Neural Network Modelling of Tds Concentrations in Shatt Al-Arab River Water

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ABSTRACT

River water salinity is a big concern in many countries, considering agricultural and drinking usages. Therefore, prediction of amount of Total Dissolved Solid (TDS) is a necessary tool for planning and management of water resources. Shatt Al-Arab river basin in Basrah which is located in south of Iraq suffer from high salinity, therefore use of the water for irrigation and drinking has become problematic. In this regard, prediction of future TDS of Shatt Al-Arab river basin was studied using Artificial Neural Network (ANN).

Data measured monthly from January 2007 up to December 2012 at monitoring station in the middle point along to the Shatt Al-Arab river has been used for training of the selected ANN.

Some of water quality parameters such as, power of hydrogen (pH), Total Hardness (TH), Magnesium hardness ($MgSO_4$), Calcium hardness ($CaSO_4$), Chlorides (Cl), Sulphates (SO_4), turbidity (TU) and electrical conductivity (EC) were considered as inputs for the ANN and Total Dissolved Solid (TDS) was the output of the model.

The validation of the neural network model showed very good agreement for predictions of the TDS concentrations between observed and simulated values.

The coefficient of correlation (R), during the validation process was found to be (1), and the mean squared error (MSE) was (0.075). This work supports the concept that the neural network approach is a successful method of modelling such complex and nonlinear behavior of TDS in the rivers with different environmental conditions.

Keywords: Artificial Neural Network, Shatt Al-Arab River, TDS, Modelling.

تمثيل تراكيز المواد الصلبه الكلية الذائبه في نهر شط العرب باستخدام الشبكه العصبيه

الخلاصه

نوعيه مياه النهر هي مصدر قلق كبير في العديد من البلدان من الناحية الزراعيه واستخدامات المياه للشرب. لهذا السبب التنبؤ بمقادير المواد الصلبه الكلية الذائبة (TDS) ضروري جدا لتخطيط وإدارة موارد المياه. حوض شط العرب في البصرة والذي يقع في جنوب العراق يعاني من ارتفاع نسبة ألملوحة وبالتالي فأن استخدام المياه لأغراض الري والشرب اصبح مشكلة. وفي هذا الصدد تم دراسة التنبؤ للـ (TDS) لحوض شط العرب باستخدام الشبكات العصبية الاصطناعية (ANN).

استخدمت البيانات المقاسة شهريا من يناير 2007 حتى ديسمبر 2012 في محطة رصد في نقطة وسطيه على طول شط العرب لتدريب ANN.

بعض معاملات نوعية المياه مثل درجة الحموضة (PH)، العسره الكلية (TH)، عسره المغنيسيوم ($MgSO_4$)، عسره الكالسيوم ($CaSO_4$)، الكلوريدات (Cl)، الكبريتات (SO_4)، العكاره (TU) والتوصيليه الكهربائييه (EC)، قد اعتبرت كمدخلات لـ ANN والمواد الصلبه الكليه الذائبه (TDS) اعتبرت كمخرجات للنموذج.
أظهر التحقق لنموذج الشبكة العصبية تطابق جيد جدا للتنبؤ بتركيزات TDS بين القيم الحقليه والمحسوبه.
قيمة معامل الارتباط (R) خلال عملية التحقق من الصحة كان (1)، ومتوسط تربيع الخطأ (MSE) كان (0.075). هذا العمل يدعم مفهوم أن نهج الشبكة العصبية هي طريقة ناجحة للنماذج ذات السلوك المعقد وغير الخطي كقيم TDS في الانهر مع الظروف البيئية المختلفة.

INTRODUCTION

One of the key elements in the global environmental monitoring policy and management is monitoring and modelling of river water quality[1]. The control of complex and nonlinear systems, such as rivers, is not an easy project. Water quality straight affects for all water uses. The evaluation of water quality parameters is requirement to increase the performance of an assessment operation develop better water resources management and a plan. Water quality modelling requires the prediction of water pollution by using mathematical simulation techniques. The interest in the use of Artificial Neural Network (ANN) for prediction has contributed to a significant increase in research activities in the past decade. Recently, research activities in ANNs indicated that ANNs have powerful rule classification and rule recognition capabilities. Inspired by biological systems, particularly by research into the human brain, ANNs are able to learn from and generalize from experience. One major application area of ANNs is prediction [1].

Shatt Al-Arab River, (as shown in Fig.1) is formed by the meet of the Tigris and Euphrates Rivers near the city of Qurna in southern of Iraq. Several tributaries join the Shatt Al-Arab during its course, most importantly the Karun and the Karkheh Rivers, which was supplied Shatt Al-Arab by fresh water. But now there was the diversion of the water of Karun and Karkheh tributaries inside the Iranian borders that’s been caused very high increase of the salinity in the Shatt Al-Arab River [2].

