Biological Denitrification in Attached-growth Reactor*

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The denitrification in attached-growth system was made using the expanded bed reactor with particle activated carbon as biofilm supporting carrier. The over 95 percent removal efficiency was achieved at a volumetric nitrogen loading of 9 Kg NO_3-N/m^3·day with the corresponding hydraulic retention time of only 9.1 min. The average concentration of biomass in the column was in the range of about 15000 to 20000 mg/l as MLSS equivalence. Therefore, it turned out that the volumetric loadings made possible by use of expanded bed increased to an order of magnitude greater, compared with those in conventional suspended-growth system.

INTRODUCTION

In recent years, much attention has been given to the removal of oxidized forms of nitrogen from wastewaters because of their association with public health and severe entrophication problem. At present, the biological denitrification process seems to have the greatest potential among the alternative techniques which have been proposed for reducing the nitrogen content of wastewaters, because of its economic feasibility. Many common facultative heterotrophs are capable of performing denitrification, reducing nitrate and nitrite to gaseous end products, principally molecular nitrogen, under anoxic condition. The molecular nitrogen end product is an inert gas which, unlike other nitrogen compounds, is relatively unavailable for biological growth. Denitrification can be carried out in either suspended-growth or attached-growth reactor. The major disadvantages of these process lie in the requirements of available carbon sources and relatively large areas of plant.

The economically attractive way for denitrification process is to use the fluidized bed or expanded bed reactors. It is possible in fluidized bed or expanded bed reactors to achieve biomass concentrations 15 to 40 g/l as MLSS, compared with 3 to 5 g/l that is usually the upper-limit in conventional suspended-growth system (e.g., [4]) because of difficulty in settling higher concentration of mixed liquor. The high biomass concentration allows the hydraulic retention time required for denitrification to be significantly reduced, leading to a five to even tenfold reduction in reactor size and cost for build and run.

The purpose of this study is to investigate denitrifying capability and to enhance the process performance of the expanded bed reactor with the aim to develope the effective operational strategies for reduction in plant area requirement.

MATERIALS AND METHODS

Experimental apparatus.

The expanded bed reactor used in this study, as shown in Fig. 1, is 3.0 mm in inner diam and 2.0 m in height (effective height of 1.7 m), having an effective volume of 1.20 liter. The column was packed with spherical activated carbon, 0.25 to 0.6 mm in diam and mean size of 0.4 mm, as biofilm supporting carrier and filled to a depth of 1.0 m, with the packing porosity of 0.37. The characteristics of the activated carbon used was as follows: bulk density = 0.5–0.55 g/ml, apparent density = 0.8–0.9 g/ml, true density = 2.0–2.1 g/ml, and specific surface area = 800–1100 m^2/g. Sampling ports of 1.0 cm in diam were positioned every 10 cm along the height of the column. The rotary mixer at the top of the column was used at

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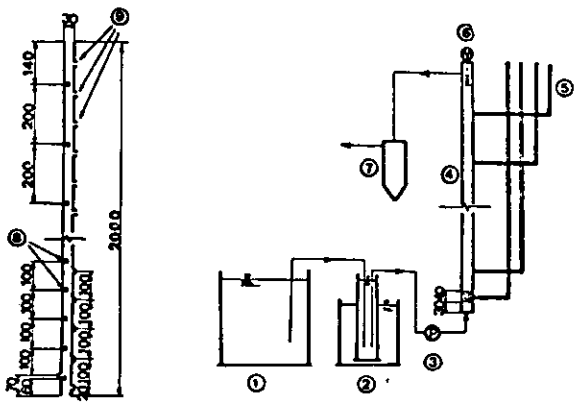

Fig. 1

Table. 1

Conditions and Efficiency	RunⅠ	RunⅡ	RunⅢ	RunⅣ	RunⅤ
L V (m/h)	11	11	6.2	8.7	11
R T (min)	8.9	9.1	15.4	11.8	9.6
NO_3-N (mg/l)	16	35	70	70	70
CH_3OH (mg/l)	48	105	210	210	210
Loading (kg NO_3-N/m^3·day)	2.8	5.7	6.4	9	10.3
Efficiency (%)	100	97	100	95	65

60 r.p.m. to control biological growth by shearing the biofilm off as particle carrier height increases.

Medium.

