Develop To Model Assess Of River Basins In Tamilnadu

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ABSTRACT

A river basin is the land that water flows across or under on its way to a river. Just as a bathtub catches all of the water that falls within its sides, a river basin sends all of the water falling within it to a central river and out to an estuary or to the ocean. The management of river water quality is a major environmental challenge. Monitoring different sources of pollutant load contribution to the river basin is quite a difficult, laborious and expensive process which sometimes leads to analytical errors also. The main objective of the present study is to develop a model to assess. Large river basins are made up of many smaller watersheds. Everyone lives in a river basin. It is part of your ecological address. You can change what happens in your river basin, for good or bad, by how you treat the natural resources – the soil, water, air, plants and animals. As water moves downstream, it carries and leaves behind gravel, sand, and silt. It was observed that the basin water had more amount of Hardness that resulted in large number of people suffering from health problems related to the kidney. Due to the correlations and interactions among water quality parameters; it is interesting to investigate whether a domain specific mechanism governing observed patterns exists to prove the predictability of the water quality variables like Hardness, TDS, and Cl. A new approach, viz. the use of ANN and GIS based analysis has been developed in this study to predict the concentrations of Hardness, TDS and Cl. It also carries bacteria and chemicals. Whatever happens to the surface water and groundwater upstream will eventually have an effect downstream. Even if you don’t live near a river, you still have an effect on your river basin. The Study area of research work is Cauvery River Basin in Tamilnadu, India. The monthly water quality parameters are collected and analyzed from five selected gauging stations of Tamilnadu during the months of January to December from 2003 to 2012. The cations such as Ca, Mg, Na, K and anions like HCO₃, CO₃, Cl, SO₄ and NO₃ were analysed in the laboratory. General statistical analyses of the bio-physico and chemical parameters of the basin's surface water quality have been carried out to find the interrelationships among them, which constitute the first phase of the present study. By this study it is found that a strong correlation exists between SO₄ and COD. This technique is particularly suitable for problems that involve the manipulation of multiple parameters, nonlinear interpolation and significance that is not easily amenable to conventional, theoretical and mathematical approaches. The physico-chemical parameters such as pH, DO, TDS, NO₃, BOD, COD, Total Alkalinity, Total hardness, Ca, Mg, Cl, SO₄ and F of the basin have been taken into account for deciding the quality characteristics of the basin.

Keywords: Develop, Model, Assess, River Basins, Tamilnadu

1.INTRODUCTION

Water is one of the prime elements responsible for life on the earth. The six billion people on earth use nearly 30 percent of the world’s total accessible renewal water supply. Yet billions of people are deprived of basic water availability. Among other countries in the world, India is one of the few selected countries endowed with reasonably good land as well as water resources. India is a country with vast geographic, biological and climatic diversity. Average annual precipitation including snowfall is approx. 4000 billion cubic meters (BCM) over the country. The average annual water resources in various river basins are estimated to be 1869 BCM, of which 1086 BCM is utilisable including 690 BCM of surface water and 396 BCM of ground water. The rest of the water is lost by evaporation or flows into the sea and goes unutilised.

India’s surface water flows through 14 major river basins. In addition to major rivers, there are 44 medium and 55 minor river basins. These rivers are fast flowing and are mostly monsoon fed. Due to the spatial and temporal variations in precipitations as well as the rapid growth of population and improved living standards, the demand for supply of water resources in general and fresh water in practical is increasing. As a result of this, per capita availability of water is reducing day by day. However, surface water resources in the country are in much greater volume when compared to the groundwater resources. The climate change is affecting the precipitation and ultimately affects the quantity of water available, on the other hand, increasing loads from point and non-point sources are deteriorating the quality of surface as well as ground water resources. As the majority of the rivers in the country are not perennial, groundwater actually sustains much of the population during the
lean months. There is a tremendous variation both in the quantity and quality of discharge from region to region in these river basins. With a few exceptions, all the medium and minor river basins originate in the mountains, and thus exhibit a common feature of fast flowing and monsoon-fed streams in the hilly regions. By the time they reach the plains they are mostly transferred as tidal streams. The treated or untreated discharges from such sources would always find a way into the rivers that oscillate like a pendulum due to the seasonal flow character of these rivers. During monsoon, when rainwater flows down the river the discharge in the pollutants, the flow rate and flow depth oscillate because of the tides in the tidal reaches. As the storm water moves downstream, the flushing out time for the pollutants decreases substantially. All the major river basins are not perennial. Many of the major river basins also go dry during the summer leaving insufficient water for dilution of waste water discharged in them.

