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Reduction performances of organic sludges from an industrial region of Taiwan by using ultrasonic wave and biotreatment technology

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Abstract. Economic growth arises fast in Taiwan because of the rapid development of industry, and many problems of environmental pollutions occur consequently. Wastewater and polluted water are the major pollutants occurred in the environment. As the result, plenty of researches related to wastewater reduction and treatment are developed to resolve the problem of wastewater production. The problem of wastewater production has been reduced after wastewater treatment tests have been used. However, the production of sludge increases accompanying with the volume of wastewater treatment, which causes numerous costs generated for dealing with sludge treatment. In general, successful technics involved in industrial sludge reduction are divided into five methods, including physical, chemical, biological, sludge hydrolysis, and a combination of the above methods. This study developed a method for sludge reduction by using ultrasonic technic with low consumed energy, combined with biotreatment (active sludge process) to conduct tests of organic sludge reduction in one industrial area of Taiwan. There is no use of chemicals on tests of organic sludge reduction, which resulted in no second pollutants generated by the application of ultrasonic technic, and organic sludges can be reduced. The results of the pilot and laboratory tests showed above 40% of sludge reduction, and this method was available to apply on the real filed operation.

1. Introduction

Industry progressed rapidly in Taiwan during the past five decades to achieve fast evolutions in the domestic economic growth, which resulted in plenty of environmental pollutions consequently, and wastewater was a major environmental pollutant. The content of wastewater generally divided as organic and inorganic materials, and biotreatment is the most common and economical method for the treatment of organic materials involved in wastewater. The activated sludge process is ranked as more ancient technics among available biotreatments, and great outcome of wastewater treatment can be accomplished by implementing activated sludge process. However, a difficult problem occurred accompanying the application of activated sludge process, and the problem is called as waste activated



sludge (WAS). Plenty of WAS generated after activated sludge process used in wastewater treatment. According to the statistical data, there are ten million and six million tons of WAS generated in Europe and the United States annually [1,2], and the amount of WAS generation (including organic and inorganic sludges) is over one million tons in Taiwan [3]. These WAS needs proper treatment before disposal process for the purpose of environmental protection because the content of WAS mostly involves of organic chemicals, heavy metals, and polluted materials. As the result, cost of WAS treatment increased with the amount of WAS generation enhanced annually. Based on available studies regarding WAS treatment, cost of WAS treatment reach to 60-65% of the total plant operation cost [4-6], which is ranked as high ratio expense of the entire operational cost, and many resolutions related to cost reduction of WAS treatment are developed for saving more expenses on WAS treatment. The efficient strategy on decreasing sludge disposal costs focused on minimization production of WAS to reduce expenses of WAS treatment. Detailedly, it is much effective in minimizing the production of WAS, if reducing excess sludge produced during wastewater treatment can be achieved.

There are numerous sludge disintegration technics, such as mechanical [7-10], thermal [4,11,12], chemical [13,14] and biological [15,16] treatments have been developed as a hydrolysis technic for sludge diminishment. Although great results of sludge reduction can be conducted by employing these technics, some second problems occur after the application of these technics on sludge treatment, including high costs of the operational process, extra chemical compounds produced, and excess products generated. Ultrasound method is investigated to overcome the problems caused by available sludge disintegration technics due to its specific function. The principle of ultrasound method aims to disruption of sludge cells, which resulted in the reaction of sludge hydrolysis, to decrease production of WAS [17-20]. Kim and Youn [18] proposed the optimal temperature of 50 °C for sludge hydrolysis reaction, and He et al., [19] investigated the excess sludge reduction of 67.6% was achieved via ultrasonic lysis tests. Moreover, Mohammadi et al., [20] mentioned 78% of excess sludge was reduced by using ultrasonic waves in biological wastewater treatment. As the result, ultrasonic method is available to conduct excess sludge reduction. Based on great result of the above studies, a self-developed ultrasonic system was applied as a sludge reduction unit in Taiwan.

2. Experimental methods

2.1. Sample

The wastewater was collected from an industrial plant in Fangyuan industrial park, Changhua, Taiwan, and the following indexes, such as total chemical oxygen demand (COD_t), soluble chemical oxygen demand (COD_s), suspended solids (SS), and volatile suspended solid (VSS), were used to present the efficiency of ultrasound method on sludge reduction.

