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A fuzzy Inference System for Pond Water Quality using MATLAB

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Abstract

Water quality is an important issue of relevance in the context of present times. The proposed model is designed to predict Water Quality Index (WQI) for pond (tank) in Kabaleeshwarar temple, Chennai. A Fuzzy Inference System (FIS) simplifies and speed up the computation of WQI as compared to the currently existing standards. In this paper, the proposed model is compared with Indian Water Quality Index (IWQI) and it is found that the designed model results in accurate prediction.

Key words: Water Quality Index, Fuzzy logic, Fuzzy Inference System, MATLAB.

1. Introduction

Now the water has been polluted and it is not useful for drinking (or) agricultural purposes. Due to pollution, the people are suffering from a number of diseases. Water quality generally refers to the composition of a water sample. Water quality modeling[12] involves the predication of water pollution using mathematical simulation techniques. All the water quality models treat Water Quality Index (WQI) as a function of pH, Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), Electric Conductivity (EC) and Temperature etc, present in the sample.

In this paper, an attempt has been made to develop in the sample Fuzzy Inference System (FIS) model for predication of Tamil Nadu Water Quality. Since fuzzy system is good predication tool for imprecise and uncertainty information.

Kabaleeshwarar Temple[7,8] is temple of Shiva located in Mylapore, which is in the Indian state of Tamil Nadu. The form of Shiva's wife Parvati worshipped at this temple is called Karpagambal (from Tamil, 'goddess of the wish-yielding tree'). The Pallava Nayanmars built this temple around the 7th century CE. The architecture of the temple, however, appears to be 300-400 years old. The AdiKesava Perumal Temple constructed in honor of Keshava or Lord Vishnu a principal God in the

Hindu pantheon and the "Savior" in the Hindu Trinity. The temple management was saying the temple and the temple tank was constructed 2000 years ago.

Two temple tanks are considered for present study. Chitrakulam tank (90×60×7 m) is located approximately two km northeast of Royapettah in Chennai, Tamil Nadu. Geographically it lies near 13^{o} 1' 52" N latitude and 80^{o} 16'14" E longitude. Kabaleshwarar (183×135×12 m) temple tank, its located approximately 7 km southeast of Mylapore in Chennai, Tamil Nadu. Geographically it lies near13^{o} 27'71" N latitude and 80^{o} 16'5" E longitude both the above tanks are multipurpose tank used for different activities like domestic purposes, gardening etc during summer season as shown in Fig. 1 and satellite images of two tanks are shown in Fig. 2 and Fig. 3.

(a)

(b)

Fig. 1 (a) Chitrakulam Tank (b) kabaleshwarar Tank

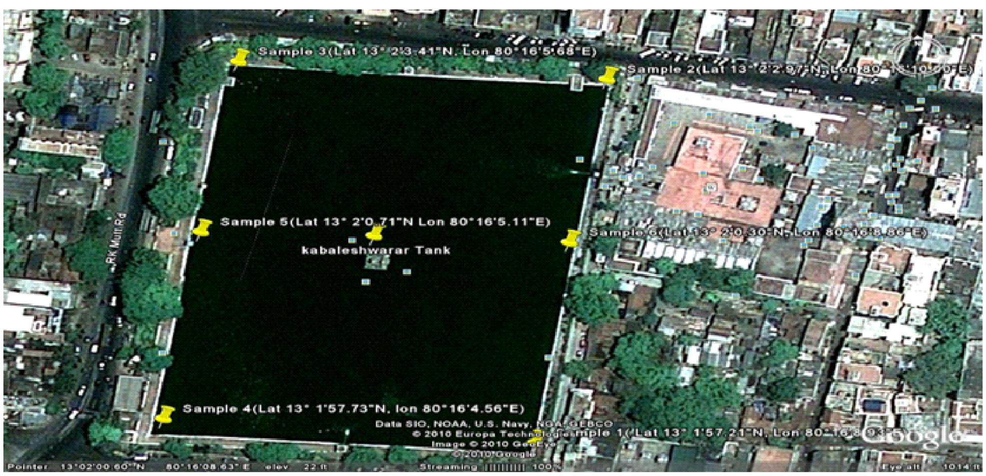

Fig. 2 Satellite image of kabaleeshwarar tank

Fig. 3 Satellite image of chitrakulam tank

In this project we selected these two temple tanks because of its historical importance and its increased pollution rates.

