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P RELEASE AND UPTAKE ACCORDING TO INFLUENT ORGANIC LOADING IN BNR PROCESS

Kwang-Soo Kim*, Chang-Hoon Ahn, and Jae-Kwang Park****

*Construction Environment Research Dept., Korea Institute of Construction Technology
**Civil and Environmental Eng. Dept., University of Wisconsin-Madison, USA
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Abstract : A batch-type study was conducted to investigate the phosphorus release and uptake under anaerobic and aerobic conditions according to organic loading changes. As organic loading increased, anaerobic P release increased but aerobic P uptake decreased. Where organic carbon contents remain high in aerobic conditions, PHB consumption within the microbial cells diminished, therefore it was found that in order to enhance P uptake rate, it should reach the endogenous growth stage where the entire organic loading was consumed.

Key Words : P release and uptake, Organic loading, Endogenous growth, PHB

INTRODUCTION

Biological P removal process contains an anaerobic and aerobic reactions in order. It is understood that the biological P removal takes place by accumulating large excesses of polyphosphate within the cell in this sequence. During the anaerobic conditions, organic matters are fermented into the acetate or other smaller fatty acids without electron accepters such as oxygen and nitrate, and PHAs (polyhydroxyalkanoates) are accumulated within the cells.[1] The energy for this process comes from the hydrolysis of ATPs, and ortho-phosphates are released during the reaction.

The bacterial species uptake excessive phosphorus to regenerate ATPs in aerobic conditions, and the phosphorus can be finally removed as waste sludge. The PHAs stored in the microbial cells are converted into the carbon dioxide and water using oxygen as an electron acceptor, and new cells are produced. In conventional biological treatment processes, the phosphorus composition in microbial cells are known stoichiometrically as 1.5~2.0 %, but it may reach 4 to 12 %, exceeding the stoichiometric demand during the anaerobic-aerobic sequencing processes.[2]

The above P removal mechanism has been applied mostly to low-level treatment such as domestic wastewater, but it requires additional chemical treatment in case of high COD and P containing wastewaters such as night soil and livestock wastewaters to meet the effluent standard.[3,4] This study aims to re-evaluate the P removal under anaerobic and aerobic conditions according to organic-loading changes.

MATERIALS AND METHODS

Batch-type Reactor

A batch-type reactor was used to test P release and uptake under anaerobic and aerobic conditions with various organic loading. The

† Corresponding author
E-mail: kskim@kict.re.kr
Tel: 031-910-0299, Fax: 031-910-0291

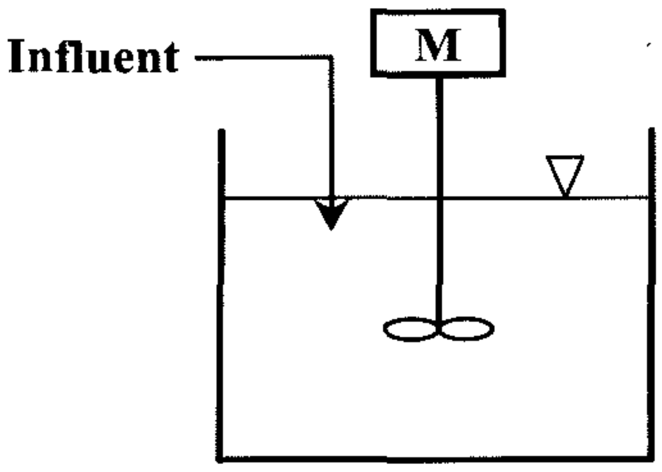

Figure 1. Schematic diagram of batch type reactor.

reactor was installed a mechanical stirrer for the sludge mixing under anaerobic condition, and a blower for the sludge mixing under aerobic condition.

