Advanced Sludge Digestion

Why is sludge valuable? Mott MacDonald principal process engineer **David Hume** outlines the evaluation and selection of advanced sludge treatment technologies in the UK.

Sewage sludge is a valuable resource, both for its nutrient value when used in agriculture and land reclamation, but also because of its significant energy generation potential. This energy can be generated through various methods including the following:

Anaerobic digestion (AD) of sludge to produce biosolids and biogas. Biogas, a gas rich in methane, can be burnt to produce heat and power or converted to biomethane for injection into the local gas grid or used as a vehicle fuel. The efficiency of biogas production can also be enhanced using various advanced AD processes.

Sludge incineration to produce heat and power using a steam turbine.

Novel processes such as gasification, pyrolysis and hydrothermal carbonisation, which can produce various energy rich outputs such as 'syn gas' and 'bio-coal'.

Advanced anaerobic digestion (AAD) typically involves the installation of hydrolysis pre-treatment upstream of conventional mesophilic anaerobic digestion. This significantly enhances the benefits of anaerobic digestion.

Some of the key advantages offered by AAD can include:

- Increased digester loading
- Increased volatile solids destruction
- Increased biogas production
- Increased opex savings (and possibly revenue) from power generation (or other biogas energy uses such as grid injection as biomethane)
- Improved sludge dewaterability (in the case of thermal hydrolysis)
- Significant sludge cake volume reduction, and hence sludge disposal costs
- Low odour, pasteurised cake (class A biosolids).

The two main AAD processes used in the UK over the past decade have been thermal hydrolysis (for example, Cambi THP or Veolia's Biothelys process) and biological hydrolysis (for example, the GE Monsal process). There are also newer entrants including Veolia' Exelys and other THP competitors, as well as water companies' in-house developed systems such as Anglian Water's HpH (Heating, Pasteurisation & Hydrolysis) process.

Mott MacDonald has been advising wastewater utilities on processes for extracting energy and other resources from sludge. MM has been part of several frameworks servicing he UK Water Utilities with the development of advanced AD projects using biological and thermal hydrolysis processes. This work has included services from strategy and feasibility studies through to detailed design, construction supervision and operational support.

ANGLIAN WATER BIOSOLIDS PROGRAMME

We have set out below how we helped Anglian Water (AW) to deliver its two successive five-year biosolids investment programmes, 2005-2010 and 2010-2015.

In its first programme (2005-10), the largest AAD programme in the UK at that time, AW constructed AAD plants, with a combined capacity of 100,000 tonnes dry solids per year (tDS/y), at four wastewater treatment plants – serving King's Lynn, Norwich, Milton Keynes and Northampton. Two plants used the Cambi thermal hydrolysis process and the other two the Monsal Enhanced Enzymic Hydrolysis (EEH) – a biological hydrolysis process. This programme helped AW to achieve £3 million annual savings in operating expenditure, a 30 percent increase in sludge treatment capacity compared to its original plan and 40 percent reduction in the volume of treated biosolids. As a result of these projects several of the sites became self-sufficient in renewable energy, meeting the needs of both sewage and sludge treatment and exporting surplus power to the national grid.

In its second programme, (2010-15), AW built on this success, using an in-house developed biological hydrolysis process, HpH, to construct a further four AAD plants. These had a combined capacity of over 60,000tDS/y and serve Colchester, Basildon, Ipswich and Grimsby.

DRIVING SUSTAINABILITY

AW's wastewater treatment plants produce 180,000tDS/y of sewage sludge. Once treated, over ninety percent is recycled to agricultural land as a soil conditioner and source of valuable phosphorus and nitrogen. In the UK, biosolids for use on land is classified (under the UK's 'Safe Sludge Matrix') as either conventional treated or enhanced treated depending on the level of pathogen reduction achieved in treatment (log 2 or log 6, respectively). Enhanced treated can be used more widely than conventionally treated biosolids.

Prior to 2005, AW relied on two sludge treatment processes – conventional AD (conventionally treated product) and lime stabilisation (able to achieve an enhanced treated product), followed by recycling of biosolids to agriculture. In lime stabilisation, sufficient lime is mixed into the sludge cake to raise the pH and achieve the required pathogen destruction.

