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Predicting the Water Quality Index with a Neuro Fuzzy Inference System

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ABSTRACT: The groundwater in the vicinity of mines is highly polluted with heavy minerals, microorganisms, acidity, alkalinity, and toxicity. Furthermore, fertilizers applied for farming purposes have an impact on groundwater's pH and nitrate concentration. In order to do this, the current study suggests an effective approach for the prediction of water quality, namely the adaptive network fuzzy inference system (ANFIS). Since the parameters used to assess water quality are typically connected, an evaluation cannot be justified. As a result, utilizing principal component analysis and varimax rotation, the parameters are uncorrelated. Fuzzification of the uncorrelated parameters values accounts for uncertainty and imprecision in data collecting and testing. The hybrid learning technique of ANFIS is utilized to generate an optimal distribution of membership function and an efficient rule base.

KEY WORDS: WQI, Water quality, Neuro Fuzzy Inference System, fuzzy logic, Prediction

I. INTRODUCTION

Exploration of groundwater for industrial, agricultural, and human usage is prompted by the need for water. Groundwater resources can get naturally contaminated by geochemical processes or by surface discharge. In general, open-dug wells are regarded as among the poorest sources of potable water. The concentration of the majority of metals in groundwater is quite low and primarily governed by weathering and mineralogy, unaffected by environmental factors. The groundwater reservoir's water composition changes due to percolation and reactions with minerals found in the rock, which can alter the composition of the water. While there are a few instances of metal pollution due to natural weathering, most of the time, metals become a problem for the environment and human health because of Human activity in the Angul-Talcher area of Odisha, India, has evaluated the transportability of ground water in relation to heavy metals. The wide-ranging effects on human health have made ground water pollution and its control crucial. Water quality control and management therefore heavily depend on understanding the quality of the water and evaluating the water quality index (WQI). WQI is often thought of as a measurement tool for condensing the numerous water quality characteristics into an easy-to-understand index. With just one numerical value, the index facilitates the interpretation of water quality (Horton 1965; Brown et al. 1970; Dinius 1972; Lohani and Todino 1984). Indicators of water quality include temperature, turbidity, pH, total dissolved solids (TDS), and total potential components for assessing WQI include suspended solids (TSS), hardness, dissolved oxygen (DO), biological oxygen demand (BOD), electrical conductivity (EC), chloride, sulfate, total alkalinity, chemical oxygen demand (COD), fluoride, iron, calcium, magnesium, lead, chromium, nitrite, and zinc. The uncorrelated metrics may be utilized with common prediction methods, such fuzzy logic or neural networks, to evaluate the quality of the water. Fuzzy logic, on the other hand, is recommended because it can account for the impreciseness and uncertainty found in the data. The fuzzy decision rules may be learned by a neural network using its learning capabilities. The advantages of a neural network and a fuzzy system are combined in this arrangement. The adaptive neuro-fuzzy inference system (ANFIS), which integrates neural networks with fuzzy logic, was suggested by Jang (1991a). ANFIS is essentially a fuzzy inference system that is integrated into the neural network architecture. The WQI of wells' groundwater in metropolitan areas next to mines was examined in this study.
is anticipated utilizing ANFIS, which enhances the prediction power by taking into account factors including pH, TDS, hardness, calcium, chloride, magnesium, DO, turbidity, total alkalinity, BOD, iron, and sulfate. To provide as input for the ANFIS system, the correlation between the parameters has been examined and translated into uncorrelated principal components.

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II. LITERATURE REVIEW

Earlier study has been done on groundwater quality by different scholars. Karnchanawong and Ikeguchi (1993) have assessed the well water quality in the vicinity of the Mae-Hia garbage disposal facility. Zhang et al. (1996) predicted the water quality index for 14 Chinese cities where nitrogen fertilizer pollution had contaminated the groundwater. The influence of mining activities on groundwater pH and its effect on water quality has been examined by Lind et al. (1998). In Slovenia, Maticie (1999) noted how agriculture affected the quality of the groundwater. The impact of environmental conditions on the quality of the Nile Valley aquifer has been researched by Shamruck et al. (2001). The effects of runoff from groundwater contamination on water quality were assessed by Ammann et al. (2003). Almasri
& Kaluarachchi (2004) have documented the presence of nickel in agricultural watersheds in Whatcom County, Washington's groundwater. The study's several associated characteristics have a significant impact on WQI. Furthermore, determining whether the parameters are appropriate is essential for a precise assessment of WQI. Water quality is often determined using physical, chemical, and biological indicators as well as pollutant concentrations, following criteria from organizations like the Bureau of Indian Standards (BIS) (1991) and the World Health Organization (WHO) (2006). According to Nagarajan and Priya's (1999) analysis of the declining ground-water quality in Tiruchirapalli, Tamil Nadu, TSS, iron, and magnesium levels are higher than allowed. A 1999 study by Singh and Parwana examined the pollutants groundwater in Punjab state as a result of industrial effluent, and it was discovered that the amount of cyanide and chromium in the groundwater exceeded the allowable limit of drinking water regulations. The physico-chemical characteristics of drinking water in the Godda district of Santal Pargana (Bihar) town area were investigated by Jha and Verma (2000).
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WQI computation