Reagents and Bacterial Culture

A synthetic wastewater was composed of sodium acetate(CH_3COONa) as a carbon source, ammonium chloride(NH_4Cl) as a nitrogen source, potassium phosphates(K_2HPO_4, KH_2PO_4) as phosphorus sources, and $CaCl_2$, $MgSO_4$ and $FeCl_3$ as trace elements. Organic loading was controlled between 100 and 2,000 mg/L COD, using the 10,000 mg/L stock. Nitrogen and phosphorus concentrations were controlled proportionally to organic contents(as BOD), in 100: 5 and 100: 8 ratios, respectively. Seeding culture was collected from a pilot scale (10 m^3/d) A^2/O process for N/P removal currently operated in stable condition.

Experimental Procedure

The concentration changes of ortho-phosphate in the sludge and influent mixture were monitored in a batch reactor under anaerobic and aerobic conditions with the time passage. The organic loading was controlled in five levels from 100 to 2,000 mg/L in COD. Anaerobic and aerobic conditions were applied for six hours each and cycled twice a day. The time for aerobic condition was then extended up to 9 hours to allow complete luxury P uptake. The MLSS levels were adapted to 1,500 mg/L at 100 mg/L COD loading, 3,000 mg/L at 500 mg/L COD, and 5,000 mg/L at higher than 1,000 mg/L COD loading conditions, so that F/M ratios were not too high to cause wash-out of P removing bacteria. The organic and P loadings based on the bacterial concentrations were 0.1-0.8 gCOD/gMLSS, and 0.005-0.03 ortho-P/gMLSS, respectively. The sludge retention time (SRT) was 5-15 days.

RESULTS AND DISCUSSIONS

Organic Removal

Figure 2 illutrates time course of COD changes at different loadings. The remaining COD levels were 18 mg/L at 100 mg/L loading, 70 mg/L at 500 mg/L loading, 386 mg/L at 1,000 mg/L and 1,499 mg/L at 2,000 mg/L, showing that untreated organic contents increased with increasing organic loading both in the

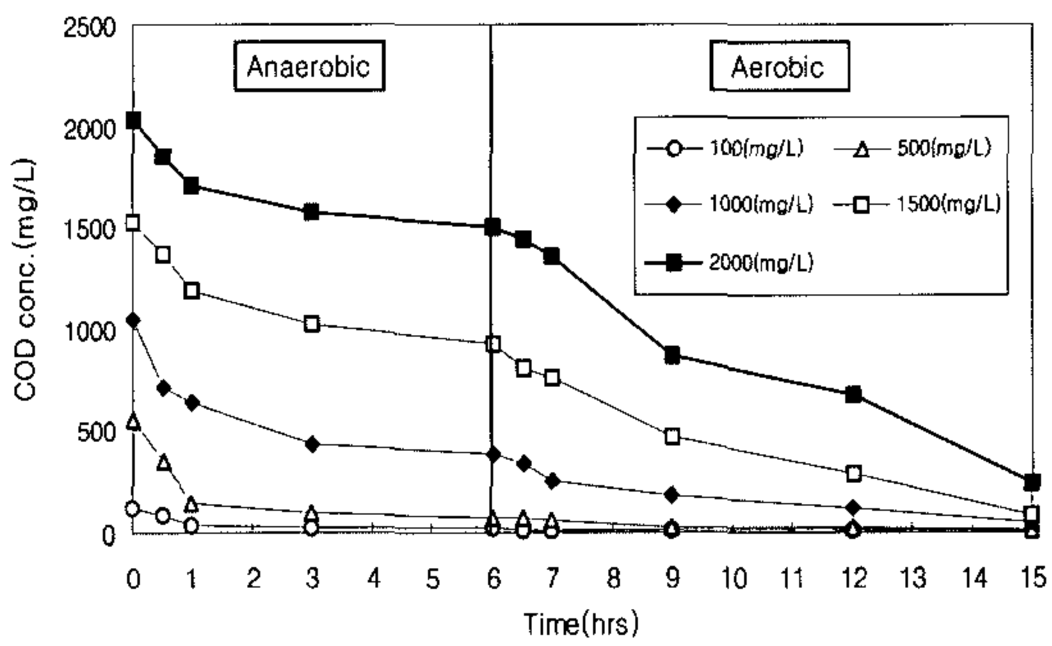

Figure 2. Time course of COD changes in anaerobic and aerobic conditions with the various influent COD loadings.