However, lime treatment increases the total volume of solids to be transported to land and is often odorous – reducing its attractiveness to farmers. AW wanted to reduce its reliance on lime stabilisation and hence reduce its operating costs (particularly transport and lime), as well as its carbon footprint.

In the face of ever tighter health legislation, AW also needed to protect its ability to recycle biosolids on arable farmland by increasing the proportion of enhanced treated biosolids cake. Alternative disposal routes such as incineration are significantly more expensive than agricultural recycling and landfill disposal is considered to be environmentally unsustainable.

INNOVATIVE TECHNOLOGY

In 2005, AW's business plan proposed to achieve an enhanced product using dedicated pasteurisation tanks followed by conventional anaerobic digestion. AW and Mott MacDonald demonstrated that pasteurisation could be successfully delivered. But they proposed an alternative technique delivering better performance and greater technical robustness – a thermal pre-digestion treatment stage providing both pasteurisation and hydrolysis.

Hydrolysis breaks down the cellular content of sludge. There are two variants – biological and thermal. With biological hydrolysis, heat stimulates naturally occurring bacteria that attack cellular material. Thermal hydrolysis 'pressure cooks' sludge at 160°C and eight times atmospheric pressure. Breaking down cellular matter reduces water content and therefore the total volume of sludge. Hydrolysis also makes sludge more amenable to digestion, converting a higher proportion of solids to biogas. Biogas production can be doubled compared with conventional digestion.

GREEN ENERGY

Biogas, with its high methane content, is used to fuel combined heat and power (CHP) engines. These can meet the electricity demands of the entire wastewater treatment plant and provide waste heat which is used to raise the steam needed to heat sludge during hydrolysis and digestion. A major innovation developed by the team was to heat sludge in the biological hydrolysis process by injecting steam, thus avoiding the risk of vivianite formation in heat exchangers.

Generating power and reducing methane emissions – a potent greenhouse gas – from the AD process has made treatment itself carbon neutral and helped offset the carbon emissions associated with importing raw sludge and exporting biosolids to agricultural land.

As a result of the Biosolids Programme, AW now generates more than 90GWh/y of green energy.

Results included:

23% MORE CAPACITY – the efficiency of the treatment process enabled AW to increase total volume of sludge treated from its baseline target of 77,000tDS/y to 100,000tDS/y.

40% REDUCTION – eliminating lime treatment and converting more solids to biogas has reduced the volume of biosolids leaving AW's sludge treatment plants by 40 percent.

40% COST SAVING – measured in terms of cost, the biosolids programme enabled AW to treat sludge for 40 percent less per tonne dry solids compared to the standard industry cost. This equated to a £3 million operational expenditure saving per annum.

King's Lynn Biosolids Treatment Centre (foreground) uses biogas CHP to generate sufficient power for the entire wastewater treatment plant.

DRIVING EFFICIENCY THROUGH THE SUPPLY CHAIN

AW set up a collaborative and integrated team including client, consultant, contractors and principal suppliers. This team developed a capital and operational incentivisation model – a first for the sector.

AW's Special Projects team appointed Mott MacDonald to provide programme management, technical support and environmental services. Contractors Galliford Try/Imtech Joint Venture (GTM) and Black & Veatch were engaged early in the design phase to advise on process selection and buildability. From the outset the contractors were asked to collaborate and share technical and commercial information and expertise with the whole team. This led to the early involvement of the key second tier process subcontractors Cambi and Monsal. AW's operating staff were also integrated into the design process to optimise the layout and equipment for long-term management, maintenance and repair. An innovative commercial model incentivised the entire delivery team to achieve both capital investment and opex efficiencies – a first for the sector. The opex incentivisation model was based on plant performance over two years post-commissioning and both contractors were required to operate the AAD plants for this period, resulting in development of solutions and specification of equipment geared to achieving optimum operational efficiency. Any savings by one party were shared among all members of the team. This led to selection of equipment delivering greatest reliability and whole life savings in preference to low cost options. WNZ