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Biochemically Stable Organic Matters in Activated Sludge Process Effluent

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Abstract

Activated sludge process effluents usually contain biochemically stable organic matters which are a matter of great concern with respect to the THM creation after chlorination. In this study, the existence and the generation of such organic matters were experimentally examined using domestic sewage.

In a batch test, the existence of such matters in the influent sewage was confirmed from the fact that the minimum levels of E_{260} and COD during aeration were proportionally increased with the initial COD concentration. For a given concentration of initial COD, the minimum levels were not affected by the SS concentration of the influent sewage, MLSS and SRT. In a continuous-flow test, the soluble COD of the effluent did not reach such a high level even after 100 h as observed in the batch test. The COD/E_{260} ratio of the effluent became lower as the detention time and this tendency was also opposed to the result of the batch test.

1. Introduction

Activated sludge process effluents usually contain some organic matters which are not detectable as BOD but measurable as bichromic acid COD or TOC. These organic matters are referred to as biochemically stable organic matters (hereafter, written as BSOM) and their impacts on the water environment are of grave concern with respect to the THM creation by chlorination, the acceleration of eutrophication and so on. Studies on BSOM should consist of the following three : (i) the evaluation of the original amount in the raw sewage, (ii) the control of the condition of treatment process to reduce the production rate, and (iii) the examination of the effect on the water environment.

In this paper, the authors intend to determine the amount of BSOM in the domestic sewage and the excretion rate of BSOM from the autoxidation process of activated sludge, and to characterize the composition of the effluent BSOM under various hydraulic conditions.

2. The Amount of BSOM in the Domestic Sewage

2. 1 Experimental Material and Method

The sewage used was obtained at the pumping station of Oasa housing development sewage treatment area which was drained by a separate sewerage system. The coarse

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particles were removed using a laboratory-scale settling tank at an overflow rate of 50 m/d. Sampling was carried out at 8 : 30 and 20 : 00 when the sewage with the highest COD in a day was obtainable. Two samples were equally mixed for the experiments (2) to (4) mentioned later and the former sample was used for the experiment (1).

The experiments were conducted in a batch type using a cone bottomed 4 l vessel as an aeration tank. The activated sludge was obtained from the aeration tank of Ebetsu municipal sewage treatment plant. The aeration was started as soon as the vessel was filled with the sewage of 3.5 l and the activated sludge of 0.5 l. The blank test was conducted with the tap water instead of the sewage.

A given volume of mixed liquor was withdrawn at times from the vessel and centrifuged for 2 minutes at 3000 rpm. The supernatant was filtered by No. 5C filter paper (the effective pore size was 1.2 μm.), and then UV absorption at 260 nm (E_{260}) and bichromic acid COD were measured. The centrifuged sediment was submitted to the determination of MLSS.

2. 2 Results and Discussion

(1) Relationship between Initial COD and Remaining BSOM The initial concentration of COD was changed by diluting the original sewage with the tap water. Fig. 1 shows the variation of MLSS, E_{260} and COD with aeration time. As in Fig. 1(b), E_{260} decreased to the minimum value and then gradually increased. The relationship between the minimum E_{260} and the initial COD_F (filtrate COD) is shown in Fig. 2. The higher was the initial COD_F, the higher the minimum E_{260} became. Fig. 2 also shows that there was the same relationship between the minimum COD_F and the initial COD_F. These results may imply that there are some BSOM originated from the raw sewage.

(2) Effect of MLSS on Remaining BSOM The MLSS concentrations were set at four levels. The initial concentration of COD_F was 187 mg/l in all cases. Fig. 3 shows that the higher was the MLSS, the more rapidly E_{260} decreased. The minimum values of E_{260} and COD are summarized in Table 1. It is noted that all the minimum values of E_{260} and COD became almost the same within 40 to 70 hours. Therefore, it is concluded that there was no effect of the MLSS on the BSOM concentration until the amount of BSOM newly produced by the autoxidation of activated sludge became significant.

(3) Effect of SS in the Sewage Two kinds of different SS concentration but with the same soluble COD were prepared by sedimentation. Table 2 shows the characteristics of the sewage used. The initial MLSS was 1260 mg/l in both tests. First, as seen in Fig. 4, the reduction rate of MLSS for the sewage of higher SS concentration was higher than that for the sewage of lower SS concentration. This means that a considerable bio-oxidation of suspended organic matters has occurred. Second, Fig. 4(b) shows that the minimum level of E_{260} was almost the same for both cases in spite of a slight difference in the decreasing rate at the early stage of aeration. A similar mode is seen in Fig. 4(c) with respect to COD. Therefore, the nonbiodegradable fraction of COD is assumed to have been derived not from the suspended organic matters but from the soluble COD.

