Wastewater Quality Forecasting by using Artificial Neural Network

Ms. Ekta S Dhande[#1]
[1] ME Student (Env Engg). Department of Civil Engineering.
D Y Patil College of Engineering, Akurdi,
Pune Maharashtra, India.

Mr S. J Mane[#2]
[2] Assistant Professor Department of Civil Engineering.
D Y Patil College of Engineering,
Akurdi, Pune
Maharashtra, India.

Abstract **---Rapid urbanization has quadrupled generation of wastewater, thus increasing the pressure on wastewater treatment plants. It is also necessary to produce higher quality treated wastewater at lower cost. The present study aims at development of a statistical model viz: Artificial neural network (ANN) for forecasting quality of wastewater. Extensive database influent parameters containing BOD, COD and SS spanning over 10 years (2004-2013) from Kasarwadi wastewater treatment plant Pimpri Chinchwad is collected for the study. In order to predict wastewater quality, multilayer perceptrons (MLP) and recurrent network (RNN) models of (ANN) were investigated and applied. The trial and error method is adopted to compare desired output with actual observed values of quality parameters in terms of error statistics. The developed model measures the trend of wastewater parameters (R=0.919) for BOD_{out} and (R=0.927) for COD_{out}. The results obtained through the proposed models show that ANN can be efficiently used in the analysis and prediction of wastewater quality.**

Keywords—Biochemical oxygen demand, Chemical oxygen demand, Artificial Neural Network.

I. INTRODUCTION

The increased concern about environmental issues has encouraged focusing attention on the proper operation and control of wastewater treatment plants (WWTPs). The characteristics of influent to the WWTPs are varied from one plant to another depending on the type of community lifestyle, time and season. Therefore, the performance of any WWTP depends mainly on local experience of a process engineer who identifies certain state of the plant. The type of influent for any plant is also time-dependent and it is difficult to have a homogeneous influent to a WWTP. This may result in an operational risk impact on the plant. Serious environmental and public health problems may result from improper operation of a WWTP, as discharging contaminated effluent to a receiving water body can cause or spread various diseases to human beings and aquatic ecosystem, if they were to be discharged into the water ways prior to treatment. Accordingly, environmental regulations set restrictions on the quality of effluent that must be met by any WWTP.

Wastewater treatment influent parameters such as biochemical oxygen demand (BOD) and chemical oxygen demand (COD) are important factors that determine the volume and strength of pollution of municipal wastewater. As a result, their amounts in the wastewater affect the quality of effluent. The connection of these parameters; both influent and effluent is always a concern to wastewater treatment plant (WWTP) process engineers in order for them to optimize the performance of the plant and ensure the safety of the environment for a proper plant operation. Owing to their high accuracy, adequacy and quite promising applications in engineering, artificial neural networks (ANNs) can be used for modeling such WWTP processes. The ANN can be used for better prediction of the process performance. It normally relies on representative historical data of the process.

The main objective of this paper is to predict the BOD and COD concentrations of a WWTP based on the concept of ANNs, a widely used application of artificial intelligence that has shown quite a promise in a variety of applications in engineering and pattern recognition.

II. ARTIFICIAL NEURAL NETWORK

An artificial neural net work can be defined as a distributed computational system composed of a number of individual processing elements operating largely in parallel, interconnected according to some specific topology, and having the capability to self-modify connection strengths during the processing of element parameters.

The ANN basically consists of an input layer, one hidden or intermediate layer and an output layer. The neuron accepts input from single or multiple sources and produces output by a simple calculating process guarded by a non-linear transfer function. As shown in figure no.(1) a three-layered network with an input layer, hidden layer and output layer the neurons of one layer are connected to the neurons of another layer with connection weight, but they are not connected to neurons of the same layer can be obtained. Each output value from a node, Y_i is weighted by the value W_i and the input to the next node, X_i is obtained by summing the product Y_iW_i. The output from this neuron is obtained by applying a non-linear activation function to X_i. All other neurons are also connected to the neurons of another layer. The connection weights between neurons are optimized using the known input and target values through an iterative process and error-minimization technique, so

