Nitrification and Organic Oxidation Using Polyethylene Bio-carrier

Presented in 12th International Conference on Integrated Diffuse Pollution Management (IWA DIPCON 2008).
Research Center for Environmental and Hazardous Substance Management (EHSM)

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Abstract

The objective of this study is to examine the effect of added polyethylene bio-carrier (SOFTRON CUBE) on nitrification and organic oxidation in the aeration tank. It was found that high microbial growth inside the bio-carrier promoted higher removal rate of ammonia nitrogen and organic oxidation in the batch aeration reactor. Addition of bio-carrier helps improve the removal efficiency without expanding the aeration tank.

Keywords: Bio-carrier, Nitrification, Organic Oxidation

Introduction

The activated sludge process is a most common process for wastewater treatment in Japan. Modification of an existing activated sludge system is required when inflow organic loading increases and exceeds the system capacity. Various methods are available for the modification of such an activated sludge system i.e. adjusting aeration, introducing pre-treatment or expanding an aeration tank, etc. Due to the limitation of area, it is difficult to improve the removal efficiency of an activated sludge system by increasing the size of the aeration tank when the influent volumetric flow or loading exceeds the design capacity or when nutrient removal is required. Addition of porous media with high specific area for microbial attached growth, so-called bio-carrier, in an aeration tank is considered as a potential alternative to increase the removal efficiency. In this study, the improvement on nitrification and organic oxidation of a conventional activated sludge system using polyethylene bio-carrier was examined. The experiments were carried out in laboratory scale and pilot scale with synthetic wastewater. Results from this study leads to a solution for improving a wastewater treatment system with limit space and budget as well as promoting nutrient removal in an activated sludge system.

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Bio-carrier: Properties and Application

A bio-carrier is a porous media made from either inorganic materials such as anthracite and granular ceramics or organic materials such as polyurethane, nylon (Heitkamp and Stewart, 1996), polyethylene (Sekisui Aqua Systems Co., Ltd. 2006) and polyethylene glycol (Nisshinbo Industries, Inc., 2003). According to its high specific surface area, the bio-carrier can hold large amount of biomass in an aeration tank without enlarging the scale of an activated sludge system. Moreover, high biomass maintained by the bio-carrier make it possible to reduce the rate of return sludge (Nisshinbo Industries, Inc., 2003). At present, bio-carrier is widely use in municipal and industrial wastewater treatment.

The polyethylene bio-carrier (SOFTRON CUBE) is developed based on bridge formation foaming technology. The SOFTRON CUBEs are shown in Figure 1. Basic properties of SOFTRON CUBE (Sekisui Aqua Systems Co., Ltd., 2006) are listed in Table 1.

After 140 days of durability test in the water, remaining weight ratio of SOFTRON CUBE is 97.6% which is 2.44 times of polyurethane bio-carrier (40%).

Table 1. Properties of SOFTRON CUBE.

Material	Polyethylene
Size	10 mm x 10 mm x 10 mm
Void ratio	96%
Specific surface area	3000 m^2/m^3
Specific gravity	0.99 g/cm^2

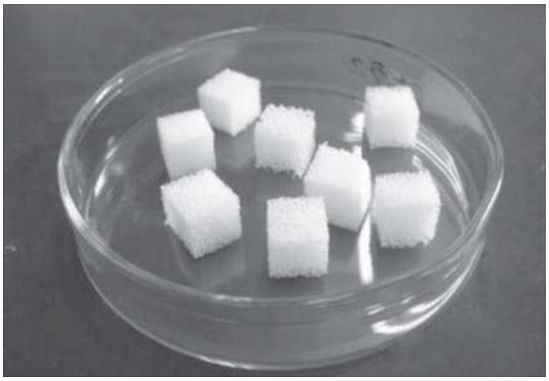

Figure 1. Polyethylene bio-carrier, SOFTRON CUBE

Methodology

Two batch experiments were carried out in this study in order to examine effects of SOFTRON CUBE on nitrification and organic removal in synthetic wastewater comparing with a conventional activated sludge system. Additional pilot scale experiment was done in order to determine the organic removal efficiency of the biomass attached inside the SOFTRON CUBE. Parameters considered in this study were concentrations of Chemical Oxygen Demand (COD), ammonia nitrogen (NH_4-N), Mixed Liquor Suspended Solids (MLSS) in the aeration reactor and biomass in the SOFTRON CUBE. To examine the organic removal efficiency, COD concentration was measured using Potassium permanganate method.

Experiment 1: Nitrification in laboratory scale experiment

Three reactors with capacity of 3 liters equipped with same size of air pumps were filled with 2 liters of activated sludge from municipal wastewater treatment plant and 1 liter of synthetic wastewater containing essential elements (Nakahara et al., 2008a). Composition of the synthetic wastewater is listed in Table 2.

