Turbulence Characteristics in a Cylindrical Reactor Mixed by Paddles and its Effect on Nitrifying Biofilm Activity

°Sivapragasam Kugaprasatham, Hiroshi Nagaoka and Shinichiro Ohgaki
Department of Urban Engineering, The University of Tokyo

1. INTRODUCTION

Biofilms are used in many wastewater treatment processes and are also important in self purification of rivers. Consequently, biofilm theories were developed to describe biofilm behaviour. Despite the fact that some biofilm surfaces are rough and flutter (Nagaoka, H. and Ohgaki, S., 1988) in the water, biofilm surfaces were assumed to be flat for simplicity. Water flow over the fluttering biofilm may produce turbulent eddies near the biofilm and turbulence near interfaces are known to increase interphase mass transfer. Thus information on the effect of hydraulic parameters such as turbulent intensity, velocity is required for understanding biofilm behaviour. The objective of this study was to investigate the effect of turbulence on biofilm activity.

2. Materials and Method

Experimental investigation was conducted as follows;
Step 1 : measurement of hydraulic conditions,
Step 2 : measurement of biofilm activity.

2.1 Measurement of hydraulic condition: Fig. 1 shows the experimental set-up. Hydraulic measurements were made without biofilm. A cylindrical reactor of 40 cm diameter and 60 cm height(working height is 46 cm) was used. Paddles of 4 cm (C04) and 8 cm (C08) width and each 2 cm height, spaced at 2 cm along the central axis of the reactor were rotated at 200 to 600 rpm and velocity variation was measured using a hotfilm anemometer at 4mm from the reactor wall along the depth of the reactor. Also, shaft without paddles (S) was rotated at 300 rpm and the above measurements were made. Temperature of the water was kept at 20.0°C. Turbulent energy spectrum (two-sided) for wave numbers upto 28 rad/cm was obtained from the velocity data using a computer program. Integrated turbulent energy spectrum was obtained by integrating the turbulent energy spectrum over an interval of wave numbers.

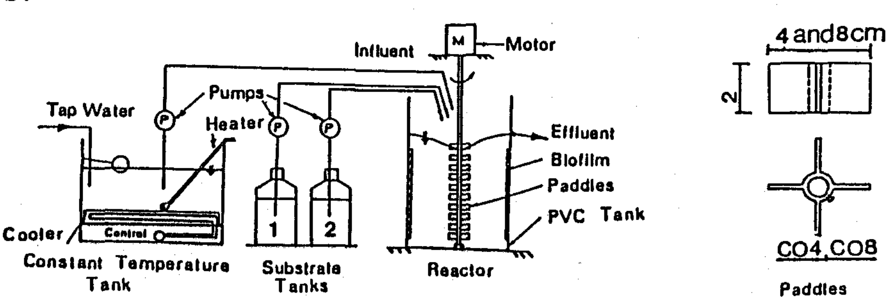

Fig. 1 Experimental Set-up

2.2 Measurement of biofilm activity: Biofilm activity was measured as the NH_4-N flux into the biofilm. Base hydraulic condition was selected as 8 cm width paddle (C08) rotating at 400 rpm to grow nitrifying biofilm. Reactor was seeded with sludge cultured using a substrate

Table 1. Contents of Substrate in g/l

Substrate 1		Substrate 2	
NH_4Cl	17.19	K_2HPO_4	3.09
$CaCl_2$	3.09	KH_2PO_4	0.96
$MgSO_4$	1.24	Na_2HPO_4	1.98
		$NaHCO_3$	56.23

(Table 1) containing ammonium chloride as sole nitrogen source and without any organic carbon source. Reactor was operated by fill and draw method until substantial biofilm growth can be observed on the wall of the reactor and continuous feeding of sustrate was commenced as shown in Fig. 1, thereafter. Hydraulic detention time during biofilm activity measurements was 1.9-2.0 h to exclude any suspended bacteria in the reactor. Change in biofilm activity for short term (6-12 h) change in hydraulic condition were measured. Sampling was done after at least three times the hydraulic detention time has passed from the time when removal of biofilm on the paddles, top and bottom 8 cm of the reactor wall and the reactor bottom was finished. Removal of biofilm was to exclude those areas where the hydraulic conditions are not uniform. NH_4-N concentrations of substrate 1, tapwater and that in different depth of the reactor were measured using indo-phenol method (Josui Shiken Hoho, 1985). DO in the reactor and the flow rate of substrate 1 and tapwater were measured individually. Temperature in the reactor was 20-22 ^oC.