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that the network produces outputs close or equal to the known target values. Equation (1) is the most commonly used transfer function is the sigmoid function as described by:

$$f(x) = \frac{1}{1+e^{-x}} \qquad (1)$$

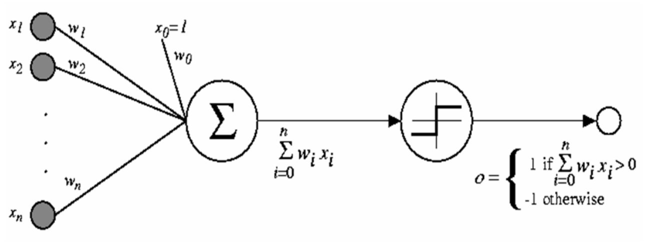

Fig.1 Layers of ANN

The above stated description produces output in the range of 0−1 and introduces non-linearity into the network, which gives the power to capture nonlinear relationships. The back propagation network is the most prevalent supervised ANN learning model which is used for obtaining the required results. It uses the gradient descent algorithm to correct the weights between interconnected neurons. One of the main features of ANN methodology is to enhance the networks' speed. Solution can be generated very quickly for most problems, if a number of conditions are followed. First, the network configuration should not be too large, so that the number of connections whose weights have to be calculated is not large. Second, the training examples set should not be too long since the smaller the set, the more times every example will go through the network and the faster the solution will be obtained. Finally, the composition of training examples must be homogenous. In other words, the more the examples are, the faster the learning process. Given these conditions, data screening process is carried out on raw experimental data to eliminate all out-of-range values the presence of which might be due to transcription or transposition errors, improper input of data, and experimental errors or human errors. The components of input layers consist of three parameters, BOD influent (BODin), COD influent (CODin).Data is subdivided into three groups; training and testing, in the ratio of 75%:15%, respectively. The data sequence of the inputs was obtained after normalization of the data. The fitting graph for inputs-output were generated.

During the learning process of the network, the algorithm computes the error between the predicted and specified target values at the output layer. The error function at the output layer can be defined by:

$$E=\frac{1}{2}\sum(O_d-O_p)^2 \qquad (2)$$

Where, E is error function, O_d is desired output and O_p is the output predicted by the network.

III. METHODOLOGY USED

To build effective ANN models of wastewater treatment processes, a sequential methodology consisting of certain stages is proposed. The relationship among each of the stages is depicted in figure:

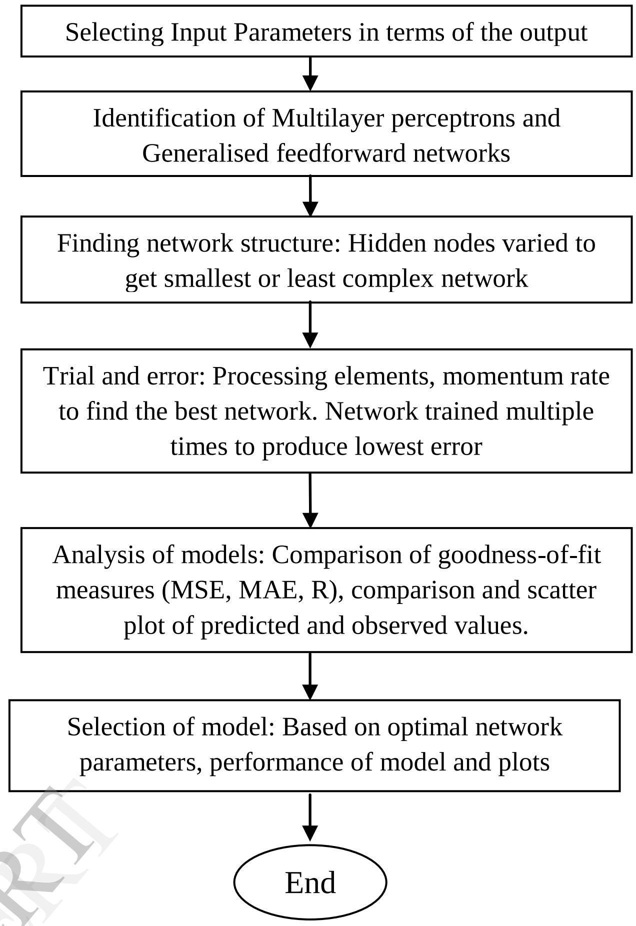

Fig.2 ANN methodology

The network to be adopted for ANN is Feed Forward Backpropagation Network. A feedforward neural network is an artificial neural network where connections between the units do not form a directed cycle.

The feedforward neural network is simplest type of artificial neural network devised. In this network, the information moves in only one direction, forward, from the input nodes, through the hidden nodes and to the output nodes. There are no cycles or loops in the network.

In this study, a neural network is trained and tested through the use of software neural network version 6.31 to examine the performance of the ANN model.

IV. DATA COLECTED:

The data is collected from Kasarwadi wastewater treatment plant which comes under Pimpri Chinchwad Municipal Corporation, Pune. from yr 2003-2013.This plant is divided into three phases. In which phase 2 and 3 uses Activated sludge process and phase-1 uses Sequential batch reactor technologies to treat the waste water. So the data used is of phase-1 whose capacity is 40 MLD. Data of different inlet as well as outlet parameters such as BOD, COD is collected of last 10 years. This is preferable because it includes all seasonal variations in. the parameter that might influence the pattern of the data. Moreover, the more the data set, the more reliable is the designed model.

