Greenhouse gas emissions from blackwater septic systems in Hanoi，Vietnam(Abstract_要旨)

AUTHOR(S):

Huynh, Tan Loi

京都大学	博士（工学）	氏名	Huynh Tan Loi
論文題目	Greenhouse gas emissions from blackwater septic systems in Hanoi, Vietnam （ベトナム・ハノイにおけるし尿腐敗槽からの温室効果ガスの排出）		

（論文内容の要旨）

This study investigated the emission rates of greenhouse gases (GHGs), namely CH_4, CO_2, and N_2O, from septic systems in Hanoi, Vietnam, which are located in a subtropical climate region. The influence of septic tank conditions such as effluent characteristics, sludge compositions, septage storage period, and hydraulic retention time (HRT) were also investigated, together with seasonal variability of GHG emissions and pollutant removals. This study might strongly conribute to improvement of the IPCC emission factor on septic sytems that was made based on the relationship between CH_4 and organic loading in anaerobic lagoons.

Chapter 1 introduced the background of the study that motivates to conduct this research and described the objectives of the study, research framework and schedule of the survey.

Chapter 2 aimed to review the current wastewater management and onsite sanitation situation in Hanoi, Vietnam. The global GHG emissions from waste sectors and wastewater handling were also studied. This chapter also reviewed the available GHG emission rates from septic systems and the research gaps.

Chapter 3 purposed to estimate GHG emissions from septic systems in a developing country, with the influential factors to the emissions, as a case study of Hanoi, Vietnam. The CH_4, CO_2, and N_2O emissions from ten septic systems (ST1 – ST10) in the urban area of Hanoi, Vietnam, were measured by the floating chamber method. The monitoring was conducted in June – July, 2019. The measured CH_4 and CO_2 emission rates were 13.9 ± 4.8 and 23.7 ± 9.6 g/cap/day (Avg ± SD), respectively, whereas those of N_2O were at the negligible levels. The CH_4 emission rates were negatively correlated with septage ORP (R = -0.68, p = 0.015) and DO (R = -0.55, p = 0.064), and positively correlated with septage COD mass (R = 0.71, p = 0.0098) and BOD mass (R = 0.65, p = 0.023). Further, the CH_4 emission rates from septic systems with longer storage periods (more than 7 years) were significantly higher than those from septic systems with shorter storage periods (less than 7 years). These results suggest that lower ORP and DO, and higher biodegradable carbon mass in association with longer septage storage periods are key conditions for CH_4 emissions from septic systems. Therefore, controlled or regular septage emptying could contribute to

improve not only the removal efficiency of septic systems but also its GHG emission rates. Thus, the results will contribute to estimate global GHGs emissions from septic systems in developing countries and be essential information for mitigating the GHG emission.

Chapter 4 evaluated mass balance of the septic systems with seasonal variation. CH_4, CO_2 and N_2O emissions were monitored in summer (26 – 33 ºC) and winter (14 – 19 ºC) in the urban area of Hanoi, Vietnam. The summer survey was conducted at the ten septic systems (ST1 – ST10), as shown in Chapter 3, and the winter survey monitored at fifteen septic systems (ST1, ST2, and ST11 – ST23) in December 2019 – January 2020. The influent, effluent characteristics, and septage composition were also monitored to evaluate the performance of the septic systems and their impacts on GHG emissions. The CH_4 and CO_2 emission rates were 13.9 ± 4.8 and 23.7 ± 9.5 g/cap/day in summer, 15.5 ± 11.2 and 29.9 ± 16.0 g/cap/day (Avg ± SD) in winter, respectively. The results indicated that the GHG emission rates were not significantly different between summer and winter in Hanoi, which could be attributed to stable conditions in septic systems (ORP, DO, organic mass). The mass balances of carbon, nitrogen and phosphorus were analyzed for ST1 and ST2. The C, N, and P removal efficiencies were 59%, 24% and 6% in ST1 and 22%, 12% and 0.5% in ST2. Higher septage storage period of ST2 might reduce removal efficiencies of ST1. The CH_4 and CO_2 emissions were not only produced from carbon in the influent, but also from carbon in the septage because septage still contained high amount of biodegradable organic matter after long storage time. The CH_4 emission rate per-capita in the present study was 59%, smaller than IPCC emission factor. This result could be attributed to lower BOD loading and removal efficiency of septic systems in the present study as 23 ± 10 g-BOD/cap/day and 33 ± 18%, respectively. Therefore, for better estimation of CH_4 emissions from septic systems, BOD loading and removal efficiency are the key factors.

