N. City is at an average elevation of around 920 metres with an area of 741 sq kms. It is known for its typically pleasant climate. Bengaluru has a population of about 13 million divided into 5 zones, namely Bengaluru North, South, East, West and Central, that currently has 243 BBMP (Bruhat Bengaluru Mahanagara Palike) wards.

DATA USED

Spatial Data : Polygon shape file of Bengaluru from The Karnataka Geographic Information system(K-GIS).

Non Spatial Data : Water Quality Data sets of pH, BOD, COD, Ammonia, dissolved oxygen, Turbidity, Total Hardness, Total coliform parameters from 12 monitoring stations, namely Nelamangala, Peenya, Mahadevpura, Bommanahalli, Yelankha, Dasarahalli, Anekal, Sarjapura, Rajarajeshwari Nagar, Bangaloresouth, Bangalore east and Bangalore west.

METHODOLOGY

CALCULATION OF WATER QUALITY INDEX:
Choose a group of water quality metrics that are pertinent to the assessment's particular situation or goal. Physical, chemical, and biological indicators, including dissolved oxygen, pH, turbidity, total dissolved solids, nutrients, and different contaminants can all be included in these parameters.
For each parameter you choose, decide what criteria or recommendations are appropriate. Depending on the jurisdiction and intended use of the water body, these standards may be established by regulatory agencies, water quality criteria, or particular water quality objectives. Obtain data on the water quality for the selected criteria for the target water body or monitoring stations. Make sure there is enough data to illustrate the variety of circumstances and fluctuations in water quality.
The data for each parameter should be normalised to a consistent scale or range. Using the proper mathematical adjustments or scaling procedures, this stage entails standardising the raw data.

Based on their respective relevance in assessing the quality of the water, give each parameter weights or important factors. By using expert opinion or input from stakeholders, various criteria's weights, which may have a higher or lower influence on water quality, can be decided. Apply the relevant formula or equation to ascertain each parameter's sub-index. This equation normally takes into account the goal standards, normalised values, and weighting factors allocated to each parameter.

To calculate the overall Water Quality Index value, combine the subindices of each parameter using an appropriate aggregation approach, such as weighted arithmetic mean or geometric mean. To effectively convey the water quality status, interpret and categorise the Water Quality Index value into several categories or classes. Based on the index value range, these categories, which can vary from good to bad, indicate the degree of water quality.

CLASSIFICATION OF WATER QUALITY DATA:

Excellent	Class A
Good	Class B
Fair	Class C
Poor	Class D
Very Poor	Class E

Q-GIS TO FORM A MAP:
Use the "Layer" menu's "Add Layer" option or the toolbar's "Add Vector Layer" or "Add Raster Layer" buttons to add your data to the map. Choose your data files by navigating to their location.

Once your data has been entered, you may symbolically represent it to see various properties. In the "Layers" panel, right-click the layer and choose "Properties." Based on your data properties, you may specify the symbology in this case, including the colours, line styles, and symbols.

To modify the order of the layers and their appearance on the map, use the "Layers" panel. The layers at the top will be visible above the layers at the bottom.

To your map, you may add labels and notes. In the "Layers" panel, right-click the layer and

choose "Properties." To set up label options, including the font, positioning, and text, select the "Labels" tab.

Tools are available in QGIS to set up the map layout. The legend, north arrow, scale bar, title, and other features are all editable. To enter the layout mode, click the "Layout" menu or the "Print Layout" button.

When you are happy with your map, you can either print it immediately or export it to a variety of formats. To save your map, pick "Export as Image" or "Export as PDF" from the "Composition" menu while in the layout mode.

INTERPOLATION:
Using the values of neighbouring known data points, interpolation is a GIS method used to estimate values for areas where data are not available. QGIS offers a number of interpolation techniques. IDW is a well-liked interpolation technique that gives close points weights based on how far apart they are from one other. The predicted value at a target position is more influenced by the closest points. The IDW interpolation tool in QGIS is accessible via the "Raster" menu or by utilising the "Processing Toolbox" (Ctrl+Alt+T) to look for "IDW Interpolation."

MINITAB:

Minitab is a statistical software programme that is often used in many sectors for data analysis and quality improvement. It offers a selection of instruments and methods for statistical analysis, graphic visualisation, hypothesis testing, regression analysis, experiment design, Control charts, and more.

ANALYSIS USING BOX PLOT:

VISUALISATION OF DATA DISTRIBUTION
The distribution of your data for each variable or category is shown graphically in the box plot. You can rapidly determine the central tendency, spread, and any potential skewness or asymmetry in the data by looking at the median, quartiles, range, and any outliers or extreme numbers.

MEDIAN AND QUARTILES: The median (50th percentile) of the data is shown as a box with a horizontal line inside it in the box plot. The interquartile range (IQR), which spans the lower quartile's 25th percentile and the upper quartile's

75th percentile, is shown by the box itself. This reveals details about the data's distribution and central tendency.

WHISKERS : The box plot's whiskers extend past the box's borders to display the range of the data, omitting outliers. By default, Minitab calculates the length of whiskers using 1.5 * IQR rule, which often covers the bulk of the data within an acceptable range.

