学位論文審査の要旨

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学位論文題名

Performance of hybrid subsurface flow constructed wetland system used for high content wastewater treatment

(高濃度排水の浄化処理を行うハイブリッド伏流式人工湿地システムの性能に関する研究)

This thesis is composed of 5 chapters, 90 text pages, 25 figures, 19 tables and attached with 3 related papers.

Hybrid subsurface flow constructed wetland (CW) system that consists of vertical flow subsurface CWs and horizontal flow subsurface CWs has begun to be used practically in world wide to treat various wastewater, with the advantages of low cost, low energy consumption, low maintenance requirement, and environmental benefit. But its performance especially when treating high concentration and/or high load of organic wastewater is still left unknown. High content piggery urine wastewater and milking parlor wastewater could cause environmental problems, such as surface water and groundwater pollution, water eutrophication, and odors. In this study, the pollutants treatment efficiencies of hybrid subsurface flow CWs were assessed, and N transformations in hybrid CWs were also indicated.

1. Treatment efficiencies of hybrid subsurface flow CWs

The raw wastewater discharged from piggery and dairy farms contained total N (T-N) of 159 ± 60 mg•L^{-1} to 433 ± 342 mg•L^{-1}, and chemical oxygen demand (COD) of 3,752 ± 2,071 mg•L^{-1} to 10,961 ± 3,146 mg•L^{-1}. With the aim of treating high content wastewater, hybrid subsurface flow CWs named Piggery-O, Dairy-G, and Diary-S were constructed in 2009, 2001, and 2006, respectively.

The average inflow loads of T-N were 11.2 ± 7.5, 3.4 ±1.7, and 1.2 ± 0.5 g•m^{-2}•d^{-1}, in Piggery-O, Dairy-G and Dairy-S, respectively. After six, four, and nine years of operation, the total removal efficiencies (REs) was around 71 ± 19% ~ 82 ± 15% in these hybrid systems. Compared with other researches, these hybrid CW systems performed well for T-N treatment. REs of T-P were 90 ± 10, 70 ± 11, and 64 ± 25% in Piggery-O, Dairy-G, and Dairy-S, respectively. The different REs might be attributed to the bed material used in these systems that had different P absorption ability. All systems received high COD loads,

especially in Diary-G, where the inflow load was 124.0 ± 58.5 $g \cdot m^{-2} \cdot d^{-1}$. Although these hybrid CW systems received high loads, they all performed high COD REs of around 93 ± 7% to 95 ± 3%. The hybrid CW systems also performed high REs in biochemical oxygen demand (BOD_5), suspended solid, and total coliform removal.

After years of operation, Piggery-O presented an increasing T-N RE year by year, and provided stable and high T-P RE. Diary-G had high RE of T-N from the beginning of construction, and it was stable after years of operation. T-P RE decreased from 80 ± 6% in the first year to 69 ± 11% in the forth year. Similar T-P removal tendency was also observed in Dairy-S. This may due to saturation of the bed material adsorption capacity over time. All these hybrid CW systems had high and stable annual REs of COD and BOD_5 since the beginning of construction. Overall, these hybrid CWs systems could be recognized as useful and effective methods for piggery and milking parlor wastewater treatment over years of operation.

2. N transformations in the hybrid subsurface flow CWs

With the aim of a better understanding of N transfer cycles in hybrid CW systems, bed material samples were taken from Piggery-O and Dairy-S systems for analysis. In Piggery-O, the amount of N stored in bed materials was 1,358 kg. This amount accounted 9 % of N removed (15,579 kg) by whole system. At each bed of Piggery-O, only 1 % to 2 % of received N was stored in bed materials. Meanwhile, 8 % to 37 % of received N was converted into gaseous N and released into the astrosphere. This illustrated that the denitrification is important process of N transformation in Piggery-O. In Dairy-S, N stored in bed materials was 869 kg, and the total amount of N removed by this system was 1,795 kg. Among them, nearly 51 % of received N was removed in form of gaseous N. In addition, nearly 9 % to 35 % of received N was stored in each bed material. In the 1st bed, nearly 690 kg of N was stored in the surface organic matter layer covering the bed surface. This indicated that the organic matter layer on the surface might be an indispensable part of N removal in hybrid CW system treating milking parlor wastewater.

The study analyzed the performance and the efficiencies of hybrid subsurface flow CWs treating high content organic wastewater under cold climate condition with several years of operation. Also the study clarified the important process of N transformation in CW system. These achievements may contribute greatly for better design of CW system, and help the social reorganization of this system as useful and effective methods of high content organic wastewater treatment in future society.

Therefore, we acknowledge that the author is qualified to be granted the Degree of Doctor of Philosophy in Agriculture from Hokkaido University.