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Review on Anaerobic Digestion and Disposal Technology of Solid Waste

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Abstract

This paper reviews the solid waste disposal technologies at home and abroad. Solid waste is rich in a large amount of organic matter. If discarded or landfilled, it will cause serious environmental problems such as greenhouse gas emissions, landfill leachate emissions, pathogen transmission and groundwater pollution. Common disposal methods of solid waste include sanitary landfill, incineration, compost fermentation, anaerobic digestion, etc. Among them, anaerobic digestion technology is an economical and efficient solid biological treatment technology, which can not only realize the degradation of organic matter components in solid waste and the removal of toxic and harmful pollutants, but also obtain biogas to realize energy recovery.

Keywords

Solid Waste; Landfill; Compost Fermentation; Anaerobic Digestion.

1. Introduction

Solid waste is produced by people in daily production and life activities. It cannot be used at a certain time and place and is discarded, which will have a certain impact on the environment [1]. According to different sources, solid waste can be divided into industrial solid waste, municipal solid waste, agricultural solid waste and human, livestock and poultry excrement. At present, the main methods of solid waste disposal include: sanitary landfill, incineration, aerobic composting and anaerobic digestion. Due to the large proportion of organic matter in various solid wastes, such as food processing industry solid waste (solid waste from juice production), biomass energy processing solid waste (solid waste from biodiesel production), urban sludge, food solid waste Waste (fruit and vegetable, kitchen solid waste), agricultural solid waste (straw waste), and human, livestock and poultry excrement, most countries in the world have clear legal and regulatory requirements for the management and disposal of these solid wastes, and strictly prohibited Solid waste is discharged directly to the sewer network system. Organic solid waste must be reduced, stabilized and harmless of organic matter before it can be allowed to discharge. In addition, these solid wastes themselves are the products of biological growth and metabolism, and are rich in a large amount of biological energy. Therefore, finding an efficient, stable and economical solid waste treatment method, and properly and effectively disposing and utilizing solid waste is an issue that human beings must solve in the process of exploring the path of sustainable development.

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2. Overview of Solid Waste Disposal Technology at Home and Abroad

At present, the common solid waste treatment methods in China are landfill, incineration, composting and fermentation. As research into new technologies, exploration of anaerobic digestion is also underway.

2.1. Sanitary Landfill

Landfilling refers to the landfilling of municipal waste and waste in sanitary landfills. Sanitary landfill is an improved mode of landfill method, which can control leachate and landfill gas, and has perfect environmental protection measures. In my country, due to the low requirements for solid waste treatment, the concept of solid waste classification treatment has not been popularized, and the composition of waste is very complex. Under the current social and economic conditions, the application of sanitary landfill in solid waste treatment Reaching more than 90%, it has become the main treatment method. The operating cost of sanitary landfill is low, the technical process is simple, the processing capacity is large, and it is not affected by the change of garbage composition, but it is difficult to select the site, covers a large area, and requires a large amount of investment to realize the anti-seepage and collection system of leachate, treatment Methane and hydrogen sulfide waste gas. The design life of landfills is usually not long, and with the improvement of people's living standards and the continuous increase of urban population, the useful life of landfills is also decreasing. Sanitary landfill has a low degree of waste volume reduction, reduction, harmlessness and recycling, and the leachate produced is difficult to meet the discharge standard, which will cause serious secondary pollution and is difficult to control. More importantly, the recovery rate of energy and resources in the process of sanitary landfill treatment of organic components of solid waste is almost zero, resulting in a great waste of energy and resources. Therefore, in most countries, the application of sanitary landfill has a declining trend year by year, and in developed countries in Europe, sanitary landfill is a method that is being phased out.

2.2. Incineration Power Generation

Incineration power generation is to collect solid waste, sort out wastes with high combustion value, such as organic combustibles, etc., for high-temperature incineration, and convert the heat energy generated in high-temperature incineration into high-temperature steam, which drives the turbine to rotate and makes the generator generate electricity. "No incineration without sorting in place" is the principle of incineration power generation, and sound garbage classification is the precondition for waste incineration power generation. The heat generated by incinerating 2 tons of garbage is approximately equivalent to 1 ton of coal. If my country can fully and effectively use garbage for power generation, it will save 50-60 million tons of coal every year, and its "resource benefit" is extremely considerable.

