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Groundwater Quality Modelling Affected by Municipal Solid Waste Dumping Yards Using Fuzzy Rule Based System

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ABSTRACT: The importance of groundwater for the existence of human society cannot be overemphasized. The water is essential for life on the earth and any other planet. It is the fundamental right to get pollution free water to the every individual but because of development we are going to pollute our water sources. Landfills are sources of groundwater and soil pollution due to the production of leachate and its migration through refuse. In the developing countries the MSW are mainly disposed to the open landfills. Since it is the simplest, cheapest and most cost-effective method of waste disposal, this practice is also adopted in the developed countries to some extent. This is due to an unscientific way of the dumping the solid wastes in an open area leading to the leachates which emerge out and percolate down to the aquifer. Municipal Solid Waste (MSW) dumping yard in Allahabad city cover large area at many sites. There is no proper sanitary landfill site available and the waste is dumped in a mixed form in an unscientific manner on open waste land or low lying areas even near the river Ganga and Yamuna at six different sites. This not only causing ground water contamination but also surface water. In this regard groundwater sample was collected from Bakshi Bandh from handpump. After examine these samples in lab four Model for groundwater were developed using fuzzy tools on matlab. After comparing the measured and predicted value and on the basis of model evaluation criteria, it is found that these models are significantly correct and will be useful for future works.

Introduction

The importance of groundwater for the existence of human society cannot be overemphasized. Groundwater is the major source of drinking water in both urban and rural India. Besides, it is an important source of water for the agricultural and the industrial sector. Being an important and integral part of the hydrological cycle, its availability depends on the rainfall and recharge conditions. Till recently it had been considered a dependable source of uncontaminated water. Pollution of groundwater resources has become a major problem today. The pollution of air, water, and land has an effect on the pollution and contamination of groundwater. The solid, liquid, and the gaseous waste that is generated, if not treated properly, results in pollution of the environment; this affects groundwater too due to the hydraulic connectivity in the hydrological cycle. For example, when the air is polluted, rainfall will settle many pollutants on the ground, which can then seep into and contaminate the groundwater resources. Water extraction without proper recharge and leaching of pollutants from pesticides and fertilizers into the aquifers has polluted groundwater supplies. In addition, leachates from agriculture, industrial waste, and the municipal solid waste have also polluted surface- and ground-water. So many people in the world over are affected by water pollution marked by excess fluoride, arsenic, iron, or the ingress of salt water.

Pollution occurs when a product added to our natural environment adversely affects nature's ability to dispose it off. A pollutant is something which adversely interferes with health, comfort, property or environment of the people. There are many types of pollution such as air pollution, soil pollution, water pollution, nuclear pollution and oil pollution (Sabahi *et al*., 2009). Large quantities of wastes from urban, municipal and industrial sectors are generated worldwide. Landfills have served for many decades as ultimate disposal sites for all types of these wastes (Abu Rukah and Al-Kofahi, 2001). Landfill is an engineered waste disposal site facility with specific pollution control technologies designed to minimize potential impacts. Landfills are usually either placed above ground or contained within quarries, pits. Landfills are sources of groundwater and soil pollution due to the production of leachate and its migration through refuse (Misra and Mani, 1991). Physical, chemical and biological processes interact simultaneously to bring about the overall decomposition of the wastes. One of the byproducts of all these mechanisms is chemically laden leachates. The major environmental problem at landfills is the loss of leachates from the site and the subsequent contamination of groundwater (Jagloo, 2002).

Modern landfills have liners at the base, which act as barriers to leachate migration. However, it is widely acknowledged that such liners deteriorate over time and ultimately fail to prevent the movement of leachate into an aquifer (Jagloo, 2002). In the developing countries the municipal solid wastes (MSW) are mainly disposed to the open landfills. Since it is the simplest, cheapest and most cost-effective method of waste disposal, this practice is also adopted in the developed countries to some extent.

The increasing production of municipal solid waste world over is an important source of groundwater contamination for the unforeseeable future. The industrialization and urbanization of Allahabad city has resulted in an exponential increase of the wastewater and solid wastes; and the groundwater contamination surrounding Municipal Solid Waste Disposal sites is threatening the health of the people. This is due to an unscientific way of the dumping the solid wastes in an open area leading to the leachates which emerge out and percolate down to the aquifer. Characterization of the leachates is necessary in the assessment of ground water pollution near such disposal sites.

