Inhibition of Anaerobic Biological Treatment :A Review

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Abstract. Anaerobic digestion is a method for treating living and industrial wastewater by anaerobic degradation of organic compounds, which can produce biogas (carbon dioxide and methane mixture) and microbial biomass. And biogas as a renewable resource, can replace the use of ore fuel. In the process of anaerobic digestion, the problems of low methane yield and unstable reaction process are often encountered, which limits the widespread use of this technology. Various inhibitors are the main limiting factors for anaerobic digestion. In this paper, the main factors limiting anaerobic digestion are reviewed, and the latest research progress is introduced.

1.Introduction

Anaerobic fermentation has many advantages, such as lower sludge yield, higher energy recovery rate and lower reaction energy consumption. Thermophilic digestion in anaerobic digestion is more stable than mesophilic digestion, and it can destroy viruses, bacteria, and other pathogens in wastewater more thoroughly. Despite these advantages, however, some operational constraints still hinder the widespread use of anaerobic digestion[1]. In anaerobic digestion, microbial anaerobic metabolism pathways are extremely complex, and acid production and methane production are produced by microorganisms respectively. There are great differences in the reaction stage, substrate requirements, growth environment and environmental sensitivity[2]. How to maintain the stable metabolism between these two stages is the main way to solve the problem of anaerobic digestion instability. As inhibitors are ubiquitous in wastewater and anaerobic sludge, they are generally considered to be the major factors responsible for anaerobic digestion. A variety of substances have been reported to inhibit anaerobic digestion[3]. When a substance changes adversely in the microbial population or inhibits the growth of bacteria, it can be identified as an inhibitory substance. Inhibition generally refers to the reduction of methane yield and accumulation of volatile organic acids. This paper mainly introduces the development status of anaerobic digestion, and the summary of various inhibitors that in anaerobic process is to focus on: (1) inhibition mechanism, (2) the inhibition effect factors, (3) the

actual problems in the wastewater treatment process.

2.Inhibitors

In the anaerobic process, the decomposition of anaerobic microorganisms using organic matter to produce methane is the main stage of anaerobic reactions. Therefore, in discussing the influencing factors of anaerobic biological treatment, the factors that affect methanogens are generally discussed. The main influencing factors are temperature, pH,presence of other ions ,toxic substances and so on.

2.1 Temperature

The effect of temperature on anaerobic microorganisms is particularly significant; anaerobic bacteria can be divided into thermophilic bacteria (or high temperature bacteria), thermophilic bacteria (medium temperature bacteria); accordingly, anaerobic digestion is divided into: high temperature digestion (55℃ or so) And the medium temperature digestion (35℃ or so); the reaction rate is about 1.5 to 1.9 times, the medium temperature digestion, the gas production rate is higher, but the methane content of the gas is low; when dealing with pathogens and parasite eggs, Sludge, the high temperature digestion can achieve a better hygienic effect, and the dewatering performance of the sludge after digestion is also good[4]. With the development and application of the new anaerobic reactor, the effect of temperature on anaerobic digestion is no longer important The biomass in the new reactor is very large) and can therefore be carried out at room temperature (20 to 25℃) to save energy and operating costs[5].

2.2 pH and alkalinity

pH is the most important factor in the process of anaerobic digestion. Methanogens are very sensitive to pH changes, and are generally considered to have an optimum pH range of 6.8 to 7.2.The methanogenic bacteria will be seriously inhibited, and further lead to the deterioration of the whole anaerobic digestion process; anaerobic system pH value by a variety of factors: influent pH, water quality (organic matter, organic species, etc.)[6]. The biochemical reaction, acid-base balance, and gas-solid solution between the dissolution balance[7]. Anaerobic system is a pH buffer system, mainly controlled by the carbonate system.The system of fatty acid content increase (cumulative) will consume -HCO_3 in general, so that the pH drop[8].But the role of methanogens can not only consume fatty acids, but also produce-HCO_3 cause the system's pH rise[9]. Alkalinity was once considered an important factor in anaerobic digestion. But in fact, its role is to ensure that the anaerobic system has a certain buffer capacity to maintain the appropriate pH. The anaerobic system in the event of acidification. It takes a long time to recover[10].