Table 1. Operating conditions for batch type experiment

Influent COD(mg/L)	F/M ratios (kgCOD/kgMLSS · d)	Soluble P loading (kgS-P/kgMLSS · d)	SRT (day)
100	0.1	0.005	15
500	0.3	0.01	10
1,000	0.4	0.01	5
1,500	0.6	0.02	5
2,000	0.8	0.03	5

anaerobic and aerobic conditions. Although the bacterial activity in anaerobic condition was not as high as 0.6-0.8 g VSS/g BOD of yield coefficient in aerobic organic-oxidizing and 0.3-0.4 g VSS/g BOD of yield coefficient in anoxic denitrification conditions, a lot of organic consumption was observed during the anaerobic condition. This was due to the adsorption of organic matters into the bacterial cells or the PHA conversion within the cells.

Phosphorus, Glycogen and PHB Removal

Figure 3 shows the phosphorus removal under anaerobic and aerobic conditions according to the organic loading changes. At 100 mg/L COD loading, P concentration after 6 hours became 100 mg/L, comparable to the initial 4mg/L of P concentration, indicating high P release at anaerobic condition. Higher anaerobic P release was observed with increasing organic loading. After anaerobic condition, aerobic P uptake took place. It took 3 and 6 hours to be 1 mg/L of effluent P concentration for COD loadings of 100 and 500 mg/L, respectively. With much higher COD loadings however, P uptake rate became low as the effluent P concentrations were 7.1, 77 and 119 mg/L after 9 hours at organic loadings of 1,000, 1,500, and 2,000 mg/L.

The efficiencies of phosphorus removal are illustrated in Figure 4, for various organic loadings. Phosphorus removal rate was higher than 70 % with less than 1,000 mg/L COD loadings, but negative P removal was observed with higher organic loading conditions such as 1,500 and 2,000 mg/L.

Figure 5 shows concentration changes of glycogen and PHB, during the P release and uptake occur at the organic loadings of 100 and 1,000 mg/L. In general biological P removal processes, glycogen and acetate utilize the energy from a hydrolysis of ATP to ADP to be stored as PHB via acetyl CoA (EMP pathway) under anaerobic conditions, and the PHB in microbial cells provides energy for ATP synthesis from ADP and thus luxury P uptake takes place in aerobic conditions.[5] Therefore, in

