FINAL REPORT

Sustainable management of waste and wastewater streams at V&V Walsh

PROJECT CODE:	2020-1030
PREPARED BY:	Fabiana Tessele, Gustavo Tedesco, Emanuel Bertizzolo TESSELE CONSULTANTS PTY LTD
DATE SUBMITTED:	**17 August 2020**
DATE PUBLISHED:	
PUBLISHED BY:	

The Australian Meat Processor Corporation acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

V&V Walsh is continuously improving their operations, with strong focus on environmental compliance. Currently the Wastewater Treatment Ponds are going through an upgrade, aiming to reduce the nutrients loads and also improving the quality of the biosolids for composting or other beneficial uses. Producing a high-quality effluent is key for environmental compliance and for ensuring the quality of turf farm irrigated with the treated water. This project will investigate alternatives to both produce a better-quality treated water and at the same time benefit from the use of the sludge, nutrients and energy. For that, tree main areas of study were as follows:

- Optimise the removal of TSS in the DAF, by optimising the use of Tanfloc and recirculation rates both in bench scale and full operation

- Assess the potential of producing biogas from the solids produced in the Abattoir, including the sludge from the DAF and other solid streams (paunch, tallow, etc.)

- Polishing of the final effluent: Jar-Tests for immobilising N and P using a modified mineral zeolite (adsorption) in combination with Tanfloc. This can potentially produce a soil conditioner that can be traded with the forestry industry

This study identified several opportunities for the more sustainable management of waste streams at V&V Walsh, including improved performance in the DAF in terms of TSS removal, high quality biosolids from DAF (no metals), and potential of recovery of biogas from the biosolids, immobilisation of nitrogen and phosphorous in a clay material for nutrient recovery at treatment ponds. This would bring V&V Walsh closer to the Circular Economy concept, where the by products currently considered as waste are being converted in products (fertiliser, energy, treated water).

The results are summarised in an integrated manner, including a revised water and nutrients balance in the plant, quantifying the potential benefits of the better management of the waste/ wastewater streams. The main outcome is improving sustainability at V&V Walsh while bringing financial returns from waste streams.

The main conclusions of the improvement on pre-treatment using Tanfloc are:

// Tanfloc is very effective on the pre-treatment of the wastewater produced at V&V Walsh. Depending on the dosing, turbidity can be reduced to below 20 NTU, and nitrogen and phosphorous can be partially removed.

// The removal of nutrients seems to be limited to the part associated to solids, being around 40-45% for Nitrogen and 15-20% for Phosphorous.

// The ideal dosing of Tanfloc has to take into consideration costs, and therefore a removal rate of around 80% was selected as ideal. This corresponds to 0.15 mL/L dosing, or 20.6 L/hour in average (considering Q = 137.5 kL/hour, or 1,100 kL/day over 8 hours).

// The use of very low dosing of anionic polymer assists on the flocculation and sludge dewatering, but can be considered optional, depending on operational circumstances.

// When considering 80% efficiency, the solids production in the DAF will be of approximately 6,300 kg/day.

// Optimising the dosing of Tanfloc will depend on the costs associated, and the removal curve produced can provide information for how low the dosing can be before the efficiency starts to get compromised.

// Around 40% savings in aeration costs can be obtained from the reduction of Nitrogen in the pre-treatment.

// We recommend replacing the use of $FeCl_3$ with Tanfloc SG, on a dosing rate of 250 L/1,000 m^3.

The main conclusions of the improvement on polishing using zeolites are:

// The Zeolite clay is efficient on removing ammonia from the effluent, with an uptake capacity of 0.39 mg/g.

// The use of Tanfloc combined with $FeCl_3$ as polishing stage improved the removal of TSS, however didn't affect the efficiency of N and P removal. Therefore, we recommend that in Pond 4 V&V maintain the dosing of $FeCl_3$.

// Zeolite on the form of filters seemed to be more efficient than in the form of powder, resulting in a lower turbidity and relatively lower consumption.

The main conclusions of the production of Biogas from V&V Walsh's Waste streams are:

// All methane potential tests were successful. There were no signs of inhibition or microbial overload observed in any tests and the performance of replicate tests showed a high degree of repeatability.

// All wastes contained a high solids concentration and a relatively low moisture content. All wastes were diluted by adding inoculum for BMP testing. The specific impacts of solids concentration were not assessed; however, solids concentrations can reduce process performance in AD and this may need to be considered in full-scale process designs.

// The methane potential of the Combined Saveall was estimated at 568 $L.kgVS^{-1}$ corresponding to a degradable fraction of approximately 84% of COD, this is consistent with highly degradable organic wastes. The degradation rate for the Combined Saveall material was 0.24 day^{-1}. An example process design for this material would be a mixed liquor style reactor with an SRT of >25 days (to convert 85% of the degradable fraction). This assumes the reactor operates at 37°C and does not experience issues with mass transfer.

// The methane potential of the DAF Belt Press was estimated at 658 L.kg/VS, again this was a highly degradable organic waste stream. The apparent hydrolysis rate of the DAF Belt

Press was estimated at 0.09 day^{-1}, which is consistent with a slowly degrading organic waste requiring a long reactor SRT (approx. 40 days in a CSTR).

- // The methane potential of the Sheep Paunch, Beef Paunch and Sheep Manure was estimated at 307, 285 and 211 $L.kgVS^{-1}$ corresponding to a degradable fraction of approximately 58%, 52% and 68% of COD, which is lower than Combined Saveall and DAF Belt Press samples and consistent with the lower degradability for such materials reported in literature.
- // Beef Paunch was the slowest degrading waste tested and could require a treatment SRT over 60 days. Sheep Manure and Sheep Paunch were also considered slowly degrading materials, however SRT of 30 – 40 days is likely sufficient for degradation of these wastes at 37°C.

Based on findings further detailed in this report, the results of NPV analysis are presented below:

PV of Capital Expenditure	$2.7 M
PV of Operating Costs	$1.2 M
PV of Income	$7.6 M
NPV	$3.7 M
ROI	5% pa
Return of Investment (from operation)	3 years

We recommend that a more in-depth feasibility study be developed, considering the changes in waste levy, energy price and emissions targets. The wastewater treatment plant needs to be integrated to the new concept, as a way to maximise returns from resource recovery.

