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Evaluation of Ground Water Quality by Fuzzy

Subramanyam Busetty, Srihari Vedartham

Abstract: Due to rapid urbanization and inadequate solid waste disposal leads contamination of ground water and surface sources in and around the dump site. In the present study groundwater quality survey was carried out at a major solid waste disposal site at the temple city of Thanjavur (Tamil Nadu, India), where groundwater samples were collected and analyzed for six chemical parameters such as pH, Total Dissolved Solids (TDS), Alkalinity, Hardness, Chloride and Turbidity to assess the effect of solid-waste disposal on the groundwater quality. The quality parameters of the samples were compared with IS code to know the suitability of water for drinking purpose. The study indicates that water quality parameters exceed the permissible limits for drinking at many locations leading the water unsuitable for drinking.

Index terms: quality Index, contamination, solid waste, percolation

I. INTRODUCTION

Since the last three decades, with galloping urbanization and subsequent growing concern for environmental protection, the management and disposal of solid waste have been one of the priority areas of research and implementation by the scientists and technocrats, respectively. Besides, the substantial change in the composition of municipal solid waste in recent years due to change in lifestyle, attitude and social structure.

In contrast to industrial solid waste (which, by virtue of its magnitude, non-degradability and toxicity, attracts most of the investigators), the research on municipal solid waste (MSW) seems relatively sparse. In fact, the fate of majority of solid waste produced in India ends up in (unsanitary) open dumping in low-lying areas (Kumar and Alappat 2005). Such disposal of solid waste by open dumping leads to environmental degradation, in the form of contamination of ground water and land with the resultant generation of leachate, a mineralized liquid waste (both organic and inorganic). There have been several reports of (and subsequent investigations on) contamination of leachates to the surrounding soil as well as surface and subsurface water (Saprykina, 1977, Zaher et al 2018). Although, normally, various pollution indices and discharge standards have been in use to evaluate pollution potentials, yet in recent time there has been much interest in use of soft-computing tools to account for the parametric uncertainties and wide spatio-temporal variability. (Mrutyunjaya Sahu et al 2011).

In the present research paper attempts are made to evaluate the pollution potentials of the study area based on Fuzzy-based analysis, for estimating its suitability for portability. In this Work a systematic physico-chemical characterization of the groundwater samples (collected from the vicinity of the presently available municipal solid waste disposal sites) was conducted.

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Subramanyam B, School of Civil Engineering, SASTRA Deemed University, Thanjavur, India.

Srihari V, National Institute of Construction Management and Research (NICMAR), Jaganguda; Shamirpet (M), Hyderabad, India..

II. METHODOLOGY

Twenty five samples were collected from the existing wells in and around the disposal sites. The various chemical parameters analyzed are pH, alkalinity, chlorides, TDS, turbidity, total hardness by standard methods. The average values of groundwater samples analysis were presented in Table-1

Table 1 Average Analysis of Ground Water Quality in the Study Area

PARAMETERS						
Sl No	**pH**	**TDS**	**Alkalinity**	**Total Hardness**	**Chlorides**	**Turbidity**
1	5.70	524.00	210.21	250.00	92.30	16.00
2	5.80	620.00	325.30	365.00	152.65	1.30
3	5.80	680.00	350.25	490.00	149.10	1.00
4	6.50	502.00	190.19	NA	110.05	1.20
5	6.50	514.00	290.29	245.00	142.00	4.50
6	6.40	2320.00	225.30	225.00	113.60	0.64
7	6.50	500.00	986.00	705.00	713.60	1.90
8	6.70	1220.00	490.50	255.00	287.60	2.00
9	6.60	575.00	250.25	160.00	131.40	24.00
10	6.30	800.00	315.30	370.00	198.80	1.30
11	6.90	523.00	270.30	280.00	159.75	0.13
12	6.40	1200.00	505.50	385.00	401.20	0.88
13	6.90	539.00	225.20	265.00	124.30	2.90
14	6.50	4060.00	510.20	1520.00	1384.50	0.48
15	6.90	1530.00	650.65	715.00	142.00	2.20
16	6.50	1220.00	575.60	590.00	319.50	4.40
17	6.80	930.00	520.50	515.00	220.00	0.70
18	6.50	600.00	210.20	215.00	85.00	14.00
19	7.10	1110.00	575.50	495.00	266.30	1.30
20	6.50	1250.00	710.70	515.00	269.80	2.90
21	6.90	640.00	285.80	320.00	163.30	1.60
22	6.50	600.00	240.00	340.00	177.50	4.90
23	6.70	900.00	435.00	565.00	512.40	2.30
24	6.90	2040.00	490.50	490.00	610.40	5.40
25	6.90	700.00	280.30	360.00	191.70	8.70

*All values are expressed in ppm except pH.

The analysis of groundwater quality has been carried out by fuzzy logic

Fuzzy logic approach is a mathematical method used to characterize and propagate uncertainty and in accuracy in data and functional relationships. Fuzzy sets are useful when insufficient data exists to characterize

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uncertainty using standard statistical measures. 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.

According to fuzzy theory, when A is a fuzzy set and X is relevant abject, the proposition 'X is a member of A' is not necessarily true or false.

