Mathematical Analysis for the Optimization of Wastewater Treatment Systems in Facultative Pond Indicator Organic Matter

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Mathematical Analysis for the Optimization of Wastewater Treatment Systems in Facultative Pond Indicator Organic Matter

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Abstract. Stabilization ponds are easy to operate and their maintenance is simple. Treatment is carried out naturally and they are recommended in developing countries. The main disadvantage of these systems is large land area they occupy. The aim of this study was to perform an optimization of the wastewater treatment systems in a facultative pond, considering a mathematical analysis of the methodology to determine the model constrains organic matter. Matlab optimization toolbox was used for non linear programming. A facultative pond with the method was designed and then the optimization system was applied. The analyse meet the treated water quality requirements for the discharge to the water bodies. The results show a reduction of hydraulic retention time by 4.83 days, and the efficiency of of wastewater treatment of 84.16 percent.

1 Introduction

In today's life, settlements are more centered on a residential area. This poses a new problem especially in sewerage systems. The precise way of disposing of wastewater that is flowing into the river was considered successful. At first, it was not cause problems because the amount of liquid waste is small compared to the river flow. But with increasing waste disposal, the pollution is increasing to pollute the environment. Centralized settlements make the collection of domestic waste water in sewerage very high. If the waste is throw without first processing, it can reduce the quality of river water. To solve the problem, wastewater needs the processing process first before it is streamed into the water system. One of the processes is using a centralized Wastewater Treatment Plant unit (WWTP).

Waste Stabilization Ponds are used to improve the quality of waste water by relying on natural processes that treat wastewater by utilizing the presence of bacteria, algae and zooplankton to reduce the organic pollutants contained in wastewater [1-4].

Commonly used waste water disposal systems are waste water coming from toilets flowed into septic tanks and runoff from septic tanks impregnated into the soil or discharged into waterways, whereas non-toilets that come from bathing, washing and kitchen waste is discharged directly into waterways.

Improper waste water management causes problems, for example, health risks due to contamination by pathogens, odors, and loss of biodiversity. The purpose of a pond system is to keep and treat wastewater with the specified retention time [5-6]. Stabilization ponds may function independently or in combination with other processing systems. Stabilization ponds are usually designed with a system which consist of 2 types of pond that is facultative and maturation, because it is easy to operate and easy to maintain [7]. The purpose of this research is to know the optimum waste load and the level of degradation of organic matter. Mathematical analysis is used by applying linear program, so the results of wastewater treatment fulfill the quality standard.

2 Materials and Methods

2.1. Linear Program Application

Linear program is applied to wastewater treatment system at Wastewater Treatment Plant (WWTP), Sewon, Bantul, Yogyakarta. Optimization is reviewed from the treated waste load by analyzing the efficiency of wastewater treatment so as to meet the quality standard.

The formulation of the model begins by determining the objective function to maximize wastewater treatment in facultative stabilization ponds. To determine the constraint function, the model is limited by the concentration of Biochemical Oxygen Demand (BOD) with the efficiency of wastewater treatment in each pond to meet the quality standard. The wastewater treatment system scheme in the stabilization pond for model formulation assuming no consider to the maturation pond can be seen in **Figure 1**.

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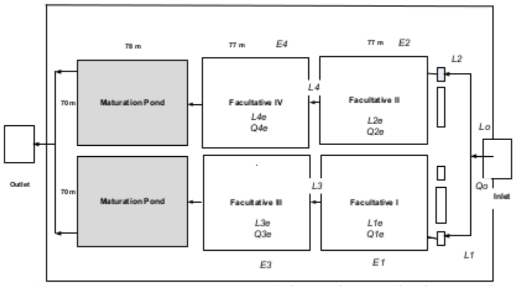

Fig. 1. Wastewater Treatment Scheme in Facultative Pond

with:

L_0 : The initial waste load that goes into the inlet (kg/day)

Q_0 : Debit of waste water in inlet (m^3/day)

Q_{ie} : Debit of waste water in pond *i* (m^3/day)

L_i : Wastewater load before entering pond *i* (kg/day)

L_e : The amount of wastewater treatment in pond i (kg/day)

C_i : Concentration of BOD of pond i (mg/L)

L : Wastewater load (kg/day)

E_i : Efficiency of wastewater treatment in pond i

BM : Wastewater quality standards

From **Figure 1** can be formulated into a model with a linear program on a water treatment system in WWTP Sewon, Bantul as follows.

Objective Function:
Maximize $Z = L_{1e} + L_{2e} + L_{3e} + L_{4e}$

Constraint Function:

- $E_1 C_1 \leq BM$
- $E_2 C_2 \leq BM$
- $E_3 C_3 \leq BM$
- $E_4 C_4 \leq BM$
- $L_{1e} \leq L_1$
- $L_{2e} \leq L_2$
- $L_{3e} \leq L_3$
- $L_{4e} \leq L_4$

The amount of incoming waste load on the wastewater treatment system in the facultative stabilization pond is the debit of waste water along with the organic material Biochemical Oxygen Demand (BOD) formulated as $L_{ie} = \frac{(Q_e . C_i)}{1000}$ and $C_i = \frac{(1000 \ L_i)}{Q_e}$, the linear program model becomes as follows.

