

# Application of Artificial Neural Network to Predict the Water Quality Index of Brahmani River Basin Odisha, India

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## Abstract:

**W**ater is one of the prime elements responsible for subsistence on the earth. The scarcity of potable water is gradually increasing with the increase in population. The surface water quality is a very crucial and sensitive issue and is also a great environmental concern worldwide. Surface water pollution by physical, chemical, radiological and biological contaminants can be considered as an epidemic at times, all over the world. The present research work aims at assessing the water quality index (WQI) in the surface water of Brahmani river basin in Odisha by monitoring five sampling locations. The surface water samples data were subjected to comprehensive physico-chemical analysis besides general parameters. The monthly water quality parameters were collected and analyzed from five selected gauging stations of Odisha during the months of January to December from 2011 to 2016. Eleven physical, chemical and biological water quality parameters viz. pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Electrical Conductivity(EC), Nitrogen as nitrate (Nitrate-N), Total Coli-form Bacteria(TC), Fecal Coli-form Bacteria(FC), Chemical Oxygen Demand (COD), Nitrogen as ammonia ( $\text{NH}_4\text{-N}$ ), Total Alkalinity (TA) as  $\text{CaCO}_3$ , Total Hardness (TH) as  $\text{CaCO}_3$  were selected for the analysis. Analysis of water quality for Brahmani River is done by Water Quality Index (WQI). Prediction of water quality index is done by using Artificial Neural Network (ANN). It is apparent from WQI values that Talcher and Panposh recorded the water quality as moderate to poor and nearly unsuitable during the years 2011-2016 indicating water as not safe for domestic purposes and needs treatment, the WQI values of Kamalanga ranged from good to poor and the WQI values of Aul and Pottamundai ranged from good to moderate. Eleven physico-chemical parameters were involved in this analysis as input variables and water quality index as output variable. Two models were proposed to identify the most effective model in an attempt to predict the WQI. Correlation between the parameters was carried out to find out the significant parameters affecting WQI. The ANN developed was trained and tested successfully using the available data sets and the performance of ANN models were determined by coefficient of determination ( $R^2$ ) and Root Mean Square Error (RMSE). Results show that ANN-1 gives the higher value of  $R^2$  in summer, monsoon and winter season (0.989, 0.976 and 0.959) and low RMSE (2.1865, 2.0768 and 1.9657) as compared to that of the second model (ANN-2) which gives  $R^2$  value as 0.933, 0.945 and 0.943 and RMSE value as 2.8765, 2.5456 and 1.2745 for summer, monsoon and winter seasons respectively. Hence this study triggered the use of Artificial Neural Network to predict the Water Quality Index (WQI) rather than using the traditional WQI equation.

**Keywords:** Water Quality Index (WQI), Artificial Neural Network (ANN), Brahmani River, Central Water Commission, Central Pollution Control Board, Coefficient of determination ( $R^2$ ), Root mean Square Error (RMSE).

## I. INTRODUCTION

Water covers about 71% of the Earth's surface. It is vital for all known forms of living organisms on earth. About 96.5% of the planet's crust water is found in seas and oceans, 1.7% in groundwater, 1.7% in glaciers and the ice caps of Antarctica and Greenland, a small fraction in other large water bodies, and 0.001% in the air as vapour, clouds and precipitation. Only 2.5% of this water is fresh-water and 98.8% of that water is in ice (excepting ice in clouds) and groundwater.

The annual utilizable surface water resources of India are estimated as 690 km<sup>3</sup>. With rapid growing population and improving living standards the pressure on the water resources is increasing and per capita availability of water resources is reducing day by day. The surface water house 80% of the total population of the country. Surface water accounts for nearly 72% of the total irrigation in the country.

Water quality refers to the chemical, physical, biological, and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. Industrial and commercial activities (such as manufacturing, mining, construction, transport) are a major cause of water pollution including runoff from agricultural areas, urban runoff and discharge of treated and untreated sewage. A change in natural process such as changes in precipitation, weathering of crustal material as well as any anthropogenic influences from urban, industrial and agricultural activities, increasing rate of consumption of water resources, cause a degrade in the quality and quantity of surface water and make it unsuitable for domestic uses.

The overall structure of artificial neural networks is biologically inspired by the human brain. Artificial neural network systems are able to perform arithmetic operations like the nervous system. The ANN has an array of advantages over

traditional phenomenological paradigms, since they require known input data set without any assumptions. ANN is used for predicting various ecological processes and phenomenon related to water resources. In recent years, there have been a broad range of applications of the ANN to predict water quality. Water quality assessment using ANN is a typical pattern recognition problem that classifies water quality according to the standards.

## II. OBJECTIVE OF THE STUDY

1. To study the hydro-geochemistry of the Brahmani River.
2. Evaluation of Water Quality Index (WQI) from the evaluated physico-chemical parameters of water in order to know the quality of water.
3. Performing correlation and compare the employed models to predict the water quality index by using Artificial Neural Network (ANN) to obtain the most suitable model.

## III. STUDY AREA AND DATA COLLECTION

### STUDY AREA

The Study area of the proposed research work is Brahmani River. The basin is an inter-state 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 Odisha. The river gets its name below the confluence point of Sankh and Koel at Vedvyas in Sunderagarh district of Odisha. The river splits into numerous channels, criss-crossing the channels of Baitarani River and finally merges to Bay of Bengal.

Five gauging stations in the state of Odisha are selected for the proposed study in the Brahmani River Basin.

