The Research and Practice of Water Quality Safety Evaluation for Ji Nan urban Water Supply System

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Abstract

The article set up a water quality safety evaluation index system on the basis of internal factors, external factors and water quality factors, through collecting and sorting of different kinds of information of Ji Nan urban water supply system. Make use of the fuzzy comprehensive evaluation methods on the basis of fuzzy mathematics and GUI in MATLAB technology for Ji Nan urban supply system’s all-round evaluation. And find the potential impact factors in order to supply the management of Ji Nan urban water supply system with theoretical basis.

Keywords: Fuzzy comprehensive evaluation; MATLAB; GUI; Urban water supply pipe network; Water quality safety evaluation

1. Overview

Regional water supply is mainly from Quehua Water Plant, mixed with a little of groundwater. Urban water supply system of Jinan City is range of the south of Jingshi road, north of Jiefang Road, west of the Second Ring Road, east of Lishan’s water supply area. Demonstration area is about 62 square kilometers (6,189,972 square meters) with the pipe (DN15 ~ DN1200) about 108 km long. The main pipe materials are PE, iron, zinc, iron, steel, PVC, UPVC. PE pipe is about 25,581.15 meters; cast iron 63,642.05 meters; galvanized 13033.64 meters; ductile iron 5508.367 meters; steel 235.195 meters; PVC 698.027 meters and UPVC 125.664 meters. Water supply demonstration area is composed by Quehua Water Plant, Yuqing Water Plant and Industrial North Road Water Plant. Quehua Water Plant and Yuqing Water Plant are water plants whose sources are from surface water, and the Industrial North Road Water Plant is Groundwater as a source of water. At present, the area which is supplied by the Quehua Water Plant is range of the south of Jiefang Road, east of Yanshan Road, west of the Second Ring Road, the north of Dianliu compressor stations and part of the regional of eastern Lishan road, and the others locations are supplied from Yuqing Water Plant. The basic water quality in demonstration area is met with national "Drinking Water Health Standards" (GB5749-2006).
2. Establishment of index system

According to the research and investigation for Jinan municipal water supply network, initially set up water quality safety evaluation system which is composed by 13 evaluation indicators, such as pressure monitoring spots, road construction, management frequency, etc. Divided into 4 layers: A layer is Jinan urban water quality level of security; B layer is divided into three major indicators, namely the network of external factors B1, internal factors B2 and water quality factors B3. C layer contains 13 factors (the pressure monitoring points C1, road construction C2, management frequency C3, position C4, pipeline pressure C5, the pipe diameter C6, interface form C7, pipe material C8, laying age C9, water quality monitoring spots C10, secondary pollution C11, terrorist attacks C12, node residual chlorine C13). At the same time, secondary pollution factors for the C11, is also divided into four sub-layers (turbidity NTU D1, Fe D2, Mn D3, Ca D4).

3. Determining Evaluation index weight

By using the improved Analytic hierarchy process[1-4] (AHP) respectively, the every layer of each index B grade C indexes of three scale method[5-7] comparisons, thus determine A - B, B1- C, B2 - C and B3 - C judgment matrix. For D layer impact factor, using weighted average type environment index evaluation model[8] to calculate.

A-B Judgment matrix          B1-C Judgment matrix
Make use of GUI interface system based on MATLAB taking judgement matrix into the system to get the total level sorting and weight of the index system (see Figure 2):

**The first layer weight is:**
\[ W_{A,B} = [0.1062 \ 0.2605 \ 0.6333] \]

**The second layer weight is:**
\[ W_{B1,C} = [0.2633 \ 0.1219 \ 0.5579 \ 0.0569] \]
\[ W_{B2,C} = [0.2967 \ 0.0377 \ 0.0721 \ 0.2967 \ 0.2967] \]
\[ W_{B3,C} = [0.1219 \ 0.5579 \ 0.0569 \ 0.2633] \]

**Total weight assembly is:**
\[ W = [0.0279673 \ 0.0129429 \ 0.0592482 \ 0.0060417 \ 0.0772934 \ 0.00982675 \ 0.0187931 \ 0.0772934 \ 0.0772934 \ 0.771819 \ 0.353313 \ 0.0360283 \ 0.166776] \]

4. **Fuzzy comprehensive evaluation calculation**

4.1 **Determining Safety Assessment Level**

According to the historical data and some experts' advice, ultimately determine the weight of 13 evaluation factors [9] (see Table 1, Table 2)