V. RESULT AND DISCUSSION:

From the available data of Kasarwadi wastewater treatment plant, a ANN program is developed to generate a relationship between in late parameters in the form of a graph. The graph is plotted using the neural network toolbox. In the graph shown in the figure below, the in late parameters has been compared with a normal value. Different structures of feed forward ANN with multi layers and a different number of neurons in the hidden layers were investigated to achieve the best ANN structure for estimating the parameters of wastewater generated. Forecasting and predicting the quantity of wastewater generated depends on to the different factors such as community lifestyle, time and season, etc. and these factors are not accurate measurement and it cannot be used as a standard precise analysis.

The results are analyzed by following parameters Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Square Error (RMSE) and Correlation Coefficient (R) suitable models were selected for study.

A. ABSOLUTE ERROR:

An error value indicates the "quality" of neural network training, which was calculated by subtracting the current output values with the target output values of the neural network.The smaller the network error is, the better the network had been trained.

B. MEAN SQUARED ERROR (MSE):

This is an absolute error measure that squares the difference between values from your target column and network output to keep the positive and negative deviations from canceling each other out. To calculate the MSE the errors for each record are squared, added together and divided by the number of records. MSE gives a single number that summarizes the overall network error.

C. R VALUE

The R value and RMS error indicate how “close” one data series is to another – in our case, the data series are the Target (actual) output values and the corresponding predicted output values generated by the model. R values range from -1.0 to +1.0. A larger (absolute value) R value indicates a higher correlation. The R values for the model on the training and test sets are close to each other, which mean the model generalizes well and is likely to make accurate predictions.

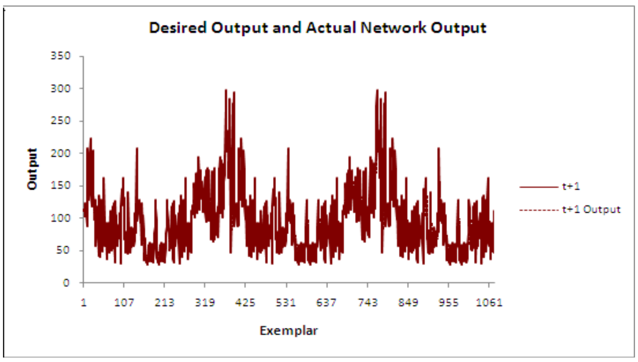

Fig 3: Desired output and actual output of ANN model for BOD_{IN}.

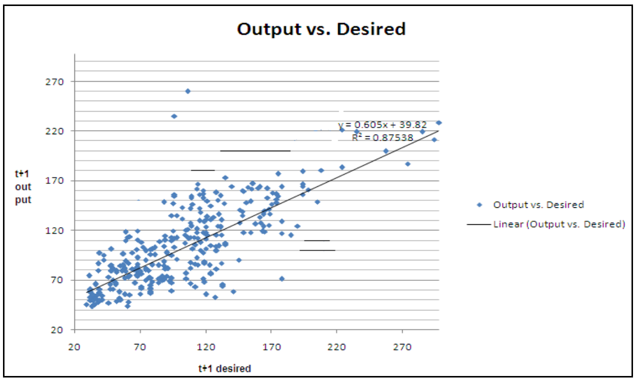

Fig 4: Scattered plot of desired output and actual output of ANN model for BOD_{IN}

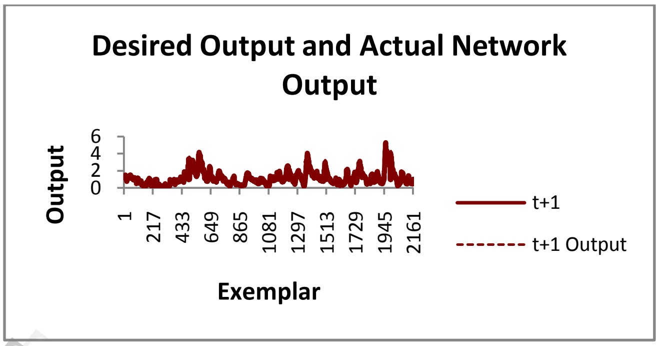

Fig 5: Desired output and actual output of ANN model for BOD_{OUT}

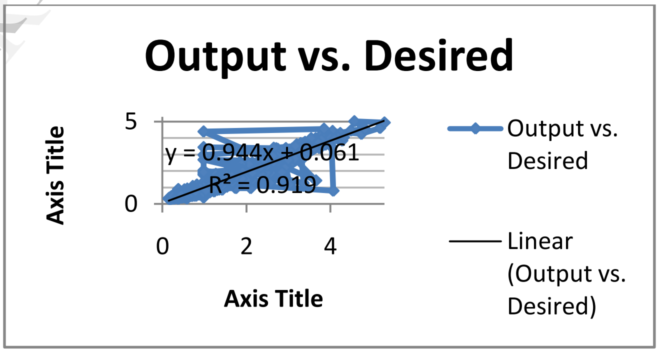

Fig 6: Scattered plot of desired output and actual output of ANN model for BOD_{OUT}