Name of the Sampling Stations	State	District
Panposh(downstream)	Odisha	Sundergarh
Talcher(upstream)	Odisha	Angul
Kamalanga(downstream)	Odisha	Dhenkanal
Aul	Odisha	Kendrapada
Pattamundai	Odisha	Kendrapada

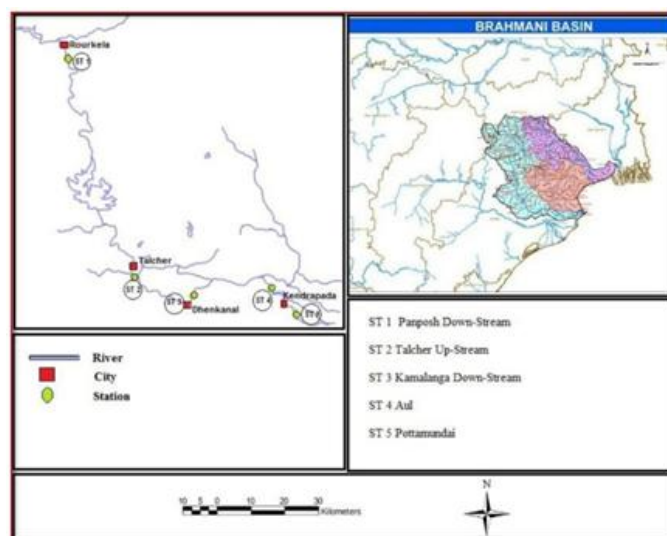


Figure 2.1 Brahmani River Basin Map showing the five selected gauging stations

### DATA COLLECTION

The monthly water quality parameters are collected and analyzed from five selected gauging stations of Odisha during the months of January to December from 2011 to 2016. The complete data sets are divided into three seasons as, summer, monsoon and winter. The summer season includes the month of March, April, May, June. The monsoon season includes the month of July, August, September and October. The winter season includes the month of 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 (NH<sub>4</sub>-N), Total Alkali as CaCO<sub>3</sub> (TA as CaCO<sub>3</sub>) and Total Hardness as CaCO<sub>3</sub> (TH as CaCO<sub>3</sub>).

## IV. METHODOLOGY

The data of the water quality parameters required for this study was collected from Central Pollution Control Board (CPCB) and Central Water Commission (CWC) for the years 2011-2015. About 80 water samples were collected for the year 2016 from January to December from five different stations as mentioned in clean and dry polythene bottles. The

water samples were collected and preserved for testing of various parameters at 10°C throughout the period of chemical analysis. The water samples were analyzed in Department of Chemistry in College of Engineering and Technology (CET).

The pH, Dissolved Oxygen and Electrical Conductivity were measured immediately after sampling at the field itself by using aquameter. The Spectrophotometer (Spectroquant Prove®300) was used to measure Nitrate-N, Ammonia (NH<sub>4</sub>-N), Total Hardness, Total Alkalinity, Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). Fecal Coliform population was measured by MPN/100 ml method by growing on M-FC medium at a temperature of 44.5°C and counted after 24 hours. Similarly, Total Coliform population was measured by MPN/100 ml method by growing on M-Endo medium at temperature of 35.5°C and counted after 24 hours.

**WATER QUALITY INDEX (WQI)**

The water quality rating  $q_n$  for  $n^{\text{th}}$  water quality parameters is obtained from the relation:

$$q_n = 100[(V_n - V_o) / (S_n - V_o)]$$

Where:  $q_n$  = Quality rating for the  $n$  water quality parameter,

$V_n$  = Estimated value of the  $n$  water quality parameters of collected sample,

$S_n$  = Standard permissible value of the  $n$  water quality parameter,

$V_o$  = Ideal value of the  $n$  water quality parameter in pure water.

(i.e. 0 for all other parameters except the parameter pH and Dissolved oxygen 7 and 14.6 mg/L respectively.) (Let there be  $n$  water quality parameters and

Quality rating or sub index ( $q_n$ ) corresponding to  $n$  parameter is a number reflecting the relative of this parameter in polluted water with respect to its standard permissible value.

Unit weight ( $W_n$ ) was calculated by a value inversely proportional to the recommended standard value  $S_n$  of the corresponding parameter,

$$W_n = K / S_n$$

Where:  $W_n$  = Unit weight for  $n$  water quality parameter.

$S_n$  = Standard permissible value of the  $n$  water quality parameter.

$K$  = Constant for proportionality.

The overall water quality index (WQI) was calculated by aggregating the quality rating with the unit weight linearly.

$$WQI = \sum q_n W_n / \sum W_n$$

Where:

$q_n$  = Quality rating for the  $n$  water quality parameter.

$W_n$  = Unit weight for  $n$  water quality parameters.

Table 3.1 Water Quality Factors: Bureau of Indian Standards assigned unit weights

	Recommended Agency	Unit Weight ( $W_n$ )
pH	BIS	0.219
Dissolved Oxygen	BIS	0.1
Biochemical Oxygen Demand	BIS	0.18
Conductivity	BIS	0.0018
Nitrate-N	BIS	0.0055
Total Coliform	BIS	0.1
Fecal Coliform	BIS	0.023
Chemical Oxygen Demand	BIS	0.18
Ammonia	BIS	0.0006
TA as CaCO <sub>3</sub>	BIS	0.0092
TH as CaCO <sub>3</sub>	BIS	0.0061

Water quality can be categorized into five classifications depending on the water quality index (WQI) of the parameters. (Chatterjee and Raziuddin 2002)

Table 3.2 Water Quality Ranges

Range	Quality
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
>100	Unsuitable

**ARTIFICIAL NEURAL NETWORK (ANN)**

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 Brahmani River is predicted depending upon the variation in water quality parameters. The prototype of artificial neural network pattern is based on direct modeling of the human neuronal system.