The interaction between free ammonia, pH and volatile fatty acids may lead to "suppressing steady state", which runs stably, but has lower methane production [11, 12]. Microbial growth The optimum pH control may reduce the toxicity of ammonia [13]. It is reported that the acidification of crab wastewater improves the performance of UASB reactors, such as the lower COD concentration of effluent [14]. During the anaerobic digestion of cattle manure, as the pH is adjusted to 7.2 to 6.8, methane production will also increase up to four to five times as high as possible[15]. During anaerobic digestion of pig manure, the volatile fatty acid reached 320mg/L when pH was 8. Adjusting the pH to 7.4 resulted in the VFAs re-use and reduced VFAs concentration of 20mg/L. The reason for

this phenomenon may be due to the inhibition of ammonia inhibition under low pH conditions[16]. More worthy of attention is that both methane and acid-producing microorganisms have their optimum pH. Even though ammonia is at a secure standard, failure to keep the pH within the proper range may cause reactor failure[16,17].

2.3 Presence of other ions

Studies have shown that some metal ions can inhibit the anaerobic digestion process, such as Mg^{2+}, Na^{+} and Ca^{2+}, which is due to the existence of other ions, resulting in the decline of the toxicity of ions[18-20]. Ammonia and sodium show antagonism in anaerobic digestion process, an ion can antagonize another ions generated toxicity. Under normal circumstances, 0.15 M ammonia can lead to a decrease to acetic acid production by 20%, but when adding 0.05 M of Na^{+} in the system, methane production will increase by 5% (without the addition of the inhibitor sample)[21]. The effect of the ion combination is higher than that of single ionic. For example, when Na^{+} and K^{+} or Na^{+} and Mg^{2+} are combined, methane production will increase by 10% compared with the single addition of Na^{+}[22]. It is reported that when NH_4Cl up to 30g/L, adding 10% (w/v) phosphate can stimulate animal manure to produce biogas increased[23]. This stimulating effect of the phosphoric acid nucleic acid is due in part to the fact that the biomass is immobilized on the mineral particles, which prevents the rinsing of biomass from the reactor. Due to the antagonistic effect of phosphate rock (K^{+}, Ca^{2+}, Mg^{2+}) minerals, inhibition of ammonia is also considered partly due. However, inhibition due to more than 50g/L of NH_4Cl is irreversible and cannot be eliminated by the addition of phosphate[24].Although they are essential for microbial growth, they also affect the specific growth rates of other nutrients. Even if the medium stimulates the growth of microorganisms, the excess will slow down the growth rate, and even higher concentrations can cause severe inhibition or toxicity.

2.4 Toxic substances

Sulfates and other sulfur oxides are easily reduced to sulfides during anaerobic digestion[25]. When the soluble sulfide reaches a certain concentration, the anaerobic digestion process is mainly due to the production of methane processes[26]. Some metals such as Fe can remove S^{2-}, or from the system to remove H_2S can reduce the inhibition of sulfide and ammonia nitrogen is anaerobic digestion of the buffer.But the concentration is too high, so it will produce toxic effects on the anaerobic digestion process[27].At the same time, heavy metals will cause damage to the enzyme system of anaerobic bacteria, cyanide is also toxic substances[28-30].Sulfate reducing bacteria can reduce sulfate to sulfide in an anaerobic reactor. Sulfate reducing bacteria can be divided into two groups, one is incomplete oxidation, mainly degrading ethyl lactate and CO_2, the other is complete oxidation and oxidation of acetic acid to CO_2. Sulfate reduction resulted in inhibition of two stages. The main inhibition was due to the competition between SRB for organic matter and inorganic substance, which inhibited the CH_4 production. The toxicity of sulfide to different bacterial communities is the result of secondary inhibition.

