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PERFORMANCE EFFICIENCY ANALYSIS OF WATER TREATMENT PLANTS BY USING MCDM AND NEURAL NETWORK MODEL

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Abstract

The organization of safe and sustainable sources of water remains a priority for decision makers around the world. The centrality of water in public health as well as in industry creates a high demand for water supply of suitable quality that many nations around the world are harassed to meet. In India, in particular, water shortages and poor water quality continue to be major challenges in both domestic and industrial sectors. That is why, the evaluation of the performance efficiency of the existing water treatment plant is essential. This paper utilizes the Non-structural Fuzzy Decision Support System (NSFDSS) as well as Artificial Neural Network

(ANN) to identify the parameter that is most significant in helping the decision makers to build an efficient water treatment plant operating system.

Keywords

Water Treatment Plant, MCDM, NSFDSS, ANN

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1. Introduction

The availability of water that meets quality standards and available in sufficient quantities plays a vital role in the flourishing of both urban and rural settlements. Yet, despite its importance to everyday life, vast numbers of people around the globe lack access to this basic need. Insufficient supplies of portable water for their household usage combined with the risks created by disease causing agents and other toxic agents present a great threat to public health. Water pollution caused by coal plants is always on large scale and often irreversible (Haneef, 2016). Indeed, nearly 75% of the three million early deaths found in developing countries are water borne (Ali, 2012). For this reason the maintenance of public health through the treatment of water remains of high importance to policy makers around the world (Hong, 2017). As such the optimization of treatment processes as well as the ability to predict the water quality over time is a key part of decision-making processes in water treatment industries as it allows the provision of a sustainable supply of good quality water to the consumers. The working procedure of a water treatment plants (WTP) is always dynamic. It can also frequently be capital intensive and as such optimization methods are essential in making projects commercially viable, technically efficient as well as able to maintain quality standards. The intention of municipal water delivery systems is to provide drinkable water from water treatment plants to the consumers for various purposes (Dorussen, 1997). The operation of Water treatment plants depend on rule-of-thumb approaches, so it becomes very important to detect the efficiency analysis technique using many performance indicators which have an impact on the quality and efficiency of the process (Kumar, 2010).

In case of waste water treatment plant, two questions are vital: a) how this treatment plant is environmentally sustainable, b) how do technologies develop energy efficiency and environmental sustainability.

The non-structural fuzzy decision support system (NSFDSS) method is applied to smooth the progress of the decision making process for the multi-objective problems (XuJia, 2011). The judgment matrix of this method is same like the construction of human thought. Secondly, the matrix judgment process to test the consistency is relatively simple. Based on the full use of human experiences and knowledge, the system is decomposed and comprehended, and also compares and quantifies large complex qualitative factors such as common importance, superiority. Finally we can get the membership degree of all the factors used in the study. This evaluation method suits for complicated social, economic, science, and engineering and technological fields which are difficult to quantify directly. Also, it can improve expert analysis judgment, reduce the difficulty of comparative judgment, improve the accuracy of solving problems, and draw an objective comprehensive evaluation conclusion more powerful (Tam C.L., 2002).

The objective of this study is to predict the most momentous parameter of WTPs by using decision making method NSFDSS. Then ANN is used to predict the quantities characteristics of the parameters.

2. Methods Adopted

2.1 Multi criteria decision making method (MCDM)

MCDM refers to methods that are specifically adapted to help decision makers to evaluate complex scenarios in order to operate in a well-informed manner that is most likely to optimize their choice sets. Often these scenarios are composed of many factors that must be considered in terms of priority as decision makers are most often subject to capacity constraints and must choose between competing parameters. The key differences between the various methods categorized as MCDM relates to the way in which they use data. Broadly there are two types of MCDM namely; multiple criteria evaluation problems and multiple criteria design problems. Whilst the former regards a finite number of alternative and the latter regards infinite or near-infinite data sets. In this study, one MCDM method, NSFDSS, that is well suited to this line of enquiry is used and then the ANN is used which are outlined briefly in the following sections.

2.2 Non-structural Fuzzy Decision Support System (NSFDSS)

NSFDSS, an MCDM method, is used to determine the comparative weight of the criteria and alternatives in a decision making model (Chen, 1998) by using Fuzzy. Fuzzy set is introduced by Zadeh (Zadeh, 1965) and it is defined as a class with grades of membership (Goguen, 1967, 1969). The working procedure of the NSFDSS is like the procedure of analytic hierarchy process (AHP) developed by Saaty (1980). Both of these methods involve decomposition, comparative judgment and synthesis of priorities (Tam et al., 2002).

