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Thermo-chemical Treatment of Solid Wastes in Biomedical Laboratories and the Coordinated Development of Environment

Chao Du[a,*], Junzhi Liu[b], Qian Xu[a], Dong Wang[a]

[a] Chengde Medical College, Chengde 067000, China
[b]The Environmental Protection Agency of Chengde, Chengde 067000, China
yjmccd@163.com

The waste emissions of biomedical laboratories are rising, and affected by the limited capacity of disposal and the management policies, wanton emissions not only pollute the environment, but also cause potential harm. In this paper, the solid waste of biomedical laboratory is used as raw material for gasification and heat treatment of oxygen control, so as to achieve high energy efficiency of waste. The results show that the conversion power of solid waste is related to the type of waste with oxygen concentration. With the increase of oxygen concentration, the specific surface area and total pore volume of solid waste increase. According to the two-stage moving bed solid waste oxygen-controlled heat conversion reaction system, the thermochemical process can be divided into dry section, pyrolysis gasification section and Coke Burnout section, and the overall temperature of the gasification chamber decreases gradually with the change of excess air coefficient.

1. Introduction

Medical laboratory waste is regarded as medical waste; a large amount of waste will not only cause the risk of infection and environmental pollution and expand the scope of infection, but also enter the field of circulation for reuse (Guida et al., 2016). According to incomplete statistics, solid emissions worldwide are more than 10 billion tons each year, and medical laboratory waste accounts for 0.68%; biomedical laboratory solid waste disposal has already become the problem that affects environmental protection and economic development (Korai et al., 2016; Alvarez Gallego et al., 2015). In a large number of solid waste, combustible solid waste emissions exceed 70% of solid waste emissions, and it contains a large number of combustible components, with huge energy utilization potential (Shen et al., 2018). The traditional medical laboratory solid waste disposal uses landfill, fermentation, incineration and other technologies, of which incineration technology has outstanding advantages in the reduction and recycling of resources and has become the main technology for the energy utilization of combustible solid waste (Hamzah et al., 2017; Jones et al., 2011; Wu et al., 2018).
Unlike the industrial and domestic solid wastes, the solid wastes of medical laboratory have brought great harm to the living environment through outdoor stacking and simple landfill (Shen et al., 2017; Kleme et al., 2010). Solid waste incineration is to place waste in a high temperature furnace and generate heat for power generation and heating (Fei et al., 2018). Different from ordinary chemical reactions, solid incineration of medical laboratories requires a large amount of oxygen. For toxic and harmful substances, incineration is generally applicable (Coelho et al., 2012). Fluidized bed, grate furnace, and rotary furnace are three types of furnaces commonly used for waste incineration. The solid wastes of medical laboratory are generally treated with the rotary furnace (Lopes et al., 2015; Viholainen et al., 2015). Disadvantages of waste incineration technology include high investment and operation costs, high demand for waste heat value, deficiency of power generation of incineration heat, and serious secondary pollution (Udofia et al., 2017). In terms of heat utilization efficiency, oxygen control technology has advantages and is conducive to reducing the generation of dioxins (Chiu et al., 2016). In this paper, the solid waste of biomedical laboratory is used as raw material for gasification and heat treatment of oxygen control, so as to achieve high energy efficiency of waste.

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2. Dynamic characterization of the interaction effects of thermal transformation of laboratory component waste

2.1 Thermochemical reaction characteristics of typical solid waste

The ignition temperature of solid waste can characterize the fuel activity, and the higher the fuel activity is, the lower the required ignition temperature will be, and the lower the combustion efficiency and the incomplete combustion loss will reduce (Hong et al., 2018). The reaction activation energy and the precursor factor of chemical reaction kinetic parameters are important characteristics of the thermal chemistry of solid waste. Assuming that the heating process of solid waste is of equal velocity, the kinetic equation is shown in formula 1 and 2:

$$\frac{d_\alpha}{d_T}=\frac{A}{\beta}\exp(-\frac{E}{RT})(1-\alpha)^n \quad (1)$$

$$\alpha=\frac{m_0-m}{m_0-m_\infty}\times100\% \quad (2)$$

Where: α is the weight loss in the thermal reaction process of solid fuel; %, m0, m and m∞ are the initial mass, instantaneous mass, and final mass after the complete reaction of solid waste, respectively; T is the thermodynamic temperature; A and E indicate the precursor factor and activation energy of the reaction respectively.