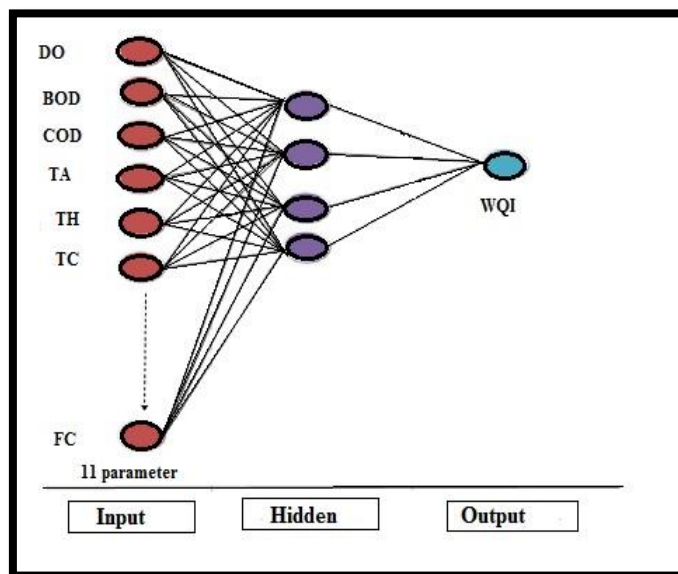


Figure 3.1 Structure of Network

In this study two different ANN models were developed. The input for the first model (ANN-1) used eleven parameters with WQI as the desired output for summer, monsoon and winter seasons respectively. While the second model (ANN-2) used only six significant parameters which is evaluated from the correlation matrices. The correlation matrices are evaluated. These two models were compared with the  $R^2$  and RMSE value to define the most suitable model.

**V. RESULTS AND DISCUSSION**

**WATER QUALITY INDEX (WQI) CALCULATION**

Temperature is an important factor to influence the physico-chemical parameters and the biological reaction in water. Higher values of temperature accelerate the chemical reaction and reduce the solubility of gases and DO. In the present study the temperature varied from 20°C to 45.4°C.

Table 4.1 Water Quality Index Of Talcher

Talcher WQI			
Year	Summer	Monsoon	Winter
2011	66.5	60.15	54.52
2012	51.39	57.51	54.33
2013	65.91	49.16	60.84
2014	53.53	59.41	58.74
2015	74.79	71.42	64.23
2016	85.68	86.1	76.92

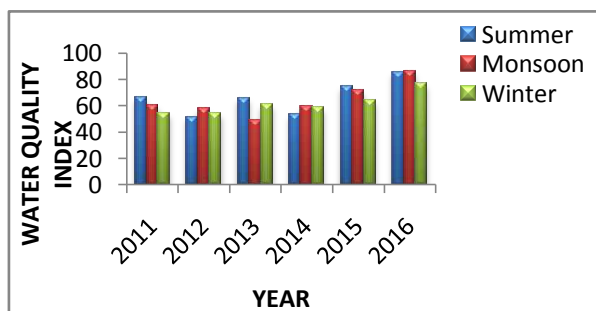


Figure 4.1 Water Quality Index of Talcher Station from 2011-2016

Table 4.2 Water Quality Index of Panposh

Panposh WQI			
Year	Summer	Monsoon	Winter
2011	70.19	75.46	71.2
2012	72.74	60.64	56.15
2013	56.96	55.45	50.11
2014	51.6	67.69	65.55
2015	58.32	62.56	64.7
2016	65.61	88.01	98.79

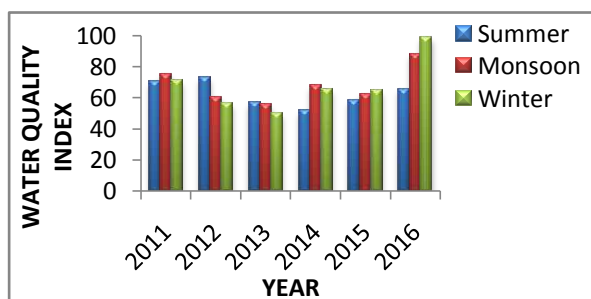


Figure 4.2 Water Quality Index of Panposh Station from 2011-2016

Table 4.3 Water Quality Index of Kamalanga

Kamalanga WQI			
Year	Summer	Monsoon	Winter
2011	70.89	73.07	52.4
2012	79.8	79.48	72.22
2013	47.34	46.35	47.97
2014	49.55	48.87	49.82
2015	57.39	55.63	50.01
2016	58.78	60.45	54.82