2.2. Ultrasonic device

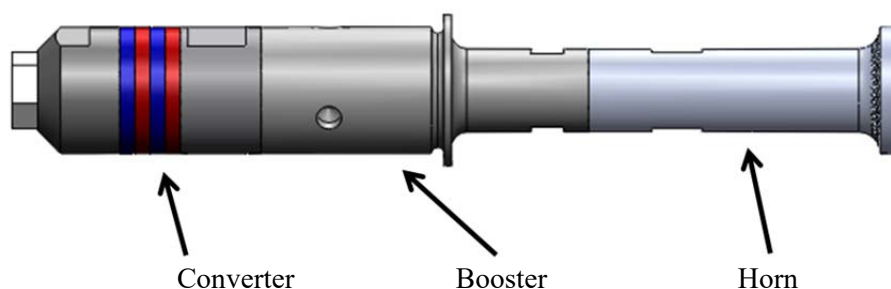


Figure 1. The diagram of ultrasonic device.

Ultrasonic device contained mechanical device and power system, and mechanical device also divided into two systems, electromechanical transformation and mechanical scale-up systems, which presented as the core device system in the facilities of ultrasonic sludge treatment. There are three components, including converter, booster, and horn, in the ultrasonic device, as depicted in figure 1. The functions of converter, booster, and horn are electromechanical transformation, deliver of ultrasonic energy, and scale-up ultrasonic intensity, respectively.

2.3. Ultrasonic operational process

Figure 2 depicts the ultrasonic operational process applied in a plant for sludge reduction, which contains primary clarifier, secondary clarifier, aeration tank, and ultrasonic reactor, and activated sludge (AS) is adjusted at a flow rate of 12,000 cubic meters per day (CMD) to treat industrial wastewater.

In general operational process, the influent volumes of AS tank and clarifier were regulated as 1,000 L and 382 L, correspondingly. Moreover, hydraulic retention time (HRT) was operated at the condition of 24 hours, and sludge retention time (SRT) was run at the condition of 20 days. Results of control and ultrasonic tests were conducted for comparison of efficiency with or without the ultrasonic device. Equation 1 was employed to calculate the efficiency of sludge decrease.

$$\text{Esd}(\%) = \frac{(SS_{cum} + WS)_{control} - (SS_{cum} + WS)_{ultrasonic}}{(SS_{cum} + WS)_{control}} \times 100\% \quad (1)$$

where the efficiency of sludge decrease is Esd (%), SS_{cum} is defined as the cumulative amount of SS in the AS process (g), and the cumulative amount of WAS is determined as WS (g) ($WS_{ultrasonic}$ equal to 0).

