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Hydrothermal and Pyrolysis Treatment for Sewage Sludge: Choice from Product and from Energy Benefit*

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Abstract

Biowastes such as sewage sludge usually have high moisture contents and thermal technologies such as pyrolysis and incineration will meet the trouble of heavy evaporation load. Hydrothermal treatment has been adopted as an energy-effective method for dewatering and avoiding water evaporation. In addition, hydrothermal treatment can involve the carbonization of sewage sludge, leaving the stabilized solid product, therefore acting as a final treatment step for sewage sludge disposal. As an energy convertor, pyrolysis is a competitive technology to incineration. In this research products and energy balance for operating the hydrothermal process within temperature range of 220-270 ^{o}C were compared with those of pyrolysis process operating within 250-700 ^{o}C for sewage sludge disposal. It has been found that the hydrothermal treatment produces less solid product (char) & gas than pyrolysis process and is more energy efficient. However, it requires a rigid high pressure reactor.

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Keywords:Sewage sludge; hyrothermal; pyrolysis; products; energy balance.

1. Introduction

Hydrothermal process and pyrolysis are two important techniques for dealing with biowastes such as sewage sludge and food wastes, which have high moisture contents [1-3]. Hydrothermal process can be defined as any heterogeneous reaction in the presence of aqueous solvents, usually water under high pressure and high temperature conditions mostly in a closed system. In a hydrothermal process, biowastes would dehydrogenize, decompose and degrade to release gas, produce oil and leave relatively stable solid, which can be easier to separate from moisture. Moisture contained in the biowastes is remained as liquid after reaction to avoid latent heat consumption. Pyrolysis process is another kind of thermolysis, it involves a thermochemical decomposition of organic material at elevated temperatures in the absence of

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oxygen under the pressure of or close to atmosphere. The products are char, gas and tar. Moisture contained in the biowastes is evaporated totally therefore highly wet wastes cannot be sent to pyrolysis reactor. Few literatures gave directions for choosing of these two technologies; in this research sewage sludge is adopted as an example of biowastes to compare the products and energy consumption from these two thermolysis processes so that to help their choice.

2. Experimental Materials and Method

(1) Materials

The sewage sludge is taken from a wastewater treatment plant in centre Shanghai, where the activated sludge process is adopted for wastewater treatment. The initial moisture content is 80.76%, and other characteristics are listed table 1.

Table 1. Primary and elemental analysis of sewage sludge (in dry mass, DM)

Primary analysis /%			Elemental analysis /%				LHV/MJ·kg^{-1}
Ash	Volatile	Fixed carbon	C	H	N	O	
24.27	67.04	8.68	38.63	5.90	6.88	24.31	17.32

(2) Methods

Hydrothermal reaction is processed in temperature range of 170-270 ^oC, after reaching the set temperature the sewage sludge was kept under that temperature for 20min, each time 2 L of sewage sludge is used in a reactor of 3 L in volume. The pyrolysis is processed under temperature range of 250-700 ^oC, the volatile is cooled to collect oil and gas. Bass balance is set up to analyse the products distribution of the two processes. To check the quality of solid products, proximate analysis and elemental analysis were performed for the solid products; and a Vario EL III type element analyzer (Elementar, Germany) was adopted for their elemental analysis. SCOD (solved chemical oxygen demand) of the hydrothermal liquid was measured with the potassium dichromate method, and BOD (Biochemical oxygen demand) of the hydrothermal liquid was measured with the dilution and seeding method.

The gas was measured with a GC-9160 type gas chromatograph (Shanghai) and the pollution components such as NH_3, H_2S and SO_2 were measured with a PGM-7800 type toxic gas detector (RAE, USA).

3. Results and Discussion

(1) Product comparison of hydrothermal and pyrolysis processes

The products distribution of the two processes are showed in Figure 1and 2. From which it can be seen

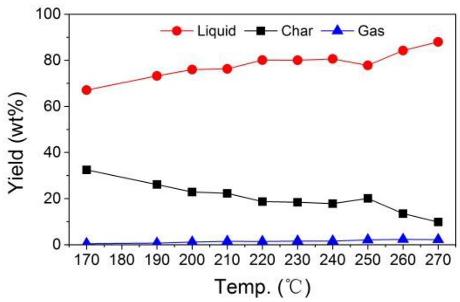


Figure 1.Product distribution from hydrothermal process at different temperature

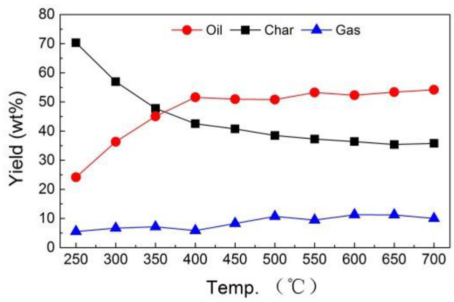


Figure 2. Product distribution from pyrolysis process at different temperature

that liquid is the main product for hydrothermal process, which increasing with temperature. The solid and gas yields from hydrothermal process are obviously less than those from pyrolysis products. As liquid hydrothermal process cannot be ignited, it should be treated again. However, when the temperature is higher than 250 ^oC, the ratio of BOD/COD is higher than 0.3, meaning that the liquid can be returned back to the wastewater treatment plant [4]. Therefore temperature of 250 ^oC or higher is required for hydrothermal process, the corresponded pressure is higher than 39.76MPa. The LHV of solid products from hydrothermal process at different temperatures have higher lower heat valves (LHV) than the chars from pyrolysis process, whose LHV decreases as temperature increases, as shown in Figure 4. But as pyrolysis temperature is higher than 300 ^oC, the LHV of oil from pyrolysis (tar) is higher than 20000kJ/k, as shown in Figure 3, suggesting it can be burnt without auxiliary fuel.

