Application of the Concept of Soluble Microbial Product in Modeling Prediction

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1. Introduction

The existence of soluble microbial products (SMP) in biological wastewater treatment process has been widely demonstrated. The incorporation of SMP into the modeling of wastewater treatment has been studied in typical activated sludge process, biofilm process, and anaerobic chemostat etc. Membrane has been proved to be an effective tool in the field of wastewater treatment and is expected to be largely used in future. A model incorporating SMP formation and degradation may offer a rational approach to the performance of membrane bioreactor process. The IAWPRC Task Group proposed Activated Sludge Model (ASM) No.1 and ASM No.3 which allowed for the dynamic simulation of nitrification-denitrification in a variety of activated sludge flowschemes. Therefore, the objective of this study is to establish an available model by incorporating SMP concept into ASM No.3 in the membrane bioreactor process in order to accurately predict the treatment performance under given feed characteristics and operating conditions.

2. Materials and Methods

Two different categories of SMP are classified based on the bacterial phase from which they are derived. One is utilization-associated product (UAP), the other is biomass-associated product (BAP). The classification of organic matters in the wastewater in this study is as the same as that in the ASM No.3. The main difference of the present study with the ASM No.3 is that biomass decay acts to convert biomass into both particulate and soluble products, each is further divided into biodegradable and non-biodegradable groups. Generally, it is assumed that the products of hydrolysis are readily biodegradable soluble organics in ASM No.1, and as either readily biodegradable or inert soluble organics in ASM No.3. Taking the concept of SMP into consideration, it is reasonable to classify the products of particulate hydrolysis as SMP. Even though it is not exactly consistent with the definition of SMP.

The typical wastewater compositions used in the model simulation were taken from ASM No.3 (Table 1). Intermittent aerobic operating condition with a 30 min aeration - 30 min non-aeration was chosen for simulation prediction. Dissolved oxygen (DO) concentration was selected to be 3.0 mg/L under aerobic condition and 0.05 mg/L under non-aerobic condition. Parameters of the model in this study were taken mostly from ASM No.3 and parameters relative to SMP were calculated by trial and error method.

3. Results and Discussion

The simulation results of one cycle (hydraulic retention time (HRT) = 12 hr, sludge retention time (SRT) = 10 days) in a global steady-state condition are shown in Fig. 1. The total soluble COD consisted of three parts: soluble biodegradable COD from influent, SMP resulted from biomass activation and particulate hydrolysis, and soluble inert organic matter from influent and biomass decay, each consisted of less than 1.0%, 15.0%, and 84.6% of total soluble COD respectively in the reactor. The high S_I concentration in the reactor was a result of the high content in the substrate (about 23% of total soluble substrate) and partial retention by membrane separation. Apparently, S_S contributed little to the effluent COD and SMP can not be ignored in the treatment performance. SMP increased under aerobic condition due to the biomass activation and decreased under non-aerobic condition, fluctuating between 6.2-8.8 mgCOD/L in a single cycle in the reactor. The predicted effluent COD varied between 33.8-35.6 mgCOD/L in one cycle and was in the average of 34.7 mgCOD/

Table 1. The typical wasteweater compositions.

Symbol	Unit	Value
S_S	g COD m^{-3}	100
X_S	g COD m^{-3}	75
S_I	g COD m^{-3}	30
X_I	g COD m^{-3}	25
$X_{B.H}$	g COD m^{-3}	30
S_{NO}	g $NO_{2,3}$-N m^{-3}	0
S_{NH}	g NH_4-N m^{-3}	16
S_{ND}	g N m^{-3}	4.0
X_{ND}	g N m^{-3}	5.0

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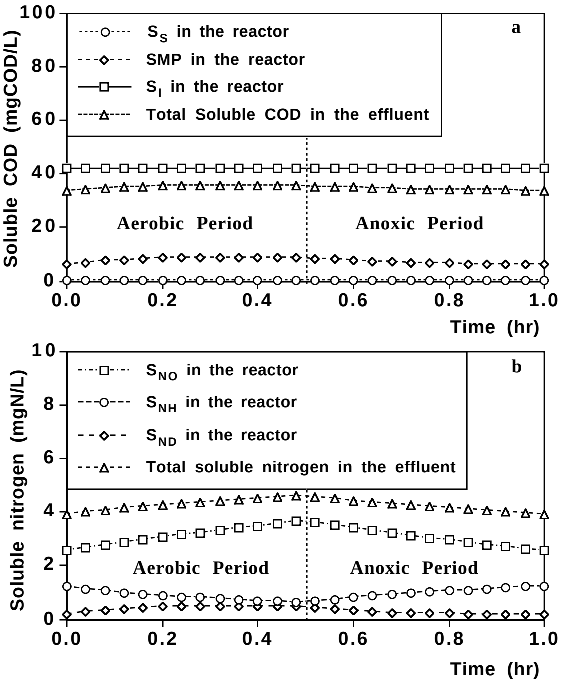
L at the steady-state condition.

