氏名	王　影（YING WANG）
学位の種類	博　士（環境学）
学位記番号	博　甲　第　　８８４１　　号
学位授与年月日	平成　３０年　９月　２５日
学位授与の要件	学位規則第４条第１項該当
審査研究科	生命環境科学研究科
学位論文題目	Study on Methanation of CO_2 and CO from Blast Furnace Gas by Anaerobic Fermentation under Mesophilic conditions （中温条件における嫌気性発酵による高炉ガス中のCO_2およびCOのメタネーション）

主査	筑波大学教授	博士（農学）	張　振亜
副査	筑波大学准教授	工学博士	雷　中方
副査	筑波大学准教授	博士（農学）	清水　和哉
副査	国立研究開発法人国立環境研究所 主席研究員　室長	工学博士	徐　開欽

論　文　の　要　旨
Abstract of thesis

Blast furnace gas (BFG) is a byproduct gas produced during the production of hot metal (liquid iron) in a blast furnace from iron and steel industry. It is currently being used primarily as fuel for steam boilers, dynamos, however, high concentrations of CO (toxic) and CO_2 (greenhouse gases, GHG) make it low calorific value. The objective of this research is mainly to find an effective and economic way to treat blast furnace gas so as to feasible research on methanation of blast furnace gas using acclimated methanogens or anaerobic granular sludge. Higher quality of fuel will be obtained through biomethanation of CO_2 and CO from BFG, which could be further utilized as heating fuel or power generation for steel industry. And it is important to understand the possible effect of CO which is toxic on the activity and ecology of the microorganisms and the possible CO methanation routes. Since H_2 is a possible inhibitor to the anaerobic process, it is challenging to add both blast furnace gas and hydrogen in the reactors at the same time.

The thesis is divided into 4 chapters.

In chapter 1, the author introduced the source and composition of blast furnace gas, summarized the different treatment methods and pointed out the advantages of biological technology of blast furnace gas. The author also gave a literature review on the previous studies relating to biological fermentation of syngas (including blast furnace gas) to methane, presented species of microorganisms and routes in syngas biomethanation and introduced the two inoculums (acclimated methanogens and anaerobic granular sludge). Then the author proposed research objectives at the end of this chapter.

In chapter 2, a semi-continuous reactor was used to cultivate methanogens sampled from a nearby pond sediment

under H_2/CO_2 conditions. The author investigated the tolerance of the enriched methanogens to CO partial pressure and determine whether it is suitable for converting BFG to methane. The results indicated that among the different factors, besides basic medium, trace metal element can maintain the performance of the system for methane production. This research also provided insight into that enriched methanogens under H_2/CO_2 was not suitable for using CO from BFG as sole energy and carbon source for CH_4 synthesis. Since CO presented inhibitory to inoculum for methane production started from P_{CO} of 0.1 atm. The CO content is 20-35% corresponding to 0.2-0.35 atm at atmospheric conditions. It is necessary to dilute the P_{CO} below 0.1 atm by nitrogen for conversion of CO to CH_4 by the acclimated methanogens which is not economic.

In chapter 3, the author explored the potential of anaerobic conversion of CO from BFG to methane via volatile fatty acids (VFAs) (especially acetate) or H_2 as intermediates under mesophilic conditions by anaerobic granular sludge. The inhibition of methane production by CO partial pressure started at 0.4 atm. By using the simulated BFG, the batch tests demonstrated that either CO or CO_2 from BFG could be effectively converted by supplying exogenous hydrogen under an appropriate hydrogen partial pressure (0.88 atm in this study). Although hydrogen partial pressure higher than 1.54 atm could rapidly convert carbon source in BFG to methane, the accumulation of VFAs implies that additional design and operation should be considered for the whole BFG fermentation system. The effects of two inoculums were also compared. Microbial populations in AGS can be more tolerant to the toxicity of CO, and be more in line with the actual demand.

In chapter 4, the author summarized the overall conclusions and future research perspectives. Further work is necessary to improve the BFG and H_2 utilization and methane production efficiencies by controlling the mixing intensity or optimization of the anaerobic reactors systems. All the experiments were conducted in batch study and laboratory scale, in order to evaluate the real application, large scale test study is needed in the future. In addition, the changes in microbial communities during a long-term test should be paid attention shedding light on the mechanisms involved in this biological process.

審 査 の 要 旨
Abstract of assessment result

This research used two kinds of inoculum, acclimated methanogens and anaerobic granular sludge, for converting BFG to methane. The obtained methane could be further utilized as heating fuel or power generation for steel industry. Therefore, this form of carbon recycling not only saves costs but also helps reduce GHG emission. When the gas substrate was CO, the inhibition of methane production by CO partial pressure (P_{CO}) started at 0.1 atm and BFG needed to be diluted with nitrogen requiring high cost. On the other hand, when the inoculum was anaerobic granular sludge (AGS), the inhibition of methane production by P_{CO} started at 0.4 atm which presented better tolerance to the toxicity of CO than acclimated methanogens. The intermediate metabolites from CO to methane included acetate, propionate and H_2. After the introduction of H_2 and BFG to the bottles, the optimum hydrogen partial pressure on CH_4 production (5.32 mmol/ g VSS) was observed at 0.88 atm. The results indicate a bright future for adopting AGS into converting BFG to CH_4, which would make this study more meaningful.

The final examination committee conducted a meeting as a final examination on 20 July, 2018. The applicant provided an overview of dissertation, addressed questions and comments raised during Q&A session. All of the committee members reached a final decision that the applicant has passed the final examination.

Therefore, the final examination committee approved that the applicant is qualified to be awarded the degree of Doctor of Philosophy in Environmental Studies.