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# An Investigation of Assessment and Modelling the Water Quality of Rivers Based on Artificial Neural Networks- An Initiative towards the River Ganga

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**Abstract**: Currently many type of research work is going on for assessing and modelling the water quality of rivers in India and especially in Abroad. There has been a lot of attention towards the use of artificial neural networks (ANNs) for solving scientific research, environmental and engineering computing based problems which are highly complex and non-linear in nature only because of their capability to be used for an extensive range of applications like classification, prediction and clustering. It is being increasingly used for prediction and forecasting in various areas like climate, rainfall and water quality. In this paper, we have presented an investigation of existing research work that has been done for assessing and modelling the water quality of various rivers using the technique of artificial neural networks. It was found that the ANN approach turned out to be an efficient approach for water quality modelling and forecasting. All these review work really stirred new researchers to work in this field by introducing new data set, parameters and an optimal approach based on ANNs. We shall take forth this work as an initiative towards the water quality (WQ) modelling of the river Ganga as our future work.

***Keywords--*** *Artificial Neural Network, Forecasting; Soft Computing;Water Quality*

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## I. Introduction: Artificial Neural Network

Water is basic need for all known forms of life. But now-a-days the society is facing a biggest challenge that is the paucity of water and the water which is available is not clean due to a gradual degradation in the quality of available water. A times ago human was looking towards rivers for his/her survival but today the scenario got reversed the water is looking towards human for its survival. Water pollution is the contamination of water bodies. Both human part and aquatic part are greatly affected by such a problem of water pollution. This form of environmental degradation occurs when pollutants are directly or indirectly discharged into waterbodies without adequate treatment to remove harmful compounds. This deterioration in the quality of river water posing threat to public health and ecosystem. In spite of various Govt. initiatives the rivers especially the GANGA, national river of India remains polluted. This is the demand of time to find out the technical solution for analyzing and maintaining proper water quality level in river Ganga so that it will be reinstated to its previous state of pious and purity i.e. research on technology based policy interface for decision makers is required. Therefore there is an urgent requisite of "Smart-Assessment Process" (SAP) on regular basis for water quality (WQ) of river GANGA (if taking about Indian scenario) in order to have smart monitoring. Recently, there has been a lot of attention all around towards the use of artificial neural networks (ANNs) for solving scientific research and engineering computing based problems which are highly complex and non-linear. They have been widely used in solving the environmental problems including water quality modelling and prediction.

An Artificial Neural Network (ANN) is an information processing model that is motivated by the manner biological nervous systems, like brain, process information. ANNs were designed to imitate the characteristics of the biological neurons in the human brain and nervous system [2]. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements termed as neurons which are working in together to solve specific problems. ANNs, learn by example as human being. An ANN is designed for a specific application, such as pattern recognition or data classification, through a learning process. ANNs can be thought of as a feature extraction and pattern recognition machine. Therefore, they can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques.

In this paper we have highlighted the key role played by one of the main component of soft computing (SC) i.e. by artificial neural network (ANN). Here, we have conducted a detailed literature survey of existing research work where the researchers utilized this technique of ANNs as a tool for assessment and modelling the water quality of different rivers at different areas. The rest of the paper is organized in five sections. Section 2 presents working of ANN with respect to the biological neural network. Section 3 illustrates

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the advantages and applications of ANNs. A review of literature is being presented in the section 4. In section 5, future scope of this paper has been presented and concludes the paper.

## II. WORKING OF ARTIFICIAL NEURAL NETWORKS (ANNs)

A biological neuron is shown in fig. 1 consists of the main cell body called as soma (circular structure), and axon (straight line) and many dendrites (curved lines). Each neuron can be in one of the states: firing and rest. The synapse present is the thin gap between axon of one neuron and dendrites of another.Natural neurons receive signals through synapses located on the dendrites or membrane of the neuron. If the received signal are strong enough (exceed a certain threshold), then only the neuron is activated and produces a signal though the axon. Similarly this signal may be sent to another synapse, and it may activate further neurons.

