Research on Urban Solid Waste Treatment Methods

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Abstract. In the background of accelerating urban modernization process, municipal solid waste is also showing a continuous growth, which not only has a great impact on people's living environment, but also seriously threatens the healthy and sustainable development of cities. Therefore, it is important to strengthen the research on municipal solid waste treatment and utilization, which can promote the resource utilization of municipal solid waste and reduce the environmental pollution caused by solid waste. This paper combines a basic overview of municipal solid waste with a detailed description of several of the more common methods of municipal solid waste treatment, and analyzes the success stories of each method as well as the challenges that exist. Based on the analysis of the advantages and disadvantages of the different methods to provide reference for the actual selection of solutions, and to contribute to the increased publicity of environmental protection and promote the resource utilization of solid waste.

1 Introduction

Municipal solid waste is the solid waste produced by urban residents in production and life, including domestic garbage, sludge, waste electronic products, medical waste, etc., which has the following characteristics: (1) A tremendous amount. With the continuous development of social and economic development, the amount of solid waste generated by people's production and living activities also continues to grow, and the variety of solid waste is relatively large, and the components involved are also complex, which not only has a great impact on people's living environment, but also increases the difficulty of solid waste disposal. (2) The potentially harmful. Municipal solid waste in the process of generation, discharge, storage and disposal, any one of them is likely to cause adverse impact on the environment, and because of the diffuse characteristics of solid waste itself, it can cause great harm to the ecological environment through water, soil and other means.

Waste classification is essential for efficient waste management practices, prioritizing recycling efforts, and optimizing resource recovery. It enables targeted strategies for collection, sorting, recycling, treatment, and disposal, ensuring effective allocation of resources. The classification of municipal solid waste mainly includes: (1) Industrial solid waste, which is usually generated in the production process of industrial enterprises, such as the waste left in the production of coal mines, calcium carbide slag, gypsum, etc., and these industrial solid waste has a large volume, complex composition and other characteristics. If it is not effectively treated, it will pose a great threat to the ecological environment and the health of urban residents. (2) Domestic solid waste, which is simply the solid waste generated by urban residents, including daily garbage, construction garbage, commercial garbage and so on, and because of the wide coverage of domestic solid waste. The daily quantity of domestic solid waste formed in the city is large, and it is also more difficult to deal with. (3) Hazardous solid waste, which is usually toxic, corrosive and flammable, such as medical waste, Electronic waste, etc. These hazardous solid wastes can also be harmful to the environment and human health if they are not reasonably treated in the production and transportation process.

In addition, discussing the hazards of municipal waste is important because it helps us understand the potential dangers and risks associated with improper waste management. Municipal waste, which comes from homes, schools, and businesses, can harm the environment and our health if not handled correctly. The main hazards of municipal solid waste are the pollution of soil, water and air. According to the relevant data, each ton of solid waste covers an area of about 657 km^2, if these solid wastes are not properly treated, it will lead to the encroachment of land resources, and in the process of accumulation will also cause some pollution to the soil, mainly because some solid wastes contain tin, cobalt and other toxic and

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harmful substances, when these harmful substances penetrate into the soil, it will not only kill the soil When these harmful substances penetrate into the soil, they will not only kill the microorganisms in the soil, but also cause damage to the acid-base balance of the soil. When the solid waste is exposed to stormy weather, the toxic and harmful substances will also seep into the surrounding rivers and lakes through the ground, which will cause serious water pollution problems and have great impact on the balance of the ecosystem and people's drinking water health. Solid waste in the accumulation process. The process will also be affected by weather factors, and a certain degree of decomposition, the release of toxic and harmful gases, will also cause pollution of the atmosphere, especially fly ash and dust into the atmosphere, will make the air PM value rise, which will lead to reduce urban air quality.

Urban solid waste treatment and utilization is an important area of research that focuses on managing the growing amount of waste generated by cities and finding ways to extract value from that waste. The background of this research can be traced back to the early 20th century, when cities began to grapple with the problem of how to manage increasing amounts of waste. At that time, most waste was simply dumped in landfills or burned, which led to environmental and health problems.