In Allahabad there is no segregation of waste take place, also systematic and scientific system of primary collection of waste does not exist. In the absence of proper segregation practices at source, rag pickers pick up parts of this waste in soiled and hazardous conditions. There is no proper landfill site available and waste is dumped in a mixed form in an unscientific manner on open waste land or low lying areas even near the river Ganga and Yamuna at six different sites. Illegal dumping of the MSW is also very common in the city. This results not only causing ground water contamination but also air pollution from the improper dumping of the solid waste. As per data available, every year Nagar Nigam Allahabad spends on an average 18% of its total budget on solid waste management. (Alok et al, 2010).

Study Area

Allahabad is a major city of east Uttar Pradesh State, situated at 25.25_ North latitude and 81.58_ East longitude. It is about 627 km from Delhi and about 815 km from Calcutta (Sharholy and Ahmad 2007). Allahabad is an ancient city of India, considered holy because it is built on the confluence (Sangam) of the rivers Ganga, Yamuna and Saraswati (T.D. 1989). The city has a population of about 5,954,391(according to census 2011). Allahabad Municipal Corporation (AMC) is responsible for the management of the MSW generated in the city.

Methodology

Fuzzy expert system based on fuzzy set theory was introduced by Zadeh in 1965, which is used for the modelling. The Fuzzy systems work on the concept of vagueness through a set of rules called the rule base. It has been developed to handle the concept of partial truth, the value between completely truth and completely false. Steps involved in the fuzzy rule based system are define the linguistic variables and terms, Construct the membership functions, Construct the rule base, Convert crisp input data to fuzzy values using the membership functions (fuzzification), Evaluate the rules in the rule base (inference), Combine the results of each rule (aggregation), Convert the output data to non-fuzzy values (defuzzification).

The suitability of models was visualized by model evaluation criteria, given below:-

Correlation Coefficient (R)

The correlation coefficient measures the statistical correlation between the predicted and actual values. It is computed as:

$$R = \frac{\sum_{i=1}^{n}(Xai - \bar{X}ai)(Xpi - \bar{X}pi)}{\sqrt{\sum_{i=1}^{n}(Xai - \bar{X}ai)^2 \sum_{i=1}^{n}(Xpi - \bar{X}pi)^2}} \quad (1)$$

where Xai and Xpi are measured and computed values of diffuse pollution concentration values in streams; $\bar{X}ai$ and $\bar{X}pi$ are average values of Xai and Xpi values respectively; i represents index number and n is the total number of concentration observations.

Root Mean Square Error (RMSE)

The root mean squared error (RMSE) is computed as:

$$RMSE = \sqrt{\frac{1}{n}\left(\sum_{i=1}^{n}(Xai - Xpi)^2\right)} \quad (2)$$

Model Efficiency (Nash–Sutcliffe Coefficient)

The model efficiency (ME_{Nash}), an evaluation criterion is employed to evaluate the performance of each of the developed model. It is defined as:

$$\mathrm{ME}_{\mathrm{Nash}} = 1.0 - \frac{\sum_{i=1}^{n}(Xa_i - X_{pi})^2}{\sum_{i=1}^{n}(X_{ai} - \bar{X}ai)^2}, \quad (3)$$

and

Mean Absolute Error (MAE)

$$MAE = \frac{1}{n}\left(\sum_{i=1}^{n}(Xai - Xpi)\right) . \quad (4)$$

Results and Discussion

By using fuzzy set theory, four models were developed for groundwater sample. The membership functions for input and output of all models were fall into three categories:-low, medium and high. In first model (M1) hardness is predicted while taking acidity as input, if-then rules for this model are-

a. If acidity is low then hardness is low.
b. If acidity is medium then hardness is medium. And
c. If acidity is high then hardness is high.

Model evaluation parameters of this model are shown below-

Model Evaluation Parameter	**Value**
Correlation Coefficient	0.91
RMSE	10.31
Model Efficiency	0.69
MAE	-2.38

Table-1 model evaluation criteria, M1.

From table 1, it is clear that model M1 is significantly correct. Comparison between actual experimented value of hardness and model predicted value of hardness is shown in fig.1.

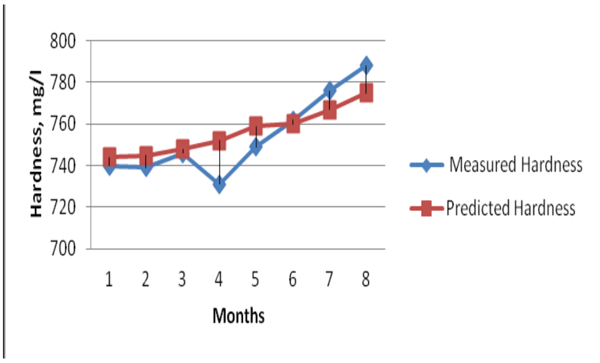

Fig.1 comparison between measured hardness and predicted hardness, M1.

