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Uptake of Wastewater Organic Matter to Activated Sludge

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Abstract: The influences of contact time and ratio of food to microorganism (F/M) on uptake of wastewater organic matter in a short contact process were investigated using three activated sludge batch reactors fed with synthetic wastewater, sewage and livestock wastewater. About 64% of influent soluble chemical oxygen demand (SCOD) in the synthetic wastewater and 61% of SCOD in the sewage and 43% of SCOD in the diluted livestock wastewater were adsorbed into the activated sludge within 30 min. The specific mass of organic matter uptaken in the synthetic wastewater was 55 mg SCOD/g mixed liquor suspended solids (MLSS). In the same manner, 20 and 14 mg SCOD/g MLSS were calculated as the values in the sewage and livestock wastewater, respectively.

Keywords: uptake, activated sludge, wastewater organic matter, contact time, ratio of food to microorganism (F/M)

Introduction

Several problems caused by nitrogenous materials in the wastewater include adverse public health effects, biochemical oxygen demand in receiving waters, eutrophication, toxicity to aquatic life, reduction of chlorine disinfection efficiency, and reduction in the suitability of treated wastewater for reuse (US EPA, 1993). For the removal of nitrogenous compounds in wastewaters, biological nutrient removal (BNR) process consisting of nitrification and denitrification has become a common technology. However, wastewater having a low chemical oxygen demand/nitrogen (COD/N) ratio is difficult to achieve a successful removal of nitrogen because it results in a lack of organic matter in subsequent denitrifying stage (Jones *et al.*, 1990; Issacs and Henze, 1995; Pawel *et al.*, 2007). In single sludge BNR processes, most of the influent organic matter is oxidized along with some ammonia-nitrogen in the aerobic stage (Tseng *et al.*, 1998; Young *et al.*, 2001). When the influent organic matter is not sufficient as an electron donor, external carbon has to be added for denitrification. One of the desirable methods to improve the denitrification efficiency is to make use of the influent organic matter. If the influent organic matter is separated from the influent, it can be utilized at the denitrification stage. The activated sludge microorganisms have capabilities of uptaking organic matters on their surfaces. Previous microbial uptake studies have focused mainly on a biosorption such as an accumulation of heavy metals or toxic compounds (Ovez *et al.*, 2006; Cho and Choi, 1995; Mary and Aiden, 1983; Nam and Choi, 2006; Nielsen, 1996; Tsezos *et al.*, 1989), however, little attention has been given to the uptake of organic matter to the activated sludge (Majone *et al.*, 1999; Elefsiniotis and Li, 2006). Thus, it was attempted to quantify the specific mass of organic matter uptaken to the activated sludge.

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Materials and Methods

The microorganisms used in this study were obtained from a sequencing batch reactor (SBR) fed on sewage (Table 1). A 3 L cylindrical sequencing batch reactor (SBR) having an agitator and a membrane air diffuser was operated to achieve organic removal and denitrification. Devices for feeding, decanting and aeration were controlled automatically by timers and solenoid valves. The operation cycle time was 8 hours consisting feeding (4 h), reaction (2 h), settling (1 h) and decanting/idling (1 h). Livestock wastewater was diluted ten times for comparison of the result with sewage. The sludge taken from the SBR at the settling stage was aerated for 2 hrs followed by washing

Table 1. Composition of sewage, livestock and synthetic wastewater

Components	Sewage	Livestock (diluted ten times)	Synthetic wastewater
TSS (mg/*l*)	214 (199~242)	115 (100~140)	-
TCOD (mg/*l*)	255 (189~281)	178 (128~244)	-
SCOD (mg/*l*)	99 (91~153)	98 (89~128)	250 as glucose
Ammonia-N (mg/*l*)	37 (22~42)	45 (37~61)	30 as $(NH_4)_2SO_4$
Nitrate-N (mg/*l*)	0.3 (0~0.6)	-	30 as KNO_3
T-P (mg/*l*)	3.9 (2~7)	5.2 (3.5~7.2)	-
Ortho-P (mg/*l*)	3.2 (2~5)	3.7 (2.8~4.1)	5 as KH_2PO_4
pH	6.7~7.3	7.6~7.7	7.1

Note) Concentrations indicate mean concentrations with the minimum and maximum values in parentheses.

twice with deionized water. Then it was introduced into the flask together with each one of the tested wastewaters as shown in Table 1, respectively. Specific mass of uptake was measured as contact time and ratio of food to microorganisms (F/M). The average MLSS in the batch reactor was kept at about 3,000 mg/*l* and the reaction was conducted at room temperature.

