Optimizing the circular economy potential of organic waste co-digestion within the Australia's Water sector

Jurgen Thiele, Ragini Prasad, Adele Faraone

Calibre Group, Melbourne, VIC, Australia

KEYWORDS

Waste to Energy (WtE), Co-digestion, Anaerobic Digestion (AD), Circular Economy

EXECUTIVE SUMMARY (100 words maximum)

This paper goes to showcase just how the Australia Water Sector can realise a number of benefits relating to the circular economy. Specifically it shows that there is significant scope to increase biogas production, reduce waste going to landfill while also demonstrating improved biodegradation of the biosolids and generating products with greater marketability. This is shown to be achieved in a relatively cost effective manner using existing digester infrastructure and therefore operational resources while drawing on a number of organic waste streams. Through the collaboration of the water and waste sectors there is significant opportunity to minimize environmental harm while improving commercial outcomes for both sectors.

INTRODUCTION

The circular economy - as it applies to the wastewater sector - comes into effect in three specific ways: diverting waste going to landfill, generating additional renewable energy and creating readily usable byproducts. Key to this is Anaerobic Co-digestion of wet organic waste (ACD) which has long been used to process organic waste materials, to generate biogas and to recycle remaining residual organics as value added fertilizer(s). Although ACD has a long history of being used across the world and is considered well established in European countries, it is still in its infancy in Australia. When used to its full potential, ACD at municipal wastewater treatment plants has the potential to (a), generate significant volumes of gas energy (about 1 PJ/annum per base of 1 million population[1]), (b) produce usable byproducts thus reducing waste disposal to landfill while (c), avoiding greenhouse gas (GHG) emissions - all of which contributes to the development of a viable and diversified future new circular economy. The need to better understand the opportunities around ACD, particularly within the water sector, is specifically pertinent today given the push to reduce GHG emissions from waste, landfilled organics going to landfill and to increase the energy self sufficiency and the resilience of the water industry in Australia.

The focus of this paper is to understand how the process of ACD can be further optimized to improve circular economy outcomes. Specifically it will look at upgrading existing municipal anaerobic digesters to co-digestion and how this presents an opportunity to further optimize the circular economy potential. Key elements of the paper include:

- Understanding the potential for creating additional treatment capacity within existing anaerobic digesters
- Once additional capacity has been created, how this opportunity can be maximized to generate better usable value-add by-products that help close waste, energy and nutrient loops.
- skill sets ACD operators require to minimize operational risks of ACD at municipal WWTPs.

Through exploring these points, the paper highlights the opportunity that presents itself to the water sector and the circular economy potential of wastewater treatment with industrial, commercial and institutional (ICI) organic waste.

PROCESS

Understanding the Circular Economy Potential

The circular economy is about matching organic waste resource outputs with applications that can use those underutilised resources to create new products. From the perspective of ACD, this can include additional energy and the production of high grade, stable biosolids and value added agricultural/ horticultural fertilizer products which can be applied to land. Ultimately, optimized co-digestion hinges on the best site specific possible blend to exploit cost reducing, synergistic and complementary effects within the digester system to maximize methane production, nutrient (N,P) capture and where needed, quantitative pathogen load reduction from the raw biosolids and untreated organic ICI waste. The following table using data from the Australian Academy of Technological Sciences and Engineering reveals the resource value in domestic sewage.

Table 1: Resource Recovery Potential of Municipal Wastewater without ACD[1]

Wastewater Target Components	Amount per kL of wastewater
Water	1 m^3
Nitrogen	0.04 kg
Methane	0.14 m^3
Organic Fertiliser	0.10 kg
Phosphorus	0.01 kg

While ACD of wastewater biosolids with organic waste is applied at some treatment plants in Australia, it is still considered to be in its infancy when compared with Europe and North America where it has been widely used for decades. This paper here explores how the resource recovery potential of ACD at existing wastewater treatment plants can be enhanced with existing infrastructure. The paper focuses on the techno-economic potential for improving pre-existing wastewater treatment plant systems to optimize their circular economy potential.

How to increase treatment capacity of existing anaerobic digesters

The opportunity for cost effective organic waste co-digestion depends on the availability of digesters with sufficient spare digestion capacity. Our experience shows that the greatest economic value can be captured when new additional ACD capacity is generated in existing infrastructure without construction of new digesters and without negative impact on the wastewater treatment. This is typically achieved by improved digester mixing, heating and contact. Our experience shows further that ACD with Recuperative Thickening; RT doubles digester throughput capacity and substantially improves organic waste co-digestion business cases. The reason for this observation is that CAPEX costs are typically less than 1/3rd of the CAPEX for the alternative, construction of new digester tanks.

Secondly, RT allows to decouple solids (SRT) and hydraulic (HRT) residence time by returning a portion of the thickened digested sludge for further digestion and digestion rate improvements (Table 2). This increases the solids concentration in the digester, the contact time for the organic waste in the digester and demonstrates that effective organic waste digestion with RT can be achieved at higher organic waste loading rates than otherwise (Table 2). A relatively minor innovation has become a “game changer” that requires only minor process modifications to existing digester plants[4]. RT installation increases wastewater and solids throughput capacity (ie. typically doubled capacity), and improves volatile solids destruction of the organic waste (Table 2).