Chapter 5 represented the summary of the thesis and recommendations for the further studies, such as the GHG emission monitoring from all the compartment should be considered for more accuracy, and the investigation of GHG emissions for different onsite sanitation facilities from different regions is recommended for a broader understanding of global GHG emissions from onsite sanitation facilities.

氏　名	Huynh Tan Loi

（論文審査の結果の要旨）

腐敗槽は開発途上国で広く利用されているが，排水由来の汚泥を嫌気条件下で堆積することから，温室効果ガス（GHG）の排出源の一つと考えられる。本研究では，開発途上国で主に利用される，し尿腐敗槽由来の GHG の排出特性の把握と腐敗槽管理状況による排出率への影響を明らかにすることを目的とした。ベトナム国ハノイ市において，合計 25 基の腐敗槽を対象にフローティングチャンバー法を用いた GHG 排出測定，汚泥堆積量・性状，流入・流出水量・性状の調査を行い，下記に示す種々の成果を得た。

（1）腐敗槽 10 基の槽内の GHG 排出率を夏季（26～33℃）に測定したところ，メタン（CH_4）および二酸化炭素の排出率（Avg±SD）はそれぞれ 13.9 ± 4.8 g/人/日および 23.7 ± 9.5 g/人/日であった一方，一酸化窒素の排出率はバックグラウンドと同程度であった。CH_4 排出率は腐敗槽内汚泥の酸化還元電位（ORP）（R = -0.68, p = 0.015），槽内堆積 COD 量（R = 0.71, p = 0.0098）および同 BOD（R = 0.65, p = 0.023）と有意な相関があった。汚泥堆積期間が長い（7 年以上）腐敗槽は，短い腐敗槽（7 年未満）より有意にメタン排出率が高かった。汚泥堆積期間の長さは槽内汚泥の性状と有意な相関があった。これらより，汚泥堆積期間が長く，これと併せて酸化還元電位が低く，槽内堆積有機物量が多いことが，CH_4 排出率増加の主因子であり，定期的な汚泥引抜きなどの槽内環境改善は，汚濁排出低減のみならず GHG 排出量低減にも貢献することが示唆された。

（2）上記夏季に加え，同冬季（14～19℃）の腐敗槽 15 基の調査をしたところ，夏季と冬季の GHG 排出率に有意な差は見られなかった。ハノイにおける夏季・冬季での水温差では排出量に有意な影響は見られず，長期の汚泥堆積により生じる槽内環境が排出量により大きな影響を与えることが示された。

（3）極めて貴重であるトイレ排水の原水組成・負荷量を 15 基の腐敗槽より実測した。さらに腐敗槽における物質収支を構築し，1 人 1 日あたり CH_4 排出率を得た。その値は IPCC デフォルト値の 59%に相当した。対象地域の腐敗槽は汚泥堆積期間および水理学的滞留時間が標準的な腐敗槽より長く，流入 BOD 負荷量，ORP および BOD 除去率が低く，これらが上記の差異の要因として示唆された。途上国の腐敗槽からの GHG 排出量推計では，こうした途上国での実態勘案が重要であることが示された。

以上のように本論文は，世界で初めての開発途上国における腐敗槽からの GHG 排出量等を実測して GHG 排出特性を示し，腐敗槽管理状況による排出率への影響を明らかにするとともに，排出量推計および腐敗槽管理の改善への示唆を与えることで，今後の途上国環境衛生改善に大きく貢献し，学術上，実務上寄与するところが多い。よって，本論文は博士（工学）の学位論文として価値あるものと認める。また，令和 2 年 8 月 24 日，論文内容とそれに関連した事項について試問を行い，申請者が博士後期課程学位取得基準を満たしていることを確認し，合格と認めた。

要旨公開可能日：　　年　　月　　日以降