1.1 Water Quality In River Basins
Water is very vital for human beings and the health of its ecosystem. Thus quality of water is extremely important. The surface water quality is a very sensitive issue and is also a great environmental concern worldwide. Surface water pollution by chemical, physical, microbial and biological contaminants can cause epidemic problems, at times all over the world. Fish survival / growth and other biodiversity, conservation activities, recreational activities like swimming and boating, industrial / municipal water supply, agricultural uses such as irrigation and livestock watering, waste disposal and all other water uses are affected by the physical, chemical, microbial and biological conditions that exist in the water courses and also in subsurface aquifers. The surface water systems are naturally open to the atmosphere, such as lakes, rivers, estuaries, reservoirs and coastal waters. A natural process such as changes in erosion, precipitation, weathering of crustal material as well as any anthropogenic influences such as urban, industrial and agricultural activities, increasing rate of consumption of water resources, degrade in the quality and quantity of surface water and make it unsuitable for domestic uses. Industrial waste water, runoff over the agricultural lands and municipal sewage disposal are the most vulnerable for water pollution. The concentration of biological available nutrients in excess and concentration of toxic chemicals leads to diverse problems such as toxic algal blooms, loss of oxygen in water, fish kill loss of biodiversity and loss of aquatic plants and coral reefs.

1.2 Statistical And Multivariate Analysis Of Water Quality
Statistical analysis is the study of collection, organization, analysis, interpretation and presentation of sample data. It also refers to a collection of methods used to process large amount of data and to report overall trends. It deals with all aspects of data, including planning of sample data collection. Statistical analysis can be broken into five discrete steps; such as (a) Describe the nature of data to be analyzed and presented, (b) Explore the relation of data with each other or underlying population,(c) Create a model to summarize or organize understanding of how the data relates to each other, (d) Prove or disprove the validity of the model, (e) Employ predictive analysis for the future trends. Multivariate statistical analysis (MVA) is based on the statistical principle of multivariate statistical analysis, which involves observation and analysis of more than one variable at a particular time.

2. THE STUDY AREA AND DATA COLLECTION
2.1 General Description Of The Study Area
The Study area of the proposed research work is Cauvery River Basin. The basin is an interstate basin which lies between latitudes of 20°28’ North to 25° 35’ North and longitudes of 80°52’ East to 82° 30’ East. The river is formed by two major tributaries namely Sankh and Koel, which originate in the state of Jharkhand and the Basin spreads across the states of Chhattisgarh, Jharkhand and Tamilnadu. The river gets its name below the confluence point of Sankh and Koel at Vedvyas in Sunderagarh district of Tamilnadu. The river splits into numerous channels, criss- crossing the channels of Baitaran River and finally merges to Bay of Bengal. (Figure.2.1)
2.1.1 Cauvery River Basin
The River basin has a total drainage area of 39,268 km², out of which 22,516 km² is in Tamilnadu state, 15,405 km² in Jharkhand state and 1,347 km² in Chhattisgarh state. In Tamilnadu, eight districts are covered by the river basin viz., Sundergarh, Keonjhar, Sambalpur, Deogarh, Angul, Dhenkanal, Jaipur and Kendrapada. The river is formed by two principal tributaries viz., Koel and Sankh, which originates in the state of Jharkhand. The river referred as Cauvery River at the confluence point near Vedvyas, in Tamilnadu at an elevation of 200m above mean sea level. Below the confluence point, the river heads its way to southeast direction up to Bay of Bengal and traverses a length of 461 km. Below Jenapur station, the Cauvery bifurcates into two major deltaic branches namely Kimiria and Kharusuan. The two deltaic branches join at the downstream almost at a distance of one hundred kilometres. The river receives flood flows from Bartarani River before discharging finally into Bay of Bengal near Dhamra.(Figure 2.2)

2.1.2 Climate And Rainfall
The river basin is under a tropical monsoon climate zone. The three well marked seasons in the river basin are winter, summer and rainy season. The climate close to the coastline, is somewhat affected by sea where as in the elevated areas of hills and plateau climate is cooler due to the altitude effect. The minimum annual temperature is 4°C in winter and maximum annual temperature is 47°C in summer. The monsoon months include June to September having normal annual rainfall of 1305 mm with a minimum of 969 mm and a maximum of 1574 mm. The water deficit in the basin is moderate from the months of November to February. However, during the months of March to May, the soil moisture deficit becomes large making it very difficult for shallow rooted crops and vegetation to survive.

