IMPROVEMENT OF OXIDATION POND EFFLUENT QUALITY BY SAND FILTRATION

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ABSTRACT

In this research, the sand filtration process is focused on as one of the techniques for raising the quality of oxidation pond effluent. Based on the data of down-flow filtration experiments, a mathematical model for DO and deposit is developed, and the behavior of the deposit in the sand filter is analyzed. The decomposition of the deposit follows a first-order reaction at a filtration rate higher than 5 m/day, while it follows a zero-order reaction at a rate lower than 1 m/day. From the relationship between deposit and head loss, the maximum quantity of the deposit is determined to be around 0.3 kg/m² at the rate of 0.5-1 m/day and 0.2 kg/m² at the rate of 5-10 m/day.

KEY WORDS

Sand filtration, mathematical model, oxidation pond, deposit, head loss, decomposition

INTRODUCTION

Sand filtration is suitable for the treatment of oxidation pond water because of its high efficiency of removal of SS material. To evaluate this treatment, information on the deposit and head loss is required. The deposit is decomposed to some extent during the filtration period before clogging. Mathematical models for the behavior of the deposit are developed and analyzed.

EXPERIMENTAL PROCEDURES AND DEVELOPMENT OF MATHEMATICAL MODEL

Experimental procedures: The experiments used for model verification are the same as the paper entitled "Water Quality Improvement of Secondary Effluent by an Oxidation Pond with Subsequent Sand Filtration Treatment" (Fujii et al., 1987*). The layout of experimental equipment is shown in Fig. 1. The

![Diagram of Experimental Equipment](https://iwaponline.com/wst/article-pdf/19/12/355/98474/355.pdf)
detention time of the oxidation pond was 3.3 days, and the effluent was filtered through the sand filter at the rate of 0.5 to 10 m/day. The conditions and results of each run are summarized in Table 1. SS, DO and head loss were measured and the final deposit mass was obtained in every run.

Model and differential equations. For the estimation of deposit behavior, a mathematical model based on material balance is developed as shown in Table 2. In the model, SS is divided into VSS and ash. The ratio of VSS to SS in influent was calculated as 0.913 from the average effluent pond values. From tracer experiments, the flow pattern was determined to be complete mixing in the water zone and piston flow in the sand layer. Since the deposit is almost completely concentrated near the sand surface, the very thin layer just below the surface is assumed to be a reaction layer where all reactions occur. The sedimentation of VSS and ash, the decomposition of VSS, the consumption of DO and the gasification of supersaturated DO are considered to be reactions in this model. The VSS decomposition rate is proportional to the VSS concentration.

### Table 1 Conditions and results of each filtration experiment

| Run    | SS loading (g/m²) | Final Deposit simulated (g/m²) | Remarks 
|--------|-------------------|-------------------------------|--------
| 1      | 1.0              | 205                          | fish   |
| 2      | 2.3              | 288                          |        |
| 3      | 8.7              | 549                          |        |
| 4      | 24              | 354                          |        |
| 5      | 29              | 401                          |        |
| 6      | 29              | 440                          |        |
| 7      | 63              | 357                          |        |

### Table 2 Model for sand filtration and fundamental differential equations

\[
\begin{align*}
\frac{dL_1}{dt} &= \left(\frac{L_0 - L_1}{T} - aL_1 \right) - rL_1 \\
\frac{dX_1}{dt} &= \left(\frac{X_0 - X_1}{T} - sX_1 \right) \\
\frac{dD_1}{dt} &= \left(\frac{D_0 - D_1}{T} - kL_1 \right)
\end{align*}
\]

Lo, Xo, Do = VSS, ash & DO in influent (g/m³)

D1 = DO concentration in effluent (g/m³)

L1, X1, D1 = VSS, ash & DO in water zone (g/m³)

D2 = DO saturation value of DO (g/m³)

Ds = saturation value of DO (g/m³)

r = decomposition rate constant (1/hr)

s = sedimentation rate constant (1/hr)

ko, n, m = parameter for gasification of DO

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Numerical calculation and verification The data of Run 1, Run 2 and Run 3 (0-88 hrs) were used for the verification of the model. The differential equations are solved using the RKG method. The values of \( r, k_o, n \) and \( m \) are determined to minimize the sum of the squares in calculation errors. Then, ko of 0.1/hr, n of 2 and m of 1 are determined in these three cases. The calculated results show that a time-series variation of DO is precisely simulated with this model. The final calculated deposits are 211 and 282 g/m² for Runs 1 and 2, while the measured ones are 205 and 288 g/m² for Runs 1 and 2, respectively. The errors are less than 3%, and thus the reliability of the model is demonstrated in this experiment.
Since modeling of the decomposition is difficult at a low rate, the deposit variation in Run 4-7 is obtained from the following procedure. First, the DO concentration for the case without biological reactions is calculated from modified differential equations, in which the decomposition rate constant $r$ is given as zero. The difference between the measured DO concentration and the calculated one is considered to be the oxygen consumption in the sand filter. The decomposed quantity is calculated from this DO consumption. As shown in Table 1, the final simulated deposit quantity is identical to the measured one. The reliability of this model is also demonstrated.

**DISCUSSION**

The behavior of the deposit. The variations of the influent SS loading, deposit mass (=VSS+ash) and cumulative decomposed mass are shown in Fig. 3. The ratio of the decomposed material increases with the decrease in the filtration rate. In Run 6, the deposit appears to be approaching the same level as the decomposed mass, while it is almost the same as influent loading in Run 1. The decomposed mass seems to increase progressively in Runs 1 and 3, but linearly in Run 6. It seems that the decomposition reaction is zero-order at a low rate and first-order at a high rate. At a low rate, the reaction may be controlled by oxygen supply rate. In Fig. 4, the VSS decomposition rate (Run 6) is plotted against temperature. In Run 6, this rate is expressed as $5 \times 1.036 \times 10^{-25}$ g/(m²·day).

**SUMMARY**

In this research, the behavior of the deposit in a sand filter was discussed with the help of a mathematical model. The degradation of the deposit follows a first-order reaction at a filtration rate higher than 5 m/day, while it follows a zero-order reaction at a rate lower than 1 m/day. The maximum quantity of the deposit in the sand filtration bed is determined to be around 0.3 kg/m² of the bed surface area at the rate of 0.5 to 1 m/day and 0.2 kg/m² at 5 to 10 m/day. Since deposit behavior is successfully simulated with this model, the length of run until clogging occurs is estimated from the time when the simulated deposit becomes this quantity.