RESEARCH ARTICLE

APPLICATIONS OF ARTIFICIAL NEURAL NETWORK IN ASSESSING WATERQUALITY: A CASE STUDY

[1],*Soni Chaubey and [2]Mohan Kumar Patil

[1]PhD Research Scholar Mewar University NH-76 Gangrar, Chhittorghara Rajasthan, India
[2]Senior Environment Professional, En Carp Solution, Nagpur, Maharashtra, India

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ABSTRACT

This is attributable to pollution due to human activities such as plunging of idols of deity and divinity in the festival season, surface runoff due to heavy rainfall, washing exercises and sewage disposal everywhere in lakes. Water environment is a complex system where theological methods cannot meet the demands of water environment preservation. To demonstrate the usefulness of the Back Propagation Neural Network (BPNN), the Water Quality Index (WQI) has been used on the basis of physical-chemical parameters of different sources of water. Water from different sources like Gandhisagar, Ambazari and Futala lake revealed significant water pollution as compared to Gorewada lake. The WQI is continuously upgrading and the situation is becoming more alarming which demands some appropriate actions with an immediate effect to get it under control. In this study, an attempt was made to assess WQI using Multi-Layer Perceptrons (MLP) architecture. The feed forward back propagation algorithm has been chosen for training and testing the experimental data. The feed forward back propagation algorithm has been chosen for training and testing the experimental data. All the calculated WQI parameters in aforesaid lakes are observed to be at a medium level in rainy season, fairer in the autumn season and comparatively higher during the summer season.

INTRODUCTION

Pollution is generally regarded as the result of the industrial revolution. Environmental quality of the area deteriorates mainly as a result of the increasing industrial activities. In order to find out the current status of the pollution in the area, due to the increasing trend in the industrial activities, it is essential to identify the various sources of pollution.All segments of the environment are being polluted by various ways. However water pollution has been taken under inspection since water forms an integral part of life on earth. On an average a human being consumes about two litre of water every day during his whole life period .The exploding population, increasing industrialization and urbanization is the most prominent factor to cause water pollution. Nagpur city being an industrial city has also enormous numbers of aquatic bodies. Nag river originating from Ambazari river forms a tributary of Kanhan flowing in the east through the Nagpur city. Draining of sewage forms the prime factor contributing to pollution in Nag river. Gorewada lake and one tank are the two significant resources which serve the drinking water purpose in Nagpur city. Water from Ambazari lake and Futula lake is used for industrial purposes and irrigation respectively.

The other aquatic bodies forming the site of water pollution in Nagpur city area, namely, Lendi lake, Sakkardara lake, Gandhisagar lake, Naik lake and Khadan lake. The dumping of sewage and other impurities in Naik and Lendilake from adjacent localities is increasing drastically (Calum2014).

The encroachment of the weeds also contributes a major portion in the overall degradation of the aforesaid lakes. The major lakes in Nagpur city which once use to be eco-friendly and useful purposes, have lost their grandeur and have rather become a source of nuisance. The water samples have been drawn from water sources of few lakes within the Nagpur city which is affected by water pollution is shown in Table 1.

Table 1. Samples of location of water from lake sources

S.No.	Lake
1	Gorewada lake
2.	Ambazari lake
3..	Futala lake
4.	Gandhisagar lake
5.	Sonegoan lake
6.	Sakkardara lake

*Corresponding author: Soni Chaubey,
PhD Research Scholar Mewar University NH-76 Gangrar, Chhittorghara Rajasthan, India.

Lakes play an important role in the, ecological and environmental aspects of the region. Climatic factors are modified by lakes by influencing relative humidity and vegetation of the region (Sharma *et al.,* 2014). It also acts as a re-charger for aquifers. The macroclimate of the lake supports a complex web of fauna and flora whose composition is not limited to aquatic and terrestrial flora and fauna but also includes the birds. These lakes and wetland ecosystem thus formed does not only support many bird sanctuaries but also provides a niche in the food web of organism in the ecosystem (Elshafie *et al.,* 2011).