The significance of different characteristics in the creation of the water quality index varies according to the intended use of the water, and the parameters are examined from the perspective of their acceptability for human consumption. The Indian Council of Medical Research recommends the "standards" (allowable values of different contaminants) for the drinking water (ICMR). The World Health Organization (WHO), Indian Standards Institution (ISI), United States Public Health Services (USPHS), and European Economic Community (EEC) standards have been cited in place of the ICMR standards when they are not available.
The relationship yields the quality rating (qi) for the ith water quality parameters:

$$q_i = \frac{v_i}{s_i} \cdot 100$$

where s_i is the standard permitted value of the i-th parameter and vi is the value of the ith parameter at a specific sample station. This formula guarantees that when a pollutant (the q_i 100 if the value of this parameter is just equal to the maximum allowable value for drinking water, and ith parameter) is not present in the water. As a result, the more contaminated the water with the ith contaminant, the higher the qi value. However, particular care must be used while managing pH and DO quality ratings. The pH range that is acceptable for drinking water is 7.0 to 8.5. As a result, the pH quality grade might be

$$q_{pH} = \left[\frac{v_{pH} - 7}{8.5 - 7.0}\right] \cdot 100$$

The system for adaptive neuro-fuzzy inference (ANFIS)
Artificial neural networks (ANN) and fuzzy inference systems (FIS) are connected in the adaptive neuro-fuzzy inference system (ANFIS). Fuzzy logic and a neural network are two complimentary technologies. Although a neural network may learn from input and feedback, it has been challenging to comprehend the knowledge or pattern that the network has discovered. However, hazy

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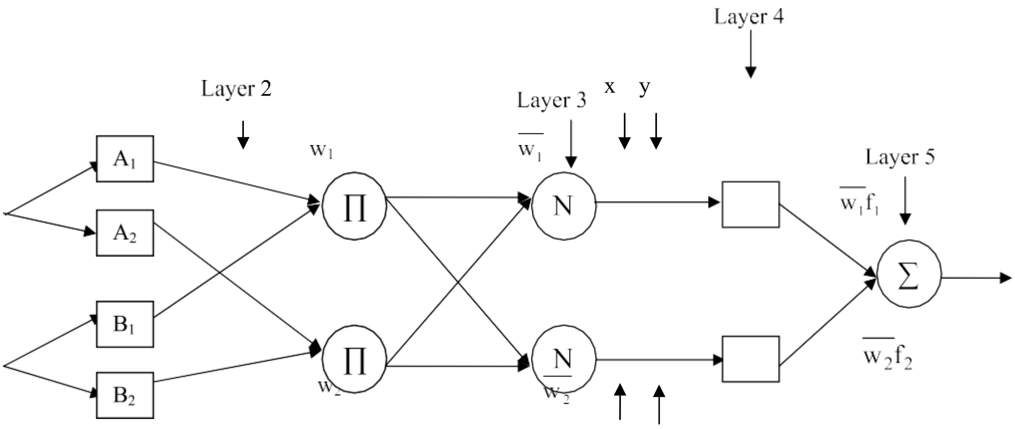

Fig. 1 A typical architecture of ANFIS system

Two rules, as stated by Sugeno and Kang (1988), comprise a fuzzy model when considering a first order Takagi, Sugeno, and Kang (TSK) fuzzy interface system.