Shatt Al-Arab River forms the main source of freshwater for the Arabian Gulf and plays an important role for marine habitats in the Gulf’s north-eastern coastal areas. However, the large-scale development of upstream water regulation and dam structures, together with the pollution by industries, chemical and fertilizers used for agriculture purpose, sewage from the cities, open defecation all along the river banks by the people who are daily using the water for drinking and bathing, and salinity intrusion of salt wedge from Arabian gulf, has caused severe salinization of the river. This not only threatens marine ecosystems in the Gulf, but also jeopardizes agricultural activity along the Shatt Al-Arab [3].

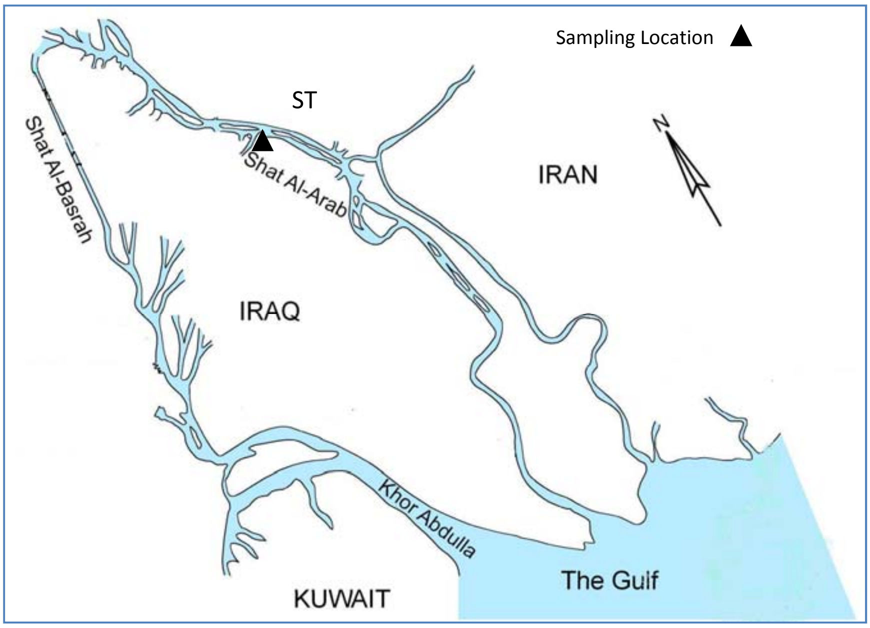


Figure.1: Map of Shatt Al-Arab River showing the sampling location

The salinization of the Shatt Al-Arab first got an issue in the 1960s. The situation further deteriorated from the 1970s onwards with the construction of dams and reservoirs on the Tigris and Euphrates Rivers. The low river runoff and high evaporation rates up to 41% in the extreme north-western part of the Gulf promote contribute to high salinity [2].

Total Dissolved Solids (TDS), are exceeding the limits for the purpose of domestic water supply and agricultural use and it is very useful, if this parameter has been modeled and predicted. This paper demonstrates the application of ANNs to simulate and predict values of TDS in Shatt Al-Arab River by depend on water quality parameters measured by a water quality monitoring program.

Quality of surface water

There was no systematic evaluation of water quality for irrigation in Iraq during the past century, However the department of environmental survey in Basrah environment directorate started to evaluate the water on a somewhat regular basis as and when facilities permit, so the water resources directorate started to measure some parameters of water from January of 2007 until December of 2012 in different locations along of Shatt Al-Arab [4]. In this context, a study was conducted in this period to evaluate the quality of surface water monthly. In this study, one location was identified in Shatt Al- Arab, this location is (ST) (See Fig. 1), which is located in the middle of Shatt Al-Arab river, near to Al Ashar region in center of Basrah. Water samples were collected from the mentioned station in Shatt Al-Arab River; the samples were collected from just under water surface for analysis of selected parameters included: power of hydrogen (pH), Total Dissolved Solids (TDS), Total Hardness (TH), Magnesium hardness (Mg SO_4), Calcium hardness ($CaSO_4$), Chlorides (Cl), Sulphates (SO_4), turbidity (TU) and electrical conductivity (EC).

In this paper, a study of ANN modelling to predict TDS in Shatt Al-Arab is presented.

Artificial Neural Network Model

ANNs have been applied progressively in recent years for the prediction and forecasting of complex hydrological relationships. ANNs have been seen as an attractive option to process based on modelling approaches, as they are capable to extract an underlying relationship from the data when knowledge of the physical process is lacking [5].