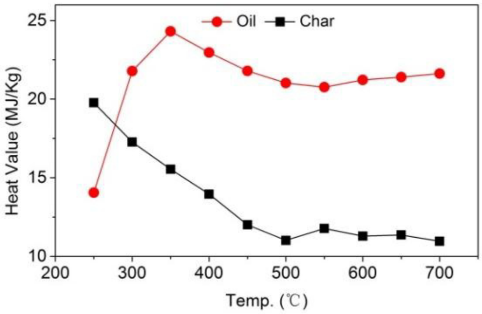


Figure 3. LHV of oil and char from sewage sludge pyrolysis at different temperatures

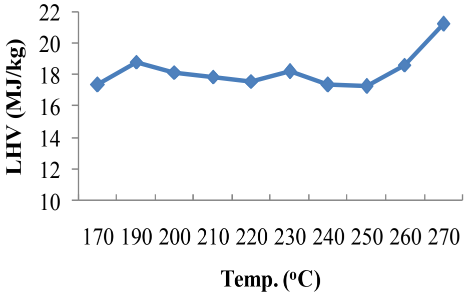
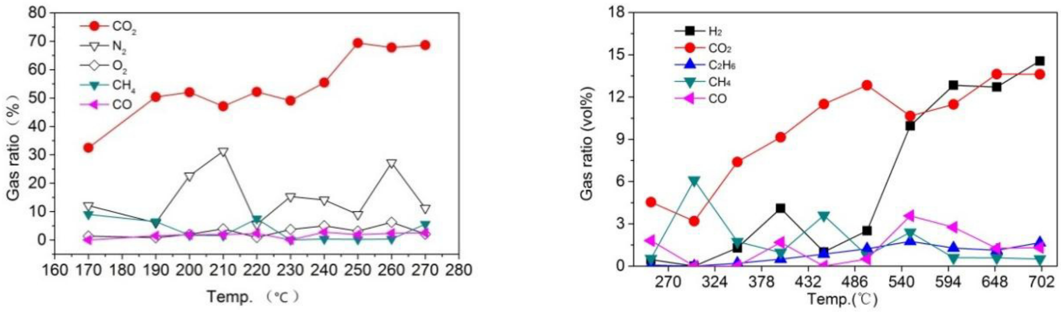


Figure 4 LHV of soild products from hydrothermal process at different temperatures

The gas products from the two processes are shown in Figure 5(a) and Figure 5(b).



(a) gas from sewage sludge hydrothermal process

(b) gas from sewage sludge pyrolysis

Figure 5. Gas products from two processes at different temperatures

It can be seen that CO_2 is the main gas component for the gaseous products from two processes; this is because oxygen content is high in the sewage sludge (24.31% in DM). But for gas product from hydrothermal process CO_2 is around 70%, than the second highest gas component is N_2; the ratio of combustibles such as CO, H_2 and C_mH_n is very small, lower than 0.35%. In addition, H_2S, SO_2 and NH_3 appeared in the gas products, therefore the gas products have no value of combustion. Figure 5(b) shows that in addition to CO_2, the second highest gas components in the gas products from pyrolysis process is H_2, especially when the pyrolysis temperature is close to 550 ^oC. In addition CO and C_nH_m (C_2H_4 and C_2H_6) also appear; therefore the gas product can be burnt to supply heat. However, existence of H_2S and NH_3 in the gas products requires flue gas cleaning before discharge.

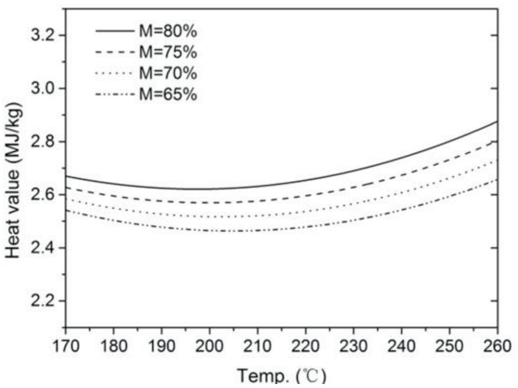


Figure 6. Energy balance of hydrothermal process when supported by solid products (in DM)

(2) Energy balance

Both thermolysis processes require energy supply for the reactions to take place. The energy consumption is the most important factors affecting sewage sludge disposal. The solid products from hydrothermal process are found to contain 40.1 ~ 65.6% of energy that originally contained in the sewage sludge, and they also have relatively high LHVs, as shown in Figure 4, therefore they can be burnt to heat up the reactor. For pyrolysis process both the gas and oil can be burnt when they emit as volatile to supply energy needed for the reaction [5]. Figure 6 shows the energy balance requirements on LHV of the sewage sludge when the solid products from hydrothermal process. It can be seen that for hydrothermal process the required LHV of sewage sludge is very low, much lower than that for pyrolysis process [5]; self-energy balance can be always reached for sewage sludge to be disposed through hydrothermal process. While for pyrolysis process the LHV should be higher than 17 MJ/kg (in DM) [5] under pyrolysis temperature of 550 ^{o}C; however in seldom cases the sewage sludge can have LHV higher than 17 MJ/kg (in DM).

4. Conclusions

(1) Products for sewage sludge disposal through hydrothermal process and pyrolysis are compared; it has been found that hydrothermal process is characterized with higher liquid yields, emitting CO_2 as main gas products, but the solid product is much lower than pyrolysis process.

(2) For hydrothermal process self-energy balance can be easily reached if the solid products from sewage sludge are used as heating source; however energy balance is usually difficult to reach for pyrolysis process of wet sewage sludge.

(3) H_2S and NH_3 are common containments when disposing sewage sludge through the two processes.

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