Industrial Sewage Evaluation Based on Fuzzy Neural Network

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Abstract

The purpose of this paper is to propose a new method of industrial sewage evaluation. A comprehensive evaluation is presented to industrial sewage on the base of fuzzy recognition firstly. Then a model of fuzzy artificial neural network recognition is set up to evaluate industrial sewage. Finally, the feasibility and the effectiveness of approaches of industrial sewage evaluation based on fuzzy neural network are validated by some examples of industrial sewage evaluation of Zigong City here.

Key words: fuzzy recognition; neural network; industrial sewage; evaluation

1. Introduction

In recent years, with the development of industry, growing industrial pollution, sewage disposal is an important factor of water pollution, environment, and biological, and human and the social economic hazard increase in chemical industry area particularly. Based on national environmental general implementation of water quality evaluation of requirements, industrial sewage evaluation should select main poison factors in water pollution as evaluation object index to set up a comprehensive evaluation model of industrial waste water. Industrial sewage evaluation is a typical of the knowledge-intensive problem [1-3]. A lot of influence factors of water pollution, environment, and biological, and human and the social economic hazard is caused by the characteristics of sewage disposal including multiple factor, poison factor such as Asia nitrate, oxygen balance factor as high manganese acid salt index (CODM), dissolved oxygen (DO), and biochemical required oxygen volume, nutrients class factor selected nitrate, and ammonia nitrogen (NH3-N) etc. [4-6]. Moreover, industrial waste water pollution is a relative degree of fuzzy concept, its change is continuous, there is intermediate transition of ambiguous and relative membership degree of pollution. Therefore, it is impossible to make it perfect to design an industrial sewage evaluation by a usual expert system staff.
In the continuing effort to improve the performance of protection of water environment management, a lot of influence factors in industrial sewage evaluation is taken into account, it also is to encourage academic and industrial interaction, and promote collaborative research in expert systems and intelligent computation technology, a scheme of industrial sewage evaluation with fuzzy neural network computation is developed in this paper.

2. Theoretical Aspects of Industrial Sewage Evaluation

\[ S = (U, A, V, f) \] is a collected database of industrial sewage evaluation system. Where \( U \) is an universe defined on a finite set \( U \), for any object \( x \in U \), and \( \text{card}(U) = |U| \) is cardinal number of some sets of \( x \) in \( U \), and \( A = C \cup D \) is an attribute set where \( C \), \( D \) is condition attribute set contained variable factors such as toxic factors nitrite, oxygen balance factors permanganate index (CODM), dissolved oxygen (DO), biochemical oxygen demand(BOD), nutritional factor nitrate salts, ammonia nitrogen (NH3-N) ,etc. and decision attributes contained credit degree respectively. \( U | C = (X_1,...,X_n) \) denote the equivalence classes of \( U \) classified on the set of condition attributes \( C \), where \( X_j \) denotes an equivalence class based on condition attributes. Where \( n \) samples of measured industrial sewage, including \( m \) evaluation indicators, then measured indicators matrix is

\[
X_{mn} = (x_{ij})_{mn}
\]

in which \( i = 1,2,...,m \); \( j = 1,2,...,n \); \( x_{ij} \) is measured value of indicator \( i \) in sample \( j \).

\( U | D = (Y_1,...,Y_m) \) denotes the equivalence classes of \( U \) classified on the set of decision attributes \( D \), where \( Y \) denotes an equivalence class based on decision attributes. If \( m \) indicators are evaluated in accordance with \( c \) class levels, taking the class’s standard value as the number interval of sewage evaluation, then the standard indicators matrix \([7-9]\) is

\[
Y_{m} = (y_{ih})_{m}
\]

In which \( h \) is category number of standard recognized matrix; \( h = 1,2,...,c \); \( c \) is the standard category number; \( y_{ih} \) is the standard value of standard class \( h \).

Based on ambiguous level of industrial sewage pollution, a standard indicator membership degree \([3]\) is defined as following:

\[
S_{ih} = (y_{ih} - y_{i1})/(y_{ic} - y_{i1})
\]

Where \( S_{m} \) denotes a standard indicator membership degree matrix, and \( 0 \leq S_{ih} \leq 1 \).