Since then, significant progress has been made in the field of urban solid waste treatment and utilization. One major development has been the adoption of the "3R" approach, which stands for "reduce, reuse, and recycle." This approach aims to minimize the amount of waste that needs to be treated by reducing the amount of waste generated in the first place, reusing materials where possible, and recycling materials that cannot be reused. Another major development has been the shift towards more sustainable waste treatment methods. For example, incineration and landfilling have been largely replaced by more environmentally friendly methods such as composting, anaerobic digestion, and waste-to-energy technologies. These methods can help to reduce greenhouse gas emissions, minimize the amount of waste sent to landfills, and produce valuable byproducts such as compost and renewable energy.

In the following sections, several common methods of municipal solid waste treatment will be described in detail, with examples of their applications and advantages and disadvantages.

2 High temperature thermal hydrolysis pretreatment (THP) technology

High temperature thermal hydrolysis pretreatment is a common treatment scheme for solid waste sludge which involves heating organic waste materials, such as sewage sludge or food waste, under high pressure and temperature conditions. When the solid content of sludge is more than 20 %, the traditional technology cannot be used. In this case, the high temperature thermal hydrolysis pretreatment technology is needed. The relevance of high temperature THP technology in urban solid waste treatment lies in its ability to effectively reduce the volume of waste, increase the production of biogas, and improve the quality of the resulting compost. By breaking down complex organic compounds into simpler molecules, high temperature THP reduces the volume of waste that needs to be disposed of, thus reducing the amount of waste sent to landfills. Furthermore, the high temperature and pressure conditions of high temperature THP promote the production of biogas, a renewable energy source that can be used for electricity generation or heating. The pretreated waste can be used as feedstock for anaerobic digestion, a process that produces biogas from organic waste. Finally, the resulting compost from high temperature THP is of higher quality than compost produced from untreated waste. This is because high temperature THP removes pathogens and reduces the amount of heavy metals and other contaminants in the waste, producing a compost that is more stable and nutrient-rich, suitable for use as a soil amendment.

The THP process typically involves heating the waste material to temperatures ranging from 140 °C to 180 °C and applying a pressure of 4 to 6 bar. The process is carried out in a closed vessel, and the high temperature and pressure conditions help to break down the complex organic molecules and sterilize the waste material, reducing pathogens and odors. During THP, complex organic matter can be broken down into smaller, soluble molecules suitable for biodegradation and cell walls rupture, releasing their contents into homogeneous solutions, the largest of which are lysed microbial cells, which can then be used for metabolic activity and microbial growth [1,2]. Xu et al. considered that the sludge pyrolysis rate increased with increasing temperature; being the highest at 200 °C [3]. Choi et al. found that methane production was the highest after 76 min of pretreatment at 180 °C [4].

One successful case study of THP in an urban area is the facility in Washington, D.C., which uses the technology to treat biosolids and food waste. The facility has demonstrated significant increases in biogas production and energy generation, while also reducing the amount of waste sent to landfills. Another example is the facility in Amsterdam, Netherlands, which uses THP to treat municipal sewage sludge. The facility has been able to achieve high levels of energy efficiency and nutrient recovery, while also reducing greenhouse gas emissions and minimizing odors.

High Temperature Thermal Hydrolysis pretreatment technology has the potential to improve the efficiency and sustainability of urban solid waste treatment. However, there are several challenges and limitations that need to be addressed. These include high energy requirements, high capital costs, and the need for skilled personnel to operate the equipment. Additionally, the effectiveness of the technology can vary depending on the characteristics of the waste being treated.

Environmental concerns, such as emissions and wastewater streams, should also be considered. Despite these challenges, high temperature THP technology remains a promising approach for reducing waste volume, increasing biogas production, and producing high-quality compost. The successful implementation of high temperature THP technology will require careful consideration of these challenges and limitations to ensure effective and sustainable use.

3 Sanitary landfill treatment technology

At present, municipal solid waste treatment mainly adopts landfill treatment technology. For example, in China, its treatment capacity accounts for about 70 % of the total amount. This technology is also the main urban solid waste treatment method currently and even in the next few years. Sanitary landfill technology is a waste treatment method that involves burying waste in the ground within designated facilities. The goal of this process is to isolate the waste from the surrounding environment and prevent the release of harmful substances into the air, water, or soil. The landfill process typically begins by excavating a large hole or pit in the ground that is then lined with a composite liner made up of different layers of materials such as clay, geotextile, and plastic. This liner is designed to create a barrier that prevents waste and leachate from coming into contact with the surrounding environment. Once the liner is in place, waste is deposited into the pit and compacted to maximize space utilization. The waste is then covered with a layer of soil or other material to reduce odor and limit the exposure of waste to the surrounding environment. As waste continues to be added to the landfill, additional layers of waste and cover material are added in a systematic and controlled manner. The goal is to create a multilayered structure that is both stable and environmentally safe. Landfills are often divided into separate cells or compartments that are used to manage different types of waste. Each cell is constructed in a similar manner, with a composite liner and multiple layers of waste and cover material.