![Figure 1](image)
Table 1 The safety level of water quality indicators

<table>
<thead>
<tr>
<th>Influencing factors</th>
<th>Restricting Factors</th>
<th>Very Safe</th>
<th>Safe II</th>
<th>Safer III</th>
<th>Dangerous IV</th>
<th>Very Dangerous V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal factors</td>
<td></td>
<td>0.1~0.2MPa</td>
<td>0.2~0.3MPa</td>
<td>0.3~0.4MPa</td>
<td>0.4~0.5MPa</td>
<td>0.5MPa More</td>
</tr>
<tr>
<td></td>
<td>pipeline diameter</td>
<td>DN100</td>
<td>DN800~500</td>
<td>DN150~100</td>
<td>DN75</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DN100 And more</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interface form</td>
<td>Ductile Pipe apron</td>
<td>Concrete Aprons</td>
<td>Plastic pipe fittings Flanges</td>
<td>Lead Port</td>
<td>Asbestos Cement</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pipe Material</td>
<td>Steel, Glass Tube</td>
<td>Ductile Iron Pipe</td>
<td>PVC Pipe</td>
<td>Prestressed Concrete Pipe</td>
<td>Gray Cast Iron Pipe</td>
</tr>
<tr>
<td>External factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The pressure monitoring points</td>
<td>Has</td>
<td>Near</td>
<td>Distant</td>
<td>Far</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Road construction</td>
<td>No excavation</td>
<td>Don’t touch</td>
<td>Touch but water pipes</td>
<td>Touch water pipes</td>
<td>Large-scale excavation</td>
</tr>
<tr>
<td></td>
<td>Management frequency</td>
<td>Frequent</td>
<td>Regular</td>
<td>Occasionally</td>
<td>Hardly</td>
<td>Never</td>
</tr>
<tr>
<td></td>
<td>Position</td>
<td>outskirts</td>
<td>suburbs</td>
<td>City</td>
<td>Center City</td>
<td>Villages</td>
</tr>
<tr>
<td></td>
<td>Water quality monitoring spots</td>
<td>More than 8</td>
<td>5-8</td>
<td>2-5</td>
<td>1</td>
<td>Nothing</td>
</tr>
<tr>
<td></td>
<td>Secondary pollution</td>
<td>See Below</td>
<td>See Below</td>
<td>See Below</td>
<td>See Below</td>
<td>See Below</td>
</tr>
<tr>
<td></td>
<td>Water quality factors</td>
<td>Multi-ring network water supply district</td>
<td>Multiple sources of water supply network does not partition ring</td>
<td>Single source of water supply network does not partition ring</td>
<td>Water is not a simple single-loop water partition</td>
<td>Single source of water supply network does not partition the tree</td>
</tr>
<tr>
<td></td>
<td>Terrorist attacks</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.05</td>
<td>0.03</td>
</tr>
</tbody>
</table>
Table 2 The safety level of D layer’s water quality factors

<table>
<thead>
<tr>
<th>Influencing Factors</th>
<th>Restricting Factors</th>
<th>Very Safe I</th>
<th>Safe II</th>
<th>Safer III</th>
<th>Dangerous IV</th>
<th>Very Dangerous V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary Pollution</td>
<td>Turbidity (NTU degrees)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Fe (mg/L)</td>
<td>Under 0.3</td>
<td>0.3–0.4</td>
<td>0.4–0.45</td>
<td>0.5</td>
<td>More than 0.5</td>
</tr>
<tr>
<td></td>
<td>Mn (mg/L)</td>
<td>Under 0.1</td>
<td>0.1–0.3</td>
<td>0.3–0.4</td>
<td>0.5</td>
<td>More than 0.5</td>
</tr>
<tr>
<td></td>
<td>Zn (mg/L)</td>
<td>Under 1.0</td>
<td>1.0–3.0</td>
<td>3.0–5.0</td>
<td>10</td>
<td>30</td>
</tr>
</tbody>
</table>

4.2 Determining The Relative Membership Vectors

Making use of collected data of Jinan urban water supply network and water quality tests’ information, according to security rating, get 13 relative membership vectors which influence evaluation factors[10].

**B1-C** Membership matrix of the evaluation factor

\[
B1 - C = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 \\
0 & 1 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0
\end{bmatrix}
\]

**B2-C** Membership matrix of the evaluation factor

\[
B2 - C = \begin{bmatrix}
0 & 0 & 0 & 0 & 1 \\
0 & 0.46 & 0.54 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 & 0
\end{bmatrix}
\]

**B3-C** Membership matrix of the evaluation factor

\[
B3 - C = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 \\
0.5 & 0.5 & 0 & 0 & 0
\end{bmatrix}
\]

4.3 Multi-Level Fuzzy Comprehensive Evaluation

Put the calculated membership degree matrix into membership calculating interface of MATLAB procedures (see Figure 2) to do the multi-grade fuzzy comprehensive evaluation, And get the final results. (see figure 3).
5. Results

The final result which is calculated by GUI is that the security level of Jinan city water supply network is 0.8. And the final evaluation is general security. It means that main factors affecting the security of water quality in the Demonstration Area are from the internal factors. The main factors are: some pipelines are too old to be used. Pipe material is aging. Partial pipeline stress is too big. In recent years, there often happened secondary pollution accidents due to tubing corrosion or tubing aging. Therefore, at present, the most important and effective way to solve the water quality problem is updating aging pipeline section.

6. Acknowledgment

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References


