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Views & Comments

Emerging Views on the Overall Process Treatment of Municipal Domestic Waste for the Sustainable Use of Landfills in China

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1. Introduction

With the continuous improvement of living standards and the rapid development of urbanization, the annual production of municipal domestic waste in China has reached over 2×10^8 t and is expected to increase in the future. Landfill technology, which is the main method for the traditional treatment of domestic waste, accounts for more than 60% of the total treatment in China. However, current single-landfill technologies have a series of problems (Fig. 1(a)). First, recyclable resources within the vast amount of domestic waste often cannot be recycled and utilized, thereby causing resources to be wasted and deviated from sustainable cycles. Second, the amount of domestic waste that is decomposed and disposed of by landfill technology is considerably less than the amount entering landfill sites each year. Accordingly, a large area of valuable land must be developed for the construction of new landfill sites. At present, more than 400 cities in China are estimated to be surrounded by domestic waste, and the total area occupied by domestic waste has reached 5×10^4 hm^2. Third, the large amount of leachate produced by domestic waste in landfills will pollute the air, soil, and groundwater, thereby deteriorating the ecological environment and decreasing the living quality of residents in urban–rural integration areas [1]. Thus, the existing single-landfill technology in China not only brings serious social and economic problems, but also restricts the sustainable development of humans and the natural environment.

The key problems of the circulation imbalance of domestic waste as a resource and the pollution from landfill leachate have become the focus of social, economic, and environmental protection efforts, and of much science and technology research. In recent years, the Chinese government has attached great importance to the improvement of environmental issues, and has increased its investment in the treatment of domestic waste, which is of great significance for the green development model in China. In this paper, we highlight the importance of the overall process treatment of municipal domestic waste (Fig. 1(b)). We also propose new ideas for classification, minimization, and resource-utilization technologies for domestic waste at the front end, and provide new suggestions for rapid digestion, anti-leakage, and remediation technologies for pollutants at the back end.

2. Conscious source classification of domestic waste

Conscious source classification of domestic waste is the most recommended activity. However, the promotion and implementation of the classification management of domestic waste in China is still relatively backward. The main reasons include the lack of top-level design and guiding ideology in waste classification; the incompatibility between waste classification and resource recycling systems; residents' lack of conception of the source classification of domestic waste; restrictions on the environmental conditions of residential buildings; and the lack of relevant laws, regulations, and policies. Potential countermeasures may include establishing a sound legal and regulatory system and waste-classification standards; carrying out education and publicity work on the basic level of environmental protection and waste source classification; designing and deploying waste collection facilities that are more convenient for users; using economic means to promote the source classification of waste; and introducing a corporate responsibility system.

3. Rapid dehydration pretreatment of domestic waste

At the current stage, it is necessary to implement passive classification of recyclable parts from mixed domestic waste into recycling and utilization modes—not only because over 70% of domestic waste is still mixed in China, but also because this method is the most effective means of reducing the annual amount of domestic waste entering landfills. However, existing classification technologies for mixed waste have major limitations in separating out non-resource materials, mainly because such materials are viscous and entangled among different waste components as a result of excessive crystalline water content. Various organic components in mixed waste contain crystalline water; thus, these organic components must be simultaneously degraded to remove the crystalline water [2]. However, this process is often performed by different

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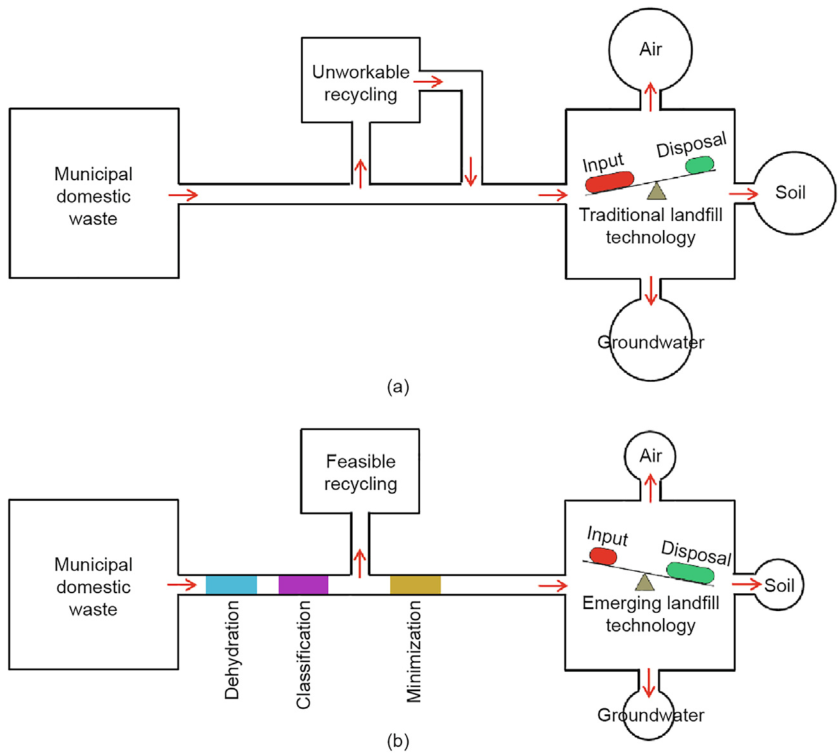

Fig. 1. (a) Traditional and (b) emerging views of the overall process treatment of municipal domestic waste affect how the green development model is promoted.

functional microorganisms, which may easily generate microbial antagonism that is detrimental to the dehydration of mixed waste. Therefore, in the future, when developing separation and classification technology for mixed waste, it is necessary to employ the directed-end targeted selection method of meta-proteomics and to screen out microbial agents that can efficiently dehydrate and produce heat during the degradation of domestic waste. In addition, it is extremely important to create a unique environment that is suitable for the survival of inoculated microorganisms while inhibiting the activity of indigenous microorganisms, by controlling the temperature change process in the stages of warming, heat-preserving, and cooling. These means aim to reduce entanglement and achieve rapid dehydration by promoting the synergistic decomposition of organic components containing crystalline water.

