An artificial neural network model for the effects of chicken manure on ground water

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ABSTRACT

In the areas where broiler industry is located, poultry manure from chicken farms could be a major source of ground water pollution, and this may have extensive effects particularly when the farms use nearby ground water as their fresh water supply. Therefore the prediction the extent of this pollution, either from rigorous mathematical diffusion modeling or from the perspective of experimental data evaluation bears importance. In this work, we have investigated modeling of the effects of chicken manure on ground water by artificial neural networks. An ANN model was developed to predict the total coliform in the ground water well in poultry farms. The back-propagation algorithm was employed for training and testing the network, and the Levenberg–Marquardt algorithm was utilized for optimization. The MATLAB 7.0 environment with Neural Network Toolbox was used for coding. Given the associated input parameters such as the number of chickens, type of manure pool management and depth of well, the model estimates the possible amount of total coliform in the wells to a satisfactory degree. Therefore it is expected to be of help in future for estimating the ground water pollution resulting from chicken farms.

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1. Introduction

Chicken farms, amounting to nearly 400, widely exist in the province of Corum and have become an important source of ground water pollution in the area. In these farms the manure is transferred by means of pressurized water to the manure pool. In the course of this transfer and following operations, chicken manure penetrates into the ground water by runoff, flooding and diffusion. Furthermore farms get their water supply from 20 to 90 m deep wells.

For predicting the degree of pollution for major pollutant constituents in ground water wells in poultry farms, one approach could be the identification of an input–output relationship between the involved variables based on the field measurements. From this perspective, artificial neural networks (ANNs) are powerful tools that have the abilities to recognize underlying complex relationships from input–output data only [1]. ANN models have been widely used tools in the field of water quality prediction [2–6]. An artificial neural network is an information processing system that imitates the behavior of a human brain by emulating the operations and connectivity of biological neurons [7]. It performs a human-like reasoning, learns the attitude and stores the relationship of the processes on the basis of a representative data set that already exists. In general, the neural networks do not need much of a detailed description or formulation of the underlying process, and thus appeal to practicing engineers who tend to rely on their own data [1].

1.1. ANN modeling

Depending on the structure of the network, usually a series of connecting neuron weights are adjusted in order to fit a series of inputs to another series of known outputs [1]. When the weight of a particular neuron is updated it is said that the neuron is learning. The training is the process that neural network learns. The adaptability, reliability and robustness of an ANN depend upon the source, range, quantity and quality of the data set.

The feed forward neural networks consist of three or more layers of nodes: one input layer, one output layer and one or more hidden layers. The input vector passed to the network is directly passed to the node activation output of input layer without any computation. One or more hidden layers of nodes between input and output layers provide additional computations. Then the output layer generates the mapping output vector. Each of the hidden and output layers has a set of connections, with a corresponding strength-weight, between itself and each node of preceding layer.

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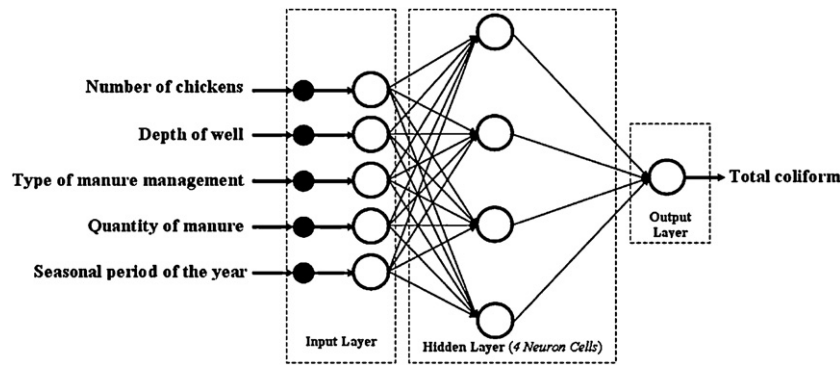E-mail address: myuceer@inonu.edu.tr (M. Yuceer).

Fig. 1. ANN architecture.

Such structure of a network is called a multi-layer perceptron (MLP) [1].

