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Analysis of greenhouse gas emission reductions by collaboratively updating equipment in sewage treatment and municipal solid waste incineration plants

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ABSTRACT

An analysis of energy balance and greenhouse gas emissions was conducted to compare alternative systems for the disposal and recycling of sewage sludge and food waste. Although the conversion of dewatered sludge to solid fuel has been a recent research focus, it is difficult to ensure that the solid fuel is needed and can be delivered to plants that can use it, such as coal-fired power plants. We therefore evaluated the effects of introducing various collaborative systems when updating existing sewage treatment plants and municipal solid waste incineration plants in Japan. Several cases were proposed and compared with a base case. In case Y, low-temperature carbonization equipment is introduced into a sludge conversion plant and dewatered sludge is converted into solid fuel. In case Z, dewatered sludge is dried to a moisture content of 40% with useable steam heat in a municipal solid waste incineration plant; the dried sludge is then combusted with municipal solid waste. Relative to the base case, greenhouse gas emissions were reduced by 25% in case Y and 26% in case Z. Therefore, a similar level of greenhouse gas reduction can be achieved by introducing a co-combustion system in a municipal solid waste incineration plant, even if there is no production of solid fuel to use in collaboration with coal-fired power plants.

1. Introduction

The use and application of renewable energy has become an exceedingly important policy matter in Japan since the Great East Japan Earthquake of 11 March 2011, which destroyed the Fukushima Daiichi Nuclear Power Plant, particularly because of the reductions in current and predicted future power production from nuclear power facilities. The use and application of biomass formed from municipal solid waste (MSW) and sewage sludge as a potential energy source are promising. A stable supply of waste biomass is produced from domestic activities, and it is a source of renewable energy in areas where energy demands and supply resources are concentrated near each other. Ideally, the environmental infrastructure formed by sewage treatment plants (STPs) and MSW incinerating plants (MSW-IPs), where this waste biomass is aggregated, can be converted into energy production centers.

Fig. 1 shows technological options for sludge disposal and utilization in Japan. Sewage sludge has three components: water, organic matter, and ash. Organic matter and ash are considered to be dry materials. The sludge recycling rate, defined by the Ministry of Land, Infrastructure, Transport, and Tourism (MOLITT), is an indicator for assessing the recycling rate on a dry solid matter basis, especially ash. The recycling rate in Japan has increased over the past 20 years and was estimated to be 78% in FY2010 (MOLITT, 2016). Although the recycling rate decreased in FY2011 because of low-level radioactive contamination of incinerated ash caused by the Fukushima accident, the rates recovered to 68% in FY2015. Under the Basic Plan for the Promotion of Biomass Utilization, proposed by the cabinet in September 2016, the aim is to bring the recycling rate in Japan up to 85% by FY2025 by encouraging the use of sewage sludge as a biomass resource. In terms of reduction of greenhouse gas (GHG) emissions from sludge disposal, the recycling rate of biomass contained in sewage sludge is viewed as an important indicator. This recycling rate is calculated by dividing the

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Abbreviations

GHG	greenhouse gas
MOE	Ministry of Environment
MOLITT	Ministry of Land, Infrastructure, Transport, and Tourism
MSW	municipal solid waste
MSW-IP	municipal solid waste incinerating plant
SCP	sludge conversion plant
STP	sewage treatment plant

"utilization volume of sludge as biomass energy and fertilizer" by the "amount of generated thickened sludge" on the basis of organic matter content. In FY2015, the recycling rate was 26%: 13% as biogas, 3% as solid fuels, and 10% as fertilizer (MOLITT, 2016). The amount recovered as biogas indicates that energy recovery from organic matter contained in sewage sludge is mainly accomplished by using digestion tanks with thickened sludge. Other energy recovery options, however, exist for dewatered sludge (shown in Fig. 1).

The two main technological systems for energy recovery from sludge in Japan are conversion to solid fuel and sludge-specific incineration with power generation, although they have yet to be introduced in Japan on a large scale. To introduce a solid fuel conversion technology, a sewage company has to establish a relationship with an industrial sector that consumes solid fuel on a massive scale, such as coal-fired power plants. Therefore, a constraint for introducing a conversion technology to solid fuel is whether the sewage company can find a consumer for its solid fuel to at least partially replace its use of coal. To increase the acceptability of solid fuel and promote its use, Japanese Industrial Standards of solid fuel derived from sludge were established by MOLITT in September 2014. Through following the standards, the improved quality of solid fuel (e.g., lower heating value, water content) should be guaranteed, which in turn will improve the market value of solid fuel.