2.0 INTRODUCTION

The Australian beef and sheep industries currently contribute around 10% of Australia's total greenhouse gas (GHG) emissions and over two thirds of this comes from cattle. In addition to methane emitted by cattle, beef production also emits GHGs through:

- Meat processing
- Loss of soil carbon in overgrazed pastures
- Clearing of primary forests
- Nitrous oxide from manure in feedlots
- Application of nitrogen fertilisers to pastures and to grow grain
- Upstream inputs such as chemicals and diesel

The growing concerns for environmentally sound operations are leading many operations to search for alternative ways to achieve environmental compliance. It is still common practice in other industries to treat the wastewater to a level to comply with land application rates, not focussing on the sustainability aspects, such as recovering value of the waste, and producing more environmentally sound by-products that can be converted into products. Figure 1 shows a schematic diagram of how the Circular Economy framework can be applied to the red meat industry.

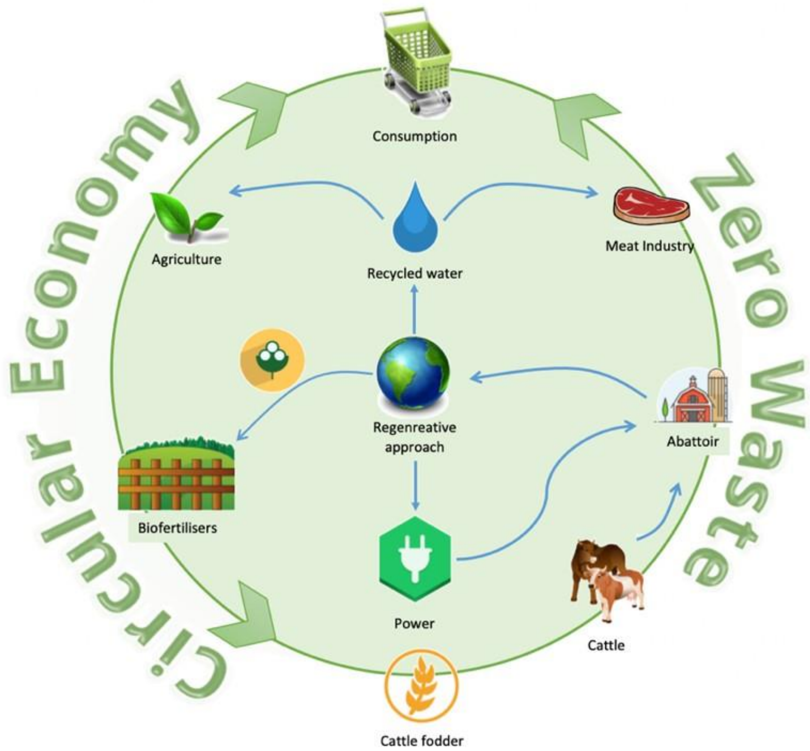


Figure 1. Representation of Circular Economy framework in the red meat industry.

The high load of nutrients in the wastewater has been historically a challenge for the meat industry. The main paradigm shift in the past few years concerning anaerobic digestion (AD) is that the technology is no longer seen as a "waste treatment" technology. Instead it is seen as a fundamental enabler of the envisaged circular economy through resource recovery, including energy, safe water and nutrients, from valuable by-products from industries, municipalities and agro-industrial settings. AD gives a "second-life" to materials that would otherwise be considered as waste, i.e. giving them value when they would have had none. The result of using this previously unwanted waste /wastewater provides a source of renewable energy in the form of biogas and organic fertiliser made from a veritable non-fossil-fuelled production method. In order to allow anaerobic digestion to meet its full potential, we must have a process which encourages the redirection from waste to landfill to waste to re-use.

Resource recovery, and circular economy approach are common practises in Europe (Tessele and van Lier, 2020), and the Australian meat Industry is heading towards the same direction. More conscious consumers, demanding green practices, and also board executives and financers, wanting so see proactivity in these areas. By leading by example, V&V could influence their counterparties in the meat industry to aim for more sustainable operations, improving the image of meat consumption amongst more environmentally conscious consumers.

Also, recovering nutrients and biogas will bring source of income and decrease the carbon footprint of the operations, in line with global trends in the food processing industry. That can unfold into improved branding of meat products, and increased aggregated value both in local and international markets.

By adopting a circular economy framework, the environmental impacts can be significantly reduced, and resources can be recovered, including:

- **Recycled Water (washing, process and irrigation)**
- **Soil conditioner (recovering overgrazed pastures)**
- **Fertiliser (replacing the use of chemical-based N and P on grain production)**
- **Energy (power & heat) from biogas, reducing the need of upstream inputs**

In this context, the study conducted for V&V Walsh Abattoir in Bunbury (WA) explores initiatives towards improving the sustainability of waste streams management, including:

// Replacing metallic coagulant use in pre-treatment with an organic, carbon negative natural coagulant (Tanfloc).

- Reducing the load of suspended solids entering the wastewater treatment system, reducing the potential of methane emission to the atmosphere by sludge degradation in the ponds.
- Assess the use of the sludges and solid streams to produce biogas.
- Recover N and P form the polishing ponds using zeolites and coagulation.

Other areas, such as commercial fertiliser production and optimisation of nitrogen removal, will be further assessed in subsequent stages of the project.

2.1 Alignment with the Australian Beef Sustainability Framework (ABSF)

According to the Australian Beef Sustainability Framework (ABSF), "*sustainability is the production of beef in a manner that is socially, environmentally and economically responsible*". This includes caring for natural resources, people and the community, the health and welfare of animals, and the drive for continuous improvement. Additionally, the rising cost of energy has encouraged the industry to investigate alternatives to use energy more efficiently and tap into renewables. The National Farmers' Federation has set the target of Australia's farm energy sources being 50% renewable by 2030[1].

The initiatives suggested in this report are aligned with several of the ABSF's key priorities outlined at the 2019 Australian Beef Sustainability Framework (ABSF 2019), such as:

Priority Area		Alignment
ECONOMIC RESILIENCE	Enhance Profitability and Productivity	Promotes value recovery from waste Reduced energy cost, via use of biogas Water recycling, lower water consumption
	Optimise Market	The product can be marketed as "Green Beef", improved customer perception
ENVIRONMENTAL STEWARDSHIP	Improve Land Management Practices	Improving soil health by employing stabilised biosolids (biofertiliser) Improves water quality, lower nutrient discharge to the environment Increase ground cover to protect waterways by using recycled water on irrigation
	Manage Climate Change Risk	Methane and other gases will be captured during wastewater treatment to create biogas that is then used in the facility reducing the use of natural gas.
	Carbon sequestration	Sequester carbon through effectively managing the integration of soil, water and plant assets assists in reducing CO_2 emissions.
	Efficient Use of Water	Reduce the amount of water used per kg live weight of produced cattle, via water recycling.

