P-12 超臨界水中における下水汚泥の全体挙動

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Total behavior of sewage sludge in supercritical water

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ABSTRACT:
Hydrothermal treatment is a promising option for wet organic waste, due to its low energy consumption. Hydrothermal treatment can also be used as resource recovery method. When considering the recovery of phosphorus from sewage sludge by hydrothermal reaction, organic phosphorus is mineralized and get precipitated, while the carbon content is gasified and recovered from other part. We report the process of efficiently recovering phosphorus based on the experimental runs in the range of 375 to 600 ℃ under 25 MPa.

[1] Introduction

Disposal of wastewater treatment sludge is a pressing environmental problem nowadays, which is aggravated by its accumulation around the world. The strict regulations for disposal and utilization of sewage sludge, coupled with the loss of traditionally accepted disposal routes, has prompted a drive for alternative uses for sewage sludge. Various technologies have been employed to convert sewage sludge into beneficial energy sources. Thermal processes of treatment have recently been considered by researchers such as combustion, pyrolysis, and supercritical water gasification[1]. However, the large amount of energy is consumed when the biomass dried in combustion and pyrolysis process. In order to avoid drying process, supercritical water gasification (SCWG) is a good technology because water can be used as a reaction medium so that wet biomass does not need to be dried. Unfortunately, in most SCWG studies, much attention had been paid to gas production from various biomass. Recently, Gong et al.[2] have conducted the gasification of humic acid as a model compound of sewage sludge in sub- and supercritical water for gas composition. Acelas et al.[3] determined the gasification of dewatered sewage sludge in SCW for energy recovery combined with phosphorus recovery. However, all of them were carried out only in the fixed-bed reactor. It is also be noted that study on gasification as well as phosphorus behavior from sewage sludge in supercritical, covering both sub- and supercritical condition has not been reported. Therefore, this study aims to investigate the effect of temperature and reaction time on the total behavior of sewage sludge during SCWG with continuous flow reactor.

[2] Experimental

All experimental runs were performed using the tubular flow reactor. The details of experimental apparatus employed in this study have been reported elsewhere[4]. Tubing made of SS316 steel (ID: 2.17 mm, OD: 3.18 mm, and length 12 m) was used as a reactor. The reaction temperature was varied from 375 to 600 ºC, and the reaction pressure kept constant at 25 MPa. The residence time was varied in the range of 5-30 s. To ensure steady state conditions, we waited for 1 h prior to sample collecting. The gas sample was collected in small vials, and their composition was determined by gas chromatography. The reactor effluent was then cooled down by a heat exchanger, and liquid phase was collected. Total organic carbon was analyzed by using a total organic carbon (TOC) analyzer to quantify the amounts of carbon in the liquid product (non-purgeable organic carbon or NPOC) and that in the dissolved gas product (inorganic carbon or IC). In case of phosphorus yield in liquid phase was determined using ion chromatography (IC) to quantify inorganic phosphorus (IP), and molybdenum blue method was employed to

quantify total phosphorus (TP). The details of experimental conditions are shown in **Table 1**.

Table 1. Experimental conditions

types of conditions	experimental range
Feedstock	active sludge
concentration of solid	0.1 wt%
Temperature	375−600 °C
Pressure	25 MPa
residence time	5−30 min
reactor type	continuous reactor

[3] Results and discussion

The effect of temperature and residence time on the carbon gasification efficiency (CGE) is shown in **Table 2**. The CGE for all runs is calculated on the basis of the carbon content. The temperature has an effect on CGE results. However, the effect of residence time was not observed for the range in this study. The results indicated that gas generation is determined by the temperature and sewage sludge is converted into gas and other product. The inorganic phosphorus was obtained as a secondary product from this experiment. The result for phosphorus yield are shown in **Table 3**. As shown in Table 3, the organic phosphorus (OP) decreased at high temperature and was completely converted into the inorganic phosphorus (IP). The mineralization of organic phosphorus was confirmed in this study which precipitates as a remaining IP. It was concluded from the formation of remaining IP took place during the reaction.

[4] Conclusion

The total behavior of sewage sludge in supercritical water using a continuous reactor was investigated. The CGE increased with temperature. However, effect of residence time was insignificant. Mineralization of organic phosphorus resulted in phosphate ion in liquid phase. The inorganic phosphorus increased with temperature and residence time.

Table 2. CGE for each temperature

Residence time [s]	Temperature [°C]					
	375	400	450	500	550	600
5	0.10	0.35	0.38	0.41	0.63	0.59
10	0.10	0.35	0.34	0.41	0.60	0.60
20	0.17	0.40	0.38	0.46	0.62	0.64
30	0.19	0.47	0.48	0.50	0.64	0.72

Table 3. Phosphorus yield

Temperature [°C]	Phosphorus yield [mol-P/mol-P]	Residence time [s]			
		5	10	20	30
375	OP	0.5	0.3	0.2	0.2
	IP	0.2	0.2	0.1	0.0
	Precipitate IP	0.3	0.5	0.8	0.8
400	OP	0.5	0.3	0.2	0.2
	IP	0.2	0.2	0.1	0.1
	Precipitate IP	0.3	0.5	0.8	0.8
450	OP	0.5	0.3	0.2	0.2
	IP	0.3	0.2	0.2	0.1
	Precipitate IP	0.3	0.5	0.8	0.9
500	OP	0.2	0.0	0.0	0.0
	IP	0.6	0.8	0.7	0.7
	Precipitate IP	0.3	0.2	0.3	0.3
550	OP	0.2	0.0	0.0	0.0
	IP	0.6	0.8	0.7	0.6
	Precipitate IP	0.3	0.2	0.3	0.3
600	OP	0.0	0.0	0.0	0.0
	IP	0.7	0.8	0.7	0.6
	Precipitate IP	0.2	0.2	0.3	0.4

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