

Anaerobic workout

Could sewage treatment follow the lead of food and drinks manufacturing in reducing energy demands? Yes, says **Ewan McAdam**

FOR the past decade, the food and drinks industry has embraced high-rate anaerobic wastewater treatment as a way of reclaiming energy, in the form of methane, from low-flow wastewaters that are rich in soluble organic carbon. By contrast, major water utilities still mainly use aerated processes in their sewage treatment to reduce organic carbon to carbon dioxide.

The energy required for aerated systems is currently ~55% of the total energy demand of a water treatment plant, which corresponds to ~0.65 kWh/m³ of treated wastewater. Anaerobic reduction of organic carbon proceeds in the absence of air, thus creating a direct energy saving. In addition, organic carbon is reduced to methane as the predominant gaseous end-product, which can be used for electrical generation. The translation of anaerobic technology by water utilities therefore presents a lateral, and significant, commercial opportunity, particularly with respect to lowering net energy demand and overall carbon footprint.

At Cranfield University's Centre for Anaerobic Science, we've made significant progress in understanding the complex transfer of knowledge to low-temperature, low-organic strength feedwaters:

process integration

In contrast to food and drinks wastewaters – which typically have low volumes of liquid, moderate temperatures of 28–32°C and high organics concentrations up to 50,000 mg/l – combined sewers in Europe generate high volume, low-temperature (UK mean 12°C), dilute organic wastewaters with organic concentrations up to 500 mg/l. Based upon these limiting factors it's been a long-held perception that domestic wastewater cannot be treated anaerobically since low organic substrate concentration and temperature will limit the microbial kinetics, leading to bacterial washout, insufficient organic biodegradation and low methane gas production. However, process intensification using high-rate reactor concepts such as upflow anaerobic sludge blanket reactors

(UASBs) or anaerobic membrane bioreactors (anMBRs) have greatly advanced the potential of low temperature anaerobic treatment by separating biomass retention from hydraulic retention times (HRT). The result is an engineered environment that combines a high density of slow-growing bacteria with high organic loading rates.

Further process intensification of the UASB process has also been pioneered at Cranfield, using a concept called "fortification" which facilitates the separation of organic loading rate from HRT. This provides the capacity to increase the biological kinetics in co-operation with an extended reaction time, resulting in increased methane production. Nevertheless, due to the lower kinetic rates at low temperature, it's only by using the physical retention afforded by the membrane in the anMBR that the produced effluent can meet the UK wastewater discharge consent for organic carbon.

The upflow anaerobic sludge blanket (UASB) reactor configuration removes slightly less organic carbon by comparison as the process relies on lamella separation for passive clarification rather than using fine pores like anMBR. This means that UASBs require a further downstream unit process to remove enough organic carbon removal to meet consent. Importantly, process modelling has demonstrated that whilst UASB configurations suffer from reduced treatment performance, integrating an UASB upstream of a conventional activated sludge process (ASP) in a conventional flowsheet under UK conditions can cut energy demand (inclusive of aeration) by around two thirds.

By contrast, whilst anMBR can operate as a single unit process for organic carbon removal, the membrane surface has to be cleaned using gas sparging to limit surface deposition, which requires extra energy. Our research suggests potential for major reductions in parasitic energy demand for the membrane process; however, at present the net energy balance does favour the uptake of UASB technology which will require downstream biological organic carbon

removal.

In reality, it's unlikely that one fixed flowsheet configuration will prevail, due to a complex number of variables surrounding implementation at full scale. Consequently, while this research continues, we are evaluating a number of flowsheets.

downstream organic and nutrient removal

At full scale, both nitrogen and phosphorus may have to be removed from the effluent of the anaerobic processes to meet consent. For classical biological unit processes incorporating aeration (eg ASP), nitrogen and phosphorus loads can be removed in addition to organic carbon in the single unit process. However, using UASB or anMBR avoids aeration, which in turn stops nitrification (the stoichiometric conversion of ammonia to nitrate in the presence of oxygen). Therefore, based on current practice for wastewater treatment, further downstream biological treatment must be used to achieve consent.

One can demonstrate the significance of nitrogen removal on total energy demand using the UASB-ASP flowsheet as an example. Since UASB has removed the principal organic load, the flowsheet shows that aeration to support downstream nitrification within the ASP becomes the predominant parasitic energy demand. A more sustainable route to minimise the internal parasitic energy demand for nitrogen removal is therefore to integrate passive aeration units downstream of the anaerobic process (eg trickling filters). The impact on the net energy balance is significant: switching to passive downstream treatment turns wastewater treatment from an energy user into an energy producer and gives the industry the potential to export electricity to the grid. However, trickling filters can become unstable at lower temperatures which risks failure to comply with discharge consent during the winter.

In addition, we have considered the argument that using biological processes to remove nutrients neglects the potential use of nutrients in secondary applications. We have extensively trialled cationic and novel polymeric anionic exchange resins bound with ferric oxide for the selective extraction of ammonia and phosphorus from anaerobic effluents into low volume, high concentration solutions.

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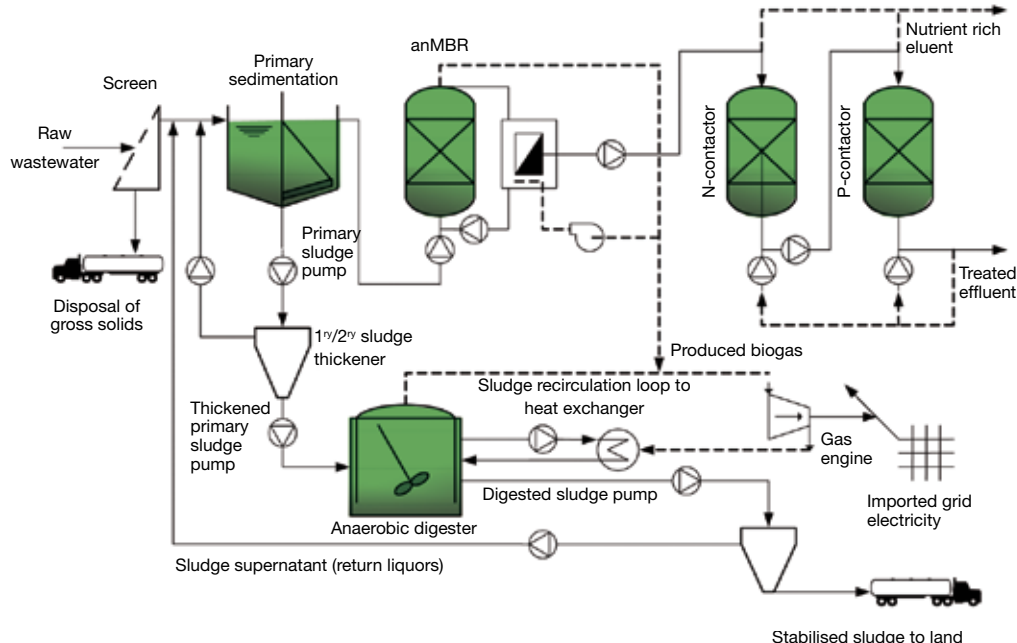
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(top) versus an alternate flowsheet proposed by Cramfield comprising anIMBR followed by physico-chemical recovery of ammonia and phosphorus (bottom).

membrane interface.

conclusion



the production of excess electricity and base fertiliser chemicals for export. [tce](#)

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