[1] https://nff.org.au/wp-content/uploads/2020/02/NFF_Roadmap_2030_FINAL.pdf

PEOPLE & COMMUNITY	Minimise Waste	Reduce the amount of solid waste per tonne Hot Standard Carcass Weight (HSCW) when processing beef, by using the solid waste for biogas production and biofertiliser. Produce Methane and fertiliser from the waste.

Summary of Previous Works

In the past two years, Tessele Consultants has worked together with V&V Walsh aiming to improve the performance of the Wastewater Treatment Plant in terms of nutrient removal. Recovering value from waste streams and improving overall sustainability of the processes is at the core of the way the projects are developed. V&V Walsh is currently using Ferric Chloride as a coagulant in the pre-treatment stage, resulting in a DAF sludge containing metals, demining close control prior to disposal. Also, the Department of Water and Environmental regulation has increasing concerns regarding to the land application of effluents containing N and P, therefore V&V has been searching for viable alternatives to remove nutrients from the treated wastewater. Aligned to the concept of recovering value of the waste streams, the assessment of the biogas production comes in line with sustainable ways of optimising the recovery of value from waste.

In the past two years Tessele Consultants and V&V Walsh undertook several initiatives aiming to achieve these goals, including the Biowin modelling and optimisation of the WTTP process, refurbishment of the existing ponds to maximise water storage, trials of phosphorous removal using zeolites, and a short trial of the use of Tanfloc in the DAF, comparing with Ferric Chloride. The preliminary results were very promising, and the removal of TSS was superior to 95%. These initiatives were all self-funded by V&V Walsh, and infrastructure has been developed to be able to do full scale testing.

3.0 PROJECT OBJECTIVES

The project objectives were to investigate alternatives to both produce a better-quality treated water and at the same time benefit from the use of the sludge, nutrients and energy. For that, tree main areas of study were:

1. Run a full-scale test the use of a metal-free coagulant based on the acacia tree bark (Tanfloc) in the DAF for TSS and fats removal at pre-treatment stage.

2. Run a series of DAF jar tests combining $FeCl_3$, zeolite and Tanfloc for nitrogen and phosphorus removal of the treated effluent (polishing stage).

3. Assess the Bio Methane Potential of the produced sludge and other solid streams at V&V Walsh, and estimate the potential for energy production

4. Integration for the results from steps 1, 2 and 3, including mass balance and recommendations on what can be implemented.

4.0 METHODOLOGY

Full-scale Tanfloc test: Tanfloc solution was dosed at various rates at the DAF system and the effects on the quality of the treated wastewater will be measured in terms of TSS, fats and turbidity. The quality of the dewatered sludge will be measured in terms of % of solids. Perform a mass balance in the pre-treatment system and estimate the quantity of sludge produced per year.

DAF Jar tests: DAF Jar tests was performed to assess the performance of immobilising Nitrogen and phosphorous in a zeolite clay. Various amounts of zeolite clay, $FeCl_3$ and Tanfloc will be tested in a combination matrix, a total of 10 series of tests, with 5 concentrations each test. Samples of the clarified water will be collected for full analysis (BOD, N, P, TSS, Pathogens).

BMP tests: The assessment the Bio Methane Potential of the produced sludge and other solid streams (including the sludge produced in the DAF trials) was be done at the Queensland University of Technology, following their standard procedures for sample collection, preservation and testing. The BMP test usually took 60 days for completion and informed the subsequent biogas/ energy calculations.

Progress reports 1 and 2 describe in details the methodology and analytical procedures.

5.0 PROJECT OUTCOMES

5.1 Improvement on pre-treatment using Tanfloc

The study confirmed the successful use of the organic coagulant Tanfloc, replacing the use of metal-based coagulants, and improving the efficiency of the DAF in terms of TSS, O&G and N. The tannin-based flocculant and coagulant is produced from the Acacia tree bark, and is designed as an organic replacement for metal-based alternatives that use aluminium and ferric salts.

5.1.1 Carbon negative

25,000 hectares of planted forests and, together with all its industrial activities, has a positive Carbon Footprint, as verified in its Inventory of Greenhouse Gas Emissions, issued by the BVQI certifier, and in the development of its activities, the company sequesters 6 tons of CO_{2e} for each ton of CO_{2e} emitted.

Considering the TSS removal efficiency was over 95% on the first run, the second run was designed using lower dosing concentrations, and testing the bottom dosing limits. The results showed a TSS removal superior to 80% for dosing rates as low as 0.15 mL/L (Figure 3).

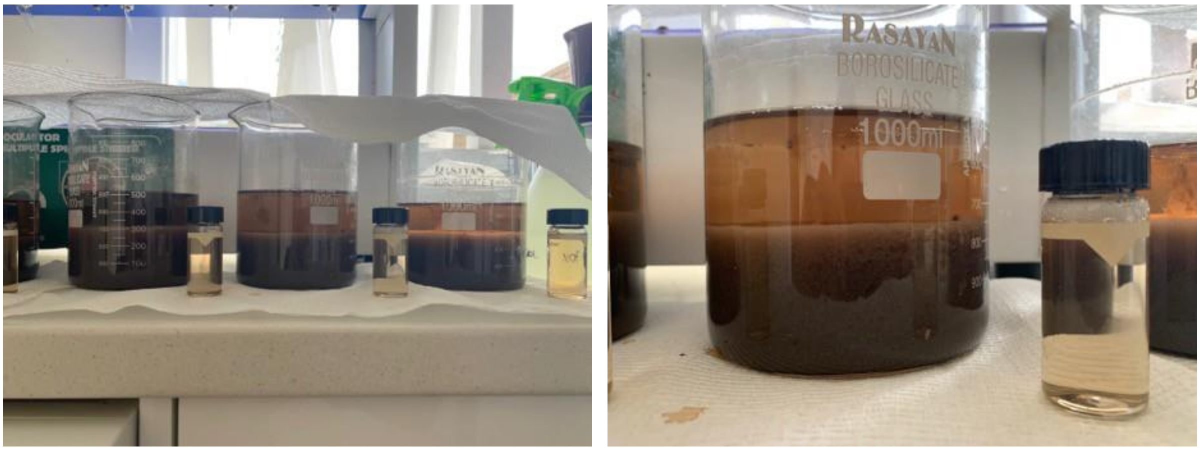


Figure 2. Turbidity removal and treated (second run) DAF effluent.

