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学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称　博士（工学）　氏名　Ham Geun-Yong

学 位 論 文 題 名

Study on Bio-drying MBT by modelling of moisture removal and evaluation as MSW management system for energy recovery
(水分除去モデリング及びエネルギー回収効率評価によるバイオドライング MBT システムの研究)

Historically, most EU countries have disposed of municipal solid waste (MSW) into landfill since it is the simplest and cheapest method. However, disposal of MSW without pretreatment increases maintenance costs and potential risks to human health and the environment due to the long-term release of leachate and landfill gas. To address this, the EU enacted a Landfill Directive (99/31/EC), ordering Member States to phase out the organic content of waste to be landfilled and as a countermeasure, mechanical biological treatment (MBT) system have emerged. A typical MBT system begins with the mechanical separation of mixed MSW, which separates the organic, combustible fractions (solid fuel) and extracts recyclable materials like metals, glass, etc. outside the system. Remaining separated materials are then subjected to biological and thermal treatments, and the stabilized residues from the processes are landfilled. Biogas can be recovered by treating the organic fraction with anaerobic digestion (AD), but the main energy recovered from this system is a solid fuel. For energy recovery, bio-drying MBT enables to obtain a higher fuel material recovery rate by using metabolic heat to reduce moisture without additional fuel input. As entering low-carbon emission society and growing emphasis on energy recovery from solid waste, attention to the bio-drying MBT system as an alternative to the conventional system is growing as well. In this context, this study aims to study the bio-drying MBT by modelling of moisture removal and evaluation of the system as MSW management system.

Chapter 1 describes the background, objective, methodology, and the organization of this thesis.

Chapter 2 conducted a lab-scale experiment to investigate the simultaneous effects of airflow rate and organic contents were examined in this study. A 25 L acrylic column reactor was filled with simulated waste, commercial dog food and wood pellet mixture. Temperature and humidity of the air inlet and outlet were continuously monitored, and CO_2 concentrations in outlet air were periodically analyzed to observe aerobic biodegradation as well as metabolic water generation. Based on the data, the different water removal contributions by airflow and biodegradation were compared and finally, evaluation of the inter-dependence of parameters and feedback effect in the bio-drying process was carried out. While the biodegradation of organics induced a significant amount of water removal due to increased temperature, high organic content has a negative effect on water removal by generating metabolic water. Water removal by air replacement is greater than that associated with temperature increases caused by biodegradation. However, excessive airflow rate can terminate biodegradation by drastically lowered moisture content even though organics remained.

Chapter 3 investigated a full-scale bio-drying MBT system. In this system, shredded MSW is mixed with recirculated wood and fine residue, and biodried outputs are mechanically separated to recover solid fuel materials. Waste samples were collected from five locations and material flow by the waste component was estimated. During the separation of biodried outputs, 62% of plastics and 54% of paper were recovered as RPF (refuse-derived paper and plastics densified fuel) material. Wood was decreased by a reduction in particle size and 90% of biodried wood is returned to the next reactor. Changes of mixed fine caused by fine wood particle and the loss of organic matters and 60% of it were returned. Operation variables are aeration rate and mixing rate of fresh air according to the operational phase. Daily water removal during 17-days of bio-drying was simulated through the model by using the operation data. Among the six operation phases, the longest stabilization phase was expected to major water removal period, but half of the water removal occurred at initial two stages and phase of cooling and drying for only 6 days in total due to the high waste temperature for sanitization (in initial stages) and high airflow rate for cooling, respectively. Decreasing waste temperature at the stabilization phase resulted in low water evaporation.

Chapter 4 evaluated four systems for recovering energy from municipal solid waste in terms of life cycle energy and CO_2 emissions. Two of these were a type of mechanical biological treatment, including a combined system of AD and incineration after mechanical separation, and bio-drying followed by mechanical separation for recovering solid recovered fuel (SRF). The other two systems were incineration with high rate power generation and refuse-derived fuel (RDF) recovery by a mechanical drying process. We compared the systems based on the data collected from Asahikawa City. Process flow and parameters for operation and utility consumption in the four systems were adopted from the literature. The bio-drying system showed the highest energy efficiency. It reduced the fuel material's energy content, but improved energy efficiency due to lower electricity and fuel consumption. The RDF production system recovered the highest energy by huge evaporation, but considerable fuel consumption resulted in the lowest energy efficiency. The combined system showed a higher energy recovery than incineration, but AD was less energy efficient due to electricity consumption. Lifecycle CO_2 emissions are closely related to energy balance. Among the various parameters, power generation efficiency and electricity consumption were highly sensitive to energy balance. The combined system showed low energy efficiency under a controlled set of parameters, but the efficiency was simultaneously compatible with the bio-drying MBT system under ideal conditions of parameters.

Chapter 5 draws an overall suggestion about the bio-drying MBT system. The system seems advantageous to the treatment of mixed MSW by converting it into fuel after moisture reduction with less energy consumption, and this can be alternative systems in developing countries where facing the problems in high moist MSW treatment. Further, it can be alternative waste management in the medium-or small-sized cities where normally small-scale incinerator has dealt with the MSW treatment without energy recovery.