Assessment and Evaluation of Groundwater Quality due to Landfill Leachate Using Fuzzy Logic

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Abstract—Groundwater is considered as an important water source due to its relatively low susceptibility to pollution. Determination of groundwater quality has become a serious problem in recent years due to indiscriminate disposal of waste water from various sources and municipal solid waste disposal. One of the major problems associated with dumping of municipal solid waste landfill is the release of leachate and its impact on groundwater.

In the present study an attempt is made to measure the impact of municipal solid waste landfill on groundwater quality around Nagole, a solid waste dumping site in Hyderabad, Telangana State, India.

Groundwater samples were collected from wells, 2km radius around the solid waste dumping site and physico-chemical parameters of water samples were analysed. The various parameters analyzed are Chlorides, Calcium, Magnesium, Potassium, Sodium, pH, Nitrate, Total Hardness, Alkalinity, Total dissolved solids, Dissolved Oxygen and BOD.

The Groundwater quality index was determined in the study area using Fuzzy logic to assess the overall quality of groundwater. The study revealed that the groundwater contained pollutants at a level beyond the permissible limit set by Bureau of Indian standards.

Keywords—Groundwater quality, water quality parameters, leachate, fuzzy logic, fuzzy value

I. INTRODUCTION

Groundwater quality determination assumes significance in the field of water quality management because of its inconsistent variation with groundwater table, geological and soil conditions and contamination through percolation etc. Periodic estimation of groundwater quality is highly necessary in order to ascertain the quality of water to use for human consumption. The pollution parameters monitored for the assessment of the quality of any system gives an idea of pollution status with respect to those particular parameters.

The representation of all water quality parameters in a single form is called quality index that facilitates to get composite inference of all the quality parameters on that system and also helps to compare overall quality of water with a unit value.

Solid wastes are being produced since the beginning of civilization. With the advent of industrialization and urbanization, the problems of waste disposal increased. High population density, intensive land use for residential, commercial and industrial activities led to adverse impact on the environment. The problem of waste generation and management is fast becoming a global problem. According to a recent United Nations report, by 2025, it is estimated that there will be a five-fold increase in global waste generation. On the basis of available data, it is estimated that the nine major metropolitan cities in India are presently producing 34,000 tons of solid waste per day. As per recent estimates, Hyderabad and Secunderabad generate about 3,400 tonnes per day.

II. AREA OF STUDY

Hyderabad, the capital city of Telangana, is one of the most populated city in India. Municipal solid waste generated in the city is around 3000 metric tonnes per day. The solid waste generated from twin cities, Hyderabad and Secunderabad is partly disposed at Nagole landfill site. The landfill site lies in latitude N17°22′23.4" and longitude E78°33′33.5". Type of climate in Hyderabad is semi-arid. Hydro-geological features of the area: pink and granite of Archaeans age, intruded at places by dolerite dykes, pegmatite and quartz veins.

In the present study, an attempt is made to study Ground Water Quality around municipal landfill site at Nagole. Groundwater samples are collected and various chemical parameters such as Calcium, Magnesium, Potassium,
Sodium, pH, Nitrate, Total Hardness, Alkalinity, Total dissolved solids, Chlorides, Dissolved Oxygen, BOD were analyzed and later used to identify the degree of pollution using Fuzzy logic.

III. EVALUATION METHODOLOGY

1. The wells near the dumping site in a distance of 2 km radius were identified.
2. Ground water samples were collected from 20 wells.
3. The water samples were analyzed for the parameters, Calcium, Magnesium, Potassium, Sodium, pH, Nitrate, Total Hardness, Alkalinity, Total dissolved solids, Chlorides, Dissolved Oxygen and BOD.
4. Membership functions were developed for all the water quality parameters considering the permissible and excessive limits of drinking water as shown in Fig. 2 to Fig. 13.
5. For the known values of chemical parameters, the fuzzy values are read from the membership functions.
6. Net fuzzy value is determined using equation (1).
7. Groundwater quality was determined using the net fuzzy values and water quality rating.