Table 2. Composition of synthetic wastewater used in the experiment of nitrification.

Component	Concentration (mg/l)
NH_4Cl	191
$NaHCO_3$	600
NaCl	73
$MgSO_4$	61.5
K_2HPO_4	34

As shown in Figure 2, SOFTRON CUBE of 5% and 10% by volume were added to each reactor respectively (Nakahara et al.,2008a; Nakahara et al., 2008b). The first reactor was operated without the bio-carrier as a control reactor.

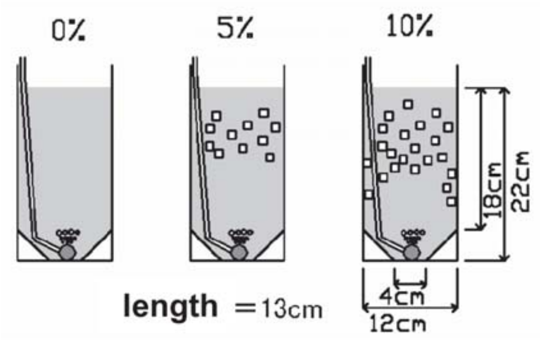

Figure 2. Reactors for nitrification experiment.

After 24 hours of aeration, 1 liter of supernatant water was replaced by the synthetic wastewater using fill and draw method. Samples were taken to determine ammonia nitrogen and MLSS in the reactor at 5, 35, 65, 95 and 120 minutes, respectively. At the same time, ten cubes were taken to examine the change in biomass concentration inside the bio-carrier.

Experiment 2: Organic oxidation in laboratory scale experiment

The experiment was carried out in batch scale in order to determine an optimum dosage of the bio-carrier. Four aeration reactors were equipped with same size of air pumps like in Experiment 1. Size of each reactor is 3 liters. Each reactor was filled with 2 liters of activated sludge from municipal wastewater treatment plant and 1 liter of synthetic wastewater (glucose solution of 1,500 mg/l). The first reactor was operated without the bio-carrier as a control reactor. The SOFTRON CUBE of 5%, 10% and 15% by volume were added to each reactor respectively (Nishidome et al., 2007) as shown in Figure 3.

Supernatant water of 1 liter was replaced by the synthetic wastewater every 24 hours of aeration. Samples were taken to determine COD and MLSS in the reactor as well as the biomass inside the bio-carrier at first 15 minutes after the fill-and-draw and every 60 minutes until 315 minutes.

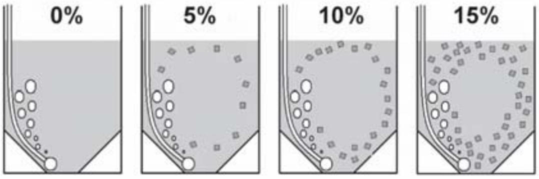

Figure 3. Reactors for organic oxidation in laboratory scale experiment.

Experiment 3: Organic oxidation in pilot scale experiment

After the optimum dosage of the bio-carrier was obtained from the laboratory scale experiment, a pilot scale experiment was set up to examine the effectiveness in organic removal of the biomass attached inside the SOFTRON CUBE. Two aeration reactors with the capacity of about 100 liters with same size of air pumps were utilized in this experiment as shown in Figure 4 (Nakahara et al.,2008a; Nakahara et al., 2008b). One reactor was filled with the SOFTRON CUBE at optimum dosage obtained from the laboratory scale experiment. Supernatant water of 50 liter was replaced by the synthetic wastewater every 24 hours using the fill-and-draw method until the steady state was achieved in both reactors.

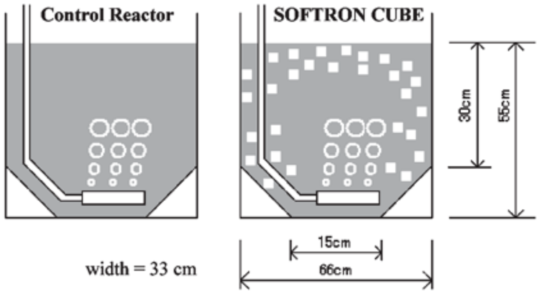

Figure 4. Reactors for the pilot scale experiment.

Table 3. Composition of synthetic wastewater used in the experiment of nitrification.

Component	Concentration (mg/l)
Glucose	500
Urea	30
Potassium dihydrogen phosphate	10
Sodium chloride	10
Magnesium sulfate	10

In order to investigate effect of the SOFTRON CUBE on organic removal under the condition of low MLSS, mixed liquor of 50 liters of each reactor was withedrawn and reolaced withe 50 liters of the synthetic wastewater in both reactor at every 24 hours, which is similar to the activated sludge system without return sludge. Ten SOFTRON CUBEs were sampled in order to measure the biomass change inside by measuring the dry weight.