As part of the N and P present in the effluent are associated with the solids, five points were selected and analysed for N and P. The results showed that around 43% of the nitrogen can be removed in the preliminary treatment, and about 23% of the phosphorous.

Removal efficiency in the primary treatment:

TSS	N-Ammonia	P-phosphate
• 93% removal • TSS_{OUT} = 180mg/L	• 42% removal • $NH_4\text{-}N_{OUT}$= 80mg/L	• 23% removal • $PO_4^{3-}{}_{OUT}$ = 97mg/L

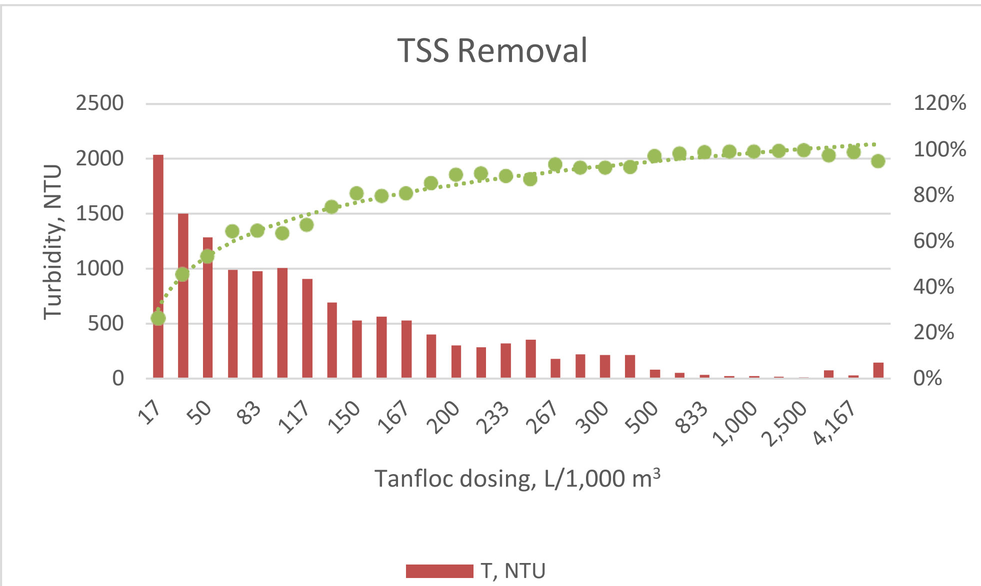


Figure 3. Turbidity and TSS removal using Tanfloc.

5.1.2 High level costs assessment

The use of Tanfloc in the raw wastewater resulted in a 42% removal of nitrogen and 23% removal of phosphorous, along with a very high removal of TSS (>90%). By introducing the use of Tanfloc pre-DAF, there will be savings associated to aeration requirements and sludge disposal. The net oxygen required for nitrogen removal is 1.71 mg O_2/mg ammonia-nitrogen converted to nitrogen gas (Daigger, 2014), as long as influent biodegradable organic matter is used to denitrify residual oxidized nitrogen. Therefore, reducing the ammonia nitrogen load to the system in 40% will directly reduce aeration costs in 40%.

The Tanfloc will replace Ferric Chloride, and the estimated consumption is around 4 IBC's per month, resulting on a cost of $8,000 per month (replacing $FeCl_3$ dosing).

5.2 Polishing system – Use of Zeolite to immobilise N and P

Bench scale Jar tests were performed to assess the efficiency of immobilising Nitrogen and Phosphorous in a zeolite clay. The Zeolite was sourced from a mine in Queensland, being predominantly clinoptilolite (Ca-rich) up to 60 weight percent association with minor mordenite, both as a result of silica glass alteration.

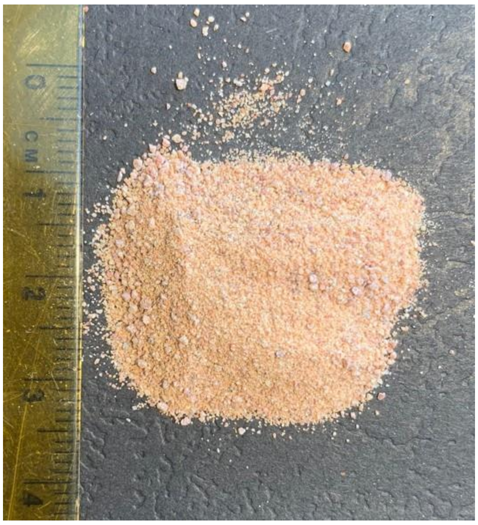


Figure 4. Powder Zeolite used in the Jar Tests.

Figure 5. Granular Zeolite used in the filters.

The first set of tests were performed using powder zeolite in a jar test. Varying amounts of zeolite clay (Figure 4), $FeCl_3$ and Tanfloc will be tested in a combination matrix. The order of adding the different reagents was:

Zeolite → $FeCl_3$ → Tanfloc → Polymer

Each test aimed to optimise one of the parameters. In the first test the concentrations of Tanfloc were varied; in the second test the concentrations of $FeCl_3$ were varied, and in Test 3 the concentrations of Zeolite were varied. Tests 4, 5 and 6 were optimisations of the first 3 tests, aiming to improve phosphorous removal. The Experimental conditions are summarised in Table 1.

Table 1. Experimental conditions for the Pond4 jar-tests using powder zeolite.

Variable		Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Sample volume	mL	300	300	300	300	300	300
Tanfloc 1%	mL	variable	0.20	0.20	0.20	removed	0.40
$FeCl_3$ 1%	mL	0.25	variable	1.00	variable	variable	variable
Zeolite	g	1.30	1.30	variable	1.30	removed	removed
Polymer 0.05%	mL	0.25	0.25	0.25	0.25	0.25	0.25
Time	sec	30	30	30	30	30	30

Due to the relatively low nitrogen removal in the first pass of the tests (detailed in the results in session 6.0), a second series of additional experiments (not initially planned) were set, using the Zeolite in granular form in filters. Samples of Pond 4 (inlet to pond 5) were collected in two different days and adsorption tests with zeolite were performed using gravity filters (Figure 6).

