論　文　の　要　旨

題目 Supercritical water gasification of sewage sludge with phosphorus recovery
（リン回収を伴う下水汚泥の超臨界水ガス化）

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Nowadays, researches on biomass, which is the fourth largest energy resource after coal, oil, and natural gas, have attracted a tremendous attention due to the effort to mitigate climate change. One of the most promising biomass sources is sewage sludge as it is a low-cost material and available in a large amount. Moreover, sewage sludge contains a large amount of organic matters such as proteins, lipids, carbohydrates, and lignin as well as nitrogen, and phosphorus. Various methods have been approached to convert sewage sludge into useful secondary energy via combustion, pyrolysis, and supercritical water gasification (SCWG). However, sewage sludge has a high moisture content (approximately 85 wt%), leading to high drying costs when combustion and pyrolysis are applied. On the other hand, SCWG is appropriate for converting biomass containing high-moisture biomass such as sewage sludge, as pre-drying of biomass is not required, and the gasification reaction takes place in water within a few minutes.　Even though studies on the conversion of sewage sludge into secondary energy using SCWG have been conducted, there are no comprehensive studies on gas generation combined with phosphorus recovery as well as detailed elucidation of the reaction kinetics for the SCWG of sewage sludge using a continuous reactor. Sewage sludge was gasified under supercritical conditions by using a continuous flow reactor. The reactor was made of SS316 steel tubing with a length of 12 m and the inner diameter of 2.17 mm. Experiments were conducted by varying the temperature (500−600 °C) and residence time (5−60 s), while the reaction pressure was fixed at 25 MPa. The results showed that a carbon gasification efficiency (CGE) as high as 0.73 was achieved at 600 °C after 50 s. Organic phosphorus was rapidly converted into inorganic phosphorus at short residence time of 10 s. Since sewage sludge contains a high amount of phosphorus and considering that sub- and supercritical water gasification could leave the phosphorus behind, the study about phosphorus behavior and its kinetics under hydrothermal condition is crucial. Using a continuous reactor at a fixed pressure of 25 MPa, sewage sludge gasification under hydrothermal condition was performed at temperature range of 300−600 °C and reaction time 5−30 s. Under subcritical condition, the yield of organic phosphorus decreases, whereas the yield of inorganic phosphorus increases. Apparently, organic phosphorus is converted to inorganic phosphorus under the hydrothermal condition.

Finally, cell structure destruction and its kinetics during hydrothermal treatment of sewage sludge was studied due to the fact that hydrothermal treatment requires high temperature, which will affect the morphological structure of sewage sludge. This is the first comprehensive studies to investigate the effect of hydrothermal treatment at various temperatures on the morphological structure of sewage sludge as well as the release of organic compounds inside the cells and its kinetics behavior. The effect of hydrothermal temperature (130−250 °C) on the total organic content (TOC) and morphology of sewage sludge was investigated for a residence time of 10 min under 5 MPa. HT damaged the sewage sludge cell structure, thereby releasing the cell contents and consequently increasing the TOC in the liquid phase. By using the Arrhenius equation, the pre-exponential factor and activation energy were successfully determined for the first time for the degradation of sewage sludge cells.