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Current Status and Development Trends of Sludge Disposal Technology

Siyan Huang[1], Liu Yang[1*], and Lianguo Ji[1]

[1]College of Geoscience and Surveying Engineering, China University of Mining and Technology (Beijing), 100083 Beijing, China

Abstract. Sludge is a typical solid waste of sewage treatment plants, and its disposal methods have attracted much attention. This paper summarized the current technical routes for sludge disposal in China, including anaerobic digestion, anaerobic fermentation, incineration, landfill, land utilization, and building materials utilization. In the context of energy saving and carbon reduction and the promotion of resource recovery, enhanced pretreatment technology of sludge anaerobic digestion and anaerobic fermentation technology for fuel gas production are the first choices for sludge disposal and resource utilization. In addition, the development trend of sludge disposal technology was analyzed.

1 Introduction

The daily sewage treatment capacity in China reached 128 million tons [1]. The huge sludge volume and high disposal cost have brought difficulties to the economic operation of sewage treatment plants [2]. The Chinese government has successively issued the Action Plan for Water Pollution Prevention and Control, the Construction Plan of the National Urban Sewage Treatment and Recyclation Facilities during the 13th Five-Year Plan Period, and Implementation Plan for Strengthening and Weaknesses of Urban Domestic Sewage Treatment Facilities, which put forward requirements for the environmentally friendly treatment of sludge. This paper systematically summarized the current technical route of sludge disposal in China, and analyzed the development trend of sludge disposal technology.

2 Typical sludge disposal technology

2.1 Anaerobic digestion technology of sludge

The anaerobic digestion technology of sludge is a biodegradation method, which can successfully treat more than 1/3 of the sludge. General sludge contains high sediment content and low organic matter content, and organisms can only decompose the organic matter in the sediment, but cannot decompose the sediment. In addition, the biodegradability of sludge is poor, and the operation of anaerobic sludge digestion equipment is unstable. Therefore, traditional sludge anaerobic digestion technology cannot be directly applied to sludge treatment and disposal, and some pretreatment technologies are needed, including ultrasonic, electrochemistry, high temperature and high pressure thermal hydrolysis and thermo-alkali pretreatment, etc.

2.1.1 Ultrasonic pretreatment

Ultrasonic pretreatment can improve the anaerobic digestibility of sludge by disturbing the original physical and chemical properties of sludge. It can effectively improve the sludge dewatering performance, promote the release of nitrogen and phosphorus, and reduce the amount of sludge. Liu et al. found that the gas and methane production of the heat-alkali ultrasonic pretreatment of straw were higher than that of the non-pretreatment [3]. Gao et al. verified that ultrasonic alkali hydrolysis could dissolve more sludge proteins by destroying sludge floc and microbial cell structure, which provided a potential application prospect for sludge protein extraction [4].

2.1.2 Electrochemistry pretreatment

Electrochemical pretreatment method is to make the nitrogen, phosphorus and cytoplasm in cells enter the supernatant by changing the permeability of microbial cell membrane in the sludge, which can be used by microorganisms in the process of aerobic digestion. Microbial metabolic speed is increased, and the aerobic digestion time is shortened. This method effectively improved the destruction of extracellular polymer matrix and anaerobic digestion. In this way, the effects of poor digestibility and slow degradation rate of waste activated sludge on the performance of sludge anaerobic digestion can be reduced [5].

* Corresponding author: yang_l@126.com

2.1.3 High temperature and high pressure thermal hydrolysis pretreatment

The high temperature and high pressure thermal hydrolysis pretreatment breaks the microbial cell wall in the sludge, dissolves the colloidal structure, releases organic matter, and reduces the viscosity. The output and energy efficiency of anaerobic digestion are improved, with a strong operability. Experiments have confirmed by Hong et al. that due to thermal hydrolysis, the polymer can be decomposed into low molecular weight compounds, the pH value is reduced, and the operation is more stable [6]. Deng et al. applied the high-temperature and high-pressure thermal hydrolysis pretreatment method to the synergistic anaerobic synthesis of banana straws with high organic content, which significantly increased the methane yield of low-organic sludge [7].

2.1.4 Thermo-alkali pretreatment

After thermo-alkali pretreatment, the organic matter in the sludge was basically released into the liquid phase. The concentrations of Solluted Chemical Oxygen Demand (SCOD), soluble protein and polysaccharide in the filtrate increased significantly. The yield of anaerobic sludge fermentation Short Chain Fatty Acids (SCFAs) under alkaline conditions was much higher than that under acidic or neutral pH conditions, which could enhance the hydrolysis and acidification process of sludge and inhibit the generation of methane [8]. Hu et al. designed the process of thermal-alkali pretreatment of sludge and semi-continuous flow anaerobic fermentation sludge treatment process, and found that the Volatile Fatty Acids produced can meet the carbon source requirements of sewage treatment plants for nitrogen and phosphorus removal upgrades [9].

2.2 Landfill

The main landfill forms include separate landfill, mixed landfill and special landfill. Mixed land landfill technology is mostly used in China, which has low cost, high efficiency and strong universality. However, it has the disadvantages of high transportation cost and pollution of the land. This method goes against China's increasing emphasis on environmental protection and will gradually be eliminated in the future.

2.3 Incineration and land utilization

Incineration is the preferred method for rapid sludge treatment. Under sufficient oxygen, the sludge is fully burned to generate H_2O, CO_2 and ash, and harmful viruses and bacteria in the sludge are eliminated. According to the survey, approximately 20% and 25% of the sewage sludge produced in the United States and the European Union are incinerated, respectively [10]. In addition, The sludge after incineration contains a lot of beneficial elements (such as P, N and K), which can be recycled for land use [11].