On the other hand, sludge-specific incineration with power generation can be introduced without a partner in the industrial sector using coal. The sewage sludge treatment system in Japan is divided into two types: with and without digestion at the stage of intermediate treatment of thickened sludge. In a system without digestion, the organic matter content in solid material is about 80% (MOLITT and JSW Association, 2004). To implement sludge-specific incineration with an energy recovery system (i.e., power generation), a sludge treatment system without digestion is necessary. When a digestion system is used, the organic content is relatively low because of degradation in digestion tanks, and sludge-specific incineration with power generation is not an option.

Because of the limitations of the two technical systems for energy recovery from sludge, in this research, we examined an alternative approach for energy recovery, namely the co-combustion of dewatered sludge with MSW in MSW-IPs. In Japan, STPs fall under the jurisdiction of MOLITT and MSW-IPs under that of the Ministry of Environment (MOE). Due to the different jurisdictions, policies for updating technology collaboratively have not yet been implemented on a broad scale. Several sewage works in Japan have started to use co-digestion of kitchen waste with thickened sludge in STPs, however, and some collaborative measures between STPs and MSW-IPs have been implemented.

The incineration process is one of the best known waste treatment processes for reducing volume of disposed sewage sludge significantly, and it is an important technology for densely populated regions where people have to deal with problem of high quantities of sludge generation and little available land (Cieślik et al., 2015). Improvement of the sludge-specific incineration without energy recovery is also a key issue for several other countries that use combustion of dewatered sludge, including Germany, Austria, Belgium, the Netherlands, Slovenia, and Greece (Alexandros and Athanasios, 2012). For these countries, updating systems to introduce co-incineration in coal-fired plants, cement kilns plants, or MSW incinerators is also an important issue.

There have been several life cycle assessment case studies of collaborative plans between sewage works and other sectors.

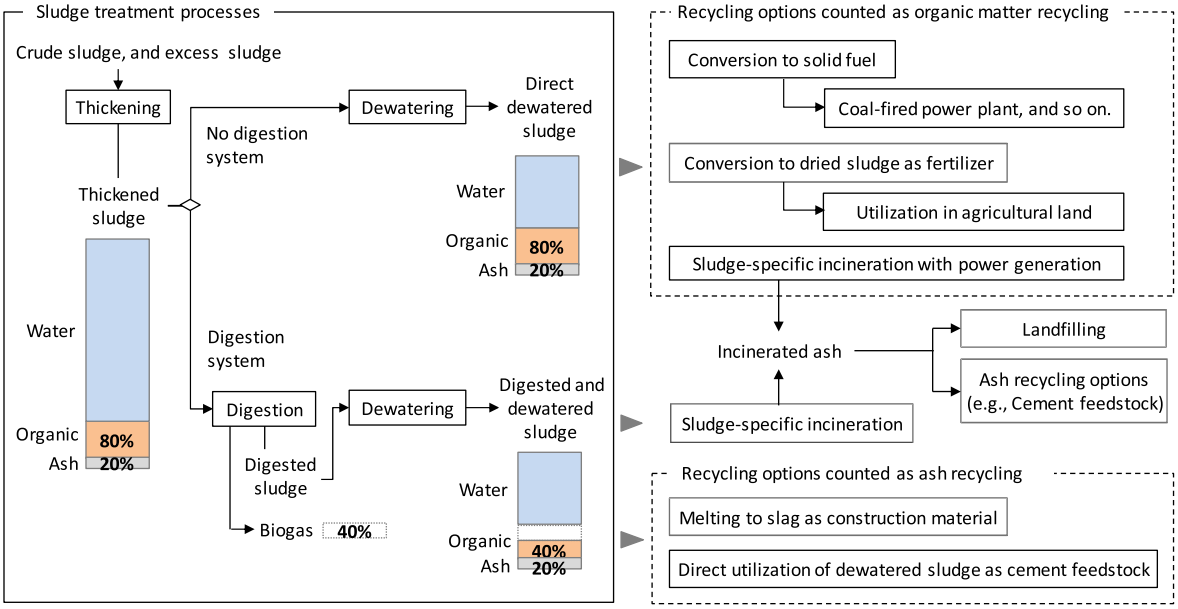

Fig. 1. Technological options for sludge disposal and utilization. The organic matter content of solid material in thickened sludge is set at 80%, and the half of organic matter in the thickened sludge is set to be degraded in a digestion tank.