2.2Kinetic quantitative characterization of interaction of component components during pyrolysis

Fuels taking biomedical laboratory solid waste for heat treatment include plastics, cotton textiles, fiber fabrics, paper, and so on, and the change of component influences the reaction temperature, time and activation energy of thermochemical process. It has been shown that there is a strong interaction between the elements of complex components of waste in the process of thermochemical treatment, causing the change of the chemical reaction kinetics; if the weightlessness of each element is independent during the pyrolysis process, the weightlessness rate of the waste is equal to the weight loss rate of the constituent components, namely:

$$\gamma=\mu_1\frac{d\alpha_1}{dt}+\cdots+\mu_n\frac{d\alpha_n}{dt}=\sum_{i=1}^{n}\mu_i\frac{d\alpha_i}{dt} \quad (3)$$

Where: γ is the heat treatment weight loss rate of the waste; %/min and μi are the mass fraction of each component, and αi is the percentage of weight loss of each component, shown as %.

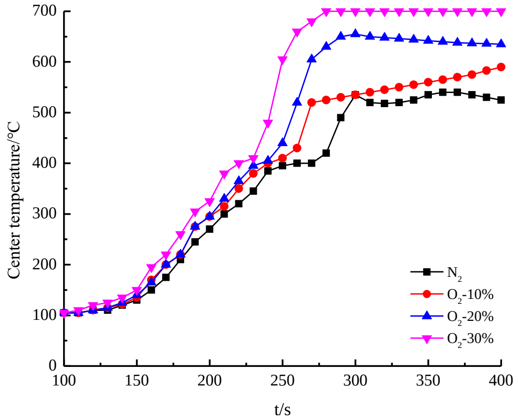
3. Kinetic model of thermal transformation of solid waste

3.1 Effect of oxygen concentration on heat transfer characteristics

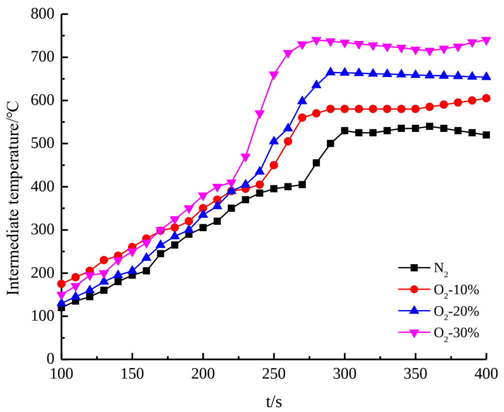
The study of chemical reaction mechanism of solid waste in biomedical laboratory is not deep enough, and the problem of low carbon conversion and high tar content in pyrolysis process has not been solved. In the experiment, the tubular fixed bed oxygen-controlled heat transfer reactor was used to record the morphological changes, internal temperature changes and weightlessness of solid wastes during the thermochemical treatment. The oxygen concentration has a significant effect on the thermochemical conversion of solid waste; when the oxygen concentration is increased, the full combustion of solid waste can be accelerated. Figure 1 shows the internal temperature increase of solid waste at different oxygen concentrations (Diagram a shows the central temperature, b shows the intermediate temperature, and C shows the surface temperature). It is obvious that the central temperature and intermediate temperature before 200s is not affected by the oxygen concentration, but when it reaches 200s, the solid particle surface temperature is quite obvious, which is mainly because that the volatile inside the solid waste is gradually volatile, hindering the oxygen entry, resulting in slow internal reaction of solid waste. The central temperature and the intermediate temperature increase rapidly at 200s-300s, and then remain unchanged. Figure 2 shows the weight loss curve of solid waste at different oxygen concentrations. The weight loss rate of solid waste first increases and then remains flat, and the weight loss increases when the oxygen concentrations rise. Figure 3 shows the internal pore structure of solid particles with different oxygen concentration. With the increase of oxygen concentration, the specific surface area and total pore volume of solid waste increase.