The investment cost and operating cost of the incineration power generation process are relatively high, and the process technology is relatively complex. Suitable for waste with low moisture content and high content of combustibles (paper, cloth, plastic). The volume reduction, quantity reduction and harmlessness of waste are high, and the energy recovery rate is high, which can be used for resource utilization. However, it is necessary to reduce the secondary pollution caused by the emission of flue gas. At present, this method is widely used in developed countries and some emerging industrial countries, and the development is very rapid.

2.3. Aerobic Composting

Aerobic composting is the use of aerobic microorganisms in the compost to absorb, oxidize and decompose under aerobic conditions. Microorganisms carry out biodegradation and biosynthesis of organic solid waste through life metabolism—oxidation, reduction, synthesis and other processes. Aerobic composting technology is an important means of recycling and

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harmless organic waste. The activity of microorganisms ultimately affects the speed and quality of composting. Therefore, the growth environment of microorganisms such as temperature, pH value, C/N, oxygen content, and organic matter content affects the The change of factors determines the quality of the composting effect. The main process of aerobic composting process can be divided into five steps: pre-treatment, main fermentation, post-fermentation, post-treatment and storage.

Compared with landfill and incineration methods, the initial cost of aerobic composting is generally lower, but some advanced high-temperature composting and rapid composting methods have higher investment. The aerobic composting method has low operating costs, simple process technology, and can recycle some organic components. It is suitable for the treatment of garbage containing a lot of perishable organic matter, such as municipal waste, secondary sludge, human and animal manure, and agricultural solid waste. However, this method covers a large area, the waste volume reduction, and harmlessness are low, the compost quality is not easy to control, it is easy to discharge harmful components in excess of the standard, and the energy recovery rate is not high. Therefore, the large-scale application of this method in various countries is less and the development is slow.

3. Anaerobic Digestion Technology

Anaerobic digestion is a cost-effective solid biological treatment technology, which can not only achieve the degradation of organic matter components in solid waste, the reduction of pathogens and the removal of toxic and harmful pollutants, but also the realization of organic matter energy and nutrients such as nitrogen and phosphorus. recycling. Compared with aerobic composting, the anaerobic digestion process is more suitable for the effective treatment of high-concentration organic solid waste. The application of anaerobic digestion technology can reduce the volume of solids (90% reduction), reduce the energy consumption of the entire process, and save engineering land [2]. More importantly, organic solid waste can be converted into methane gas, a renewable energy source, during anaerobic digestion [3,4]. Depending on the nature of the organic solid feedstock, 50–500 m3 of methane gas can be recovered by processing 1 ton of feedstock in an anaerobic digestion reactor [5,6]. In recent years, due to the development and application of anaerobic digestion technology, people have gradually realized that organic solid waste is no longer a kind of waste, but a potential resource and energy material, and it is very important for the anaerobic digestion of organic solid waste. Digestive technology has generated new concerns and expectations[7~10].

Although the anaerobic digestion process can be simply described as a reaction using organic solid raw materials to ferment and produce biogas with carbon dioxide and methane as the main components, it is a complex process involving microbial action and thermochemical reactions. In 1979, J. G. Zeikus put forward four theories of group theory at the first International Conference on Anaerobic Digestion, that is, hydrolytic fermentation bacteria, hydrogen-producing acetogenic bacteria, homoacetogenic bacteria and methanogenic bacteria jointly participate in the anaerobic digestion process[11]. In the process of anaerobic digestion, various bacterial groups restrict and promote each other. In order to better explain the operation mechanism of anaerobic digestion reaction in solid reaction system, the International Water Association proposed a general model of anaerobic digestion process, namely anaerobic digestion process. Digestion Model 1 (ADM1) [12,13]. The ADM1 model divides the anaerobic digestion process into four stages: Hydrolysis, Acidogenesis, Acetogenesis, and Methanogenesis.