3. Engineering significance in industry

3.1. Food processing industry wastewaters

In food processing industry, anaerobic digestion process can be used in vegetable and fruit canning, milk and dairy products, meat and seafood processing and starch sugar production process. The content of organic matter in food processing wastewater, anaerobic digestion treatment is ideal for use. However, due to the presence of inhibitors, the application of this technique may be hindered. Ion of seafood processing wastewater containing high concentration, including Na^+, Cl^- and sulfate etc.. Also the production of high salt wastewater in vegetables, milk dairy processing industry. Contains a lot of fat, protein and carbohydrate in milk production in dairy wastewater. Contain fat, blood, feces and recalcitrant organic substances in meat processing wastes. The degradation of these proteins and lipids resulted in accumulation of ammonia and long-chain fatty acids, thereby inhibiting the activity of anaerobic microorganisms [31]. These wastes also contain certain concentrations of fungicides and disinfectants, which also inhibit the anaerobic digestion reaction[32]. However, the increase of C / N ratio and dilution can reduce the toxicity of these inhibitors in the combined digestion process.

3.2 Papermaking wastes

Papermaking wastewater mainly comes from the industrial production of paper pulp washing and bleaching two production process. When washing, the effluent is called black water. The concentration of pollutants in black water is very high, and contains a lot of fiber, inorganic salts and pigments and other substances. Papermaking wastewater discharged from the bleaching process also contains a large amount of acid and alkali substances called white water, which contains a large number of fibers and fillers and resins added to the production process.Sulfates are produced mainly in sulfite pulping processes[33, 34]. The removal of sulfide can be realized by converting sulfide ions into elemental sulfur by sulfur bacteria. Removal of sulfate from COD and newsprint mill wastewater by two-stage anaerobic aerobic process reported by Chen and Horan. In the process of peeling wastewater, tannin contributed up to 50% of COD. It is well known that they exhibit methane toxicity that is proportional to the degree of polymerization. Many studies show that halogen compounds are toxic to anaerobic microorganism. In the papermaking process, a large amount of halogenated substances are produced in the bleaching process, and the anaerobic microorganisms are toxic to the wastewater. Some organic inhibitors can be microbial degradation[33]. Therefore, it is important to clarify the sources of inhibitors that may be contained in the waste water for subsequent anaerobic biological treatment.

3.3 Weaving industry wastes

The wastewater from weaving industry is mainly derived from washing, bleaching and dyeing processes of fibrous matter. Several laboratory scale studies show the ability of anaerobic / aerobic biological treatment of textile wastewater[35]. Other studies have shown that textile wastewater easily inhibits methane production and COD removal. Textile wastewater may be potential inhibitors of components of dyes, auxiliaries (polyacrylic acid, phosphonic acid), surfactant (alkyl phenol polyoxyethylene ether), chloroform, and heavy metals[36, 37].

4. Conclusion

Anaerobic digestion is a kind of waste treatment technology that uses anaerobic microorganisms to degrade the waste to produce methane. It is mainly used in domestic wastewater and industrial waste.

But solid waste or wastewater may contain substances that inhibit normal anaerobic reactions, and even toxic substances. It is mainly ammonia, sulfide, heavy metals etc.. The accumulation of these inhibitors can lead to abnormal processes in anaerobic digestion, such as decreased methane production or reduced methane content. Due to the different reaction substrates and experimental conditions, the research results of inhibition factors in anaerobic process are different. Therefore, the stable operation of anaerobic reaction can be ensured only when the composition information of anaerobic reaction substrate is known. The present study results show that, with other waste digestion, and in anaerobic reaction before the removal of inhibitory substances in the substrate, can improve the ability of anaerobic microorganisms resistance to toxic substances, so as to improve the efficiency of anaerobic digestion.

5. Acknowledgments

This work was supported by the National Key Technology Research and Development Program of the Ministry of Science and Technology of China [grant numbers 2014BAC25B01, 2014BAC28B01]; the Technology Development Plan of Jiangsu Province, China [grant number BE2015662]; and the Open Subject of Jiangsu Key Laboratory of Anaerobic Biotechnology [grant number JKLAB201605].

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