3.2 Experimental study on gasification characteristics of mixed waste

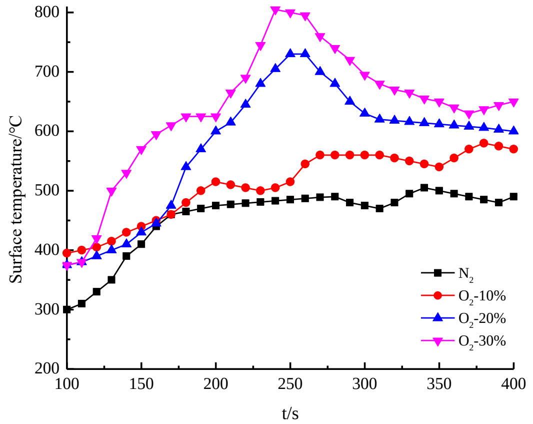
The original samples were from the biomedical laboratory. For the convenience of the test, we broke the solid waste and made simple pretreatment, so as to study the product yield when the excess gasification air coefficient are from 0.3 to 0.7, the calorific value and energy conversion efficiency of combustible gas, and so on. Figure 4 shows the effect of excess air coefficient on gasification yield of laboratory solid waste. With the increase of excess air coefficient, the gas yield increases and the hydrogen yield and the tar yield also decrease. Figure 5 shows the effect of excess air coefficient on gasification characteristics of laboratory solid waste. With the increase of excess air coefficient, the carbon conversion rate increases and the gas heat value and the energy conversion efficiency decrease.



(a) Center temperature

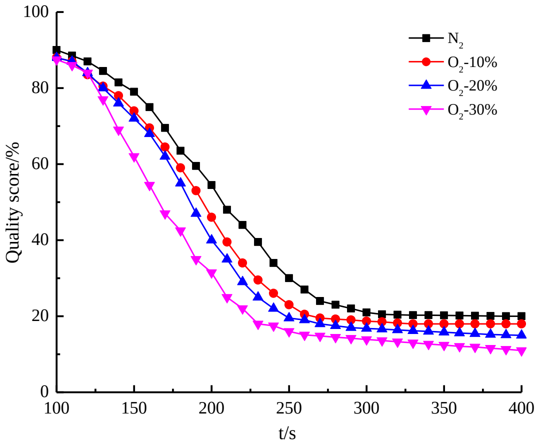


(b) Intermediate temperature



(c) Surface temperature

Figure 1: Internal heating rate of solid waste at different oxygen concentrations



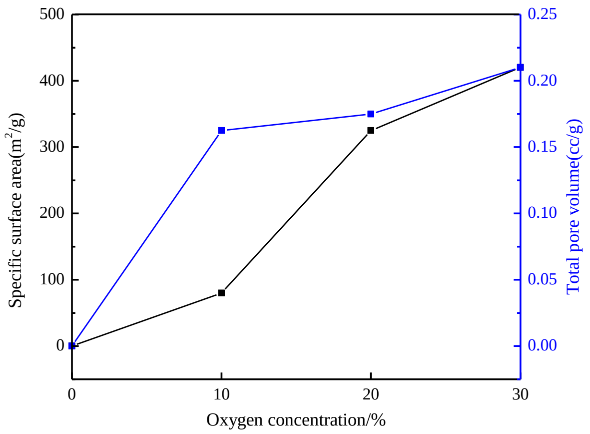
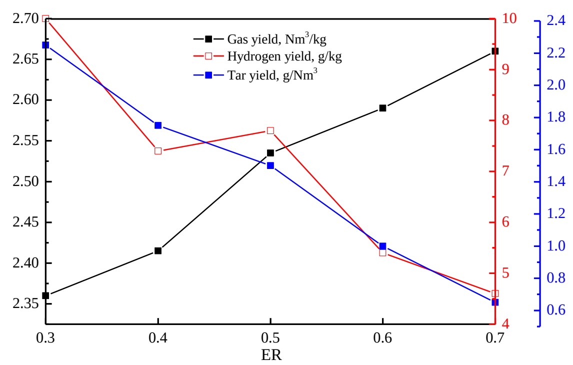