3.1. Hydrolysis Stage

Organic solid waste contains complex organic components, mainly carbohydrates (starch, cellulose, hemicellulose, lignin, etc.), fats and proteins. Microorganisms cannot directly metabolize such biomacromolecules. They must be degraded into soluble polymers or

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monomer compounds before they can be used by acidifying bacteria. Therefore, hydrolysis is a biochemical process that decomposes the above-mentioned complex compounds into two or more simple compounds under the action of hydrolase, an active extracellular enzyme secreted by hydrolyzing bacteria [14,15]. For example, cellulose is decomposed into cellobiose and glucose under the action of cellulase, protein is broken into peptide bonds under the action of protease to generate dipeptides and polypeptides, and then amino acids are generated [11], fat is hydrolyzed into long-chain fatty acids under the action of lipohydrolase and glycerin. Common bacteria involved in the hydrolysis of organic matter in anaerobic reaction systems include Clostridium, Bacteroides, Acetivibrio, etc. [16]. It should be noted that since the hydrolysis of complex organic matter occurs outside the bacteria, the energy generated by the reaction cannot be directly absorbed by the bacteria to maintain growth and metabolic activities. The bacteria need to obtain energy from the acidification reaction of the hydrolyzate for cell growth and division. The bacteria involved in the reaction during the hydrolysis stage also continued to remain active during the acidification stage [17].

3.2. Acidification Stage

The acidification stage process refers to the absorption of organic substances in the form of soluble monomers or dimers, such as monosaccharides, glycerol, higher fatty acids and amino acids, into cells. After intracellular metabolism of bacteria, it is converted into terminal products mainly composed of short-chain fatty acids or alcohols, and produces gases CO_2, NH_3, H_2S and H_2 at the same time. Among them, 50% of the organic carbon is converted into acetic acid, and another 20% is discharged in the form of CO_2 [3]. Among many metabolites, inorganic CO_2 and organic molecules such as formic acid, acetic acid, methanol and methylamine can be directly absorbed and utilized by methanogens and converted into NH_3 and CO_2. Other products such as propionic acid, butyric acid, ethanol and lactic acid are utilized by hydrogen producing and acetic acid producing bacteria. The microorganisms of *Actinomycetes*, *Bacteroidetes*, *Chloroflexi*, *Firmicutes* and *Proteobacteria* all participate in the acidification stage.

3.3. Acetogenic Stage

The acetic acid production stage is also called the hydrogen production and acetic acid production stage, because in this stage, the production of acetic acid is often accompanied by the production of hydrogen. This stage is mainly the process of converting the organic acids or ethanol with three carbons or more produced in the acidification stage into small molecular substances such as acetic acid, H_2 and CO_2 that can be directly utilized by methanogens. The main flora in the reaction process is hydrogen-producing acetogens, including *Syntrophomonas*, *Syntrophobacter*, *Clostridium*, *Pelobacter*, etc. [18].

3.4. Methanogenic Stage

The methanogenesis stage is the final stage of the anaerobic digestion process, which is the process by which strictly anaerobic methanogens convert compounds such as acetic acid and formic acid, and H_2, CO_2, etc., into CH_4. *Methanogens* are classified into three groups according to their phenotype and evolutionary relationship [19,20]. The first category is *Methanosarcinales*, which belong to the acetotrophic methanogens, which can use acetic acid, methanol, methylamine and other one-carbon compounds to produce methane gas. The second category is *Methanomicrobiales*, which are hydrogenotrophic methanogens that can use formic acid and CO_2 and H_2 as substrates to generate methane [21]. The third group includes the order *Methanobacteriales*, *Methanococcales* and *Methanpyrales*, which also belong to the hydrogenotrophic methanogens.

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4. Conclution

Anaerobic digestion of solid waste is a resource technology with great commercial and industrial potential. At present, a large number of studies on anaerobic digestion technology are focused on sewage treatment, and there are few studies on anaerobic digestion of solid waste in China, which is still in its infancy. Because the influence of the characteristic difference between solid organic matter and high concentration organic wastewater on anaerobic digestion is not well understood, it is necessary to conduct in-depth discussion and Research on the anaerobic fermentation process and mechanism of organic solid waste, which is of great significance to the development of anaerobic fermentation technology of solid organic waste.

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