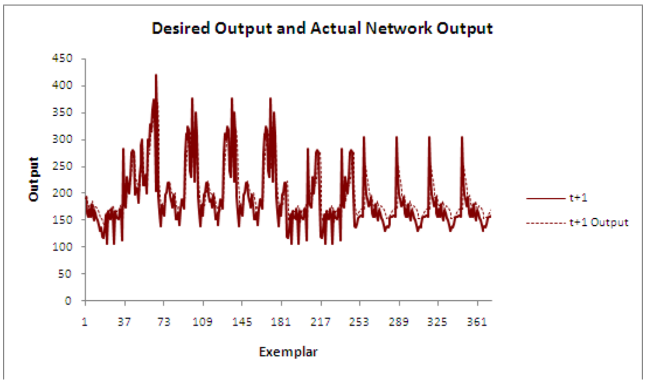

Fig 7: Desired output and actual output of ANN model for COD_{IN}.

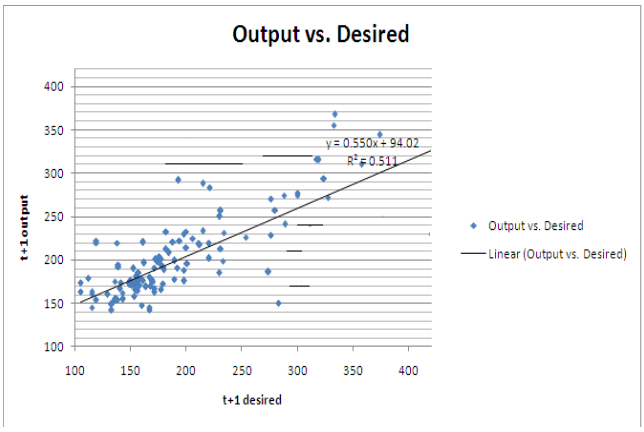

Fig 8: Desired output and actual output of ANN model for COD_{IN}

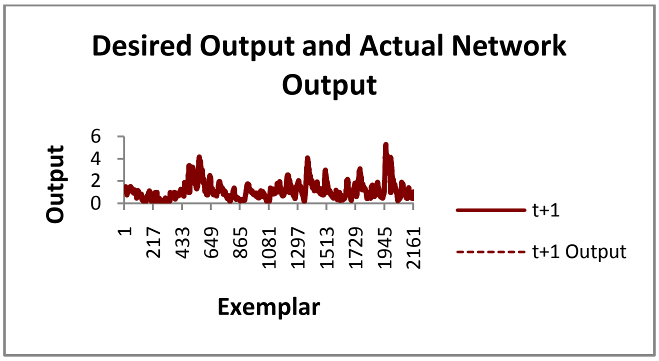

Fig 9: Desired output and actual output of ANN model for COD_{OUT}

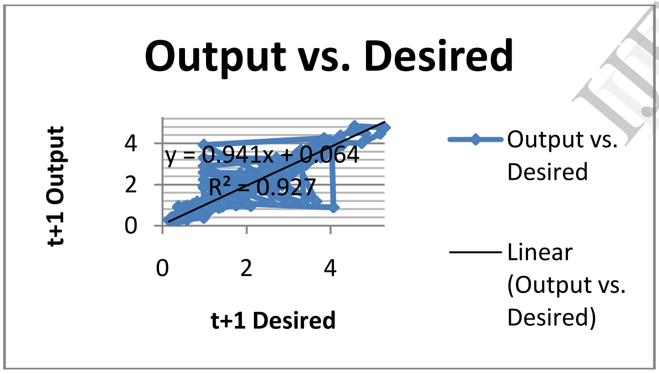

Fig 10: Desired output and actual output of ANN model for COD_{OUT}

6. CONCLUSION:

Present study reveals that prediction of BOD and COD using ANN proves to be better technique than conventional mathematical modeling. Treatment of wastewater by wastewater treatment plant consists of sequence of complex physical, chemical and biological processes, and their dynamics are non-linear. Still ANN gives very satisfactory results for models. For BOD model, value of R = 0.919. Whereas for COD model, value of R = 0.927 Both the models show the satisfactory results. ANN learns from the historical data available, so as the time passes ANN will give more accurate results. Therefore from the above stated results we can conclude that Artificial Neural Network is the promising tool in the prediction and forecasting.

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