The influent substrate concentration employed for expanded bed experiment is shown in TABLE 1, together with operational condition and removal efficiencies. Methanol was used as the sole carbon source, and the influent ratio of CH_3OH/N was adjusted to approximately 3. Throughout the study, sodium sulfite at concentration of 70 mg/l was added to control the influent dissolved oxygen below 2.0 mg/l. The inorganic salts was compounded as follows: 125 mg of KH_2PO_4, 40 mg of $MgSO_4$, 3 mg of $CaCl_2$, 0.4 mg of $CuSO_4$, 0.08 mg of $MnSO_4 \cdot H_2O$, and 0.12 mg $FeCl_2 \cdot 6H_2O$ per liter of tap water.

Operational procedures.

A long-term operation of the column lasted at a superficial upflow rate (termed linear velocity hereinafter) of 11 m/hr and influent nitrate concentration of 16 mg NO_3-N/l, until steady state reduction of nitrate and biofilm growth onto the carriers were accomplished. Then, two series of experiments were carried out. At the first stage, the influent nitrate concentration was adjusted to 16, 35, and 70 mg NO_3-N/l, keeping the CH_3OH/N ratio the same at 3, at a fixed linear velocity of 11 m/hr. In the second stage, the linear velocity of the feed was adjusted to 6.2, 2.7 and 11.0 m/hr, at a fixed influent concentration of 70 mg NO_3N/l.

RESULTS AND DISCUSSION

The recycle of the raw sewage was used to aid in developing biofilm growth on the carrier particles during a start-up period of about two weeks, and the system was run up to steady

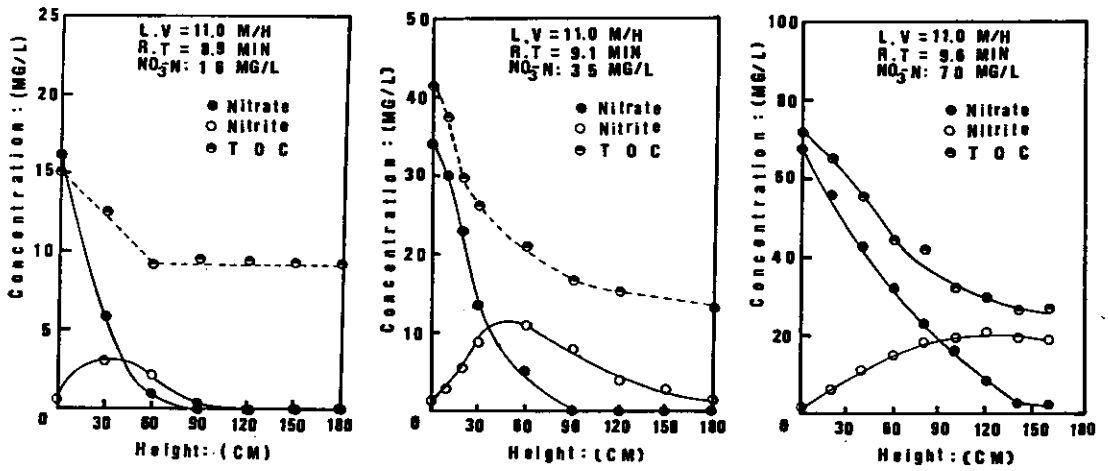

Fig. 2

state using the synthetic waste containing nitrate nitrogen of 16 mg/l at a linear velocity (LV) of 11.0 m/hr over a period of 30 days.

Once the expansion of bed accompanied with the biofilm growth had ceased and the bed was constantly removing nitrate, the following experiments were carried out to determine the operational characteristics at a high linear velocity of 11.0 m/hr.

In the first experiments (run I, II and V), the influent concentration of nitrate varied between 16 mg NO_3-N/1 and 70 mg NO_3-N/1 at a fixed linear velocity of 11.0 m/hr, resulting in the retention time of only approximate 9 min.

Figure 2 shows the profiles of nitrate, nitrite and total organic carbon through the column for the run I, II and V, respectively. Figure 3 shows the results of the second experiments (run III, IV and V) in which the linear velocity of influent varied between 6.2 m/hr and 11.0 m/hr at a fixed influent nitrate concentration, 70 mg NO_3-N/1. The accumulation of nitrite increased through the bed with the increase in influent nitrate concentration together with the decrease in retention time, that is, with the increase in volumetric nitrate loading rate, as shown in Figs. 2 and 3. The dependence of nitrate removal efficiency on volumetric nitrate loading rate is shown in TABLE 1. The data show a significant removal of nitrate nitrogen (70 mg NO_3-N/1) in a superficial retention time of only 12 min. The removal efficiency greater than 95% was achievable up to the volumetric nitrate loading of 9 Kg NO_3-N/m^3·day, which is much higher than was achieved in the expanded bed experiment (2.7 Kg NO_3-N/m^3·day) made by Bailey et al. [1], and compared well with that reported by Jeris *et al.* [2], for fluidized bed using methanol. This volumetric rate of denitrification is nearly an order of magnitude greater than that in the conventional suspended-growth system.