2.1.3 Soils
Soil in the Cauvery river basin can be classified into two groups based on soil formation namely residual and transported soil. The upper Basin of river is grouped under red gravel, red earth and yellow soil. The central region of river basin goes under mixed red and black loams, where as the lower basin grouped under red loam lateritic and lateritic soils. The delta region of Cauvery river basin goes under alluvial soil.

2.1.4 Population And Urban Growth
The total population of the basin area is 9,547 million according to census 2011, of which 2,252 million is urban population and 7,295 million is rural population. The live stock population is 3,928 million in the basin area. The basin has witnessed rapid growth of towns and total urban population which has led to extraction of large mineral wealth and consequent industrial growth. A number of towns including Rourkela Steel City , Talcher Thermal Complex, Angul, Raigarh, Dhenkanal. Birmitrapur have received a great impetus for the growth of industrial setups, which has led to the growth socio economic activities.

2.1.5 Industries
An integrated steel plant at Rourkela in Sundergarh district includes associated mines, Ancillaries’ by-products and downstream product units which has led to a wide scale industrialization of the area. The river basin with rich minerals and cheap labor offer an ideal ground for industrial growth. Sundergarh, Angul and Dhenkanal districts have a major share of industries. The Angul-Talcher complex has a significant water requirements, wastewater generation and environmental implications due to the consequent growth of industries in a few towns of the area. The growth of consumer goods and agricultural product processing units mostly for Rice and Oil start growing fast due to growing demand for their product in this region.

2.1.6 Flood Management And Drainage
During floods, the River turns into a large turbulent channel with a potential threat to life and property of the population in the basin area. The worst flood was observed on 20th August 1975 with 24, 246 m³/s with gauge level of 24.78 m at gauge site against the danger level of 23 m. The entire flood spill of the River Cauvery
continued to the sea over a 10 to 20 km wide and 70 km long flat flood plain. Cauvery River bifurcates below Jenapur and consequently conveys 60 to 70 percent of the discharge to Baitarani and Mahanadi. The entire delta area of 3500 km² is significantly flood prone. But to protect the densely populated Aul area, a 70 km long river bund is constructed blocking a part of the flood plain and protecting 25000 ha of agricultural land and 1,50,000 of population. The annual maximum flood discharge was recorded at Jenapur. The flood plain of 1500 km² is within the delta area experiences flooding of up to 1 to 2 m depth. Rengali Dam has moderated the high floods significantly and reduces the submersion of agricultural land during the kharif crop season.

2.2 Data Collection And Analysis

The complete data sets are divided into three seasons’ viz., summer, monsoon and winter season. Summer season includes the month of March, April, May, June. The Monsoon season includes the month of July, August and September. The winter season Include the month of October, November, December, January and February. Eleven physical, chemical and biological water quality parameters are selected for the analysis. The parameters are pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Electric Conductivity, Nitrogen as nitrate (Nitrate-N), Total Coliform (TC), Fecal Coliform (FC), Chemical Oxygen Demand (COD), Nitrogen as ammonia (NH₄-N), Total Alkali as CaCO₃ (TA as CaCO₃)and Total Hardness as CaCO₃ (TH as CaCO₃). The collected water quality parameter from five gauging stations viz., Panpash down-stream, Talcher up-stream, Kamalanga down-stream, Aul and Pottamundia data are tested, analyzed and validated with the data of Central Water Commission, Bhubaneshwar, Tamilnadu (CWC) and Tamilnadu Pollution Control Board, Bhubaneswar, Tamilnadu (OPSC) in the Environmental Laboratory of National Institute of Technology, Rourkela.

2.2.1 pH

pH is a measure of acidity or alkalinity of water, pH is an important limiting factor for aquatic life as well as for domestic uses. Pure distilled water is neutral with a pH of 7. It is expressed in a scale which ranges from 1 to 14. The geology and soils of the catchment largely determine the pH of stream waters under base flow conditions. Photosynthesis by aquatic plants and algae can cause significant variations in pH. Excessive growth of algae and in-stream aquatic plants can lead to elevated pH at certain times of the day. Industrial wastewater or contaminated storm water can cause significant changes to either acidic or alkaline conditions. A pH range of 6.5 – 8 is acceptable for freshwater. A range of 8 – 9 is optimal for estuary and sea water.

2.2.2 Dissolved Oxygen (DO)

The amount of oxygen in water to a degree shows its overall health. Dissolved Oxygen (DO) is a measure of quantity oxygen in milligrams per liter present of water. Dissolved Oxygen saturation is vital for aquatic organisms. Sewage effluent, decaying aquatic vegetation, contaminated storm water discharges and wastewater from human activities all reduce DO levels as they are decomposed by micro-organisms present in river water. River water that has adequate levels of DO can usually sustain a diverse aquatic community. In general, DO level of 3 mg/L are stressful to most aquatic organisms. Water with low DO from 0.5-2 mg/L is considered hypoxic and waters with less than 0.5 mg/L are anoxic.