OUTLIERS : Outliers are any data points that lie outside of whiskers and are shown as distinct points or dots in the plot. Outliers can shed light on odd observations or extreme values that differ dramatically from the rest of the data.

GROUP COMPARISIONS : To compare the distributions of several groups visually, Minitab generates distinct box plots for each category when you specify a categorical variable for grouping. To find patterns, similarities, or differences amongst groups, this is helpful.

STATISTICAL SUMMARY : Along with the box plot, Minitab also displays a statistical summary table. The sample size, mean, standard deviation, median, quartiles, and any identified outliers are among the important summary statistics included in this table. The data distribution for each variable or category is shown in numerical form.

CORRELATION:

CORRELATION COEFFICIENT:
Minitab calculates the correlation coefficient, which expresses the strength and direction of the relationship between two variables. From -1 to 1, the correlation coefficient is available. A value near zero denotes a weak or no connection, a value close to zero denotes a positive correlation (variables move in the same direction), and a value negative correlation (variables move in opposite directions).

SIGNIFICANCE LEVEL: In addition, Minitab includes the p-value for the correlation coefficient. The p-value displays the statistical significance of the association. The connection is likely to be statistically significant, which means that it is unlikely to

have happened by chance, if the p-value is less than a preset significance level (for example, 0.05).

SCATTER PLOT : In order to show how the variables are related, Minitab creates a scatterplot. Each data point on the scatterplot represents an observation and compares the values of one variable against the values of the other variable. You can see the general pattern and spot any possible linear or nonlinear relationships between the variables thanks to this technique.

CORRELATION MATRIX: Minitab displays a correlation matrix when you examine the correlations between several variables. The matrix shows the correlation coefficients between each pair of variables, giving a thorough breakdown of how all variables relate to one another.

CORRELATION MATRIX PLOT: Minitab may also produce a correlation matrix plot, sometimes referred to as a heat map or correlation plot, in addition to the correlation matrix. Darker colours represent stronger correlations in this figure, which uses colour to represent correlations between variables. It is beneficial to concurrently spot trends and connections between several variables.

COVARIANCE MATRIX : Minitab may also offer a covariance matrix, which shows the covariances between each pair of variables and gauges how closely they vary.

These results from Minitab's correlation analysis help in understanding how variables relate to one another, evaluating the degree and importance of correlations, and identifying patterns in the data. They offer insights into the relationships between variables and can aid in the exploration of correlations in research or analysis, the identification of possible predictors, or the formulation of data-driven choices.

MATRIX ANALYSIS:

MATRIX MANUPULATION:

Minitab enables input, editing, and matrix manipulation. You can build, transpose, add, subtract, multiply, and do other arithmetic operations on, as well as apply functions or transformations to, matrix elements.

MATRIX SUMMARY STATISTICS:
The variables mean, median, variance, standard deviation, minimum, maximum, and percentiles are examples of descriptive statistics for matrices offered by Minitab. These statistics provide a summary of the values in each matrix column or row.

MATRIX OPERATIONS :

Minitab supports a number of matrix operations, including matrix multiplication, matrix inversion, eigenvalue analysis, and determinant analysis. Numerous mathematical and statistical investigations, including linear regression, multivariate analysis, and matrix algebra, can benefit from these processes.

MATRIX VISUALISATION :
Matrix visualisation tools are available in Minitab. To visualise the relationships or patternspresent in the matrix data, you may construct scatterplots, line plots, or bar charts. To see the size or distribution of values across matrix members, you may also generate heat maps or color-coded matrices.

MULTIVARIATE ANALYSIS :
Principal component analysis (PCA), factor analysis, and discriminant analysis are just a fewof the multivariate analytic methods that Minitab offers. These methods are employed to examine connections, trends, and resemblances between variables inside a matrix.

MATRIX DECOMPOSITION :
Singular value decomposition (SVD), LU decomposition, and Cholesky decomposition are three matrix decomposition methods that Minitab supports. These methods dissect a matrix into its component parts and reveal details about the structure or characteristics of the data.

RESULTS AND DISCUSSION

SPATIAL AND TEMPORAL MAPS:

The generation of maps were done for the following seasons:

Pre-Monsoon Season (March – May)
Monsoon season (June – September)
Post-Monsoon Season (October – November)

PRE-MONSOON SEASON
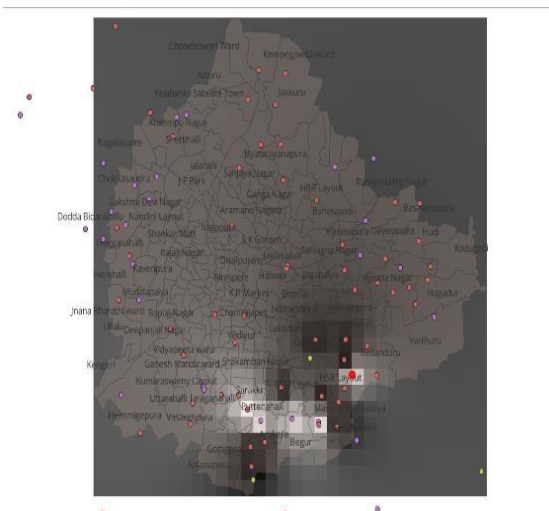
Figure 1: Interpolated map of Bangalore region in Pre-Monsoon season

In Pre-Monsoon Season the WQI value varyfrom (88.2052-98.7489), for which the representation on the map varies from Black – White. Black being indicating comparatively less polluted and white being the most polluted lake. the color intensity will indicate the intensity of contamination of water.