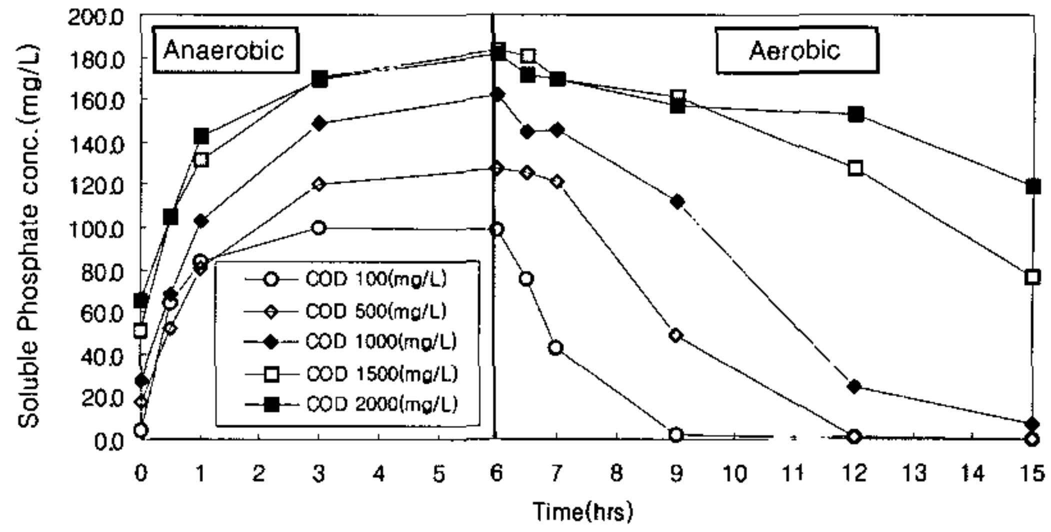

Figure 3. Time course of soluble phosphate changes in anaerobic and aerobic conditions with the various influent COD loadings.

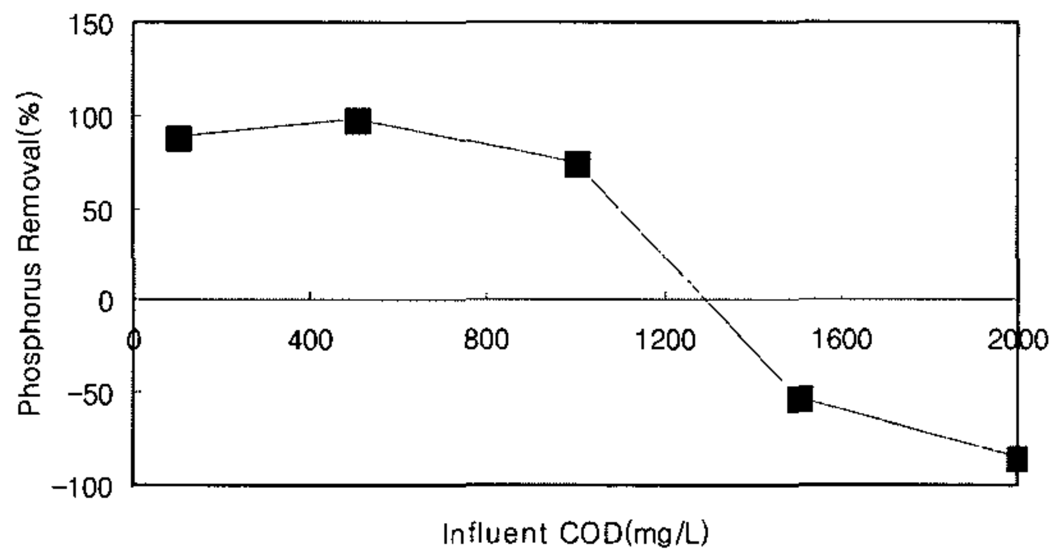

Figure 4. Phosphorus removal (%) to the changes of influent COD loading.