2. *Fuzzy logic :*

The fuzzy logic set was introduced in 1965 as mathematical way to represent linguistic vagueness (Zadeh,1965). According to the fuzzy logic concept, factors and criteria can be classified without certain limits. Fuzzy logic is very useful for addressing real-world problems, which usually involve a degree of uncertainty. Fuzzy logic uses variables like "low", "Medium", "High" in place, of "True/False" or "yes/no" variables. Fuzzy sets are determined by membership functions. The membership function of a fuzzy set is expressed as pH and membership degree of its fuzzy set is determined as a number between 0 and 1.

The structure of a fuzzy rule based system is the fuzzy algorithm the fundamental concepts of which are derived is the fuzzy algorithm the fundamental concepts of which are derived from fuzzy logic[1,2]. The rules represent the relationship between the inputs and the output of the system. The generalized structure of a fuzzy system is presented in fig. 1. Two commonly used inference system are, *i.e.* Mamdani fuzzy model and TSK fuzzy model. They use different types of fuzzy reasoning and formulation of fuzzy IF-THEN rules. Mamdani fuzzy model[3] is based on the collections of IF-THEN rules with both fuzzy antecedent and consequent parameters. Takagi and sugeno proposed sugeno fuzzy model[4]; where as sugeno and kang[5] built up a methodical approach to generating fuzzy rules from a given input-output data. These model are built with if-then rules that have fuzzy antecedent and functional consequent.

Fuzzy system is comprised of four block viz: Fuzzification, Fuzzy rule base, Fuzzy Decision, Defuzzification.

- Fuzzification : is the operation of transforming a crisp set to a fuzzy set. The operation translates crisp input or measured values into linguistic concepts by using suitable membership functions.

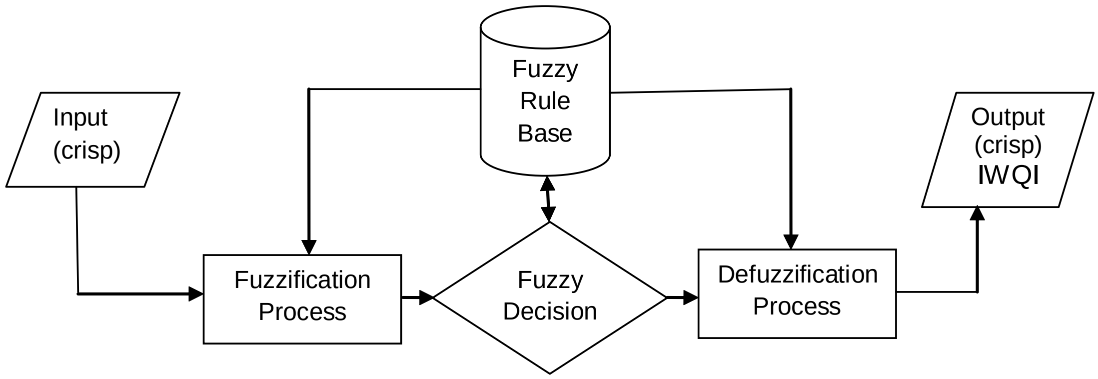

Fig. 4. A Fuzzy Inference System for Water Quality Index

- Fuzzy Decision and Rule base : Once the inputs are fuzzified, the corresponding inputs fuzzy sets are passed to the Fuzzy decision that processes current inputs using the rules retrieved from the rule base.
- Defuzzification : At the output of the fuzzy inference there will always be a fuzzy set that is obtained by the composition of the fuzzy sets output by each of the rules. In order to be used in the real world, the fuzzy output needs to be interfaced to the crisp domain by the defuzzifier by using suitable membership functions.

3. *Introduction to water quality index(WQI):*

Water quality index is ranging from 1 to 100; a higher number indicative of better water quality.WQI rating scale is as follows: 91-100:excellent water quality,71-90:good water quality,51-70:mediul water quality,26-50:fair water quality,0-25: poor water quality[11]. The parameters used in defining WQI are pH, Biological Oxygen Demand(BOD),Dissolved Oxygen(DO),Turbidity. The criteria given in Table 1 to determine how healthy the water is on a given day.