The below table will show the list of the highly polluted lakes and their ward to which it belongs to.

TABLE 1:HIGHLY POLLUTED LAKES IN PRE-MONSOON SEASON

LAKE	WARD
Kaikondanahalli lake	Bellandur
Singasandra lake	Singasandra
Kodi-Singasandra lake	Singasandra
Begur lake	Begur
Arakere lake	Arakere
Putenahalli lake	Putenahalli

Let us focus on Kaikondanahalli lake and study its variation parameter vise using MINITAB

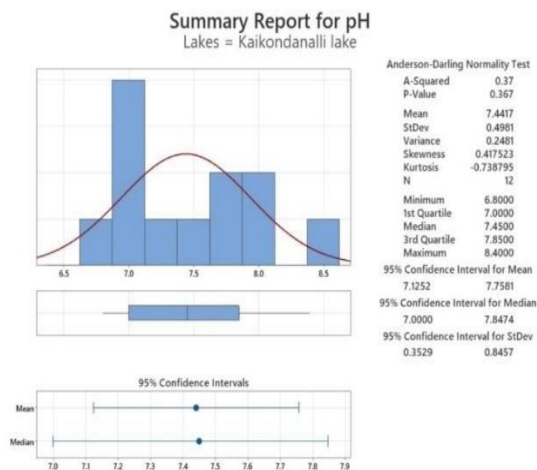SUMMARY REPORT FOR
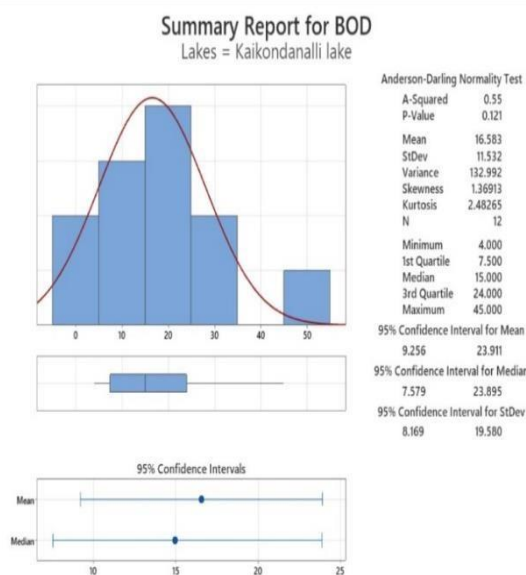KAIKONDANAHALLI LAKE

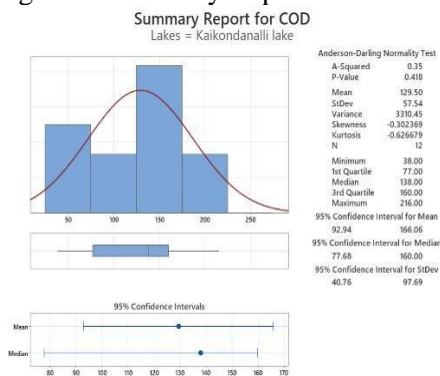Figure 2: Summary Report for Ph

Figure 5 : Summary Report for DO

Figure 3: Summary Report for BOD
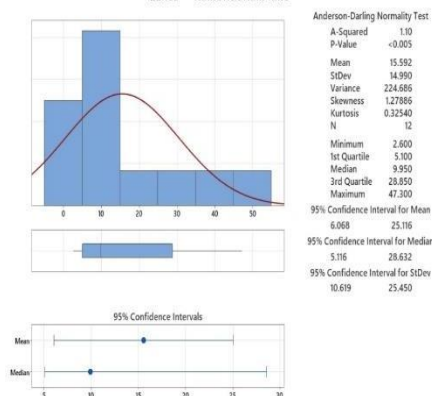
Figure 6 : Summary Report for Turbidity
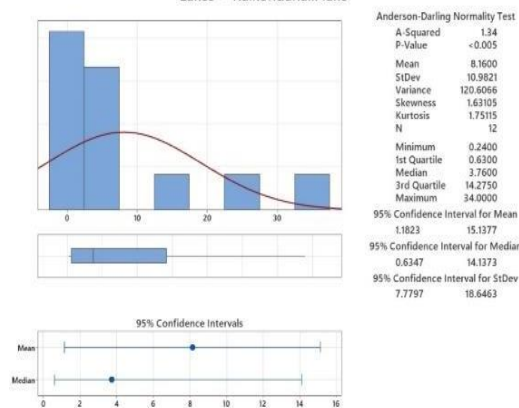