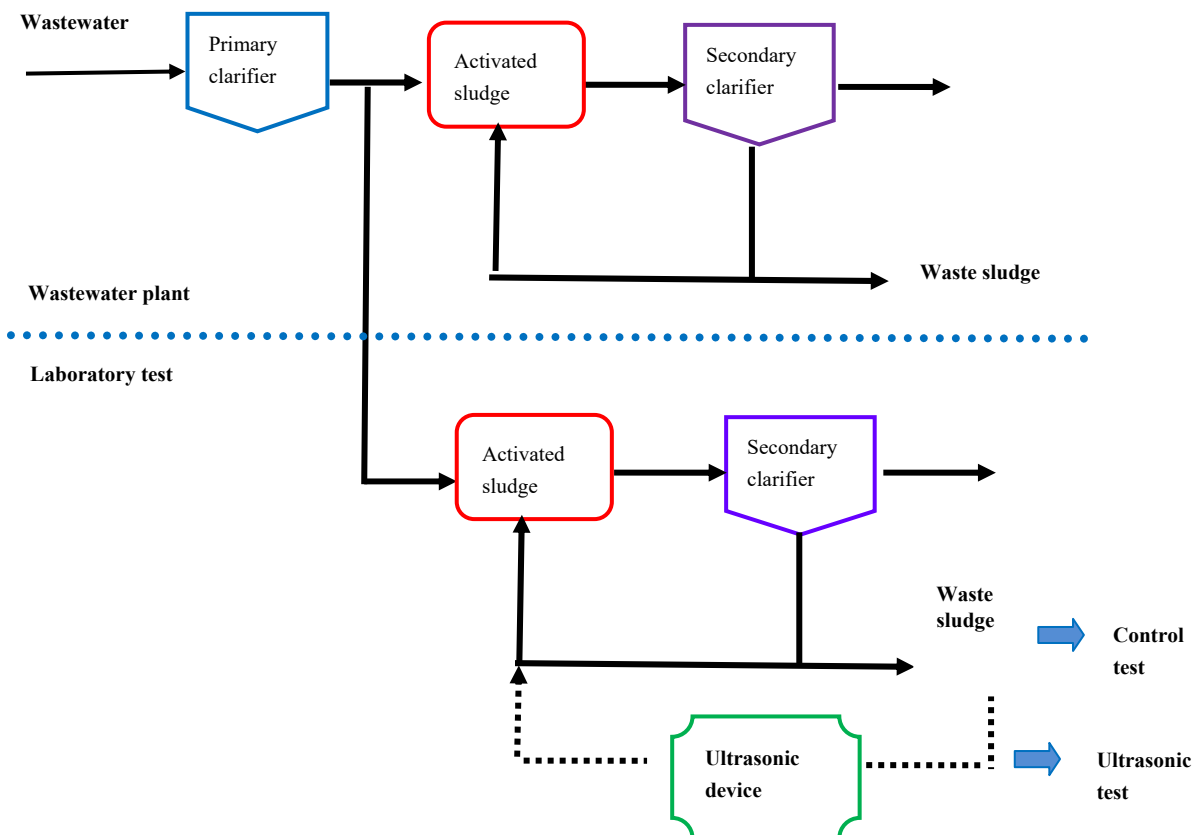


Figure 2. The operational process of sludge reduction test by the ultrasonic device.

2.4. Parameters analysis

The analysis method of samples used the standard methods from Environmental Protection Administration (EPA), Executive Yuan, ROC, and the analytic parameters included SS, VSS, pH, CODs and CODt. Furthermore, the parameters analysis of SS and VSS followed the standard of W210.58A, and the method of W515.54A was employed to analyze parameter of COD.

3. Result and discussion

3.1. Efficiency of sludge decrease by ultrasonic method

There are three flow rates of the ultrasonic system used in sludge decrease tests for determining the best experimental condition. The first condition is set as flow volume of 720 L/day, and HRT is adjusted as 5 min. Flow volume and HRT of the second condition are arranged as 3,600 L/day and 1 min, respectively. In the third condition, 7,200 L/day and 0.5 min were used as conditions of flow volume and HRT, correspondingly. Furthermore, the operational parameters of flow volume and HRT in the fourth condition are adjusted as 3,600 L/day and 1 min, respectively, and the additional condition is external microbubbles. Table 1 depicts test results at four various operational conditions. COD, SS, and VSS arise a bit at the effluent of AS process because of sludge hydrolysis reaction. Efficiency of sludge hydrolysis enhanced with the application of the ultrasonic method, compared with the test without the usage of ultrasonic step. Additionally, the flow rate of ultrasound enhanced from 720 L/day to 7,200 L/day to alter the efficiency of sludge decrease (59% to 34%), which demonstrated the inverse reaction occurred between the efficiency of sludge decrease and flow rate of ultrasound increase. Therefore, the installation of ultrasound help enhance the efficiency of sludge decrease, and the proper flow rate of ultrasound was 3,600 L/day for further tests.

Table 1 Sludge decrease efficiency and water quality variation under four various operational conditons.

Condition	Flow rate of ultrasound (L/day)	Influent/ Effluent	CODt (mg/L)	CODs (mg/L)	SS (mg/L)	VSS (mg/L)	Sludge decrease (%)
1	720	Inf.	282	258	25	20	59
		Eff. 1	75	65	23	17	
		2	72	56	18	15	
2	3,600	Inf.	267	258	25	19	40
		Eff. 1	92	73	32	24	
		2	75	58	21	17	
3	7,200	Inf.	318	274	21	17	34
		Eff. 1	101	79	33	23	
		2	69	53	18	14	
4	3,600*	Inf.	300	246	32	27	58
		Eff. 1	77	58	28	22	
		2	59	52	11	10	

* Test by ultrasonic reactor with additional condition of external microbubbles

1 ultrasonic test

2 control test

3.2. Efficiency of sludge decrease by ultrasound method with microbubbles

Ultrasound method with microbubbles resulted in cavitation effect to disintegrate sludge cell [21]. Table 1 depicts the result of sludge decrease by ultrasound method with the addition of external microbubbles, and the efficiency of ultrasound method with microbubbles reaches to 58%, which was higher than the test of ultrasound method without microbubbles addition at the same flow rate of 3,600 L/day (40%). As the result, microbubbles addition can increase the efficiency of sludge decrease.

4. Conclusions

According to previous studies, 67.6% and 78% of sludge reduction could be achieved via ultrasonic lysis tests and using ultrasonic waves [19] in biological wastewater treatment [20]. This study aimed on developing an ultrasonic system to reduce excess sludge. Because the contents of wastewater are huge different in various countries, and results of sludge reduction present dissimilar in various countries via ultrasonic methods. A self-developed ultrasonic system was developed for sludge decrease of industrial wastewater. After four conditions tests, the sludge decrease at 720 L/day reached 59%, but the volume of flow rate was too small to handle the influent volume of the plant. There is 59% of sludge decrease occurred in the condition of ultrasound with microbubble in the sludge hydrolysis reactor at 3,600 L/day. Therefore, ultrasonic method resulted in sludge reduction of the wastewater treatment, and the combination of ultrasound with microbubble enhanced the percentage of sludge decrease.

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