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Anaerobic Production of Poly-Hydroxy-Alkanoates (PHA) and Consumption of Intracellular Carbohydrates by Anaerobic Aerobic Sludge in Practical Sewage Treatment Plants

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1. INTRODUCTION

The anaerobic aerobic activated sludge process has been recognized as a promising method for biological excess phosphate removal from wastewater. Satoh et al (1992) have shown that the anaerobic aerobic sludge, which has a high capability to accumulate phosphorus, take up organic substrates and convert them to poly-β-hydroxy-alkanoates (PHA) under anaerobic conditions with simultaneous consumption of carbohydrates in the sludge. They proposed a biochemical model for the anaerobic uptake of acetate and/or propionate by phosphorus accumulating organisms (PAO) in which carbohydrates are considered to be the source of reducing power in the form of NADH necessary for the PHA synthesis. However, it has been questioned whether or not actual anaerobic aerobic sludges treating real wastewater consume carbuhydrates as the source of reducing power under anaerobic conditions.

We carried out several batch experiments by using sludges and wastewaters from full scale activated sludge plants in order to confirm the occurence of the anaerobic consumption of carbohydrates in the sludge even in practical situations and find evidences to support the biochemical model proposed by Satoh et al. In the present paper results of a typical batch experiment are reported.

2. EXPERIMENTAL METHODS

The batch experiment was carried out in the following way. Activated sludges were taken from a return sludge line of a full scale anaerobic aerobic process treating municipal sewage. Three portions of 100 ml of sludge were put into three glass bottles and aerated with N_2 gas so that an absolute anaerobic condition could be achieved. The experiment was started by adding to each bottle 100 ml of A)raw sewage, B)filtered sewage (GF/C glass fiber filter used) or C)500 mg/L acetate solution. After 6 hours, aeration was started instead of N_2 gas bubbling to provide aerobic conditions. Samples were taken at the predetermined times. Mixed liquor samples were analyzed for carbohydrates (the anthrone method), PHA composition (Satoh et al, 1992), T-P and MLSS. Filtered samples (GF/C Glass fiber filter) were analized for TOC (Shimadzu TOC-500) and orthophosphate.

The sludge characteristics before the experiment were as follows : phosphorus content (3.27%), carbohydrate content (8.42%), MLSS (6204 mg/L).

3 . RESULTS

Profiles of Supernatant TOC, PO_4-P, carbohydrate in the sludge and PHA composition are shown in Fig.1-4. As shown in Fig.1, dissolved TOC increased under the anaerobic conditions when sewage or filtered sewage was used as substrate and there was no significant reduction of TOC when acetate was used as substrate. This result is totally different from the usual observation in theanaerobic aerobic process. This may be because dissolved TOC was produced through the anaerobic hydrolysis of particulate substeate and the rate of the dissolved TOC production was greater than that of TOC uptake by the sludge. Release of phosphate, reduction of carbohydrate in the sludge and increase of PHA under the anaerobic conditions were observed as expected, and they imply the utilization of polyphosphate as energy source, consumption of intracellular carbohydrate and conversion of organic substrates to PHA, respectively (Fig.2-4).

4 . DISCUSSION

Mino et al (1987) reported that the molar ratio of acetate uptaken, carbohydrate consumed, PHA synthesized and phosphorus released in the anaerobic phase can be theoretically estimated to be 6:1:4:3, and Satoh et al (1992) extended this theory to propionate uptake metabolism. Arun et al (1988) experimentally confirmed the occurrence of carbohydrate consumption and PHA synthesis when various organic compounds were fed to anaerobic aerobic sludges grown in the laboratory. In the present study, the amount of TOC uptaken by the sludge could not be determined