Table 2: Performance and capacity enhancement from Recuperative Thickening Installation in Municipal sludge digesters[2]

---

[1] Calibre, 2018. Calibre Submission Re: Low Emissions Economy DRAFT Report *https://www.productivity.govt.nz/view/submissions/3254*

[2] Wastewater – An Untapped Resource – Australian Academy of Technological Sciences and Engineering (ATSE), 2015

[3] Anaerobic digestion with recuperative thickening minimizes biosolids quantities and odours in Sydney, Australia *www.ozwater.org/sites/all/files/ozwater/118%20GBharambe.pdf*

[4] Thiele et al (2016). Improved Trade Waste Co-digestion. Water e-journal Vol 1 (No 3). On-line journal of the Australian Water Association. ISSN 2206-1991

[5] J H Thiele et al (2014). Capacity Upgrade of municipal sludge digesters – The Hamilton Experience. Proceedings of Water NZ Annual Conference , Hamilton 17-19 September 2014

Plant	Solids Residence Time increase	Relative change in dewatered biosolids wet mass	Biogas production increase	Hydraulic loading rate capacity
Bondi WWTP (biosolids only)[3]	From 15 days to 40 days	22 % reduction	20 % increase	Not determined
Palmerston North (NZ)[4]	From 12 days to 40 days	30-40 % reduction	220 % increase (ACD)	2 fold increased
Hamilton (NZ) (biosolids only)[5]	From 12 days to 40 days	10 - 20 % reduction	10- 20 % increase (no ACD)	2 fold increased

And, reduced biosolids production and odour emissions while increasing biogas production, gas sales and the nutrient value of the final digestate fertilizer (Table 2). Recent RT projects designed by the Calibre team for the Hamilton and Palmerston North have shown that the site specific sized and custom designed “plug and run” RT system can be added to existing digesters with minimal cost (Table 2).

Maximising the commercial benefits of increased treatment capacity

The key to success of ACD is “engineering” the digester feed composition and optimizing the mixing/contact in the RT-digesters to “boost” the activity of the bacterial biomass in the anaerobic process. Understanding ACD feed composition and managing your process to digest certain “problematic” feed stocks (attracting high gate fees) presents a low cost opportunity to maximize the commercial benefits from an improved digester capacity. To maximize capacity this papers explores proven solutions. In particular, the technical potential for using Grease Trap Wastes (GTW) and other high fat organic waste as a primary feedstock source to triple the biogas production in ACD of trade waste. Currently Australia produces significant volumes of GTW along with FOGs from major agro-industrial players including dairy factories, food processing factories, biodiesel plants and livestock units which all produce significant liquid and solid organic waste. These all present significant ACD opportunities with sewage sludge. Maximised ACD results in avoided landfill costs while enhancing digestion capacity to produce higher quality (grade) biosolids and higher biogas volumes.

For example: Typical co-digestion loading rates for FOG are 0.5-0.7 kg FOG/$m^3_{digester}$/day. FOG digestion can typically contributes up to about 60 % of the daily biogas production in a co-digestion facility. The Calibre team conducted a pilot scale test that involved loading a digester with sheep tallow in a continuously operated digester at mesophilic temperatures without addition of co-substrates. The typical FOG loading rate at “steady state” with active digester sludge growth was up to 2 kg FOG/$m^3_{digester}$/day and FOG contributed 100 % of the biogas produced.

Additionally, full scale operation experience at the Palmerston North Wastewater Treatment Plant for over 5 years was used to understand the maximum biogas production potential for FOG within ACD. Palmerston North (Table 2) looked at two sludge digesters – one worked as a control with no recuperative thickening (RT) while the second did use RT. The digester operation was with high FOG content DAF sludge from dairy plants, with up to 70% FOG in dry matter. The results showed that recuperative thickening increased permissible FOG loading rates without digester inhibition substantially to about 2 kg FOG/$m^3_{digester}$/day. RT at high digester loading rates also lowered the presence of volatile fatty acids (VFA) and the occurrence of digester process stability issues, such as inhibition, acidification, scum formation and blockages, or mechanical issues. The application of the innovation in the Palmerston North digesters combined with organic waste co-digestion has now consistently tripled the normal biogas production [5,7] from 750 m^3/day per digester tank to over 2,200 m^3/day/tank. The increased digester capacity and throughput was achieved without construction of new digesters.

This level of success is also widely reported in the literature where Luostarinen et al reported a 60% increase in methane yield in municipal sludge digesters when grease from a meat plant was co-digested with sewage sludge – however at much lower FOG loading rates that the Palmerston North experience.

OUTCOMES

The outcome of our analysis shows that there is significant potential within the Australian water sector to increase the circular economy potential. Specifically it shows that there is significant scope to increase biogas production, reduce waste going to landfill while also demonstrating improved biodegradation of the biosolids. This is shown to be achieved in a relatively cost effective manner using existing digester infrastructure and therefore operational resources while drawing on a number of organic waste streams.