2.4 Building materials utilization

After sludge drying and dewatering, porous energy saving brick can be prepared by high temperature calcination. It is generally used to make ceramsite, cement, brick, biochemical fiberboard and other infrastructure materials. Using sludge in cement construction materials can effectively reduce the negative impact on the environment [12].
The main process routes of sludge disposal market in China are shown in Fig. 1.

3 Development trend of sludge disposal technology

3.1 Anaerobic fermentation technology

Anaerobic fermentation is an environmentally friendly waste activated sludge disposal technology that can realize resource recycling (CH_4, H_2). However, the traditional sludge anaerobic fermentation efficiency is low. Freezing and potassium ferrate can be combined for sludge pretreatment to promote the production of hydrogen by anaerobic fermentation. Zhao et al. proposed the strategy of adding lye to the AD system driven by biogas recirculation for sludge management (Fig. 2), which can not only achieve biogas upgrade, but also achieve good settling/dewatering capacity of sludge and improve its stability [14].

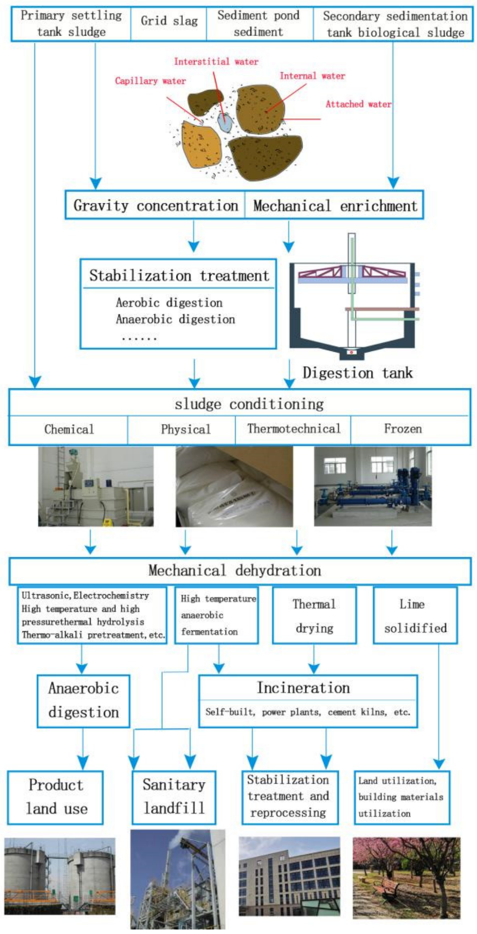

Fig. 1. The main process routes of sludge disposal in China [13]

3.2 Preparation of degradable plastics

The interaction of certain types of microorganisms and sludge can promote the reproduction of microorganisms. By adding carbon sources and inorganic salts to the sludge to accumulate polyhydroxy fatty acids, it can be used to prepare degradable plastics. Chen obtained nutrients such as Poly-3-hydroxybutyrate and Acetic Acid, which can be used for microbial culture, as raw materials of biodegradable plastics through pyrolysis of sludge at high temperature [15]. Chua et al. designed anaerobic-aerobic activated sludge process model to successfully produce polyhydroxyalkanate materials (Fig. 3) [16].

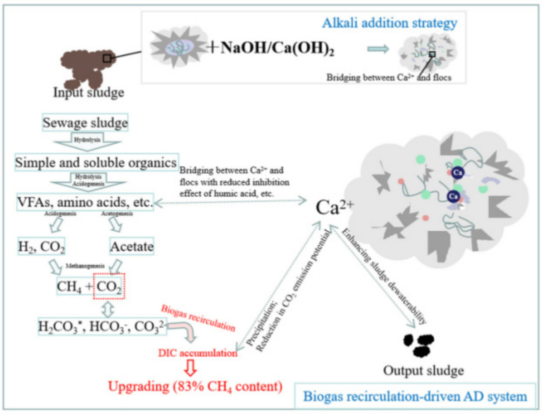

Fig. 2. The strategy of adding lye to the AD system driven by biogas recirculation for sludge management [14]

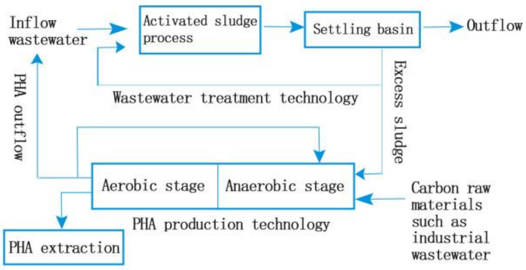

Fig. 3. Process flow model of PHA production by anaerobic-aerobic activated sludge [16]

3.3 Preparation of activated carbon

Activated carbon prepared from sludge has good application prospects in the fields of wastewater, waste gas and soil improvement. Zeng et al. used sewage sludge and corn stalks as raw materials to prepare sludge-based activated carbons (SACs), modified with ferric nitrate, and treated landfill leachate with unmodified and modified SAC as adsorbents to remove COD and organic matter in the leachate [17]. Du et al. discussed the effects of different sludge sources such as oil sludge and municipal sludge, as well as different pyrolysis processes such as microwave pyrolysis and hydrothermal carbonization, as well as the types of activators and additives on the performance of activated carbon from sludge [18]. Wu et al. designed an experiment using sludge-poplar sawdust co-pyrolysis as raw material, and successfully prepared activated carbon by KOH chemical activation method [19].

4 Summary

At present, most of the sludge treatment plants in China still use traditional methods such as aerobic composting, incineration and landfill, land utilization and other technical means. However, in the long run, the traditional methods do not conform to China's sustainable development strategy. Anaerobic fermentation technology is the most potential sludge disposal method, which has the advantages of sludge reduction and resource utilization. The comprehensive utilization of sludge based on multiple and multi-stage treatment is worthy of further exploration.

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