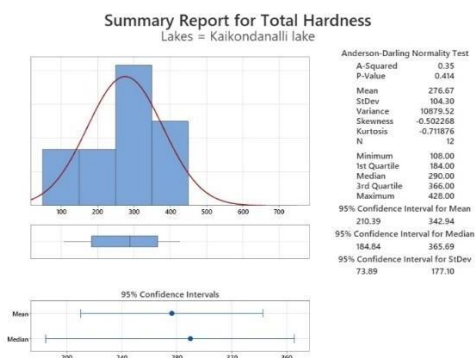Figure 4 : Summary Report for COD

Figure7 :Summary Report of ammonia
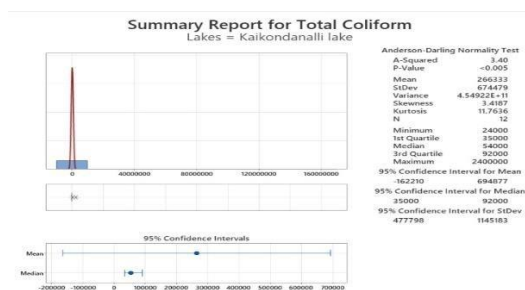
Figure 7:Summary Report for Total Hardness

Figure 9 :Summary Report for Total Coliform

P-value in the normality test helps to determine whether the database follows a normaldistribution or not . if,

• P-value is <0.05 indicates that the data is not normal.

• P-value is >0.05 indicates that the data is normal.

Since the p value on normality test for data on is less than 0.05, the data is non-normal.

Hence for testing the equality of medians Kruskal Wallis test is done.

Kurtosis gauges how peaky or flat a distributionis in comparison to a normal distribution. Understanding the relevance of kurtosis can help reveal a dataset's form and properties.

Three types of Kurtosis are:
1. Leptokurtic
2. Platykurtic
3. Mesokurtic

TABLE 2 : P VALUE FOR KAIKONDANAHALLI LAKE

NORMAL DISTRIBUTION	NON NORMAL DISTRIBUTION
pH	TURBIDITY
BOD	AMMONIA
COD	TOTAL COLIFORM
DISSOLVED OXYGEN	-
TOTAL HARDNESS	-

TABLE 3: KURTOSIS FOR KAIKONDANAHALLI LAKE

PLATYKURTIC	LEPTOKURTIC	MESOKURTIC
Ph	TOTAL COLIFORM	-
COD	-	-
DISSOLVED OXYGEN	-	-
TURBIDITY	-	-
TOTAL HARDNESS	-	-
AMMONIA	-	-
BOD		

MONSOON SEASON
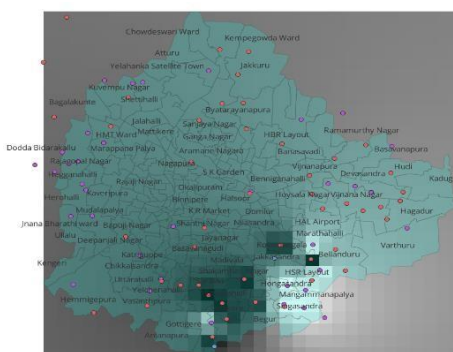
Figure 10 : Interpolated map of Bangalore region in Monsoon season.

In Monsoon Season the WQI value vary from (88.0146-99.6914) , for which the representation on the map varies from Black – White . Blacking indicating comparatively less polluted and white being the most polluted lake. the color intensity will indicate the intensity of contamination ofwater.

The below table will show the list of the highly polluted lakes and their ward to which it belongs to.

TABLE 4 : HIGHLY POLLUTEDLAKES MONSOON SEASON

LAKE	WARD
Bellandur lake	Bellandur
Kaikondanahalli lake	Bellandur
Kasavanahalli lake	Bellandur
Somasandrapalya lake	Hsr Layout
Harlur lake	Singasandra
Parappana Agrahara lake	Singasandra
Singasandra lake	Singasandra
Kodi Singasandra lake	Singasandra
Kalena Agrahara lake	Begur

Let us focus on Bellandur lake and study its variation parameter vise using MINITAB
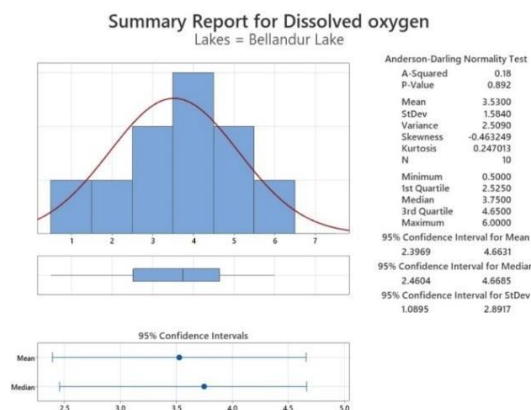
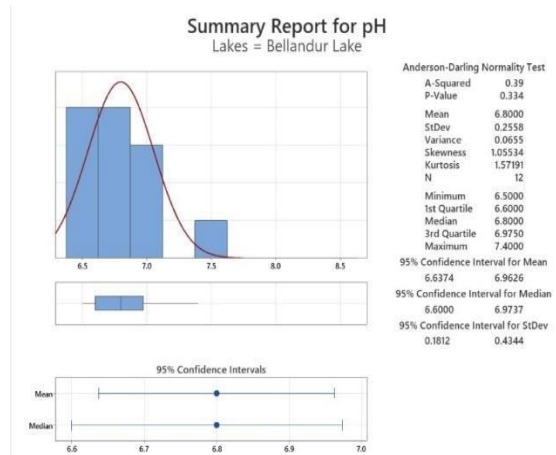SUMMARY REPORT FOR BELLANDURLAKE