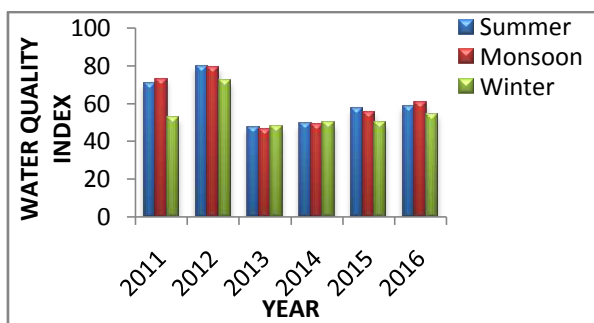


Figure 4.3 Water Quality Index of Kamalanga Station from 2011-2016

Table 4.4 Water Quality Index of Aul

Aul WQI			
Year	Summer	Monsoon	Winter
2011	35.71	47.51	46.74
2012	46.29	74.98	68.47
2013	50.56	60.83	51.08
2014	39.46	60.52	42.82
2015	44.28	63.76	62.53
2016	40.81	40.68	38.2

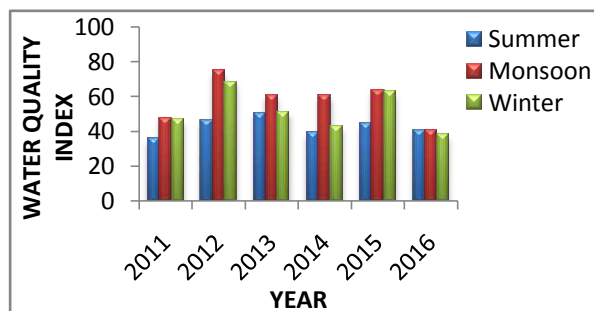


Figure 4.4 Water Quality Index of Aul Station from 2011-2016

Table 4.5 Water Quality Index of Pottamundai

Pottamundai WQI			
Year	Summer	Monsoon	Winter
2011	49.38	44.94	37.06
2012	48.41	58.58	46.14
2013	60.8	53.46	59.02
2014	51.34	48.64	47.14
2015	30.32	32.35	30.97
2016	29.16	40.11	42.6

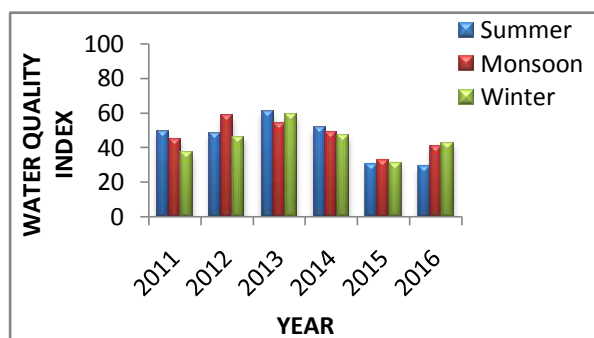


Figure 4.5 Water Quality Index of Pottamundai Station from 2011-2016

In consequence, the data were divided into a training set made-up of validation and testing subsets. As the number of hidden layer in network algorithm of the model is increased or decreased, there is a change in goodness of fit statistics. So it is clear that, the goodness of fit statistics had been done for training, validation and testing of data with fixing the hidden layers to 3 during modeling process.

Table 4.6 Correlation Matrices for Water Quality Parameters during summer

Summer											
	pH	DO	BOD	Cond.	Nitrate-N	TC	FC	COD	NH4-N	TA	TH
pH	1										
DO	0.838	1									
BOD	0.451	0.848	1								
Cond.	-0.581	-0.372	0.082	1							
Nitrate-N	0.538	0.908	0.980	-0.062	1						
TC	-0.609	-0.417	0.033	0.999	-0.111	1					
FC	-0.609	-0.417	0.033	0.999	-0.111	0.323	1				
COD	-0.229	0.153	0.597	0.848	0.474	0.821	0.821	1			
NH4-N	0.573	0.918	0.924	-0.179	0.981	-0.226	-0.226	0.354	1		

TA	0.012	0.317	0.653	0.759	0.557	0.727	0.727	0.960	0.455	1	
TH	-0.312	-0.042	0.384	0.943	0.251	0.925	0.925	0.963	0.129	0.932	1

Table 4.7 Correlation Matrices of water quality parameters during monsoon

Monsoon											
	pH	DO	BOD	Cond.	Nitrate-N	TC	FC	COD	NH4-N	TA	TH
pH	1										
DO	0.594	1									
BOD	0.527	0.607	1								
Cond.	-0.579	-0.553	-0.086	1							
Nitrate-N	0.591	0.667	0.997	-0.146	1						
TC	-0.611	-0.589	-0.142	0.998	-0.202	1					
FC	-0.611	-0.589	-0.142	0.998	-0.202	0.976	1				
COD	-0.235	-0.175	0.423	0.865	0.368	0.835	0.835	1			
NH4-N	0.594	0.659	0.978	-0.223	0.981	-0.276	-0.276	0.294	1		
TA	0.611	0.668	0.931	0.063	0.932	0.009	0.009	0.542	0.916	1	
TH	-0.319	-0.278	0.211	0.946	0.158	0.927	0.927	0.971	0.076	0.379	1

Table 4.8 Correlation Matrices of water quality parameters during winter

Winter											
	pH	DO	BOD	Cond.	Nitrate-N	TC	FC	COD	NH4-N	TA	TH
pH	1										
DO	0.842	1									
BOD	0.554	0.863	1								
Cond.	-0.589	-0.389	-0.156	1							
Nitrate-N	0.449	0.817	0.987	-0.011	1						
TC	-0.612	-0.425	-0.195	0.996	-0.050	1					
FC	-0.612	-0.425	-0.194	0.999	-0.050	0.765	1				
COD	-0.265	0.085	0.361	0.864	0.493	0.843	0.844	1			
NH4-N	0.402	0.753	0.980	0.003	0.989	-0.034	-0.036	0.497	1		
TA	-0.022	0.220	0.392	0.795	0.500	0.772	0.962	0.953	0.494	1	
TH	-0.330	-0.070	0.151	0.944	0.288	0.930	0.430	0.970	0.289	0.948	1

These correlations indicate the waste water from domestic and industrial and its organic load are disposed to the river. The results of the correlation analysis are considered in the subsequent interpretation. A high correlation coefficient (nearly 1 or -1) means a good relationship between two variables, and a correlation coefficient around zero means no relationship. Positive values indicate a positive relationship while negative values indicate an inverse relationship.

