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Effect of Oxidation Coefficient on Products of Sewage Sludge Treatment in Supercritical Water

Guike Lin, Donghai Xu*, Zhijiang Ma, Shuzhong Wang, Yang Guo

Key Laboratory of Thermo-Fluid Science & Engineering, Ministry of Education, School of Energy and Power Engineering, Xi'an Jiaotong University, Xi'an, Shaanxi Province 710049, China

Abstract

Supercritical water treatment is a promising technology for sewage sludge disposal. The influences of oxidation coefficient (OC) as well as temperature on products of sewage sludge treatment in supercritical water were studied systematically. The results show that CO_2 yield obviously increased with raising OC or temperature. Oxidant helped to convert N-containing compounds into N_2. A small amount of oxidant increased H_2 yield but excess oxidant decreased it. OC had significant effect on the COD (chemical oxygen demand) and NH_3-N (ammonia nitrogen) concentration of liquid products. Most of organic compounds disappeared at OC=1.0 as temperature changed from 450 to 500 ℃, and diethyl phthalate was main stubborn substance in the liquid phase. The contents of some elements (such as Si, Al and Ca) in solid residue was almost double compared with those in dry basis SS.

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Keywords: Oxidant; oxidation coefficient; sewage sludge; supercritical water

1. Introduction

Sewage sludge (SS) is one of the products of city wastewater treatment. In recent decades, SS has become a public focus because of its environmental harm and ever-increasing amount [1,2]. SS consists of plenty of water,

* Corresponding author. Tel.: +86-29-82665749; fax: +86-29-8266-8703.
E-mail address: haidongxu93346423@aliyun.com (D.H. Xu)

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nontoxic organic and inorganic compounds, toxic organic pollutants, heavy metals, viruses, bacteria and other pollutants [3,4]. SS disposal is an important problem for the development of water treatment industry, due to the high concentration of heavy metals, organic pollutants and pathogens and other microbiological pollutants [5].

Traditional land utilization, landfill and incineration, etc, are the main methods of SS disposal. However, those ways are facing great challenges such as secondary pollution, low economy and incompletely disposal [3,6]. Using the special properties of supercritical water (SCW), can quickly and thoroughly decompose toxic organic compounds of MSS into non-toxic substances. SCW treatment methods contain supercritical water gasification, supercritical water partial oxidation and supercritical water oxidation technologies with oxidants content rising [7]. Combustible gases (e.g., H_2, CH_4) can be generated by SS supercritical water gasification or supercritical water partial oxidation technology by using oxidant less than theoretical oxygen demand.

In this work, the influences of oxidation coefficient on the gas-liquid-solid products of SS treatment in SCW were investigated systematically. Furthermore, SS treatment in SCW in a short preheating and reaction time was explored to determine the optimum treatment method and condition. This information is valuable for operating parameters optimization of SS disposal in SCW.

2. Experimental section

2.1. Experimental apparatus and procedure

The high purity oxygen used as oxidant and helium used as an internal standard gas were all purchased from Baoguang Gas Co., Ltd (Shaanxi Province, China). SS was taken from the Beishiqiao wastewater treatment plant (Xi'an city, China). The concentration of SS was diluted to 8 wt.% with deionized water for experiments, because this content can ensure continuous flow in the future application. Its physicochemical property is listed in Table 1. Thus, its initial COD concentration was 73130 mg/L, and the ash content (dry basis) was 35.5 wt.%.

We used 4.4 ml mini-batch reactor with a high-pressure valve for the experiments. The reactor was purchased from Shanghai Mian on Hay Hydraulic Equipment Co., Ltd. A certain amount of wet SS was loaded into the reactor to ensure the same reaction pressure (24 MPa) at different reaction temperatures. The wet SS loadings were listed in Table 2. The reactor was evacuated into a negative pressure with a vacuum pump, and then filled with helium. This cycle was repeated three times to ensure reactor completely to be filled with helium, and the 0.1MPa (absolute pressure) helium was served as an internal standard gas. Finally, oxygen was added into reactor, and its loading was listed in Table 2 as well. OC was defined as follows:

$$OC = \frac{\text{the actual oxygen added}}{\text{the theoretical oxygen demand}} \tag{1}$$

The COD removal efficiency was calculated as follows:

$$COD\ removal\ efficiency\ (\%) = \frac{COD_{SS} - COD_{Liquid\ product}}{COD_{SS}} \times 100\% \tag{2}$$

Table 1. Chemical characteristics of sewage sludge.

Moisture (wt.%)[1]	Ash (wt.%)[2]	Elemental analysis (wt.%)[2]					HHV (MJ/kg)	COD (mg/L)
		C	H	N	S	O[3]		
92	35.5	33.85	5.14	5.81	3.201	16.499	16.14	73130

[1] On a received basis.

[2] On air dry basis.

[3] By difference (O% = 100% – ash% – C% – H% – N% – S%).