LABORATORY STUDY OF DYNAMIC-STATE CONTROL OF ACTIVATED SLUDGE PROCESSES

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Introduction

Two types of control are generally required for the normal operation of an activated sludge process. They are the steady-state control and the dynamic-state control. The steady-state control is to maintain the process stability which will, otherwise, be lacking on account of seasonal variations of the influent sewage characteristics. The dynamic-state control, however, is to maintain the proper solids distribution in the system during the diurnal fluctuation of influent sewage characteristics.

A recent study[1] indicates that the solids flux curve may be used for the dynamic-state control. However, this study is mainly on the theoretical development. In order to gain more insight into the new approach, an actual test is necessary. The research work done in this study is mainly laboratory experience in the determination of g and h constants for establishing the sludge solids flux curve and control experience in using the new approach for a lab-scale activated sludge process unit.

Theoretical Background

The typical diurnal influent sewage flow variation is shown in Figure 1. Without the proper recycle flow control system, excessive sludge solids will be carried over from the

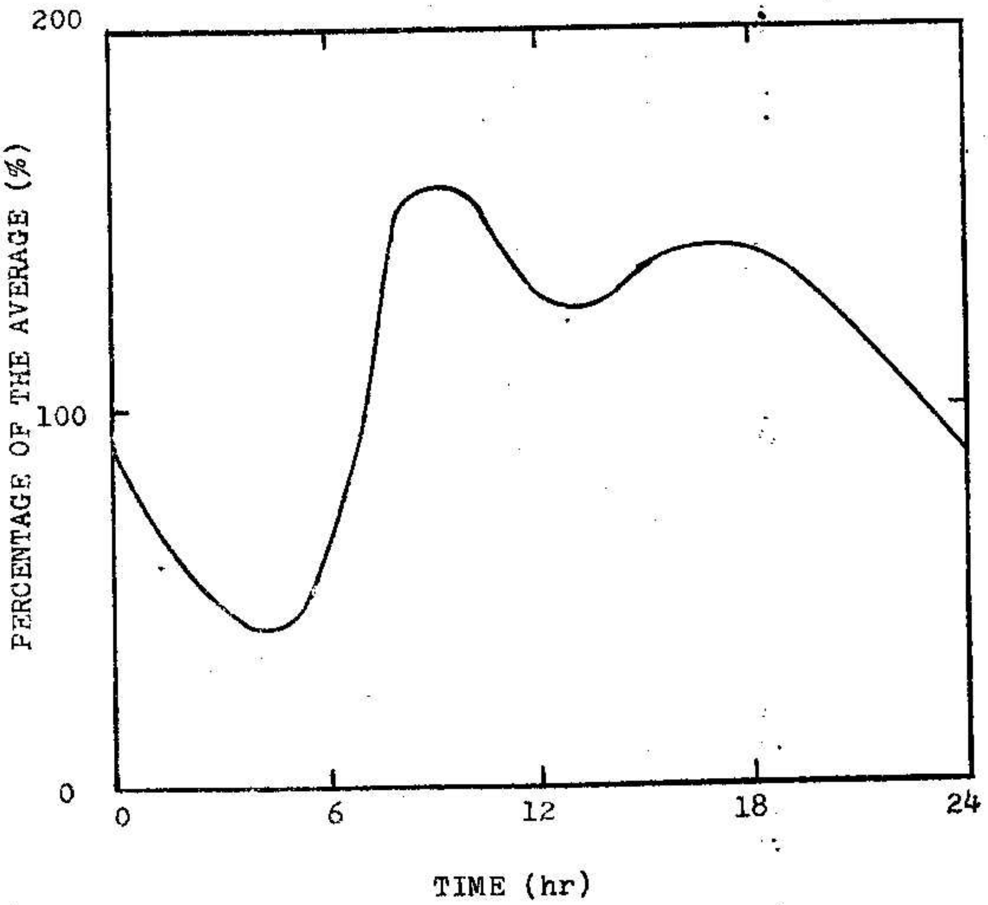

FIGURE 1 TYPICAL DIURNAL FLOW VARIATIONS OF SEWAGE INFLUENT

aeration tank to the settling tank during the period of high sewage flow, and excessive energy will be consumed by the unnecessarily high rate of the recycle flow pumping during the period of low influent sewage flow. To solve these problems, an appropriate control strategy is needed to ensure the proper distribution of the sludge solids in both the aeration tank and the settling tank, and to reduce energy consumption to a minimum.

