The Production And Use As Biofertiliser Of Digestate Derived From Source Segregated Organic Waste

BANZ TECHNICAL GUIDE 8

March 2021

Acknowledgement

Thanks for the preparation of this Guide are to Alzbeta Bouskova, Alistair Broughton and Jurgen Thiele.

About this Guide:

1. The compilation of this Technical Guide has been facilitated by contributions and oversight of the relevant expert members of the Bioenergy Association.
2. The aim of the Association's Technical Guides is to encourage delivery of high quality and consistent best practice bioenergy solutions. These Guidelines are voluntary but essentially provide a regulatory framework for the New Zealand bioenergy and biofuels sector.
3. The Guide is an outcome of industry discussion and collaboration. It captures the collective technical knowledge of a range of relevant leading bioenergy sector personnel. In addition, it benefits from the collective review and use by relevant asset owners, guide users, policy makers and regulators.
4. This guide is provided in good faith as an addition to the ongoing body of knowledge relating to the bioenergy and biofuels sector in New Zealand and Australia. However, as the guide is general and not specific to any application the Association and none of those involved with its preparation accept any liability either for the information contained herein, or its application.
5. As with all Bioenergy Association technical guidance documents, this guide is a 'living document' and will be revised from time to time and reissued, as new information comes to our attention. If you have suggested additions to this guide please contact admin@bioenergy.org.nz.
6. Any enquiries regarding these guidelines should be referred to:

Executive Officer
Bioenergy Association
P O Box 11595, Manners Street
Wellington 6142

executive@bioenergy.org.nz

www.bioenergy.org.nz

Caveat

Bioenergy Association recommends that any party undertaking a project to upgrade or replace a bioenergy facility should undertake a full evaluation of all possible options prior to fixing on a specific new project solution.

As a decision maker, it's important to understand the pros and cons of each option and have them set out by an appropriate expert in a way that ensures they are easily comparable. Too often a client rushes into a solution without properly evaluating all the options.

These Technical Guides are only a guide and users should ensure that they have engaged an appropriate expert to consider their specific application.

Table of Contents

1 FOREWORD

Anaerobic digestion (AD) of animal manure, organic wastes of industrial or municipal origin, and energy crops is gaining substantial interest around the world due to its indisputable economic and socio-environmental benefits; these being the production of renewable energy and fertiliser, reduction of the amount of waste disposed at landfills and the reduction of greenhouse gas emissions.

Anaerobic digestion converts organic waste material into two economically beneficial products: biogas and digestate.

Biogas can be used as a substitute for natural gas for industrial, commercial and residential use. Using established technologies, biogas can be converted to electricity, or heat, or be upgraded to biomethane for injection into the national gas distribution grid, or compressed for use as a transport fuel.

The liquid residues from the anaerobic digestion of organic waste are referred to as either digestate or biosolids. Digestate is the residue from the anaerobic digestion of non-human organic waste, while biosolids is the residue from the anaerobic treatment of municipal sewage waste. Both materials can be beneficially used as a soil fertiliser and conditioner, although stricter regulatory limits apply to the disposal of biosolids to land in order to minimise potential health risks for humans and the environment.

Digestate contains high levels of macro- and micro-nutrients and as such presents an environmentally sound alternative to mineral or synthetic fertilisers. Nevertheless, the use of digestate as biofertiliser has been limited by the perception of farmers, food wholesalers, food retailers, politicians, decision makers and the general public as being unsafe due to its origin from waste materials and/or animal by-products. Separate consideration of the different attributes of digestate from those of biosolids will decouple them from the low value of biosolids and assist in maximising the value of the products from anaerobic digestion of non-human organic wastes.

Due to the high proportion of greenhouse gas emissions associated with waste disposal in New Zealand and Australia, anaerobic digestion plays a key role in the countries' ability to meet their greenhouse gas emissions reduction targets. As more and more communities and business adopt circular economy principles, the production of digestate (biofertiliser) is expected to increase. Providing a clear framework and developing sustainable markets and viable methods of beneficially utilising digestate is essential for the wider uptake of the AD technology.

The ultimate goal of this Technical Guide 8 (TG8) is to provide incentives for further investment in anaerobic digestion applications for processing of source-segregated organic waste[1] in New Zealand, Australia and the South Pacific, by improving the awareness of the monetary, social and environmental benefits this technology offers for the treatment of organic waste.