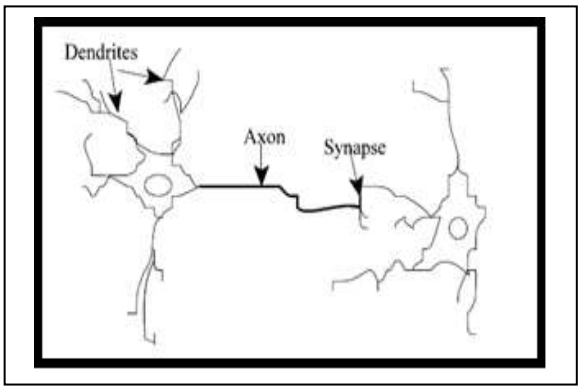


**Fig. 1**:Biological Neuron [3]

As per the theories available regarding the brain's working for processing the information, in the human brain, a typical neuron collects signals from others through a host of fine structures called *dendrites as shown in figure 1*. The neuron sends out spikes of electrical activity through a long, thin stand known as an *axon*, which splits into thousands of branches. At the end of each branch, a structure called a *synapse* converts the activity from the axon into electrical effects that inhibit or excite activity from the axon into electrical effects that inhibit or excite activity in the connected neurons. When a neuron receives excitatory input that is sufficiently large compared with its inhibitory input, it sends a spike of electrical activity down its axon. Learning occurs by changing the effectiveness of the synapses so that the influence of one neuron on another changes. The artificial neuron is the computing equivalent of the human neuron and is designed to perform in the same way. The basic mechanism of the artificial neuron is the same as in the human neuron and it is designed to pass messages on if the sum of the inputs is greater than a certain threshold level as shown in the following fig. 2.

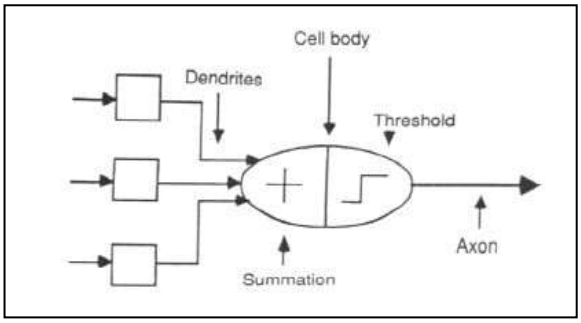


**Fig.2**: The basic structure of neural network (Source: NEURAL NETWORKS by C. Stergiou and D. Siganos)

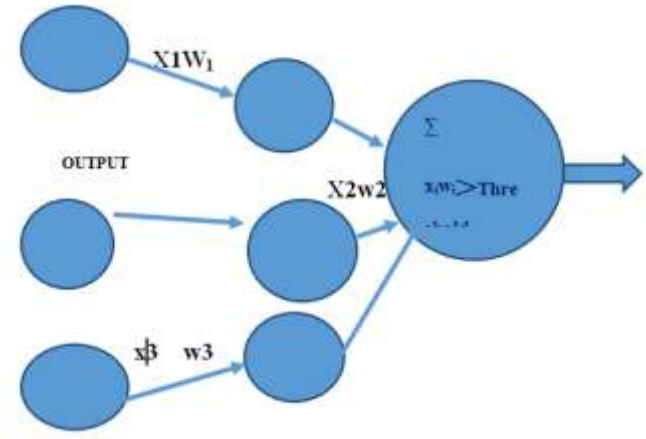


**Fig.3**: An Artificial Neuron

The complexity of real neurons is highly abstracted when modeling artificial neurons. These basically consist of inputs (like synapses), which are multiplied by weights (Strength of the respective signals), and then computed by a mathematical function which determines the activation of the neuron. Another function (which may be the identity) computes the output of the artificial neuron (sometimes in dependence of a certain threshold). ANNs combine artificial neurons in order to process information. The weights are chosen randomly and are optimized/adjusted during the process of training in order to minimize the gap between actual output and desired output. The artificial neuron is the computing equivalent of the human neuron and is designed to perform in the same way. The basic mechanism of the artificial neuron is the same as in the human neuron and it is designed to processinformationfurther if the sum of the inputs is greater than a certain threshold level as shown in the figure 3 where if the sum of the inputs, $\Sigma x_i w_i$ is greater than a definite threshold then only the neuron fires.

## III. ADVANTAGES OF ANNs

1. Adaptive Learning: They can adapt to changes in the environment by changing their connection strength or structure by being self-trained instead of programmed [2] which makes them flexible and efficient tool.