An Artificial Neural consists of three components including weighting (w), bias (b) and transfer function (f). These three components are unique for each Neural. Fig.2 shows schematic of Artificial Neural. As shown in the Figure, p and a, are input and output of a Neural, respectively. Parameter n is called net input, which is input of transfer function and it is built according to input p and Neural parameters. Mentioned Artificial Neural can be modeled by the following equations [6].

$$n = wp+b \quad \text{.....(1)}$$

$$a = f(n) = f(wp+b) \quad \text{.....(2)}$$

In Neural instruction process, w and b (Neural parameters) change until the best approximation for an output member corresponding to the input member is obtained. Weight of Neural determines the rate of p effect on "a" and parameter "b" causes Neural to be transformed to sub-space of bias input space. There are some types of transfer functions (activation functions), some of which are as follows:

- Linear, transfer function
- Hard-limit transfer function
- Log-Sigmoid transfer function
- Tan-Sigmoid transfer function and
- Tan-Hyperbolic transfer function

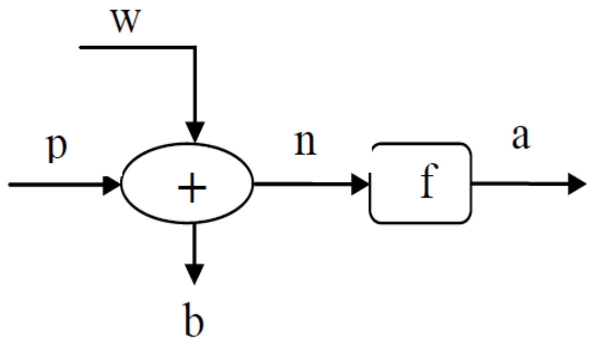


Figure. 2: basic architecture of a neuron[6]

The signal passing through the neuron (node), is modified by weights and transfer functions. This process is repeated frequently until the output layer is achieved [6].

The basic structure of an ANN model usually comprised three distinctive layers; the input layer, where the data are introduced to the model and computation of the weighted sum of the input is performed; the hidden layer or layers, where data are processed; and the output layer, where the results of ANN are produced. Each layer consists of one or more basic element(s) called a neuron or a node. A neuron is a non-linear algebraic function, parameterized with boundary values. The number of neurons in the input, hidden, and output layers depends on the problem. If the number of hidden neurons is small, the network may not have sufficient degrees of freedom to learn the process correctly. On the other hand, if the number is too high, the training will take a longer time and the network may over-fit the data [6].

A three layer Feed Forward Neural Network (FFNN) was developed using Neural Network Toolbox in the MATLAB R2012a software. Each layer of the ANN is linked by weights and it will be determined through a learning algorithm. Back propagation algorithm has been used to train the network. Sigmoid activation function was applied as a transfer function for all nodes in the hidden layer as well as output layer. The Mean Squared Error (MSE) was utilized as an objective function to compute the error between predicted outputs and measured values.

Fig.3 illustrates the feed forward neural network model used in the present investigation. The number of hidden layer nodes will be determined by optimizing the performance of the network.

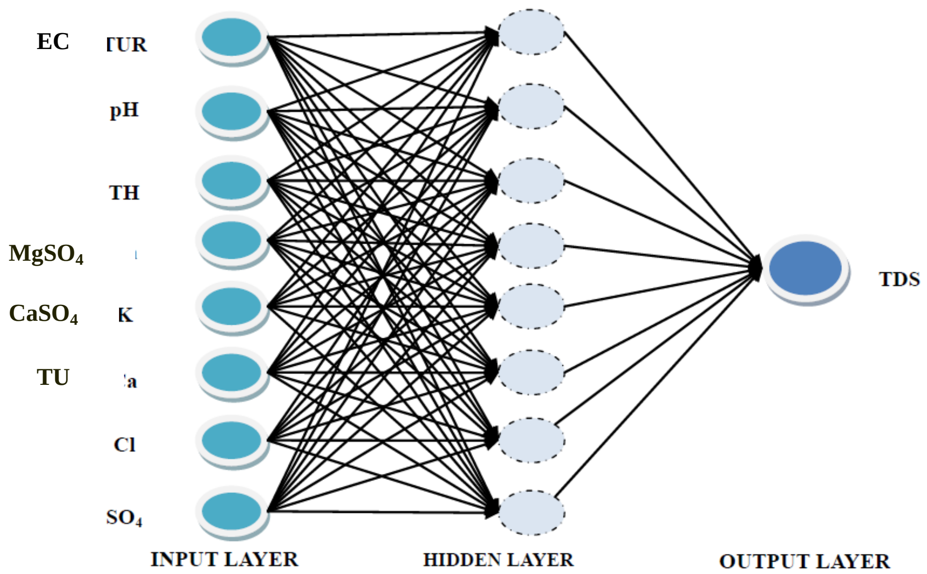


Figure. 3: Three Layer Feed Forward Neural Network

Results and Discussion

The purpose of current research is to evaluate an intelligent model to determine the quality of river water via estimating the values of TDS as outputs of model. As the experimental measurement of TDS are basically expensive, they were assumed as the outputs of the FFNN-based model in which the values of: power of hydrogen (pH), Total Hardness (TH), Magnesium hardness ($MgSO_4$), Calcium hardness ($CaSO_4$), Chlorides (Cl), Sulphates (SO_4), turbidity (TU) and electrical conductivity (EC).were considered as inputs of the model.

