Total Dissolved Solids (TDS) Modeling by Artificial Neural Networks in the distribution system of drinking water of Hyderabad city

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Abstract: - Demanding public opinion for providing safe drinking water is now an increasing constant pressure on the authorities concerned to prevent the human health from contaminated drinking water. Hence latest techniques are employed to predict the critical parameters like, pH, chlorine, turbidity, TDS, and Electrical conductivity, in the distribution systems. In this study Radial Basis Function RBF model is presented to predict the TDS, one of the important parameters of distribution system of drinking water of Hyderabad city. The mean value of TDS observed at 10 locations is 586.418 mg/l with standard deviation 0f 5.734. ANN model is trained, tested and validated for the data available from a 3 years study completed on weekly basis. Input and output weights are generated and the Sum of Square Error (SSE) is 0.139088 with faster training time of 0.95300 seconds. 09 Neurons in the hidden layer of the model reveal that the ANNs modeling for predicting the parameters of the drinking water is highly successful; which is the prime object of this study.

Key-Words: - ANNs, TDS, water supply, distribution system, Modeling, Hyderabad

1 Introduction

Hyderabad is one of the biggest cities of Pakistan with 1.8 million populations. The latitude is 25° 22’ North and longitude 65°-41’ East, with a typical arid topography [1]. The major source of intake for supply of drinking water to the city is River Indus which receives highly contaminated water from the Manchhhar lake, one
of the biggest lake in Asia [2]. The efficiency of the
filter plants in the city remains questionable.
Consequently a number of cases of gastroenteritis have
been reported in Hyderabad. About 98 patients having
majority of children were admitted in the local hospitals
for Gastro [3]. There are 02 filter plants supplying 40
MGD drinking water to the city. Coagulation process is
not working because at present the Alum dozer is not
functional; chlorine is not added for disinfection process
throughout the city. (Personal communication)
During this study it is observed that the Electrical
conductivity is beyond the WHO Standards therefore the
Total Dissolved Solids exceeds in mean value of 586
mg/l at all 10 locations. Identically Total Dissolved
solids may describe the inorganic salts and small
amounts of organic matter present in solution in water.
The principal constituents are usually Calcium,
magnesium, sodium and potassium cat-ions and
carbonate, hydrogen-carbonate chloride, sulfate and
nitrate ions [4].

1.1 Organoleptic Properties
The presence of dissolved solids in water may affect its
taste. The palatability of drinking water has been rated
by panels of tasters in relation to its total dissolved
solids is considered as Excellent if less than 300 mg/l.
Water with extremely low concentrations of TDS may
also be unacceptable because of its flat insipid taste [5].

1.2 Effects on Humans
From the literature available no recent data on health
effects associated with ingestion of TDS in drinking
water appears to exist. However, associations between
various health effects and hardness have been
investigated in many studies. An inverse relationship
was reported between TDS concentration in drinking
water and the incidence of cancer, Coronary heart
disease CVD arteriosclerotic heart disease and
cardiovascular diseases [6-11].
In another study of Australia the mortality from all
categories of ischemic heart disease and acute
myocardial infarction was increased in a community
with high level of soluble solids, calcium, magnesium,
sulfate, chloride, fluoride, alkalinity, total hardness, and
pH when compared with one in which levels were
lower[12].

An association between Magnesium in Drinking water
and Ischemic Heart Disease was studied by Arthur Marx
in 1997. Discussing the matter, Magnesium balance in
human body is found of importance in accordance with
the functionality of kidney [13]. Therefore has become
necessary to maintain a standard value of TDS in the
distribution system of the drinking water supplied to the
city of Hyderabad as well. The association of heart
diseases and TDS in the samples taken from the filter
plant and distribution system of drinking water of
Hyderabad city may or may not be true in our case.
To prove, it needs much more specific mortality data
associated with CVD, IHD, in the area we have taken
under study. However it has created the need to monitor
the water distribution system with the help of latest
techniques or data driven modeling. For Water quality
modeling, hydraulic network models are used more and
more for water quality related subjects, such as
determining residual chlorine [14], and disinfection
byproducts in the Drinking water distribution system
(DWDS) under US EPA Rule 2006[15], optimum sensor
placement for detection of biological and chemical
contaminations[16] and source locations inversion after
contaminant is detected[17]. The object of this study is
to develop a data driven model to best fit the prediction
of the total dissolved solids TDS in the water supply
system including the bulk water distribution network of
the city of Hyderabad. Therefore the feasibility of the
use of Artificial Neural Network (data-driven technique)
modeling is assessed in this study.

