ESTIMATION OF BIOLOGICAL OXYGEN DEMAND USING ARTIFICIAL NEURAL NETWORK

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ABSTRACT *Recently Artificial Neural Networks (ANNs) have been used increasingly to predict water resources phenomenon. Feed-forward neural network modeling technique is the most widely used ANN type in water resources applications. The main purpose of this study is to investigate the abilities of an artificial neural networks (ANNs) model to improve the accuracy of the biological oxygen demand (BOD) estimation. Many of the water quality variables (Chemical oxygen demand, temperature, dissolved oxygen, water flow, chlorophyll-a and nutrients, ammonia, nitrite, nitrate) that affect biological oxygen demand concentrations were collected at eleven sampling sites in the Melen River Basin during 2001-2002. Comparison of results reveals that the ANN model gives reasonable estimates for the BOD prediction.*

INTRODUCTION

Biochemical oxygen demand is an important parameter for usage conditions of surface waters. It is an approximate measure of the amount of biochemical degradable organic matter present in a water sample. It is defined by the amount of oxygen required for the aerobic microorganisms present in the sample to oxidize the organic matter to a stable organic form (Chapman, 1992). Excessive BOD loads damage the quality of river water. It causes low DO (Dissolved Oxygen) concentration and unsuitable life conditions for flora and fauna in the river. At the same time, BOD-DO relationships include exchange with the river bed and nitrification and denitrification (Radwan et al., 2003). Nutrients and light in the phytoplankton growth, the relationship between DO and phytoplankton concentrations and ammonia effect the BOD degradation (Lopes et al., 2005). Dissolved oxygen levels, water temperature, water flow, chlorophyll-a and nutrient levels (ammonia, nitrite, nitrate) are among the most critical factors for biochemical oxygen demand (BOD) in the rivers. The oxygen consumption from degradation of organic material is normally measured as BOD and COD, so there is an important relation between them. Performing the test for BOD requires significant time and commitment for preparation and analysis. This process requires five days, with data collection and evaluation occurring on the last day. A test is used to measure the amount of oxygen consumed by these organisms during a specified period of time (usually 5 days at 20 oC). The difference in initial DO readings (prior to incubation) and final DO readings (after 5 days of incubation) is used to determine the initial BOD concentration of the sample. This is referred to as a BOD_5 measurement (Delzer and McKenzie, 1999). Several water quality models such as traditional mechanistic approaches, have been developed in order to manage the best practices for conserving the quality of water. Most of these models need several different input data which are not easily accessible and make it a very expensive and time consuming process (Suen and Asce 2003). ANNs are computer techniques that attempt to simulate the functionality and decision-making processes of the human brain and have become the center of interest across many scientific studies, including water quality. ANNs have been successfully used in hydrological processes, water resources, water quality prediction, and reservoir operation (Suen and Asce 2003, Zaheer and Bai 2003). Especially, they have been used for forecasting of water quality parameters and estimating nutrient concentration from pollution sources of watershed (Sengorur et al.). The main purpose of this study is to analyze and discuss the performances of ANN in prediction of biological oxygen demand in the Melen River. The data were collected from 11 sample points on a monthly basis from 2001-2002. ANN was applied to the data set obtained from 11 sample points. Laboratory data set from stations 1, 3, 9, 11 were selected as training and laboratory data set from stations 2, 5, 8, 10 were used as testing. The performance of ANN models is determined by using sensitivity analysis such as R^2 and MSE.

BASIC PRINCIPLES OF THE NEURAL NETWORKS

Artificial Neural Networks (ANNs) consist of large number of processing elements with their interconnections. ANNs are basically parallel computing systems similar to biological neural networks. They can be characterized by three components:

- Nodes
- weights (connection strength)
- An activation (transfer) function

ANN modeling is a nonlinear statistical technique, it can be used to solve problems that are not amenable to conventional statistical and mathematical methods. In the past few years there has been constantly increasing interest in neural networks modeling in different fields of hydrology engineering (ASCE, 2000a). The basic unit in the artificial neural network is the node. Nodes are connected to each other by links known as synapses, associated with each synapse there is a weight factor. Usually neural networks are trained so that a particular set of inputs produces, as nearly as possible, a specific set of target outputs. The most commonly used ANN is the three-layer feed-forward ANN. In feed-forward neural networks architecture, there are layers and nodes at each layer. Each node at input and inner layers receives input values, processes and passes to the next layer. This process is conducted by weights. Weight is the connection strength between two nodes. The numbers of neurons in the input layer and the output layer are determined by the numbers of input and output parameters, respectively. In the present feed-forward artificial neural networks are used. The model is shown in Figure 1. In the Figure 1, i, j, k denote nodes input layer, hidden layer and output layer, respectively. w is the weight of the nodes. Subscripts specify the connections between the nodes. For example, w_{ij} is the weight between nodes i and j. The term "feed-forward" means that a node connection only exists from a node in the input layer to other nodes in the hidden layer or from a node in the hidden layer to nodes in the output layer; and the nodes within a layer are not interconnected to each other. Commonly, neural network modeling follows these steps: database collection; analysis and preprocessing of the data; training of the neural network. The latter includes the choice of architecture, training functions, training algorithms and parameters of the network; testing of the trained network; and using the trained neural network for simulation and prediction. The model developed here has adopted these steps.