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2. Perform a task that a linear program cannot.
3. Unresponsive to the noise corrupting the input pattern.
4. Fault Tolerance: information is spread throughout the network (redundant) because of distributed processing. Part of destruction of a network leads to the corresponding degradation of performance. However, some network abilities may be retained even after a big damage in the network.
5. Graceful Degradation: network performance decays gradually in the presence of very noisy or contradictory inputs.
6. Generalization: ability to give correct response for the unanticipated data pattern (not included in the training pattern).
7. Reliable and offers low maintenance cost as more effective to reprogram the NN than to replace it.
8. Speed of operation: involves characteristic of parallelism.
9. Self-Organization: An ANN can create its own representation of the information it receives during learning time.
10. Real Time Operation: ANN computations may be carried out in parallel via designing special hardware devices.
11. NN are very flexible w.r.t. incomplete, imprecise, missing or noisy data and have potential as associative memory.
12. NN models can easily be updated hence suitable for dynamic environments.
13. Accuracy of NN models can be assessed using the traditional statistical measures of mean square error and correlation coefficient r.
14. NN technology performs "intelligent" tasks similar to those performed by human mind that's why termed as ANN.
15. No need to formulate an algorithm, there is no need to understand the internal structure or mechanism of problem under consideration.
16. Appropriate for the areas where little or incomplete understanding of the problem is existing however the training data is readily available.

### APPLICATIONS OF ANNS

- ANNs are proficient of dealing with prediction or forecasting problems like [2]: water quality forecasting, whether forecasting, rain forecasting, sales forecasting, industrial process control, customer oriented research, stock market forecasting etc.
- Medicinal Science
- Pattern recognition
- Time Series Tourism Prediction
- Handwritten word recognition
- Stock Market Prediction
- Animal Management
- Agriculture Management
- And many others.

The ANN-based modelling approaches are data-oriented, nonlinear, flexible, required no explicit knowledge about the system under consideration, require minimum human involvement [4]. The models developed using ANNs are computationally very fast, require only few input data and parameters and provides a cost-effective solution than process based models [5]. Due to these reasons, the data oriented modelling approaches are being widely used. ANNs are capable to approximate accurately non-linear, complex and unknown input-output complicated relationships like the case of environmental modelling [6]. For example to utilize ANN as a tool for water quality assessment modelling of River.

## IV. REVIEW OF LITERATURE

A variety of research work in many fields has been going on using artificial neural networks (ANNs). ANNs have become extremely prevalent and being used in one of the critical fields of ecological modelling i.e. to predict/forecast water resource variables.

**SovanLek et al.** [6] presented their work in a paper titled "Artificial neural networks as a tool in ecological Modelling, an introduction", in 1999. In this paper, the authors presented some of the important papers of the 1st international workshop about ANNs in ecological Modelling organized in Toulouse, France (December 1998) discussing different methods, ecological applications of ANNs as well as the future development of ANNs. Also the growing development and accessibility of computer-aided analysis increased the applications of ANNs in ecological Modelling.

**Ingrid M. Schleiter et al.** [7] discussed their work as "Modelling water quality, bioindication and population dynamics in lotic ecosystems using neural networks", in 1999.They have performed analysis of modelling water quality, bio-indication of chemical and long-term population dynamics of aquatic insects using neural networks model for the river Lahn (Germany).They used multi-layer-perceptrons with the Backpropagation (BP) algorithm. The results shown that ANNs can successfully be applied in the analysis of the prediction of system behavior. Finally they concluded that the quality of the neural networks based models greatly depends on the quality of the data base due to their ability of learning from examples.

**Holger R. Maier, et al.** [1] have published his research on "Neural networks for the prediction and forecasting of water resources variables: a review of Modelling issues and applications", 2000. In this paper the authors presented the steps that should be followed in the development of prediction and forecasting models. These include the choice of performance criteria, the division and pre-processing of the available data, the determination of appropriate model inputs and network architecture, optimization of the connection weights (training) and model validation.

**Mehdi Khashei et al.** [8] have published their paper on "An artificial neural network (p,d,q) model for time series forecasting", 2010. They focused on artificial neural networks (ANNs) as flexible computing frameworks and universal approximators that can be applied to a wide range of time series forecasting problems with a high degree of accuracy. In the first stage, an auto-regressive integrated moving average model was used to generate the necessary data, and then a neural network was used to determine a model for capturing the underlying data generating process and predict the future, using preprocessed data. They concluded that their proposed model can be an effective way in order to yield more accurate model than traditional artificial neural networks.

