論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Green Solvent-Assisted Hydrothermal Liquefaction of Sewage Sludge: Enhancing Biocrude Quality and Socio-Economic Feasibility
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出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第12891号, 授与年月日:2024年9月20日, 学位の種別:課程博士, 審査員:CROSS JEFFREY SCOTT,大友 順一郎,高橋 史武,江頭 竜一,藤井 学
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第12891号, Conferred date:2024/9/20, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）

Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	TSE GEDES	系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	（ Engineering ）
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要旨（英文 800 語程度）

Thesis Summary（approx.800 English Words ）

The dissertation entitled, Green Solvent-Assisted Hydrothermal Liquefaction of Sewage Sludge: Enhancing Biocrude Quality and Socio-Economic Feasibility, is a comprehensive study on advancing sustainable waste management and renewable energy production through the Hydrothermal Liquefaction (HTL) process of sewage sludge (SS). Each chapter addressed critical aspects of this research, highlighting innovative approaches, significant findings, and future directions.

Chapter 1: Introduction and Background of the Study
This chapter laid the foundation by discussing global challenges such as fossil fuel dependency, greenhouse gas emissions, and the limitations of traditional sewage sludge management methods, including incineration. It introduced HTL as a promising alternative for converting SS into valuable products. The chapter reviewed relevant literature on HTL and emphasized the need for green solvents to enhance the process. The novelty of this research lay in its focus on exploring eco-friendly solvents for HTL, troubleshooting and fixing the reactor, setting the stage for the subsequent experimental chapters.

Chapter 2: Green Solvent-Assisted Hydrothermal Liquefaction of Sewage Sludge and Biocrude Hydrotreatment for Sustainable Biofuel Production
This chapter explored the effectiveness of eco-friendly solvents, Ethyl Acetate (EA) and Ethyl Butyrate (EB), in improving the extraction and hydrotreatment (HDT) of biocrude derived from SS via HTL. Conducted at temperatures ranging from 250-375 °C, the HTL process was followed by extraction with DCM, hexane, EB, and EA. The biocrude was then subjected to hydrotreatment using a Ni/SiO_2-Al_2O_3 catalyst. The results demonstrated that EB-extracted biocrude had the highest yield and quality, with lower nitrogen and heteroatom levels, compared to conventional solvents. EB's biocrude exhibited superior characteristics, including a higher concentration of alkanes and fewer heterocyclic nitrogen compounds, contributing to improved bioenergy and chemical production.

Chapter 3: Nitrogen Minimization in Hydrothermal Liquefaction Biocrude from Sewage sludge with Green Extraction Solvents
Chapter 3 investigated the effectiveness of various solvents, including conventional options like DCM and hexane, and green alternatives such as EB and EA, in converting SS into high-quality biocrude through HTL. The experiments, conducted at 350 °C, revealed that EB yielded the highest biocrude extraction (50.1 wt%) with the lowest nitrogen content (5.4% with 0.32 wt %) and the highest energy recovery (74%). The GC-MS analysis showed that EB-derived biocrude had minimal heteroatoms and nitrogenous compounds. In addition, solid residues from hexane, EB, and EA displayed the highest nitrogen distribution range (62–68%), hinting at potential applications in further processes. The chapter provided insights into solvent selection for efficient waste-to-energy conversion and highlighted the importance of solvent choice in enhancing biocrude quality.

Chapter 4: Socio and Techno-economic Study of Biofuel Production from Sewage Sludge via Transesterification and Hydrothermal Liquefaction
Chapter 4 offered a thorough techno-economic analysis of two innovative processes utilizing SS for biodiesel production and HTL process. Using Aspen Plus simulations, the study evaluated the economic feasibility and potential profitability of these processes, particularly when integrated into Japanese wastewater treatment plants (WWTPs). The analysis revealed that biodiesel production from SS was economically advantageous, with estimated production costs of 0.09 USD/kg for dewatered

SS and 0.084 USD/kg for wet SS. The potential break-even price for biodiesel was as low as 540 USD/t, which was approximately 70% below the current market price. This significant cost reduction highlighted the economic viability of using SS as a feedstock for biodiesel production. Integrating this process within WWTPs not only supported circular economy principles but also reduced waste management costs and aligned with global sustainability goals.

On the other hand, the HTL process demonstrated considerable economic potential. The analysis was conducted at two different scales: 100 tonnes and 2,641 tonnes of SS annually. For a 100-tonne HTL plant, the annual revenue was approximately 1.5 million USD, and scaling up to a 2,641-tonne HTL plant, the annual revenue rose to approximately 41 million USD. These figures illustrated the HTL process's potential for substantial revenue and profitability. Notably, HTL showed a competitive edge over traditional biogas production methods in Japan, which typically involved higher costs and lower revenue potential. By converting SS into high-value biocrude, HTL offered a more profitable and sustainable alternative to conventional biogas production.

Chapter 5: General Conclusions and Impacts of this Research
This chapter synthesized the key findings of the dissertation, emphasizing the successful demonstration of eco-friendly solvents in HTL, the superior performance of EB in biocrude extraction, and the promising techno-economic feasibility of biodiesel production and HTL from SS. It highlighted the potential for these technologies to contribute to sustainable waste management and renewable energy production, aligning with global sustainability goals.

Chapter 6: Limitations of this Research and Future Research
This chapter discussed the limitations of the study, such as the need for further research on large-scale implementation, HTL byproducts investigation, and solvent recovery. It outlined future research directions, including the exploration of advanced analytical techniques, comprehensive product analysis, and engagement with policymakers to create supportive regulatory frameworks for broader adoption of these technologies.