2.2.3 Biochemical Oxygen Demand (BOD)

BOD is a measure of the amount of oxygen used by biological and chemical processes in a stream of water over a 5-day. BOD is calculated by measuring the oxygen used of the water on collection and then 5 days after storage in the dark at a constant temperature of 20°C. The difference between DO and BOD is the demand or consumption of oxygen by chemical and biological process. The BOD is measured in milligram per liter of water. Unpolluted and natural waters should have a BOD of 5 mg/L or less. Raw sewage may have BOD levels ranging from 150-300 mg/L.

2.2.4 Electrical Conductivity (EC)

Electrical Conductivity (EC) is a measure of the ability of water to pass electric current through it in water is affected by the presence of dissolved solids such as chloride, nitrate, sulphide, phosphate, sodium, magnesium, calcium, iron and aluminium. Electrical Conductivity also is affected by water temperature with warmer the water, the higher would be the EC. On the other hand streams that run through areas with clayey soils tend to have higher conductivity because of presence of materials that ionize when washed into water. The basic unit of measurement of EC is micro mho per centimetre or micro Siemens per centimetre. Distilled water has EC in a range of 0.5 to 3μmho/cm. The conductivity in rivers ranges from 100 to 1000 μmho/cm. The streams mixed with industrial waters can range as high as 10,000μmho/cm.

2.2.5 Total Coli Form Bacteria

Total Coli-forms (TC) are not likely to cause illness, but their presence indicates that your water supply may be vulnerable to contamination by more harmful microorganisms. The main sources of these pathogens are through improperly treated septic and sewage discharges, leaching of animal manure, storm water runoff, domestic animals or wildlife. The total coliform count can be done by Most Probable Number (MPN) per 100 ml of water. The TC count should be in a range of 50-500 MPN/100 ml in drinking water.
2.2.6 Faecal Coliform Bacteria
Like Total Coli-form, Fecal Coli-forms (FC) are the sources of pathogenic or disease causing bacteria and viruses. The disease causing organisms are accompanied by other common types of non-pathogenic bacteria found in animal intestines, such as faecal coli-forms bacteria. Enterococci bacteria and Escherichia coli (E.Coli) bacteria. The fecal coli-form count should be 150 MPN/100ml in primary contact like swimming. For drinking purposes the FC count should vary from 0-700 MPN/100ml.

2.2.7 Chemical Oxygen Demand
The Chemical Oxygen Demand (COD) is used to measure the amount of organic compounds in water. COD can be related empirically to BOD, organic carbon or organic matter. COD is an index of organic content of water because the most common substance oxidized by dissolved oxygen in water is organic matter having a biological origin; that is dead plant and animal waste. The concentration of COD is more in the bottom of water due to more organic matter in the bottom than the surface layer of water.

2.2.8 Total Hardness Expressed As Calcium Carbonate
Total hardness is the measurement of divalent cations (+2 ions) in the water and, like total alkalinity, is expressed as milligrams per litre (mg/L) of calcium carbonate (CaCO₃). When limestone and dolomite dissolve in water, one half of the molecule is calcium (the "hardness") and the other half is the carbonate (the "alkalinity"), so most of the times they are equal. One of the most obvious signs of water hardness is a layer of white film left on the surface of showers. The concentration of calcium ions (Ca²⁺) in freshwater is found in a range of 4 to 100 mg/L (10-250 mg/L of calcium hardness as CaCO₃). The heart of evaluation research is gathering information about the program or intervention. The evaluation and analysis is it to determine what it tells about the effectiveness of the research work, as well as about how effectiveness can be maintained and improved. Collecting quantitative data – information expressed in numbers – and subjecting it to a visual inspection or formal statistical analysis can tell whether the research work is having the desired effect, or may be able to tell about why or why not as well.

3. METHODOLOGY

3.1 Time Series Trend And Correlation Analysis
Trend analysis determines whether the measured values of a water quality parameter increase or decrease over a period that may be temporally or spatially. There are several statistical techniques available for trend analysis depending upon the characteristics of water quality data. Spearman’s Rank Correlation analysis was used for the trend and correlation analysis.