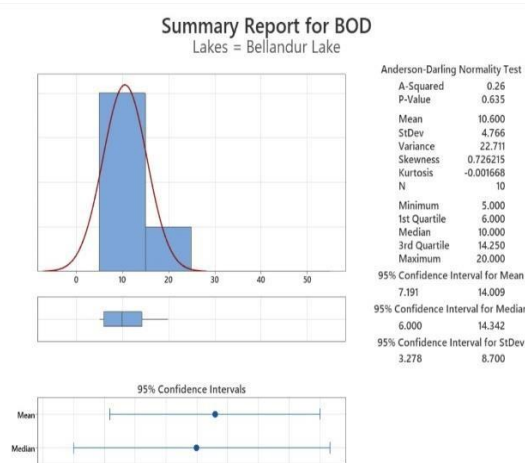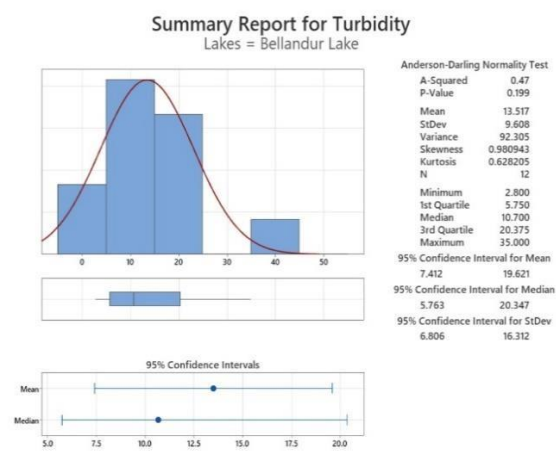Figure 11: Summary Report for pH
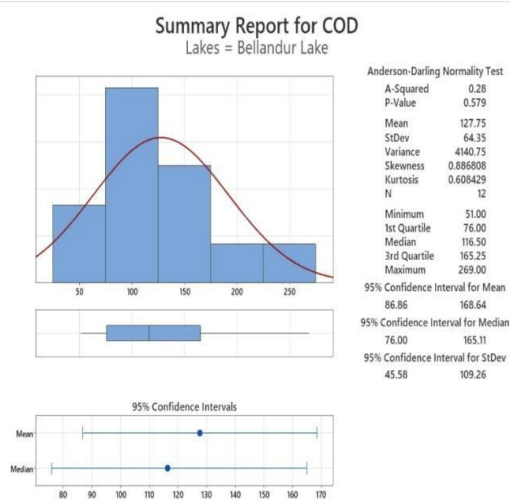

Figure 12 : Summary Report for BOD

Figure 13 : Summary Report for COD

Figure 14 : Summary Report for DO

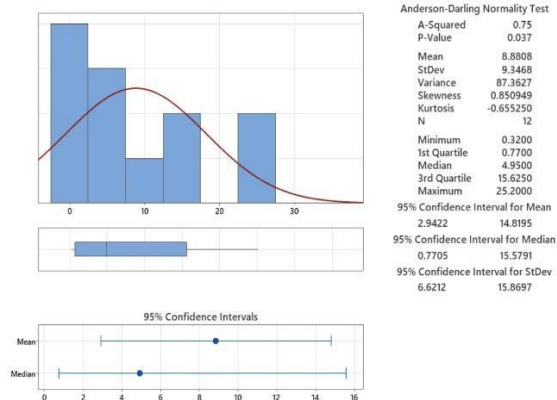Figure 15 : Summary Report for Turbidity
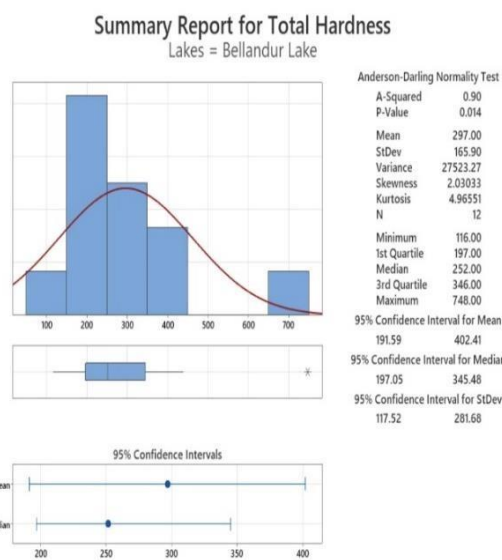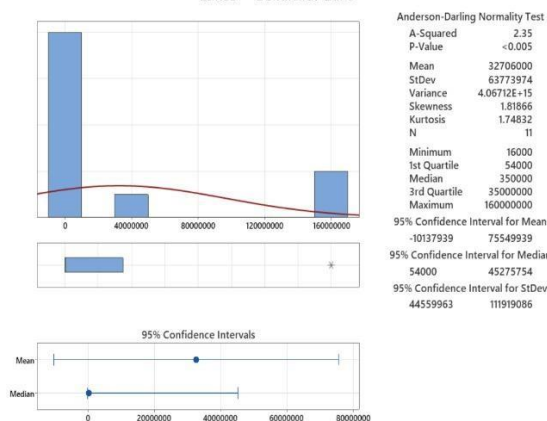