IV. FUZZY LOGIC

Fuzzy logic approach is a mathematical method used to characterize and propagate uncertainty and inaccuracy in data and functional relationships. The idea of Fuzzy Logic was first proposed by Dr. Lotfi A. Zadeh [5] of the University of California in his paper [1965]. The capability of Fuzzy logic to express gradual transitions from membership to non-membership has broad utility. It provides us not only with a more meaningful and powerful representation of vague concept expressed in natural language. The main concept of Fuzzy theory is that the membership function for a variable represents numerically the degree to which an element belongs to a set.

Since the transition from member to non-member appears gradual rather than abrupt, the Fuzzy set introduces vagueness by eliminating sharp boundary dividing members of the class from non-members. Notable contributions are Akinbile C.O. and Yusoff, M.S. [1], Amadi, A. N., et al., [2], Bhide A.D. & Muley V.U. [3], Ashwani, K.T. and Abhay, K.S [4] and so on.

To study ground water pollution, membership functions were developed for all the chemical parameters. From the known values of chemical parameters, fuzzy value was determined from membership function. Lastly Net Fuzzy value was computed using equation (1).

V. MEMBERSHIP FUNCTIONS

Fig 1: Location of water samples collected from the bore wells

Fig 2: Membership function of alkalinity
Fig. 3 Membership function for Chloride

Fig. 4 Membership function for Calcium

Fig. 5 Membership function for Total Hardness

Fig. 6 Membership function for Magnesium

Fig. 7 Membership function for Nitrates

Fig. 8 Membership function for sodium
To find out the net fuzzy value, it is necessary to combine all the fuzzy values for various chemical parameters. The major advantage with the Fuzzy Logic approach is that the final result of this method gives a single unique value for each site that can precisely confirm the extent of ground water pollution. This unique distinct value is called as the net fuzzy value.

The net fuzzy value for any site can be calculated using the weightage and the fuzzy values for each chemical parameter. This calculation is done by using the formula.

\[ F_i = \frac{\sum_{i=1}^{n} W_i C_i}{\sum_{i=1}^{n} W_i} \quad (1) \]

where \( W_i \) = Weightage factor and \( C_i \) = Fuzzy Value

\( W_i = \frac{K}{s_i} \) where \( K = \frac{1}{(1/s_1)+(1/s_2)+...+(1/s_n)} \)
s₁, s₂, s₃, ..., sᵢ are standard values of various parameters from 1, 2, 3, ..., i.

Chemical Analysis of water gives a concept about its physical and chemical composition by some numerical values but for estimating exact quality of water, it is better to depend on rating the water quality which gives the idea of quality of drinking water. Similar to groundwater quality index rating, the water quality rating is given in Table 1. The net fuzzy values are presented in Table 2 and the variation of water quality is shown in Fig. 14.

Table 1 Water Quality rating based on Fuzzy value

<table>
<thead>
<tr>
<th>Net Fuzzy Value Range</th>
<th>Water Quality Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 0.25</td>
<td>Excellent</td>
</tr>
<tr>
<td>0.26 – 0.50</td>
<td>Good</td>
</tr>
<tr>
<td>0.51 – 0.75</td>
<td>Poor</td>
</tr>
<tr>
<td>0.75 – 1.0</td>
<td>Unfit</td>
</tr>
</tbody>
</table>