An appropriate control strategy which is theoretically sound is to employ the batch solids flux curve in deciding the recycle flow rate. The batch solids flux curve reflects the settling characteristics of the sludge solids. The allowable amount of solids passing through the settling tank in the downward direction is related to both the settling characteristics of the sludge solids and the recycle flow rate. A higher recycle rate allows a greater amount of solids to pass downward through the settling tank than a lower recycle rate does even if the sludge settling characteristics are unchanged. This new control approach is to manipulate the recycle rate in accordance to the fact that a definite allowable amount of solids flux exists for a given type of sludge in a given settling tank.

The complete theoretical development is discussed in detail in the previously cited study[1]. In brief, the new control approach involves the establishment of the solids flux curve, the overflow operating line, and the recycle operating line as shown in Figure 2. The intersection of the two operatin lines which is called the state point determines the MLSS in the aeration tank. The recycle operating line is tangent to the solids flux curve. Based on these relationships, the overall governing equation is as follows:

$$\frac{Q}{A} = \frac{g(h-1)(h/(h-1))^{h} R^{h-1}}{C_o^{h} (1+R)^{h}} \qquad (1)$$

in which

Q = plant flow rate

A = surface area of the settling tank

g, h = constants related to the establishment of the solids flux curve

C_o = MLSS concentration in the aeration tank

R = sludge recirculation ratio = $\frac{Q_r}{Q}$

Q_r = recycle flow rate

For a given plant flow with the average value of C_o, the recirculation ratio can be calculated by equation 1. Thus, the recycle flow rate is determined.

Using equation 1 for the dynamic-state control of an activated sludge process ensures that no sludge accumulates in the settling tank during the daily period of high flow, and that no excess recycle pumping rate occurs during the daily period of low flow.