Rule 1: If x is A_1 and y is B_1 then $f_1 = p_1x + q_1y + r_1$

Rule 2: If x is A_2 and y is B_2 then $f_2 = p_2x + q_2y + r_2$

ANFIS Network Training and Testing

Principal component analysis (PCA), as detailed in Section Principal Component Analysis (PCA), is performed after normalizing the data gathered on water quality metrics. After being normalized, the chosen principle components are sent into the ANFIS system. The WQI determined in accordance with the steps listed in Section Calculation of WQI is the output for each set of data. Training and testing sets of data comprise the total experimental data set. There are a total of 120 data sets used, as indicated in Table 5. Thirty of the 120 data are regarded as testing data, and the remaining 90 as training data. A five-layered ANFIS model is trained.
built in accordance with the discussion. During training, the number of nodes in the second layer is progressively raised from two. It was shown that when the number of nodes is increased to seven, the error is converging (decreasing). As a result, seven nodes are fixed in the second layer, and more analysis is done. One input, three hidden, and one output layer are the names given to the five layers. Fig. 4 displays the flow chart for the whole method, which includes the ANFIS algorithm. A Pentium IV desktop computer running the MATLAB platform was used to operate the network. The fuzzy membership function is generated using a constant type membership function for the output and a Gaussian type membership function (guessmf) for the inputs.

III. RESULTS AND DISCUSSIONS

For the training and testing data sets, the pattern of fluctuation of the actual and predicted WQI is displayed in Figs. 6 and 7, respectively. The red dots show the anticipated data, and the blue dots show the actual output. The charts demonstrate how the data distribution is coherent. In Figure 8, the surface plot is displayed. It is evident that the surface encompasses the whole choice space. Fig. 9 displays an example set of rules generated for entry length prediction. To perform the residual analysis, the residuals from the training and testing data sets' actual and anticipated WQI are computed. The residuals are found to be uniformly distributed along the centerline. As a result, it can be claimed that the data exhibit non-linearity between WQI and quality indicators and are well-trained, tested, and correlated.

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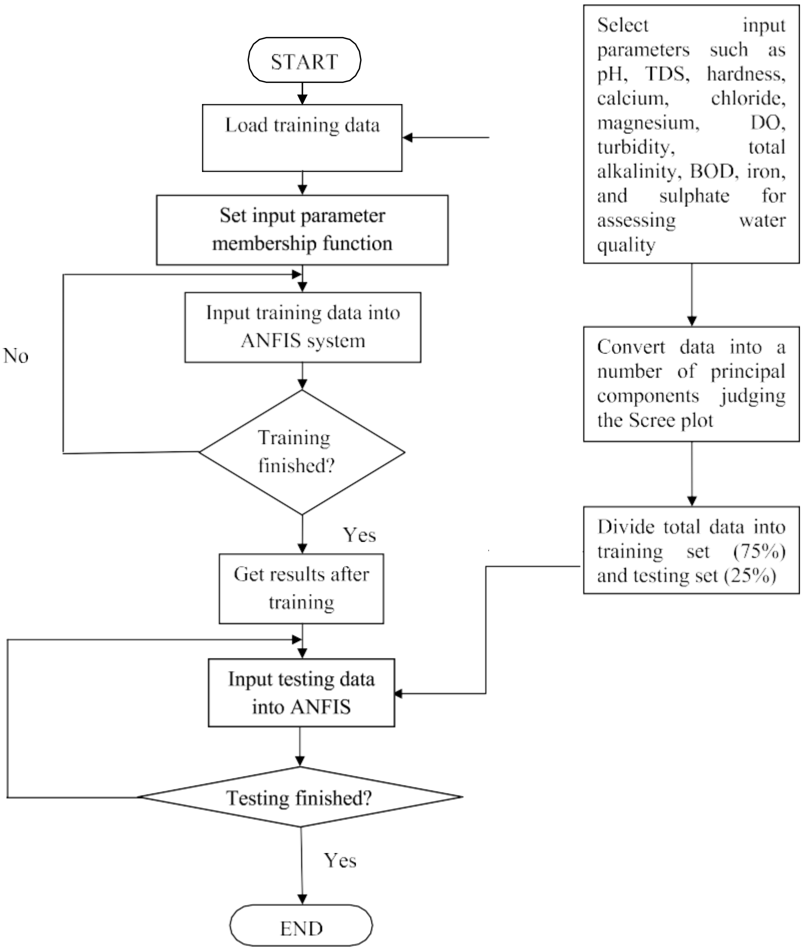