When comparing the removal of nitrogen with and without the zeolite, there is a slight improvement (10%) on the removal rates when the Zeolite dosing is optimised. However, the solid/liquid separation operation involved could be costly for such a marginal increment on N removal. Therefore, we decided to test the granular Zeolite in the form of filters, aiming to compare the efficiencies.

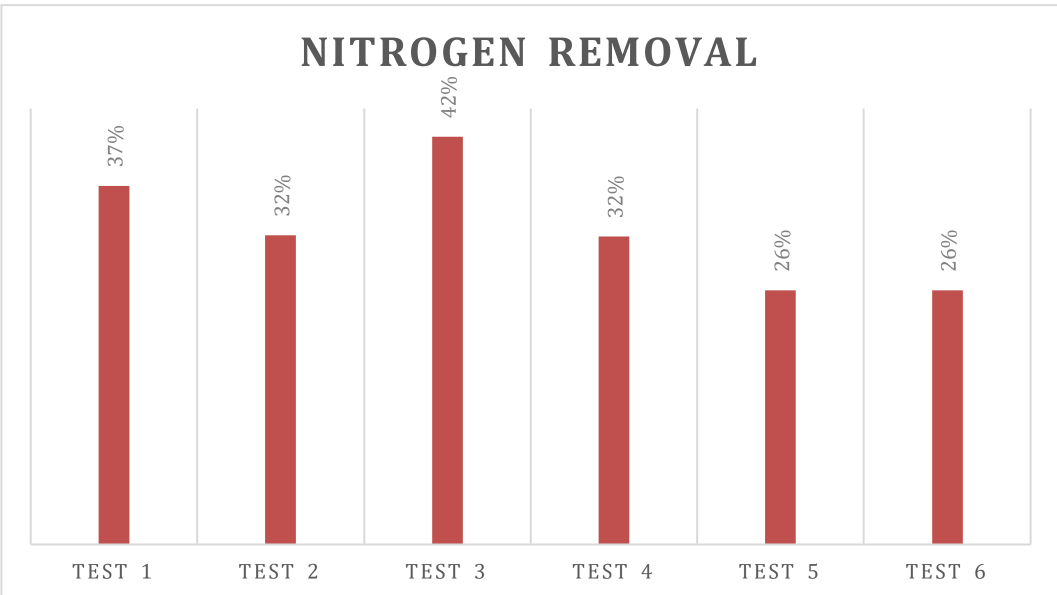


Figure 6. Comparison between the tests in terms of Nitrogen removal. Test 3 is the test where Zeolite dosing was optimised.

Zeolite Filters

Filters were made using plastic water bottles of 350 mL lined with semipermeable nylon cloth and packed with 300g of pre-washed granular zeolite. For Filter 5 a plastic bottle of 1.5 L and 500 g of zeolite were used. The Zeolite used in Filter 4 was previously conditioned with ferric chloride solution overnight. After that, the solid was dried in oven under 120 ^oC for 3 hours. The original light brown colour changed to yellowish brown.

For filters F2 - F5, there was a pre-coagulation stage, aiming to remove algae and TSS prior to filtration, preventing filter clogging and improving significantly its performance, as described below.

5.2.1 High level costs assessment

The results above show that the Zeolite is efficient on removing ammonia nitrogen, reaching high removal rates. However, due to limited adsorption capacity, the amount of zeolite that would be required to remove 40% of ammonia nitrogen would be around 16 ton/day, representing a cost of around $65,000 per month on zeolite material. If the material could be sold in the market as fertiliser, it could generate an income of $150,000 per month. However, there are two limiting factors to be considered: (i) Securing a client that would consume 330 ton/month of Zeolite consistently; (ii) Logistics aspects on replacing the filter media on a daily basis, and moving in-an-out 16 tons per day of clay. Therefore, we do not recommend going forward with this option at this stage, until an off-taker can be identified.

5.3 Production of Biogas from the solid streams and sludge

The utilization of the organic solid waste from V&V Walsh presents a unique opportunity for recovering energy and nutrients from organic waste while minimizing carbon footprint, reducing cost for disposal of the current residues, minimizing environmental impacts and creating revenue from the by-products. The Anaerobic Digestion (AD) technology can be used as the central pillar of resource recovery in the abattoir moving towards a circular economy approach and “greener/sustainable” meat production practice.

5.3.1 Potential of the organic waste

Five types of organic waste generated in the abattoir were considered with potential for biogas production via Anaerobic Digestion process: beef paunch, DAF belt press, sheep paunch, beef paunch and sheep manure. Waste samples (Figure 7) were sent to The Advanced Water Management Centre at The University of Queensland and submitted to Biomethane Potential (BMP) tests confirming the suitability of the material to produce methane via AD, described in details in the Milestone 3 Report.

Figure 7. Waste Samples as received and as subsampled for testing.

BMP tests were successfully performed, and the key findings are:

- No signs of inhibition or microbial overload observed in any tests (Tanfloc application has not impacted the process for DAF Belt Press substrate)
- The performance of replicate tests showed high degree of repeatability (consistent methane production)
- All samples contained high solids content and relatively low moisture content (dilution to be considered for AD process)
- The methane potential of all samples is consistent when compared to similar waste composition from literature
- The material is suitable for AD process at Mesophilic temperature range (37˚C) with solids retention time of 30 – 40 days for optimum Biogas production.

Figure 8 presents the sources and summary results of Biogas Production from the organic waste.