The parameters was chooses because it seen from previous research that the eight parameters showed higher correlation with TDS values.

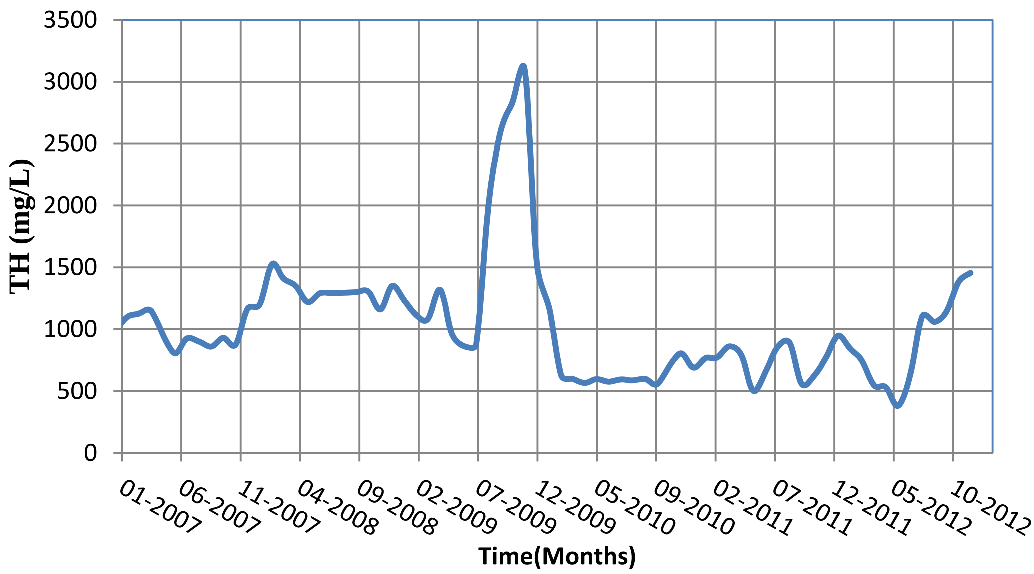
Several ANN networks in multi-layer perceptron (MLP) was constructed and tested in order to determine the optimum number of nodes, hidden layers, and transfer functions, the performance of the network was optimized with 5 to 25 nodes in the hidden layer as trial and error method. It has been found that the lowest mean squared error was obtained by the network with 12 nodes in the hidden layer, the number of hidden layers was one because it reasonable to involve the convergence.

Among the training algorithms, the RPROP back-propagation algorithm was selected, due to its fast convergence ability. Also, the Log Sigmoid was selected as transfer function of the hidden and output layers, this option was used after multi trials to found out the optimum choose of these algorithm and transfer function. Linear transformation method was used to normalize the data to a range (0, 1). At the model initialization stage, the initial weightages between the nodes were randomly assumed. Then the model training was started with the learning rate of 1 and up to 50000 iterations. The training process is terminated after a preset stopping criterion such as a fixed number of error reduction operations. Here the Mean Squared Error (MSE) was used as a performance criterion and it has been fixed initially to 10^{-2} as a minimum performance goal.

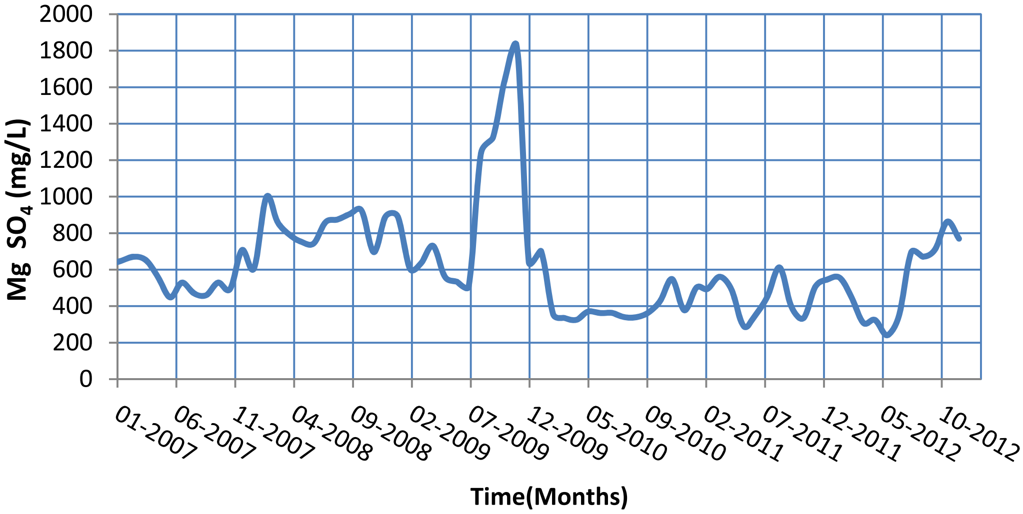
The networks were trained using the training data set, and then it was validated with the validation data set. The optimal network size was selected from the one which resulted in maximum coefficient of correlation (R) and minimum of root mean square error (MSE) in training and testing data sets. For ANN identification, the complete river water quality data set was divided into two sub-sets. The calibration (or training) and validation (or testing) of data subsets comprised as (80% and 20%), respectively.