For the analysis of soluble parameters, samples were pre-filtered by a membrane filter (1.2 μm, glass fiber). COD was determined by the closed reflux titrimetric method. The measurements of other parameters followed the procedures described in *Standard Methods* (APHA, AWWA, WEF, 2005).

Results and Discussion

Specific Mass of Organic Matter

The carbon removal process is carried out in the contact tank. In this tank, easily degradable organic material was uptaken at high concentrations, while the larger and slowly degrading material was encapsulated within the floc. Soluble material is removed rapidly under these conditions, and colloidal material can be subjected to partial attack by extracellular enzymes, but significant quantities of larger particulate material and storage compounds would be retained for the later use by the organisms in denitrification.

The specific mass of organic matter uptaken by activated sludge was determined by measuring SCOD concentration. The mass of organic matter uptaken (x) was equal to the decreased SCOD concentration in the reaction time (Eq. 1). Specific uptake of organic matter (mg SCOD/g MLSS) was SCOD (x) uptaken in unit microorganism (M_b) (Eq. 2).

$$x\ (mg\ SCOD) = V(SCOD_0 - SCOD_t) \quad (1)$$

$$x/M_b\ (mg\ SCOD/g\ MLSS) = V(SCOD_0 - SCOD_t)/M_b \quad (2)$$

where x is the mass of organic substrate (mg SCOD) uptaken to the activated sludge, M_b (g MLSS) is the total mass of microorganism in the reactor, V (L) is the liquid volume added to the reactor, $SCOD_0$ (mg/*l*) is the initial SCOD, and $SCOD_t$ (mg/*l*) is the SCOD at time t.

Uptake of Organic Matter

As shown in Fig. 1 and Table 2, approximately 64% of SCOD in the synthetic wastewater and 61% of SCOD in the sewage were reduced by the activated sludge in 30 min contact. While the SCOD of the diluted livestock wastewater was decreased about 43% in the same contact time. As shown in Fig. 2, the uptaken organic matter in the synthetic wastewater was 166 mg as SCOD/L in 30 min, however, it was increased by only about 6% in another 30 min. Based on the result, the specific mass of organic matter uptaken was 55 mg SCOD/g MLSS in 30 min. In the same manner, it was about 20 and 14 mg SCOD/g MLSS for the sewage and livestock wastewater, respectively. In case of sewage, there was no more uptake after 30 min contact time. The maximum SCOD uptake in the livestock wastewater was measured at 30 min and the X_{30}/X_{60} ratio was 1.16. And the ratios of synthetic wastewater and sewage

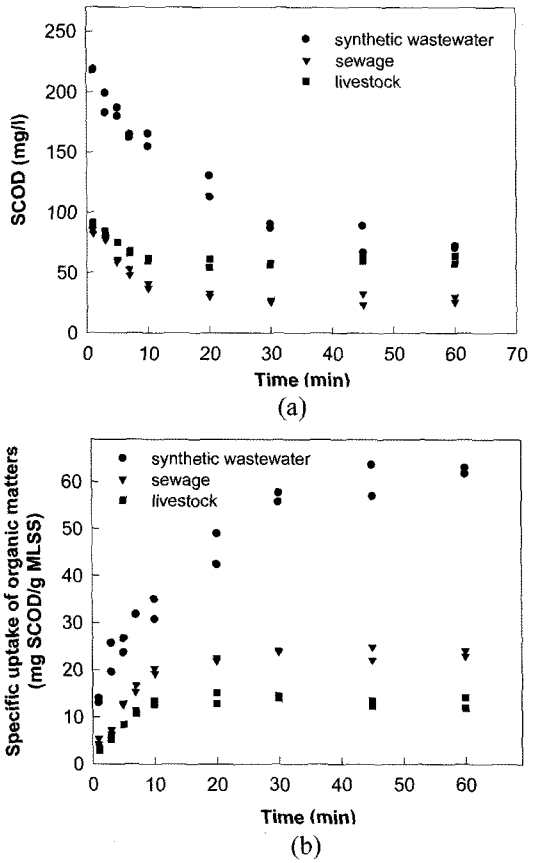

Fig. 1. Organic (SCOD) sorption (a) and mass of organic matter uptaken (b).