**Nabeel M. Gazzaz et al.** [9] have published their paper on "Artificial neural network Modelling of the water quality index for Kinta River (Malaysia) using water quality variables as predictors", 2012. They used feed-forward, fully-connected, three-layer perceptron neural network model for computing the water quality index (WQI) for Kinta River (Malaysia).The approach presented in this article offers useful and powerful alternative to WQI computation and prediction, especially in the case of WQI calculation methods which involve lengthy computations.

**Kumar Abhishek et al.** [10] presented their work titled "A Rainfall Prediction Model using Artificial Neural Network", 2012. In their research, possibility of predicting average monthly rainfall over Udupi district of Karnataka has been analyzed through artificial neural network models. In formulating artificial neural network based predictive models three layered network has been constructed. Training was done using matlab Back-propagation Algorithm (BPA). Authors concluded that development in the application field of ANN has opened up new avenues to the forecasting task involving environment related phenomenon.

**Majid Heydari et al.** [11] published their paper on "Development of a Neural Network Technique for Prediction of Water Quality Parameters in the Delaware River, Pennsylvania", 2013. In this study, authors made use of artificial neural networks (ANN) to derive and to develop models for prediction the monthly values of dissolved oxygen (DO) and specific conductance (SC). Authors said that ANN models have been widely applied to the water quality problems. The back-propagation multi-layer perceptron (MLP) was considered with the logistic function as its activation function. The results for the training and the test data sets were satisfactory. With this proposed model applications it is possible to manage water quality parameters like DO and SC in a more cost-effective and easier way.

**HosseinBanejad et al.** [12] published their paper on "Application of an Artificial Neural Network Model to Rivers Water Quality Indexes Prediction – A Case Study", 2011. In this work the authors presented an empirical multi-layer perceptron neural network to estimate water quality indexes (BOD, DO) in Morad Big River, Iran. The back-propagation algorithm based upon the generalized delta rule was used for training. The results show the identified ANN's great potential to simulate water quality variables.

**Archana Sarkar et al.** [13] presented her work on "River Water Quality Modelling using Artificial Neural Network Technique" in 2015. The authors used the artificial neural network (ANN) technique to estimate the dissolved oxygen (DO) for the River Yamuna in Mathura city, Uttar Pradesh, India. Water quality data for the years 1990 to 1996 used in this study. The feed forward error back propagation neural network technique has been applied. Monthly data sets on flow discharge, temperature, pH, biochemical oxygen demand (BOD) and dissolved oxygen (DO) at three locations have been used for the analysis. It was found that the ANN approach turned out to be an efficient approach for water quality Modelling.

**Sujana Prajithkumar et al.** [14] have presented their paper on "Application of ANN model for the prediction of Water Quality Index", in 2015. The authors predicted WQI using ANN model for the Pavna River in Pune, Maharashtra, India using the collected data for the point Ravet Intake from 2001 to 2014 on monthly basis. Among the selected two ANN models the developed ANN model with Recurrent Neural Network model stimulated the WQI of Pavna River with great accuracy when compared with Multilayer neural network architecture.

**Sundarambal Palani et al.** [5] discussed their work on "An ANN application for water quality forecasting", in 2008. In this paper, a study of ANN Modelling to predict and forecast temperature, salinity, DO, and chlorophyll-a in Singapore coastal waters was presented. The results demonstrated the

ANN's great potential to simulate water quality variables. Authors concluded that ANN model may provide simulated values for desired locations at which measured data are unavailable yet required for water quality models. They also highlighted that ANN modelling is a useful tool that optimizes monitoring networks by finding essential monitoring stations thus leading to cost reduction.

**Thair S.K. et al.** [15] presented their research on "Prediction of Water Quality of Euphrates River by Using Artificial Neural Network Model (Spatial and Temporal Study), in 2014.In this study, Artificial Neural Network model (ANN) model was used for prediction and forecasting the monthly Total Dissolved Solid (TDS) parameter in water using Feed Forward Back Propagation (FFBP). The authors stated that self-learning and automatic abstracting capability of ANN technique may reduce the time of modelling the complex systems. Finally they concluded that ANNs outperform conventional statistical techniquesin data analysis and modelling in forecasting which have limitations of strict assumptions of normality, linearity, variable independence and dimensionality.

