Evaluation of Household Solid Waste Treatment Alternatives toward GHG Mitigation in Vietnam
ベトナムにおける温室効果ガス削減に向けた家庭系廃棄物の処理手法に関する評価

August 2018

LE HOANG SON

Graduate School of Environmental and Life Science
OKAYAMA UNIVERSITY

ABSTRACT

Rapid urbanization, economic growth, and changing life style have led to a drastic increase in the amount and the variety of municipal solid waste (MSW) in Vietnam. . Household solid waste (HSW) has become a major challenge for waste management authorities in urban areas of developing countries. The total amount of collected municipal solid waste in Vietnam was estimated to be 15.6 million tons as of 2015, of which 71.1% (11.1 million tons) was directly landfilled, and the total solid waste generated in 2020 and 2025 are expected to be approximately 67.6 million tons, and 91 million tons, respectively. To establish sustainable society, the central government and local government in Vietnam have established various kinds of laws and regulations. According to the national strategy to manage waste and discarded material (Decree no. 38/2015/NĐ-CP) issued by Vietnamese central government in 2015, the daily-life solid waste must be sorted and collected separately by three categories: biodegradable organic, reusable and recycled, and other.

To develop a rational strategy of waste management toward sustainable society, it is important to understand the amount of waste generation, the waste composition, the waste stream, and the contribution by each source. However, the reliable data on MSW in Vietnam are limited and not comparable; because of the main categories of waste classification are variety between municipal, region levels and national levels. Some past literatures examined the waste generation from HSW by detailed categories and estimated the total waste amount; but the waste generation rates (WGRs) was described by mean and standard deviation, without mention about the distribution and reliability of data. In addition, waste treatment technologies such as incineration, composting, bio-gasification have been not applied successfully in Vietnam due to lack of technical attention, lack of feasibility study for local waste such as waste generation, characterization, waste practice at source. Implementation of waste separation at source is also a cause of ineffective treatment application. Therefore, the study on HSW characteristic with the influencing factors and the efficiency of waste treatment alternatives is meaningful for waste management authorities. The limited reliable data on HSW generation and characteristics has become a burden for decision makers in waste management. It is important to understand the amount of waste generated, the waste composition, and the waste treatment alternatives as the first step in developing an effective HSW strategy that includes 3R promotion (reduce, reuse, and recycle).

This dissertation focuses on (1) waste generation and characteristic from household in urban areas in Danang, the third largest city in Vietnam, (2) Greenhouse gas (GHG)

emissions and reduction of heat recovery technology in Japan, and (3) GHG emission and reduction of recycling technologies. The author presents the following issues: (i) HSW generation and composition in Danang (physical composition, basis composition, recovery potential by detailed composition, and energy content); (ii) Influence factors for HSW generation(iii) Estimation of total household solid waste generation and recycling potential; (iv) GHG emission and reduction heat recovery technology in Japan and modeling; (v) Scenario analyses on GHG mitigation alternatives by heat recovery and recycling; (vi) Interval estimation and uncertainty analysis of parameters.

First, to understand the characteristics of HSW, the author conducted surveys of 150 households in Danang, Vietnam in December 2016. The target samples were selected by consideration of socioeconomic factors, such as urbanization level, population density, family size and income level. Daily discharged waste from each target was collected and classified into ten physical categories and 66 sub-categories. The compositions of ten physical components were analyzed to identify the moisture content, volatile solid content, and ash content. Meanwhile, the heating values of these components were also examined at laboratory to estimate the energy content in HSW. The recycling and composting potentials were aggregated based on the detail composition by 66 sub-categories. The average HSW generation rate was 231.5 g/cap/day. For ten physical waste compositions, the food waste accounted the highest proportion (68.23%), followed by plastic (10.95%) and paper (9.40%). The composting potential and recycling potential accounted for 72.73% and 13.77%, respectively. The average moisture content, volatile solid content, and ash content were 45.16%, 42.75%, and 12.08%, respectively. The energy content of household solid waste was calculated to be 6,801 kJ/kg, which was acceptable for incineration treatment processes.