The main objectives of the present study is to obtain the experimental data of the status of water quality based on the physico-chemical parameters of Lakes over an annual cycle, during a period from January to December 2013 and to have an overall picture of the drastic impacts of pollutants and human actives on Gandhisagar, Ambazari, Futala and Gorewada Lake. It also aims at predicting the status of water quality in the future by using Artificial Neural Network (ANN) and concluding recommendation for improving water quality and determining the suitable usage of lakes.

MATERIALS AND METHODS

The water samples from four lakes (namely Gandhisagar, Ambazari Futala and Gorewada) were collected. The testing was done in the Hydrology project division Nagpur, in a water quality lab, Nagpur. ANN was used to predict WQI of water in the future.

For the purpose of present investigation, twelve water quality parameters have been selected. These twelve parameters are pH, Dissolved Oxygen, Turbidity, Electrical Conductivity, Total Dissolved Solids, Hardness, Calcium, Magnesium, Chloride, Biochemical Oxygen Demand, Iron and Sulphate. In the formulation of WQI, the importance of various parameters depends on the intended use of water; here water quality parameters were studied from the point of view of suitability for human consumption. The weighted arithmetic index method (Yogendra *et al.,* 2008) has been calculated. The rating scale (q_i) for i^{th} water quality parameters (i = 1,2,3-----12) was obtained from the relation

$$q_i = 100 \ (\ V_i - V / \ S_i - V) \qquad \text{-------------------(1)}$$

(Where V_i= value of the ith parameter at a given sampling station S_i= Standard permissible value of ith parameter V=Ideal value of ith parameter in pure water (i.e.,0 for all other parameter except the parameter pH and dissolved oxygen that is 7.0 and 14. 6 mg/L respectively)

The 'weights' for various water quality parameters are assumed to be inversely proportional to the recommended standards for the corresponding parameters was obtained from the relation

$$W_i = \frac{K}{S_i} \qquad \text{...........................(2)}$$

(Where W_i= unit weight for the *n*th parameter (i.e. i= 1, 2, 3 ------12), k = constant of proportionality which is determined

from the condition and k =1 for sake of simplicity).To calculate WQI, first the sub index $(SI)_I$ corresponding the ith parameter was calculated. These are given by the product of the quality rating q_i and the unit weight W_i of the ith parameter (Purushottam J. Puri *et al.,* 2010)

$$(SI)_i = q_iW_i \qquad \text{--(3)}$$

The following formulae are used to calculate the WQI:

$$WQI = \sum(SI)_i / \sum W_i \qquad \text{....................................(4)}$$

Collection, preparation of water samples and analysis

One liter water samples contain were taken in transparent plastic bottles during summer, winter and rainy seasons for quality index analysis. Each sample was characterized water quality throughout the main basin of Lake, four permanent stations for monthly sampling were established and marked within the inflow (S_1), outflow (S_2), mid-lake region (S_3) and corner (S_4). Laboratory samples were stored on ice at 4^oC until transport for analysis.

Water quality analysis

The water samples were analyzed for physico-chemical (i.e. pH, free from carbon dioxide, dissolved oxygen, biochemical oxygen demand, total alkalinity, hardness, calcium, magnesium, phosphate and ammonia). pH was evaluated by EUTECH instrument pH-510. In the laboratory electrical conductivity was calculated with microprocessor based on the conductivity TDS meter. The temperature was recorded with laboratory thermometer. These instruments were used in the limit of precise accuracy and chemicals used were of analytical grade.

Neural Network Training and Validation

ANN is a tool for data processing and consist of a large number of interrelated processing elements i.e. artificial neurons in an architecture inspired by the structure of the cerebral cortex of the brain (Tsoukalas and Uhrig, 1997). The Neural Network is based on the concept of 'Learn from Pattern'. In this paper, Back Propagation Neural Networks (BPNN), when trained with sufficient data, proper inputs and with proper architecture has predicted the water quality very well.