From the above correlation matrices it was found that a strong correlation is maintained between the parameters BOD, COD, Nitrate-N, NH<sub>4</sub>-N, TA and TH.

Depending upon the correlation matrices the six significant parameters (BOD, COD, Nitrate-N, NH<sub>4</sub>-N, TA and TH) are fed as input to the ANN as the second model as described above to predict the water quality index for summer, monsoon and winter season respectively.

The network was trained using the feed forward network. The first model (ANN-1) involves eleven parameters as inputs with three hidden layers and one output (WQI). The structure of the network is 11-3-1. The second model (ANN-2) involves six parameters as input with three hidden layers and one output (WQI). The network of the structure is 6-3-1.

The target values are iterated by the model after the target time steps given. Simultaneously, the autocorrelation, input-output correlation and error correlation are calculated by the model. Root mean squared error (RMSE) is the average squared difference between outputs and targets. Here, regression R values measure the correlation between outputs and targets. Regression (R) value of 1 means a close relationship and Regression (R) value of 0 means random relationship.

The WQI predictions of the first model ANN-1 trained had a significant, positive, very high correlation with the measured WQI values. The WQI predictions of the second model ANN-2 trained does not have a significant and high correlation with the WQI values as that of model ANN-1. The results are shown in Figures 4.6, 4.7, 4.8, 4.9, 4.10 and 4.11 respectively for summer, monsoon and winter seasons respectively.

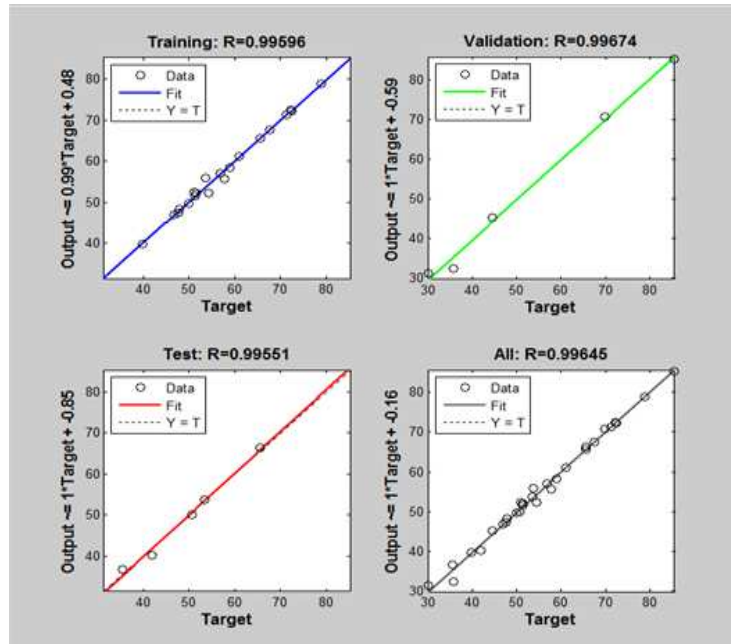


Figure 4.6 Regression Output of ANN for Summer (ANN-1)

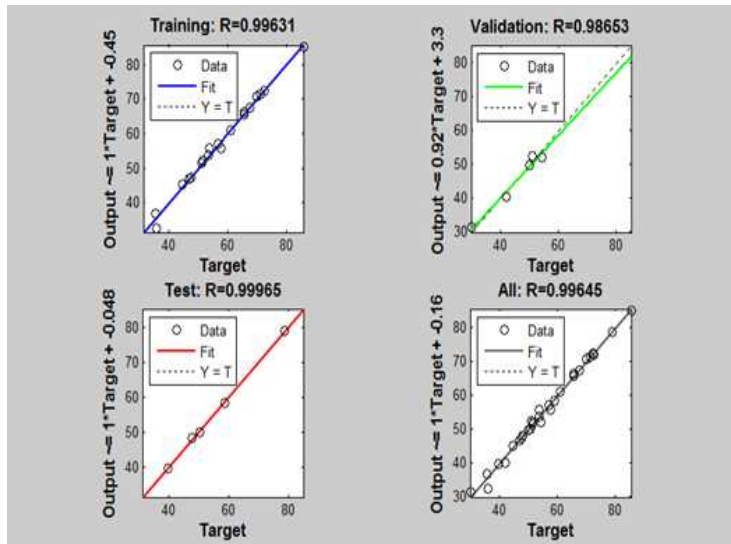


Figure 4.7 Regression Output of ANN for Monsoon (ANN-1)

