論文の内容の要旨

Abstract of Dissertation

Effect of Sludge Retention Condition on Operational Performance, Bacterial Community and Enzymatic Activities in Inclined Plate Membrane Bioreactors

（傾斜板付き膜分離活性汚泥法における処理性能、細菌叢および酵素活性に対する 汚泥滞留条件の影響）

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An inclined plate membrane bioreactor (ip-MBR) has been developed as a powerful wastewater treatment process. The process includes sludge thickening function with the inclined plate module in the mainstream that enables recovery of dense excess sludge directly from the reactor and maintains the suitable sludge concentration in the membrane tank. To achieve optimal MBR design and control operation, information on the sludge retention condition, bacterial community and enzymatic activity dynamics of the ip-MBR system are needed.

The objectives of this study were *(i)* to investigate the reproducibility of two identical ip-MBRs on treatment performance, bacterial community and enzymatic activity, *(ii)* To establish design criteria related to sludge retention in terms of inclined plate function and treatment performance, *(iii)* To investigate relationship among sludge retention conditions, bacterial community and enzymatic activities in ip-MBRs and *(iv)* To compare bacterial community of ip-MBRs with conventional activated sludge process (CAS) and inclined tube membrane bioreactor (it–MBR) for sludge production.

Two identical bench scale inclined plate-membrane bioreactors (ip-MBRs: ip-MBR unit1 and unit 2) were operated with treating real municipal wastewater for almost 3 months under two different sludge retention times (SRT): short (20 days) and infinite. Both reactors showed similar results in terms of treatment efficiency, bacterial community and enzymatic activities. High efficiencies of COD and ammonia removal more than 90% and total nitrogen removal up to 70% were achieved with complete sludge retention. There were no significant differences among the enzymatic activities; glucosidase, aminopeptidase and esterase tested between both reactors ($p>0.05$). Cluster dendrogram and Nonmetric Multidimensional Scaling (NMDS) plots of TRFLP profiles for determining bacterial community similarity demonstrated that the bacterial community composition in both reactors showed similar sequential shifts with time.

The ip-MBR unit 1 was continuously operated with two different hydraulic retention time under a long term operation (1 year). Removal rate of COD and ammonia over 90% and of total nitrogen more than 70% were achieved without sludge withdrawal. When the MLSS concentration in the anoxic tank exceeded 15 g/L, the failure of inclined plate function was observed resulting in no difference in MLSS concentration between aerobic and anoxic tanks. Meanwhile, the ip-MBR unit 2 was operated under different SRTs in long term period of 1 year. Short SRT (20 days) negatively affected total nitrogen removal. In order to maintain both inclined plate function and efficient nitrogen removal, SRT between 40 days and 80 days are suggested for ip-MBR. However, the optimum SRT should be further clarified.

Cluster dendrogram and NMDS plot of T-RFLP fingerprints showed similar changes of ammonia oxidizing bacteria community and total bacterial community in terms of bacterial member and abundance with time in both reactors. It was probably due to different SRTs had a slight effect on their community dynamics. However, it was observed the significant difference in dominant bacterial community when both reactors were operated with a largely different SRT (ipMBR unit 1: infinite SRT and ip-MBR unit 2: SRT of 20 days). The T-RF size of F253/R227 from bacterial *amoA* gene dominated in the entire experiment. This T-RF size was identified as *Nitrosomonas* like bacteria, however, the availability of database on functional gene sequences was not enoung to distinguish in the species level. The sequences of bacterial 16S rRNA gene were constructed into 6 libraries of A-F. The largest group of sequences belonged to *Proteobacteria.* Phylum *Bacteroidetes* was dominant in the seed sludge retrieved from CAS (library A) as T-RF of F49/R294 (as *Flavobacterium* sp.) was dominantly observed. Under MBR operation (libraries B-F), an abundance of bacterial community was changed to phylum *Proteobacteria.* Most of them might be responsible for protein degrader as these bacteria were highly abandant in accordance with relatively increased aminopeptidase activity. Moreover, dominant nitrite oxidizing bacteria was identified as *Nitrospira* sp belonging to *Nitrospira* phylum.

All enzymatic activities (glucosidase, aminopeptidase and esterase) in the ip-MBR unit 1 and unit 2 showed similar sequential changes related to dominant bacterial community shift with time which were observed in the sequence libraries (A-F) of bacterial 16S rRNA. Aminopeptidase exhibited high activity during the long term operation probably due to additional protein source from sludge decay. Meanwhile its activity in an aerobic tank was greater than that in an anoxic tank due to high oxygen supply.

When three different processes, ip-MBRs, it-MBR and CAS, were compared for their bacterial communities, it was elucidated that the influent wastewater fluctuation, temperature and different SRTs were the main factors for bacterial community changes but not for the ammonia oxidizing bacteria community. Ammonia oxidizing bacteria communities were slightly changed in three different processes. Meanwhile bacterial communities in both reactors which were operated under SRT more than 20 days at temperature of 30°C were entirely different from those in the CAS and it-MBR which were operated in the condition of lower SRT at ambient temperature.

The obtained knowledge of a critical SRT on the treatment performance and the inclined plate function gives a design criterion for ip-MBR to effectively treat municipal wastewater. The information of bacterial communities and enzymatic activities related to sludge retention condition makes more understanding of their dynamic changes, although they are almost independent of treatment performance. Nevertheless, the information will be useful to mitigate the process once it encounters a failure of operation in a long term period.