Figure 2: Solid waste weight loss curves at different oxygen concentrations; Figure 3: Internal pore structure of solid particles with different oxygen concentrations



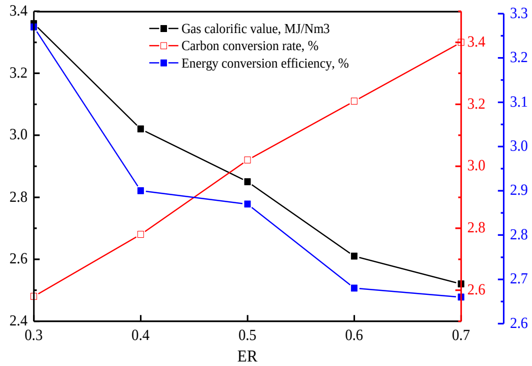


Figure 4: Effect of gasification excess air coefficient value on laboratory solid waste gasification product yield; Figure 5: Effect of gasification excess air coefficient value on laboratory solid waste gasification characteristics

4. Thermo-chemical treatment of solid wastes and coordinated development of environment

4.1 Pilot test and simulation optimization of oxygen-controlled heat transfer of solid waste

In light of the gasification theory of the existing solid waste thermochemical treatment and the mechanism of oxygen-controlling heat transfer, a two-segment moving bed solid waste oxygen-controlled heat conversion reaction system is proposed in this paper. In the process of simulation, the process of thermochemical treatment is divided into drying section, pyrolysis gasification section and Coke Burnout section, and the simulation process flow chart is shown in Figure 6. The gas phase space combustion process is simulated by using the Fluent model according to the Cantera partition gasification model to simulate the different gasification products based on the entrance boundary conditions of the gas phase combustion space. Table 1 shows the arrangement of five test conditions in the actual experiment process. In order to achieve the purpose of regulating atmosphere, the excess air coefficient of the gasification chamber will be reduced from 1.3 to 0.3. Figure 6 to Figure 8 respectively show the temperature detection of gasification chamber in different working conditions and the temperature detection of the secondary combustion chamber and the furnace outlet. It can be seen that under the five kinds of working conditions, with the decrease of the excess air coefficient value of the gasification room, the overall temperature of gasification room gradually reduced; the overall temperature of the secondary combustion chamber under working condition 3 was the highest, followed by working conditions 4, 2, 1 and 5. The temperature regularity of furnace outlet is consistent with that of the secondary combustion chamber.

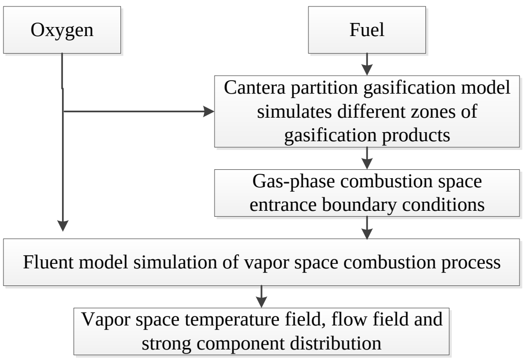
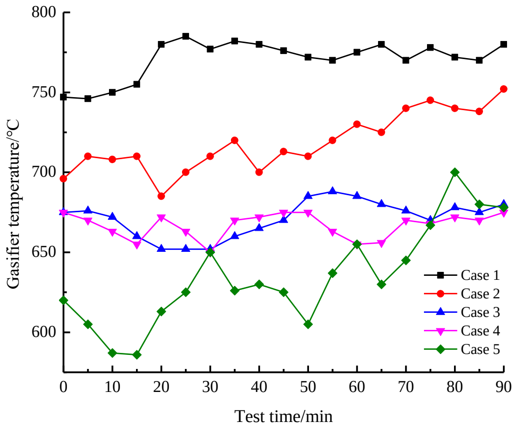


