Activated Sludge Systems

INFLUENCE OF CONTACT LOADING ON POLYSACCHARIDE STORAGE AND SETTLEABILITY OF ACTIVATED SLUDGE

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ABSTRACT

A new concept of substrate loading of activated sludge, "contact loading" is introduced, which means the instantaneous contact ratio of substrate to sludge. Using a substrate made up of glucose and peptone the activated sludges were cultivated under several contact loadings. The influence of contact loading on the capacity of polysaccharide storage and settleability related to the growth of filamentous bacteria was examined. The competition of filamentous and non-filamentous bacteria was analyzed under the different conditions of contact loading and aeration time.

Keywords: activated sludge; contact loading; polysaccharide storage; sludge settleability; filamentous bulking; regeneration period.

DEFINITION OF CONTACT LOADING (CL)

In the case of the fill and draw process, when sludge concentration and mixed liquor volume before feeding are M₀ and V₀ respectively and substrate Sᵢ is fed at the rate of Q, the organic loading F in respect to the feeding period ¢t min. is calculated as follows:

F = \frac{Sᵢ \times Q \times ¢t}{M₀ \times V₀} (g COD/g MLSS).

In this equation, when ¢t approaches 0, F approaches 0. However when feeding period is very short, Q \times ¢t is nearly equal to the volume of substrate fed, V₁. Furthermore in constant operation, M₀ \times V₀ = M \times V, in which M is average MLSS and V is aeration tank volume. Therefore the contact loading (CL) can be calculated using the following equation.

CL = \frac{Sᵢ \times V₁}{M₀ \times V₀} = \frac{Sᵢ \times V₁}{M \times V} (g COD/g MLSS).

This equation is the same as floc loading which was defined by Eikelboom (1982) as an indicator of the loading during the mixing stage.

In the case of the continuous process, when substrate concentration and MLSS in the first compartment of aeration tank are S₀ and M₀, respectively, the volume of the first compartment is V₁ and substrate Sᵢ is fed at the rate of Q, the organic loading F for ¢t min. is as follows:

F = \frac{S₀ \times V₁ + \left( Sᵢ \times Q \times ¢t \right) - \left( S₀ \times \left( q + q \right) \times ¢t \right)}{M₀ \times V₀} - \frac{\left( Mᵢ \times q \times ¢t \right) - \left( M₀ \times \left( q + q \right) \times ¢t \right)}{M \times V₁} \times \frac{M₀ \times V₀}{M \times V₁} 

in which Mᵢ and q are the concentration and flow of the recycled sludge respectively. In order to obtain CL for the continuous process, ¢t approaches 0, and CL becomes as follows:

CL = \frac{S₀ \times V₁}{M₀ \times V₁} = \frac{S₀ \times V₁}{M \times V₁} (g COD/g MLSS).
CL can be calculated from concentrations of the sludge and remaining substrate in the first compartment of the aeration tank.

MATERIALS AND METHODS

Experimental procedures are illustrated in Fig. 1. The activated sludges used for the capacity test were cultivated under several conditions. The activated sludge capacity test was carried out in a 4 L plastic vessel maintained at 25 °C. After settling and withdrawing, the sludge was resuspended in the cultivation medium. Immediately after mixing, the first sample was taken for determination of the 0 hr state value. The vessel was aerated and several samples were taken at 0.5 to 6 hr intervals. Intra- and extra-cellular carbohydrates of each sample were analyzed by a new combination of the established extraction method. PHB contents were analyzed using disk assay (Ward and Dawes, 1973). MLSS was measured using an electronic moisture balance (Shimazu Co. Ltd., Type ED-200MO) after centrifugation. In order to compare the settling characteristics, a diluted SVI test was carried out, and SVI at Phase I, which means the value of SVI when SV30 is less than 30 %, was measured (Matsui and Yamamoto, 1984).

RESULTS AND DISCUSSION

Results of Capacity Test

Figure 2 shows an experimental result of the capacity test with the activated sludge of Run 6. Glucose in liquid phase rapidly disappeared in the nearly 0 order reaction. Since inactive stored materials were included in MLSS, the biomass concentration was calculated after subtracting the increase of total carbohydrates from the MLSS. The calculated biomass concentration rapidly increased until glucose and peptone disappeared. Afterward it decreased at a slow rate. Extracellular carbohydrate concentration per unit biomass did not change significantly when the substrate was added. It is understood that...
glucose is immediately transported into the cell. Therefore glucose is not kept outside the cell by adsorption. Intracellular polysaccharides increased until glucose in the liquid phase disappeared, and polysaccharides decreased by metabolism. The time course of total carbohydrate concentration was similar to that of intracellular polysaccharides. This result shows that since glucose transported into the cell is immediately synthesized to polysaccharides and also metabolized, accumulation of glucose in the cell and low polymerized polysaccharides are very little. In this study, the maximum values of intracellular polysaccharides and PHB were regarded as storage capacities.