3. RESULTS AND DISCUSSION

Velocity and turbulent intensity along the depth of the reactor was found to be within 10 % and 15 % of the maximum value, respectively except in the top and bottom 8 cm of the reactor. The

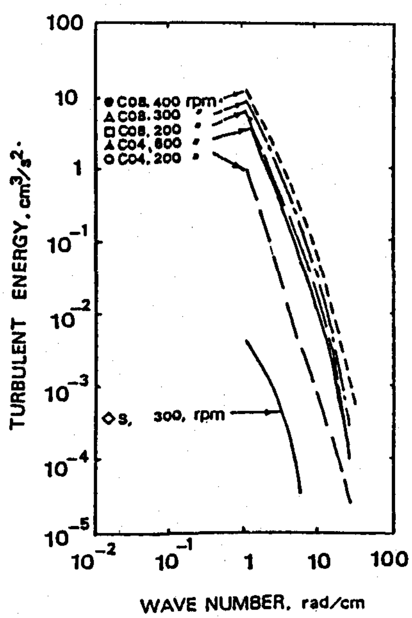

Fig. 2 Integrated turbulent energy spectrum

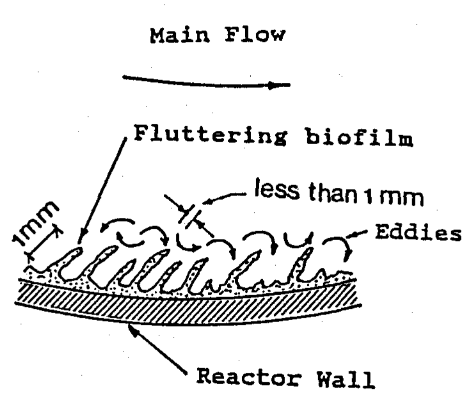

Fig. 3 Schematic of the nitrifying biofilm

above variations were assumed to be uniform for the biofilm activity measurement. Due to support arrangements to the hotfilm anemometer, velocity could not be measured closer than 4 mm from the reactor wall. However, difference between the integrated turbulent energy spectrum at 6 mm and 20 mm to that of 4 mm was found to be negligible. Fig. 2 shows smooth curves drawn from the integrated turbulent energy spectrum and the shape of the curves are only a little different.

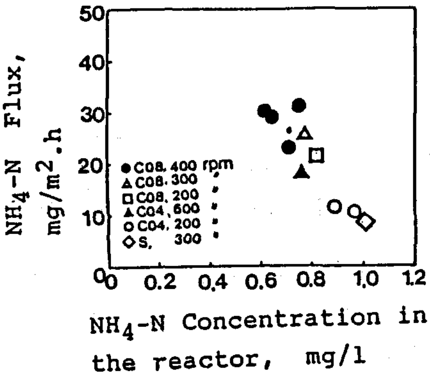

Fig. 4 Biofilm activity at different ammonia concentrations

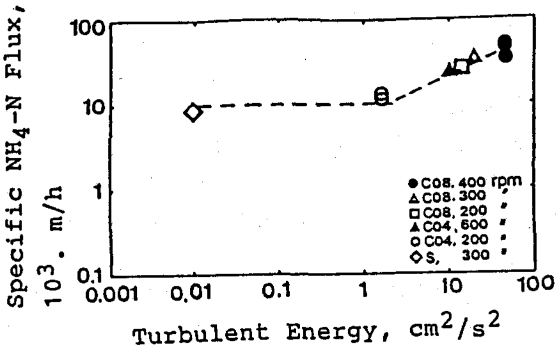

Fig. 5 Variation of biofilm activity with turbulent energy near biofilm

Biofilm observed on the wall was very thin and having fluttering parts of about 1 mm in length (Fig. 3). Width was less than 1 mm. DO concentration in the reactor was above 6 mg/l. Fig. 4 shows the NH_4-N flux and NH_4-N concentration in the reactor. NH_4-N flux was the maximum at base condition and decreased for short term decrease of velocity and turbulent intensity. Influent NH_4-N concentration was 1.0-1.1 mg/l. Biofilm reaction kinetics was assumed to be first order. Thus, specific NH_4-N flux (NH_4-N flux/ NH_4-N concentration) was obtained from Fig. 4 and its variation with turbulent energy is shown in Fig. 5. Specific flux increased with turbulent energy. However, when the turbulent energy was very small (**S**, 300rpm and **C04** 200 rpm) fluttering of biofilm was not observed. During the above conditions, molecular diffusion occurs, thus the flux did not change very much showing a lower limit of flux. However, fluttering of biofilm was observed at high velocities which may be the cause of increased biofilm activity.

REFERENCE

Nagaoka, H. and Ohgaki, S.(1988) Effect of turbulence on biofilm activity, in Water Pollution Control in Asia, proceedings of second IAWPRC Asian Conference on water pollution control, Bangkok, Thailand, T. Pansawad, C. Polprasert and K. Yamamoto (editors), pp 155-161.