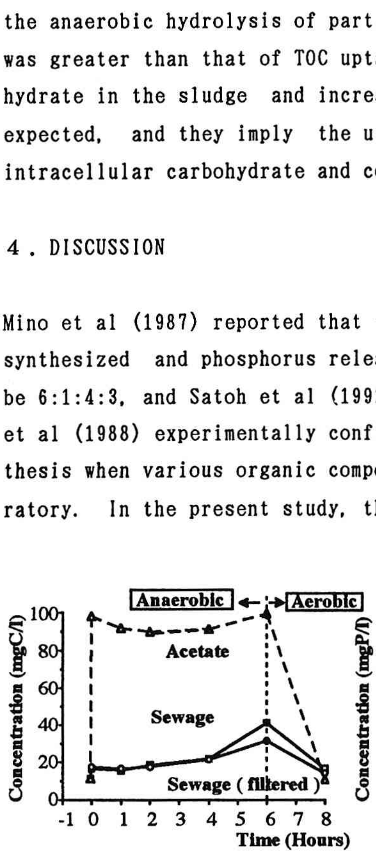

Fig. 1 Profiles of TOC

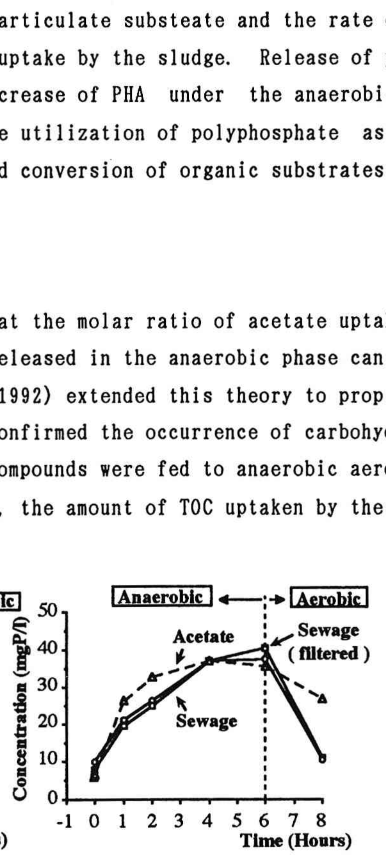

Fig. 2 Profiles of Phosphate Release

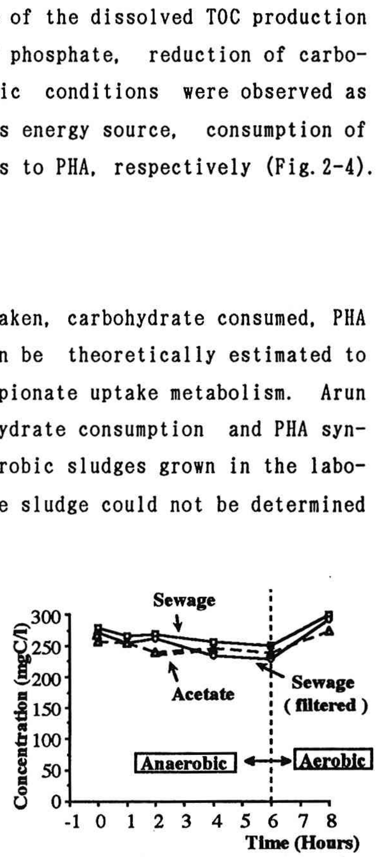

Fig.3 Profiles of Carbohydrates in Sludge

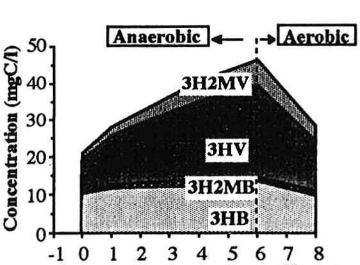

Fig. 4A Profile of PHA in Sludge (Substrate : Sewage)

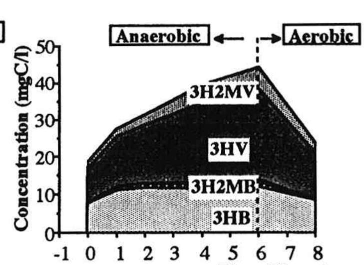

Fig. 4B Profile of PHA in Sludge (Substrate : Filtered Sewage)

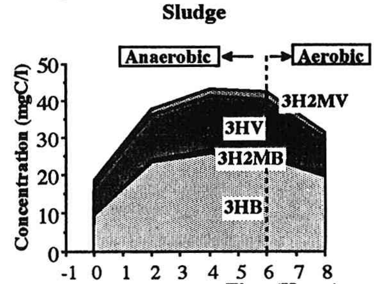

Fig. 4C Profile of PHA in Sludge (Substrate : Acetate)

Table 1. Changes of Carbohydrate Consumed, PHA synthesized and Phosphorus Released in the Anaerobic Phase on a common basis of 4 mole carbohydrate consumption. (Expressed in Molar Ratio)

	Raw Sewage	Fltrd Sewage	Acetate Sol.	Satoh(HAc)	Theoretical
Carbohydrate consumed	2.32	3.65	1.44	1.23	1
PHA synthesized	4.00	4.00	4.00	4	4
PO_4-P released	15.9	13.7	14.2	5.33	3

because of apparent increase of dissolved TOC in the anaerobic phase, but both carbohydrate consumption and PHA synthesis were observed. It can be seen from Table 1 that the ratio of carbohydrate consumed, PHA synthesized and phosphorus released in the present study was 1.44-3.65:4.00:13.7-15.9, which means that a greater amount of carbohydrate was consumed and a greater amount of polyphosphate was utilized by practical sludge than by laboratory sludge for a certain amount of PHA synthesis, implying higher necessity for the reducing power and energy in the anaerobic uptake of substrates.

Four PHA forming units, 3HB, 3HV, 3H2MB and 3H2MV, were found in the present anaerobic aerobic sludge. When sewage or filtered sewage was used as substrate, 60 % of PHA was composed of 3HV as shown in Fig.4A and 4B. Two unique units, 3H2MB and 3H2MV, were first found in laboratory anaerobic aerobic sludge fed with synthetic wastewater (Satoh et al, 1992). In the present study, it is experimentally shown that even anaerobic aerobic sludges grown in practical situations fed with actual municipal sewage also have the capability to synthesize 3H2MB and 3H2MV. The observed level of PHA accumulated in the sludge was 11.8-13.0 mgPHA/gMLSS and much smaller than the levels reported for laboratory sludges (50-100 mgPHA/gMLSS, calculated from the data given by Satoh et al, 1992).

5. CONCLUSION

The consumption of carbohydrate proved to be an essential process in the anaerobic phase of the anaerobic aerobic process even under practical conditions. This fact supports the idea that intracelular carbohydrate has a function to regulate the oxidation-reduction balance by providing reducing power in the anaerobic uptake of organic substrates. The capability to synthesize two unique PHA forming units, 3H2MB and 3H2MV, is common to the anaerobic aerobic sludge.

6. REFERENCES

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