3.1.1 Spearman's Rank Correlation Analysis
In the test for trend, time series plots of all parameters at five selected consecutive gauging stations were produced temporally including water quality data about 12 months from 2003 to 2012. These plots provided a general indication of trend and supported observations were made later in statistical analysis. Spearman’s Rank Correlation coefficient is a non-parametric measure of statistical dependence between two variables. It assesses how well the relationship between two variables can be described using monotonic function. For the second test for trend, the entire data series for each parameter, paired with cumulative season for temporal variation, were analyzed using non-parametric Spearman’s criterion to detect the existence of trends in water quality parameters. The existence of a trend in temporal variation of data was checked for significance at a level of 5% from statistical tables of Student’s t-distribution.

3.2 Overall Water Quality Index (WQI)
In the calculation of water quality for river water, the importance of various water quality parameters depends on the intended use of water and from the point of view of suitability for domestic purposes. The standards (permissible values of various water quality parameters) for drinking water were recommended by Indian Council of Medical Research (ICMR). When ICMR standards for water quality were not available, the standards of United States Public Health Services (USPHS), World Health Organization (WHO), Indian Standard Institution (ISI) and European Economic Community (EEC) were considered.

3.3 Calculation Of Parts Of Water Quality Parameter In River Water
The ppm values of eleven water quality parameters from 2003 to 2012 were selected for the calculation of parts of each parameter in water in three respective seasons of summer, monsoon and winter at the gauging station; Panposh down-stream. Along with the water quality parameter, the daily discharge values at the given station of the respective years were collected for the analysis. The parts of each parameter can be calculated as:ppm of water quality parameter Discharge of the Panposh down-stream station in mm³/sec parts of parameter in water. From the above formulation, the increase or decrease of the parts of parameter in the river water was found out at the selected station i.e. Panposh down-stream, which was influenced mostly by industries and also by other effluents.

3.4 Multivariate Statistical Analysis
3.4.1 Multivariate Analysis Of Variance (MANOVA)
In many ecological or biological analyses, the variables are not independent at all over each other. The variables
have strong actual or potential interactions many times, inflating the error even higher than expected. In many such cases where the sequence of Analysis of Variance (ANOVA) was done, Multiple Analysis of Variance (MANOVA) was actual appropriate test for the study.

3.4.2 Multivariate Parameter Contrast Analysis
In certain cases, the analyses of parameters were found to be significantly different through MANOVA. The error in variance covariance matrix was however generally unknown. Therefore, the estimated value of error in variance-covariance matrix was used. The error in variance-covariance matrix was estimated by sum of squares and cross product (SSCP) matrix for the error divided by the error degrees of freedom. The statistic and Wilk’s Lambda were the approximate solution.

3.5. The Visual Approach For Defining Correlation
A visual aspect of correlation can be obtained by representing each one of a pair of variables as an axis in Cartesian coordinate system. The visual aspects of understanding may supply crucial insight about structures in the data being analysed and prevented the potential biases that may arise by directly interpreting numerical results yielded by running computational procedures. PCA deals with linear correlation focus on describing the connection between the points in the plot and a linear trend line. This linear trend line was constructed such that it minimized the perpendicular distances, from it to each point in the plot. It was known as the least squares fitted in line. Correlation might be confused with regression, thus it was important to stress out the differences between the two. In regression analysis; the dependable variable, Y and the variable designated a predictor variable called independent variable, X was tested.

3.5.1 Extraction Of Principal Components
The central idea of principal component analysis (PCA) is to reduce the dimensionality of a data set consisting of a large number of interrelated variables, while retaining as much as possible of the variation present in the data set. This was achieved by transforming to a new set of variables, the principal components (PCs), which were uncorrelated, and which were ordered so that the first few retain most of the variation present in all of the original variables. Principal component analysis was an analytical technique whereby a complex data set containing \( p \) variables was transformed to a smaller set of new variables, which maximized the variance of the original data set. All of the new variables were independent, i.e., were not correlated with each other (whereas the original, untransformed variables may have been correlated to a lesser or greater extent).

3.6 Factor Loadings
The factor loadings were also called as the component loadings in PCA, were the correlation coefficients between the variables in rows and factors in columns. Analogous to Pearson’s \( r \), the squared factor loadings was the percent of variance in that indicator variable explained by the factor. The percent of variance was obtained in all variables accounted by each other, the sum of squared factor loadings were added for that factor in column and were divided by the number of variables.

3.7 Communalities
The sum of squared factor loadings for all factors for a given variable in row was considered as the variance in that variable accounted for by all the factors and this was called as the communality. The percent of variance was measured by the communality in a given variable explained by all the factors jointly and were interpreted as the reliability of the indicator.

