Reduction of Excess Sludge Using Different Methods in SBR Process for Biological Wastewater Treatment (Emphasizing on Ultrasonic Usage)

Mehrdadi, N.[1], Mohammadi, A.R.[2*], Torabian, A.[3]

1-Assoc. Prof., Department of Environmental Engineering, Tehran University, Tehran-Iran mehrdadi@ut.ac.ir

2-Ph.D. student, Department of Environmental Engineering, Tehran University, Tehran-Iran

3- Prof., Department of Environmental Engineering, Tehran University, Tehran-Iran atorabi@ut.ac.ir

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Introduction

A problem with Conventional Activated Sludge (CAS) is that it yields too much sludge in such a way that biomass yield coefficient in this process is approximately 0.5 kg of biomass per removal of one kg of the removed COD. Treatment and disposal of sludge resulted from municipal wastewater treatment comprises approximately 50 to 60 percent of the total costs of a wastewater treatment plant. Therefore, regarding the environmental constraints for final disposal of sludge and soaring costs of sludge treatment and disposal in current methods, naturally, research centers all over the world are attempting to find and develop new methods for minimizing produced sludge in wastewater treatment plants. One of these ideal solutions for solving the sludge problem fundamentally is using those sludge processes which yield less sludge compared to current processes.

Lysis-cryptic Growth: When a cell is disintegrated, its contents and its stored nutrients release within the wastewater. This increases the organic load of wastewater. Organic materials released due to disintegration of cells re-enter into the metabolic cycle of other microorganisms. Some of such carbonic materials are consumed for vital activities of other microorganisms which in turn generally reduce the amount of yielded sludge. Since the biomass growth due to the existence of such carbonic materials can't be measured separately from the growth due to that of original carbonic materials, it is called cryptic-growth. Cell disintegration processes used whether in laboratory and pilot scales or in full scale so far include:

1-Thermal lysis in temperature range between 40 to 180° C
2-lysis due to chemical agents such as acids and bases
3-Mechanical or physical disintegration such as milling, equalizers or ultrasonic energy
4-Consequent freezing and thawing
5-Biological hydrolysis by adding enzymes
6-Using advanced oxidation processes such as using ozone and water peroxide
7-Combined methods such as thermal - chemical lysis or ultrasonic energy and alkalis

All studied methods so far have their own advantages and disadvantages and most of the studies are in the laboratory and pilot scale and need further researches. Accordingly, this paper aims to study and compare the efficiency of some methods based on lysis and cryptic growth process in pilot-scale, using SBR reactor. These methods include: lysis using ultrasonic waves, intermittent ozonation, thermal lysis and loading reduction and dissolved oxygen increase.

Materials and Methods

Sludge lysis using ultrasonic waves

For producing ultrasonic waves, an ultrasonic homogenizer device (Bandelin-SONOPULS HD3400) made in Germany with a 25mm-probe (VS 200T) and adjustable output power ranging from 0 to 300 watts was used. The waves generated by this device are of 20 KHz frequency and it can generate both continuous and pulsed waves.

Corresponding author: Tel: 09133813460 E-mail: a dehcheshmeh@yahoo.com

When in pulsation mode, the duration of pulses can be adjusted by the user.

In this study pulsed waves with generating duration of 1.5 seconds and rest intervals of 0.5 second were used. The supplied energy to the cellular mass unit was approximately 35000 (KJ/KgVSS). This energy was provided using the power of 100 Watts. The volume of sludge, which was disintegrated each time and returned to the system, was approximately 30 percent of the total available sludge in the system.

Sludge lysis using Ozone

At this stage of the research, to study the impact of ozone on about 30 percent sludge reduction in the test reactor, the sludge was extracted and exposed to ozone with the ratio of 25mg of ozone per 1 gram of SS. The sludge was then returned into the reactor. For producing ozone, an ozone producer device in laboratory scale (CGET company, Model: KED-A08-20, made in China) with the capacity of 20 liters ozone per hour was used.

Thermal lysis

Thermal degradation of about 30 percent of the total sludge was carried out in the temperature of 80°C for 3 hours. The disintegrated sludge was returned to the system.

Simultaneous loading reduction and DO increase

In order to investigate the impact of loading and dissolved oxygen concentration on the biological sludge yield, the operating conditions of the test reactor were changed. Its loading was decreased from 0.6 to 0.19 Kg/m^3.day. Also dissolved oxygen concentration was increased up to about 6 mg/l.

SBR Reactor

For this study, two SBR reactors (one as the control and one for performing tests) made of Plexi glass were used with an internal diameter of 20 cm, a height of 50 cm, and useful volume of 12 liters and treatment capacity of 7 liters in each working cycle. Reactors were operated at room temperature and for supplying required airflow. Also, some aerators with the capacity of 11 liters per minute are equipped with an air distributor of circular shape with 18cm diameter and air particle size of 1 to 3 mm, were employed. To ensure the uniform air distribution, especially in lower aeration rates and to provide the necessary mixing energy, a mixer with a flat tow-paddle blade, a vertical shaft and an engine with the speed of 110 rpm (made in France) was installed on each reactor.