A feed-forward back-propagation artificial neural network (BPNN) is chosen in the present study since it is the most prevalent and generalized neural network currently in use, and straightforward to implement. Fig. 1 illustrates the basic configuration of the network model. Each interconnection in the model has a scalar weight associated with it, which modifies the strength of the signal. The function of the neuron is to sum the weighted inputs to the neuron and pass the summation through a non-linear transfer function. In addition, a bias can also be used, which is another neuron parameter that is summed with the neuron s weighted inputs. Back-propagation refers to the way the training is implemented and involves using a generalized delta rule [1]. A learning rate parameter influences the rate of weight and bias adjustment, and is the basis of the back-propagation algorithm [8]. The set of input data is propagated through the network to give a prediction of the output. The error in the prediction is used to systematically update the weights based upon gradient information [9].

The network is trained by altering the weights until the error between the training data outputs and the network predicted outputs is small enough. There are many back-propagation training algorithms available. The choice of algorithm depends on the type of problem and may require experimentation of different algorithms. The algorithms have different computation and storage requirements, and train data at different speeds [10]. The goal of selection is to efficiently and accurately train the network while keeping the speed of training relatively fast.

After generating sets of training patterns, appropriate NN architecture and associated parameters must be chosen for the particular application. The main design parameters are the number of hidden layers, number of neurons in each layer, and the neuron processing functions. The choice of these parameters will depend on the complexity of the system being modeled and they will affect the accuracy of the model. If the number of hidden neurons is too high, the network may over fit the data. On the other side if the number of hidden neurons is small, network may not have sufficient degrees of freedom to learn the process correctly [11]. There is no exact guide for the choice of the numbers. The architecture of most ANN model is designed by trial and error [12].

In this work, we have investigated the modeling of the effects of chicken manure on ground water by artificial neural networks. An ANN model was developed for predicting the total coliform in the ground water well in poultry farms. The back-propagation algorithm was applied to training and testing the network. Levenberg–Marquardt algorithm [13] was used for optimization. The model holds promise for use in future in order to predict the degree of ground water pollution from nearby chicken farms.

2. Methods and materials

2.1. Experimental

In this study 20 chicken farms, comprising a chicken population of 10 000–40 000 and a manure quantity between 2.4 and 7.0 tons/day, were picked from the area. Geographical coordinates, types, design capacity, operation capacity of the farms; geographic features of the land, depth of well, distance to the Derincay river, ways and capacity of manure stocking, number of chicken and feeding type were followed during a period of 8 months at 5 different times. Water samples were taken from the wells, and pH, electrical conductivity, salinity, total dissolved solid, turbidity, nitrite nitrogen, nitrate nitrogen, ammonia nitrogen, organic nitrogen, total phosphor, total hardness and total coliform analysis were performed. The analysis results were in the range of 0.5–5.2 mg NO_3-N/L, 0.02–3.90 mg NH_3-N/L, 0.51–1.89 mg total PO_4/L, 481.0–1852.0 mg/L total dissolved solid, 93–1100 MPN (most probable number)/100 mL total coliform.

2.2. Modeling procedure

An artificial neural network (ANN) model was constructed by using the experimental observations as the input set in order to identify the possible effects of chicken manure resulting from the farms on the ground water. A three-layered feed forward and back propagation algorithm with 5 neurons in the first layer, 4 neurons in the interim layer and 1 neuron in the last was chosen. The network had one input layer, one hidden layer and one output layer as represented in Fig. 1.

The output of a neuron can be defined as:

$$out = f(m) \tag{1}$$

where

$$m = \sum_{i=1}^{N} w_i x_i + b \tag{2}$$

where x_i and w_i are the input signals and the weights of neuron, respectively. b is the bias, $f(.)$ is the activation function.

The most common used activation functions in configuration of ANNs are sigmoid and linear functions:

Linear transfer function $(purelin) : f(m) = m$

Log-Sigmoik transfer function $(logsig) : f(m) = \dfrac{1}{1 + e^{-m}}$

Hyperbolic tangent sigmoid transfer functions $(tansig) : f(m)$