3.8 Artificial Neural Network (ANN)
The artificial neural network (ANN) has the capability to learn from the pattern known before. The artificial neural network can make predictions on the basis of its previous learning about the output related to new input data set; both set should be of same pattern. The prediction can go further once the network has been sufficiently trained. In the present study the water quality of Cauvery River was predicted depending upon the variation in water quality parameters. The paradigms in artificial neural network pattern were based on direct modelling of the human neuronal system. Back Propagation algorithm was the most effective learning technique in multilayer neural network structure. The feed forward back propagation neural network (BPNN) was always consisted of at least three layers: input layer, hidden layer and output layer as given in Figure 4.7. A network was needed to be trained before interpreting new information for the next process. Each layer was consisted of neurons and each neuron was connected to the next layer through weights those were called neurons in the input layer which sent its output as input for neurons in the hidden layer and similar was the connection between hidden and output layer. Number of hidden layer and number of neurons in the hidden layer were changed according to the problem was to be solved. The number of input and output neuron was same as the number of input and output variables.

To differentiate between the different processing units, values were called as biases were introduced in the transfer functions and were referred as the temperature of a neuron. The bias was like a weight and has an input of 1, while the transfer function filtered the summed signals received from this neuron. The transfer functions were designed to map neurons or layers net output to its actual output and they were simple step functions either linear or nonlinear functions. Except for the input layer, all neurons in BPNN were associated with a bias neuron.
and a transfer function. The application of transfer functions was depended on the purpose of the neural network. Output layer was produced and the vectors corresponding to the solution was computed.

3.9 Monte Carlo Simulation (MCS)
Simulation is generally defined as the process of replication of the real data based on a certain assumptions and the reality of the models are conceived (Kotegodaea al., 1998). Monte Carlo Simulation was applied as an experimental probabilistic method to solve deterministic problems. Monte Carlo Simulation in computers can easily simulate a large number of experimental trials that have random outcomes. When MCS was applied to uncertainty estimation, random numbers were used to randomly sample parameters. The analysis was closer with the underlying physics of actual measurement processes that were probabilistic in nature. Nicolis et al., 1995 was pointed out in nature the process of measurement, by which the observer communicated with a physical system, and was limited by a finite precision.

3.10 Root Mean Squared Error (RMSE)
Root Mean Squared Error or Root Mean Squared Deviation was a measure of the differences between values predicted by model or an estimator and the actually observed values. These individual differences were called as residuals when the calculations were performed over the data sample that was used for estimation, and were known as estimation errors when computed out of the sample. The RMSE was served to aggregate the magnitudes of errors in predictions for various times into single measure of predictive power. Root Mean Absolute Error was a good measure of accuracy, but was used only to compare forecasting errors of different models for a particular parameter and not between the parameter, as RMSE was a scale dependent error analysis.

3.11 Comparisons Between The Models
The eleven water quality parameters in five selected gauging stations of Cauvery River were estimated and predicted temporally i.e. depending upon seasonal variation by different models such as Adaptive Neuro-Fuzzy Inference System (ANFIS), Artificial Neural Network (ANN) and Monte Carlo Simulations (MCS) as discussed above. Comparisons were made with the help of graphical representation, correlation analysis and error analysis between the output values of the models and with the input values of the water quality parameters given to the applied models.

4. RESULTS AND DISCUSSIONS

4.1 Spearman’s Rank Correlation Analysis
Correlation plots with Spearman’s correlation coefficient value of all parameters at five selected consecutive gauging stations are made for summer, monsoon and winter for 12 months from 2003 to 2012. These plots provide a general indication of trend and supported observations were made later in statistical analysis. At the right hand corner of the graph, it shows the numbers of data taken, mean, Standard deviation, maximum and minimum ranges of the data. Depending upon the maximum and minimum ranges of data, the graphs are plotted for Spearman’s Rank Correlation Analysis.

The Spearman’s rank correlation analysis of pH shows the moderate values of correlation coefficient ($R_{sp}$) of 0.55 for summer, 0.50 for monsoon and 0.55 for winter seasons respectively. The correlation coefficients ($R_{sp}$) of dissolved oxygen (DO) for summer, monsoon and winter seasons were 0.56, 0.52 and 0.56 respectively. The correlation coefficients ($R_{sp}$) for Biochemical Oxygen Demand (BOD) were -0.52, -0.48 and -0.51 for summer, monsoon and winter respectively. The negative correlations with moderate values are due to the decreasing values of BOD at the particular season. The values for COD were -0.50, -0.52 and -0.54 for the respective seasons as shown in the above figures. The correlation coefficient for the conductivity in three seasons of summer, monsoon and winter showed the negative moderate correlation values of -0.55, -0.51 and -0.54 respectively as extracted from the Spearman’s correlation analysis. The correlation coefficients ($R_{sp}$) for Nitrate-N in the respective seasons are -0.52, -0.59 and -0.55 respectively. The values varied negatively with moderate variation. Likewise the negative correlation coefficients for NH$_4$-N are -0.62, -0.52 and -0.53 for respective seasons.

