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FACTSHEET

COMBINED HEAT AND POWER: IDEAL DESIGN AND STRUCTURE OF WASTEWATER TREATMENT PLANTS

There is a growing interest among municipal entities operating wastewater treatment plants (WWTPs) to improve the energy and operational efficiency of these facilities. This is prompted by the need for municipalities to cut costs and contribute to global and national efforts to reduce greenhouse gas (GHG) emissions.

This factsheet gives examples of how these barriers could be overcome to ensure that more anaerobic waste treatment and combined heat and power (CHP) projects could be developed at municipal WWTPs.

The design and structure of future anaerobic waste treatment and CHP projects will therefore have to be carefully considered to ensure that these projects achieve financial viability or create a cost-effective solution for sludge treatment at municipal WWTPs, as well as alternative sources of municipal or private sector waste streams.

The design and structure portion of this fact sheet focuses on the development of projects for the treatment of wastewater sludge, but it also applies to the treatment of other waste streams.

The feasibility team responsible for the CHP project development work of the City of Tshwane's Zeekoegat WWTP confirmed that for a CHP project to be financially viable it should first be structured so that all critical sludge train processes are part of the process, so as to maximise power generation – the primary source of revenue for CHP projects.

An example of the critical sludge train processes that should be included is shown below. The example is based on the process design of the Zeekoegat WWTP of the City of Tshwane.

This is part two of a four-part factsheet series based on lessons learned from a feasibility study and project development process for a combined heat and power project at the City of Tshwane's Zeekoegat Wastewater Treatment Plant and existing projects at the City of Johannesburg and eThekwini Municipality.

The following factsheets and additional resources in this series can be found on Climatelinks.org.

- Overview
- Project Development
- Project Procurement
- Case Study
- CHP GHG Calculator

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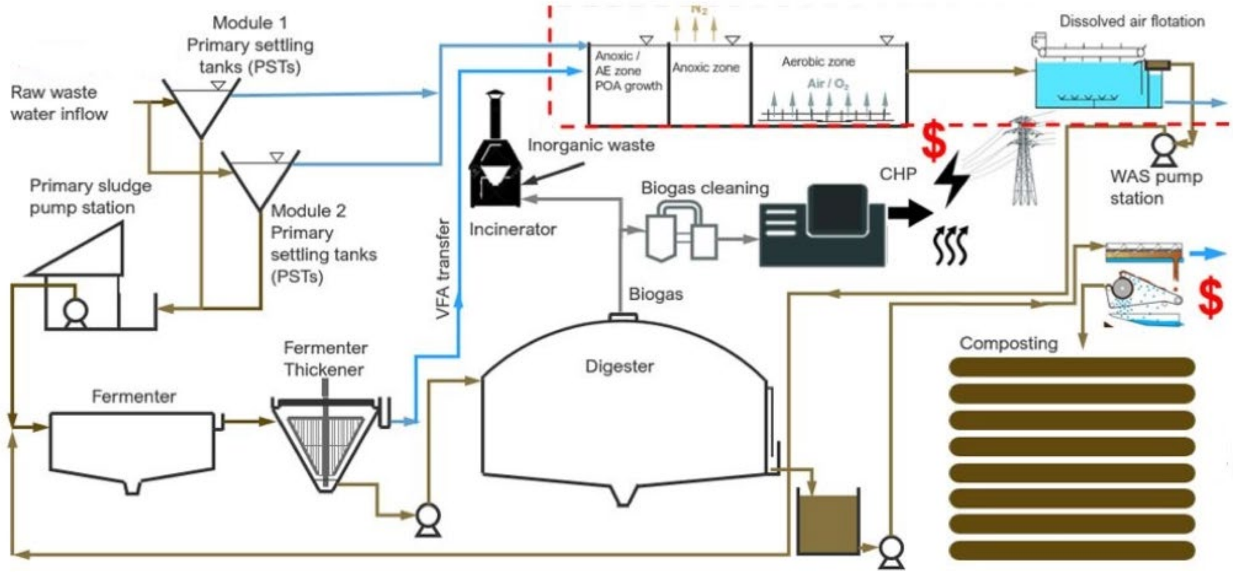

An example of the critical sludge train processes.

Second, the project's financial viability could further be improved by including other revenue streams. To convert dewatered sludge to an industrial organic fertiliser is a promising opportunity that the Zeekoegat team investigated, as the drive to move away from chemical fertiliser in the agricultural sector intensifies. Another opportunity is selling Renewable Energy Certificates[1] (RECs) into the voluntary South African market, as happens in the United States.

In the next section of this document, we motivate that certain critical elements of the sludge train should be under the control of the anaerobic digester (AD) and CHP operator.

CRITICAL ELEMENTS TO INCLUDE UNDER THE OPERATIONAL CONTROL OF THE ANAEROBIC DIGESTER AND COMBINED HEAT AND POWER (AD/CHP) OPERATION

CONTROL OVER THE FEEDING OF THE DIGESTER

The **feeding frequency**, the **composition of the feedstock** and the **total solids content of the feedstock** have a large impact on both process performance and the microbial communities in the

[1] A renewable energy certificate, or REC (pronounced: rěk), is a market-based instrument that represents the property rights to the environmental, social and other non-power attributes of renewable electricity generation. RECs are issued when one megawatt-hour (MWh) of electricity is generated and delivered to the electricity grid from a renewable energy resource. zaRECs (Pty) Ltd. administers the South African voluntary Renewable Energy Certificate (REC) market along the lines of the European Energy Certificate System (EECS) specifications on behalf of members of the voluntary Renewable Energy Certificate South Africa market participant's association (RECSA).

anaerobic digester. The operation of the primary settling tanks[2] (PSTs) impacts directly on the feeding frequency and the composition of the feedstock, and as a result the PSTs should be operated in such a way to ensure regular de-sludging – four to six times a day – so that the primary sludge extracted is of a dry matter content of more than 3 percent, preferably above 3.5 percent, and consistently so.