Table 1. Indian water quality criteria classes(Central Pollution Control Board)(CPCB)[6]

S. No.	Parameters	Requirement for waters of class		
		A-Good	B-Medium	C-Bad
(a)	pH	6.5-9.0	6.5-9.0	7.0-8.5
(b)	DO	2-5	4-8	7-10
(c)	BOD, mg/l	Below 2	Below 3	Below 6
(d)	Turbidity(NTU)	5-10	10-25	-

4. *Fuzzy Inference System :*

In this paper, an attempt has been made to use Fuzzy Inference System (FIS) model to predict (or)estimate the water quality index (WQI) given pH, Biological Oxygen Demand(BOD),Dissolved Oxygen (DO), Turbidity as input parameters. Fig. 5 represents the architecture of the Mamdani fuzzy expert system. As maintained in the inputs, pH, DO, BOD, Turbidity. The output of the system are taken as IWQI. Hence, it is a very helpful to estimate WQI to design a fuzzy inference system. The methodology for the development of the fuzzy Inference System (FIS) based water quality index(WQI) model involves the following steps:

1. Fuzzification of input and output variables.
2. Selection of membership functions for input and output variables.
3. Determination of application rule base.
4. Defuzzification of IWQI.

4.1step 1: Fuzzification of input and output variables

first we select the system variables *i.e.* the fuzzy system modeling is the identification of input and output variables. The most important input variables are pH, DO, BOD, Turbidity. Suppose select of more number of inputs to the system inputs to the system requires more number of rules and hence the complexity increases. The input and output are taken in the form of linguistic format. For example, pH={low, medium, high}, DO={low, medium, mediumhigh, high}, BOD={low, medium, high}, Turbidity={low, medium}. The output variable similarly divided into Indian WQI={A-Good, B-Medium, C-Bad}.

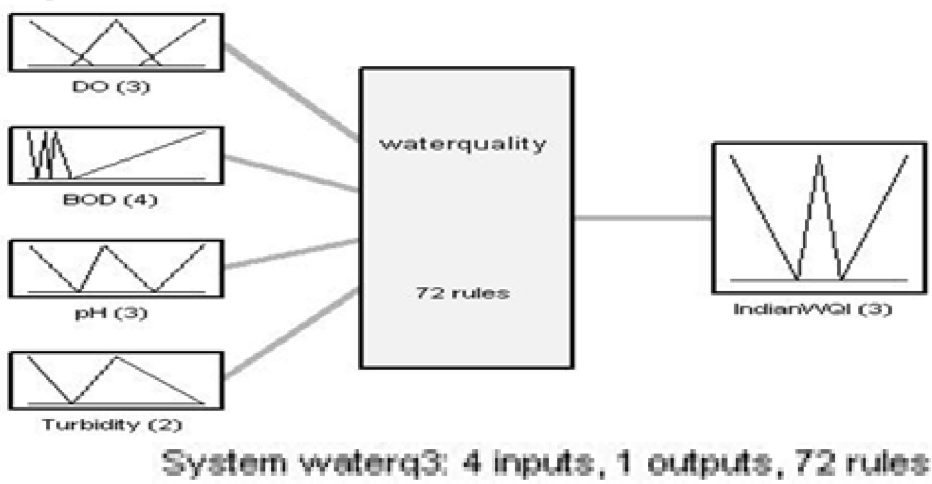

Fig. 5. Determination of Water Quality Index using fuzzy logic

4.2 step 2: Selection of membership functions for input and output variables

Linguistic values are expressed in the form of fuzzy sets. A fuzzy set is usually defined by its membership functions. In general, triangular membership function is used to normalize the crisp inputs because of its simplicity and computational efficiency. It is described mathematically in the manner[10]:

$$\text{triangle}(a;x,y,z)=\begin{cases} 0, & a \le x \\ \frac{a-x}{y-x}, & x \le a \le y \\ \frac{z-a}{z-y}, & y \le a \le z \\ 0, & z \le a \end{cases} \quad (1)$$

$$\text{triangle}(a;x,y,z)=max\left(min\left(\frac{a-x}{y-x},\frac{z-a}{z-y}\right),0\right) \quad (2)$$

where x, y, z are the parameters of the linguistic value and a is the range of the input parameters. This triangular membership function as described in the above expressions (1) and (2) convert the linguistic values to a range of 0 - 1. The membership function of input and output are represented in fig. 6 and fig. 7.