* Solids retention time, defined as a ratio of the mass of MLSS in the aeration tank to the mass of MLSS lost and wasted from the system per day.

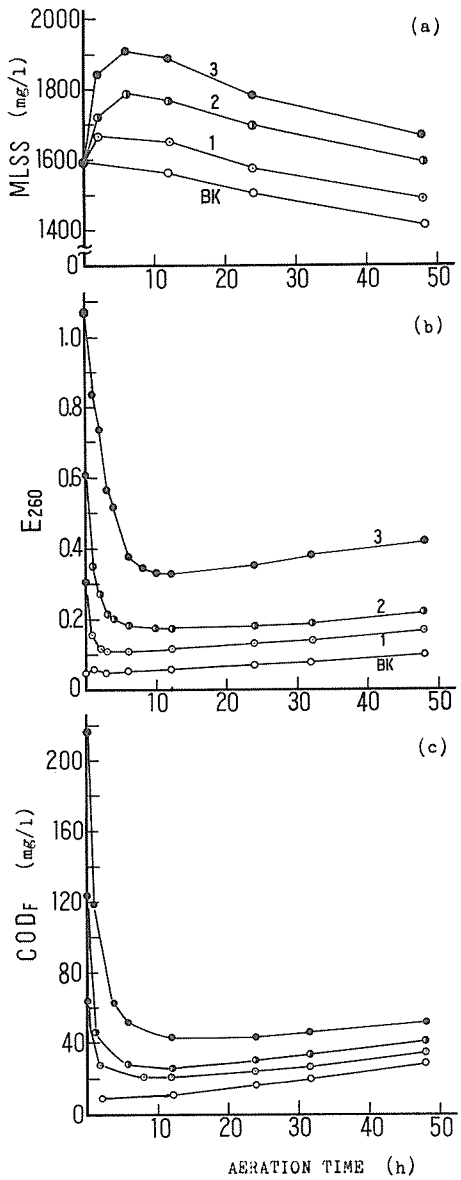

Fig. 1 Variation of MLSS, E_{260} and COD_F with aeration time

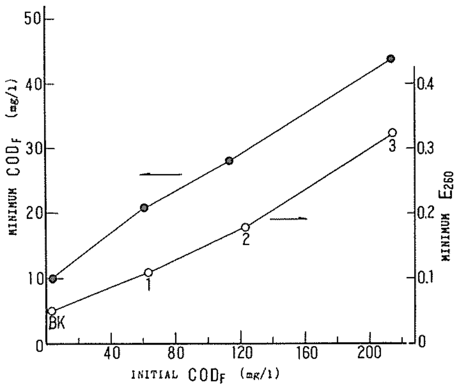

Fig. 2 Relationship between the minimum COD, E_{260} and the initial COD

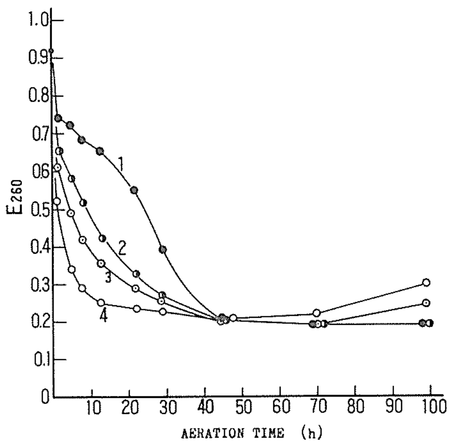

Fig. 3 Variation of E_{260} with MLSS and aeration time

(4) Effect of Seed Sludge Two kinds of activated sludge were used as seed. The SRT* was 8 and about 60 days, respectively. The former was obtained from a municipal sewage treatment plant and the latter was acclimatized in the laboratory as will be described later. The initial MLSS was 1680 mg/1 for the former and 2195 mg/1 for the latter, and the percentage of MLVSS was 69% for both sludges.