The parameters of water quality which were used as input to neural network model were shown in Figs. (4 to 11). The best structure with the highest (R), and lowest in mean square error (MSE) was found. The correlation coefficient between the model output and the measured value (target output) is 1, as shown in (Fig.12).

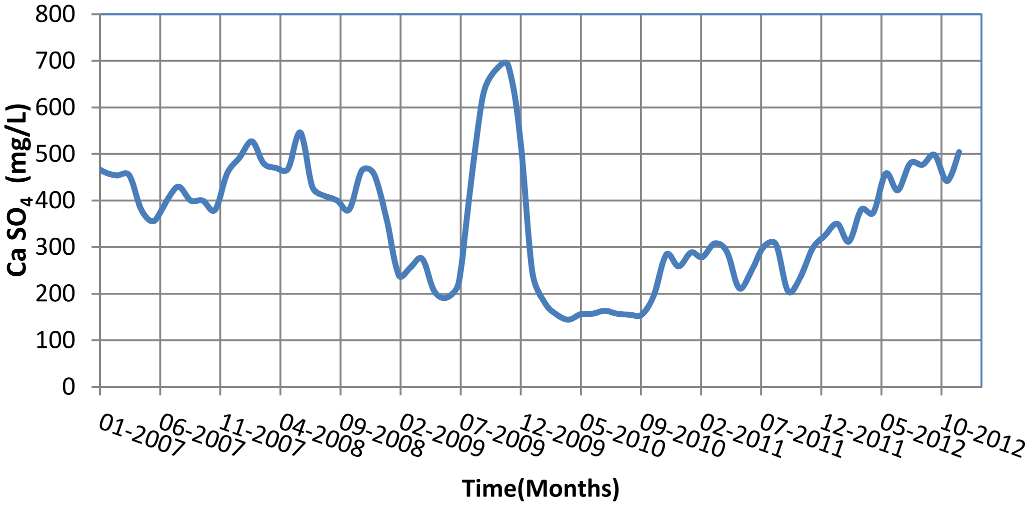
During the training process, the MSE was gradually decreased and reached the performance goal of 0.075 after 3704 iterations (Epoch). A graphical representation for Learning curve of RPROP Back propagation algorithm was given in (Fig.13). A comparison graph has been plotted for the predicted output and the target output in predicting the TDS concentrations, as shown in (Fig.14). It shows that the two graphs show maximum convergence.



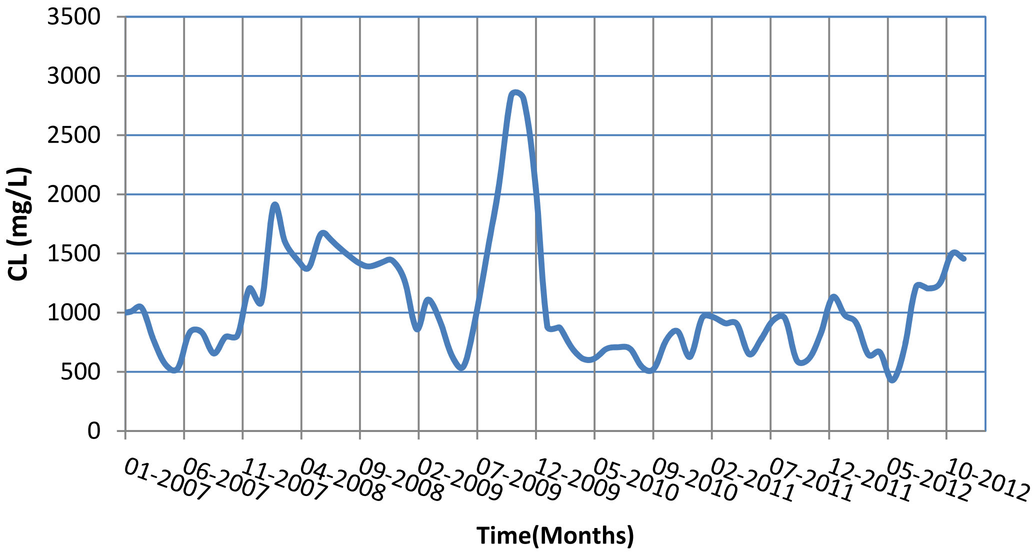
(Figure.4): Total Hardness (TH), diagram in Shatt Al-Arab River from Jan. 2007 up to Dec. 2012.



