An Artificial Neural Network Approach to Evaluate Cation and Anion changes in Electrical Conductivity Change procedure in Underground water resources, Case Study: Damghan Plain, Semnan Province, Iran

Mohammad Ahmadi*, A. Fazeli Oladi[1], Reza Pirmoradi[2], S. Partani[3]

Corresponding author: MSc. Student of civil Engineering, Bu Ali Sina University, Hamedan, Iran.

E-mail address: mohammad_ahmadi8m@yahoo .
Tel: +98-912-2974529

Abstract

Ions, which have positives or negative Electrical charge that could be called as cation and anion respectively, could be classified as one of the effective and important factors in underground water table quality. In this way and in order to Electrical conductivity potential of water which contained with ions, Electrical Conductivity (EC) have been defined as a quality index in underground water resources. Solution of ions in water could be affect this index; for example, the EC of pure water is less than the same water when it contains ions and increasing the amount of solved ions could be increased the EC index. In presented research, by employing chemichal analyze samples which get from Damghan plain in semnan province, an Artificial Neural Network (ANN) which could estimate EC of underground water by using cations and anions has been designed. By random selection of about %80 of mentioned samples, ANN has been trained and with %20 of them, estimator network has been validated. Comparison of observed and estimated values gives any suggestions about efficiency and accuracy of designed ANN. In this way, application of any statistical indices, could be useful for assessing accuracy and efficiency of designed network.

Finally, to evaluate cations and anions changes and them effect on change rate of EC in underground water table of Damghan plain, sensitivity analysis of ANN input variables4 have been conducted. These variables effect on EC changes has been encountered and any conclusions have been extracted.

Keywords*: underground water; Artificial Neural Network; Sensitivity Analyze; EC;*

1- Introduction

The amount of soluble salts could be mentioned as the indices for expressing quality of surface and subsurface water resources. In this regard, some ions such as Ca^{2+} ،Na^{+} and Mg^{2+} which are classified as cations and some others such as So_4^{2-} ،Cl^{-} and HCo_3^{-} that identified as anions compared with other salts are more important. It should be mentioned that Electrical conductivity of water has direct relationship with the amount of solution salts and could be said that more dissolved salts causes more EC and vice versa. In this way and for expressing the amount of salts in water, an index has defined as the Electrical Conductivity (EC). Mentioned index shows the rate of electrical conductivity of water. It should be mentioned that anions and cations and percent of their presence could be affect on this index. But the rate of effects of each salt on EC change procedure is a topic that requires more investigations. For

1 M.S.c Student of Economic Geology, Islamic Azad University, Khoram Abad Branch, Khoram Abad, Iran
2 M.S.c Student of Hydrogeology, Islamic Azad University, Science and Research Campus, Tehran, Iran
3 PhD Student of civil engineering in water and environmental engineering, Tehran University, Tehran, Iran
4 Anions and Cations

this purpose, for assessing the rate of change procedures of target value in order to independent variables change require some methods which describe relationships with mathematical equations. Artificial Neural Network method, which is the following set of meta-heuristic methods, could discover the hidden relations between system parameters. This method has the ability to discover the relation between target value and independent variables by employing the observed data set. In this way, employing best Artificial Neural Network for prediction, which by handling special topology, learning rule and transfer function can predict the objective value in non-measured locations, seems essential. Sensitivity analysis of changes of independent variables on change procedure of EC and anions and cations influence on electrical conductivity is one of the most interesting research fields for hydrogeological studies. Mentioned subjects with more detail have been provided in next sections.

2- Location of Study Area

The study area is located in Semnan province in the center of Iran and its coordinate has been limited between 53° 21' 00" and 54° 43' 44" eastern hemisphere and 35° 42' 38" and 36° 32' 06" northern hemisphere. The area of study area is about 5905 square kilometers. The main city in study area is Damghan and Damghan township is its center. Location of study area has been shown at figure (1).

3- Methodology

First of all, gathering dataset from qualitative data sources such as observation wells and any exploration logs has been done. Then, qualitative analysis and some experiments have been carried out. ANN Design, finding the best transfer function, learning rule and number of processors in neuron, Validating ANN, extracting weights and employ them in a calculation could be mentioned as the next steps. Eventually, the Sensitivity analysis has been encountered. The mentioned steps, has been shown in figure(2).