4. Recycling of resources separated from domestic waste

Metal and nonmetal solid-phase fractions separated by means of classification technology can be easily incorporated into the steel and nonferrous metal industries and the building materials industry, respectively. Separated organic solid waste with high heating value, including wastes of cloth, paper, and plastic, can be made into refuse-derived fuel (RDF) for heating and electricity production. To prepare RDF, high-heating-value components can be screened for in the source classification of domestic waste. It is also necessary to investigate the effects of final pyrolysis temperature, material ratio, excipient type, and temperature-rise rate on the thermal solution of RDF through simulation experiments in order to provide sufficient basic research data to completely clarify the reaction process and reaction mechanism of the RDF heat-treatment process. Such theoretical research results must be further combined with an assessment of market economy competitiveness and ecological economic benefits in order to promote the subsequent energy utilization and industrialization of RDF.

At present, separated organic solid waste with low heating value is mainly converted into fertilizer products through composting technology for farmland use. However, it is difficult for farmers to accept most fertilizer products formed by the existing composting technology, resulting in a large amount of residual products that further become wastes (Fig. 1(a)). This outcome is mainly due to a lack of organic matter—especially quinone-rich humic substances that can enhance the productivity and anti-pollution capability of soil. The directional coupling polymerization of quinones and small amide groups generated during composting is the most effective means of protecting quinones by improving degradation resistance. However, directional coupling polymerization between these molecular compounds is often difficult to achieve, mainly because they are produced in different composting stages and are easily decomposed. Considering that lignin and protein components in mixed waste are precursor substances for forming quinone and amide groups, respectively [3], corresponding microorganisms must be simultaneously inoculated to enhance the degradation of lignin and protein and to develop a dynamic back-mixing composting technology in order to achieve the recycling of organic solid waste separated from mixed waste (Fig. 1(b)).

5. Disposal of the non-recyclable fraction of domestic waste in landfills

After separation and classification, domestic waste inevitably leaves a residue that cannot be recycled. A technology that can quickly eliminate the old waste in landfills must be developed to provide additional space for new non-recyclable waste. Such technology can ensure that waste can be recycled without the need to develop new landfills. With their rich redox-active functional groups, humic substances can not only be used as an extracellular electron shuttle for mediating the degradation and conversion of pollutants, but also act as an electron acceptor for suppressing methane emissions [4]. Therefore, we suggest that non-recyclable domestic waste and artificial humic substances be layered and landfilled in order, so that waste can be quickly eliminated and the annual disposal amount of waste in landfills can become greater than the amount entering the landfills (Fig. 1(b)). This process can also reduce the contribution of greenhouse gas emissions from landfills to global warming.

6. Prevention and control of leachate pollution in landfills

Leachate production is inevitable during landfill treatment. The anti-seepage system not only is the last barrier to prevent leachate from entering the groundwater and surrounding soil through leakage, but also guides and discharges leachate [5]. Therefore, the design of the seepage prevention system is a crucial part of landfill design. We suggest that the main and auxiliary drainage layers in the leachate drainage layer of the landfill anti-seepage system be designed to collect and monitor the leachate and effectively reduce the probability of it infiltrating groundwater. The main drainage layer, which is used to reduce the leachate of the upper source and transfer the leachate to the bottom collection container, can be composed of a water-permeable material. The upper part of the main drainage layer is the filter layer. The material of this layer should have good water permeability for a long time and should avoid blockage by fine solid particles. The lower part of the main drainage layer can be composed of an artificial impervious film. The auxiliary drainage layer is mainly responsible for monitoring the main drainage layer and collecting leachate through the main drainage layer in order to control leachate pollution effectively. During monitoring, the amount of leachate should be considerably less than the corresponding design amount, indicating that the main drainage layer system is reliable. If the amount of leachate is greater than the critical amount, but no pollutants are found in the downstream groundwater, then the auxiliary drainage layer system is indicated to be intact.

We suggest that the above anti-seepage system should be designed to accurately intercept target pollutants. However, once pollutants inevitably enter the geological layer below the landfill, there is a significant risk to groundwater safety and human health. Due to the heterogeneity of porous media in the geological layer, pollutants trapped in it will be repeatedly released during the removal process, resulting in low removal efficiency and easy rebounding of pollution [6]. Accordingly, we propose building a targeted remediation technology system for already-contaminated landfill groundwater. The main remediation principle in this system is to add green low-carbon and slow-release composite material to force pollutants into the three-stage purification process of activated reduction, autocatalytic oxidation, and cycle backwashing.

7. Conclusion

Overall, landfill treatment of domestic waste in the future must be a systematic project, which requires coordinated development of classification, minimization, and resource-utilization technologies for domestic waste at the front end, as well as rapid digestion, anti-leakage, and remediation technologies for pollutants at the back end. The suggestions provided here can promote the upgrading of municipal domestic waste from the current passive treatment to a "resource regeneration and contamination control" process that will conserve land resources by recycling the waste in landfills, and that will realize the sustainable development of the ecological environment through the resource utilization of domestic waste.

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