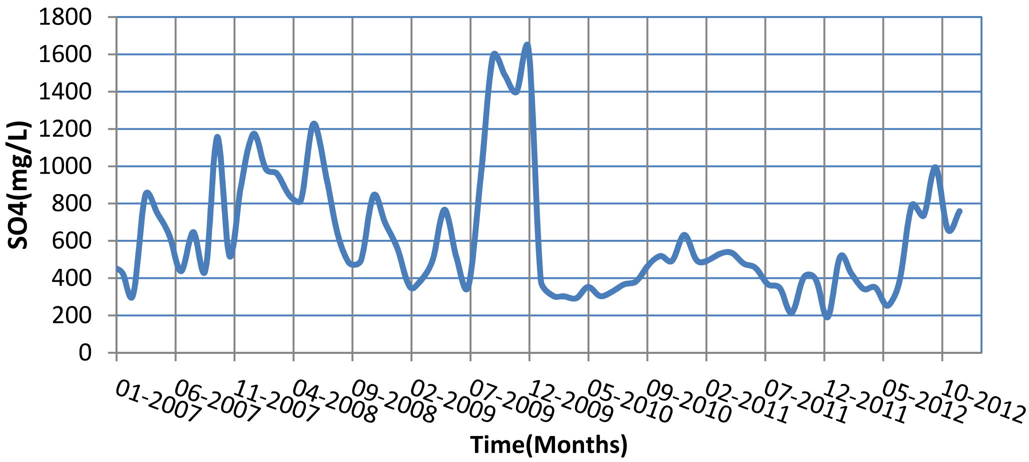
(Figure.5): Magnesium hardness ($MgSO_4$), diagram in Shatt Al-Arab River from Jan. 2007 up to Dec. 2012.



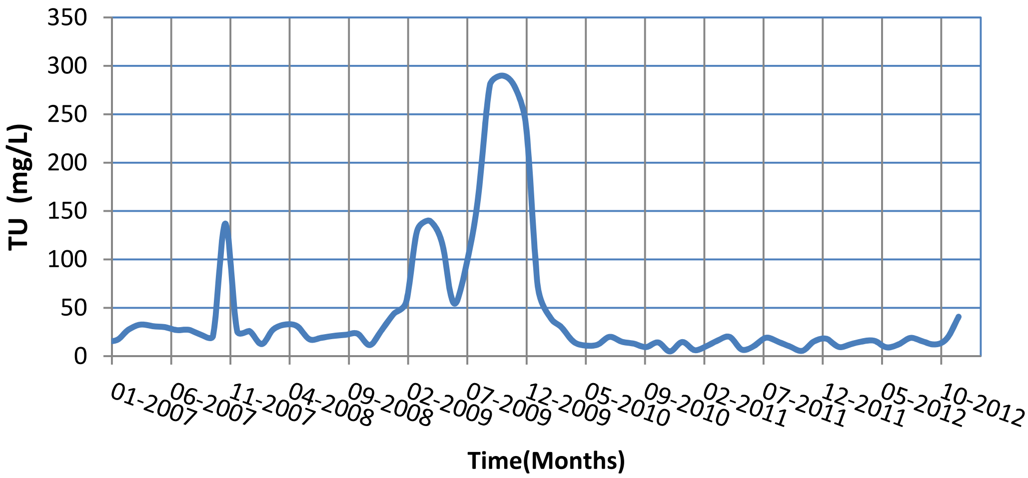
(Figure.6) :): Calcium hardness ($CaSO_4$) diagram in Shatt Al-Arab River from Jan. 2007 up to Dec. 2012.



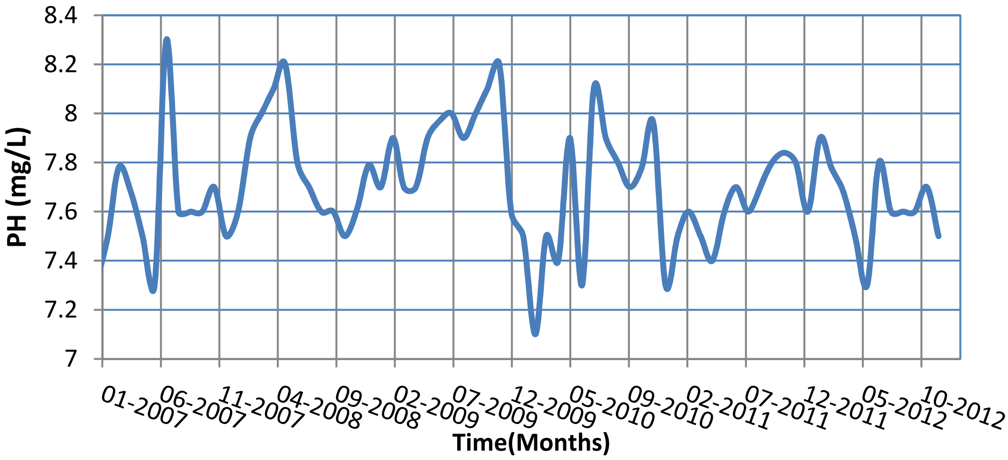
(Figure.7) :): Chloride (Cl), diagram in Shatt Al-Arab River from Jan. 2007 up to Dec. 2012.



