Reaction Rate Analysis on Phosphorus for Hydrothermal Treatment of Sewage Sludge

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下水汚泥の水熱処理におけるリンの反応速度解析

Reaction Rate Analysis on Phosphorus for Hydrothermal Treatment of Sewage Sludge

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The purpose of this study was to investigate the effect of temperature and reaction time on the behavior of phosphorus in sub- and supercritical water gasification of sewage sludge. Gasification was carried out using a continuous flow reactor, and experimental runs were conducted by varying temperature as 300, 350, 500, and 550 ºC and reaction time in the range of 5− 30 s. The pressure was fixed at 25 MPa. The effect of temperature and reaction time on P behavior of sewage sludge was investigated. The results showed that organic phosphorus (OP) was almost completely converted into inorganic phosphorus (IP) under supercritical condition and shorter residence time (10 s).

Key Words: phosphorus, reaction time, sewage sludge, supercritical water, temperature

1. Introduction

Phosphorus is an irreplaceable, essential element for all living organisms, especially for agriculture. The primary source for fertilizer, mined phosphate rock, is a critical non-renewable globally demanded resources and there is an increasing concern about the commercial availability of this resource in the near future. Sewage sludge represents an important secondary phosphorus source, 14% to 25% PO_2O_5 contained in sewage sludge ash[1].

Various technology has been employed to convert wet biomass into secondary energy sources via combustion, pyrolysis and supercritical water gasification[2]. A large amount of energy is consumed for drying when the combustion and pyrolysis is applied. Thus, supercritical water gasification (SCWG) is useful technology because water can be used as a reaction medium so that wet biomass do not need to be dried. The gasification of sewage sludge in supercritical water has been investigated by some researchers. Recently, Aceles at al.[3] have conducted the gasification of dewatered sewage sludge in SCW for energy recovery combined with phosphorus recovery. However, their study was carried out only in batch reactors. It is also to be noted that study on phosphorus behavior from sewage sludge in supercritical water, covering both sub− and supercritical condition has not been reported. Thus, the purpose of this study is to investigate the effect of temperature and reaction time on phosphorus behavior from sewage sludge under sub− and supercritical conditions.

2. Experimental

All experimental runs were performed using the tubular flow reactor. Tubing made of SS316 steel (ID: 2.17 mm, OD: 3.18 mm, and length 12 m) was used as a reactor. 0.1 wt% of sewage sludge feedstock mixed with deionized water was prepared. Before feeding the feedstock to the reactor, the reactor pressure was maintained at 25 MPa by feeding only water controlled by back-pressure regulator, and the reactor temperature was raised to the required temperature. The feedstock was fed into the reactor for 1 h prior to sampling. After passing through the reactor, the effluent was cooled down in a heat exchanger and then sampled. The liquid sample was analyzed

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by using total organic carbon (TOC) analyzer. Phosphorus yield in the liquid phase was determined using ion chromatography (IC) to quantify inorganic phosphorus. The experiment was conducted in the temperature range of 300–550 °C and the residence time range of 5– 30 s.

3. Results and Discussion

The effect of temperature and reaction time on the behavior of phosphorus is shown in Table 1.

Table 1. Phosphorus yield

P yield [mol-P/mol-P]	Residence time [s]	Temperature [°C]			
		Subcritical region		Supercritical region	
		300	350	500	550
Inorganic P	5	0.33	0.43	0.60	0.60
	10	0.54	0.63	0.81	0.79
	20	0.64	0.67	0.68	0.70
	30	0.65	0.65	0.65	0.61
Organic P	5	0.54	0.37	0.16	0.15
	10	0.30	0.17	0.03	0.00
	20	0.15	0.09	0.01	0.00
	30	0.12	0.00	0.00	0.04
Remaining IP	5	0.09	0.05	0.24	0.26
	10	0.10	0.10	0.16	0.21
	20	0.13	0.21	0.31	0.29
	30	0.18	0.20	0.33	0.35

As shown in Table 1, the organic phosphorus (OP) decreased at the higher temperature and OP was completely converted into the inorganic phosphorus (IP). The IP yield is high at 500 and 550 °C. Interestingly, the yield of remaining IP generally increased with temperature and time. This behavior supports that IP precipitation in the reactor.

4. Conclusions

The effect of temperature and reaction time on P behavior was determined. OP decreased under a supercritical condition. OP was converted to IP. The yield of remaining IP generally increased with temperature and time. This behavior supports that IP precipitation in the reactor.

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