Strategy for Introducing Sewage Sludge Energy Utilization Systems at Sewage Treatment Plants in Major Cities in Japan: Comparative Assessment

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INTRODUCTION

The energy conversion rate of sewage sludge is defined in the Third Social Capital Development Plan in Japan, and the sewage sludge recycling strategy is shifting to a phase focusing on energy use especially in major cities' sewage treatment plants (STPs). At present, the treatment of dewatered sludge depends on incineration (high-temperature incineration at 850 °C) without any energy recovery equipment, and it is necessary to convert it into energy conversion technologies. Therefore, in this study, we developed a heat balance analysis model for designing and evaluating several sewage sludge energy utilization systems. The targeted energy conversion technologies are advanced incineration systems and solid fuel conversion systems. The former includes three technologies: incineration with power generation equipment from low-pressure steam (ST & BC: screw turbine, and binary cycle power generation), incineration with power generation equipment from high-temperature steam (CT: condensing turbine), and incineration with ST and indirect heat exchange dryer (DRY). The latter includes dry granulation (DSF) and low-temperature carbonization (CSF). The purpose of this study is to evaluate the effects of introducing advanced incineration systems and solid fuel conversion systems focused on connection with digestion and biogas use. The system evaluation indicators were energy balance, greenhouse gas emissions, and cost. This paper reports only the result of energy balance.

MATERIALS AND METHODS

The target sewage sludge energy utilization system was set up based on the presence or absence of a digestion tank: With digestion or without digestion. OI means old-type incineration without energy recovery, and the three types of advanced incineration system (AI) are targeted for: AI-ST&BC, AI-CT, and AI-ST&DRY. The cases introducing solid fuel conversion system stand for DSF and CSF, respectively. Although biogas can be recovered by decomposing a part of organic matter in sludge under the condition that a STP has a digestion tank, the organic matter content in solid matter of dewatered sludge decreases, which causes a decrease in efficiency in the dewatered sludge conversion processes. In this study, we focused on how the presence or absence of digestion affects each technology when considering the energy conversion of dewatered sludge.

The function unit was set to a treatment amount of 30 t-DS/d of concentrated sludge. In the case AI-ST&BC without digestion and AI-CT without digestion, high-efficiency dewatering equipment can be adapted: the effect of dewatering of concentrated (non-digested) sludge is improved by using both organic coagulant and inorganic one. Water content of dewatered sludge, adapted to high-efficiency dewatering equipment, is 70%, and input of incinerator becomes 100 t-wet/d. Condensing turbine (CT) can be introduced on the condition that the input of dewatered sludge is more than 100 t-wet/d, and ST&BC is adopted when it does not reach 100 t-

wet/d. 100 t-wet/d is a turning point, and both power generation methods were targeted. In the case that a STP has a digestion, AI-ST&DRY was set to be planned because digested and dewatered sludge cannot be incinerated at 850 °C. OI-GE stands for old-type incineration and gas engine (GE), biogas is input into a GE.

Regarding solid fuel conversion systems, digestion gas can be used as the heat source for drying when a STP has a digestion tank, and the heat-exchanged cooling water (exhaust heat recovered as hot water) can be used as energy for heating and retaining of digestion tank. In this study, biogas was set to be used for drying in case DSF and CSF with digestion.

RESULTS AND DISCUSSION

Figure 1 shows the estimated results of the energy balance.

Looking at advanced incineration systems, AI-CT without digestion showed the best energy balance (-56.9 GJ/d). AI-CT without digestion was superior to AI-ST&DRY with digestion (-5.4 GJ/d), however, AI-ST&BC without digestion (37.9 GJ/d) was inferior to AI-ST&DRY with digestion. This means that advanced incineration system without digestion is superior when the disposal amount of dewatered sludge is more than 100 t-wet/d (70% of water content) and CT can be introduced. On the other hand, it was shown that advanced incineration system with digestion was superior in the case of a scale where CT power generation cannot be introduced and ST & BC was adapted.

Looking at the cases of solid fuel conversion system, the estimate value of DSF with digestion was -34.6 GJ/d and superior to DSF without digestion (54.6 GJ/d). Similarly, CSF with digestion was estimated to 3.3 GJ/d and superior to CSF without digestion (104.4 GJ/d). This means that reduction amount of city gas consumption by using biogas is larger than the substitute amount of coal. Solid fuel conversion systems (both systems) with digestion were superior in terms of energy balance.

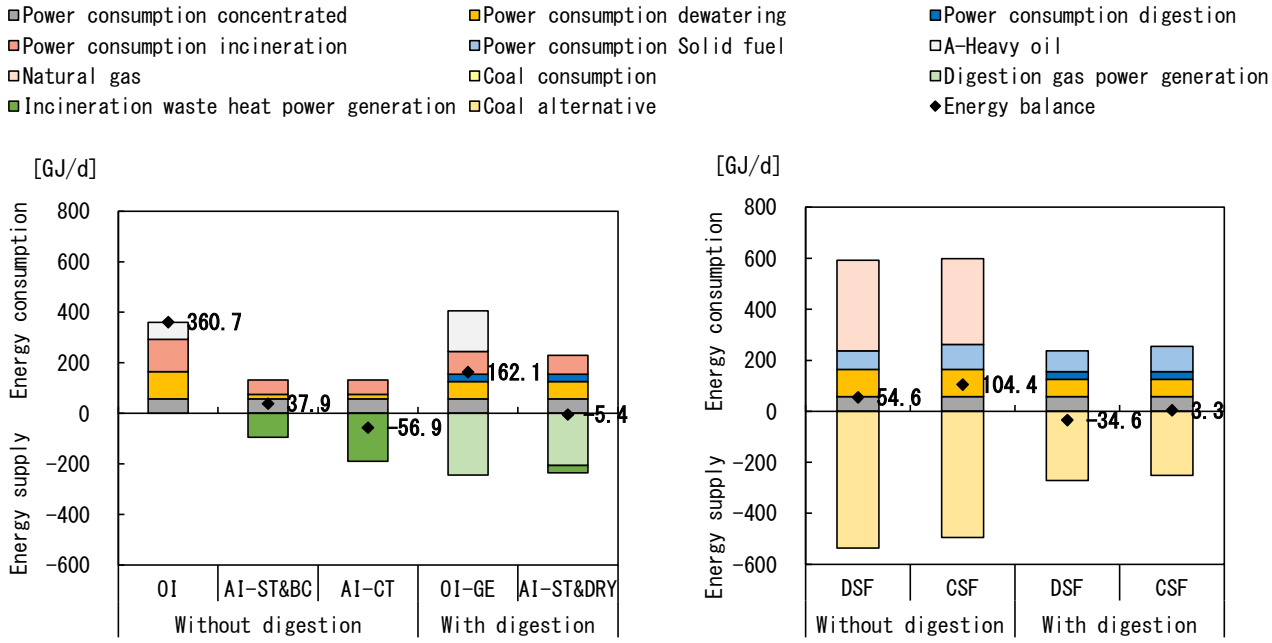

Figure 1 Estimated results of the energy balance (primary energy)

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