Composition of the synthetic wastewater prepared for the pilot scale experiment was shown in Table 3. The synthetic wastewater consisted of carbon source (glucose), nutrients and elements which are essential for suitable microbial growth in the reactor (Nakahara et al.,2008a).

After MLSS in both reactors reached stable level, the COD removal in each reactor was examined. The influent COD concentration was 310 mg/l. Water temperature was controlled at 201C in both reactors. Sample was taken from each reactor every 30 minutes to determine COD concentration inside the reactor.

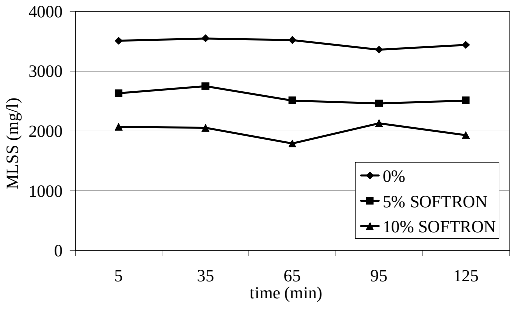

Figure 5. MLSS inside the reactors of nitrification experiment (63 days).

Results

Experiment 1: Nitrification in laboratory scale experiment

As shown in Figure 5, average MLSS in the reactor with 0%, 5% and 10% addition of SOFTRON CUBE was 3,476, 2,572 and 1,994 mg/l, respectively.

The biomass concentration in a bio-carrier was 10,400 and 7,800 mg/l for the reactor of 5% and 10% addition of SOFTRON CUBE, respectively. From Figure 6, average rate of ammonia nitrogen removal of each reactor was not much different.

As a result, the rate of nitrification can be maintained even if the MLSS in the reactor with addition of bio-carrier is low. Therefore, the microbes in the bio-carrier contribute greatly on the nitrification.

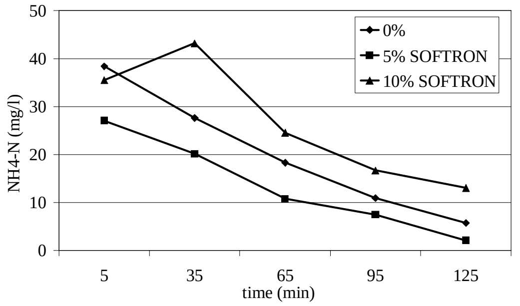

Figure 6. Ammonia nitrogen in the reactors of nitrification experiment (63 days).

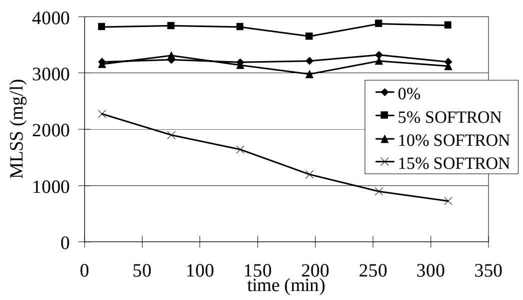

Figure 7. MLSS in the reactors of organic oxidation experiment (29 days).

Experiment 2: Organic oxidation in laboratory scale experiment

MLSS in each reactor after the experiment of organic oxidation started for 29 days is shown in Figure 7. It was found that, on the 29th day of experiment MLSS in the reactor with 15% addition of SOFTRON CUBE decreased to less than 1,000 mg/l while the MLSS in other reactors was almost constant. Average biomass concentration in a bio-carrier was 9,500, 13,300 and 15,000 mg/l for the reactor of 5%, 10% and 15% addition of the SOFTRON CUBE, respectively.

As shown in Figure 8, concentration of COD on the 29th day of experiment in each reactor decreases with time. Rate of organic removal in the reactor was 21, 30, 37 and 36 mg/l/hr, respectively. Comparing with the rate of organic removal of 21 mg/l/hr in the control reactor, it indicated that the addition of the polyethylene bio-carrier like SOFTRON CUBE can increase the organic removal efficiency of the activated sludge system. The optimum content of the SOFTRON CUBE is 10% by volume which has COD removal rate of 1.76 times of a conventional activated sludge system. In order to determine the organic removal efficiency of the biomass attached inside the SOFTRON CUBE, a pilot scale test of the optimum dosage was carried out.

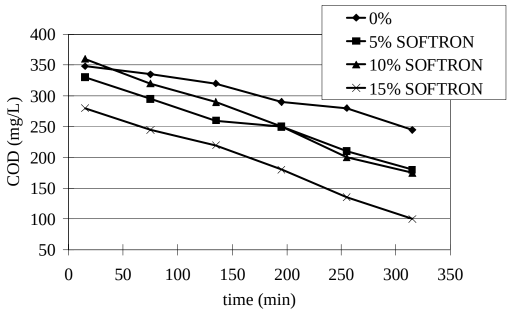

Figure 8. COD inside the reactors of organic oxidation experiment (29 days).