2. Artificial Neural Networks Modeling
Artificial Neural Networks (ANNs) are used due to their
ability to handle nonlinearity and large amounts of data,
as well as their fault and noise tolerance and their
learning and generalization capabilities [18]. Artificial
neural networks provide an excellent mathematical tool
for dealing with non-linear problems [19, 20, 21]. They
have an important property according to which any
continuous non-linear relation can be approximated with
arbitrary accuracy using a neural network with a suitable
architecture and weight parameters. Their attractive
property is the self-learning ability. A neural network
can extract the system features from historical training
data using the learning algorithm, requiring little or no a
priori knowledge about the process. This provides the
modeling of non-linear systems with a great flexibility
[19, 22]. However, the application of neural networks to
the modeling or fault diagnosis of control systems
requires taking into account the dynamics of processes
or systems considered. A neural network to be dynamic
must contain a memory. The memory can be divided
into a short-term memory and a long-term memory,
depending on the retention time [23, 24, and 25].
Artificial Neural Networks are basically identified with
the ability of implementing algorithms to mimic the
neuron processing functions of true neural networks.
The back propagation algorithm is a common algorithm
generally used by ANNs. Often it is referred to as back-propagation training algorithm. This algorithm involves calculating the derivatives of the network training error with respect to the weights by the application of chain-rule and gradient decent optimization to adjust the weights to minimize the error [26]. The popularity of this algorithm is evident from the literature available on ANNs. Comparatively, its slow and may stuck-up to global minima of the error surface during training, if compared to Radial Basis Function Algorithm. Niaz et-al concluded that RBF neural network models have the powerful capability of predicting the Electrical conductivity of drinking water of Hyderabad city [27]. In this study another RBF Model is trained, tested for predicting the TDS at 10 different locations to affirm the ability of faster training and better prediction of RBF ANNs used for water quality monitoring.

3. Case study

Hyderabad, one of the major cities of Pakistan is situated on left bank on the River Indus. The drinking water supplied to the city is taken from both up and downstream of the river. 02 treatment Filter Plants are operative to supply 40 MGD drinking water to the different areas of the city. Ascertaining the quality of the drinking water according to WHO standards, study is conducted to evaluate the different parameters like, pH, EC, TDS, free and total chlorine, Dissolved oxygen, iron, Ca, Mg, total Hardness, sulfates are observed by using HACH, SensIon59, multi-parameter, Meter and HACH DR-2700 Digital Spectrophotometer. Real-time assessment is carried out in order to avoid the uncertainty in collecting data for the study. 10 different locations are selected as follows: 1. Intake from the River Indus, 2. North Lagoon storage, 3. Inlet of New Treatment Plant (NTP), 4. Filtration Gallery NTP, 5. Inlet of Old treatment Plant (OTP), 6. Outlet of OTP, 7. 1MGD pumping station opposite citizen colony, 8. Inlet and outlet of pumping station Military Engineering services (MES), 9. Inlet of the reservoir pumping station Thandi sark, and 10th outlet of the same reservoir. This network is continuously monitored and analyzed by sampling the supplied water twice in a week at different timings. 40 samples for each location are taken, hence a comprehensive data of 400 samples is available now to evaluate the performance of the water distribution system and the quality of the drinking water supplied. The important parameter Total Dissolved solids, is taken in this study to be predicted by using ANNs at these locations and the results so obtained are discussed below.

4. Results and Discussions

Typically, single hidden layer RBF model with Gaussian function as activation function for hidden neurons, and linear function for output neurons is trained and tested with different data sets available from the above study. The mean values were calculated for each parameter with additional data available previously from the different sources and stakeholders. The selection of input variable is made such way that scaling or normalization of the data be avoided as the noisy input data effects the training speed of the model. The observed values and predicted values by the model are presented in the graph. The model used 09 neurons in hidden layer and 01 neuron in outer layer. The Sum of the square Error SSE is found 0.139088 and the elapsed training time is 0.95300 seconds. These results are in line with [27] with a slight difference in SSE and time elapsed, and there seems no technical reason beyond that in developing this model. The model generated input and output weights with the biases. Another data set (unseen to the model) is tested and simulated. The test error graph (Fig3) shows the difference between trained and tested results. These results reveal that the model is intelligent and faster to predict the quality of drinking water of Hyderabad city.

![Graph of TDS concentrations in drinking water of Hyderabad city](image-url)
5. Conclusion

It is found that the ANN model performed reasonably to predict TDS in the water supply distribution system of the city. The training error for predicting the targeted value is very low, representing the effective predictive potentiality of the neural networks. Because of the slight difference between the former model used for predicting EC and newly developed model indicates that the testing performance of the models be frequently carried-out periodically to lower the predictive differences under a similar set of conditions. However, the overall predictive and forecasting efficiency of ANNs (RBF) models can not be denied, when used for approximating the target values of the parameters of the drinking water in the distribution system of the city of Hyderabad.

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