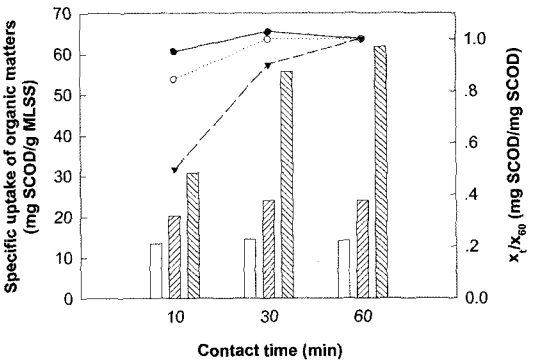

Fig. 2. Specific uptake of organic matter to activated sludge; (▭) livestock, (▨) sewage, (▩) synthetic wastewater, (—●—) x_t/x_{60} livestock, (···○···) x_t/x_{60} sewage, (–▼–) x_t/x_{60} synthetic wastewater.

were 0.91 and 0.99, respectively. Thus, the 30 min contact time was enough to achieve the responsible organic uptake reaction.

The reversibility of the uptake process was studied by examining desorption of the same compounds from the sludge, but it was not observed during the contact time. Once the organic material has been removed, a number of intermediate reactions including intracellular and extracellular could be possible. Intracellular substrate can be oxidized for energy production, incorporated into new cellular components, or stored as glycogen, PHB, or other storage compounds. Synthesis of easily degradable storage compounds is particularly important because they can be used for denitrification under starvation conditions. During biological uptake, organic materials metabolized only slightly and most of them were stored as an available substrate form (Alleman and Irvine, 1980). Based on the above facts, a rapid-reaction mode results in uptake but incomplete metabolism of organic material. Thus, the preserved organic material can contribute to the following denitrification.

The specific values of organic matter uptaken were measured at the different F/M ratios. The specific uptake rates of the synthetic wastewater were investigated around 55 mg SCOD/g MLSS over the F/M ratios from 0.45-1.1. In cases of the sewage and the livestock wastewater, the specific uptake rates increased slowly in the studied F/M

Table 2. Result of batch experiment (average value)

Sludge used	$SCOD_0$ (mg/l)	$SCOD_{uptake}$ (mg)		mg $SCOD_{uptake}$/g MLSS	
	t = 0 min	t = 30 min	t = 60 min	t = 30 min	t = 60 min
G	259[a]	166 (64%)	187	55	63
S	99[b]	60 (61%)	61	20	21
S	100[c]	43 (43%)	39	15	14

Note) a: synthetic wastewater, b: sewage, c: livestock (diluted), G: sludge acclimated with glucose, S: sludge acclimated with sewage, MLSS: 3,000 mg/l, Reactor volume: 1,000 ml, (%): $SCOD_{uptake}$ at 30 min/$SCOD_0$.

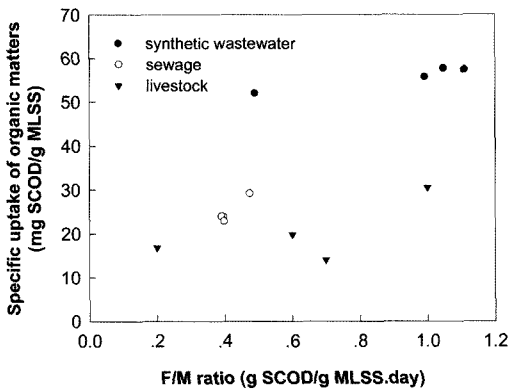

Fig. 3. Specific mass of organic matters at the several F/M ratios.

ratios (Fig. 3).

Conclusion

Approximately 64% of soluble chemical oxygen demand (SCOD) in the synthetic wastewater and 61% of SCOD in the sewage were reduced by or sorbed into the activated sludge in 30-min contact. While the SCOD of the diluted livestock wastewater was reduced by about 43% at the same contact time. Based on the result, the specific mass of organic matter uptaken was 55 mg SCOD/g mixed liquor suspended solids (MLSS) in 30 min. In the same manner, about 20 and 14 mg SCOD/g MLSS were calculated as the values in the sewage and livestock wastewater, respectively.

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