It is clearly seen from Fig. 5 that the removal rate of E_{260} for the smaller SRT sludge was higher than that for the larger SRT sludge but that the minimum level was almost identical (E_{260} : 0.175 and 0.195 ; COD : 26 and 27 mg/1). Whereas, the blank values did not show

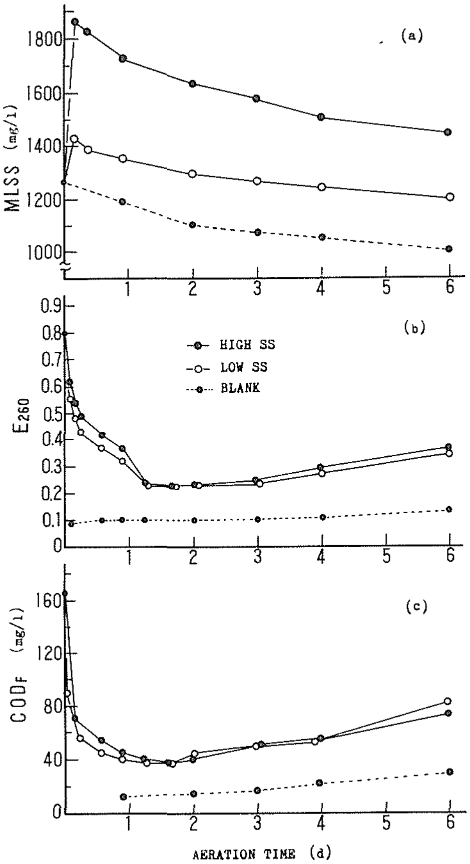

Fig. 4 Variation of MLSS, E_{260} and COD_F with aeration time and SS of sewage

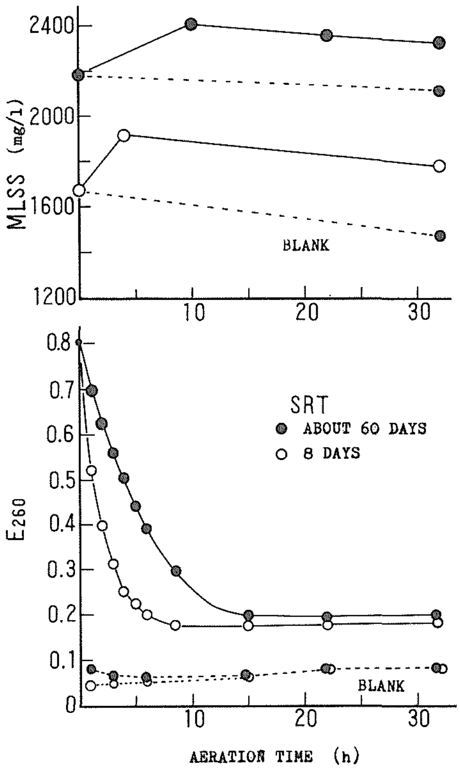

Fig. 5 Variation of MLSS and E_{260} with aeration time for different SRT

Table 1 Minimum values of E_{260} and COD_F

No.	Initial MLSS (mg/l)	Minimum E_{260}	Minimum COD_F (mg/l)
1	152	0.210	37
2	380	0.202	31
3	760	0.206	32
4	1520	0.210	33

Table 2 Initial concentrations of SS, COD_T and COD_F in the experiment (3)

Kind of sewage	SS (mg/l)	COD_T (mg/l)	COD_F (mg/l)	E_{260}
low SS	93	310	160	0.780
high SS	473	750	160	0.780

remarkable changes but they were almost the same in both cases. These results imply that the BSOM constituents included in the raw sewage were truly nonbiodegradable, contrary to an expectation that the activated sludge of large SRT could intensively oxidize the BSOM constituents due to the existence of the low growth-rate bacteria.