In order to avoid its pollution to the surrounding environment, leachate collection and disposal systems and gas recovery or discharge channels should be installed. The exhaust system mainly deals with the methane and carbon dioxide gases produced during the fermentation process. These gases are collected into the gas collecting tank and transported to the pumping station through centralized transportation. After condensation and dehydration, these gases can also become fuel energy. It is also necessary to monitor groundwater near the landfill. To prevent contaminating the water table, all the landfill design will include a liner system at the bottom or base [5].

One successful case study of sanitary landfill treatment technology is the Puente Hills Landfill in Los Angeles, California. This landfill was one of the largest in the world, serving as the primary waste disposal site for the city of Los Angeles for over 50 years. The landfill was designed with advanced technology and waste management practices to minimize environmental impacts and protect public health. Another example is the Bordo Poniente Landfill in Mexico City, which was transformed from an open dump to an engineered landfill with improved waste management practices. The transformation of this landfill has significantly reduced the amount of waste sent to the landfill and improved environmental conditions in the surrounding area.

Sanitary landfill technology has the advantages of less construction investment, large treatment capacity, low treatment cost and many types of waste treatment. It also has the characteristics of land restoration and biogas collection. Sanitary landfill is a kind of urban waste treatment method with good operability and economic security.

4 Incineration treatment technology

Incineration is a waste treatment technology that involves the combustion of organic waste materials at high temperatures. The process is designed to reduce the volume of waste and convert it into ash, gases, and heat. The incineration process works by feeding waste material into a furnace where it is subjected to high temperatures ranging from 800 ℃ to 1200℃. The waste is then combusted, and the organic compounds in the waste material are broken down into carbon dioxide, water vapor, and other gases. The gases are released through a chimney, while the remaining ash and other solid residues are collected for disposal.

There are several types of incinerators that are commonly used in the treatment of urban solid waste. Here are some of the most common ones:

Rotary kiln incinerators: Rotary kiln incineration plays an important role as a traditional harmless disposal technology [6]. This type of incinerator uses a rotating cylindrical chamber to burn the waste. The waste is fed into one end of the chamber, while a burner at the other end provides heat to initiate the combustion process. The waste is continually moved through the chamber by the rotation of the kiln, which helps to ensure complete combustion.

Fluidized bed incinerators: In a fluidized bed combustor (FBC), a bed of sand, combustion ash, or other sand-like material is suspended in an upward flowing airstream [7]. The high turbulence and mixing in the bed help to ensure that the waste is completely burned, while also reducing the production of harmful emissions.

Multiple hearth incinerators: This type of incinerator uses a series of shallow, circular hearths that are stacked on top of each other. The waste is fed onto the top hearth and is gradually moved down through the stack as it is burned. Each hearth has its own combustion zone, which helps to maintain a high temperature and ensure complete combustion.

Liquid injection incinerators: This type of incinerator is used to burn liquid wastes, such as hazardous chemicals or medical waste. The waste is injected into a high-temperature combustion chamber, where it is vaporized and burned. The high temperature helps to break down the waste into its constituent parts, which are then released as harmless gases and ash.

Incineration is a controversial waste treatment technology due to concerns about air pollution, greenhouse gas emissions, and the potential release of toxic ash. However, there are some successful case studies and best practices for incineration treatment technology in urban areas.One example is the waste-to-energy plant in Vienna, Austria, which uses a combination of incineration and recycling to manage municipal solid waste. The plant produces electricity and heat for local residents, while also reducing the amount of waste sent to landfills. The plant uses advanced air pollution control technologies to minimize emissions and has been recognized as a model for sustainable waste management.Another example is the incineration plant in the city of Rotterdam, Netherlands, which is equipped with state-of-the-art technology for energy recovery and air pollution control. The plant has been able to achieve high levels of energy efficiency and minimize environmental impacts, while also reducing the amount of waste sent to landfills.