Figure 16 : Summary Report for Total Hardness

Figure 17 : Summary Report for Ammonia

Figure 18 : Summary Report for Total Coliform

TABLE 5 : P VALUE FOR BELLANDUR LAKE

NORMAL DISTRIBUTION	NOT NORMAL DISTRIBUTION
pH	TOTAL HARDNESS
BOD	AMMONIA
COD	TOTAL COLIFORM
DISSOLVED OXYGEN	-
TURBIDITY	-

TABLE 6 : KURTOSIS FOR BELLANDUR LAKE

PLATYKURTIC	LEPTOKURTIC	MESOKURTIC
pH	TOTAL HARDNESS	-
BOD	-	-
COD	-	-
DISSOLVED OXYGEN	-	-
TURBIDITY	-	-
AMMONIA	-	-
TOTAL COLIFORM	-	-

POST-MONSOON SEASON
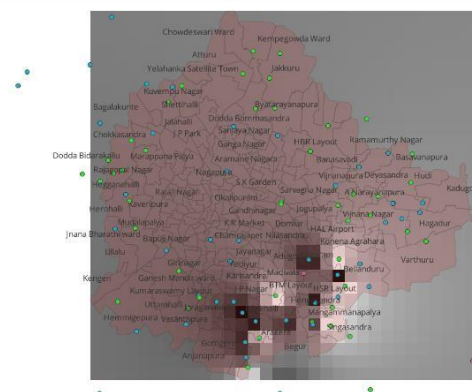
Figure 19 : Interpolated map of Bangalore region in Post Monsoon season.

In Post-Monsoon Season the WQI value vary from (88.8215-99.9114), for which the representation on the map varies from Black – White . Blacking indicating comparatively less polluted and white being the most polluted lake the color intensity will indicate the intensity of contamination of water.

The below table will show the list of the highly polluted lakes and their ward to which it belongs to.

TABLE 7 : HIGHLY POLLUTEDLAKES IN POST-SEASON SEASON

LAKE	WARD
Bellandur lake	Bellandur
Kaikondanahalli lake	Bellandur
Parappana Agrahara lake	Singasandra
Madiwala lake	Bilekhalli
Basavanapura lake	Begur

Let us focus on Parappana Agrahara lake and study its variation parameter vise using MINITAB

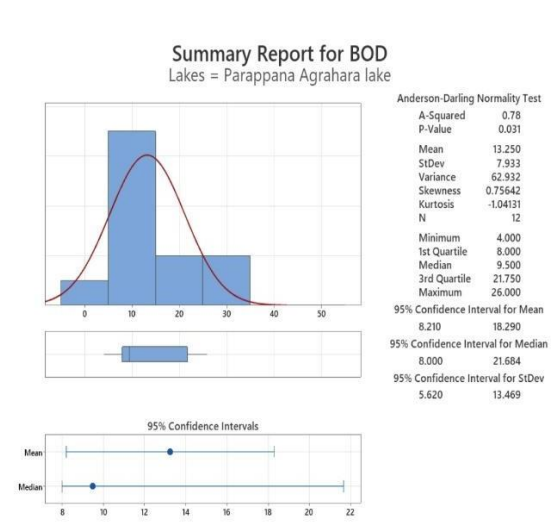SUMMARY REPORT FOR PARAPPANA AGRAHARA LAKE
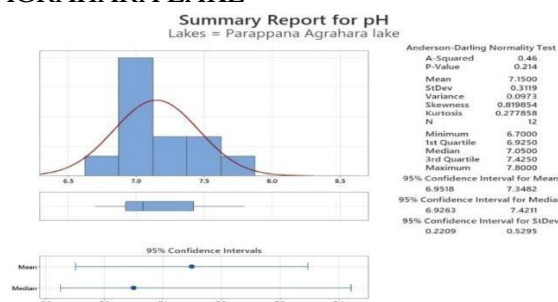
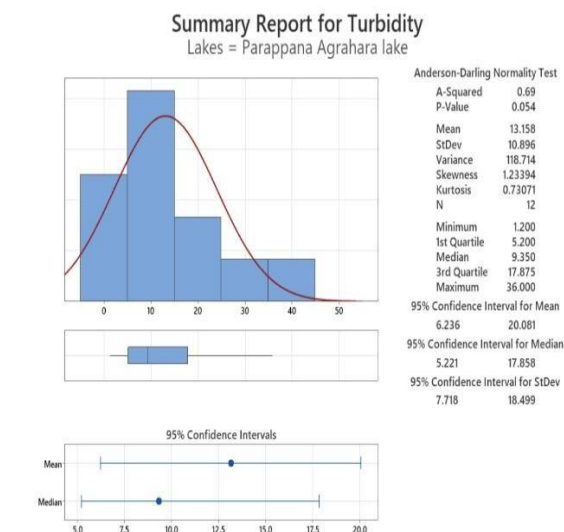Figure 20 : Summary Report for pH