A relative membership degree \( r_{ij} \) can be as:

\[
r_{ij} = (x_{ij} - y_{i1})/(y_{ic} - y_{i1})
\]

Where \( R_{mn} \) denotes a relative membership degree matrix.

A category’s relative membership degree matrix is defined as:

\[
U_{cxn} = (u_{hj})_{cxn}
\]

Where \( u_{hj} \) denotes a relative membership degree for sample \( j \) is belong to class \( h \). and matrix \( U_{cxn} \) meets with the constraint condition:
\begin{equation}
\sum_{h=1}^{c} u_{hj} - 1 = 0 , \quad 0 < u_{hj} < 1 , \forall h , \forall j
\end{equation}

A comprehensive evaluation to sewage samples on the base of \( \tilde{H} \) is computed as:
\begin{equation}
\tilde{H} = (\underbrace{1,2,3, \cdots, c}_c) * U_{c \times n} = (H_1, H_2, H_3, \cdots, H_n)
\end{equation}

Where \( \tilde{H} \) is a eigenvalue vector of sewage samples.
The category of sewage level is determined by the eigenvalue method [10]:
If \( c - 1 \leq H_j < c \), let \( H_j = c - 1 \); It denotes sample \( j \) is belong to level \( c - 1 \).

3. A Model of Fuzzy Neural Network for Industrial Sewage Evaluation

A model of artificial neural network is build by 3-layer network as Figure 1 shown. A fuzzy optimization model function herein is designated as activation function [11-12].

For the hidden layer
\begin{equation}
u_{kj} = \frac{1}{1 + \left( \sum_{i=1}^{m} w_{ik} r_{ij} \right)^{-1}} = \frac{1}{1 + \left( I_{kj}^{-1} - 1 \right)^2}
\end{equation}
\begin{equation}
I_{kj} = \sum_{i=1}^{m} w_{ik} r_{ij}
\end{equation}

Where \( j \) is sample industrial sewage; \( r_{ij} \) is the input of input layer; \( w_{ik} \) is the weight from layer \( i \) to layer \( k \); \( u_{kj} \) is the output of \( k \) layer node.

For the output layer
\begin{equation}
\begin{split}
v_{hj} = \frac{1}{1 + \left( \sum_{k=1}^{l} w_{hk} u_{kj} \right)^{-1}} = \frac{1}{1 + \left( I_{hj}^{-1} - 1 \right)^2}
\end{split}
\end{equation}
\[ I_{hj} = \sum_{k=1}^{l} w_{kh} u_{kj} \]  

(11)

Where \( u_{kj} \) is the input of hidden layer; \( w_{kh} \) is the weight from layer \( h \) to layer \( k \); \( u_{kj} \) is the output of \( h \) layer node.

Some of the measured sample of industrial sewage are used as training samples. Based on China sewage effluent standard (GB 8978-1996), assigning the standard value of each level of classification as the standard indicator value. The training samples are shown as table 1.

<table>
<thead>
<tr>
<th>Level</th>
<th>Standard Indicators</th>
<th>RMDM</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>s, s, s, s, 1, 0, 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>s, s, s, s, 0, 1, 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>s, s, s, s, 0, 0, 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. An Implementation of Industrial Sewage Evaluation of Zigong City

Sewage disposal is an important factor affecting the surface water quality in chemical industry area particularly area. Comprehensive evaluation of industrial waste water purpose is to accurately reflect the quality of the environment and pollution, forecast future trends of protection of water environment management and governance. In order to validate the feasibility and the effectiveness of the proposed approaches of industrial sewage evaluation based on fuzzy neural network, Some of examples industrial sewage evaluation of Zigong City are given.

Zigong City is chemical industry area in which toxic factors nitrite, etc., oxygen balance factors permanganate index (CODM), dissolved oxygen (DO), biochemical oxygen demand(BOD), nutritional factor nitrate salts, ammonia nitrogen (NH3-N) etc. are main hazard elements in water pollution. These hazard elements in industrial sewage come from BOD, COD, NH3-N and OIL mainly. The basis data of industrial sewage is collected from 6 administrative districts in Zigong City as shown in Table 2 and the standard level of indicators selected in industrial sewage is shown in Table 3.

