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TREATMENT OF PERSISTENT ORGANIC POLLUTANTS BY HYPER AEROBIC IMPROVED ACTIVE SLUDGE

USUWANIE TRWAŁYCH ZANIECZYSZCZEŃ ORGANICZNYCH W PROCESIE HIPERAEROBOWEGO OSADU CZYNNEGO

Hyper Aerobic Improved Active Sludge (HAIAS) developed by IBIDEN is remarkably effective in the treatment of plating wastewater. It has also been suggested as having the capability to eliminate persistent chemicals such as surface-active agents and lignin.
HAIAS is usually operated at concentrations of 2 mg/L of DO; under this condition, the percentage removal of surface-active agents, raw starch, and lignin was 98%, 99%, and 96%, respectively. The typical treatment conditions were as follows: number of tanks, 7; individual tank volume, 100 m^3 for 5 tanks and 60 m^3 for 2 tanks; total HRT, 1.55 d; and overall volume loading, 2.4 g TOC/L/d. It is noteworthy that HAIAS indicated a degradation activity 6-fold higher than conventional activated sludge. HAIAS also eliminated nitrogen and phosphorus and exhibited deodorizing properties.
The unique feature of this sludge was that about 75% of the granule mass constituted inorganic components. Calcium, most of which existed as calcite-type $CaCO_3$, accounted for 44% of the inorganic constituents. Both calcium phosphate (apatite) and calcium sulfate (gypsum) were barely present in the granules. The MLSS of HAIAS remained constant for over 4 years along with the MLVSS. Interestingly, the level of MLSS remained high between 20000 and 70000 mg/L, and that of MLVSS was between 8000 and 15000, without drawing out the sludge for more than 4 years.
In the HAIAS granule, the consortium was composed of various bacteria chiefly consisting of Paracoccus, Mesorhizobium, and Thauera. It contained 55% aerobes, 14% facultative anaerobes, 2% strict anaerobes, and 29% microbes with indeterminate respiratory mechanisms, suggesting that both aerobic and anaerobic processes function in the HAIAS system. Strictly anaerobic bacteria such as Clostridium, Moorella, and Thermoanaerobacter species were found in the granules, although the conditions maintained were aerobic.
This study indicates that HAIAS can be effectively applied to the treatment of various pollutants. However, the mechanism of degradation remains unknown. Optimized techniques for management and equipment design would ensure a more effective operation and stable treatment.

1. Introduction

We humans require water not only for sustenance but also for carrying out productive activities. However, only 0.0001% of the total water on earth can be used. The amount of water usage worldwide has increased 6-fold than that 100 years ago. An optimal water treatment technology is needed for recycling water, which is a limited natural resource.

The merits of water treatment by the conventional activated sludge process are as follows: (1) inexpensive and ongoing, (2) relatively less unpleasant odor, (3) smaller amount of suspended solids in treated water with membrane filtration, and (4) widely applicable to organic compounds. However, it also has demerits such as (1) expensive treatment installation, (2) compounds and concentration with limited acceptance compared to anaerobic process, (3) excess mud production, (4) drawn-out degradation process, (5) risk of of bacteriophage attack on microorganisms that degrade organic compounds, and (6) bulking and foam formation.

We have developed a novel water treatment system with a greater degradation capacity and relatively less mud production. This active sludge named Hyper Aerobic Improved Active Sludge (HAIAS) works under aerobic conditions to degrade persistent organic compounds. Here, we describe the HAIAS system.

2. Methods

2.1. Treatment conditions

The typical treatment conditions were as follows: number of tanks, 7; individual tank volume, 100 m^3 for 5 tanks and 60 m^3 for 2 tanks; total HRT, 1.55 d; and overall volume loading, 2.4 g TOC/L/d. The treatment process is as shown in Fig.1. The usual operation conditions for HAIAS were as follows: over 2 mg/L of DO and MLSS and MLVSS values of ca. 40000 and ca. 10000, respectively (Table 1).