Figure 6: Simulation process flow chart

Table1: Test working condition arrangement

Case	Gasification chamber excess air coefficient	Total excess air ratio	Feed quantity（kg/h）
1	1.29	1.54	500
2	0.99	1.47	500
3	0.69	1.59	500
4	0.49	1.51	500
5	0.29	1.58	500



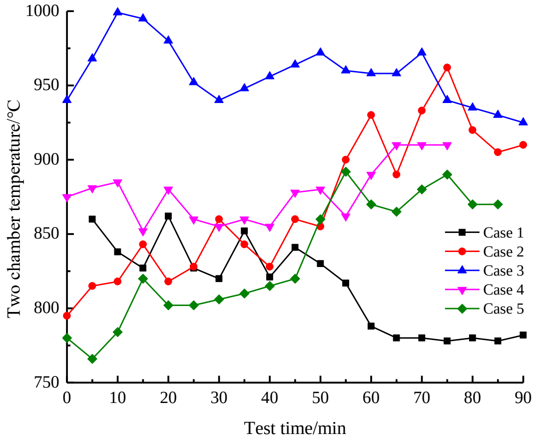


Figure 6: Temperature detection in gasification chamber under different working conditions; Figure 7: Two-burner indoor temperature detection under different conditions

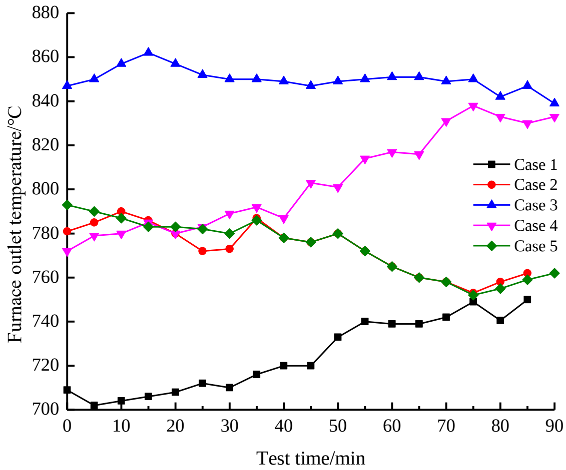


Figure 8: Furnace outlet temperature detection under different working conditions

4.2 Policy recommendations for coordinated environmental development

It is an important measure to keep the harmonious development of the ecological environment to solve the disorderly dumping of solid wastes from biomedical laboratories. The coordinated development of environmental protection and ecological environment is complementary, and the protection of ecological environment should start from the root of destroying the ecological environment. It is a must to solve the contradiction between the industrial structure and the local solid waste thermochemical treatment ability, establish the perfect ecological environment coordinated development protection mechanism, and improve the public environmental protection consciousness of the biomedical system personnel.

5. Conclusions

In this paper, the solid waste of biomedical laboratory is used as raw material for gasification and heat treatment of oxygen control, so as to achieve high energy efficiency of waste. Specific conclusions are as follows:
(1) The weight-loss rate of solid waste at different oxygen concentrations increases first and then remains flat, and with the increase of oxygen concentration, the ratio of loss of mass, the specific surface area of solid waste, and the volume of total pore will all increase.
(2) With the increase of excess air coefficient of gasification, gas yield increases, hydrogen yield, and tar yield all decrease, carbon conversion rate increases, and gas heat value and energy conversion efficiency decrease.

(3) In this paper, the simulation process of thermal chemical treatment is divided into dry section, pyrolysis gasification section and Coke Burnout section. The five groups of experiments shows that, with the decrease of the excess air coefficient of the gasification chamber, and the overall temperature of the gasification chamber reduces gradually, and the temperature regularity of the furnace outlet is consistent with the temperature rule of the secondary combustion chamber.

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