(5) Excretion Rate of BSOM in Autoxidation Process of Activated Sludge As in Figs. 1(b) and 3, both of E_{260} and COD gradually increased after reaching the point of minimum level. The specific excretion rates of BSOM, defined as the mass of BSOM excreted into the aqueous solution per unit mass of activated sludge decayed per day (Δg-COD/Δg-MLSS/d), were 0.066, 0.049, 0.040 and 0.023 for the blank test and the tests 1 to 3,

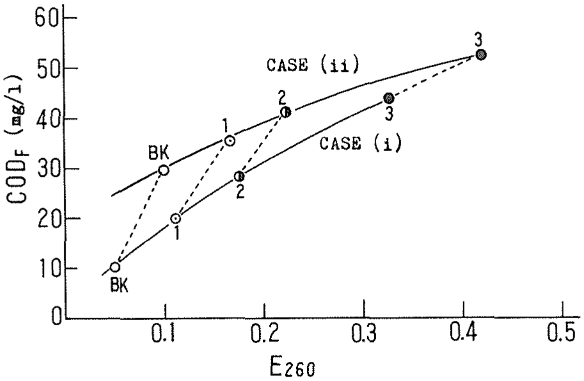

Fig. 6 Relationship between E_{260} and COD in the experiment (1)

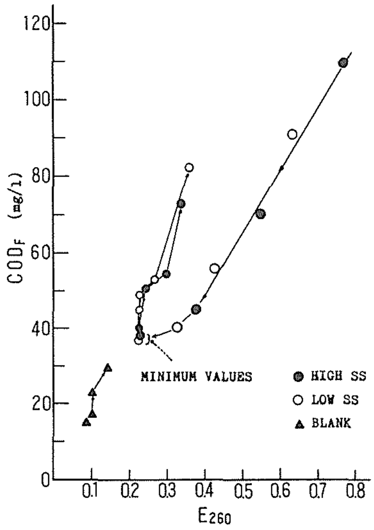

Fig. 7 Relationship between COD and E_{260} in the experiment (3)

respectively. These values were in the reverse order of the initial COD concentration. Figs. 1(c) and 3 also show that the lower the COD-SS loaidng was, the sooner the BSOM excretion started and the higher the specific excretion rate in the autoxidation stage was.

(6) Change of BSOM Constituent with Aeration Time Fig. 6 shows the relationship between E_{260} and COD obtained (i) at the point of time of the minimum level and (ii) after 48 hours. These data were obtained from the results of the experiment (1).

For the equiconcentration of initial COD slope became sharper as the initial concentration of COD decreased, and the two broad curved lines approached each other as the initial COD concentration became higher. Fig. 7 represents, in the same manner as shown above, the relationship between BOD and E_{260} corresponding to the results of Fig. 4. Before the time the minimum level was attained the slope was mild, whereas it became steeper after the excretion started. In the blank test, the slope was the same as in the latter case. From these results, it follows that the ratio of COD/E_{260} of newly excreted organic matters became higher as the initial organic loading decreased.

3. BSOM in Effluent from Continuous-flow Activated Sludge Process

3. 1 Experimental Material and Method

Two acryl resin tanks each which were divided into two parts by a partition wall were used for the experiment. The volume of the aeration part was 25 l for the detention time of 5 and 10 h and 50 l for 20, 40 and 100 h. The volume of the sedimentation part was about one fourth of the aeration part. The aeration part was mixed completely by diffused air and the temperature was kept at 20±1°C. The equally mixed sewage mentioned before was used except that the overflow rate of the sedimentation tank was about 70 m/d. The sewage was stocked in a cooled room at 1 to 2°C and fed continuously into the aeration part with a rotary pump. The domestication period of the sludge was about twice of SRT.

Table 3 Experimental conditions for continuous-flow test

Detention time (h)	Initial COD (mg/l)		MLSS (mg/l)	SRT (d)
	Total	Soluble		
5	530	190	2500～3100	5.2
10	490	170	2100～2500	15
20	340	182	2000～2300	27
40	475	195	1800～1900	37
100	490	200	1400～1500	60

Table 4 Experimental results

Detention time (h)	E_{260}		COD_F (mg/l)		COD_F/E_{260}		MLVSS (%)
	0.45 μm	5C	0.45 μm	5C	0.45 μm	5C	
5	0.171	0.295	39	59	228	200	83
10	0.165	0.210	33	43	200	205	80
20	0.175	0.187	35	38	200	203	77
40	0.166	0.197	25	30	151	152	71
100	0.231	0.260	32	40	139	154	69

The composite effluent was obtained every day and the soluble part was separated by a filtration using 5C and 0.45 μm membrane filter paper. The samples were analyzed by the usual gel-chromatographical technique using Sephadex G-15 gel. The measurement of COD and E_{260} was made on the mixture of three fractions around the E_{260} peak and ratio of COD/E_{260} was used as an index to evaluate the gel-chromatogram. Other conditions are summarized in Table 3.