4.2 Overall Water Quality Index (WQI) Calculation
The water quality indices are calculated by applying the formulations and calculations as discussed in chapter IV. According to the water quality indices the level of pollution of water varies from excellent to unsuitable for use are known at five selected gauging stations in three seasons from January 2003 to December 2012. Physio-chemical characteristics of surface water quality of Cauvery River depend upon the water quality parameters. These physio-chemical parameters show the temporal variations in water quality. Water is slightly alkaline with its pH ranging from 7.56 to 7.75. Dissolved Oxygen exceeds the permissible range and it varies from a mean value 8.60 mg/L in monsoon to a maximum value of 12.10 mg/L in summer. The values of Biochemical Oxygen Demand are within the permissible limits from 2.02 mg/L in monsoon to 2.35 mg/L in summer. Electrical Conductivity shows its maximum mean at summer season of 211.77 mmho/cm. The Nitrate-N in mg/L varies its value from 0.87 mg/L to 1.17 mg/L, which is the range with in the permissible limit. The total Coliform exceeds
the permissible range in three consecutive seasons. Likewise the Faecal Coliform were within the permissible range in summer, exceeds slightly Conductivity of the surface water of Cauvery River Basin also within the permissible limits, which in monsoon and again within the range in winter season. The COD values are within the permissible range from 18-30 mg/L in three seasons. The Nitrogen as Ammonia exceeds slightly from its permissible range at summer and monsoon but exceeds a bit in winter season. The values of TA as CaCO₃ and TH as CaCO₃ are lower than their permissible limits in all the three seasons. The water quality Index shows the temporal variation of the given water quality parameters in Cauvery River Basin. Figure.5.1 shows Temporal variation of WQI

4.4 Multivariate Analysis Of Variance (Manova) With Discriminant Analysis
The summary of descriptive statistics of the results of the analysis is indicating the maximum, minimum, mean values of the parameters and the standard deviation. In summer season, TH as CaCO₃ has the high value of 132 mg/L, where as BOD has the highest value of 8.90 mg/L. Likewise in monsoon, TH as CaCO₃ has the high value of 111 mg/L and Ammonia-N has the maximum value of 4.48 mg/L. Similarly, in winter season again TH as CaCO₃ has the high value of 120 mg/L and BOD has a maximum value of 7 mg/L. The standard deviation around the means is substantially high and random. This may be the results of temporal as well as spatial changes and also the different anthropogenic activities surrounding the study area. In order to explore the spatial variation among different gauging stations and seasonal changes, Analysis between and within the water quality parameters shows the small significant differences at a significant level of α=0.05. From these results it can be concluded that the spatial sampling interval of 400 km is too a long distance to focus properly in Cauvery River Basin for the gauging stations situated. The river is impacted by the same or similar influences over the spatial sampling interval which explain the lack of large significant variation in the properties in the study area in three consecutive seasons. This will be useful in monitoring protocol, but there should not be much change in the properties will be not be expected in the river. Any observed significant change could suggest a point source polluting it. It measures each parameter’s potential before the discriminate model is created. Each test displays the results of one-way ANOVA for the parameter using season as the grouping variable. As shown by p-value (Sig.), all the water quality parameters significantly contributes to the model. The value of Wilk’s lambda indicates the parameter is better at discriminating between groups. The parameters discriminating ability is ranked from the highest to the lowest in summer, as follows: Nitrate-N, BOD, Electrical Conductivity, COD, pH, NH₄-N, TH as CaCO₃, TC, DO, TA as CaCO₃ and FC. Likewise the parameters listed in monsoon are: pH, TH as CaCO₃, DO, Nitrate-N, COD, BOD, Conductivity, NH₄-N, TA as CaCO₃, TC and FC. For the season of winter the parameters are listed as: COD, BOD, TH as CaCO₃, Nitrate-N, Conductivity, pH, DO, TC, TA as CaCO₃, FC and NH₄-N. Two discriminate functions are obtained and the total variance cumulative was 100% between the seasonal months. The first function in the summer explained 63.8% of the total variance between the months while second function explained 36.12%. For the season of monsoon, the first and second function explained 63.2% and 36.7% respectively. Likewise for the season of winter, the two functions explained 63.9% and 36.0% respectively. Fisher’s linear discriminate function coefficient which can be used for predicting the likely season a particular water sample is collected in Cauvery River. Wilk’s lambda is equal to the proportion of the total variance in the discriminate scores not explained by differences among groups. Smaller values of Wilk’s lambda tests indicate greater discriminatory ability of the function. The small values of Wilk’s lambda of 0.079 in summer to 0.082 in winter shows the discriminate functions, which expressed those very small portions of the discriminate scores, is not explained by the differences among seasonal months in three seasons. The Chisquare test as given in the table is tested the hypothesis that all the means of the functions are listed as functions 1 and 2, and are equal across groups of seasonal months. The small p-value of 0.00 to 0.40 indicates that discriminate functions separating the seasons from one another moderately. Temporal variation of the River is
also analysed using discriminate functions as shown in Table. The validity of using discriminate functions for the prediction is certain as 99.2% of original group cases correctly classified or predicted in Table.