Table 2 Estimation of Net fuzzy values

<table>
<thead>
<tr>
<th>Bore Well No.</th>
<th>Net Fuzzy Value</th>
<th>Water Quality Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.753</td>
<td>Unfit</td>
</tr>
<tr>
<td>2</td>
<td>0.783</td>
<td>Unfit</td>
</tr>
<tr>
<td>3</td>
<td>0.762</td>
<td>Unfit</td>
</tr>
<tr>
<td>4</td>
<td>0.659</td>
<td>Very Poor</td>
</tr>
<tr>
<td>5</td>
<td>0.753</td>
<td>Unfit</td>
</tr>
<tr>
<td>6</td>
<td>0.875</td>
<td>Unfit</td>
</tr>
<tr>
<td>7</td>
<td>0.891</td>
<td>Unfit</td>
</tr>
<tr>
<td>8</td>
<td>0.899</td>
<td>Unfit</td>
</tr>
<tr>
<td>9</td>
<td>0.774</td>
<td>Unfit</td>
</tr>
<tr>
<td>10</td>
<td>0.750</td>
<td>Unfit</td>
</tr>
<tr>
<td>11</td>
<td>0.774</td>
<td>Unfit</td>
</tr>
<tr>
<td>12</td>
<td>0.788</td>
<td>Unfit</td>
</tr>
<tr>
<td>13</td>
<td>0.894</td>
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</tr>
<tr>
<td>14</td>
<td>0.831</td>
<td>Unfit</td>
</tr>
<tr>
<td>15</td>
<td>0.888</td>
<td>Unfit</td>
</tr>
<tr>
<td>16</td>
<td>0.811</td>
<td>Unfit</td>
</tr>
<tr>
<td>17</td>
<td>0.878</td>
<td>Unfit</td>
</tr>
<tr>
<td>18</td>
<td>0.767</td>
<td>Unfit</td>
</tr>
<tr>
<td>19</td>
<td>0.812</td>
<td>Unfit</td>
</tr>
<tr>
<td>20</td>
<td>0.900</td>
<td>Unfit</td>
</tr>
</tbody>
</table>

V. RESULTS & DISCUSSIONS
1. The values of almost all the parameters are above the permissible limits. The wide variation is due to dissolved materials from leachate.
2. pH values are found to vary from 7.45 – 9.42. Though pH has no direct effect on human health, all bio-chemical reactions are sensitive to the variation of pH. The limit of pH value for drinking water is specified as 6.5 – 8.5.
3. Conductivity is very important parameter for determining the water quality for drinking and agriculture purpose. The values in the study area are from 0.53 – 4.95 millisimons/cm.
4. Total alkalinity of water is mainly due to presence of bicarbonate contents in water. This is also associated with calcium and magnesium contents in water. The alkalinity of samples is very high and varies between 240 to 500 ppm. The maximum permissible limit is 250 ppm.

5. Total hardness of water is characterized by contents of calcium or magnesium salts or both. The concentration of calcium and magnesium in potable water ranges from 75 - 200 ppm and 30 - 100 ppm respectively. The calcium and magnesium sulphates exert a cathartic action on human beings. It is also associated with respiratory diseases. In the study area calcium and magnesium contents of water vary from 50 to 220 ppm and 255 to 875 ppm respectively. The magnesium content being higher than calcium in the samples indicate the occurrence of magnesium salts in this study area.

6. DO and BOD is very important pollution parameters. The values of DO and BOD indicate degree of contamination. Generally low DO values indicate high pollution nature and high BOD values indicates presence of organic materials in water sources. The observed values of DO and BOD varies from 6.4 to 7.6, 3 to 19 ppm respectively. Water samples with DO values less than 5 ppm and BOD value greater than 5 ppm respectively are polluted.

7. Chlorides are considered to be pollution indicating parameters. They impart salty taste to water. The limiting value for chlorides is 250 ppm at which the water will not taste salty. The range of chlorides in the study area 105 to 779 ppm.

8. Net Fuzzy values were found to be above 0.5, thus indicating degree of pollution is above 50% in the entire area.

9. Thus, the results indicate that ground water is polluted near the landfill site and is unfit for drinking.

10. High values of sulphates and TDS in drinking water are generally not harmful to human beings, but high concentration of these may affect persons suffering from kidney and heart problems.

11. The sanitary landfill site is to be used to dispose the municipal solid waste.

VI. CONCLUSIONS

1. The ground water quality near the Municipal solid waste dumping site is of poor quality.

2. The sanitary landfills are to be built with liners to prevent leachate from seeping through soil into aquifers. Leachate collection systems store the liquid away from the water table. Clay caps prevent rainwater runoff from carrying pollutants from the landfill into the groundwater.

3. The municipal solid waste must be managed by adopting composting, incineration and power generation techniques.

References