[1] *Source-segregated organic waste - materials or biowastes that are stored, collected and not subsequently combined with any nonbiodegradable wastes, or any potentially polluting or toxic materials or products, during treatment or storage (whether storage is before or after treatment). NOTE Source-segregated materials can include collection of a mixture of biowaste/biodegradable material types, from more than one source. Such materials do not include sewage sludges and their derivatives, or physical contaminant removal prior to loading the biowaste/biodegradable material into the working digester.*

This Technical Guide 8 (TG8) provides specific guidance on the production of high-quality, safe and healthy digestate for use as a fertiliser substitute. It provides a fundamental basis for the AD facility certification of their digestate as Biofertiliser. The Biofertiliser status decouples the use of the certified product from the regulatory requirements associated with handling and use of waste products.

As such the TG8 creates a parallel and a new alternative to the composting practices currently regulated by the Composting Standard NZS4454.

The Technical Guide 8 does not cover the disposal or beneficial reuse of biosolids to land. These are covered extensively for New Zealand in the *Guidelines for Beneficial use of Organic Materials on Land* (Water NZ, 2020)[2](further referred to as The Guidelines). For more discussion on the relationship between the TG8, Biofertiliser certification and the Guidelines, refer to section 2.6.

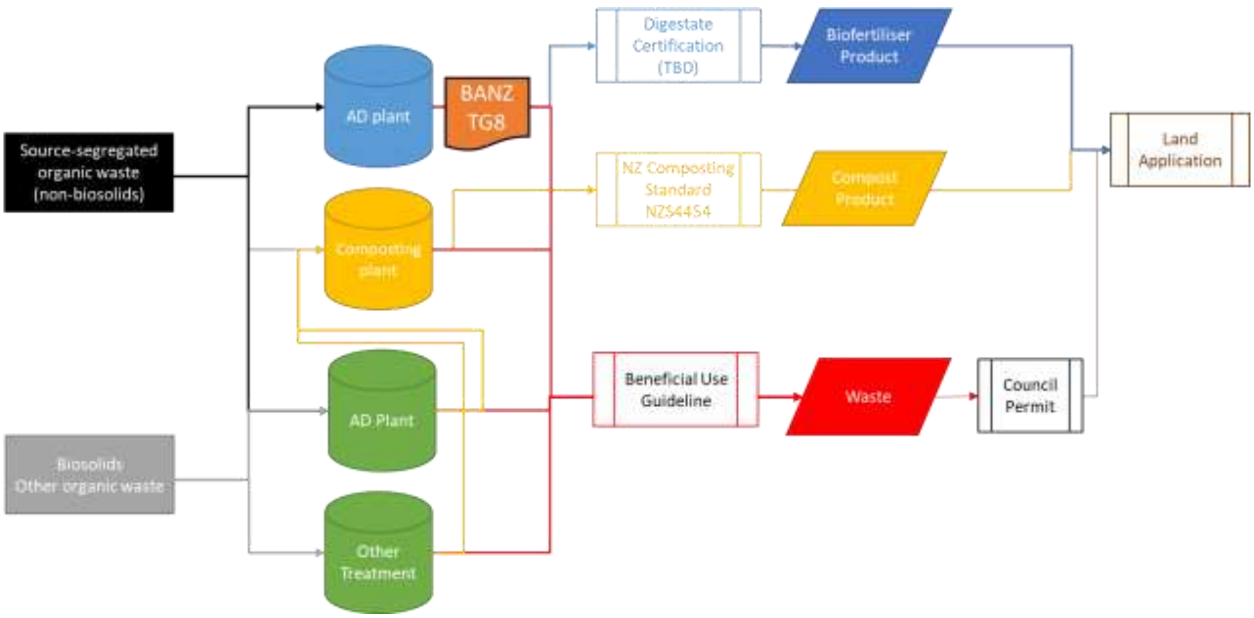


Figure 1 - Organic waste processing pathways.

2 INTRODUCTION

2.1 Anaerobic digestion and its products

Anaerobic digestion (AD) is a collection of naturally occurring processes that convert organic matter, in the absence of oxygen, into energy-rich biogas and liquid residue, known as digestate. Anaerobic digestion has been widely used around the world for the processing of waste organic materials and its popularity is still growing due to its key role in business and communities moving to adopt circular economy principles. In its most important role, anaerobic digestion can facilitate a diversion of large

[2] https://www.waternz.org.nz/Attachment?Action=Download&Attachment_id=3291

volumes of agro-industrial, domestic and commercial waste and by-products from landfill disposal and reduce the methane emissions this practice creates.