Second, the author analyzed the relations between HSW generation rates and influence factors by physical categories and sub-categories by non-parametric methods. The positive correlations between waste generation rates (WGRs) and urbanization level, population density, income level were indicated by rank correlation analysis. On the other hand, the WGRs were negatively correlated with family size. Factors significantly affecting WGRs were also discussed by Kruskal-Wallis H test. Based on the WGRs and population in Danang, the total HSW amount in urban areas was estimated to be 210 tons/day, and the 95% confidence interval was estimated to be 187 – 234 tons/day by non-parametric bootstrap method. Compostable waste, Recyclable waste and Non-recyclable waste were 155 tons/day (131 – 177 tons/day, 95%CI), 29 tons/day (25 – 33 tons/day, 95%CI), and 26 tons/day (21 – 31 tons/day, 95%CI), respectively. The expected revenue from recyclable contained in HSW

was estimated to be 79 million VND/day (71 – 89 million VND/day, 95%CI), which was equivalent to 716 labors to be employed by the minimum wage standard. The sensitivity analysis shows that kitchen waste generation rate had highest contribution to the variance of total estimation of waste. Further study should focus on kitchen waste to improve the reliability of estimation.

Third, in order to understand the Waste-to-energy technology, the author aims to estimate the detailed composition of GHG emissions and reductions from the waste incineration facility and their influence factors using two Japanese databases on the operation of incinerators from Japan Ministry of the Environment (1,243 facilities) and Japan Waste Research Foundation (814 facilities). The databases cover detailed data on MSW amount and characteristics, specifications of the facility, annual utility consumption, and annual energy/material recovery. The authors analyze the correlations among them and develop predictive models for the detailed components of GHG emissions and reductions. Japan Ministry of the Environment intended to group small municipalities for replacing small-scale incinerators to large-scale waste-to-energy (WtE) facilities with a higher energy recovery efficiency. Based on the abovementioned data and models, the authors estimate the expected effects of the block formation and major technological alternatives for GHG mitigation by the national level. The current net GHG emission rate from 1,243 operating waste incineration plants in Japan in 2009 was estimated to be 653 kgCO_2e/t. By the block formation based on the master plans collected from 47 prefectures, 1,007 plants were assumed to be closed; 236 kept operating; and 286 facilities would be newly built. The net GHG emission rate could be cut off to 454 kgCO_2e/t by applying the block formation and technological alternatives with a higher energy recovery efficiency (stalker furnace with power generation by extraction condensing turbine providing steam higher than 3MPa and 300 °C). Ash melting caused a larger GHG emission by the increase in energy consumption. The GHG reduction by slag recycling was limited. Furthermore, the net GHG emission rate could be reduced to 242 kgCO2e/t by applying the Best Available Technique (BAT) for combined heat and power plants. When compared with the current status, BAT can reduce 185 kgCO2e/t by improving the power generation efficiency and 187 kgCO2e/t by expanding heat utilization. At present, heat utilization is very limited in Japan, but heat utilization should be more focused and promoted for GHG mitigation decisions.

Finally, the contributions of household solid waste treatment alternatives to mitigate greenhouse gas emissions were investigated by various possible scenarios. The waste treatment alternatives included: (i) landfill without landfill gas recovery; (ii) landfill with

landfill gas recovery and power generation; (iii) Composting; (iv) Anaerobic digestion; (v) Incineration; (vi) Material recycling; (vii) Combination of different treatments. For business as usual scenario, the current GHG emission rate was estimated to be 1,242 $kgCO_2e$ per ton of waste (990 – 1,370 $kgCO_2e/t$, 95%CI). The emission could be reduced to 426 $kgCO_2e/t$ (410 – 510 $kgCO_2e/t$, 95%CI) by landfill recovery gas for power generation scenario. By assuming 70% of recyclables and food waste were separately collected for recycling and animal feeding, the GHG emission was estimated to be 274 $kgCO_2e/t$ (120 – 650 $kgCO_2e/t$, 95%CI). Meanwhile, the GHG emission rates of composting and anaerobic digestion scenario were 408 $kgCO_2e/t$ (300 – 800 $kgCO_2e/t$, 95%CI) and 223 $kgCO_2e/t$ (200 – 760 $kgCO_2e/t$, 95%CI), respectively. The incineration is the best waste treatment alternative with 96 $kgCO_2e/t$ (80 – 150 $kgCO_2e/t$, 95%CI). In addition, the results showed that the integrated HSW management considering material recycling, food waste separation for anaerobic digestion and waste-to-energy was the most favorable alternative for GHG mitigation, with GHG emission rate was estimated to be -5 $kgCO_2e/t$ (-50 – 90 $kgCO_2e/t$, 95%CI).

The results of this dissertation suggested the methodology for household solid waste survey, the analysis and evaluation for household solid waste characteristics (waste generation rates based on types, purposes and functions, recovery material and energy contents). For waste to energy incineration, the heat utilization should be improved to enhance the efficiency of facility, as well as cut off the GHG emission. The findings in this study are expected to be useful for decision-makers, planners of 3R programs, authorities of waste management to improve the household solid waste management to achieve the sustainable development.

TABLE OF CONTENT