Influence of CL and F/M ratio on Polysaccharide Storage and Settleability

Figure 3 shows the relationship between the polysaccharide storage capacity and the initial glucose removal rate. It was understood that the polysaccharide storage capacity of the activated sludge had a great influence on glucose removal from the liquid phase. Walters et al. (1968) have reported that F/M ratio had a significant effect on the capacity of activated sludge organisms to synthesize storage materials. However in this study, F/M ratio was not well related to both storage capacities. In Walters's experiments, since the F/M ratio was established by the concentration of the influent substrates in a fill and draw unit with a once-a-day feeding schedule, the CL increased as the F/M ratio increased. Figure 4 shows the relationship between the CL and the specific storage capacities. It was found that the polysaccharide storage capacity increased as CL increased except in Run 5, while the PHB storage capacity decreased as CL increased. The amount of PHB storage was generally much smaller than polysaccharide storage. Figure 5 shows the relationship between average CL and SVI at Phase I. It was understood that when CL fell in the range between 0.37 and 0.71 g COD/g MLSS, the settling characteristics were good except in Run 5. When CL value becomes lower than 0.37 g COD/g MLSS, filamentous bulking occurred frequently. The relationship

![Fig. 3 Relationship between the polysaccharide storage capacity and the initial glucose removal rate.](image)

![Fig. 4 Relationship between contact loading and the specific storage capacities: (a) polysaccharides; (b) PHB.](image)

![Fig. 5 Relationship between contact loading and average SVI at Phase I.](image)
between F/M ratio and the sludge settleability was not clear in this experiment. Matsui and Yamamoto (1984) reported a clear relationship between filamentous length and SVI at Phase I. Various types of filamentous bacteria were microscopically observed during our experiments. Predominant bacteria were *Sphaerotilus* sp.. It can be assumed that the values of SVI at Phase I related to the amount of *Sphaerotilus* sp.. The polysaccharide storage might have a relation with the filamentous bulking caused by mainly *Sphaerotilus* sp..

**Influence of Aeration Time on Polysaccharide Storage and Settleability**

In Figs 4 and 5, which show the relationships between CL and various parameters, all data of Run 5 were exceptional. Yasuda (1981) defined the ratio of starvation time/substrate removal time as 'the hungry time ratio' and reported that the larger the hungry time ratio, the better the settling characteristics from his experiments. Grau et al. (1982) proposed the accumulation-regeneration theory and reported that at a short regeneration period the activated sludge could not restore the accumulation capacity, then the sludge settleability became poor. In this study in the case of Run 5, the sludge was cultivated under conditions of high CL and short aeration time. In these conditions, a sludge which had small polysaccharide storage capacity and contained a large amount of filamentous bacteria was produced. This result suggested that a sufficient aeration time is needed to restore the storage capacity.

**CONCLUSIONS**

A summary of this study is illustrated in Table 1. Microorganisms M1 which had large polysaccharide storage capacity could become dominant when the contact loading was high, while microorganisms M2 which had small polysaccharide storage capacity could coexist with the former microorganisms (M1) when the contact loading was low. When aeration time is not sufficient to restore the storage capacity, microorganisms M2 could coexist with M1 although CL was high. The filamentous bacteria might belong to the latter group of microorganisms (M2) which had a small polysaccharide storage capacity.

**Table 1** Competition of microorganisms in activated sludge.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>CL</th>
<th>AT</th>
<th>M1 microorganisms with large polysaccharide storage capacity</th>
<th>M2 microorganisms with small polysaccharide storage capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>long</td>
<td>dominant</td>
<td>minor</td>
<td></td>
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<td>low</td>
<td>long</td>
<td>coexist</td>
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<tr>
<td>high</td>
<td>short</td>
<td>coexist</td>
<td>coexist</td>
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</tr>
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Filamentous bacteria might belong to M2.

**REFERENCES**