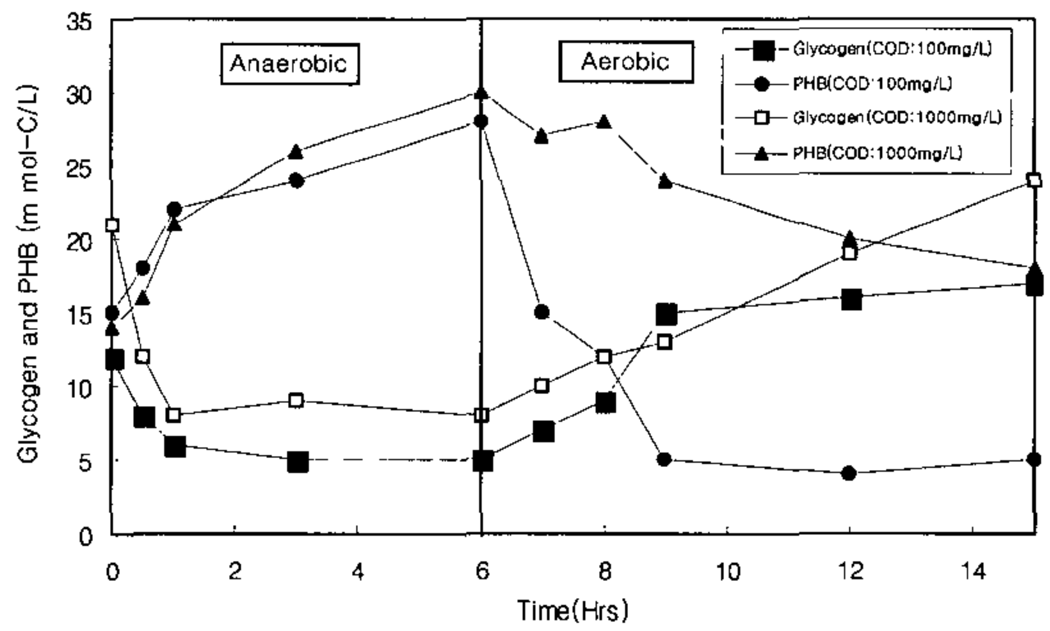

Figure 5. Time course of glycogen and PHB contrations in activated sludge of anerobic and aerobic processes with influent COD of 100 mg/L and 1,000 mg/L concentrations.

anaerobic conditions, the composition of glycogen decreases in microbial cells while PHB increases, and the opposite should occur in aerobic conditions. In the experiment, the decrease of glycogen in anaerobic conditions and the increase of PHB levels in aerobic conditions were confirmed. The effect of organic loading on the level changes was not shown in anaerobic condition, however, under aerobic conditions, PHB consumption rate was very fast with low organic loading, and it became slow with high organic loading conditions.

Organic Residuals

The reasons for the fast P release under anaerobic condition, and the slow aerobic P uptake and PHB consumption rate in high organic loading condition were investigated by HPLC analysis for the filtered sludge samples from the reactor. Where higher organic was loaded, more untreated organics were observed. Comparing the results in Figure 6 and Figure 7 to Figure 5, it is clear that the PHB oxidation became slow when higher organic residual remained. Consequently, for the active luxury P uptake in aerobic conditions, the organics should be consumed as soon as possible, microbial community to be sustained in endogenous growth stage.