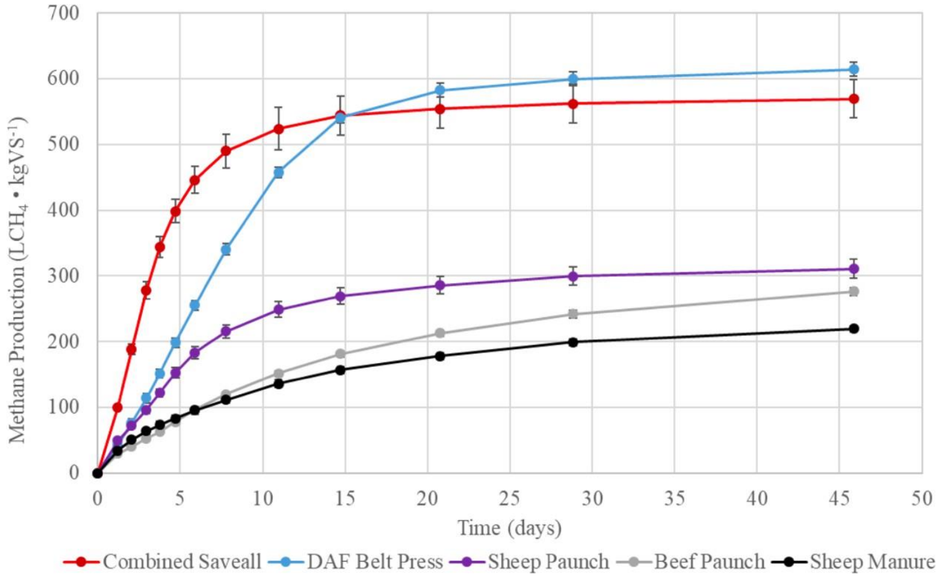


Figure 8. Methane production from BMP tests digesting V&V Walsh waste sample at 37˚C using digested sludge from LP WWTP (normalized to 0˚C and 1 atm and expressed as methane volume per mass of volatile solids)

The results have indicated the material is highly suitable for the AD process offering to the abattoir an opportunity to process the organic waste on-site. The methane production for both materials Combined Saveall (568 $L.kgVS^{-1}$) and DAF Belt Press (658 $L.kgVS^{-1}$) are consistent with highly degradable organic wastes. For the other materials the methane production results are consistent with lower degradable materials reported in the literature, being Sheep Paunch, Beef Paunch and Sheep Manure was estimated at 307, 285 and 211 $L.kgVS^{-1}$.

5.3.2 Organic waste characteristics and availability

The AD facility has to be developed to receive and process the organic waste based on the material characteristics and quantities. In addition to suitability for AD process, the technology selection criteria include the solids content of the material. A summary of characteristics and the availability of each material has assessed and is presented in the Table 2.

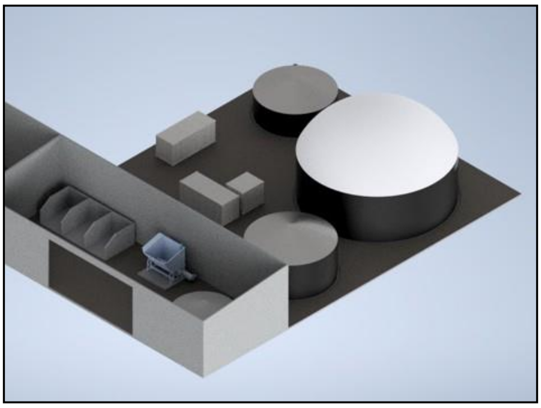
Table 2. Daily solids production at V&V Walsh

Substrate	BMP $L.kgVS^{-1}$	TS kg/ton	VS kg/ton	BMP m^3 CH_4/ton	Solids Production ton/ day
Combined Saveall	568	287	275	156	4
DAF Belt Press	658	379	341	224	12
Sheep Paunch	307	184	159	49	10
Beef Paunch	285	189	181	52	10
Sheep Manure	211	749	595	126	4

Combining all the material the daily organic waste production is 40 ton/day, with an average total solids (TS) content of 31 %. The proposed AD technology for processing this type of organic waste is the Continuous Stirred Tank Reactor (CSTR), which typically operates with TS around 15-17%. In order to reach adequate solids content for the process, about 30 m^3/day of raw wastewater will be added to the solids. This will result in 50 ton per day of combined streams (seven days a week) with total solids suitable for feeding the Biogas Plant.

5.3.3 Biogas plant concept and outcomes

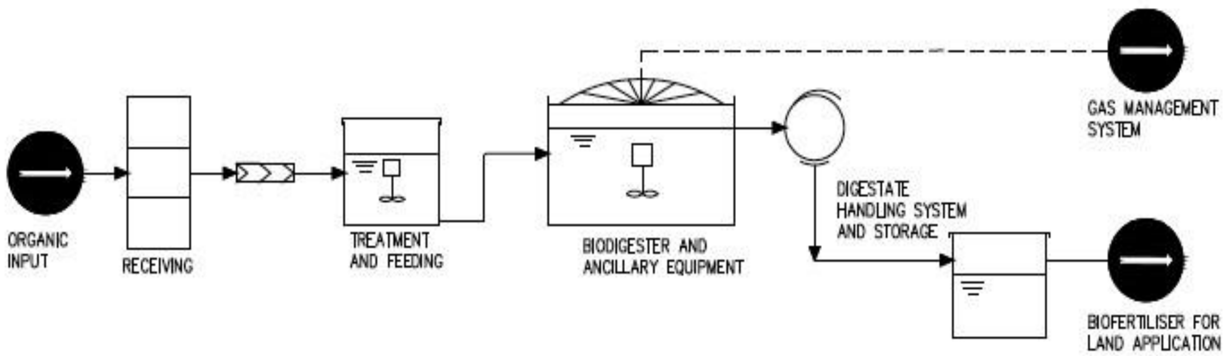
Based on the BMP results and quantities we propose a facility with ability to process combined organic waste, receiving and mixing the solid and liquid streams prior entering the digestor. Several plants using this concept have been fully operational in Europe for over two decades, and more recently this technology is starting to be developed in Australia.



The proposed System Concept is a Wet Co-Digestion Biogas Plant developed by Zero6[2] with 40 days solids retention time operating in a Mesophilic temperature range (37°C). By-products to be originated from this plant includes fuel (biogas), energy (heat and electricity); and biofertilizer (in the form of slurry or pellets).

The plant is modular, and capacity can be increased over time. Initial estimates have considered a facility able to process a total of 50 tonnes of combined organic waste per day (equivalent to 18,250 tonnes per year).

The high-level process flow diagram illustrates the AD system, as follows:



The components are described in more detail in Table 3.

