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ACTIVATED SLUDGE PROCESS
CONTROL BY BEHAVIOUR OF
SECONDARY SETTLING TANKS
ACTIVATED SLUDGE PROCESS CONTROL BY BEHAVIOUR OF SECONDARY SETTLING TANKS

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ABSTRACT

The mathematical models of activated sludge kinetics and solids flux have been investigated; the constants have been derived experimentally. By developing the equations of the two models, an operational chart for activated sludge process control has been plotted.

KEYWORDS

Wastewater; activated sludge; process control.

INTRODUCTION

Variations in influent organic load in an activated sludge plant are usually absorbed by changing the sludge recycle ratio (R) to increase the concentration (C0) of suspended solids in the aeration tank. However, as the limiting solids flux of the secondary settling tank is related to R, this procedure is not without its limitations. In this paper we compare the two mathematical models of the kinetics of the biological removal of organics and solids flux. The findings clearly show that R is a parameter of the control of the process. The results are presented in an operational chart from which, for given aeration and settling tank volumes, it is possible to:

(a) determine the parameters of the process (C0 expressed as MLSS and R) for a given sludge age (θc) and for different characteristics of the influent flow (flow rate, Q; concentration of the soluble organic substances, S0);
(b) evaluate the flexibility of the plant, i.e., its capacity to absorb organic load increases without altering the design θc;
(c) determine the operating conditions that lead to process failure and to estimate the variations to be made to θc.

EXPERIMENTAL PROCEDURES

The experiments were performed on an activated sludge pilot plant with a θc of 7 days. Batch settling tests were carried out on samples of activated sludge with C0 in the range of 2 to 8 kg/m3. Three perspex cylinders 130 cm high, 14 cm diameter, with a control valve on the bottom for the intake and discharge of the sludge, were fitted with a two-rod stirrer set at 1 rpm. The samples to be tested were aerated for about 5 minutes to strip out dissolved gases produced during sample preparation and transport. The settling velocity (v) of the sludge solids was calculated from the fall in height with time.
RESULTS AND DISCUSSION

The model with the best fit between \( v \) and \( C_0 \) can be expressed by an exponential function \( v = v_0 \exp(-\alpha C_0) \). The experimental data have shown that \( v_0 = 5.68 \text{ m/h} \) and \( \alpha = 0.48 \), with regression coefficient \( r = 0.95 \).

Applying the exponential model and equalling total flux of solids applied to a settler of surface \( A \) to the limiting solids flux for concentration \( C_L \), we get:

\[
Q = \frac{v_0 \alpha C_0^2}{A} e^{-\alpha C_L} \quad \text{for} \quad R < R_C \tag{1}
\]

\[
Q = \frac{v_0 e^{-\alpha C_0}}{A} \quad \text{for} \quad R > R_C \tag{2}
\]

where:

\[
C_L = \frac{(1 + R) C_0}{2R} + \left[ \frac{(1 + R)^2 C_0^2}{4R^2} - \frac{(1 + R) C_0}{\alpha R} \right] \tag{3}
\]

\[
R_C = \frac{C_0}{4/\alpha - C_0} \tag{4}
\]

Figure 1 shows the overflow rate, \( Q/A \), as a function of \( R \) for different values of \( C_0 \), using Equations (1) and (3) for \( R < R_C \), and Equation (2) for \( R > R_C \). For \( R < R_C \), the curves show a trend which increases as \( R \) increases, until a maximum value of \( Q/A \) is reached, which coincides with the velocity, \( v \), of undisturbed sedimentation of the sludge in the batch test. In this plot area, for a given \( C_0 \), increments in \( Q/A \) require increments in \( R \); the higher the \( C_0 \), the greater the increase in \( R \). For \( R > R_C \), we get straight lines parallel to the abscissa, since \( Q/A \) is independent of \( R \); in this plot area, for a given \( C_0 \), no increases in \( Q/A \) are permitted. In fact, as previously mentioned, \( Q/A \) assumes its maximum value. It follows that for a given \( Q \) influent to the plant, the minimum area of the settler compatible with a concentration, \( C_0 \), is obtained for \( R > R_C \). The plot also illustrates that, for an assigned value of \( Q/A \), increasing \( R \) results in increases in \( C_0 \) in the oxidation tank. The increases, however, become less relevant as \( R \) approaches \( R_C \), which corresponds to the highest concentration of \( C_0 \) compatible with proper operation of the settler.

The most widely used model for the kinetics of activated sludge is:

\[
v = \frac{Y Q (S_0 - S)}{X (1/8_c + b)} \tag{5}
\]

where:

\( Y = 0.6 \) and \( b = 0.005 \text{ days}^{-1} \);

\( X = \text{MLVSS (mg/l)} \);

\( S = \text{concentration of the soluble substances in the effluent (mg/l)} \).

The diagram shown in Fig. 2 was plotted using Equations (1), (2) and (5). The first quadrant shows the straight lines which express the relationship between \( Q/A \) and \( X \cdot V/A \), for \( S_0 \) between 100 and 400 mg/l, \( \theta_c = 7 \text{ days} \) and \( S = 20 \text{ mg/l} \). The second and third quadrants show the relationships between \( X \cdot V/A \) and \( X/A \) for different values of \( V \), and between \( X/A \) and \( X \) for different values of \( A \), respectively. Finally, the fourth quadrant shows the relationship between \( C_0 \) and \( Q/A \) for different values of \( R \), with the assumption \( C_0 = 1.25X \); as \( Q/A \) increases, each of the curves meets the curve of the equation \( Q/A = v_0 \exp(-\alpha C_0) \), which coincides with the velocity, \( v \), of undisturbed sedimentation of the sludge in the batch test. This curve divides the fourth quadrant into two areas. In the first, whatever the variation of \( Q/A \), it is possible to find a value of \( R \) that satisfies the condition of a lower applied
Fig. 1. \( Q/A \) versus \( R \) for various \( C_o \)

Fig. 2. Operational chart for the activated sludge process
solids flux than the limiting one, and that assures the necessary concentration of suspended solids in the oxidation tank. In the second, whatever the Q/A, no value of R gives a C₀ compatible with the proper working of the settler: Each point in this area represents a failure of the whole activated sludge process which leads to the rising of the sludge blanket in the settler and the presence of suspended solids in the final effluent. For a θ_c interval falling between 5 and 10 days, in which the constants maintain the values obtained experimentally for θ_c = 7 days, the diagram can still be used by adopting the nomogram reported in the first quadrant (see example).

EXAMPLE

Let V = 1000 m³ and A = 200 m³. From Fig. 2, for Q/A = 0.8 m/h and S₀ = 200 mg/l, we get C₀ = 3 kg/m³ and R = 0.4; with the same S₀, for Q/A = 1.0 m/h we get C₀ = 3.6 kg/m³ and R = 0.8; whereas C₀ = 4.3 kg/m³ corresponds to Q/A = 1.2 m/h, i.e point C which falls inside the area of process failure. For Q/A = 1.2 m/h, the maximum concentration compatible with proper operation of the sedimentation tank is equal to 3.25 kg/m³, which corresponds to point B on the ordinate X . V/A. The slope of the straight line AB on the nomogram yields the new operating value θ_c = 5 days.

REFERENCES