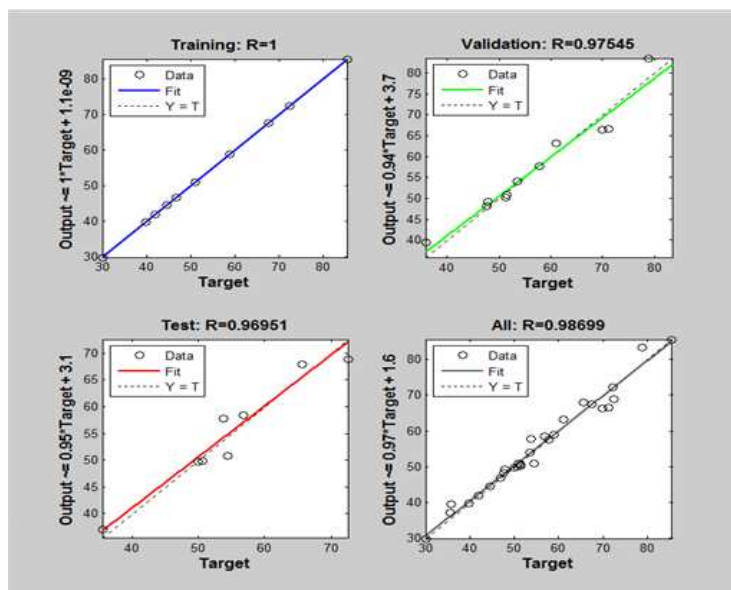


Figure 4.8 Regression Output of ANN for Winter (ANN-1)

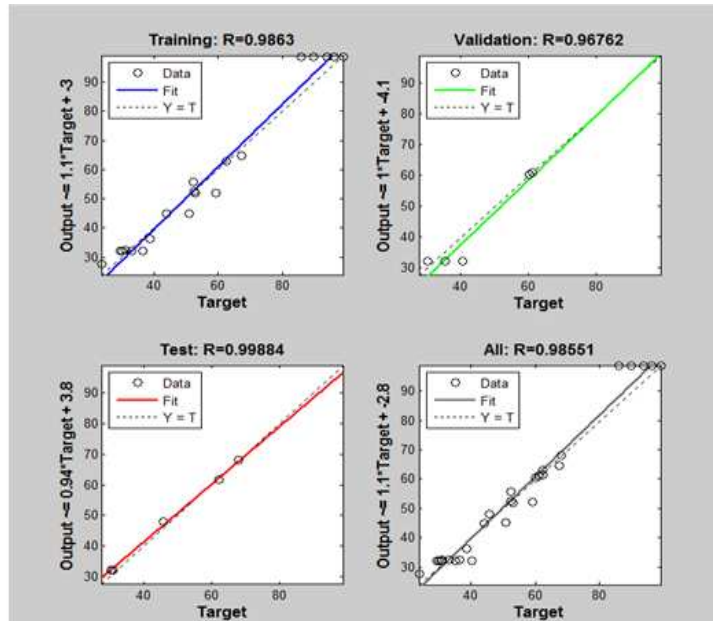


Figure 4.9 Regression Output of Ann for Summer (ANN-2)

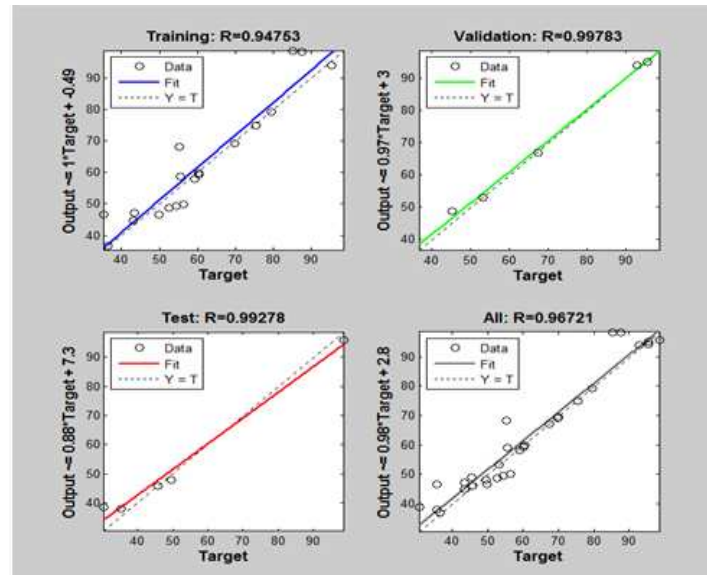


Figure 4.10 Regression Output of Ann for Monsoon (ANN-2)

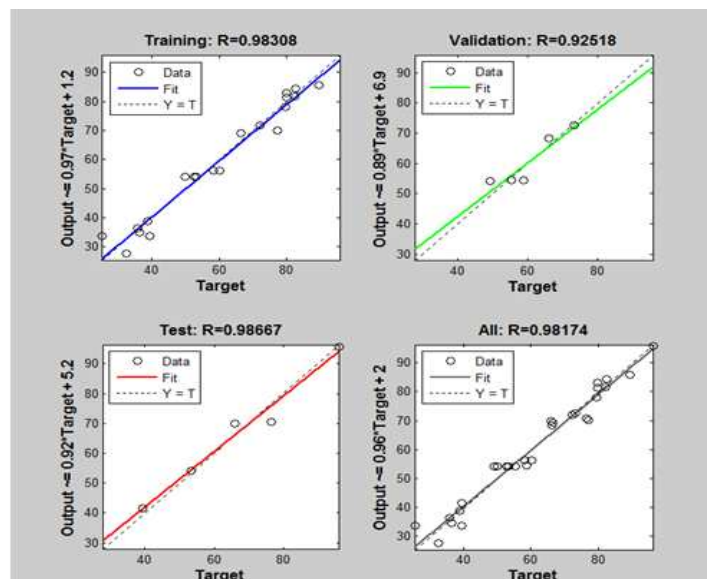


Figure 4.11 Regression Output of Ann for Winter (ANN-2)