Research has shown that there is a greater fluctuation in digester variables such as pH and acetate concentration when feeding is done at **lower feeding frequencies**. An estimated two-thirds of the methane (CH_4) is generated from the conversion of acetate. These acetate-utilising methanogens (i.e., microorganisms that produce methane as a metabolic by-product in anaerobic conditions) have a fundamental role in digester capacity and stability, as they are highly sensitive to digester operating conditions.

Frequent feeding, as well as a constant digester loading rate, ensure that volatile fatty acids[3] (VFAs) and acetate production rates do not exceed the capacity of the acetate-utilizing methanogens and keep the anaerobic system in balance, resulting in maximised methane production.

Therefore, to maximise methane yield, full operational control should be ensured over the feeding frequency, the composition of the feedstock and the digester loading.

TOTAL SOLIDS CONTENT OF THE FEEDSTOCK

Feeding the digester with variable and low dry matter-content primary sludge will increase the heat requirement to maintain the digester temperature – which is a critical control parameter to maintain stable digester operation and to maximise biogas generation.

If sludge is introduced at a lower total solids content, more heat input is required to ensure constant digester temperature and could result in not enough heat being available to maintain the digester's operating temperature.

CONSISTENCY OF THE COMPOSITION OF THE FEEDSTOCK

The microbial population must adapt to the composition of the feedstock that it is fed; feedstock changes inhibit the efficiency of the anaerobic process. Gradual feedstock changes can be introduced, but sudden changes will impact negatively on the methane production of the digester. At WWTPs, the feedstock available could be included as primary sludge, fermented primary sludge and/or waste activated sludge (WAS). Care should be taken to use the available buffers to allow for consistent feeding of the digester. For example, PSTs could be used as a buffer to allow a constant seven-day availability of primary sludge or fermented primary sludge. Similarly, secondary clarifiers and a separate fermenter unit, if available, could be used to allow for consistent VFAs and fermented sludge to be made available to the digester.

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[2] The primary settling tanks are designed to reduce the velocity of the wastewater flow for organic solids (called raw sludge) to settle. The raw sludge is then pumped to the sludge digesters (de-sludging) for biological treatment.

[3] Volatile fatty acids (VFA's) such as acetic, formic, and butyric acid are by-products of anaerobic bacterial digestion of organic matter and hence a common constituent of wastewater process streams and sludge.

This will only be possible if these activities are under the control of the AD/CHP operator.

ALL WASTEWATER SLUDGE DIGESTED FOR MAXIMUM BIOGAS GENERATION

To maximise the biogas generated, all available sludge should be made available to the anaerobic digester, and therefore all waste activated sludge and primary sludge should be aerobically treated.

During the Zeekoegat CHP feasibility study, the team had external laboratory testing done to confirm the biological methane potential (BMP) of waste activated sludge and primary sludge.

The BMP test results, based on the 70 mega-litre/day wastewater inflow into the Zeekoegat works, indicated an estimated methane production of 83 Gigajoules (GJ) per day, if only the primary sludge were used for biogas generation, and 115.5 GJ per day of methane if a waste activated sludge/primary sludge mixture was used. This will result in a 40 percent increase in biogas production using mixed sludge, compared to using only primary sludge. It is expected that the methane potential will be higher when operating the **actual** process, as the AD/CHP operator has the option to operate and optimise the fermenter and the digesters in different ways to maximise methane generation, which is not possible in the combined digesters process in the BMP **test** setup.

MIXING THE ANAEROBIC DIGESTER

The pH in the anaerobic digester content drops as a result of the organic acids formed during the hydrolysis process, which can inhibit the formation rate of methane. The drop in pH is buffered to an extent by an increase in alkalinity through the formation of carbon dioxide and regular feeding of large quantities of fresh feedstock into the AD reactor. Both these buffering mechanisms require good digester mixing to be effective.

A combination of the mixing and the feeding operations ensures that the anaerobic reactor is maintained at the correct pH and that feedstock is made available to the microbial population. The mixing needs to be controlled for the methanogens to exist in an environment that is conducive to their growth and to ensure access to acetate and other feedstock streams.

AEROBIC STABILISATION OF THE SLUDGE

Dewatering and thermal stabilisation of anaerobic digestate is required at WWTPs, as specified by the Water Research Commission (WRC) Guidelines for the Utilisation and Disposal of Wastewater Sludge.

If these requirements can be met, the treated sludge could be a source of additional revenue for the AD/CHP project as the treated sludge can be sold as fertiliser products containing sludge. Therefore, it is suggested that the dewatering and thermal stabilisation of sludge should be included in AD/CHP projects to increase the financial viability of such projects.

Dewatering is expensive from a capital equipment and an operating point of view and more innovative methods of dewatering should be introduced to increase the financial viability of this element of the process.