The aim of the proposed method is to forecast the WQI of the water samples of various lakes around Nagpur. The artificial neural network is used as a tool for forecasting WQI using the available data. For this purpose, 12 month data were extracted from each sample (i.e. for sample location of different sites) and are used as the input of each BPNN model. The WQI in studying lakes is higher throughout the year despite the reduction effect experienced in the rainy season. The study area experiences a seasonal climate and can be broadly divided into three seasons i.e. winter (November to February), summer (March to June) and rainy (July to October).These four Samples are: S_1, S_2, S_3 and S_4 for each location and samples were collected in summer winter and rainy as output (i.e.

target) as shown in Table 3. The WQI were determined with the assistance of physico- chemical data as shown in Table 4 and Table 5.

and testing purpose, the number of input layer used are one hundred ninety two (12x4x4) of Gandhisagar, Ambazari, Futala and Gorewada lake, choice of hidden layer and three

Table 2. Rating scale for water quality parameter in mg/L

Water Quality Index Level	Water Quality Status	Extent of Pollution
0-25	Excellent water quality	Permissible
26-40	Good water quality	Slight
51-75	Poor water quality	Moderate
76-100	Very poor water quality	Excessive
>100	Unsuitable for drinking	Severe

Table 3. Average Water Quality Index in summer, winter and rainy season for sample location from *Gorewada lake*

Location of source	Summer	Rainy	Winter
S_1	58	48	47
S_2	61	46	47
S_3	58	47	43
S_4	56	45	47

Table 4. Water Quality Index for sample location from Gorewada lake

Source\ Month	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
S_1	56	55	77	87	88	47	48	58	58	47	48	19
S_2	48	46	81	71	59	49	51	49	48	89	49	59
S_3	44	42	48	58	47	47	48	47	46	78	57	48
S_4	49	45	54	53	35	45	46	55	45	83	44	54

Table 5. Water Quality Index for *sample location from* Ambazari lake

Source \ Month	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
S_1	71	47	54	64	61	51	52	51	43	36	54	75
S_2	80	45	57	57	59	50	50	50	57	48	29	78
S_3	50	40	53	54	55	45	56	54	54	54	54	54
S_4	45	50	54	53	53	43	44	44	54	53	43	53

Data Normalization

The data are to be normalized before sending for network training. During the training of the neural network, a higher valued input variable tends to suppress the influence of the smaller value input. To eliminate this problem and in order to make neural networks perform better, the data must be well managed and scaled before giving as input to the ANN. The features data are normalized in the range 0.1 to 0.9 to minimize the effect of the input variable. The range 0.1 and 0.9 is selected in place of zero and one because zero and one cannot be realized by the activation function (sigmoid function and tansig function). All the WQI value of selected sample is normalized using the following equation.

$$X_i = 0.8 \times \left[\frac{\left(X_i^{old} - min_{value} \right)}{\left(max_{value} - min_{value} \right)} \right] + 0.1 \quad , \qquad \ldots\ldots\ldots\ldots(5)$$

Where X_i^{old} = actual data, max_{value} and min_{value} are the maximum and minimum value of the data respectively and X_i is the normalized data.

BPNN Model Development and Classification Accuracy

Selecting the amount of hidden neurons is important to develop the architecture of different neural network models. It consists of the input layer, hidden layer and output layer. For training

output layers. Since the input layer has one hundred ninety two neurons (i.e., 12 different months and each lake having four WQI four source location i.e, S_1 S_2 S_3 and S_4 (12X4)) and similar way to calculate other location (12x4x4)), therefore, the models with four input layer size also differ in hidden layer size. The numbers of output neurons are constant. The difference between each model depends on the number of input neurons and hidden neurons. The size of input layer which is supposed to avoid under fitting and the number of neurons in a neural network model should not be large so that it is away from over fitting. The next step is to generate target vector data set. The target vector is chosen to be same as the number of source i.e. four. The target vector will have a value of 0.9 for its first element and all other elements will have a value of 0.1. Typical training vectors created after extracting the features from source of lakes is shown in Table 6.

