A STUDY ON SOLUBILIZATION OF EXCESS SLUDGE BY HIGH SPEED ROTARY DISK PROCESS

T. Imai*, M. Fukagawa**, M. Ukita*, M. Sekine*, T. Higuchi*, and T. Kawamura**

* *Dept. of Civil Engineering, Yamaguchi University, Tokiwadai, Ube, Yamaguchi 755-8611, JAPAN*

** *Ube National College of Technology, Tokiwadai, Ube, Yamaguchi 755-8555, JAPAN*

ABSTRACT

This study describes the solubilization of excess sludge by high speed rotary disk process. The excess sludge from final sedimentation tank in wastewater treatment plant was used in this study. The experiments of sludge through the high speed rotary disk were carried out. The results indicated that it was possible to improve the solubilization of excess sludge by this treatment process. Significant decrease of particle size after first time treatment was observed. With the increase of recycle time of treatment, the solubilization was obviously improved. It was suggested that the solubilization of microorganisms due to the function of hydrolase from broken microbial cell was promoted .

KEYWORDS

Solubilization; excess sludge; high speed rotary disk process; biodegradability; organic solid waste; hydrolase

INTRODUCTION

The consumption of resources and energy based on human activities followed by huge amount of wastes has being one of the most serious problems all over the world. It leads to terrible destruction of the global or regional environment, and its negative effects on human being's health as well as global ecosystem are appearing evidently. It is therefore necessary to establish the effective technology, i.e., prevention of emissions and saving resources and energy.

Recently, approximately 1.7 million tons of sludge (as dry weight) are discharged on an annual basis. In Japan, where space is quite limited, volume reduction technology based on incineration was started at an early stage due to the difficulty of obtaining landfill space. Currently, approximate 60% of sludge is incinerated. On the other hand, effective use of sludge through composting, energy recovery by anaerobic digestion and other technology are pretty low (about 15%), such uses are the focus of intensive study. The reason for this is that construction costs and operating costs related to incineration-based treatment are predicted to rise further in the future because of the technology to reduce secondary pollutants such as dioxins.

As mention above, the treatment of solid waste has become an utmost important in Japan, particularly the methods of high water content organic solid waste for recycle or energy recover are under development. There are mainly two methods to turn the high water content organic solid waste into recovering energy or recirculating resource: producing fuel technology (such as RDF) and resource recovery technology by biological treatment. The basic principle in the development of the later technology is the solubilization of organic solid waste and now is studied by many researchers. The degradation by high energy such as supercritical and subcritical water treatment (Goto *et al.*, 1997), ozonation (Yasui *et al.*, 1997), hot alkali treatment (Suzuki and Inagaki, 1994),

biodegradable method by thermophilic bacteria (Hasegawa *et al.*,1997; Imaoka *et al.*,1998; Li and Noike, 1992; Liu and Mori, 1993) and physical treatment (Nawa, 1995) are in development.

This paper describes the solubilization of excess sludge by high speed rotary disk process. This method is a kind of physical treatment. The excess sludge from final sedimentation tank in wastewater treatment plant was used in this study. The objectives of this study are to improve the solubilization of excess sludge by grind and shearing force through high speed rotary disk process and to promote the solubilization of microorganisms due to the function of hydrolase from broken microbial cell.

MATERIALS AND METHOD

Description of experimental apparatus

The experimental apparatus used in this study is shown in **Fig.1**. Different concentrations of sludge were processed the experiments. The sludge samples (10L each) were input at the inlet of fixed upper disk. The samples were treated though the high rotary speed of lower disk. The treated samples flew out from the gap of disks and were collected, then recirculated for 25 or 50 times. It is possible to be cooled the treated samples, if the samples become high temperature due to many times of recirculation. The experiments were conducted with gaps between two disks of 200 μm , 250 μm and 500 μm , respectively, and rotating speed was set equivalent to 3500 r.p.m.

Fig.1 Experimental apparatus of high speed rotary disk.

Experimental procedures

In this study, it takes 1 minute for one recycle of sample. The relationships among the concentration of MLSS, recycle times and particle size distributions were investigated. The particle size distribution, soluble BOD₅, DOC, MLSS and MLVSS were measured. In addition, samples after 25 times recycle treatment were stirred slowly at room temperature for 24 hours, then filtered through a 1.0 μm filter, and filtered samples were analyzed for DOC measurement.

Analytical method

Dissolved organic carbon (DOC) concentration and Total organic carbon (TOC) in liquid samples were determined by a SHIMADZU model TOC-5000 analyzer. BOD₅, MLSS and MLVSS were determined according to Standard Methods (1992). Particle size distribution was analyzed by a Horiba model LA-920 analyzer.

RESULTS AND DISCUSSION

Relationships between recycle times and particle size distributions

The relationship between recycle times and particle size distributions are shown in **Fig.2**. Four different concentrations of excess sludge (i.e. MLSS of 1300, 4700, 8800, and 11300 mg/L) were used. The average particle size of samples was about 70 μm . The gap between two disks was set at 250 μm . After first time treatment, the particle size of sludge decreased rapidly to 20 μm . It seemed no significant change with the increase of recycle time and became relatively steady-state after 50 times recycle treatment with a particle size of 10 μm . There is no difference between 1 time treatment and 25 times treatment as shown in **Photo.1** (MLSS = 4700 mg/L). The median of particle size before treatment was about 70 μm as shown in **Fig.2**. This might be due to the protozoa and fine sands. The floc of sludge had no influence on the particle size, and this was demonstrated by supersonic treatment test. The remarkable efficiency was observed in the first time treatment. This was probably due to the function of grind between two disks on the samples. However, it seemed no effect on bacteria because of their small size. On the other hand, the concentration of MLSS had no effect on the particle size of treated samples (50 times treatment) in this range of MLSS.