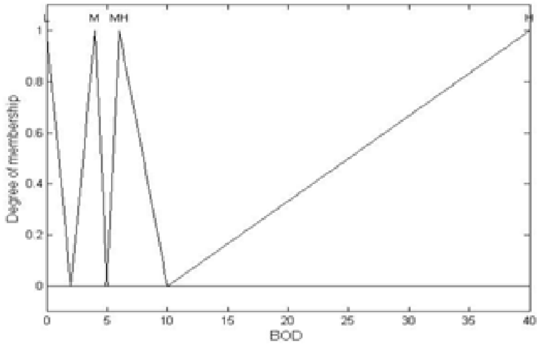

Fig. 6.1 membership function of BOD

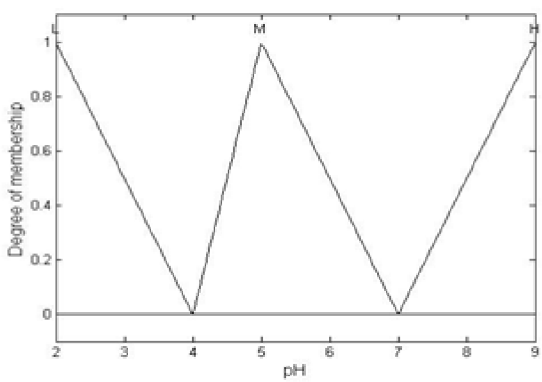

Fig. 6.2 membership function of pH

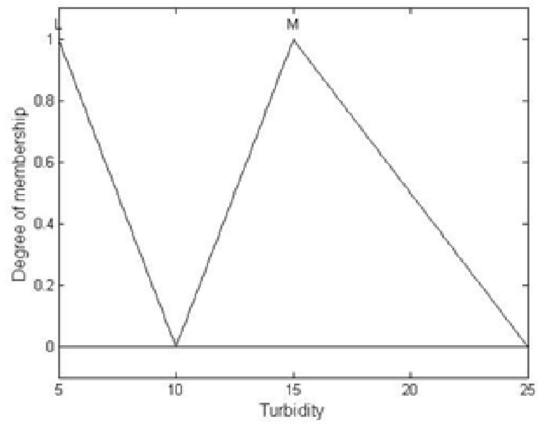

Fig. 6.3. Membership function of Turbidity

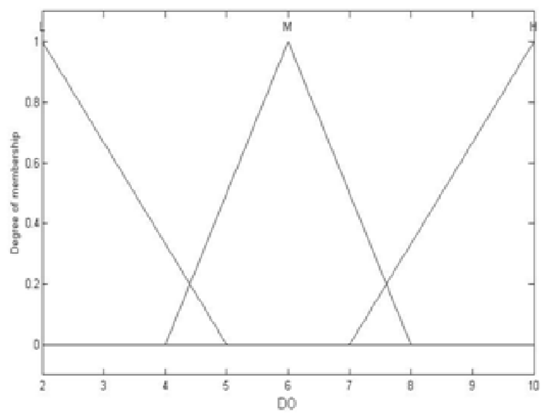

Fig. 6.4 membership function of DO

Fig. 6. Graphical representation of membership function of inputs of FIS

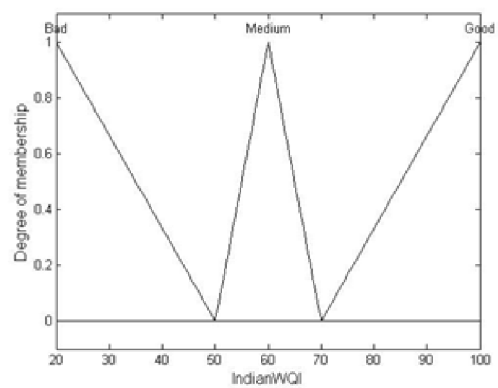

Fig. 7. Membership function of output of FIS

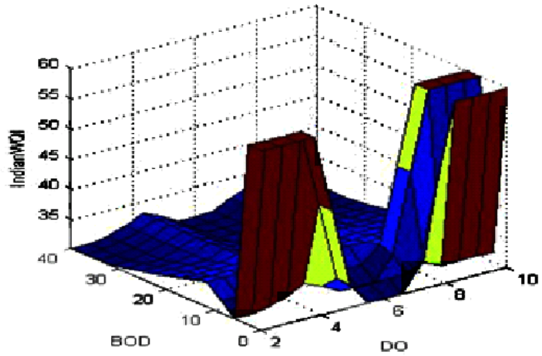

Fig. 8 Surface view of the water quality in FIS

4.3 step 3: Determination of application rule base

The rules determine input and output membership functions that will be used in inference process. These rules are linguistic and also are entitled "IF-THEN" rules. In this system, pH have three MF,DO have three MF,BOD have four MF, Turbidity have two MF. The fuzzy system is designed for predicating Indian WQI (IWQI) and it has four inputs as pH, DO, BOD and Turbidity. So the fuzzy system has 72 rules (3×4×3×2). The proposed fuzzy model is based on Mamdani fuzzy model architecture and Max-Min inference was applied. The rules of the Mamdani fuzzy system are generated in fig. 9.