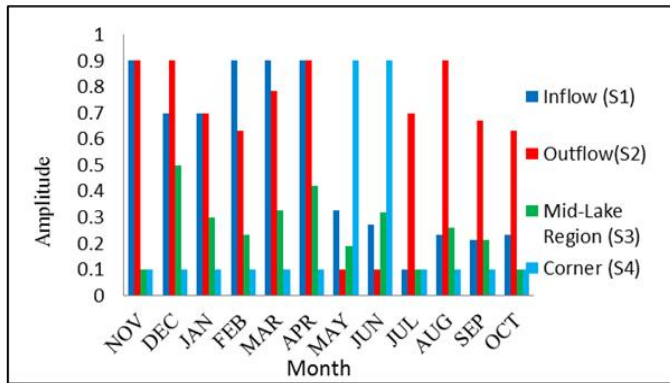**Table 6. Target vector used for Back propagation**

S.No.	Source of water	Target		
		Summer	raining	winter
1	S_1	0.9	0.1	0.1
2	S_2	0.1	0.9	0.1
3	S_3	0.1	0.1	0.9
4	S_4	0.1	0.1	0.1

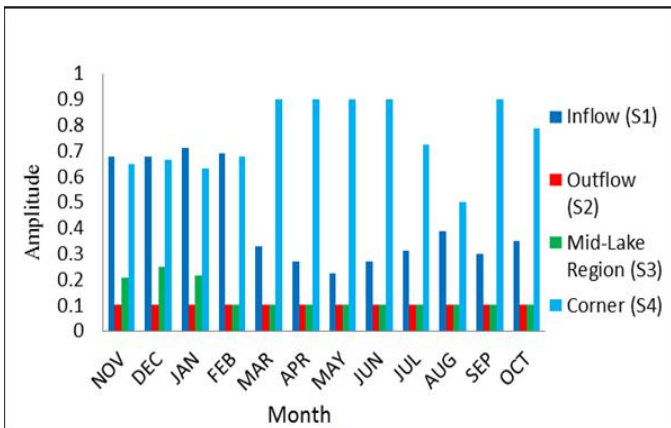## RESULTS AND DISCUSSION

The data in neural networks can be characterized into two sets: training sets and test sets.
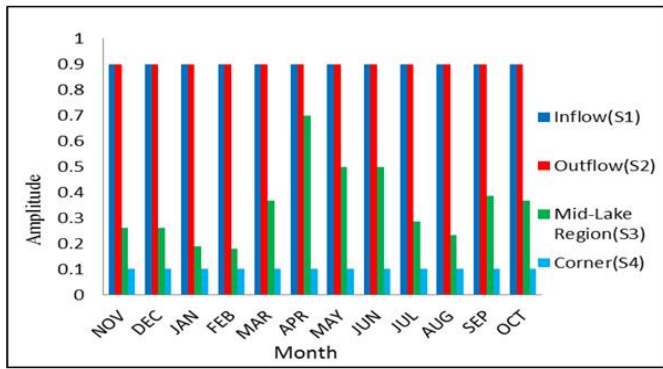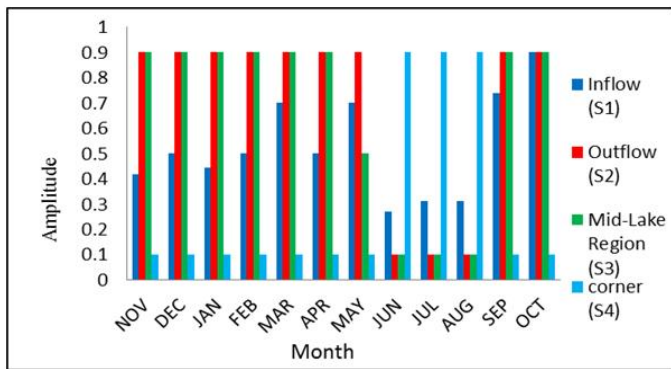
(a)

(b)

(c)

(d)

Fig. 1. WQI of normalized value form (a) Futala, (b) Ambazari, (c) Gorewada and (d)Gandhisagar lake during year of session 2014 in Nagpur

The training set is used to determine the biases of a network and adjusted weights. The test data set is used for calibration, which prevents networks from essence over trained. The general approach for selecting a good training set from available data series involves including all of the extreme events (i.e. all possible minimum and maximum values in the training set).