2.2. Degradation of organic compounds in the treated water

CODs, BODs, and TOCs of raw water and treated water were measured, and the capacity to eliminate organic compounds was evaluated.

2.3. Analysis of HAIAS

MLSS and MLVSS values of HAIAS were measured in terms of its concentration. ICP analysis assayed the inorganic elements in HAIAS. Analysis of crystallization in HAIAS was performed by x-ray diffraction.

2.4. The microbial community in HAIAS

The microbial community in HAIAS was assessed by 16S rDNA sequence analysis. The genomic DNA was obtained from the isolated microbes and from HAIAS directly by the bead-beating method (Ultraclean Soil DNA Extraction Kit, Mo Bio, USA). After PCR amplification of the genomic DNA by using 27F and 1525R primers, each PCR product was subjected to sequence analysis.

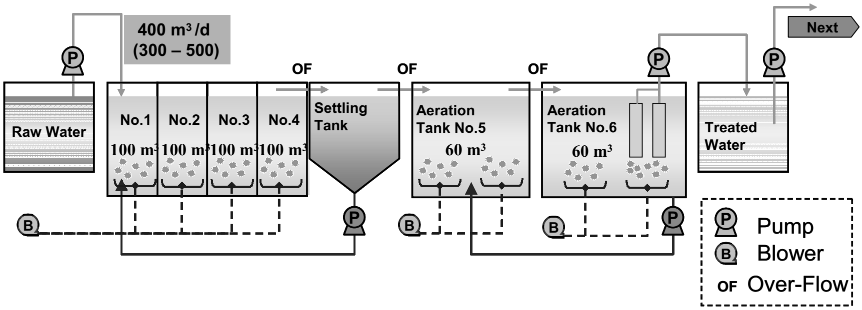

Fig. 1 Treatment process using HAIAS in Ogaki factory, IBIDEN

Tab. 1 Treatment conditions

Detention	1.15 (d)
DO	2.0 – 6.0 (mg/L)
pH	7.0 – 9.0
MLSS	ca. 40000 (mg/L)
MLVSS	ca. 10000 (mg/L)

3. Results and Discussion

Plating wastes include various persistent organic compounds such as glycol ethers. The active sludge known as HAIAS has been in operation for over 4 years in Ogaki factory, IBIDEN. The percentage removal of the BOD, COD, and TOC in the plating wastes was 99%, 94%, and 96%, respectively, in a total HRT of 1.55 d (Table 2). It is noteworthy that HAIAS indicated a 6-fold higher degradation activity than the conventional activated sludge. HAIAS showed also decreased the nitrogen (84%) and phosphorus (79%) content in the raw water (Table 2). HAIAS is shown to possess a higher capacity for the removal of nitrogen and phosphorus as compared to the conventional aerobic water treatment system.

The MLSS and MLVSS are maintained at a higher level in the HAIAS system than in the conventional system (Fig. 2). Therefore, the BOD volume load and BOD sludge loading of HAIAS are calculated to be 2.5–3.5 kg BOD/m^3/d and 0.17 kg BOD/kg/d, values that are 10 times and twice higher, respectively, than that of the conventional system. In fact, this is suggested to be one of the factors for the higher removal capacity of the HAIAS system. The MLSS and MLVSS of HAIAS were measured for about 110

d. The MLSS level was maintained between 20000 and 70000, while that of MLVSS was maintained between 8000 and 15000 (Fig. 2). These data indicate that no or a negligible amount of excess mud is produced, which is an excellent feature of the HAIAS system.