Experiment 3: Organic oxidation in pilot scale experiment

In the pilot scale experiment, the SOFTRON CUBE was added at 10% by volume which was the optimum dosage. The MLSS in both reactors decreased to almost same level on the 5th day of the experiment which is about 300 mg/l as shown in Figure 9. After that, the MLSS in the control reactor increased and became stable around 500 mg/l while the MLSS in the reactor with the SOFTRON CUBE kept on decreasing and became stable around 50 mg/l.

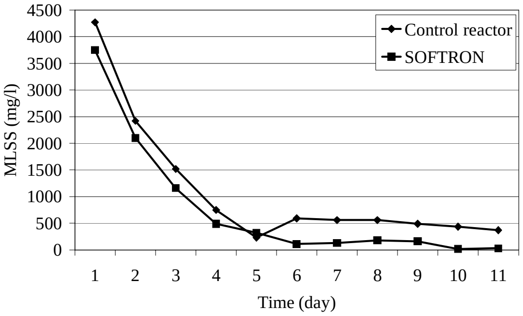

Figure 9. MLSS content in the organic oxidation reactors in pilot scale experiment.

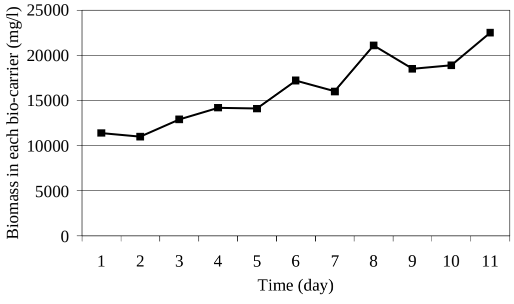

Figure 10. Biomass inside the SOFTRON CUBE in pilot scale experiment.

As shown in Figure 10, it was found that the biomass inside the SOFTRON CUBE increased from 11,400 mg/l to 22,500 mg/l after starting the experiment for 10 days. Since total volume of the SOFTRON CUBE is 10% of wastewater in the reactor, the biomass of 22,500 mg/l inside the SOFTRON CUBE can be converted to MLSS concentration of 2,250 mg/l in the reactor.

The change of COD concentration in both reactors on the 7th day of experiment is shown in Figure 11. After 125 minutes of aeration, COD concentration in the control reactor decreased to 230 mg/l while the COD concentration in the reactor with 10% SOFTRON CUBE equaled to 100 mg/l. Considering the reaction from 5 to 35 minutes of aeration as the zero order reaction, COD removal rate in the reactor with the SOFTRON CUBE is 230 mg/l-hr which is 2.875 times faster than COD removal in the control reactor. It indicated that COD removal efficiency in the reactor with the SOFTRON CUBE did not change even the MLSS in the reactor was decreased. High attached growth of biomass inside the SOFTRON CUBE makes it possible to reduce the rate of return sludge while high efficiency of organic removal can be achieved.

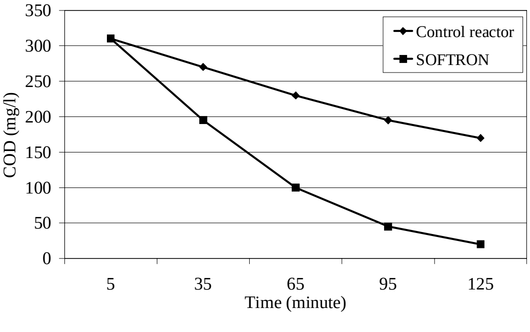

Figure 11. COD inside the SOFTRON CUBE in pilot scale experiment.

Conclusions

1. Polyethylene bio-carrier (SOFTRON CUBE) was found to have contribution on nitrification and organic oxidation because of high microbial growth inside.

2. With addition of the SOFTRON CUBE, the rate of nitrification can be maintained even the MLSS in the reactor was low. As a result, the microbes in the SOFTRON CUBE were found to contribute greatly on the nitrification.

3. High biomass content in the SOFTRON CUBE results in higher rate of COD removal in batch scale experiment. The optimum rate of COD removal in laboratory scale was obtained by adding the SOFTRON CUBE 10% by volume.

4. High organic removal efficiency can be maintained in an aeration tank by applying the SOFTRON CUBE even under low concentration of MLSS due to high attached growth of biomass inside the SOFTRON CUBE.

5. Without the requirement for return sludge, addition of the SOFTRON CUBE helps reduce the size of activated sludge system and improve the removal efficiency.

6. In the future, the effect of sludge recycling on the nutrient removal of the SOFTRON cube in an existing activated sludge system will be investigated.

Acknowledgments

The authors are very grateful to Sekisui Aqua Systems Co., Ltd. for their kindly cooperation and offering very useful information for this research.

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