Modeling prediction of soluble nitrogen showed that the total effluent nitrogen varied between 3.9-4.6 mgN/L. Ammonia nitrogen was consumed under aerobic condition and rose steadily under non-aerobic condition. Nitrate nitrogen was produced during aerobic period and decreased during non-aerobic period. The soluble organic nitrogen increased a little under aerobic condition and decreased a little under non-aerobic condition, It has a minimal effect on the total soluble nitrogen. Total soluble nitrogen increased gradually under aerobic period due to the input of substrate. It decreased under non-aerobic period due to exposure of N_2 by denitrification.

Modeling prediction showed that there was no significant variation of $X_{B.H}$, $X_{B.A}$, X_I, and MLVSS in one cycle at a global steady-state condition except of X_S, which varied between 11.2-17.7 mgCOD/L. The average values of particulate matters in the reactor were $X_{B.H}$: 1900 mgCOD/L; $X_{B.A}$: 32.6 mgCOD/L; X_I: 810 mgCOD/L; X_S: 14.4 mgCOD/L; MLVSS: 2070 mg/L under HRT = 12 hr and SRT = 10 days of operating condition.



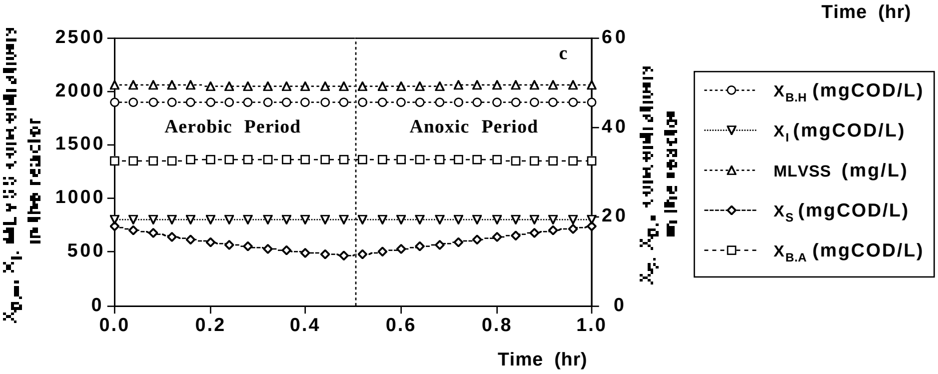


Fig. 1. Simulation results of one cycle in a global steady-state condition (HRT = 12 hr, SRT = 10 days) : (a). soluble COD; (b). soluble nitrogen; (c). biomass and particulate concentrations, in the reactor.

The results of HRT and SRT influences on the treatment performance are shown in Figs. 2 and 3. Effluent COD and nitrogen varied negligibly when HRT was between 8-24 hr. Under higher HRT condition, more substrate was available for biomass growth, and an efficient treatment performance was due to more heterotrophic and autotrophic bacteria remaining in the reactor. However, particulate inert organic matter (X_I) was also remained in the reactor and it contributed to about 29% of total sludge. On the other hand, effluent nitrogen decreased remarkably with the increase of SRT, and effluent COD seemed to vary negligibly. Biomass lost under lower SRT condition has significantly affected effluent nitrogen. With the increase of biomass concentration in the reactor, X_I also increased due to retention by membrane and it contributed to the total sludge from 22% (SRT = 5 day) to 40% (SRT = 20 day).

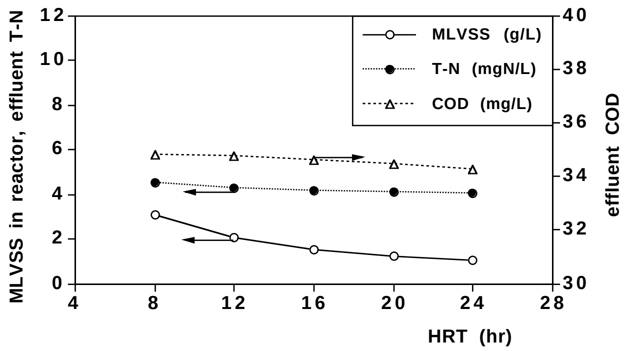


Fig. 2. Influence of HRT on the treatment performance (SRT=10 days).

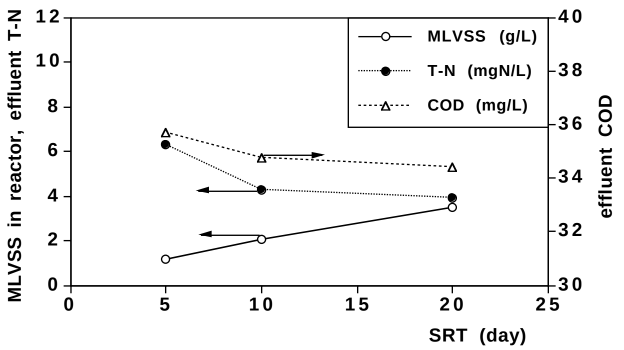


Fig. 3. Influence of SRT on the treatment performance (HRT=10 hr).

4. Summary

By incorporating SMP concept into ASM No.3, the model could provide a more comprehensive image for biological wastewater treatment process and therefore make it a more reasonable tool for practical engineering.