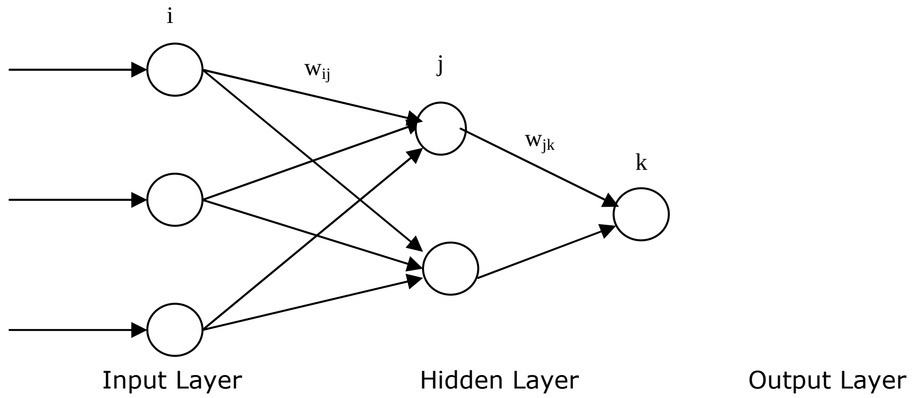

Fig. 1 A typical three-layer feed forward ANN

APPLICATION OF NEURAL NETWORK

To develop an ANN model for estimating BOD, the available data set was partitioned into a training set and a test set according to station. About 51% (52 laboratory data set from station 1, 3, 9, 11) of the available record was selected for training while the remaining 49% (50 for laboratory data set from station 2, 5, 8, 10) was used for testing. For all created neural networks the general structure of input, one hidden and one output layer was used. In order to determine the optimal architecture, several neural networks were trained with different iteration number (epoch) and number of nodes in the hidden layer. After training the neural network, test performance was checked. The performance of neural network for prediction of BOD is demonstrated in Figure 2. Figure 2 also shows an analysis between the network outputs (estimations) and the corresponding targets (observed data) for the test dataset. It is obvious that the predicted values from the trained neural network outputs catch the targets well.

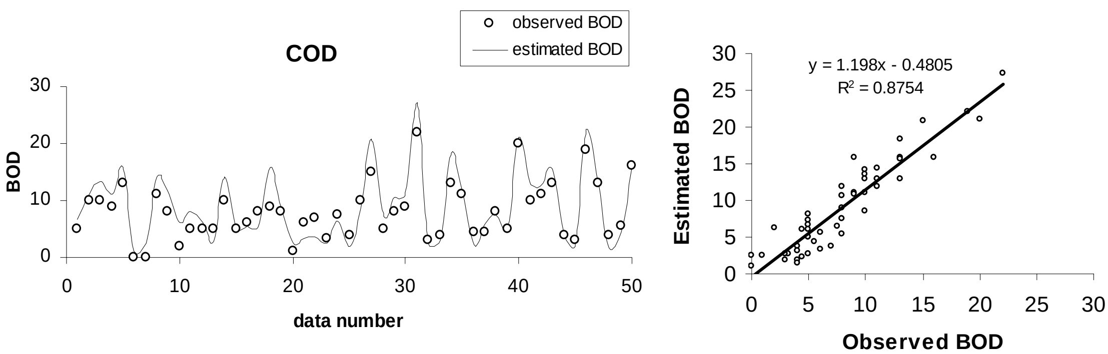

Fig. 2 Estimated BOD vs. Observed BOD

CONCLUSION

The potential of an artificial neural network technique (ANN) in BOD estimation in the Melen River was examined in this paper by comparing the results with observed BOD. From the results obtained, an ANN model appears to be a useful tool for prediction of the

BOD in the Melen River. This study was performed to reduce the stations of BOD that require significant time and commitment for preparation and analysis. BOD analyze requires five days, with data collection and evaluation occurring on the last day. Based on the comparison results, the ANN technique was found to perform well.

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