Tab. 2 Treatment by the HAIAS

	Raw Water	Treated Water
pH	7.0 (5.1 – 8.5)	8.3 (6.9 – 9.0)
BOD (mg/L)	5000 (1200 – 13000)	15 (3 – 83)
COD (mg/L)	3300 (800 – 7100)	200 (100 – 360)
TOC (mg/L)	3400 (1400 – 5800)	140 (90 – 250)
T-N (mg/L)	790 (160 – 1800)	130 (36 – 460)
T-P (mg/L)	140 (2 – 530)	30 (0 – 60)

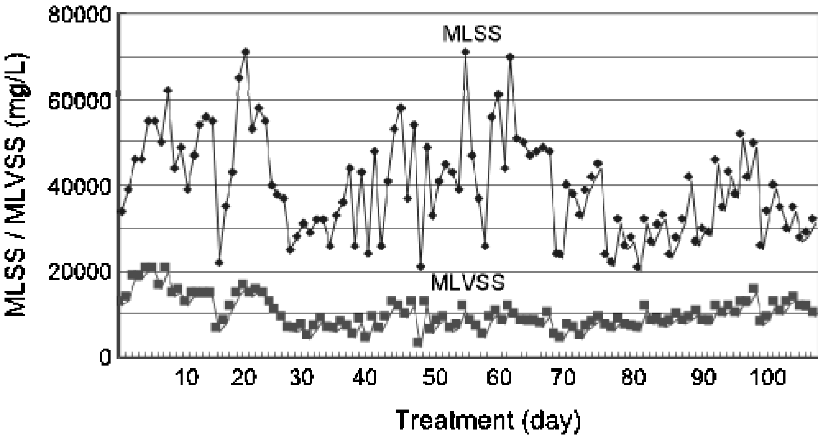

Fig. 2 Time courses of MLSS and MLVSS of HAIAS

Inorganic element analysis showed that calcium constituted 43.6% of HAIAS (Table 3). The mode of crystallization of calcium in the HAIAS was estimated to be calcite-type $CaCO_3$ (data not shown). The high concentration of calcium in the raw water may be associated with the high calcium level in HAIAS.

Analysis of the bacteria in HAIAS was performed using 16S rDNA sequence analysis. Proteobacteria accounted for 77.6% of the bacterial population (Table 4). In the HAIAS granule, a consortium of various bacteria, chiefly consisting of *Paracoccus*, *Mesorhizobium*, and *Thauera* species, was formed. It comprised 55% aerobes, 14% facultative anaerobes, 2% strict anaerobes, and 29% unknown, suggesting that both aerobic and anaerobic processes function in the HAIAS system. Strict anaerobes such as *Clostridium*, *Moorella*, and *Thermoanaerobacter* species were also found in the granules, although the sludge was aerobic. Both aerobic and anaerobic processes appear to function in parallel in HAIAS. This might be the mechanism underlying the high performance of the system.

Tab. 3 Inorganic elements in HAIAS

Elements	Mass %
C (Igloss)	24.4
Na	8.8
Mg	0.2
Al	2.5
Si	0.9
P	7.7
S	8.6
Cl	1.6
Ca	43.6

Tab. 4 Phylum in HAIAS

phylum	number	%
Acidobacteria	5	2.4
Actinobacteria	12	5.7
Bacteroidetes	2	1.0
BRC1	1	0.5
Chloroflexi	12	5.7
Deinococcus-Thermus	2	1.0
DSS1	1	0.5
Firmicutes	6	2.9
Gemmatimonadetes	1	0.5
Planctomycetes	4	1.9
Proteobacteria	163	77.6
Unclassified	1	0.5
total	210	100

4. Conclusion

Here, we have shown that HAIAS demonstrates a high performance in the removal of persistent organic pollutants in plating wastes. It has a degradation capacity 6-fold higher than the conventional treatment system and does not result in the production of excess mud. This feature appears to be attributable to the parallel functioning of aerobic and anaerobic processes in the system. It has been shown that HAIAS degrades persistent substances such as raw starch and lignin. Therefore, the treatment system can be applied to the degradation of various persistent compounds. Moreover, it can also be applied to a small set up as well because of its high performance and relatively less mud production.

Further investigations on the mechanism of degradation by HAIAS are needed. Optimized techniques for management and the equipment design would ensure more effective operation and stable treatment.

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