Biogas produced from residual organic waste typically consists of 35–75% methane, 25–65% carbon dioxide, 1–5% hydrogen along with minor quantities of water vapor, ammonia, hydrogen sulphide and other contaminants. The biogas can be used for generation of heat and/or electricity or purified, compressed and used as vehicle fuel. More recently, biogas has been used for production of carbon dioxide, methanol or other added-value chemicals.

During the AD process, the majority of nutrients contained in the reclaimed wastes are retained in the form of liquid residue digestate. Digestate can provide an alternative supply of nutrients to farmers as a substitute for mineral fertilisers. This can result in energy, fossil fuel and greenhouse gas emissions savings[3]. The use of digestate derived from food waste can save 20-40 kg CO_2e per tonne of digestate in comparison to mineral fertiliser.

Further to the above listed benefits, digestate can improve New Zealand's balance of trade since a large majority of mineral fertilisers or their raw ingredients are currently imported.

Nutrients (N, P, K, etc.) in digestate are present in a more plant-accessible form than in its raw solid organic waste form, hence increasing the nutrients' utilisation efficiency and reducing pollution of the environment from leaching of the non-utilised portion of the nutrients. The nutrient content of digestate is consistent over time, provided it is stored and handled correctly. This makes it easier for farmers to calculate the required fertiliser application rate to meet crop needs (Birkmose, 2007).

In addition to its nutrient value, digestate also provides large quantities of organic carbon to the soil, which is beneficial for soil and crop health. Research has shown that the use of digestate as biofertiliser leads to an increase in yield, protein content of crops and improved soil moisture-retention properties, and consequently increases quality and quantity of food without adverse effects on the environment (Makadi, Tomoscik, & Orosz , 2012, Wager-Baumann, 2011).

2.2 What is biofertiliser?

Digestate which is suitable for application to productive land as a fertiliser is often referred to as biofertiliser. Internationally, there have been many different definitions. In some parts of Europe digestate cannot be called a biofertiliser unless it is certified. In this document the term Biofertiliser refers to digestate that meets the minimum quality criteria specified in the TG8 and the requirements of the (future) Biofertiliser Certification Framework.

2.3 Anaerobic digestion in Oceania

The use of anaerobic digestion for processing of organic wastes in New Zealand and Australia has been very limited in comparison with other developed countries. This can be mainly attributed to the

[3] 1.2% of annual energy used by mankind is to synthesise N-fertilisers (Wood & Cowie, 2004).

investors' focus being on the biogas production as a source of energy and little regard being given to the value of digestate. The economic benefits of proposed AD projects have therefore been understated because of the relatively low cost of energy, the majority of which is produced from renewable sources in New Zealand, and the low landfill charges.

Anaerobic digestion, despite the low adoption rates to-date, aligns well with a number of core governing principles and policies of New Zealand and Australia:

- Since 2015, New Zealand and Australia have both been committed to achieving the United Nations 17 Sustainable Development Goals (SDGs) and 169 targets. In both countries this is set to be achieved through a combination of domestic and international actions, including sustainable strategies, policy actions and support programmes. Anaerobic Digestion can make a significant contribution to these targets and goals, not only through generating ultra-low carbon energy and biofertiliser, but also through the reduction of harmful methane emissions from food and farming wastes, providing energy and food security, improving waste management and sanitation, and reducing poverty and hunger.

- As part of ratifying the Paris agreement on climate change, the New Zealand government has committed to reduction of greenhouse gas emissions in the Climate Change Response (Zero Carbon) Amendment Act 2019. With 5.1% of New Zealand's total greenhouse gas emissions and equipped with proven and readily available mitigation technologies such as Anaerobic Digestion, the waste sector plays a key role in New Zealand meeting its emission reduction targets.

- Similarly, in Australia the focus on augmenting diminishing natural gas supply by renewable natural gas is driving a greater interest in the production of biogas from organic waste.

- Anaerobic Digestion has the potential to assist with a reduction in reliance on imported fossil fuels driven by an ever-increasing demand for fuel and energy and declining domestic natural gas reserves. Increasing global competition for fossil fuel resources will require the energy mix to change from predominantly coal, oil and gas to being predominantly based on renewable energy from hydro, geothermal, wind, solar, marine and biomass (Biogas Strategy 2010 to 2040, 2011).

- In New Zealand the Waste Minimisation Act encourages a reduction in disposal and an increase in recycling and reuse of waste in order to protect the environment from harm and provide environmental, social, economic and cultural benefits. In Australia most states have now developed strong waste strategies which include incentives for the production of energy.

- Overseas experience shows that segregation of organic waste at source for AD processing incentivises reduction of waste disposal, and increases recycling and use of waste, which is in line with the waste hierarchy as defined by the New Zealand Waste Minimisation Act.