Results and Discussion

As obviously indicated in Fig. 1, in all of the employed methods, sludge yield coefficient is lower than that of the control reactor. The amount of sludge yield will be the minimum in the case of using waves with aforementioned amplitude. Ozonation also reduces the amount of sludge but at a lower level compared to the waves being added. Fig. 1 shows the mean amounts of the measured values during 60 working cycles. According to this figure, operation yield is 0.48 in the control reactor but it is 0.1, 0.18, 0.24 and 0.3 for ultrasonic, ozonation, thermal and low rate loading reactors, respectively. Therefore, the highest efficiency in sludge reduction is attributed to ultrasonic waves with up to 78 percent of reduction in sludge yield.

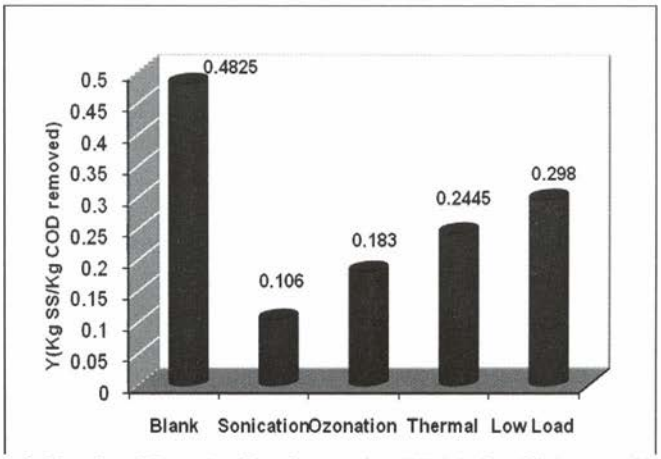

Fig. 1: The Mean of Obtained Results for Operation Yield Coefficients of Different Methods

The performance of this technique in sludge reduction is highly depended on the ability of these agents in sludge degradation. Sludge decay is the disintegration of sludge and converting their components into solution so that it can be used by other microorganisms and this process is called "Solubilisation".

Conclusion

The results of this study show that the disintegration of 30 percent of the sludge of a reactor using ultrasonic waves of 35000 (KJ/KgVSS) can reduce bio-sludge yield as much as 78 percent in a SBR reactor. This is due to the Solubilisation of COD of sludge and its reuse by other microorganisms. In this case, the COD removal efficiency decreases slightly and reaches down to 84 percent, which is still suitable for effluent discharge to receiving water resources according to environmental standards provided by Iranian Department of Environment. Ultrasonic waves, with aforementioned conditions can convert up to 53 percent of COD of sludge into solution (i.e. soulubilisation), a usable form for other microorganisms, so these waves can be used as a pre-treatment on sludge digestion. The waves have a negative impact on specific oxygen uptake rate (SOUR), but it is not so great to disrupt the treatment process, the SOUR rate will decrease from 17.4 (mg DO/gSS.hr) to 11.6 (mg DO/gSS.hr), but the sedimentation properties of sludge improves significantly, and the SVI rate improves from 104 to 82, so ultrasonic waves can be used as a controlling factor of bulking in wastewater treatment.

Low rate of loading, in the presence of high concentrations of oxygen (mg/l >6), yields less sludge in comparison with normal loading and normal dissolved oxygen rate. The amount of yielded sludge in these systems is about 0.3 Kg of suspended solids per 1 Kg of removed COD, which is approximately 37 percent lower than the rate in the control reactor. COD removal efficiency of such reactors is desirable, but the sedimentation properties and specific oxygen uptake rate of them decreases and their sludge volume index amounts to 124 (ml/g).

Alternating ozonation of 30 percent of the sludge of the system with the amount of 25 (mgO3/gSS) can reduce the sludge yield coefficient (operation yield) from 0.48 to 0.18 which means 63 percent reduction of biological sludge. In this case, COD removal efficiency decreases down to 83 percent which makes some problems for wastewater discharge into surface water bodies and groundwater resources. Thus, it is recommended that a lower amount of ozone per mass unit of sludge is used. Specific oxygen uptake rate of the sludge in ozonated reactors decreases drastically and SOUR rate reaches down to 8 (mg DO/gSS.hr.) and sludge sedimentation properties also declines, leading to the possible occurrence of dispersed growth phenomenon.

Thermal lysis of 30 percent of the system sludge at the temperature of 80°C for 3 hours and returning the sludge back into the reactor can reduce the biological sludge yield up to 49 percent. COD removal efficiency in this case is 86 percent. Sludge sedimentation properties improve in this situation, but specific oxygen uptake rate slightly decreases in such a reactor down to 12 (mg DO/gSS.hr.).

Key words

Excess Sludge Reduction, Biological Wastewater Treatment, Ultrasonic, Ozonation, Thermal lysis, SBR Reactors.