III. FUZZY LOGIC THEORY

Generally any fuzzy set characterized by a unique and a distinct function called as the membership function. It is most common but not required to express the degree of membership in fuzzy sets by numbers with in a closed interval [0, 1]. The extreme values 0 and 1, respectively, represent the total denial and total affirmation of the membership of an object in a given fuzzy set. A fuzzy set is denoted in practice as(KODA et al, 2015):

$$A : X \rightarrow [0,1]$$

Where

A Fuzzy set

X Universal set

$X \rightarrow [0,1]$ Membership Function

The canonical form of a fuzzy proposition of this type, P, is expressed by the sentence

P:a if F , where a is a variable that takes values v from universal set'V', and F is a fuzzy set on 'v' that represented as the degree of truth, T(p), of proposition P.

T (p)=F (v) for each given particular value v of variable in proposition P there exists a truth-value T (p).

IV. MEMBERSHIP FUNCTION FOR WATER QUALITY PARAMETER

Before analyzing the GWQ in the present study area, it is essential to estimate the membership function of the various chemical parameters. To get the total fuzzy value for the groundwater in each site, it is necessary to estimate the fuzzy value for each chemical parameter to draw the membership functions for each variable. Groundwater quality can be studied by analyzing the concentration of p^H, Total Dissolved solids (TDS), total alkalinity, total hardness, chlorides and turbidity. The proportion to the study the groundwater quality using the fuzzy logic in our present paper.

A. The membership functions for the parameters described **p^H**

As per IS standards the permissible limit for pH is 6.5 – 8.5 and the excessive limit is 6.5 – 9.2 from a drinking water perspective, one can say that groundwater is polluted if the pH for that sample is more than 8.5. Assuming a leaner variation for the membership function of these parameters a graph can be plotted as shown in Fig.1.

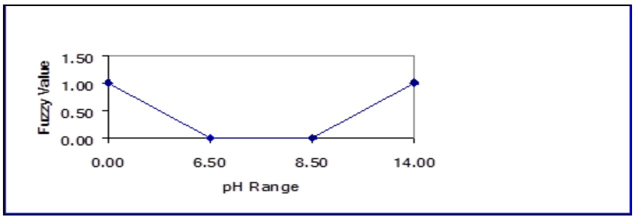

Figure 01 Membership function for pH

B. **Total dissolved solids (TDS)**

As per IS standards the permissible limit for total dissolved solids is 500 mg/l and excessive limit 1000 mg/l from a drinking water perspective. One can say that groundwater is polluted if the total dissolved solid for that sample is more than 500 mg/l assuming a leaner variation for the membership function of this parameters a graph can be plotted as shown in Fig.2.

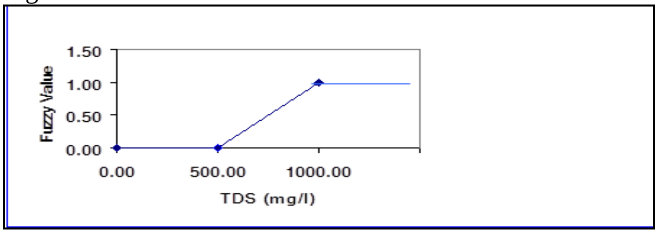

Figure 02 Membership function for TDS

C. **Total alkalinity**

As per WHO standards the permissible limit and excessive limit for total alkalinity is 250 mg/l from a drinking water perspective. One can say that groundwater is polluted if the total alkalinity for that sample is more than 250 mg/l assuming a leaner variation for the membership function of this parameter a graph can be plotted as shown in Fig.3.

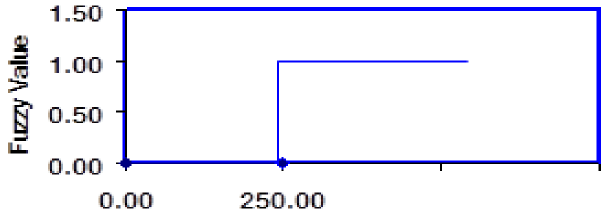

Figure 03 Membership function for Alkalinity

D. **Total Hardness**

As per IS standards the permissible limit for total hardness is 300 mg/l and excessive limit is 600 mg/l from a drinking water perspective. One can say that groundwater is polluted if the total hardness for that sample is more than 600 mg/l assuming a leaner variation for the membership function of these parameters a graph can be plotted as shown in Fig.4.

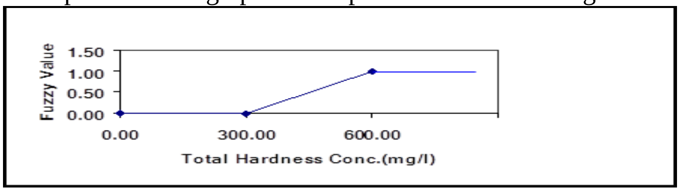

Figure 04 Membership function for Total Hardness

E. **Chlorides**

As per IS standards the permissible limit for Chlorides is 250 mg/l and excessive limit is 1000 mg/l from a drinking water perspective. One can say that groundwater is polluted if the Chlorides for that sample is more than 1000 mg/l assuming a leaner variation for the membership function of this parameters a graph can be plotted as shown in Fig.5.