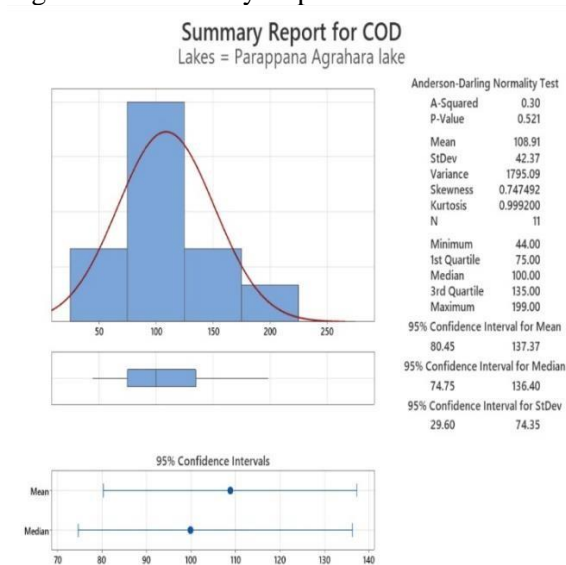Figure 21 : Summary Report for BOD

Figure 22 : Summary Report for COD

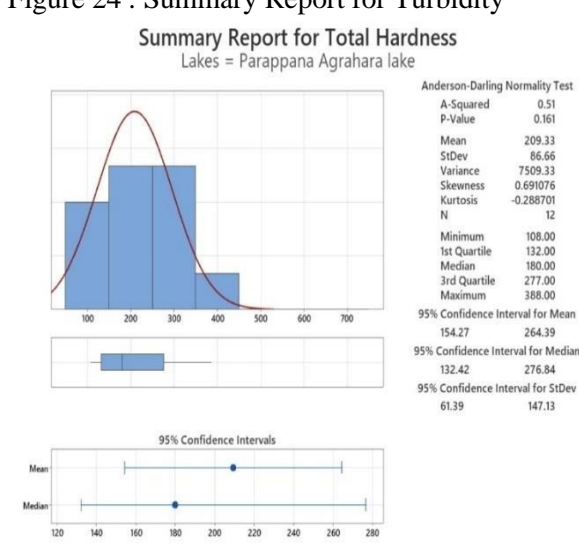Figure 23 : Summary Report for DO

Figure 24 : Summary Report for Turbidity

Figure 25 : Summary Report for Total Hardness
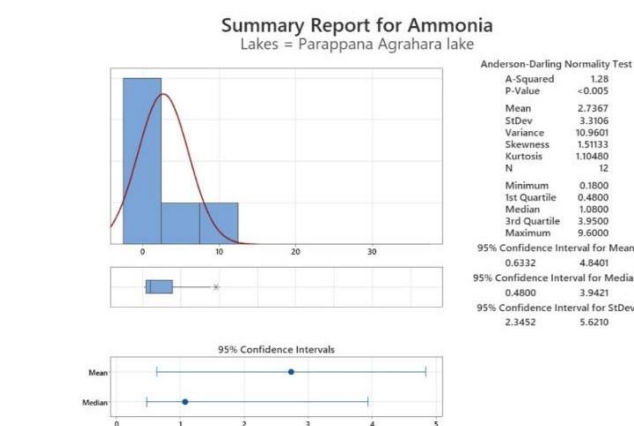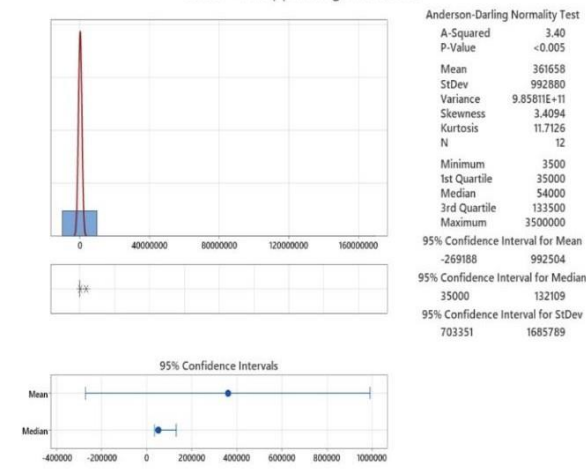