**Nibedita Guru et al.** [16] discussed their work in the paper titled "Simulation of BOD-DO Modelling in Mahanadi River System lying in Odisha using ANN, India", in 2013. The Multi-layer Perceptron (MLP) neural network techniques was used for estimating the point of source pollution in terms of BOD and DO concentration. The neural network model was developed using the data collected from the upstream and downstream stations on Mahanadi river system lying in Odisha using the multilayer perceptron technique. It was found that for prediction of the BOD and DO in the Mahanadi River, Odisha the ANN model found to be a useful tool.

**S. Wechmongkhonkon et al.** [17] described their work titled as "Application of Artificial Neural Network to Classification Surface Water Quality", in 2012. Their study classified water quality using 6 parameters in Bangkok, Thailand during a period of five years 2007-2011. 385 samples were taken for the analysis in water quality classification. A MLP neural network using the Levenberg-Marquardt algorithm was used. The results draw attention to the fact that the neural network perform with a high accuracy classification percentage of 96.52%.

**Shilpi Rani et al.** [18] presented their research work as "Predicting Reservoir Water Level Using Artificial Neural Network", in 2014. Authors presented an Artificial Neural Network (ANN) approach for forecasting of reservoir water level using Feed Forward Back Propagation in an effective and timely way that can also help in disaster monitoring, response and control. The authors explained that the traditional methods of time series analysis used by the researchers such as autoregressive method of Box-Jenkins (AR), auto-regressive moving average (ARMA), auto-regressive integrated moving average (ARIMA), etc. but they suffer with the problem of stationary and linearity and gives only reasonable accuracy. While the ANN concept was introduced as an efficient tool of Modelling and forecasting since two decades.

**Anita Talib et al.** [19] presented their work on "Prediction of Chemical Oxygen Demand In Dondang River Using Artificial Neural Network", in 2012. They applied the Neural networks to study the factors that affect water quality of Dondang River. Total nine different variables considered as input at three stations different sites.The Multi-Layer Perceptron (MLP) was used as an ANN structure. MLP works through back-propagation method. The prediction was made for Chemical Oxygen Demand (COD). They come to the result that neural networks can be applied to study the factors that affect water quality of Dondang River.

**Venkata Rao, K et al.** [20] published their work on "A Classical Way of Finding Water Pollution by Using Artificial Neural Network" in 2013. The authors classified the ground water quality into four classes by means of Artificial Neural Network (ANN) method using the back propagation algorithm. Indian Standard Specifications for Drinking Water IS: 10500 was taken for the classifications of ground water quality. Authors discussed that, there are several methods to classify the water quality like Gray correlation analysis method, gray clustering method, integrated pollution index method, Fuzzy Comprehensive Evaluation etc. All these traditional methods cannot provides precision efficiency to solve the complicated nonlinear relationship existing between the factors affecting water quality water quality. An ANN could simulate any non-linearity mapping relations in theory and the results are also proved more close to the reality.

**VesnaRankovi et al.** [21] proposed their work in the paper titled as "Neural network Modelling of dissolved oxygen in the Gruza reservoir, Serbia", in 2010. Their aim was to develop a feedforward neural network (FNN) model to predict the dissolved oxygen in the Gruza Reservoir, Serbia. The neural network model was developed using experimental data which are collected during a three years (2000–2003) and implemented using MATLAB Neural Network Toolbox. Results of simulation, showed that the application of the neural network to prediction of dissolved oxygen gives satisfactory results.

**Holger R. Maier et al.** [22] discussed their research work as titled "Methods used for the development of neural networks for the prediction of water resource variables in river systems: Current status and future directions" in 2010.The authors conducted a detailed survey of 210 journal papers that were published from 1999 to 2007 and stated that artificial neural networks (ANNs) have been used progressively for prediction and forecasting in water resources and environmental engineering. But the methods used for developing ANN models are not yet well established so they mentioned a systematic step-by-step process in the development of ANN models. They concluded that majority of studies more than 90% of the papers focused on water quantity i.e. flow prediction, with very few applications to water quality.

**Sirilak Areerachakulet al.** [23] had presented their research paper titled "Water Quality Classification using Neural Networks: Case Study of Canals in Bangkok, Thailand", in 2009.This study was done to automatically classify water quality. The water quality classes are evaluated using 3 chemical factor pH, Dissolved Oxygen and Biochemical Oxygen Demand. The confusion matrix was used that demonstrates information about the target (actual class of surface water standard) and the output (predicted class by the network). It can be seen that the network correctly classified 4697 records from a total of 4728 records. A high accuracy classification percentage of 99.34% proven the importance of the neural network.