Table 2. Simulation result for prediction of WQI in Kabaleeshwarar pond as per Indian water quality criteria.

S.No.	Month	DO	BOD	pH	Turbidity	I-WQ Criteria	Predication result of FIS
1.	September	7.2	31	8.4	9.7	Class-C	32.48%
2.	October	7.4	22	8.2	9.5	Class-C	32.68%
3.	November	7.7	27	8.4	8	Class-C	33.19%
4.	January	7.7	33	8.3	8.6	Class -C	33.19%
5.	February	7.4	33	8.3	8.9	Class -C	32.68%
6.	March	7.1	40	8.3	9.1	Class -C	31.78%
7.	April	7.1	40	8.2	9.5	Class -C	32.31%

I-WQ - Indian water quality, FIS - Fuzzy Inference system

Table 3. Simulation result for prediction of WQI in Chitrakulam pond as per Indian water quality criteria.

S.No.	Month	DO	BOD	pH	Turbidity	I-WQ Criteria	Predication result of FIS
1.	September	4.8	13	6.9	7.9	Class-B	60%
2.	October	5.1	12	6.8	7.8	Class-B	60%
3.	November	5.9	9	7	6.7	Class-B	60%
4.	January	5.3	12	14	6.9	Class-B	60%
5.	February	5.2	14	6.8	7.5	Class-B	60%
6.	March	4.9	15	6.7	7.7	Class-B	60%
7.	April	4.8	14	7.1	8	Class-B	58%

I-WQ - Indian water quality, FIS - Fuzzy Inference system

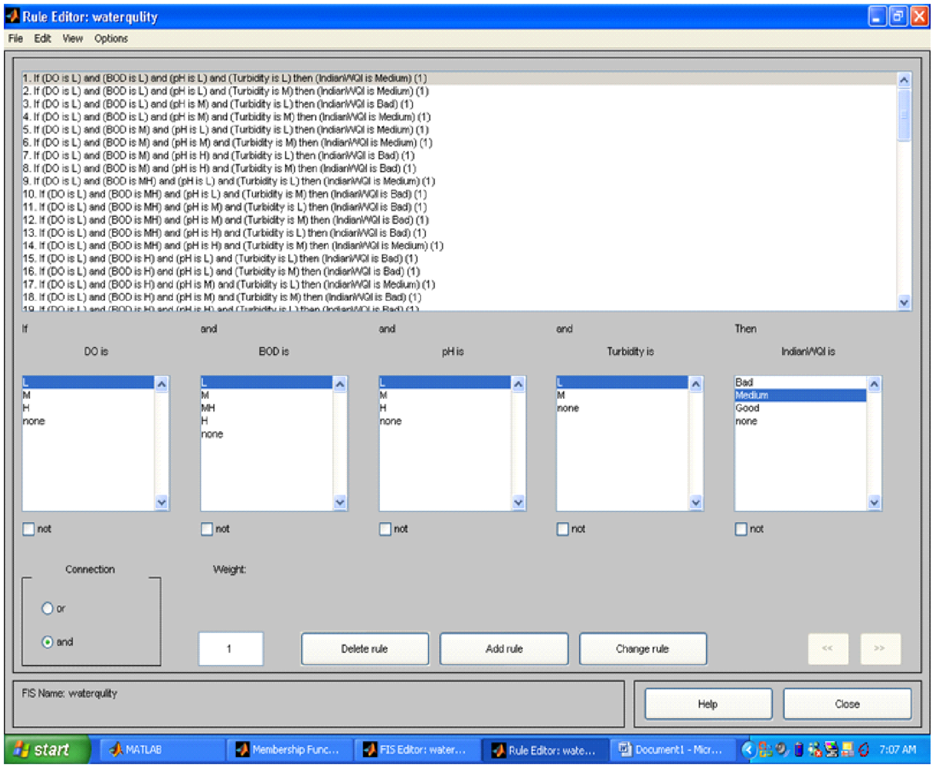

Fig. 9. The rule base coded using MATLAB software.