- The increasing interest in circular economy principles at both a governmental and business level is bringing the utilisation of organic waste, rather than disposal to landfill, into the strategic thinking of communities and businesses.

2.4 The processing of residual organic materials

Residual organic waste is the waste remaining after minimisation, recycling and reuse has been maximised.

Figure 2 - The position of Anaerobic Digestion within the waste hierarchy (EU's Waste Framework Directive 2008/98/EC).

For the purpose of this Technical Guide, there are four types of organic waste:

- Mixed waste (typically municipal liquid or solids)
- Source-segregated industrial, domestic or commercial organic waste (liquid or solid)
- Animal residue (manure, litter)
- Biosolids

While this TG8 is specifically designed for the source-segregated organic waste and animal manure, it is important to describe the other categories to provide better clarity to the users.

2.4.1 Mixed Organic Waste

Municipal liquid or solid waste streams are generally mixed and often have variable compositions.

Mixed organic waste is often disposed of to landfill where it decomposes to produce biogas and leachate. Only about 60% of biogas is captured from a modern designed landfill so decomposition of organic waste in a landfill is a very inefficient means of processing organic waste. It also does not produce a solid residue which can be used as a fertiliser substitute.

2.4.2 Source-segregated organic waste

Source-segregation is a process of separating organic materials from other waste to avoid sending organic materials to landfill. Separating organic waste at its source and treating it helps to reduce the amount of waste that goes to landfill, which reduces emissions from landfill. The separated organic waste material is treated separately to produce a low emission alternative such as anaerobic digestion (AD) or composting.

Organic waste may be source segregated, and of known consistent composition (although the feedstock may change seasonally), or mixed source in which case the composition of the feedstock cannot be guaranteed as being known and consistent. If a feedstock is known and consistent then the form and frequency of testing of the resulting digestate can be simplified, but if the feedstock composition is not known then more extensive and frequent testing may be necessary.

AD plants can be purpose-built waste processing facilities for a variety of source-segregated organic residues or be part of the waste management and treatment at the originating industrial processing plant.

AD systems located at an originating food-processing site are designed for removing organic matter from wastewater. They generally do not receive materials from other sites and will only handle their own by-products. These facilities may have the advantage of using co-generation to produce electricity as well as heat, reducing on-site energy costs.

Centralised or non-farm AD systems treating organic wastes are becoming more common outside Europe where they have been used for a number of years. In Europe, centralised AD systems often receive material from many farms and food-processing plants. The digestate is transferred to agricultural fields where the nutrients are needed (away from the original livestock farm sources).

In North America, the current trend is for centralised AD systems to only handle food-processing waste and urban source-separated organics. In some cases, the treated liquid digestate is discharged into municipal sewers for further treatment at the municipal wastewater treatment plant. Centralised systems are often located on the edge of urban areas where there may be opportunities for heat from the centralised AD system to be used at other nearby commercial or industrial facilities.

2.4.3 Animal manure and agricultural waste

Agricultural manure and crop production residual wastes are generally from a single source.

Farm-based processing systems are designed for farm manure, for the manure from several nearby farms, or for the use of residues from crops from local fields. Internationally many farm-based systems will rely on off-farm feedstocks such as food processing by-products to boost biogas production and increase operational effectiveness. Farm-based systems have the advantage of a local source of inputs and the ability to handle digestate nutrients for self-use. When compared to the management of raw manure, farm-based systems experience the additional benefits of odour reduction, pathogen treatment and improved manure handling.

In New Zealand farm dairy effluent discharge to land without prior processing is regulated by regional councils under the Resource Management Act and, in addition, there are a number of good management practice guidelines available from the Dairy NZ website.

It should be noted that the 2019 Biogro compost guidelines[4] allow the use of anaerobic digestion residues as input for certified primary producers producing compost on site in the production of anaerobic compost/bokashi as long as manure is not included and as long as the compost is made for own use (i.e. not for sale of a biofertiliser).

2.4.4 Biosolids

Biosolids are treated sewage sludges from a wastewater treatment plant. It is important to distinguish between sewage sludge and biosolids. Biosolids can only be considered as such once they fulfil the requirements of a set of approved biosolids management guidelines[5].

Sewage sludge is the solids that are collected from the wastewater treatment process, but which have not undergone further treatment. Sludge normally contains up to around 3% solids. Sewage sludge is regarded as having become biosolids once it has undergone further treatment to reduce disease causing pathogens and volatile organic matter significantly, producing a stabilised product suitable for beneficial use.