It is clear from fig.1, that there is not much difference between measured and predicted values of hardness. In second model (M2), iron was predicted after taking acidity as input. If-then rules for this model is given below-

a. If acidity is low then iron is low.
b. If acidity is medium then iron is medium. And
c. If acidity is high then iron is high.

Model evaluation parameters of this model are shown below-

Model Evaluation Parameter	Value
Correlation Coefficient	0.97
RMSE	0.11
Model Efficiency	0.74
MAE	0.025

Table-2 model evaluation criteria, M2.

From table 2, it is clear that model M2 is significantly correct. Comparison between actual experimented value of iron and model predicted value of iron is shown in fig.2.

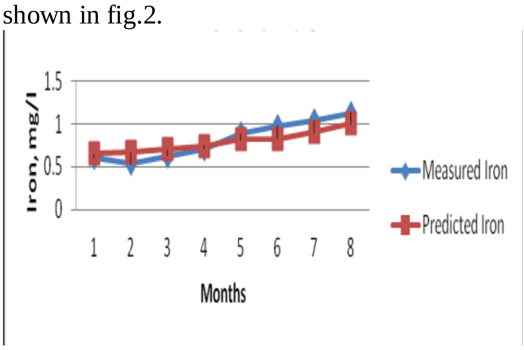

Fig.2 comparison between measured iron and predicted iron, M2.

It is clear from fig.2, that there is not much difference between measured and predicted values of iron. In third model (M3), alkalinity was predicted after taking iron as input. If-then rules for this model is given below-

a. If iron is low then alkalinity is low.
b. If iron is medium then alkalinity is medium. And
c. If iron is high then alkalinity is high.

Model evaluation parameters of this model are shown below-

Model Evaluation Parameter	Value
Correlation Coefficient	0.95
RMSE	20.34
Model Efficiency	0.67
MAE	0.875

Table-3 model evaluation criteria, M3.

From table 3, it is clear that model M3 is significantly correct. Comparison between actual experimented value of alkalinity and model predicted value of alkalinity is shown in fig.3.

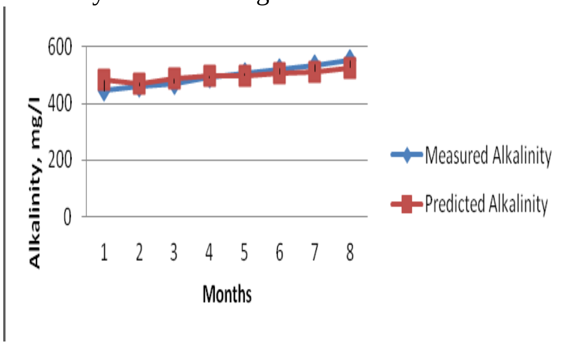

Fig.3 comparison between measured alkalinity and predicted alkalinity, M3.

It is clear from fig.3, that there is not much difference between measured and predicted values of alkalinity. In fourth and last model (M4), chloride was predicted after taking acidity as input. If-then rules for this model is given below-

a. If acidity is low then chloride is low.
b. If acidity is medium then chloride is medium. And
c. If acidity is high then chloride is high.

Model evaluation parameters of this model are shown below-

Model Evaluation Parameter	Value
Correlation Coefficient	0.99
RMSE	11.14
Model Efficiency	0.78
MAE	-2

Table-4 model evaluation criteria, M4.

From table 4, it is clear that model M4 is significantly correct. Comparison between actual experimented value of chloride and model predicted value of chloride is shown in fig.4.

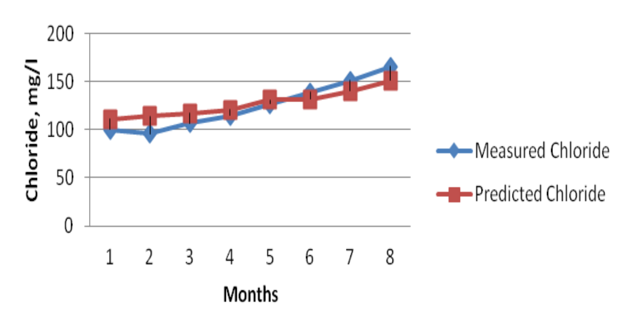

Fig.4 comparison between measured chloride and predicted chloride, M4.

It is clear from fig.4, that there is not much difference between measured and predicted values of chloride.

Conclusions

In this paper, four models have been developed. Comparison of measured data with model predicted data establish potential applicability of fuzzy rule based models. Predication of hardness, iron, and chloride using acidity while prediction of alkalinity using iron respectively are encouraging. However, an extensive evaluation of models using more data sets may improve the results further.

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