The predicted outputs by ANN simulation are saved and the correlations are found out between the actual WQI and predicted WQI by ANN. The results are shown by the Figure for summer, monsoon and winter respectively. The degree of coefficient of determination ( $R^2$ ) between actual and predicted WQI by ANN-1 in summer, monsoon and winter are 0.989, 0.976 and 0.959 respectively as shown in Figures 4.12, 4.13 and 4.14 and by ANN-2 in summer, monsoon and winter are 0.933, 0.945 and 0.943 respectively as shown in Figures 4.15, 4.16 and 4.17 respectively.

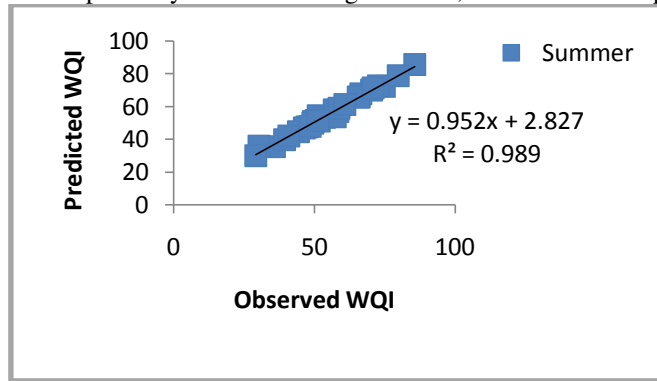


Figure 4.12 Correlation of Observed and ANN predicted WQI for Summer (ANN-1)

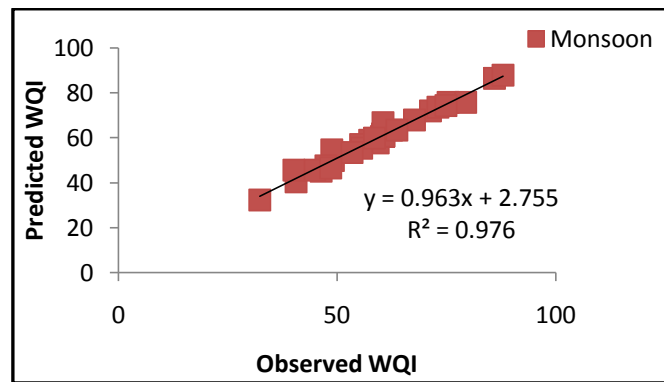


Figure 4.13 Correlation of Observed and ANN predicted WQI for Monsoon (ANN-1)

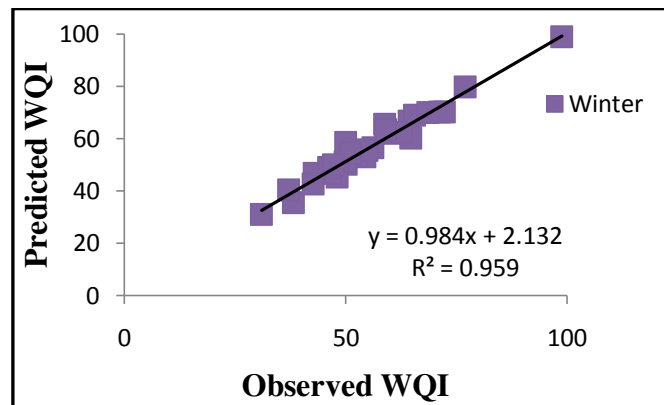


Figure 4.14 Correlation of Observed and ANN predicted WQI for Winter (ANN-1)

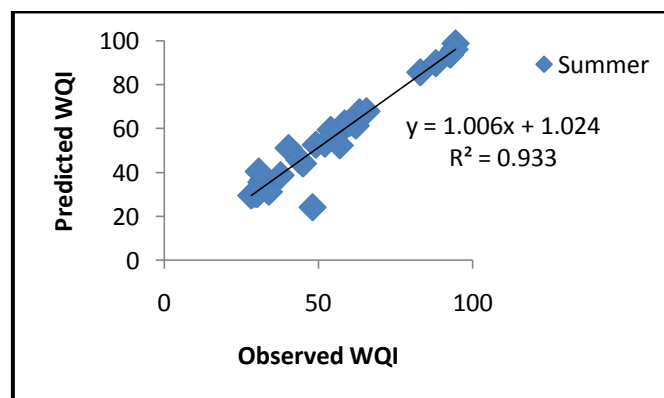


Figure 4.15 Correlation of Observed and ANN predicted WQI for Summer (ANN-2)

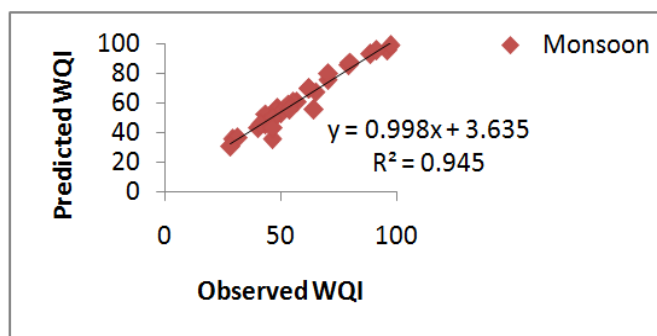


Figure 4.16 Correlation of Observed and ANN predicted WQI for Monsoon (ANN-2)