Figure 26 : Summary Report for Ammonia

Figure 27 : Summary Report for Total Coliform

TABLE 8 : P VALUE FOR PARAPPANA AGRAHARA LAKE

NORMAL DISTRIBUTION	NOT NORMAL DISTRIBUTION
pH	BOD
COD	DISSOLVED OXYGEN
TURBIDITY	AMMONIA
TOTAL HARDNESS	TOTAL COLIFORM

TABLE 9 : KURTOSIS FOR PARAPPANA AGRAHARA LAKE

PLATYKURTIC	LEPTOKURTIC	MESOKURTIC
pH	TOTAL COLIFORM	
BOD		
COD		
DISSOLVED OXYGEN		
TURBIDITY		
TOTAL HARDNESS		
AMMONIA		

MATRIX PLOT

The matrix plot conducted here shows the relation between all the parameters of all the three lakes taken together . The parameters taken here for comparing for all the months throughout the year are

- pH
- Bod
- Cod
- Dissolved oxygen
- Turbidity
- Total alkalinity
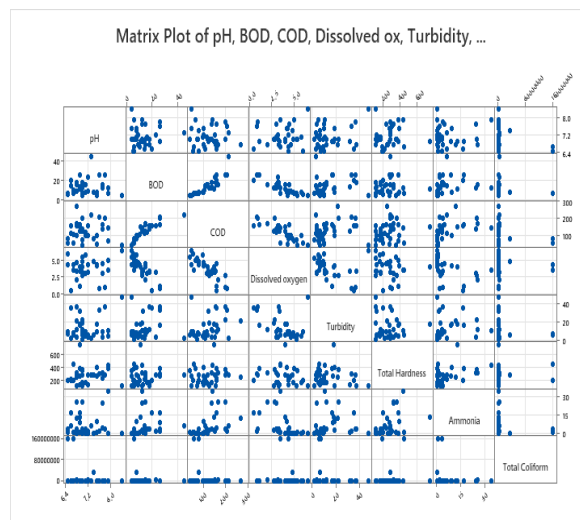- Total hardness
- Calcium hardness
- Magnesium hardness

Figure 28 : Matrix plot of various parameters

CORRELATION

TABLE 10 : CORRELATION ANALYSIS

	pH	BOD	COD	Dissolved oxygen	Turbidity	Total Hardness	Ammonia
BOD	-0.089						
COD	-0.054	0.851					
Dissolved oxygen	0.100	-0.810	-0.800				
Turbidity	0.226	0.217	0.295	-0.386			
Total Hardness	0.095	0.054	0.142	-0.170	-0.134		
Ammonia	0.068	0.295	0.448	-0.451	0.087	0.439	
Total Coliform	-0.327	-0.057	-0.072	-0.307	0.160	-0.011	0.090

The correlation coefficient shows the extent of association exists between two variables.

The greater the value of coefficient indicates a good relationship between two parameters.
According to our study, there is a direct relationship between two parameters on decrease or increase of one parameter the other will also change.
From the matrix plot we can conclude that BOD and COD are positively related. The correlation coefficinet is 0.851 confirms this relationship.
Dissolved oxygen is having negative relationship with BOD and COD. The correlation coefficient is -0.810 and -0.8 between these variables.

CONCLUSIONS

For a developing country like India, it is necessaryto depend on industrial activities to give a push forit's economical growth but at the same time it is crucial to maintain the quality of environment. Our study focuses on major water quality parameters (pH, BOD, COD, DO, Turbidity, Total Hardness ect) .And their impact for the seasonal variation. With reference to our above study and from the data given to our from the KSPCB office

, we can conclude that all the lakes in Bangalore region are not satisfactory. From the spatial and temporal analysis of the pre monsoon season , it is evident that the WQI for Kaikondanahalli lake , Singasandra Lake , Kodi-Singasandra lake , Begur lake, Arakere lake & Puttnahalli lake are high compared to other lakes in bangalore region and for the monsoon season , it is evident that the WQIfor Bellandur lake, Kaikondanahalli lake ,Kasavanahalli lake, Somasandrapalya lake,Harlur lake, Parappana Agrahara lake, Singasandra Lake, Kodi-Singasandra lake, Kalena Agrahara lake are high comparatively to the other lakes and in the post-monsoon season, the WQI for Bellandur lake, Kaikondanahalli lake, Parappana Agrahara lake, Madiwala lake, Basavanapura lake are high comparatively to the other lakes in bangalore.

Normality tests for Kaikondanahalli lake during the pre monsoon season shows us that the parameters pH , Bod , Cod , Dissolved oxygen and Total harndess show normal distribution and Turbidity, Ammonia and Total Coliform show non normal distribution.Normality test forBellandur lake during the monsoon season showsus that the parameters pH , Bod, Cod , Dissolvedoxygen , Turbidity show normal distribution and the parameters Total hardness , ammonia and Total coliform shows non normal distribution. Normality test for Parappana Agrahara lake during the post monsoon season shows us that the parameters pH, Cod, Turbidity , Total hardness show normal distribution and the parameters Bod, Dissloved oxygen, Ammonia, Total coliform show non normal distribution.

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