5. CONCLUSIONS

Analysis of water quality for Cauvery River is done by various techniques like Spearman’s Rank Correlation, Calculation of Parts of water quality parameters, Overall Water Quality Index(WQI), univariate Analysis of variance (MANOVA) with Discriminant Analysis, Principal component Analysis and Factor Analysis, Canonical Correlation Analysis (CCA), Cluster Analysis (CA). Modelling is done using Adaptive Neuro-Fuzzy Inference System (ANFIS) in MATLAB, by Artificial Neural Network (ANN) and risk based analysis by Monte Carlo simulations (MCS). The Error analysis and performance evaluation of these models was also done to know the best fit model for this study.

Conclusions from the present research work can be listed as follows:

• Spearman’s Rank Correlation Analysis indicates season showing increasing trend. Biochemical Oxygen Demand, Chemical Oxygen Demand, Electrical Conductivity, itrate as Nitrogen, Total Coliform bacteria, Faecal Coliform bacteria, Nitrogen as Ammonia, Total Hardness as CaCO$_3$, Total Alkalinity as CaCO$_3$ in monsoon and winter seasons show decreasing trend. These variations are due to the temporal variations in gauging stations.

• From the calculation of parts of parameter in river water, it can be stated that the quantity of water parameters in three consecutive seasons follow an equal trend. It can be concluded that, the inflow of effluents to the river are constant throughout the year.

• The Water Quality Index (WQI) values for the gauging stations vary from excellent to good in monsoon season and from good to poor during summer and winter seasons. The ranges of water quality parameters were within the range as recommended by ICMR and the water can be used for domestic purposes. However, necessary preventive measures to maintain good water quality of Cauvery River Basin must be taken up to ensure the safety of the River Basin and to preserve this valuable resource to the future generations. Water Quality Index may be used as a tool to convey the useful information regarding the quality of water in an easy and understandable way to the public and policy makers.

• Multivariate statistical techniques are used to examine spatial and temporal variations in water quality. Discriminant analyses on the gauging stations show that three is small difference between the stations at three seasons investigated. This suggests that the anthropogenic activities, mainly the effluents of industries, runoff from agricultural lands and waste water from residential areas into the river account for the observed variability in the water quality (especially with respect to pH, Electrical Conductivity and Chemical Oxygen Demand).

• Water Quality is a vague term that cannot easily be described using crisp data set. Instead, it made a sense when it is considered to be a fuzzy set that provides the mathematical foundation to express the term water quality in a linguistic way, e.g. excellent. Good, poor, very poor and unsuitable. Fuzzy reasoning technique does not rely on a crisp data set, rather uses linguistic terminology to process the output. To this end the Adaptive Neuro-Fuzzy Inference System (ANFIS), which integrate fuzzy logic with neural network, are proposed to predict WQI along with ANN model. The ANFIS and ANN model predicts the water quality with a reasonable accuracy. Regression plots between actual and predicted WQI through ANFIS model for training and testing data have revealed a high degree of coefficient of determination ($R^2$) values of 0.994 and 0.995 for training and testing in summer, 0.985 and 0.990 in monsoon and 0.992 and 0.993 in winter respectively. However, the coefficients of determination ($R^2$) for Artificial Neural Network (ANN) between actual and predicted values of WQI are 0.945, 0.941 and 0.956 for summer, monsoon and winter respectively. Depending upon the degrees of freedom ascalculated in canonical correlation analysis, Monte Carlo Simulations is applied, which provides technique for simulating the parameters having high degrees of freedom. The coefficients of determination ($R^2$) for the actual and simulated values of WQI are found to be 0.929, 0.953 and 0.970 for summer, monsoon and winter respectively.

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