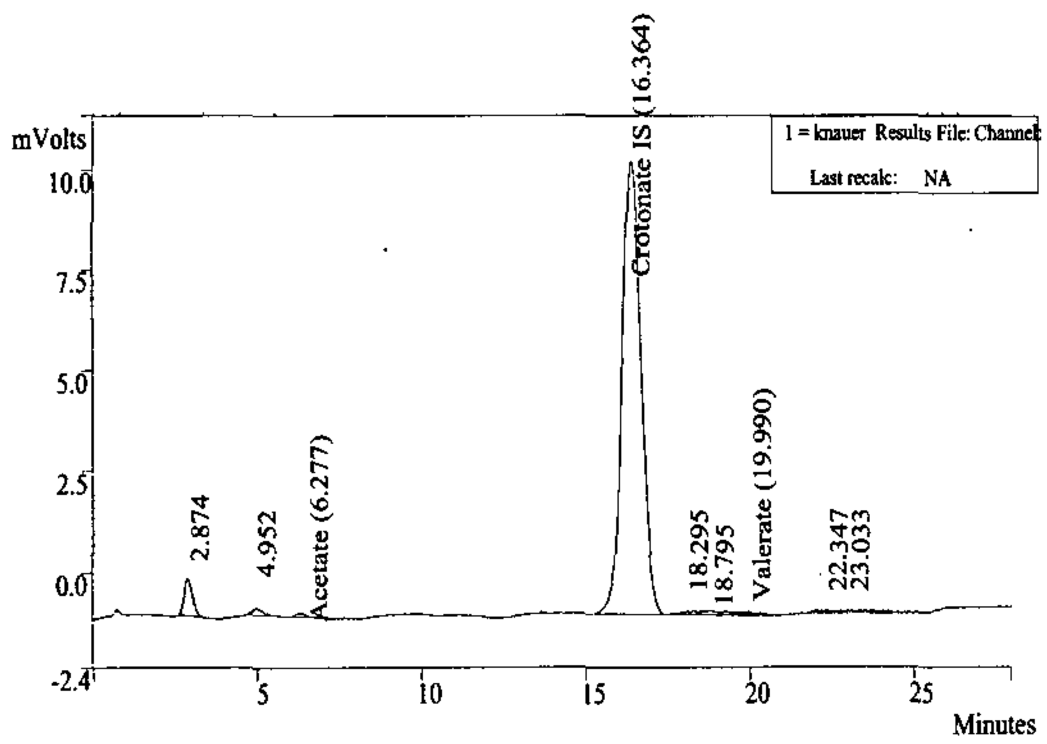

Figure 6. Peaks of organic residuals by HPLC after influent COD 100mg/L was treated aerobically.

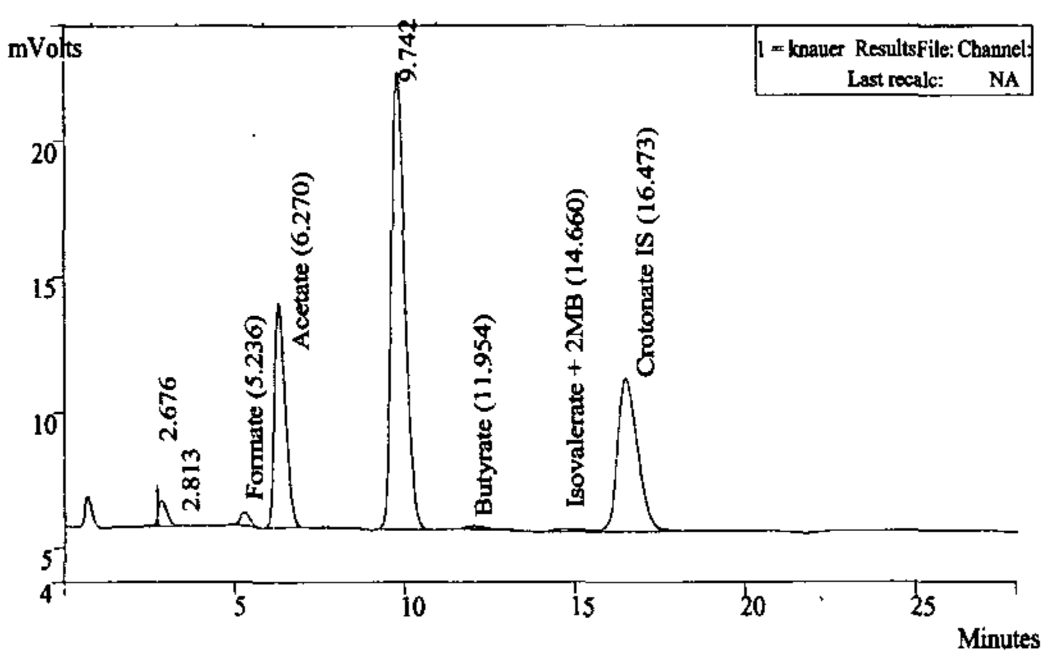

Figure 7. Peaks of organic residuals by HPLC after influent COD 1,000mg/L was treated aerobically.

CONCLUSION

The removal of organic and phosphorus under anaerobic-aerobic conditions was studied with organic loading changes; Higher organic loading remained more organic residual in the treated waters both in the anaerobic and aerobic conditions. P release under anaerobic condition increased with high organic content, but P uptake were less under aerobic condition with higher untreated organic residual.

Where levels of organic residual were high in aerobic condition, the PHB consumption rate within the microbial cells became slow. Therefore, in order to accomplish high P removal, it is understood to reach endogenous growth stage having no or very low organic content.

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