**Kwokwing Chau** [24] had presented his work in paper "A review on the integration of artificial intelligence into coastal Modelling", in 2006. This paper aimed to review the state-of-the-art in the integration of different AI technologies into coastal modelling. The algorithms and methods studied include knowledge-based systems, genetic algorithms, artificial neural networks, and fuzzy inference systems. He described that the accuracy of designed ANN model is affected by various factors like the choice of performance criteria, division and pre-processing of the available data, appropriate model inputs determination and network architecture, optimization of the connection weights, and the validation of the model. He had concluded that the integrated model might be very powerful, since the advantages of each technique can be combined.

**Weizhong Yan** [5] presented his research work titled as "Toward Automatic Time-Series Forecasting Using Neural Networks", in 2012. He had developed an automatic ANN Modelling scheme for time series forecasting(TSF)based on the generalized regression neural network (GRNN), with the objectives of requiring minimal human intervention, achieving computationally efficient scheme for a large number of series and to have good overall forecasting performance. Author stated that as compared to statistics-based forecasting techniques, neural network approaches have various advantages like ANNs are data driven, nonlinear, no requirement for an explicit underlying model and more flexible, thus applicable to more complicated models.

**Imran Maqsood et al.** [25] presented their research work as "An ensemble of neural networks for weather forecasting", in 2004. They proposed applicability of an ensemble of artificial neural networks (ANNs) for weather forecasting in the area of southern Saskatchewan, Canada in two steps, first training a number of component neural networks and then combining the component predictions. Finally they concluded that the ensemble networks can be trained effectively in comparison with the regression models, the ensemble networks forecast the weather parameters with higher accuracy.

## V. CONCLUSION AND FUTURE SCOPE

From the survey of existing research literature, it is concluded that soft computing techniques especially Neural Networks has become interesting preference for researchers to solve problems based on water quality assessment or any other time-series forecasting with greater efficiency. It was found that the ANN approach turned out to be an efficient approach for water quality modelling and forecasting based problems. This fact will seriously open out plentiful scopes for the researchers' community. Present paper highlighted working, advantages, applications of ANN in various fields as well as existing literature study is also being done and presented in a summarized way. It is concluded that the applicability ANNs seriously opens out ample scopes for the researchers' society particularly for the novice individuals. As such modelling approaches are data-driven, nonlinear, flexible, required no explicit knowledge about the actual system. As a consequence, the models developed using ANNs are computationally very quick and provides a lucrative solution. Because of these reasons, ANNs are being widely used to approximate accurately water quality prediction and forecasting type of environmental problems which are highly non-linear, complex in nature. Having such a descriptive studies over a wide range of literature we are also trying to take an initiative towards development of a "Smart-Assessment Process" (SAP)for the River Ganga using different computation techniques on the basis of collecting the historical time-series quality dataas a part our future work. Our little efforts in this paper will definitely be helpful to the novice researchers and the research society.

## REFERENCES

[1] H. R. Maier, Graeme C. Dandy, "Neural networks for the prediction and forecasting of water resources variables: a review of Modelling issues and applications", Environmental Modelling& Software 15,ELSEVIER, pp. 101–124, 2000.

[2] A. Abraham, B. Nath, "A neuro-fuzzy approach for modeling electricity demand in Victoria",Applied Soft Computing 1, ELSEVIER, 127–138, 2001.

[3] Carlos Gershenson, "Artificial Neural Networks for Beginners".

[4] Weizhong Yan, "Toward Automatic Time-Series Forecasting Using Neural Networks", IEEE Transactions on Neural Networks and Learning Systems, VOL. 23, NO. 7, JULY 2012.

[5] SundarambalPalani, Shie-YuiLiong, PavelTkalich, "An ANN application for water quality forecasting",Marine Pollution Bulletin 56 1586–1597, ELSEVIER, 2008.

[6] Sovan Lek, J.F. Guegan, "Artificial neural networks as a tool in ecological modelling, an introduction", Ecological Modelling, ELSEVIER,65–73, 1999.

[7] Ingrid M. Schleiter , Dietrich Borchardt, Rudiger Wagner, Thomas Dapper, Klaus-Dieter Schmidt, Hans-Heinrich Schmidt, Heinrich Werner, "Modelling water quality, bioindication and population dynamics in lotic ecosystems using neural networks", Ecological Modelling 120, ELSEVIER, pp. 271–286, 1999.