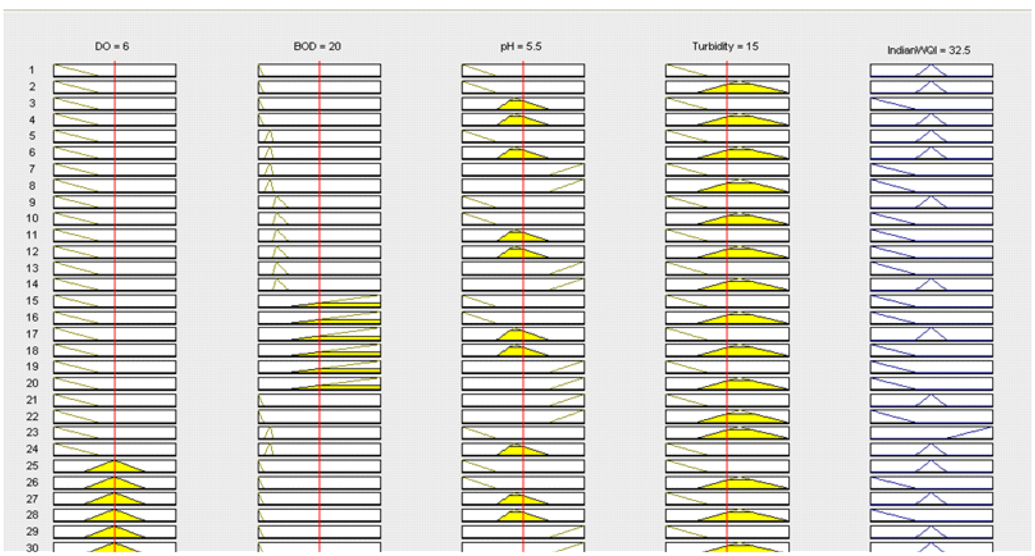

Fig. 10 Active rules and membership function input and output of WQI

The fuzzy rules are coded using MATLAB software as shown in Fig. 9. The Mamdani type fuzzy Inference System (FIS) shown in Fig. 5 shows the basic input/output system of the water quality index model for the rule viewer while a sample of defuzzified outputs are as shown in Fig.10 with surface view in Fig. 8.

4.4 step 4: Defuzzification of IWQI

After completing the fuzzy decision process, the fuzzy number obtained must be converted to a crisp value. This process is entitled defuzzification. Many method have been developed for defuzzification. In this study, a "centroid" (center of Area) technique was applied, which is one of the most common methods. After defuzzification process, obtained fuzzy number is geometrical figure. The crisp value is calculated as below (Equation 3)[9].

$$z^* = \frac{\int \mu_{c(z)} \times z \times dz}{\int \mu_{c(z)} \times dz} \tag{3}$$

5. *Simulation results :*

The prediction of water quality index of two pond as per Indian water quality criteria is discussed first. Table 2 and Table 3 represented simulation results. According to table 2, the designed model predict class C category for Kabaleeshwarar pond (between 31% to 34%). As per the Table 3, the designed model predict class B for Chitrakulam pond(60%). From this above simulation result, it is clear that the proposed FIS model gives very close result.

6. **Conclusion**

Based on the fuzziness and imprecision of water quality, the fuzzy inference system bas been used it simulate the fuzzy and imprecise relations in pond water quality modeling in this article. This proposed model gives very close result as compare with national water quality criteria. From simulation study it is found that, the water quality of Chitrakulam pond is better compare to Kabaleeshwarar pond, but unusable for drinking purpose. Seasonal variation in two temple tanks is studied in 2 different seasons, winter (for the month September, October, November)and summer (for the month January, February, March, April) using 4 different parameters (pH, Turbidity, DO, BOD) from the results and if BOD value is high, DO will be less. From the data obtained it's very clear that Kabaleeshwarar pond is much more polluted than Chitrakulam tank. The main concern of everybody involved was to ensure the quality of water for domestic purposes. The temple tanks assumed significance in olden days as a source of water for domestic and other purposes. According to surface water quality standards of India, permissible BOD limit's is 3 mg/l. In order to obtain that standard, a suitable design with secondary and tertiary treatment is proposed. By fixing the spray or surface or diffused aerator or by treating the water by partial dilution (as mention in the remedies) surface water quality can be improved. Keeping this analysis as model we can go for surface water quality modeling which can be used as tool for any other surface water bodies.

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