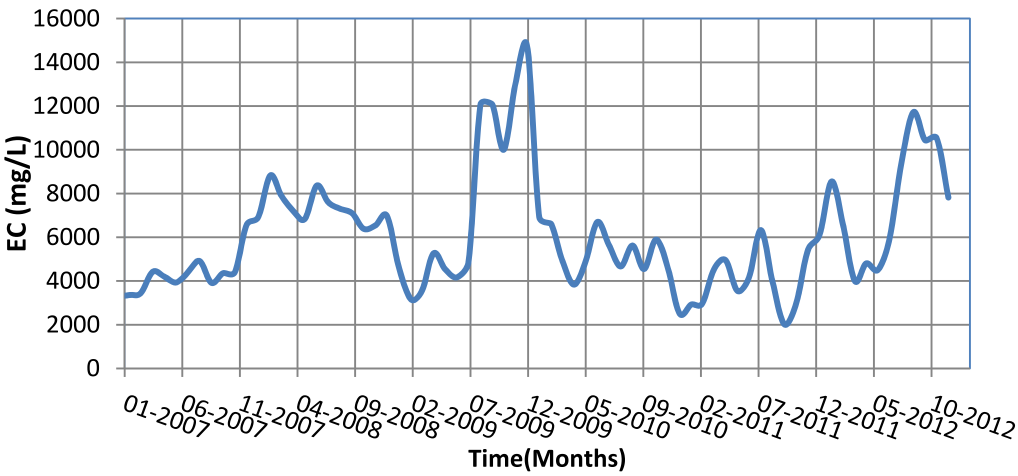
(Figure.8): Sulphates (SO_4) diagram in Shatt Al-Arab River from Jan. 2007 up to Dec. 2012.



(Figure.9): Turbidity (TU) diagram in Shatt Al-Arab River from Jan. 2007 up to Dec. 2012.



(Figure.10): Power of hydrogen (pH) diagram in Shatt Al-Arab River from Jan. 2007 up to Dec. 2012.



(Figure.11): Electrical conductivity (EC) diagram in Shatt Al-Arab River from Jan. 2007 up to Dec. 2012.