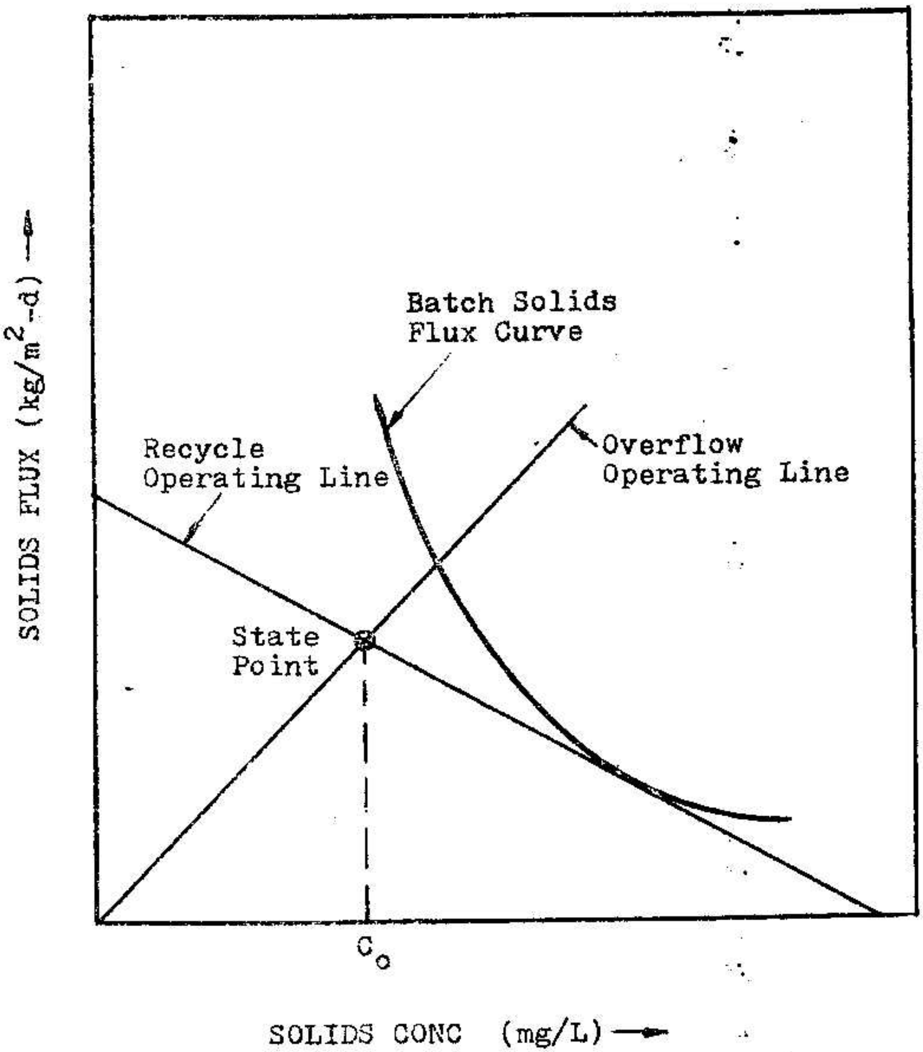

FIGURE 2 TYPICAL BATCH SOLIDS FLUX CURVE AND OPERATING LINES

Experimental Set-up and Methods

1. Source of Sewage Sludge

The sewage sludge for the experiment came from the sewage treatment plant in Cabo Rojo which is located about 10 miles from the university. This plant has a flow capacity of nearly 1.0 MGD. The treatment plant has been operated reasonably well. Both BOD and suspended solids had more than 80% removal during the month of July, 1982. The average BOD and suspended solids in both influent and effluent of the plant during the period in which sewage sludge was obtained for the experiment are shown in Table 1. Figures 3 and 4 show the aeration tank and the final settling tank of the treatment plant, respectively.

Sludge was transported to the university by using a 50-gallon drum. At times recycled sludge was used for obtaining higher initial solids concentration. Figure 4a shows the sludge recirculation line of the Cabo Rojo treatment plant.

2. Batch Solids Flux Curve

The batch solids flux curve is a plot of the solids flux versus the solids concentration. Solids flux is the product of the initial settling velocity and the given initial solids concentration. The initial settling velocity for a given initia solids concentration can be determined by the initial interface settling velocity.

A two-liter graduated cylinder was used for the determination of the initial interface settling velocity. In order to speed up the experiment, a set of four cylinders was instal

Table 1 The Performance of the Cabo Rojo Sewage Treatment Plant

Parameter	Average Value (June, 1982)			Average Value (July, 1982)		
	Influent	Effluent	%Rem.	Influent	Effluent	%R
BOD(mg/L)	193	69	64	264	44	83
Suspended Solids (mg/L)	136	70	48	394	63	84