[2] www.zero6.com.au

Table 3. AD System Components and Description

Components	Description
Waste receiving station, pre-treatment and feeding system	In order to have flexibility with the types of substrates handled, the system will include a liquid receiving station and a solid receiving area. After receival, solids and liquids are mixed by using a specific feeding hopper and then fed into the digester.
Pumping system	Due to the solids content the plant will be dealing with (up to 20%), the pumping and recirculation systems opted includes progressive cavity pumps. The pumps vary in sizes and type depending on location and function in the plant. Progressive cavity pumps allow pumping high solids content at low rates and easy maintenance.
Biodigester and ancillary equipment	The proposed configuration for this Biogas plant includes three main tanks responsible for different stages of the anaerobic digestion process: hydrolysis tank, primary digester and post digester. By using this configuration, the substrate mixing ratios, solids content and temperature in each stage of the process can be managed in order to achieve optimum biogas production and avoiding risk of acidity in the primary digestor.
Plant automation monitoring and control	- Sensors monitoring alarms (pressure, temperature, level, pH, flow measurement). - Process Monitoring - Off-site control flexibility
Gas management system and combined heat and power (CHP)	- Gas treatment - Flare (security) - CHP gas utilization (energy and heat)

Based on the BMP analysis results, the daily resulting biogas production and potential energy equivalent, as well as other details of the AD Facility are summarized in the

Table 4. Main outcomes of the AD facility

Substrate		
Capacity of treatment	18,250	Tonnes per year
Solids content feed	<19%	Total solids
Biogas Production	5,900	Nm^3 per day
Energy equivalent	136 GJ or 38 MWh	per day
Biofertilizer production	42	Tonnes per day

5.3.3 Biogas plant cost estimate (+/- 30%) and NPV

Capital Cost

The capital cost was estimated with base on previous projects costing and costing database developed by our cost estimator. Table 5 summarises all installation and construction items considered in building up the cost estimate, including equipment and services, with +/- 30% accuracy (pre-feasibility level).

Table 5. Equipment and Associated Service Capex

Item No	Capital Expenditure
1	Site Preliminaries
2	Biodigester unit
3	Fertiliser plant & sludge drying (in-house)
4	Buildings, services, firefighting etc.
5	Civil works
6	Installation
7	Engineering design
8	Project management
9	Delivery of equipment
10	Strat-up/Commissioning/Training & Handover

The total capital cost estimated for the items above is approximately $3 million.

Net Present Value

To calculate the Net Present Value (NPV), we have assumed that the sources of revenue are the gate fees (avoiding costs of waste disposal to landfill) and sale of biofertilizer. As informed by V&V Walsh, their current costs for waste disposal are:

- $11 for beef and sheep paunch + DAF
- $61.85 for sheep manure

The value of the sale of biofertilizer was adopted as $15/ton. The revenue from biogas, electricity and heat was accounted “behind the meter”, as it will be used to power both the digester and the V&V facility, reducing overall operation costs. Further assessment is required to identify gas, electricity and heat allocations as per facility and site requirements, and this has to be refined in further engineering stages. At this stage we have assumed that all of the Biogas will be used for the boiler. However, in further stages of development a more detailed analysis on the predicted energy will inform this decision more accurately. According to the Integrated Regional Waste Management report recently issued by the South West Regional Waste Group (BHRC, 2020), the gate fees expected to be applied to the South West in the next years will increase to the range of $200-240 per ton. Also, it is unlikely that new landfill areas will be approved, increasing the demand for the existing licensed disposal facilities.

The energy market has been fluctuating with the disruption caused by the introduction of renewables (mainly solar). According to Swoboda (2020) gas prices for households and businesses are expected to increase significantly in Australia, as the development of new gas export terminals leads to a tightening of supply.

Therefore, the estimate presented here is rather conservative, and these market trends need to be taken into consideration in more detailed scenarios of feasibility analysis.

Table 6. Sources of revenue considered in the NPV calculations.

Item	Value	
Waste processed per day (5 days/week)	40	Tonnes/day
Operational days	260	per year
Gate fee per tonne	11-62	$
Fertilizer production	15,712	tonnes/year
Revenue from fertilizer	15	$/tonne
All gas being directed to heat production (Boiler)	45	MJ per year
Gas price	7.00	$/GJ
Total Revenue Per year	**595,000**	**$/year**

The financial indicators used on the NPV calculations are shown in Table 7.

Table 7. Financial Indicators Used to Calculate the NPV

PV Cost Analysis with Tax Effect	
Nominal discount Rate	8%
Escalation Factor	2.5%
Tax rate	0.0%
Effective Tax Cash Coefficient	100.0%
Project life (years)	25

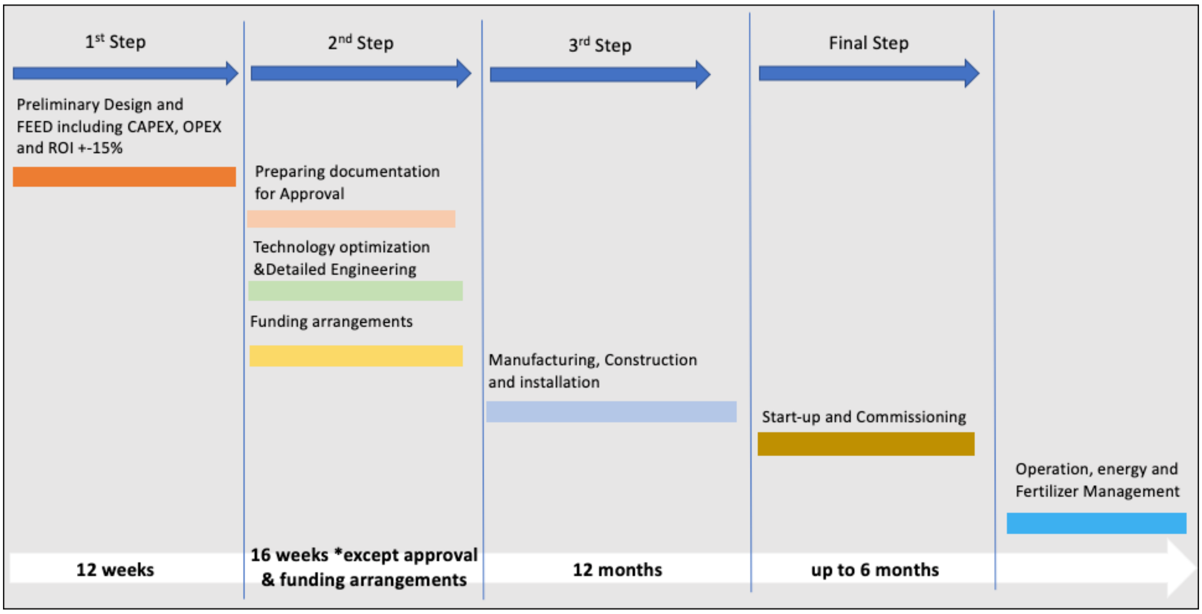
Pre-feasibility financial results

Based on all the assumption above, results of NPV analysis are presented below:

PV of Capital Expenditure	**$2.7 M**
PV of Operating Costs	**$1.2 M**
PV of Income	**$7.6 M**
NPV	**$3.7 M**
ROI	**5% pa**
Return of Investment (from operation)	**3 years**

5.3.4 Steps for implementation

The following steps are recommended towards Biogas system full implementation.