4- Overview of Neural Networks

McCulloch and Pitts (1943) developed the first artificial neuron. However, it was not until the psychologists David Rumelhart, of University of California at San Diego, and James McClelland, of Carnegie-Mellon University, developed the back-propagation algorithm for training multi-layer perceptrons, that interest in ANNs flourished [1].

Recently, ANNs have been applied extensively to many prediction tasks. ANNs are able to determine the relationship between a set of input data and the corresponding output data without the need for predefined mathematical equations between these data. Artificial neural networks (ANNs) are a form of artificial intelligence which, in their architecture, try to simulate the biological structure of the human brain. ANNs try to mimic the behavior of the basic biological and chemical processes of ANNs. ANNs learn “by example” and therefore are well suited to complex processes where the relationship between the variables is unknown [2].

Many authors have described the structure and operation of ANNs [3]. ANNs consist of a number of artificial neurons (variously known as “processing elements”, “PEs”, “Nodes” or “Units”) representative of the neurons in ANNs. Each processing element has several input paths and one output path, as shown in Figure (3). An individual PE receives its inputs from

many other processing elements via weighted input connections. These weighted inputs are summed and passed through a transfer function to produce a single activation level for the processing element, which is the node output.

A typical structure of artificial neural networks consists of many processing elements that are arranged in layers: an input layer, an output layer, and one or more layers in between, called intermediate or hidden layers .Each processing element in a specific layer is interconnected to all the processing elements in the next layer via weighted connections. The scalar weights determine the strength of the connection between interconnected neurons. A zero weight refers to no connection between two neurons and a negative weight refers to a prohibitive relationship [3].

The propagation of information starts at the input layer where the input data are presented. The inputs are weighted and received by each node in the next layer. The weighted inputs are then summed and passed through a non-linear transfer function to produce the node output, which is weighted and passed to the processing elements in the next layer. The network's output is compared with the actual value and the error between the two values is calculated. This error is then used to adjust the weights until the network can find a set of weights that will produce the input-output mapping with the smallest possible error [3, 4 and 5].

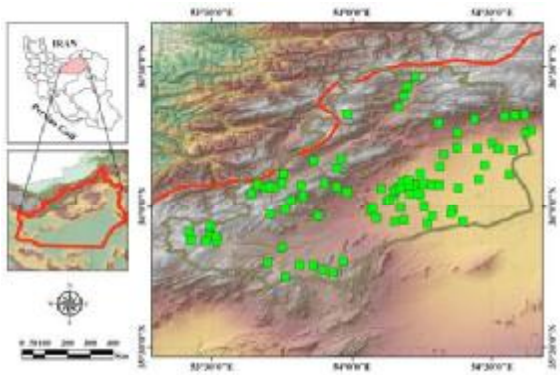

Figure (1): Location of study area and hydro-meteorological stations

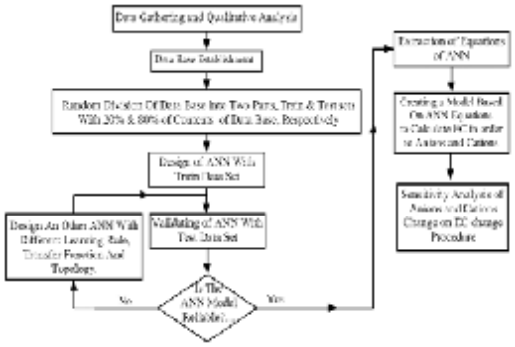

Figure (2): Methodology of this study

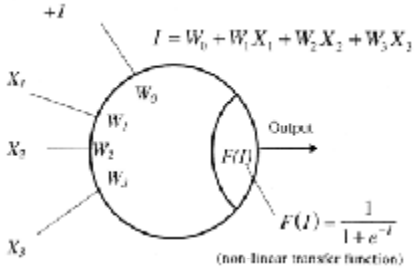

Figure (3): Typical processing element (PE) in a neuron [3]

5- Input datasets

In this research for design of artificial neural network, an extended data set has been employed. The data set has been derived from Damghan plain in Semnan province. The location of mentioned data set has presented in figure No. 1. This data includes the location of observations and amount of anions and cations which has been extracted [6].

