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Bacterial communities in different locations, seasons and segments of a dairy wastewater treatment system consisting of six segments

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ABSTRACT

A dairy wastewater treatment system composed of the 1st segment (no aeration) equipped with a facility for the destruction of milk fat particles, four successive aerobic treatment segments with activated sludge and a final sludge settlement segment was developed. The activated sludge is circulated through the six segments by settling sediments (activated sludge) in the 6th segment and sending the sediments beck to the 1st and 2nd segments. Microbiota was examined using samples from the non-aerated 1st and aerated 2nd segments obtained from two farms using the same system in summer or winter. Principal component analysis showed that the change in microbiota from the 1st to 2nd segments concomitant with effective wastewater treatment is affected by the concentrations of activated sludge and organic matter (biological oxygen demand [BOD]), and dissolved oxygen (DO) content. Microbiota from five segments (1st and four successive aerobic segments) in one location was also examined. Although the activated sludge is circulating throughout all the segments, microbiota fluctuation was observed. The observed successive changes in microbiota reflected the changes in the concentrations of organic matter and other physicochemical conditions (such as DO), suggesting that the microbiota is flexibly changeable depending on the environmental condition in the segments. The genera *Dechloromonas*, *Zoogloea* and *Leptothrix* are frequently observed in this wastewater treatment system throughout the analyses of microbiota in this study.

Introduction

Dairy wastewater is highly polluted in terms of its scale as well as concentration of organic matter. Actually, the amounts of dairy wastewater are 35,000 and 67,000 m^3/day in Hokkaido, Japan and in all of Japan, respectively. It contains high amounts of proteins, fatty substances and lactose (Tocchi et al., 2012). Dairy wastewater exhibits a biochemical oxygen demand (BOD)

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of approximately 2000–5000 mg/L. Considering that the BOD of ordinary sewage is approximately 200 mg/L, which of dairy wastewater leads to a high-load operation of a wastewater treatment system owing to the concentrations of organic matter. Therefore, if dairy wastewater were dumped into a river or lake, it would be a heavy burden to the natural environment. Because of the amount of dairy wastewater and its high density of organic matter, it should be properly treated by appropriate methods.

Among the organic matter contained in dairy wastewater, milk fat is difficult to degrade owing to its water insolubility, and fatty substances are fundamentally difficult to degrade by microorganisms in a short time. Furthermore, milk fat particles are too large to be easily degraded by microorganisms. In a wastewater treatment system, owing to the milk fat on the surface of the wastewater, vigorous aeration is difficult for the degradation of organic compounds by aerobic microorganisms. Vigorous aeration produces large amounts of foam and scum, which cover the surface of the wastewater. Moreover, dairy wastewater contains various chemicals for cleaning (Kosseva et al., 2003) such as detergent and hormones (Cai et al., 2012, 2013). In addition, it sometimes contains milk that cannot be shipped owing to the remaining high concentration of antibiotics. For the reasons described above, it is difficult to degrade organic compounds using an ordinary wastewater treatment system. Therefore, the establishment of a new and effective treatment system for dairy wastewater is desired.

A dairy wastewater treatment system composed of six separate activated sludge water treatment segments equipped with a facility for the physical destruction of milk fat particles was developed. The main segments of the dairy wastewater treatment system are one segment equipped with a facility for the destruction of milk fat particles, four activated sludge treatment segments, and the last segment for activated sludge settlement. This system has already run in several dairy farms in Hokkaido, Japan. It can reduce the BOD of the original wastewater from 4600 to 4.4 mg/L. Concentrations of nitrogen and phosphate are decreased from 340 and 80 mg/L to 9.8 and 22 mg/L, respectively. Although the system has proven its efficiency for dairy wastewater in different locations and seasons, there is no information available on whether the microbiota is changed depending on the location and season. In addition, although BOD is sequentially decreased from the 1st to the 5th segments, the difference in microbiota in the six separate segments is unknown. Microbiota was examined to ascertain the efficiency of the dairy wastewater treatment system placed at different locations and in different seasons and segments of the total system by a culture-independent method.

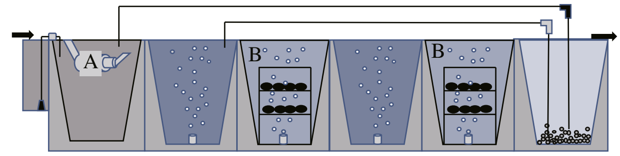

Fig. 1 – Total scheme of wastewater treatment system consisting of 6 segments of 10 m^3 volume each. Each segment is connected following the sequence of treatment steps from the 1st to the 6th segments. The particle size of the milk fat that accumulated on the surface of the 1st segment of the wastewater treatment system was reduced by aspiration in the facility and by beating against a ceramic balls with a surface having a sharp corrugation (at the 1st segment, indicated as “A”). Wastewater is treated with activated sludge by vigorous aeration from the 2nd to the 5th segments. Among them, the 2nd and 4th segments are for ordinary aeration with the activated sludge. Activated coal, the surfaces of which possesses pores for carrying bacteria, is equipped at the 3rd and 5th segments (indicated as “B”). The activated sludge is allowed to settle in the 6th segment. The sludge is occasionally fed back to the 1st and 2nd segments for recycling.

1. Materials and methods

1.1. Configuration and operation of the wastewater treatment system

The total scheme of this wastewater treatment system is shown in Fig. 1. This system consists of six separate segments of 10 m^3 volume each. These segments are connected in line in the order of treatment step (from the 1st to the 6th). The total volume is 60 m^3, consisting of 50 m^3 for the wastewater treatment segment and the last 10 m^3 for the sludge settlement. The flow volume is 8–9 m^3/day. Therefore, the retention period of wastewater in the system is approximately 7 days. The sediment in the 6th segment is sent back to the 1st and 2nd segments. Wastes from cattle shed include wasted milk, water used for washing the floor and detergents. A facility for the reduction of the size of milk fat particles is attached to the 1st segment of the system. The milk fat that accumulated on the surface of the 1st segment of the wastewater treatment system was aspirated using a pump into a tube and the particle size was physically broken down by strongly stroking on the sharp corrugation on the surface of the ceramic balls that filled the tube. By this treatment, the size of the milk fat particles is reduced from 1.90 to 0.82 μm on average. In the 1st segment, no aeration is performed. Wastewater is treated with activated sludge by vigorous aeration from the 2nd to the 5th segments. A carrier consisting of activated coal, the surface of which possesses pores for carrying bacteria, is equipped at the 3rd and 5th segments. The activated coal has bacterial cells in the pores on the surface. The activated sludge is allowed to settle in the 6th segment and the supernatant is made to flow outside as treated water. The settled sludge is sent back to the 1st and 2nd segments for recycling. One of the typical stepwise BOD reductions in this system is as follows: 2800, 1200, 660, 80 and 60 mg/L in the 1st, 2nd, 3rd, 4th and 6th segments, respectively. On the other hand, the stepwise nitrogen removal is as follows: 170, 160, 130, 23 and 23 mg/L in the 1st, 2nd, 3rd, 4th and 6th segments and the phosphate degradation is as follows: 49, 51, 46, 22 and 22 mg/L in the 1st, 2nd, 3rd, 4th and 6th segments, respectively. These values are changeable depending on the wastewater characteristics such as the concentration of organic matter, the amount of activated sludge and temperature.