<table>
<thead>
<tr>
<th>A.D.</th>
<th>BOD</th>
<th>COD</th>
<th>NH3-N</th>
<th>OIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ziliujing</td>
<td>1.4</td>
<td>49</td>
<td>1.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Gongjing</td>
<td>3.1</td>
<td>117</td>
<td>83.3</td>
<td>1.7</td>
</tr>
<tr>
<td>Da'an</td>
<td>35</td>
<td>185</td>
<td>3.5</td>
<td>13.7</td>
</tr>
<tr>
<td>Yantan</td>
<td>47</td>
<td>165</td>
<td>3.3</td>
<td>1</td>
</tr>
<tr>
<td>Rongxian</td>
<td>39.1</td>
<td>213.6</td>
<td>3</td>
<td>5.9</td>
</tr>
<tr>
<td>Fushun</td>
<td>14.2</td>
<td>77.8</td>
<td>28.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Standard</td>
<td>BOD≤</td>
<td>COD≤</td>
<td>NH₃-N≤</td>
<td>OLI≤</td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
<td>------</td>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>Lev.1</td>
<td>20</td>
<td>100</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>Lev.2</td>
<td>60</td>
<td>200</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Lev.3</td>
<td>600</td>
<td>1000</td>
<td>100</td>
<td>20</td>
</tr>
</tbody>
</table>

According to the requirements of fuzzy neural network for industrial sewage evaluation, a model of artificial neural network is build by 3-layer network as Figure 1 shown. 4 neurons in input layer denotes BOD, COD, NH₃-N and OIL inputs, 5 neurons are selected in hidden layer, 3 neurons in output layer denotes 3 outputs standard level of indicators,  A fuzzy optimization model function herein is designated as activation function.

After input the relative membership degree of the 6 administrative districts’ samples into the trained network, the relative membership degree matrix $U_{3x6}$ of industrial sewage to the standard level is obtained.

$$U_{3x6} = \begin{bmatrix}
0.9945 & 0.0159 & 0.9943 & 0.9980 & 0.9996 & 0.9298 \\
0.0082 & 0.9853 & 0.6480 & 0.0029 & 0.0658 & 0.1193 \\
0.1947 & 0.0004 & 0.0258 & 0.1534 & 0.0434 & 0.0558
\end{bmatrix}$$

and then the level eigenvalue vector $\tilde{H}$ about 6 administrative districts in Zigong City is got as following

$$\tilde{H} = (1,2,3) * U_{3x6} = (1.59501.9877, 2.36771.46401.26141.3358)$$

A comparison of industrial sewage evaluation of Zigong City is made based on Fuzzy Recognition FR (Given in reference [2]) and fuzzy neural network computation (FNNR) proposed here. Table 4 also shows the comparison result between FNNR and FR (Given in reference [13]).

<table>
<thead>
<tr>
<th>Evaluating Method</th>
<th>Ziliujing</th>
<th>Gongjing</th>
<th>Da’an</th>
<th>Yantang</th>
<th>Rongxian</th>
<th>Fushan</th>
</tr>
</thead>
<tbody>
<tr>
<td>FNNR</td>
<td>Lev.2</td>
<td>Lev.2</td>
<td>Lev.3</td>
<td>Lev.2</td>
<td>Lev.2</td>
<td>Lev.2</td>
</tr>
<tr>
<td>FR</td>
<td>Lev.2</td>
<td>Lev.2</td>
<td>Lev.2</td>
<td>Lev.2</td>
<td>Lev.2</td>
<td>Lev.2</td>
</tr>
</tbody>
</table>

5 Conclusions

It is very important for us to evaluate industrial sewage with the development of industry. Since industrial sewage evaluation is a typical of the knowledge-intensive problem. It is call for availability and applicability of industrial sewage appraisement based on fuzzy comprehensive appraisement. The artificial neural network (ANN) and the fuzzy recognition (FR) are both information process systems simulating biological mechanism. These two theories are widely applied to many fields currently. Taking their advantages into consideration, this paper proposes a fuzzy artificial neural network recognition model (FANNNR) with the fusion of ANN and FR; thereby, the flexible industrial sewage evaluation ability of the network is enhanced. Finally, the model was used to evaluate industrial sewage in chemical industry area of Zigong city, and the result obtained indicates that FANNNR model is objective and reliable.

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References