Objective Function:
Maximize $Z = L_{1e} + L_{2e} + L_{3e} + L_{4e}$

Constraint Function:

- $E_1 \frac{(1000 \ L_1)}{Q_{1e}} \leq BM$
- $E_2 e \frac{(1000 \ L_2)}{Q_{2e}} \leq BM$
- $E_3 \frac{(1000 \ L_3)}{Q_{3e}} \leq BM$
- $E_4 \frac{(1000 \ L_4)}{Q_{4e}} \leq BM$
- $L_{1e} \leq L_1$
- $L_{3e} \leq L_1 - L_{1e}$
- $L_{2e} \leq L_2$
- $L_{4e} \leq L_2 - L_{2e}$

To solve the equation, we assume the model with the facultative stabilization pond conditions as follows.

1. The amount of waste water debit in inlet Q_0 with period of time for 1 year (January - December 2016) is 11,238.38 m^3/day.
2. The waste retention time in the facultative pond is an average of 4.83 days and the retention time of waste in each month as in **Table 1**.

Table 1. Waste Retention Time the Period from January to December 2016

No	Month	Debit (m^3/day)	Retention Time (day)
1	January	10.997,22	3,97
2	February	11.853,80	3,68
3	March	15.951,28	3,94
4	April	13.937,84	4,13
5	May	13.187,30	4,31
6	June	12.071,40	4,82
7	July	10.616,44	4,11
8	August	8.243,10	5,6
9	September	7.534,32	5,8
10	October	8.044,08	5,43
11	November	10.378,02	6,3
12	December	12.045,77	5,83
	Average	11.238,38	4,83

3. The waste load on the Facultative I (L_1) and Facultative II Pond (L_2) are half of the inlet initial load (L_0). The organic waste load is known from the number of residents connected with the Sewon WWTP system which includes the number of households as many as 54,440 people, social places (worship places and others) as many as 8,550 people, commercial places as many as 49,350 people and hotels as many as 7,650 people, so wastewater comes from 119,990 people. The standard clean water requirement in developing countries is 120 L/person/day and each person produces 40 grams of BOD per day. So the BOD concentration of Sewon is equal to 0.41667 gr/L or 416,67 mg/L and total BOD load or inlet load (L_0) is 119,990 x 40 gr/person/day which is 4,799,600 gr/day Or 4,799.6 kg/day. Thus the load of BOD (L_1) and (L_2) is 2,399.8 kg/day.
4. The coefficient of degradation of BOD (k) for the effective volume of 86.240 m^3 in 1 year is 1.1, with C_{in} is the rate of change of BOD concentration at

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the inlet and C_{ef} is the rate of change of BOD at the outlet.

Thus, the formulation of the level of degradation of organic material which capable doing in the facultative pond system is as follows.

$$E = \frac{k.t}{1 + k.t}$$

with:

k : Rate of degradation BOD

t : Waste retention time (days)

From the calculation result obtained that effectivity of wastewater treatment system in facultative pond able to degrade waste equal to 84,16%.

3 Results and Discussions

The system of linear program equations is done by simplifying the equation, i.e. by entering the value of known variables. Known variables are debit of waste water in each pond (Q_w), waste load in each pond (L_e), efficiency of pond (E_i) and predetermined quality standard (BM). The quality standards of waste water based on the Decision Letter of the Governor of Yogyakarta Special Region No. 214/KPTS/1991 on the domestic waste water quality standard is 50 mg/L. By entering these values of variables, so the objective function of the constraint function is obtained as follows.

Objective Function:
Maximize $Z = L_{1e} + L_{2e} + L_{3e} + L_{4e}$

Constraint Function:

– $0.84 \times \frac{(1000 \;\; L_1)}{13,475} \leq 50$

– $0.84 \times \frac{(1000 \;\; L_2)}{13,475} \leq 50$

– $0.84 \times \frac{(1000 \;\; L_3)}{13,475} \leq 50$

– $0.84 \times \frac{(1000 \;\; L_4)}{13,475} \leq 50$

– $L_{1e} \leq L_1$

– $L_{3e} + L_{1e} \leq L_1$

– $L_{2e} \leq L_2$

– $L_{4e} + L_{2e} \leq L_2$

Equation systems solved by using software POM-QM version 3.0. This software is used to help math calculations by using the simplex method.

To know the suitability of the model with conditions in the field, so the model is verified with observation data in Sewon's IPAL, Bantul. The observational data were organic BOD concentrations in inlets range from 68.3 mg/L - 177.2 mg/L and at outlets range from 13 mg/L-18.8 mg/L.

4 Conclusions

Wastewater treatment systems in facultative ponds using mathematical analysis (linear program) are able to degrade organic matter. The intended organic matter is BOD with degradation rate of 84.16% and can meet the domestic waste water quality standard with waste retention time 4.83 days.

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