FIGURE 3 AERATION TANK OF THE CABO ROJO SEWAGE TREATMENT PLANT

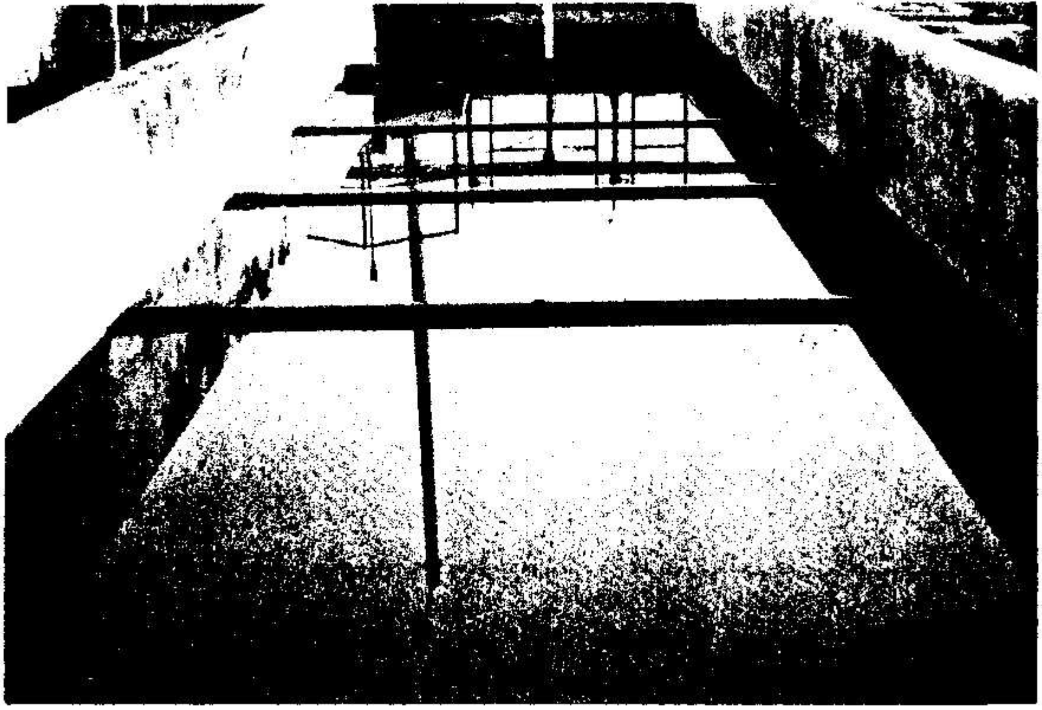

FIGURE 4 FINAL SETTLING TANK OF THE CABO ROJO SEWAGE TREATMENT PLANT

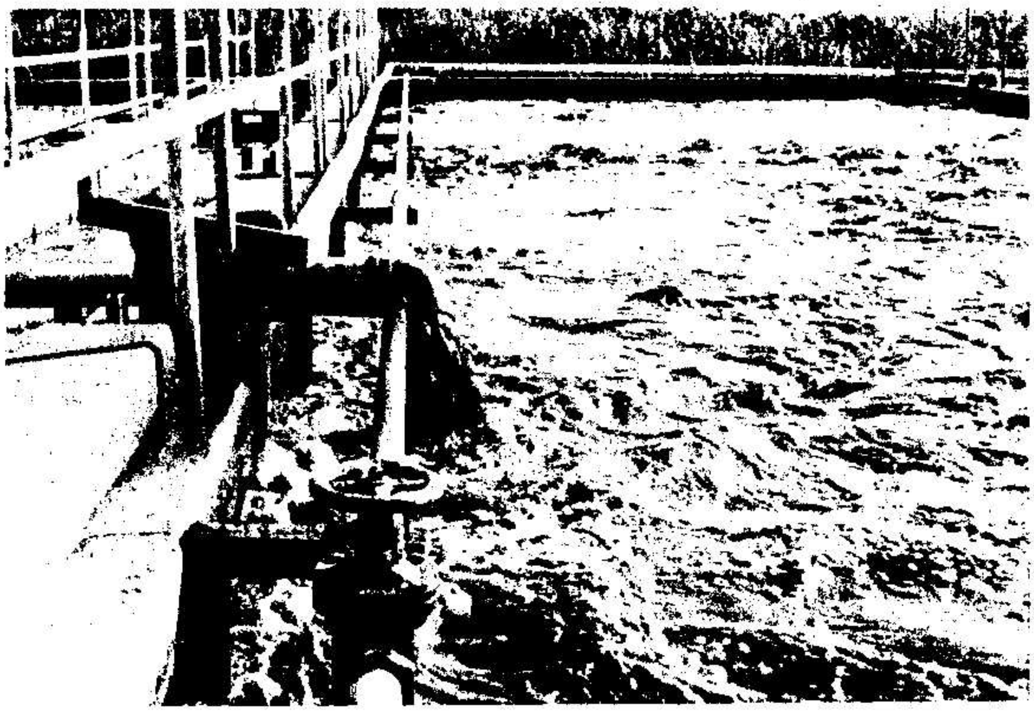

FIGURE 4a SLUDGE RECIRCULATION LINE OF CABO ROJO SEWAGE TREATMENT PLANT

A slowly rotating and stirring rake was installed in each cylinder. The moving mechanism was provided by a jar test mixer. The lowest rotation speed was measured approximately 2 rpm. At this speed, the trapped air could be released during the test without interfering with the settling velocity of the sludge. The set-up is shown in Figure 5. The typical solids-liquid interface height versus time for a given initial solids concentration is given in Figure 6. Initial settling velocity