6.0 DISCUSSION

N/A

7.0 CONCLUSIONS/RECOMMENDATIONS

The main conclusions of the improvement on pre-treatment using Tanfloc are:

// Tanfloc is very effective on the pre-treatment of the wastewater produced at V&V Walsh. Depending on the dosing, turbidity can be reduced to below 20 NTU, and nitrogen and phosphorous can be partially removed.

// The removal of nutrients seems to be limited to the part associated to solids, being around 40-45% for Nitrogen and 15-20% for Phosphorous.

// The ideal dosing of Tanfloc has to take into consideration costs, and therefore a removal rate of around 80% was selected as ideal. This corresponds to 0.15 mL/L dosing, or 20.6 L/hour in average (considering Q = 137.5 kL/hour, or 1,100 kL/day over 8 hours)

// The use of very low dosing of anionic polymer assists on the flocculation and sludge dewatering, but can be considered optional, depending on operational circumstances.

// When considering 80% efficiency, the solids production in the DAF will be of approximately 6,300 kg/day.

// Optimising the dosing of Tanfloc will depend on the costs associated, and the removal curve produced can provide information for how low the dosing can be before the efficiency starts to get compromised

// Around 40% savings in aeration costs can be obtained from the reduction of Nitrogen in the pre-treatment.

// We recommend replacing the use of $FeCl_3$ with Tanfloc SG, on a dosing rate of 250 L/1,000 m^3.

The main conclusions of the improvement on polishing using zeolites are:

// The Zeolite clay is efficient on removing ammonia from the effluent, with an uptake capacity of 0.39 mg/g.

// The use of Tanfloc combined with $FeCl_3$ as polishing stage improved the removal of TSS, however didn't affect the efficiency of N and P removal. Therefore, we recommend that in Pond 4 V&V maintain the dosing of $FeCl_3$.

// Zeolite on the form of filters seemed to be more efficient than in the form of powder, resulting in a lower turbidity and relatively lower consumption.

The main conclusions of the production of Biogas from V&V Walsh's Waste streams are:

// All methane potential tests were successful. There were no signs of inhibition or microbial overload observed in any tests and the performance of replicate tests showed a high degree of repeatability.

- // All wastes contained a high solids concentration and a relatively low moisture content. All wastes were diluted by adding inoculum for BMP testing. The specific impacts of solids concentration were not assessed; however, solids concentrations can reduce process performance in AD and this may need to be considered in full-scale process designs.
- // The methane potential of the Combined Saveall was estimated at 568 $L.kgVS^{-1}$ corresponding to a degradable fraction of approximately 84% of COD, this is consistent with highly degradable organic wastes. The degradation rate for the Combined Saveall material was 0.24 day-1. An example process design for this material would be a mixed liquor style reactor with an SRT of >25 days (to convert 85% of the degradable fraction). This assumes the reactor operates at 37°C and does not experience issues with mass transfer.
- // The methane potential of the DAF Belt Press was estimated at 658 L.kg/VS, again this was a highly degradable organic waste stream. The apparent hydrolysis rate of the DAF Belt Press was estimated at 0.09 day^{-1}, which is consistent with a slowly degrading organic waste requiring a long reactor SRT (approx. 40 days in a CSTR).
- // The methane potential of the Sheep Paunch, Beef Paunch and Sheep Manure was estimated at 307, 285 and 211 $L.kgVS^{-1}$ corresponding to a degradable fraction of approximately 58%, 52% and 68% of COD, which is lower than Combined Saveall and DAF Belt Press samples and consistent with the lower degradability for such materials reported in literature.
- // Beef Paunch was the slowest degrading waste tested and could require a treatment SRT over 60 days. Sheep Manure and Sheep Paunch were also considered slowly degrading materials, however SRT of 30 – 40 days is likely sufficient for degradation of these wastes at 37°C.

Based on findings, the results of NPV analysis are presented below:

PV of Capital Expenditure	$2.7 M
PV of Operating Costs	$1.2 M
PV of Income	$7.6 M
NPV	$3.7 M
ROI	5% pa
Return of Investment (from operation)	3 years

8.0 BIBLIOGRAPHY

Australian Beef Sustainability Annual Update (2019). www.sustainableaustralianbeef.com.au.

Bunbury Harvey Regional Council (BHRC), 2020. Integrated Regional Waste Management. South West Regional Waste Group. https://bhrc.wa.gov.au

Daigger GT. (2014). Oxygen and carbon requirements for biological nitrogen removal processes accomplishing nitrification, nitritation, and anammox. Water Environ Res. 2014 Mar;86(3):204-9.

Flood, P.G. and Taylor, J.C., 1991. Mineralogy and Geochemistry of Late Carboniferous zeolitites, Australia. N. Jb.Miner.Mh.2, 49-62.

Moraes, B., Schneider, I., Carissimi, E. (2019). Coagulant production based on Acacia mearnsii tannin and potential uses in the industrial sector in water treatment for human consumption: The Brazilian experience. AIDIS Magazine Vol.12, No.1, 169–180

Oliveira, A., Borges, A., Matos, A. and Nascimento, M. (2018). Estimation on The Concentration of Suspended Solids from Turbidity in The Water of Two Sub-Basins in the Doce River Basin. Doi: http://dx.doi.org/10.1590/1809-4430-Eng.Agric.v38n5p751-759/2018.

Swoboda, K. (2020). Parliament of Australia. Economics. Energy prices—the story behind rising costs. https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BriefingBook44p/EnergyPrices

Standards Australia, Standards New Zealand (reconfirmed 2016). AS/NZS 5667.1:1998 Water quality—Sampling Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples.

Tessele, F. van Lier, J. (2020). Anaerobic Digestion and the Circular Economy. Water e-journal. ISSN 2206-1991 Volume 5 No 3.