6- ANN Design for Calculating EC in order to the Anion and Cation Amount

Multi-Layer Perceptron ANN with learning rule on back propagation was design for calculation of EC based on anions and cations. As it's said before, the learning rule of this ANN is back propagation and hyperbolic tangential transfer function has been applied in the neural cells. The ANN has eight entrances, one hidden layer including one processor neural cell and one estimated output result; in afterward it will be called MLP BP TANH 2-1-1 in abbreviation. Synaptic weight and bias term weight is shown in figure (4). In this figure the equations used in processor cells for estimating outputs has been presented. Following, using the output results of ANN and comparing them with observed data, the ANN verified [7].

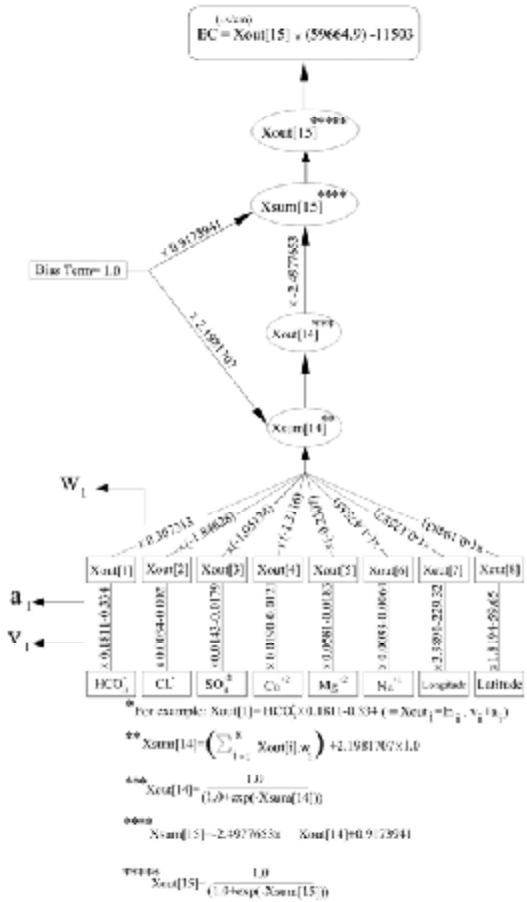

Figure (4): Synaptic weight and bias term weight in designed ANN

7- Sensitivity Analysis of Anion and Cation Change on EC change Procedure

As can be seen, in order to EC estimation, first of all designed ANN verified in observed and planned points. Then using the ANN equations and applying them on main layers of data and by using topology, effects of main input layers on EC can be investigated. The effects of main layers on annual mean precipitation is shown in figure (5).

8- Conclusion and Results

- According to presented figures in section number 6 and 7 it can be said that anion change has more effect on the rate of change procedure of EC. Change of HCo3-, So42- and Cl- ions has the most rules in EC changes within anions, respectively. Within cations, Na+, Mg2+ and Ca2+ play the most rules on EC change procedure, respectively. Ca2+ change has the lowest effect on EC change procedure.
- By employing the ANN method, hidden relations between system parameters could be carried out. Having in hand these relations that could be expressed by equations, review of system elements could be encountered, also the influences of independent variables on target value could be carried out.
- The accuracy of investigations preliminary depends on the ANN model accuracy. And eventually, application of statistical analysis and statistical indices for estimator selection is inevitable.

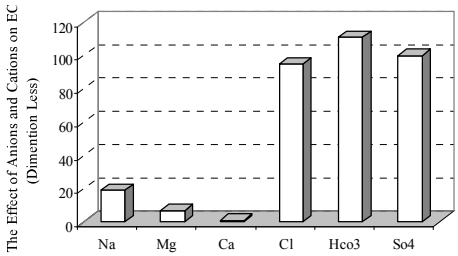

Figure (5): The effect of Anions and Cations on EC in a Dimension less Diagram

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