

題 目: Biological Phosphorus Recovery From Municipal Wastewater Using UASB-DHS System

(UASB-DHS システムを用いた廃水からの生物学的リン回収)

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Phosphorus (P) is important nutrients for food productions that cannot be substituted by any other element, thus become a major component in fertilizers. Nowadays, the increased demand for food along with the global population increases must also be understood as an inevitable increase in the world's phosphorus demand. Consequently, the finite phosphate rock reserves as the main source of P will become scarce in the near future. On the other hand, P consumption activities by human also potentially cause negative effects on the aquatic environment, which can result in eutrophication. There is a rising awareness of the finite phosphorus resources and the importance of environmental preservation, which make P recovery from domestic wastewater become more attractive. Beside produce fertilizers, P recovery also can prevent eutrophication to some extent.

Kodera et al, (2013) have proposed a novel concept of technology for P recovery, straight from the liquid phase of wastewater without any sludge withdrawal from the system. The system consisted of the up flow anaerobic sludge blanket (UASB) and the down-flow hanging sponge (DHS) reactor for sludge reduction technology. In subsequent, a modified DHS reactor (cloth carrier) is specifically operated for biological P recovery process. This laboratory scale experiment demonstrated that polyphosphate accumulating organisms (PAOs) could be proliferated in the biofilm carrier by alternatingly exposed to anaerobic and aerobic conditions. As a result of the PAOs enrichment, more than 100 mg P L^{-1} of P can be recovered as a concentrated solution from a low phosphate of synthetic wastewater. Those results have motivated us to upscale the system in a pilot scale.

The goal of this research was to evaluate whether UASB-DHS system could be applicable for biological phosphorus recovery from real wastewater. The assessment of UASB-DHS system involved investigation on various aspects of biological phosphorus recovery process especially on the microbiology of Accumulibacter and the technical operation of pilot scale UASB-DHS system. The experimental outcomes and conclusions drawback from this study are briefly described as follows:

Dominant of enriched Accumulibacter Type in response to phosphate concentration.

In **Chapter 3** an attempt to clearly identify the relationship between phosphate concentration and dominant Accumulibacter type was executed. DHS reactor was used for PAOs enrichment while maintaining stable phosphate concentrations in the reactor throughout the aerobic periods. The results of the present study revealed that phosphate concentration is a significant factor influencing dominant PAOs (Accumulibacter) type and population size in enriched biomass. In which the phosphate removal activity of a bioreactor increasing with increasing phosphate concentration. However, it found that excessive phosphate levels inhibited Accumulibacter activity, that this inhibitory effect was greater for Type II. In addition, the affinity of Type II for phosphate was higher than that of Type I. Type IIA-B dominated at a phosphate concentration below 5 mg P L^{-1} , while Type IA was dominant at 50 and 500 mg P L^{-1} , and these patterns of enrichment could be explained by an inhibition kinetics model.

Phosphate recovery from sewage in a pilot scale UASB-DHS

The operation of combined up flow anaerobic sludge blanket (UASB) and down flow hanging sponge (DHS) system for biological phosphate recovery form synthetic sewage is presented in **Chapter 4**. The combined UASB-DHS system could achieve good organic removal efficiencies accounted for 87%, 84% and 90% for BOD, COD, and SS respectively. Under the optimum operational condition, the P-DHS reactor was able to concentrate phosphate up to 120 mg P L^{-1} in the recovery solution even from real sewage. Nevertheless, high phosphate concentration could not be easily maintained over the years. It started to worsen when the pH in F-DHS effluent dropped until below 6, but then slightly increased when the pH is being controlled in a range of 7-8. Moreover, High phosphate concentration only achieved temporally during spring ($16 < T < 20^\circ\text{C}$) and further become deteriorated as temperature rise in summer ($T > 30^\circ\text{C}$). Therefore, to achieve satisfactory phosphate recovery performance the UASB-DHS system should be operated in temperature range of $15\text{--}20^\circ\text{C}$, in which very challenging to apply this tecnology on tropical climate region.

Troubleshooting the pilot scale operation of UASB-DHS reactor

In **Chapter 5**, describe the experienced reactor operational problem and the solution, in expect to be guidance for future oepration and prevent the problem from re-occurring. These reactor problems include wastewater distribution, sewage pump, reactor hydraulic, disfunction in some mechanical and electrical parts of the reactor. Other reactor operational problems like excess biomass in P-DHS that interfere the COD removal performance, and UASB biomass wash out that assumed causing pH drop in F-DHS effluent. Most of those mentioned problem have been tackled and could be controlled during the operation. However, an attempt to reveal the roots of problem behind the pH drop by UASB biomass washout have produced unsatisfied results.

Preferable saline environment for enrichment different type of Accumulibacter

The experimental work in **Chapter 6** was conducted because there is still a lack of specific knowledge about characteritics and activity a saline tolerant (halophile) type of PAOs. DHS reactors inoculated with tidal flat sediment and activated sludge was applied for PAOs enrichment process. The biological phosphorus (BPR) activity of PAOs was investigated under different level of salinity environment including: fresh water, brackish water, and seawater. The result showed that BPR activity could be observed in all salinity level, which suggesting that PAOs was successfully enriched. On the other hand, some enriched PAOs still could perform a substantial BPR activity even when the operation conditions were switched reversibly into fresh or seawater, implying the existence of saline tolerant PAOs. Results of 16S rRNA and *ppk1* gene analysis revealed that Accumulibacter Type IIA, IIB, and IIC could be categorized as saline tolerant (halophile) since it always detected from the seawater, Type IB slightly halophile enriched from brackish water, while Type IA and ID are non saline tolerant as it not possible to be enriched under seawater.