The amount of methanol required for nitrate reduction to nitrite and nitrogen gas were calculated from the data obtained in the runs I, II and V.

The calculated values for the runs II and V, 2.45 and 2.57 (g CH_3OH/g NO_3-N), respectively, were well in agreement with the observation by McCarty *et al.* [3], whereas that for the run I was about a half of these values for the runs II and V.

Figure 4 shows the variation in attached biomass concentration and voidage of particles coated with biofilm with the height of column at a linear velocity of 11.0 m/hr.

biomass (Y coordinate) which was measured by CN analyzer, as shown in the insert of Fig.

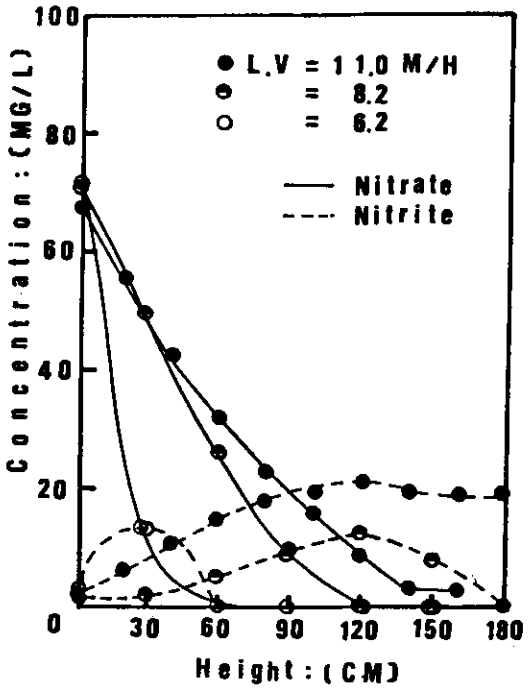

Fig. 3

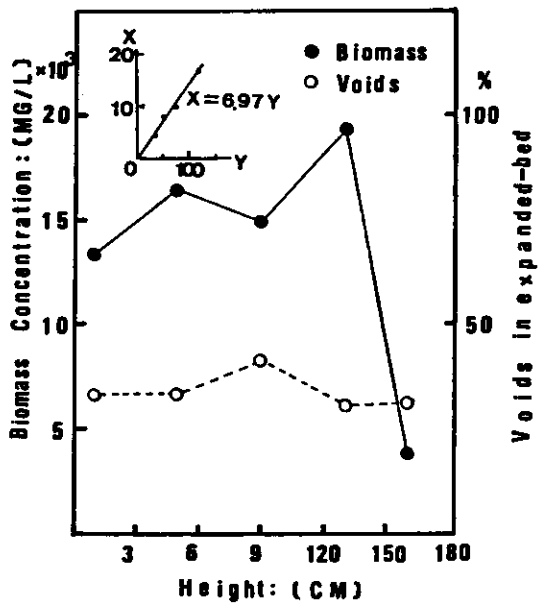

Fig. 4

The relationship between dry weight of detached biomass from supporting particle (X coordinate) and nitrogen content of detached 4, was used to determine the attached biomass concentration through the column. The biomass concentration ranged between 15 g/l and 20 g/l and decreased remarkably near the outlet of the column. The rate of denitrification expressed in terms of the biomass, in the range of 17–24 (mg NO_3/N/g cell·hr), was as high as the maximum rates reported for suspended-growth systems [4]. Therefore, the denitrification capability of expanded bed, even an order of magnitude greater than that of suspended-growth system, is attributable to high biomass concentration in the column.

CONCLUSIONS

Expanded bed reactor with particle activated carbon as the biofilm supporting carrier was employed with an aim to develope the strategy of high rate denitrification. The rate of denitrification achievable in the expanded bed was observed to be approximately 9 Kg NO_3-N/m^3·day, indicating an order of magnitude greater than that in conventional suspended-growth system.

ACKNOWLEDGEMENT

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