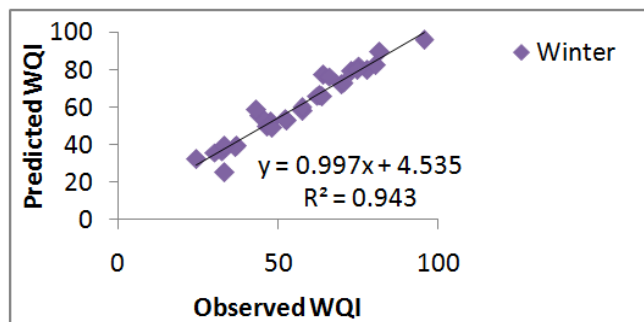


Figure 4.17 Correlation of Observed and ANN predicted WQI for Winter (ANN-2)

Table 4.6 Performance of ANN models for Summer

Input data	Network	R <sup>2</sup>	RMSE
ANN-1	[11,3,1]	0.989	2.1865
ANN-2	[6,3,1]	0.933	2.8765

Table 4.7 Performance of ANN models for Monsoon

Input data	Network	R <sup>2</sup>	RMSE
ANN-1	[11,3,1]	0.976	2.0768
ANN-2	[6,3,1]	0.945	2.5456

Table 4.8 Performance of ANN models for Winter

Input data	Network	R <sup>2</sup>	RMSE
ANN-1	[11,3,1]	0.959	1.9657
ANN-2	[6,3,1]	0.943	1.2745

The tables show the performance of ANN models for forecasting WQI values. The model ANN-1 with all the eleven parameters as input is selected as the most suitable model for WQI forecasting with high R<sup>2</sup> and low RMSE values as compared to that of model ANN-2. The best network model was chosen based on the highest coefficient of determination (R<sup>2</sup>) and lowest RMSE (Daliakapolous).

For the calculation of the WQI using the WQI formula requires manual calculations whereby the raw data of eleven water quality variables (pH, dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), electrical conductivity (EC), total hardness, total alkalinity, total coliform, fecal coliform, Chemical Oxygen Demand (COD), Nitrogen as Nitrate and Nitrogen as ammonia) have to be converted into sub-indices before the WQI can be calculated. The calculations are not performed on the parameters themselves but rather on their sub-indices. To the contrary, the ANN approach utilises archived data to establish a model that can be used for direct calculation of the WQI from raw water quality variables without the need for sub-indexing. The suggested ANN approach is therefore a direct, rapid and convenient means of calculation of the WQI than the conventional WQI equation.

## VI. CONCLUSION

Analysis of water quality for Brahmani River is done by Water Quality Index (WQI) and by Artificial Neural Network (ANN) in MATLAB. Conclusions from the present research work can be listed as follows:

The Water Quality Index (WQI) values for the gauging stations vary from good to very poor in all the three seasons. The water quality of Brahmani River is quite safe at the two stations i.e. Aul and Pottamundai but at other three stations i.e. Talcher, Panposh and Kamalanga necessary treatment of water is required. High awareness of the pollution is required

and preventive measures should be taken. The sewage effluents from the industries should be given proper treatment before allowing it to enter into the river. The ranges of water quality parameters were within the range as recommended by ICMR/BIS and the water can be used for domestic purposes. However, necessary preventive measures to maintain good water quality of Brahmani River Basin must be taken up to ensure the safety of the River Basin and to preserve this valuable resource for future generations.

This research work described the application of ANN to a prediction (or function approximation) problem implying the use of archival measurements on water quality variables of surface water for the model capable of calculating and forecasting the WQI. The models show the ability of ANNs to predict WQI by using only six significant parameters after conducting the correlation analysis which is compared to all the available water quality parameters (eleven inputs). The analyzed data show better prediction performance in model ANN-1 since it gives the higher  $R^2$  value (0.989, 0.976 and 0.959 for summer, monsoon and winter seasons respectively) and lowest RMSE (2.1865, 2.0768 and 1.9657 for summer, monsoon and winter seasons) values compared to model ANN-2 with low  $R^2$  value (0.933, 0.945 and 0.943 for summer, monsoon and winter season respectively) and high RMSE value (2.8765, 2.5456 and 1.2745 for summer, monsoon and winter seasons). Accordingly, this study gives prominence that ANN constitutes an effective tool for assessment of the water quality that simplifies computation of the WQI and saves substantial efforts and time by optimizing the calculation.

### **SCOPE FOR FUTURE WORKS**

- ❖ The modelling study can be extended for the other water quality parameters.
- ❖ A study on surface water quality as well as groundwater quality movement can be carried out.
- ❖ A detailed study on consumptive use of surface water and ground water can be carried out.
- ❖ ANNs in civil engineering, including geotechnical engineering, can be used mostly as simple vector mapping devices for function modeling of applications that require rarely more than a few tens of neurons without higher-order structuring. Together, improvements in these issues will greatly enhance the usefulness of ANN models and will provide the next generation of applied artificial neural networks with the best way for advancing the field to the next level of sophistication and application.
- ❖ This approach can be commonly used and it can be applied equally successfully to any aquatic system worldwide.

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