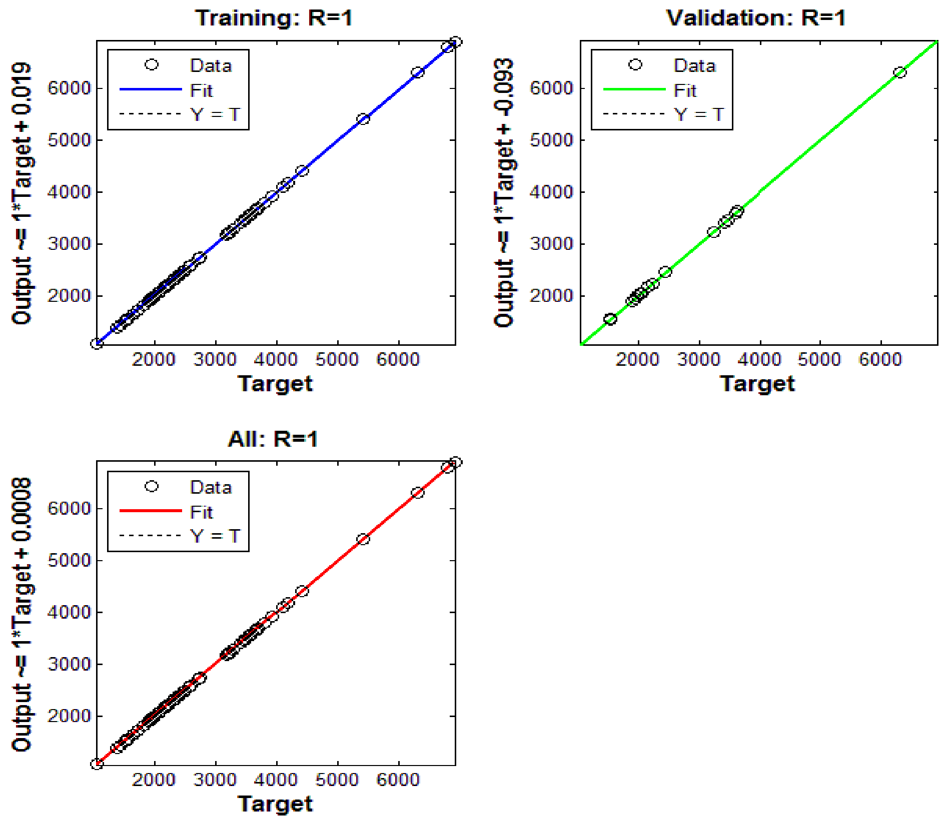


Figure.12: Comparison between NN outputs and targets for training and test data

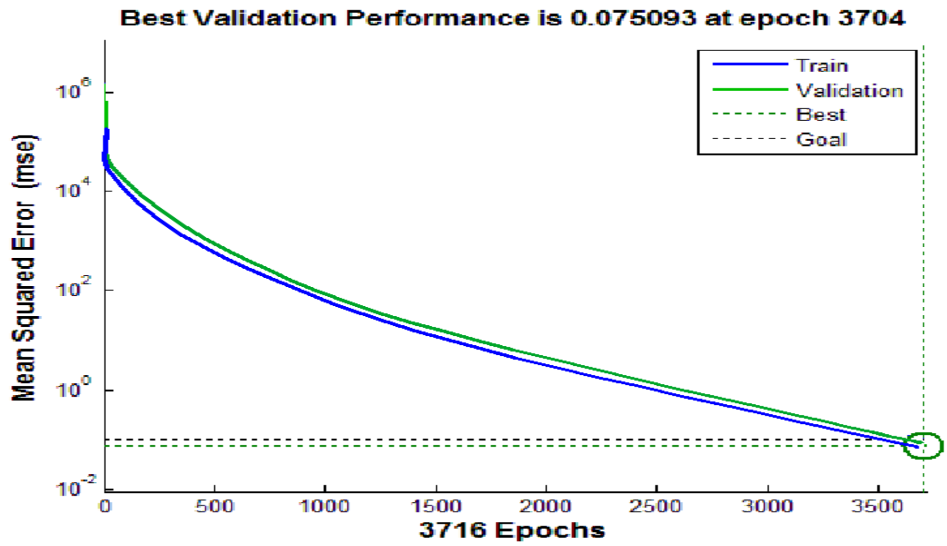


Figure.13 Learning curve of RPROP back-propagation training algorithm

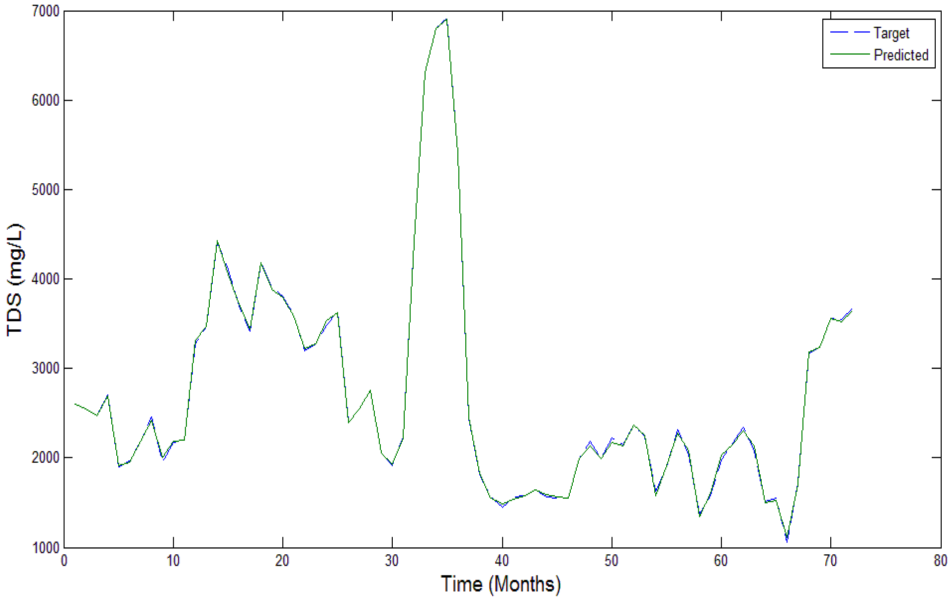


Figure.14: Comparison Graph for TDS during Validation Process

CONCLUSION

With the aid of the available data of water quality parameters, from January 0f 2007 up to December of 2012, an attempt has been made to model the concentrations of TDS in Shatt Al-Arab river.

The validation of the neural network model showed very good agreement for predictions of the TDS concentrations. The coefficient of correlation during the validation process was found to be 1 and the mean squared error (MSE) was 0.075.

It has been shown that the values of TDS in Shatt Al-Arab River suffer of high values, therefore Shatt Al-Arab River considered as brackish to saline water. The reason behind that was due to salt water intrusion from Arabian Gulf as well as the water has been polluted by industries, chemical and fertilizers used for agriculture purpose, sewage from the cities and by open defecation all along the river banks by the people who are daily using the water for drinking and bathing. Effluents from the industries and agricultural must be treated properly before discharging in the river so that it can ensure the requirement of environmental standards.

In conclusion, the work signifies that the neural network approach is effective method of modelling TDS concentrations in Shatt Al-Arab River with different environmental conditions.

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