Fig. 2 Flow chart of the ANFIS model

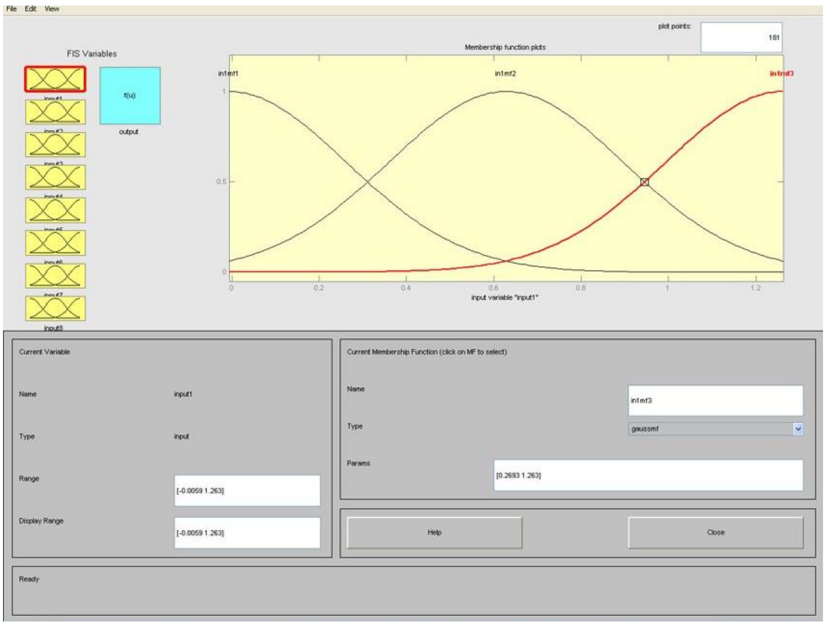

Fig. 3. Membership function of FIS inference system

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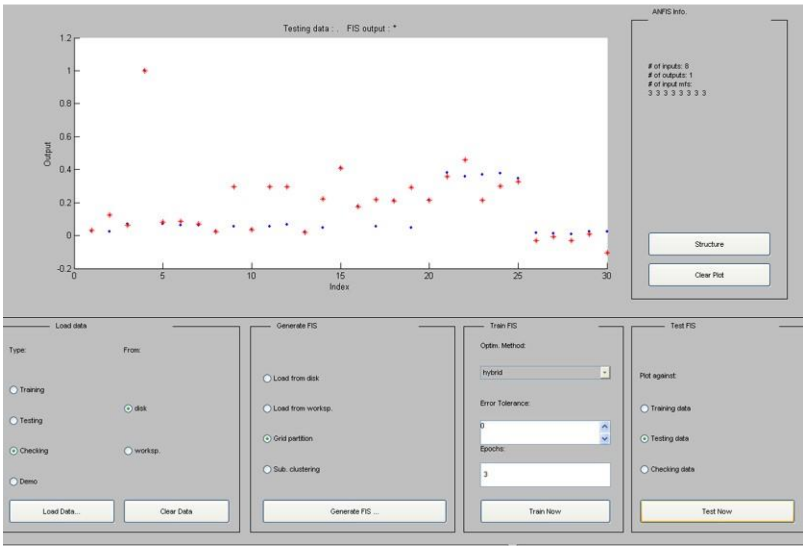

Fig. 4. (Color online) Distribution of predicted and actual WQI (testing)

IV. CONCLUSIONS

The percolation and interactions of the water with the minerals in the rock can change the composition of the water in the groundwater reservoir. Natural weathering causes metal pollution, and anthropogenic activity makes metals a health and environmental concern. Because groundwater pollution has a broad influence on human health, it has become crucial to manage. As a result, understanding water quality and evaluating the water quality index (WQI) are crucial for managing and controlling water quality.

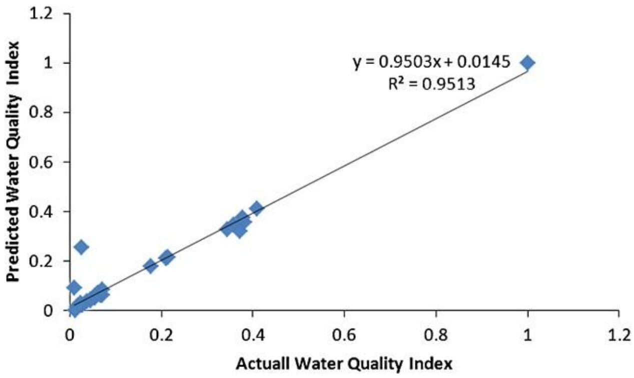

Fig. 5.Correlation of predicted and actual data (testing)

The fuzzy reasoning approach processes the result using linguistic terminology instead than relying on a clear set of data. In order to anticipate WQI, the ANFIS model—which combines fuzzy logic and neural networks—is put forth. The water quality is predicted by the model rather well. The ratings obtained for water quality ranged from 9 to 47. It follows that the water that emerges from the wells is typically safe for human consumption. A high degree of coefficient of determination (R2) is shown in regression graphs between real WQI and projected WQI using the ANFIS model for training and testing data, with values of 1.000 for training and 0.951 for testing, respectively. For training data, the average absolute % relative error is obtained.

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