The steps of NSFDSS are as follows:

(i) Breakdown the goal or the problem into different levels of independent elements;

(ii) Relative importance of each criterion is compared with others in the same level and ranks the alternatives with respect to aggregated score (Tam *et al*, 2002).

(iii) Derive the weightage of normal semantic score to determine the result. The NSFDSS, introduced by Chen in 1998, is aimed to improve the weaknesses of AHP by providing a qualitative scale on which to approach imprecise or qualitative data. Of note is that NSFDSS has been successfully applied on various fields e.g. site layout planning (Tam et al., 2002a).

2.3Artificial Neural Network (ANN)

Proposed by the psychologist Frank Rosenblatt in 1958, the ANN is also an MCDM process that considers the interrelations between parameters and the evaluation criteria, however it does so with a much larger degree. ANN networks are in essence algorithms that emulate the biological structure of neurons. In nature neurons operate by transmitting an impulse only when a certain threshold has been surpassed. Once an impulse is initiated, it moves between different neurons in order to initiate a reaction within the organism. In a similar way ANN networks consist of a set of input characteristics that are processed by “hidden” functions, which then map them to outputs. They are particularly well adapted to approximating complex decision making situations as “hidden” functions work to identify the most significant factors and to generate the output also. This aspect of the ANN has contributed to its wide applicability in a range of real time applications, including functional approximation, or regression analysis, as well as time series prediction and modeling etc. ANN does not solve the daily-to-day problems. Yet, despite these challenges the ANN still remains a system that is particularly well adapted to identify the most significant criteria from a set that is likely to contribute to the optimal functioning of the system as a whole.

3. Methodology

In this study, NSFDSS is applied to a hypothetical problem regarding the choice of a waste water treatment technology. When applying this method in this manner, the consultation of experts are often beneficial, because, the process can enrich the decision with judgments of the experts regarding the problem and can obtain a method to solve it in a better way. For this reason, this study sought the expertise of five experts who have studied the sector of waste water treatment extensively. After discussions with these experts, some criteria and alternatives were identified and finalized.

3.1 Application of MCDM

The application of MCDM involves the selection of criteria, alternatives and method as detailed below. Each of the parameters selected for evaluation of water treatment plant was identified by a group of Experts. Then the relative significance of the parameters is determined by the Literature review, hazard potential, consumer's feedback, and Engineer's feedback. The relative weights of importance are then estimated by the application of MCDM methods.

3.1.1 Selection of criteria

Some criteria are selected on the basis of which the alternatives will be compared and their importance can be determined. In this regard the following factors are considered as Criteria:

a. Literature Review
b. Hazard Potential
c. Consumer's Feedback
d. Engineer's Feedback

3.1.2 Selection of alternative

Some alternatives were identified according to the criteria and after comparing, the weightage can be determined. The selected alternatives are:

1. Amount of intake water
2. Time of treatment
3. Discharge rate

4. Amount of output water
5. Efficiency of Clariflocculator
6. Efficiency of filter bed
7. Efficiency of chlorination unit
8. Channel efficiency

3.2 Development of Index

Now, an index was developed by using the weightage and the magnitude of the parameters. The weighted average of all the parameters are given in the following equation,

$$I = \frac{\sum_{i=1}^{n}(Wn*An)}{\sum_{i=1}^{n}Wn} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, Wn is the weightage of importance of the parameters determined in the previous section?

3.3 Application of Neural Network

The present study aims to develop an automated framework. That's why; algorithms have to be arranged so that it can be easily calculated by putting the values of the parameters. In ANN model, the complicated non-linear input-output relationship can be approximated. In the present study, the ANN models were applied to express the values of selected water quality variables. The inter relationship between the input and output variables were mapped by ANN.

4. Result and Discussion

4.1. MCDM results

The weightage of the selected criteria and alternatives are given in the following tables. Table 1 and 2 shows the weightage of criteria and alternatives respectively.

