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# Effects of cell lysis in gas yield and sludge stabilization by combined process of thermophilic aerobic and anaerobic digestion

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**Abstract**

A novel process of combining thermophilic (55 °C) aerobic digestion as pretreatment with mesophilic (<35 °C) anaerobic digestion process (TAD-MAD) was designed to stabilize sludge and produce CH4 biogas. TAD-MAD processes can yield energy-rich biogas, save aeration energy, short retention time, which is prior to single TAD or MAD process. TAD pretreatment play an important role in decomposing cell of sludges and enhancing the hydrolysis process. Other two pretreatment of Alkali and Ultrasonic following MAD process were investigated in this paper to compare with effect of TAD-MAD process on sludge stabilization and biogas production. The results showed that VSS removal rates for three processes of TAD-MAD, Alkali-MAD and Ultrasonication-MAD could achieve 40% at 10d or 11d, which can meet the requirements of the GB18918-2002 guidelines. soluble chemical oxygen demand (SCOD) and volatile fatty acid (VFA) in the supernatant could increase to the highest values at initial 4d for three different processes, and subsequently decline during the latter part of digestion. For TAD-MAD process, SCOD and VFA could rapidly reach to the highest values 16000 mg/L and 7222 mg/L at initial 2d respectively, which achieved more significant effect on cell lysis. All three pretreatments improved biogas production, but TAD-MAD process could produce the most amounts of CH4 (481mL CH4 g−1 VSS) and cumulative biogas production of 12496mL at end of digestion. pH between 7.04 and 7.92 in three systems could maintain in neutral and subalkaline values. Alkalinities of sludge in three systems could meet need for methanogenic population inside the anaerobic digester. In conclusion, TAD-MAD has similar VSS removal rate with other two processes, but could produce more CH4 and biogas yield than other two processes.

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*Keywords:* *Pretreatment; thermophilic aerobic digestion; alkali; ultrasonication; cell lysis; biogas;*

## 1. Induction

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Sewage sludge disposal has been a puzzle for most of Wastewater Treatment Plants (WWTPs)[1]. Biological treatment methods of anaerobic and aerobic digestion processes are commonly used to achieve sludge stabilization. Among these processes, autothermal thermophilic aerobic digestion (ATAD) has been paid significant attention in sludge stabilization because of its produce Class A biosolids [1-4].

However, process of ATAD can't produce biogas of hydrogen and methane [5,6]. Although anaerobic digestion process(AD) can provide useful methane production, and doesn't require an oxygen supply[7], it clearly has limitations in terms of long retention times to achieve biostabilization and low overall degradation efficiency of the organic matter. Actually, the rate-limiting step in WAS digestion is the hydrolysis of organic matter, or cell walls lysis[8]. Therefore, a novel combined processes of thermophilic aerobic digestion and mesophilic anaerobic digestion (TAD-MAD) in two-stage digester has been investigated by bath mode. The processes TAD-MAD can yield energy-rich biogas, save aeration energy, short retention time to stabilize the sludge.

Therefore, TAD as pretreatment process need to be investigated whether to better lyse the cells in waste activated sludge(WAS) to readily biodegradable low-molecular-weight compounds. Many different pretreatment technologies have been studied to overcome these limitations, such as mechanical[9], ultrasonic[10], alkaline[9,11], and enzymatic[12] methods could disrupt the cell walls and increase WAS biodegradability by enhancing the hydrolysis process.

This work focus on combination of co-treatments with mesophilic anaerobic digestion in WAS system. The sludges were treated by TAD-MAD, in comparison with other two pretreatment processes of alkali and ultrasound to determine the effect of cell lysis. Based on the obtained results of optimum operation parameters and fundamental theories of aerobic and anaerobic digestions, batch experiments are performed. This study investigates the factors of VS removal, release of intercellular organic matters and volatile acid, production of biogas and methane. This work aims to evaluate the effectiveness of TAD-MAD and provide recommendations for its large-scale application.

## 2. Materials and methods

### *2.1 Sample of sludge*

Sewage sludge was sampled from a municipal wastewater treatment plant in Changzhou, China in which an anaerobic-anoxic–oxic process was applied to remove biological nitrogen and phosphorus. The sampling sludge, which had originally been stored for about 24 h in a settling tank, was centrifuged at 3500 rpm for 5 min to obtain a total suspended solid (TSS) level between 5% and 6% solids.

### *2.2 Start-up of tree different pretreatment process*

Three combined processes are MAD digestion connecting with three different processes alkaline, ultrasonic and TAD as pretreatment, respectively. After the pretreatment process was initiated, MAD process was operated. In Alkali-MAD process, the sludge was firstly treated by alkali (pH of 12, NaOH) for 0.5h under room temperature at 24°C during process of alkaline pretreatment. In Ultrasonication-MAD process, the sludge was treated by ultrasonication at 20kHz and 60w (FS-300, Shengxi Ultrasonic Instrument Co. Ld., Shanghai ) for 0.5h during ultrasonic treatment process. In TAD-MAD process system, the sludge was aerobically operated for two days in batch mode at 55°C for TAD process as pretreatment. The sludges, treated by three different pretreatment processes, were inputted in MAD digester to be anaerobically digested for 18d at 35°C, respectively.

### *2.3 Experimental facilities*

The process of TAD-MAD is consisted of two digesters of TAD and MAD, which were two cylindrical glass digesters in a water bath shaker to maintain a specific digestion temperature. MAD digester is 3L effective volume with 40mm diameter and 65mm height. A gas collection bottle is connected on top of MAD digester by an effluent gas pipe for the collection of effluent gas. Effective volume of TAD digester is 2 L, and 30mm diameter and 50mm height. Air was supplied through a microporous diffuser in TAD digester with a flow rate of 0.1 L $min^{-1}$[13] .

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