[8] M. Khashei , M. Bijari, "An artificial neural network (p,d,q) model for timeseries forecasting", Expert Systems with Applications 37,ELSEVIER, pp. 479–489, 2010.

[9] N. M. Gazzaz, MohdKamil Yusoff, Ahmad ZaharinAris , Hafizan Juahir, Mohammad FiruzRamli, "Artificial neural network Modelling of the water quality index for Kinta River (Malaysia) using water quality variables as predictors", Marine Pollution Bulletin, ELSEVIER, 2012.

[10] K. Abhishek, A. Kumar, R. Ranjan, S. Kumar, "A Rainfall Prediction Model using Artificial Neural Network", Control and System Graduate Research Colloquium (ICSGRC), IEEE, 2012.

[11] M. Heydari, E. Olyaie, H. Mohebzadeh and O. Kisi, "Development of a Neural Network Technique for Prediction of Water Quality Parameters in the Delaware River, Pennsylvania",Middle-East Journal of Scientific Research 13 (10): pp.1367-1376, 2013.

[12] HosseinBanejad, EhsanOlyaie, "Application of an Artificial Neural Network Model to Rivers Water Quality Indexes Prediction – A Case Study", Journal of American Science, 7(1) 2011.

[13] Archana Sarkar, Prashant Pandey "River Water Quality Modelling using Artificial Neural Network Technique", International Conference on Water Resources And Ocean Engineering (ICWRCOE), ELSEVIER,2015.

[14] SujanaPrajithkumar,ShwetaVerma, B V Mahajan, "Application of ANN model for the prediction of Water Quality Index ", International Journal of Engineering Research and General Science Volume 3, Issue 1, ISSN 2091-2730, January-February, 2015.

[15] Thair S.K., Abdul Hameed M. J., Ayad S. M., "Prediction of Water Quality Of Euphrates River By Using Artificial Neural Network Model (Spatial and Temporal Study), International Research Journal of Natural Sciences Vol.2,No.3,pp.25-38, September 2014.

[16] Nibedita Guru, RamakarJha, "Simulation of BOD-DO Modelling in Mahanadi River System lying in Odisha using ANN, India", IOSR Journal Of Environmental Science, Toxicology And Food Technology (IOSR-JESTFT) ISSN: 2319-2402, ISBN: 2319-2399. Volume 2, Issue 4, PP 52-57, Jan. - Feb. 2013.

[17] S. Wechmongkhonkon, N.Poomtong, S. Areerachakul, "Application of Artificial Neural Network to Classification Surface Water Quality", World Academy of Science, Engineering and Technology, Vol: 6 2012-09-29, 2012.

[18] Shilpi Rani, Falguni Parekh "Predicting Reservoir Water Level Using Artificial Neural Network", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 7, ISSN: 2319-8753, July 2014.

[19] Anita Talib, MawarIdatiAmat, "Prediction of Chemical Oxygen Demand In Dondang River Using Artificial Neural Network", International Journal of Information and Education Technology, Vol. 2, No. 3, June 2012.

[20] Venkata Rao, K, Swarnalatha P. "A Classical Way of Finding Water Pollution by Using Artificial Neural Network", IRACST – Engineering Science and Technology: An International Journal (ESTIJ), ISSN: 2250-3498, Vol.3, No.3, June 2013.

[21] Vesna Rankovi, Jasna Radulovic, Ivana Radojevic, Aleksandar Ostojic, Ljiljana Comic, "Neural network Modelling of dissolved oxygen in the Gruza reservoir, Serbia", Ecological Modelling 221 (2010) 1239–1244, ELSEVIR, 2010.

[22] Holger R. Maier, Ashu Jain, Graeme C. Dandy, K.P. Sudheer, "Methods used for the development of neural networks for the prediction of water resource variables in river systems: Current status and future directions", Environmental Modelling & Software 25, ELSEVIER, pp.891-909, 2010.

[23] SirilakAreerachakul, SiripunSanguansintukul, "Water Quality Classification using Neural Networks: Case Study of Canals in Bangkok, Thailand", IEEE, 2009.

[24] KwokwingChau, "A review on the integration of artificial intelligence into coastal Modelling", Journal of Environmental Management, ELSEVIER, 47–57, 2006.

[25] Imran Maqsood, Muhammad Riaz Khan, Ajith Abraham, "An ensemble of neural networks for weather forecasting", Neural Comput&Applic, Springer-Verlag London Limited 4, 13: pp. 112–122, 2004.