Incineration as a waste treatment technology offers several advantages, including volume reduction, energy recovery, and the ability to destroy hazardous waste. However, there are also several significant disadvantages, including air pollution, the release of toxic substances, the need for air pollution control devices, high capital costs, and the potential for decreased recycling rates. To ensure that the benefits of incineration outweigh the risks, it is important to carefully consider the potential environmental and health impacts before deciding to use this technology. Additionally, it is crucial to implement measures to minimize air pollution and the release of toxic substances, and to encourage recycling and waste reduction as much as possible.

5 Organic solid waste treatment technology

Organic solid waste refers to waste material of plant or animal origin that is biodegradable and can be broken down by natural processes. It typically includes a mixture of carbohydrates, proteins, fats, and other organic compounds, and may contain contaminants such as plastics and metals. Due to its biodegradability, organic solid waste can be broken down by microorganisms such as bacteria and fungi, but the rate of biodegradation can be affected by various factors. Organic waste retains high moisture content, and directly affects urban living environments with its odor and other unwanted byproducts [8]. The excess moisture content increases the volume of organic waste, shortening the life of landfill sites and lowering incinerator temperatures, resulting in an increase in the overall load on waste disposal [9]. If organic matter can be selectively removed from waste, it would not only reduce the volume of waste sent to final disposal but also bring considerable benefit to the collection and temporary storage of waste as well as the extraction of recyclable material [10,11].

Composting, anaerobic digestion, and vermicomposting are the three main technologies available for organic solid waste treatment. Composting involves the aerobic degradation of organic matter, resulting in the production of compost, which can be used as a soil amendment or fertilizer. Composting is a low-cost technology and has low environmental impact. However, it requires a significant amount of space and time to produce high-quality compost. Anaerobic digestion is a process in which microorganisms break down organic matter in the absence of oxygen, producing biogas and digestate. The biogas can be used as a source of renewable energy, while the digestate can be used as a soil amendment. Anaerobic digestion is an efficient technology that can reduce greenhouse gas emissions, but it requires a high level of technical expertise and investment, and the digestate may contain pathogens and heavy metals. Vermicomposting involves the use of earthworms to break down organic matter, producing vermicompost, which can be used as a soil amendment or fertilizer. Vermicomposting is a low-cost technology that has high nutrient content and improves soil health. However, it may require a significant amount of space and time, and the earthworms may be sensitive to environmental conditions.

There are several successful case studies and best practices for organic solid waste treatment in urban areas. One example is the city of San Francisco, which has implemented a comprehensive waste management program that includes mandatory composting of food waste and yard trimmings. As a result, the city has been able to divert up to 80% of its waste from landfills and reduce greenhouse gas emissions. Another example is the city of Bangalore, India, which has implemented a decentralized system of composting that involves the community in the management of organic waste. This system has reduced the amount of waste sent to landfills and improved soil health, while also providing employment opportunities for local residents.

Despite these successes, there are also several challenges and barriers to the implementation of organic solid waste treatment in urban areas. One challenge is the lack of infrastructure and resources, which can make it difficult to establish and maintain waste management programs. Another challenge is the lack of awareness and education among the public, which can lead to improper disposal of organic waste. Additionally, there may be regulatory and policy barriers that make it difficult to implement organic waste management programs. For example, some regulations may prohibit the use of compost or digestate as a soil amendment, which can limit the potential benefits of these technologies. Finally, there may be financial barriers that make it difficult to invest in organic waste management technologies, particularly for low-income communities. To overcome these challenges, it is important to establish partnerships between government, industry, and communities, and to develop policies and programs that prioritize the sustainable management of organic waste.

6 Conclusion

Municipal solid waste has a large amount, complex composition, toxic and harmful characteristics, if it is not effectively treated in a timely manner, it will probably cause great harm to the urban ecological environment. In practice, incineration, landfill composting, organic treatment, high-temperature thermal hydrolysis and other technical means can be used for effective treatment of municipal solid waste. Various technologies have been successfully implemented, but challenges remain in their practical application and requires further research. The implementation of a variety of technologies can also be applied in combination, the results achieved will be more satisfactory. Even the extraction of valuable components, recovery of various useful substances, production of construction materials and other ways to promote the comprehensive use of solid waste to achieve resourcefulness.

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