Table 1: *Weightage of the criteria*

Criteria	Weightage
Literature Review	0.38
Hazard Potential	0.25
Consumers Feedback	0.20
Engineers Feedback	0.16

Table 2: *Weightage of the alternatives*

Alternatives	NSFDSS
Amount of intake water per day	0.101
Time of treatment	0.131
Discharge rate	0.101
Amount of output water	0.101
Efficiency of Clarifloccculator	**0.152**
Efficiency of filter bed	0.131
Efficiency of chlorination unit	0.131
Channel efficiency	0.151

4.2. ANN result

The ANN model uses an algorithm to find the optimal topology for the model and accordingly trained the model for determination of the weights. After the weights are determined, the model output was predicted and found to be in good coherency with the actual output.

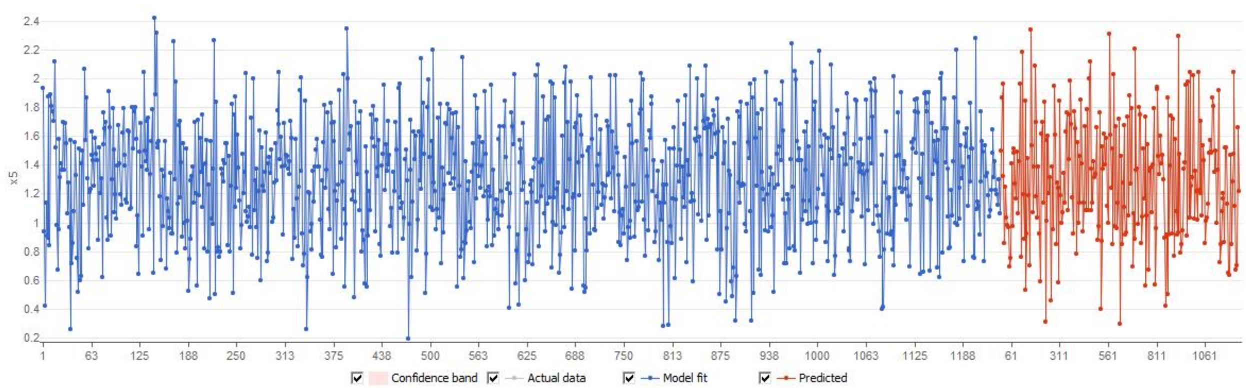

Figure 1: *The link between actual and predicted data*

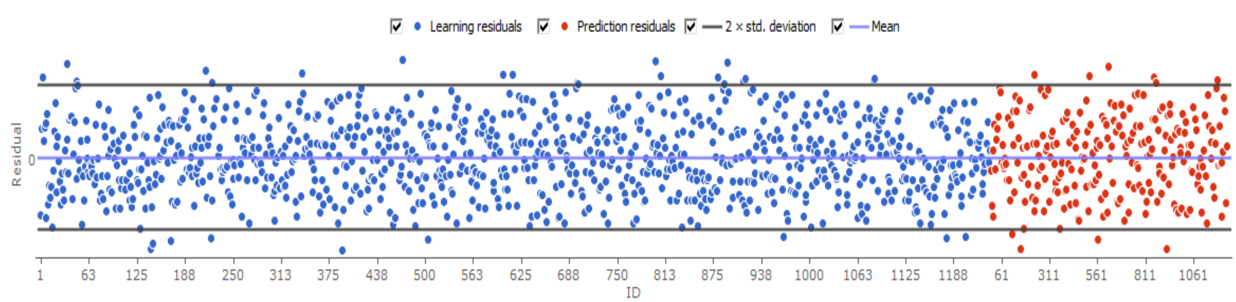

Figure 2: *The remaining error of neural network model*

The model equation is:

Y1 = 5.6033e-14 + x1*0.742775 + x2*0.272646 + x3*0.793524 + x4*0.824404….. (2)

5. Conclusion

The results obtained from the application of the NSFDSS shows that the Efficiency of Clarifl occculator is the most sustainable parameter for the water treatment plant. This study has shown that this method can be applied in a manner that allows it to adapt to situations where interdependency of factors influencing output are prevalent. Indeed this can be particularly effective at considering resource allocations in public service provision, such as water treatment plants where competing options for allocation may share similar significance with respect to particular criteria. For instance if the cost of implementing training for staff was similar to the cost of implanting specialized pumps that could increase technical efficiency then the relative significance of cost as a criteria for judgment can be reduced using the ANN method. That is, supplementary criteria that can better differentiate between two competing factors can be applied to help decision makers choose between alternative courses of action that may display similar characteristics. In this present work, the MCDM method NSFDSS is to deal with complex decision-making problems involving various criteria and alternatives and also comparing them.

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