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論 文 内 容 の 要 旨

Abstract of Dissertation

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Pollutants including organic carbon and dissolved inorganic nitrogen (DIN) are still major issues in wastewater. Anaerobic digestion has long been practiced for recovering organic matters via methane-rich biogas as fuel. Besides, conventional nitrogen removal needs to go through autotrophic aerobic nitrification, then heterotrophic anaerobic denitrification. This approach is a high-energy-consuming and resource demanding process. Recently, two novel nitrogen removal processes, i.e. anammox and methane-driven denitrification (MDD), have been discovered and combined as an efficient alternative for complete DIN removal. They possess remarkable advantages, such as co-occuring in an oxygen-depleted environment, using methane gas (CH_4) from anaerobic digesters instead of extra organic carbon substrate. However, there are two major limitations, the poor solubility of CH_4 in water and the slow growth rates of involved microorganisms. Therefore, this research developed three anaerobic bioreactors: anaerobic baffled reactor (ABR) converted organic matters (OM) to CH_4-rich biogas, then closed-type downflow hanging sponge (DHS) and an upflow hollow fiber membrane reactor (UHFMR) was introduced to enhance gas-liquid interaction and retain slow-growth microbes for MDD process to remove nitrogen.

In the first study, the ABR consisted of ten compartments was installed to treat natural rubber processing wastewater. It achieved the highest COD and total suspended solid removal efficiencies at 92.3 ± 6.3% and 90.0 ± 6.0%, respectively, under an OLR of 1.4 ± 0.3 kg-COD.m^{-3}.d^{-1} without any pH adjustment and rubber trap in advance. The microbial analysis of biomass in each compartment revealed methanogens, particularly acetate-utilizing methanogens, were predominantly distributed in the 3rd, 4th, and 5th compartments, where volatile fatty acid concentration considerably decreased and the highest biogas production was observed; whereas several acetogens growing under low pH and ammonia-utilizing bacteria were detected in front compartments.

The closed-type DHS in the second study assessed effects of operational conditions on nitrogen removal and N_2O emission. Under the most optimal operational conditions including hydraulic retention time of 12 h, the addition of 25 μM Ti(III), the nitrogen removal rates doubled to 4.1 ± 1.9 gNO_3^--N.m^{-3}.d^{-1} and 6.6 ± 3.3 gNO_2^--N.m^{-3}.d^{-1}; and the N_2O emission reduce to a range of 0.7 x 10^{-4}% to 61.4 x 10^{-4}% of removed NO_x^-.

The UHFMR in the third study evaluated the effects of inocula on nitrogen removal and microbial dynamics. The reactor inoculated with sludge mixture from parent reactors performed better in specialized conditions (i.e., anammox, nitrite-MDD, or nitrate-MDD processes) with the higher removal rates of 31.4 mgNH_4^+-N.L^{-1}.d^{-1}, 21.4 mgNO_2^--N.L^{-1}.d^{-1}, and 14.6 mgNO_3^--N.L^{-1}.d^{-1}. Meanwhile, the reactor inoculated with paddy soil could quickly adapt to any changes and reached higher nitrogen removal under non-specialized conditions. The microbial communities were dominated by bacteria, especially aerobic methanotroph. They may directly denitrify or indirectly contribute to denitrification

via syntrophic association with heterotrophic denitrifying bacteria (DNB). The higher abundance of DNB in the reactor with paddy soil likely contribute to its high adaptation.

Overall, the results of this research demonstrated potential bioreactor configurations to facilitate MDD process and provided evidence for the predomination of aerobic methanotrophic bacteria instead of well-known anaerobic methanotrophs in MDD reactors.