Evaluation of Wastewater Treatment Quality in the West Bank-Palestine

Based on Fuzzy Comprehensive Evaluation Method

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Abstract - Treated wastewater reuse has an important significance to solve the water shortage in the West Bank-Palestine. Based on fuzzy comprehensive evaluation method, the water quality of Al-Birch WWTP is evaluated by referring to Chinese water quality evaluation criteria. It can help the Palestinians understand the current situation of sewage treatment and establish nationally appropriate water quality evaluation system.

Keywords - Fuzzy comprehensive evaluation, treated wastewater, west bank

I. INTRODUCTION

A. Wastewater situation in the West Bank-Palestine

Water is a major concern in the West Bank (WB) since it’s considered one of the poorest regions of the Middle East in terms of water resources. Water scarcity is mainly attributed to the Israeli control over the majority of the Palestinian water resources, as well as the arid and semi-arid climate conditions of the region [1]. The occupied Palestinian territories (Opt) are divided into sixteen Governorates. Eleven of these are located in the WB, the others in the Gaza Strip. The Oslo Accords divide the Opt into three types of areas, A, B and C. where areas A are under Palestinian control, areas B are under Palestinian administrative control and Israeli security control and areas C are under total Israeli control.

The wastewater sector in Opt has been neglected under Israeli occupation since 1967 with most attention focused on measures to solve water quantity and supply problems. A lack of wastewater treatment plants, of sewerage systems and wastewater collection for recycling, leads to the uncontrolled discharge of wastewater into the environment. There were insufficient financial resources within the Palestinian community to pay for new wastewater collection, disposal and treatment systems [2]. Israel collected taxes from the Palestinians through the Israeli Civil Administration, but they never spent the money on infrastructure for the Palestinian communities.

There are three old treatment plants in the West Bank, namely Ramallah, Jenin, Tulkarm [3-4]. All have operational difficulties and are not functioning effectively, and some are not functioning at all. Most of these plants are overloaded, under-designed or have experienced mechanical failures. In addition, the fourth plant, Al-Birch, considerable new treatment plant, was constructed in the 2000 with support of German Government. It’s over 22 dum dums of land. The system is designed to cover a population of 50,000 with enough capacity to serve future expansion. Daily wastewater flow rate 5000 m3/day.

B. Palestinian standards of Wastewater Quality

Wastewater treatment and reuse criteria differ from one country to another and even within a given country. Some of the main discrepancies in the criteria are, in part, due to differences in approaches to public health and environmental protection.

For a long time, Palestine did not have any specific wastewater regulations and references were usually made according to the WHO recommendations or to the standards of neighboring countries (as Egypt, Jordan) [5]. Recently, the Environmental Quality Authority, in coordination with Palestinian ministries and universities, has established specific wastewater reuse regulations. The draft of the Palestinian legislation for reuse of treated wastewater is still under study in the Palestinian Standard Institute [6].

Treated wastewater disposed by the sewage treatment plant is evaluated according to China’s "Surface Water Quality Standards". The difference in standards is concluded between the two countries, contributing to the establishment of water quality evaluation system in the West Bank-Palestine.

II. METHODOLOGY

Fuzzy phenomena is everywhere in the nature, such as meteorological phenomena, land cover classification, spatial data quality, etc. Treated wastewater quality is also fuzzy. One cannot tell good or bad simply. Further, treated wastewater quality is affected by several factors and every type of factor has different effects on water quality [7]. As to this, a fuzzy comprehensive evaluation method is used in treated wastewater quality assessment. The method is a qualitative one and the following is the principle procedures of it:

1) Establishing element set: To find different factors in evaluating wastewater quality and put forward factor set:

   \[ U = \{u_1, u_2, \ldots, u_m\} \]

   In (1), \( u_i \) represents the i-th water quality indicator, \( m \) is the number of water quality indicators.