Fig.2 Relationships between recycle times and particle size distributions.

Fig.3 Relationships between disk gap, recycle times and particle size.

Photo.1 Microscopic photographs of excess sludge (MLSS=4700mg/L).
(a)no treatment, (b)1 time recycle, (c) 25 times recycle

The particle sizes of samples after treatment through two kinds of gaps (200 μm and 500 μm) were investigated, and the results are shown in **Fig.3**. After first time treatment, the particle size through small gap (200 μm) decreased more than that through large gap (500 μm). However, it seems no difference in size between these two operating conditions after 25 times treatment, and particle sizes become about 20 μm in both conditions, that was a little larger compared with the results shown in **Fig.2**. This was probably due to the grinding loss of disk surface by fine sands in the samples.

Relationships between recycle times and BOD_5

The changes of BOD_5 concentration with the recycle times are shown in **Fig.4**. After 25 times treatment, BOD_5 increased significantly, and it seems that there is an influence of recycle times on BOD_5 concentration as compared with that of particle size. With the increase of recycle times, the BOD_5 concentration was increased. For improvement of sludge solubilization, sludge treatment through small gap (200 μm) is a little better than that through large gap (500 μm). However, the balance between treatment efficiency and grinding loss of disks should be considered for the application of this process.

The changes of BOD_5 with time after 25 times treatment stirred slowly at room temperature are shown in **Fig.5**. BOD_5 concentration increased rapidly to 4000 mg/L during the initial 4 hours by disk treatment through 200 μm gap. Then it decreased quickly to 900 mg/L. These phenomena of rapid increase of BOD_5 in the initial period might be due to the following two reasons. Firstly, hydrolase solubilized through the break of cell, then high molecular organism hydrolyzed gradually to low molecular organism by enzyme function. Secondly, particle organism gradually hydrolyzed to low molecular organism. The rapid decrease of BOD_5 was probably due to reuse of this readily degradable BOD_5 as substrate by active (survival) biomass. After 24 hours, BOD_5 concentrations in both operating conditions decreased to 1200 mg/L. It was considered that a balance between the production of BOD_5 by hydrolase and the consumption of BOD_5 by active biomass. Therefore, the rapid increase of BOD_5 during the initial period was likely due to hydrolyzation of fragment of cell by enzyme and active cells in lag-growth period. The rapid decrease of BOD_5 after 4 hours was likely due to active cells in exponential-growth period and reused of solubilized BOD_5 as substrate.

Relationships between recycle times and DOC

The relationship between the change of DOC and recycle times is shown in **Fig.6**. Even though the pattern of DOC change was almost the same with that of BOD_5 after 25 recycle times through 200 μm gap treatment. DOC concentration was only about a quarter of BOD_5 concentration. The significant difference of the DOC

Fig.4 Relationships between recycle times and BOD_5 concentration.

Fig.5 Changes of BOD_5 concentration with time course.

Fig.6 Relationships between recycle times and DOC concentration.

Fig.7 Changes of DOC concentration with time course.

Table 1 Classification of organic compound for the biodegradability.

Dissolved organics		Suspended organics	
Biodegradable organics	Refractory organics	Biodegradable organics	Refractory organics

values resulted from two gaps treatment was observed, and DOC values through small gap (200 μm) treatment was about 4 fold than that of through large gap (500 μm) treatment. It is supposed that increased quantity of soluble BOD_5 through small gap compared with that through large gap was almost refractory organic matter.

The variation of DOC concentration with time after 25 times recycle treatment is shown in Fig.7. There seems to have the same trend as that of BOD_5 during the initial 4 hours period. However, there was no rapid decrease of DOC concentration after 24 hours. This was considered that refractory organic matter existed most in soluble compositions. In addition, the rapid increase of BOD_5 concentration during the initial 6 hours was the result of hydrolysis from suspended solids by comparison of the BOD_5 results.

Evaluation about definition of “solubilization”

In this study, BOD_5 and DOC were measured after the pretreatment of samples through GF/C filter. However, at present there is no clear definition of “solubilization”. If biodegradability of samples is used as explanation of solubilization, the definition of this basic standard should be necessary. From the view of the change of the ratio of readily biodegradable matter and slowly- biodegradable matter in soluble condition and suspended solid condition to explain the solubilization as shown in Table 1, the quantitative definition of the ratio should be demonstrated in the future study.

CONCLUSIONS

In this paper, the experiments of excess sludge through the gap of high speed rotary disk were carried out. The results showed that it was possible to improve the solubilization of sludge by grind and shearing force, and

therefore to promote solution of lower molecular material from intracellular biomass. The following conclusions were drawn from the results of this study.

1. The particle size of sludge decreased rapidly after first time treatment, and it seemed no significant change of particle size of samples with the increase of recycle time. However, there was a great influence of recycle time on BOD₅ concentration as compared with that of particle size, and the more the recycle time of treatment, the higher the function on BOD₅ concentration improvement. The experiment indicated that it was possible to improve the solubilization of sludge by high speed rotary disk treatment process.
2. The increase of soluble organic component was a little higher than that through large gap. However, such small difference between both treatments supposed that refractory organic matter existed most in soluble compositions.
3. The rapid increase of BOD₅ concentration during the initial 6 hours was considered to be the result of hydrolysis from suspended solids by comparison of DOC and BOD₅ results.
4. The future research should be emphasized on the followings: 1) observation on the treatment of high concentration of sludge; 2) investigation of optimal operating condition; 3) extent of improvement of lower molecular through hydrolysis; 4) estimation of the existence of biomass; 5) exhaustion of disk in treatment of samples including high inorganic materials such as sand; 6) type of surface materials of disk.

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