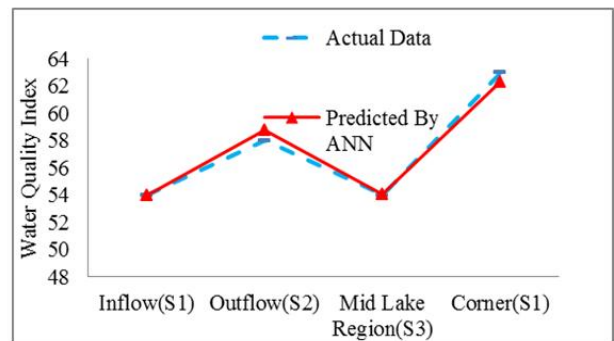**Table 7. Forecasting of water quality index of inflow in month of May July and Dec in year 2013**

Lake	Desire(In 2013 on basis of WQI)			Prediction by ANN (In 2013 on basis of WQI)		
	May	Dec	Jul	May	Dec	Jul
Gandhisagar	52	51	53	51	51	54
Ambazari	58	56	50	58	56	50
Futala	50	55	52	51	54	52
Gorewada	51	64	54	51	53	54
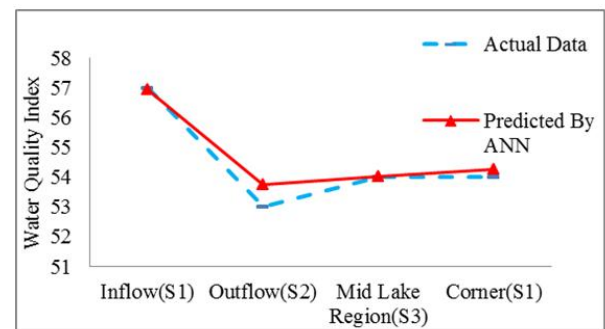
(a)
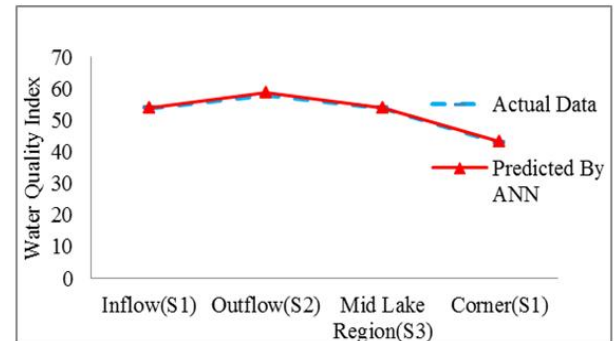
(b)

(c)

Fig. 2.Comparison between Actual data and predicted by ANN for (a) summer, (b) rainy and (c) winter season for Gorewada Lake

In this study, the data were divided into two sets. The second contained 70% of the data set used as the training. The first set contained 30% of the data set used as the testing set. Furthermore, one of the most important attributes of ANN is the number of neurons in the hidden layer. If an insufficient number of neurons are used, the resulting fit will be poor and the network will be unable to model the complex data. On the contrary, physico-chemical parameters in studying lakes presented distinct, temporal and spatial variants throughout the study period. Lake WQI parameters undergo seasonal changes and values are generally higher during summer season data collected from inflow, outflow, mid-lake region and corner. The current study has shown that Futala, Ambazari, Gandhisagar and Gorewada lakes are much more polluted in terms of WQI. The WQI of different lake is calculated which shows in Table 4 and 5.The features of quality of water of four samples have WQI values lying between 45 to 85. The water of lake source is unfit for human consumption. The comparison of actual data obtained from different season as well as source and predicted by ANN almost same as shown in Figure 2. ANN structure has been outlined and prepared utilizing the MATLAB neural network toolbox. The ANN method is excellent in prediction of future data basing on the previous data provided the number of data are more. So it is suitable methods can be developed to predict any physico-chemical parameter for any future years. The forecasting of WQI of inflow is shown in Table 7.

Conclusion

As compared to existing methods, proposed scheme is simple, accurate, reliable and economical. In fact, the ANN provides better results in predictions. Neural network model and regression model could develop and validate the results with those of the experimental outcomes. These approaches are also used to compare with other techniques such as multilayer regression method, fuzzy logic technique and genetic algorithm.

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