香港特別行政區政府渠務署
Drainage Services Department
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# *RESEARCH & DEVELOPMENT REPORT NO. RD 2090*

# *Study on Anaerobic Digestion of CEPT Sludge*

*(Final Report)*

**Research and Development Section**
**Electrical & Mechanical Projects Division**
**Drainage Services Department**

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# Final Report

## Study on Anaerobic Digestion of CEPT Sludge and Metagenomic Analysis of Digester Sludge

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## Executive Summary

Anaerobic digestion (AD) is employed by Drainage Services Department to reduce sludge amount to be disposed of at landfills, as well as to eliminate pathogens and produce biogas as a source of renewable energy. Chemically Enhanced Primary Treatment (CEPT) plants treat about 75% of sewage in Hong Kong. Most of Hong Kong's CEPT sludge is saline in nature with high chloride and sulfate contents because of seawater toilet flushing. Through laboratory tests, this study investigated the treatability of CEPT sludge by AD. The key variables in the tests included the nature of feed sludge (e.g. CEPT sludge versus combined sludge), organic loading, hydraulic retention time (HRT), ferric chloride dosing, temperature, and sewage salinity.

In this study, saline and non-saline sewage sludge samples were collected from the Stonecutters Island (SCI) Sewage Treatment Works (STW), Siu Ho Wan (SHW) STW, and Sham Tseng (SmT) STW, respectively. Digestion of CEPT sludge from SCI STW was examined in great details. Results of the study clearly demonstrated good volatile solids reduction (VSR, 48-69%; 58% in average) and biogas production (0.44-1.47 $m^3$/kg-VS destroyed; 0.92 in average) under the conditions investigated. AD could achieve at least the same benefits of digestion of combined sewage sludge as in secondary treatment works.

The effect of *Ferric Chloride* dosing was evaluated using saline CEPT sludge from SCI STW. The result showed that *Ferric Chloride* addition had a positive impact on the increase of biogas production and VSR. Moreover, it significantly reduced the hydrogen sulfide content (mainly due to sulfate reduction from the sulfate in seawater) in biogas and facilitated cleaning of biogas for power generation. With ferric dosing, digestion performance in terms of VSR and biogas production of *saline* CEPT sludge was found to be comparable with that of non-saline CEPT sludge.

The effect of varied *organic loading rates* (OLRs) was investigated using CEPT sludge from SCI STW and SmT STW. At an HRT of 16 days, biogas production and solid reduction of SCI STW sludge at higher OLR (1.3-2.0 kg VM/$m^3$/d was better than that at lower OLR (0.9-1.1 kg VM/$m^3$/d). Percentage VSR (VSR%) of SmT STW sludge at higher OLR (1.9 kg VM/$m^3$/d) was similar to that at lower OLR (1.4 kg VM/$m^3$/d).

The effect of HRT (7, 9, 12 and 16 days) was tested using CEPT sludge from SCI STW. All HRTs gave reasonably good VSR% and the highest biogas production was obtained at 9 days HRT, and followed by 12 days. However, biogas production (both volume and yield) was the lowest at an HRT of 7 days probably due to the increased OLR (2.5-3.8 kg VM/$m^3$/d). When the experiment was repeated using two CEPT sludge sources (SCI STW and SHW STW) and at identical and moderate OLR (for 7 and 12 days HRT), biogas production (L/d) at 7 days HRT was comparable to that of 12 days. This suggests that both HRT and OLR are important to AD of CEPT sludge. At moderate OLR (1.8-2.4 kg VM/$m^3$/d), the HRT as short as 9 to 12 days performed well.

Temperature also affected digestion performance of SCI CEPT sludge. 35$^oC$ provided significantly higher (P-values <0.05) biogas production, specific methane production and methane content in biogas than 30$^oC$. $NaHCO_3$ dosing helped to control pH within favorable ranges for methane production. Future studies are required to evaluate whether the digesters work well without pH adjustment or $NaHCO_3$ supply.

Finally, advanced metagenomic analysis of AD sludge samples shed light on the microbial community structure in three full-scale combined sludge digesters and six laboratory-scale CEPT sludge anaerobic digesters. Principal component analysis revealed that the anaerobic digesters harbored diverse bacterial and archaea populations shaped by sludge salinity (saline vs. non-saline), feed sludge (primary vs. combined), or ferric chloride dosing.

Overall, the feasibility of AD of saline CEPT sludge has been clearly demonstrated in this study. Digestion of CEPT sludge could bring the same benefits as digestion of combined sewage sludge in secondary treatment works on sludge VSR and biogas production as renewable energy. Taken together, AD is a promising technique for volume reduction and bioenergy recovery from CEPT sludge, offering great environmental and economic benefits.

**Key words:** Chemically Enhanced Primary Treatment; Anaerobic Digestion; Biogas Production; Solid Reduction; Metagenomic Analysis; Hong Kong