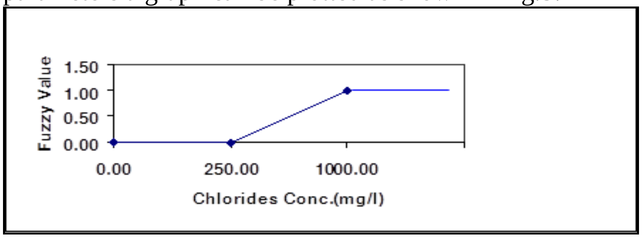

Figure 05 Membership function for Chlorides

F. **Turbidity**

As per IS standards the permissible limit for

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Turbidity is 10 mg/l and excessive limit is 25 mg/l from a drinking water perspective. One can say that groundwater is polluted if the Turbidity for that sample is more than 25 mg/l assuming a leaner variation for the membership function. Table 2 shows the water quality rating.

Table 2 Fuzzy Values for Different Parameters (Ci)

Well No	pH Fuzzy Values	TDS Fuzzy Values	Total Alkalinity Fuzzy Values	Total Hardness Fuzzy Values	Chlorides Fuzzy Value	Turbidity Fuzzy Values	Fuzzy Value of a Sample
1	0.123	0.048	0.841	0.000	0.000	0.400	0.2530
2	0.108	0.240	1.000	0.217	0.000	0.000	0.0952
3	0.108	0.360	1.000	0.633	0.000	0.000	0.1017
4	0.000	0.004	0.761	1.000	0.000	0.000	0.0386
5	0.000	0.028	1.000	0.000	0.000	0.000	0.0334
6	0.015	1.000	0.901	0.000	0.000	0.000	0.0461
7	0.000	0.000	1.000	1.000	0.618	0.000	0.0563
8	0.000	1.000	1.000	0.000	0.050	0.000	0.042
9	0.000	0.150	1.000	0.000	0.000	0.933	0.4062
10	0.031	0.600	1.000	0.233	0.000	0.000	0.0574
11	0.000	0.046	1.000	0.000	0.000	0.000	0.0336
12	0.015	1.000	1.000	0.283	0.202	0.000	0.0563
13	0.000	0.078	0.901	0.000	0.000	0.000	0.0305
14	0.000	1.000	1.000	1.000	1.000	0.000	0.0704
15	0.000	1.000	1.000	1.000	0.000	0.000	0.0544
16	0.000	1.000	1.000	0.967	0.093	0.000	0.0555
17	0.000	0.860	1.000	0.717	0.000	0.000	0.0496
18	0.000	0.200	0.841	0.000	0.000	0.267	0.1358
19	0.000	1.000	1.000	0.650	0.022	0.000	0.0501
20	0.000	1.000	1.000	0.717	0.026	0.000	0.0511
21	0.000	0.280	1.000	0.067	0.000	0.000	0.0363
22	0.000	0.200	0.960	0.133	0.000	0.000	0.0352
23	0.000	0.800	1.000	0.883	0.350	0.000	0.0569
24	0.000	1.000	1.000	0.633	0.481	0.000	0.0572
25	0.000	0.400	1.000	0.200	0.000	0.000	0.039

V. RESULTS & DISCUSSION

The use of water for drinking and personal hygiene has been treated as the primary consideration in the present study. The reason for this is that nearly 80% of populations in are not getting potable water. The major water source is groundwater. The importance of safe water supply and sanitation is to prevent diseases. The Fuzzy theory showed most of the study area as having high groundwater quality. In order to assess the correctness of this method, six different points were indiscriminately selected. It is concluded that the Fuzzy method allows for obtaining results that correspond to the current conditions in the study area. As the age of the disposal site increases the leaching of pollutants over certain time also increases in to the ground water (KULIKOWSKA and KLIMIUK, 2008).

The results reveal that the groundwater in the study area is slowly degrading. This fact is reinforced by the fuzzy index. If observe the individual fuzzy membership of Total Solids, 50% of the results are varying 0.6 to 1.00,that itself indicates the water quality rating varies from poor to unfit. As well as the fuzzy membership for Total Alkalinity, 100% of the results are varying 0.76 to 1.00, indicates the water quality rating is unfit for drinking purpose. The fuzzy membership for Total Hardness, 50% of the results are varying 0.63 to 1.00, indicates the water quality rating is varying from poor to unfit for drinking purpose.

VI. CONCLUSIONS

This study included the development of a new index called the Fuzzy water quality index. It offers a simple depiction of the widespread and intricate variables that rule the overall quality of ground water that is intended for drinking purpose. Based on expert opinions and national experiences, six water quality parameters including Chlorides, turbidity, pH, TDS, Total hardness, and Total Alkalinity were considered as the significant indicator parameters of FWQI to assess the quality of ground water sources. The application of the new index was established at a sampling station in and around solid waste dumping site in Thanjavur, Tamil Nadu, and India. The Fuzzy index is supposed to assist decision makers in reporting the condition of ground water quality.

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