is determined from the slope of the linear segment of the trace. The initial curved portion is excluded on account of sludge reflocculation during that period.

Figure 7 shows the typical plot of the initial settling velocity versus the initial solids concentration. The relationship between the two can be expressed as[2]

$$U = gC^{-h} \qquad (2)$$

where

U = initial settling velocity, m/d

C = initial solids concentration, dimensionless form in kg of solids per kg of water

g = empirical constant, m/d

h = empirical constant, dimensionless

Equation 2 can be expressed in the following form:

$$\log U = \log g - h \log C \qquad (3)$$

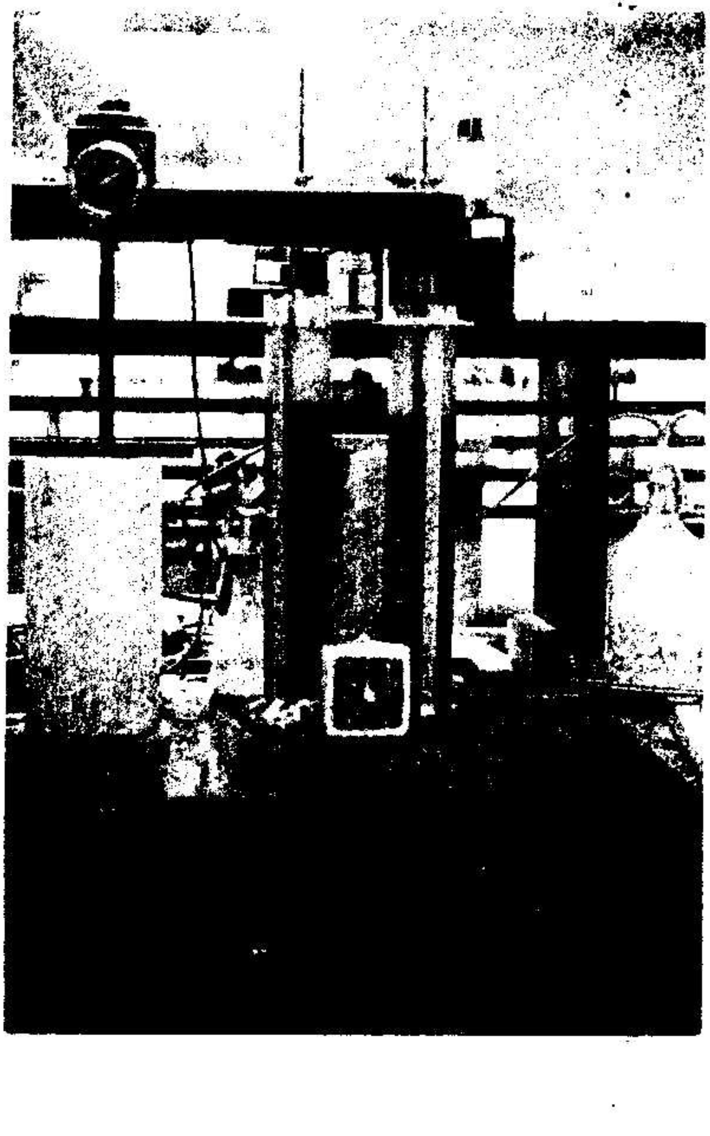

FIGURE 5 LAB SET-UP FOR THE DETERMINATION OF THE INITIAL INTERFACE SETTLING VELOCITY OF SLUDGE