   According to the Palestinian water environmental conditions and China’s water quality evaluation, six indicators are determined as evaluation elements, which are TP, TN, DO, BOD5, CODMn and NH3-N.\n
   \[ U = \{\text{TP}, \text{TN}, \text{DO}, \text{BOD}_5, \text{CODM}_\text{Mn}, \text{NH}_3 - \text{N}\} \] (2)

2) Establishing grade factor set:

   \[ V = \{v_1, v_2, \ldots, v_p\} \]

   In (3), \( v_j \) is the assessment grade; \( n \) is the number of assessment grades.
According to China’s "Surface Water Quality Standards", five assessment grades can be determined [8]: I (v1), II (v2), III (v3), IV (v4) and V (v5).

\[ V = \{I, II, III, IV, V\} \] (4)

3) Establishing weight coefficient matrix: Weight measures the size of the water pollution which a factor affects. The larger the weight coefficient, the greater the impact on water quality. In fuzzy evaluation, every evaluation element has different contribution to image quality. Thus, the weight coefficient matrix of evaluation element is calculated according to "excessive multiples method" [9].

\[ l_i = c_i/s_i \] (5)

In (5), \( l_i \) is a dimensionless number and represents the exceeding multiples of evaluation element compared with standard value. \( c_i \) is the monitoring value, and \( s_i \) is the mean of kinds of water quality standards limit.

Then to be normalized, the weight of each evaluation can be calculated:

\[ w_i = l_i/\sum l_i \] (6)

The weight coefficient matrix is also determined:

\[ W = \{w_1, w_2, \ldots, w_m\} \] (7)

4) Establishing comprehensive evaluation matrix: Due to the extent of water pollution and grading standards of water quality are vague, so it is reasonable to describe the boundaries with membership classification. It is a fuzzy mapping from \( U \) to \( V \). \( r_{ij} \) represents the possibility of \( i \)-th water quality indicator can be evaluated as class \( j \). The corresponding judgment matrix can be attained as follows.

\[ R = \begin{bmatrix}
  r_{11} & r_{12} & \cdots & r_{1(n-1)} & r_{1n} \\
  r_{21} & r_{22} & \cdots & r_{2(n-1)} & r_{2n} \\
  \vdots & \vdots & \ddots & \vdots & \vdots \\
  r_{m1} & r_{m2} & \cdots & r_{m(n-1)} & r_{mn}
\end{bmatrix} \] (8)

Membership can be determined through the membership function and the membership functions are commonly described with a trapezoidal distribution. The membership of water quality with each category is described with a trapezoidal distribution. The membership function and the membership functions are

\[ m_1 = \frac{s_j - c_i}{s_{j+1} - s_j}, \quad 0 \leq c_i < s_j < s_{j+1}, \quad c_i \leq s_j \]

\[ m_2 = \frac{s_{j+1} - c_i}{s_{j+1} - s_j}, \quad c_i \geq s_{j+1} \leq c_i, \quad s_{j+1} - s_j \leq c_i \leq s_j \]

\[ m_3 = \frac{s_{j+1} - c_i}{s_{j+1} - s_j}, \quad s_{j+1} - s_j \leq c_i \leq s_{j+1}, \quad s_{j+1} \leq c_i \leq s_j \]

\[ m_4 = \frac{c_i - s_{j-1}}{s_j - s_{j-1}}, \quad s_{j-1} < c_i < s_j, \quad c_i \leq s_{j-1} \]

\[ m_5 = 1, \quad c_i \geq s_{j-1} \]

In (9), \( c_i \) is the monitoring value, and \( s_j \) is the standard value of \( j \)-th water quality indicator.

5) Establishing Fuzzy Comprehensive Evaluation model: After determining the fuzzy evaluation matrix \( R \) and weight coefficient matrix \( W \), fuzzy comprehensive evaluation model is also determined.

\[ B = W \cdot R = (w_1, w_2, \ldots, w_m) \begin{bmatrix}
  r_{11} & r_{12} & \cdots & r_{1(n-1)} & r_{1n} \\
  r_{21} & r_{22} & \cdots & r_{2(n-1)} & r_{2n} \\
  \vdots & \vdots & \ddots & \vdots & \vdots \\
  r_{m1} & r_{m2} & \cdots & r_{m(n-1)} & r_{mn}
\end{bmatrix} \] (10)

\[ = (b_1, b_2, \ldots, b_n) \]

\( B \) is a fuzzy vector which not only represents all evaluation elements’ contribution, but also reserves all degree of membership of every grade. Water levels should be evaluated for the class \( j \) if \( b_j = \max(b_1, b_2, \ldots, b_n) \).