3. 2 Results and Discussion

(1) Relationship between Effluent COD and Detention Time The results are summarized in Table 4. The effluent COD_F was the highest in the case of 5 h detention and was low in other cases. It is noted that a long detention time such as 100 h did not produce such a high COD as observed in the batch experiment mentioned before. The ratio of COD/E_{260} for both filtrates obtained using 0.45 μm membrane and No. 5C filter paper had a tendency of decreasing with detention time. It follows that the nonbiodegradable fraction of the effluent organic matter would increase as the organic load decreased. The percentage of the MLVSS representing the extent of autoxidation of the activated sludge decreased with detention time and this tendency was in agreement with the change of the COD/E_{260} ratio.

(2) Gel-chromatographical Characteristics of Organic Matters in Effluents The gel-chromatograms are shown in Fig. 8. When the E_{260} concentration was taken as an indicator, soluble organic matters in the effluent were classified into three groups invariant with the aeration time. Of the three peaks, the highest one was that of the group II and that of the group III was the lowest. Fig. 9 shows the relationship between the ratio of COD/E_{260} and the detention time for the groups I and II. All the ratios of COD/E_{260} for group I were much greater than those for group II. Fig. 9 also shows that the ratio of COD/E_{260} decreased with detention time for both groups except for the case of 5 h and that the difference between the groups I and II became smaller as the detention time was extended. From these facts it is assumed that the degree of aerobic biological treatment can be evaluated by use of the COD/E_{260} ratio of the effluent organic matters.

4. Summary

In order to examine the existence and the generation of biochemically stable organic matters, a batch and a continuous-flow test were conducted using domestic sewage from a housing development area. The concluding remarks are as follows.

1) The existence of BSOM in the raw sewage was confirmed from the fact that the

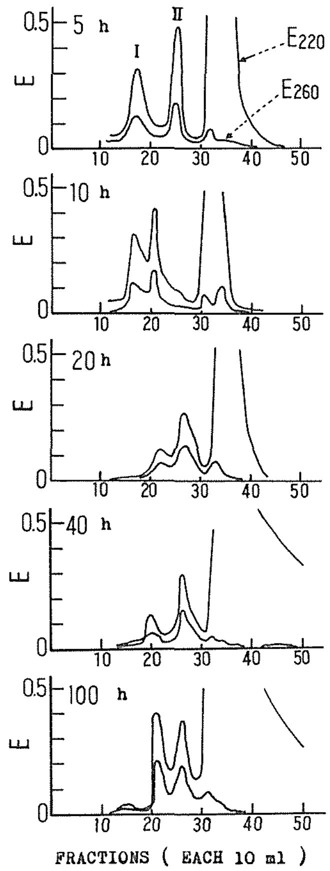

Fig. 8 Gel-chromatograms for the effluents

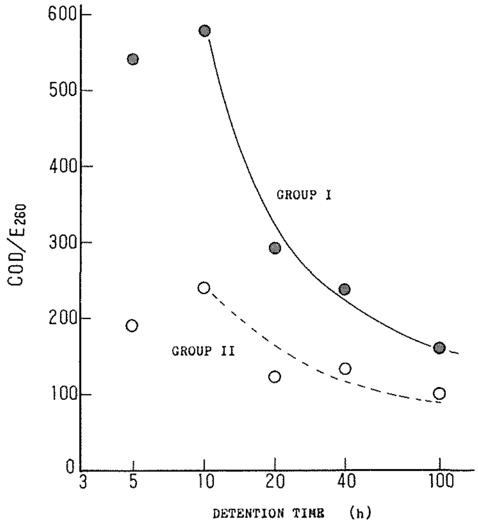

Fig. 9 Relationship between COD/E_{260} and detention time

minimum concentration level of E_{260} and COD proportionally increased with the initial COD concentration.

2) For a given initial COD concentration, the minimum level of COD and E_{260} was not affected by the SS concentration of the influent sewage, MLSS and SRT.

3) In the batch test, the lower the organic load was, the earlier the autoxidation accompanied with a newly excreted nonbiodegradable organic matter was initiated and also the higher the specific rate of BSOM excretion became.

4) Unlike the batch test, the soluble COD of the effluent in the continuous-flow test did not reach a high level even after 100 h.

5) The COD/E_{260} ratio of the effluent became higher as the aeration time in the batch test increased, whereas it became lower in the case of the continuous-flow test.