III. APPLICATION&RESULTS

The Al-Bireh reuse demonstration project conducted the different aspects of reclaimed water use in irrigation by developing a set of different effluent polishing and irrigation techniques on crops. The primary goals of the project were to build the initial institutional relationships, raise the profile of wastewater reuse and compost use, and to develop the first stage of on-the-ground experience and capacity, in the field of wastewater reuse.

Based on the above fuzzy comprehensive evaluation model, the water quality of Al-Bireh WWTP is evaluated. The values of water quality indicators in Al-Bireh WWTP from June to November 2013 are shown in Table I.

<table>
<thead>
<tr>
<th>Index</th>
<th>TP</th>
<th>TN</th>
<th>DO</th>
<th>BODs</th>
<th>CODm</th>
<th>NH3-N</th>
</tr>
</thead>
<tbody>
<tr>
<td>201306</td>
<td>0.037</td>
<td>1.124</td>
<td>4.16</td>
<td>2.76</td>
<td>1.04</td>
<td>0.087</td>
</tr>
<tr>
<td>201307</td>
<td>0.026</td>
<td>0.916</td>
<td>5.23</td>
<td>1.92</td>
<td>0.94</td>
<td>0.064</td>
</tr>
<tr>
<td>201308</td>
<td>0.024</td>
<td>1.295</td>
<td>8.53</td>
<td>1.65</td>
<td>0.77</td>
<td>0.169</td>
</tr>
<tr>
<td>201309</td>
<td>0.052</td>
<td>1.432</td>
<td>6.56</td>
<td>3.41</td>
<td>1.36</td>
<td>0.213</td>
</tr>
<tr>
<td>201310</td>
<td>0.050</td>
<td>1.355</td>
<td>6.02</td>
<td>4.72</td>
<td>1.41</td>
<td>0.146</td>
</tr>
<tr>
<td>201311</td>
<td>0.046</td>
<td>1.116</td>
<td>5.14</td>
<td>1.88</td>
<td>1.59</td>
<td>0.073</td>
</tr>
</tbody>
</table>

The values of the indicators used are the limit of qualities of the surface water environments in China. They are shown in Table II.

<table>
<thead>
<tr>
<th>Index</th>
<th>TP</th>
<th>TN</th>
<th>DO</th>
<th>BODs</th>
<th>CODm</th>
<th>NH3-N</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.01</td>
<td>0.2</td>
<td>7.5</td>
<td>3</td>
<td>2</td>
<td>0.15</td>
</tr>
<tr>
<td>II</td>
<td>0.025</td>
<td>0.5</td>
<td>6.0</td>
<td>3</td>
<td>4</td>
<td>0.5</td>
</tr>
<tr>
<td>III</td>
<td>0.05</td>
<td>1.0</td>
<td>5.0</td>
<td>4</td>
<td>6</td>
<td>1.0</td>
</tr>
<tr>
<td>IV</td>
<td>0.1</td>
<td>1.5</td>
<td>3.0</td>
<td>6</td>
<td>10</td>
<td>1.5</td>
</tr>
<tr>
<td>V</td>
<td>0.2</td>
<td>2.0</td>
<td>2.0</td>
<td>10</td>
<td>15</td>
<td>2.0</td>
</tr>
</tbody>
</table>

According to the preceding formula, take the measurement data in June 2013 for example and weight coefficient for each evaluation factor is calculated.

\[ W = \{0.150, 0.338, 0.276, 0.166, 0.044, 0.026\} \]

The comprehensive evaluation matrix in June 2013 is as follows.