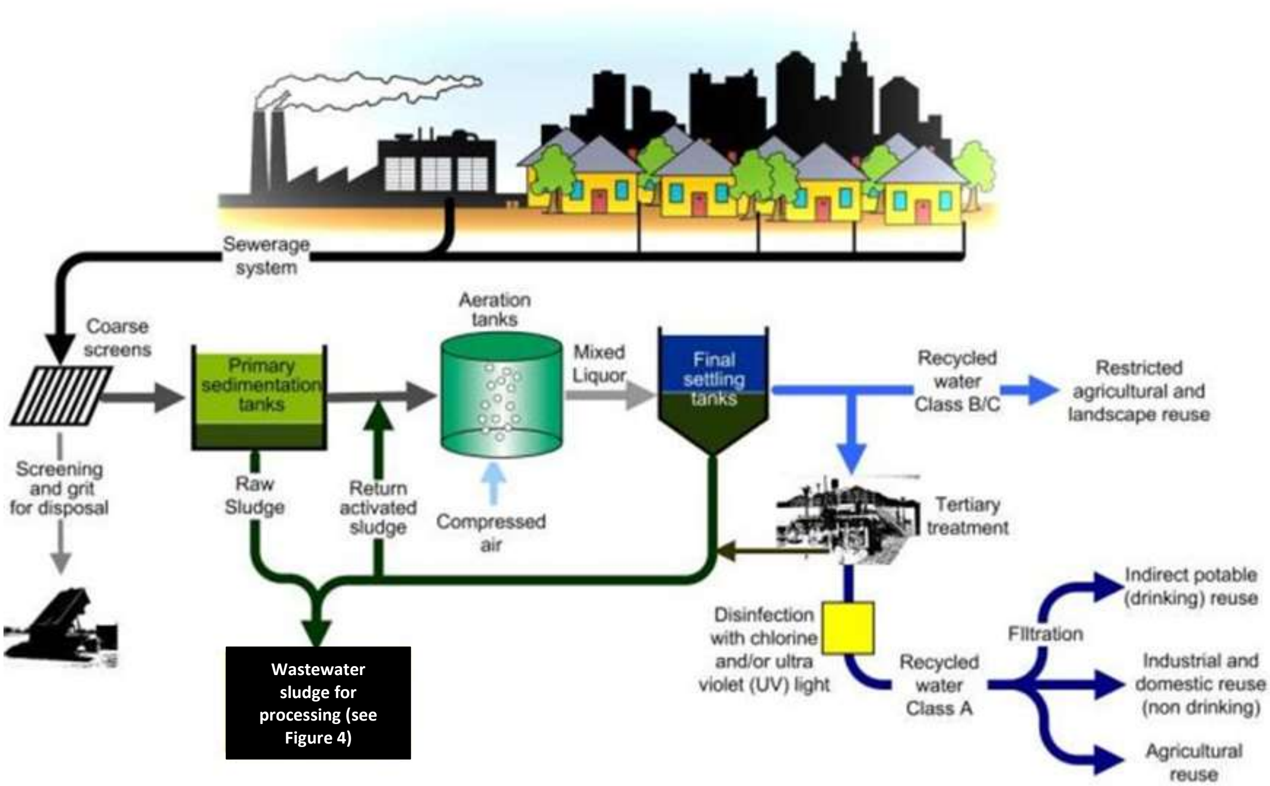


Figure 3 - Processes in a typical wastewater (sewage) treatment plant producing wastewater sludge for processing into biosolids. Source: Australian Water Association.

---

4 ttps://static1.squarespace.com/static/5783012e1b631b1a87b5f0de/t/5e44601260eb477252c92bd6/1581539348008/BioGro+Compost+Guideline_.pdf

5 https://www.biosolids.com.au/info/what-are-biosolids/

Biosolids may contain:

- Macronutrients, such as nitrogen, phosphorus, potassium and sulphur and
- Micronutrients, such as copper, zinc, calcium, magnesium, iron, boron, molybdenum and manganese

Biosolids may also contain traces of emerging organic micropollutants (PFAS, PFOS, others, microplastics), synthetic organic compounds used in the treatment (such as dewatering polymers) and metals, including arsenic, cadmium, chromium, lead, mercury, nickel and selenium. These contaminants limit the extent to which biosolids can be used, with all applications regulated by appropriate regulations. Treatment processes produce a stabilised product suitable for beneficial use.

Biosolids, normally contain between 15% to 90% solids. Biosolids are carefully treated and monitored and they must be used in accordance with regulatory requirements.

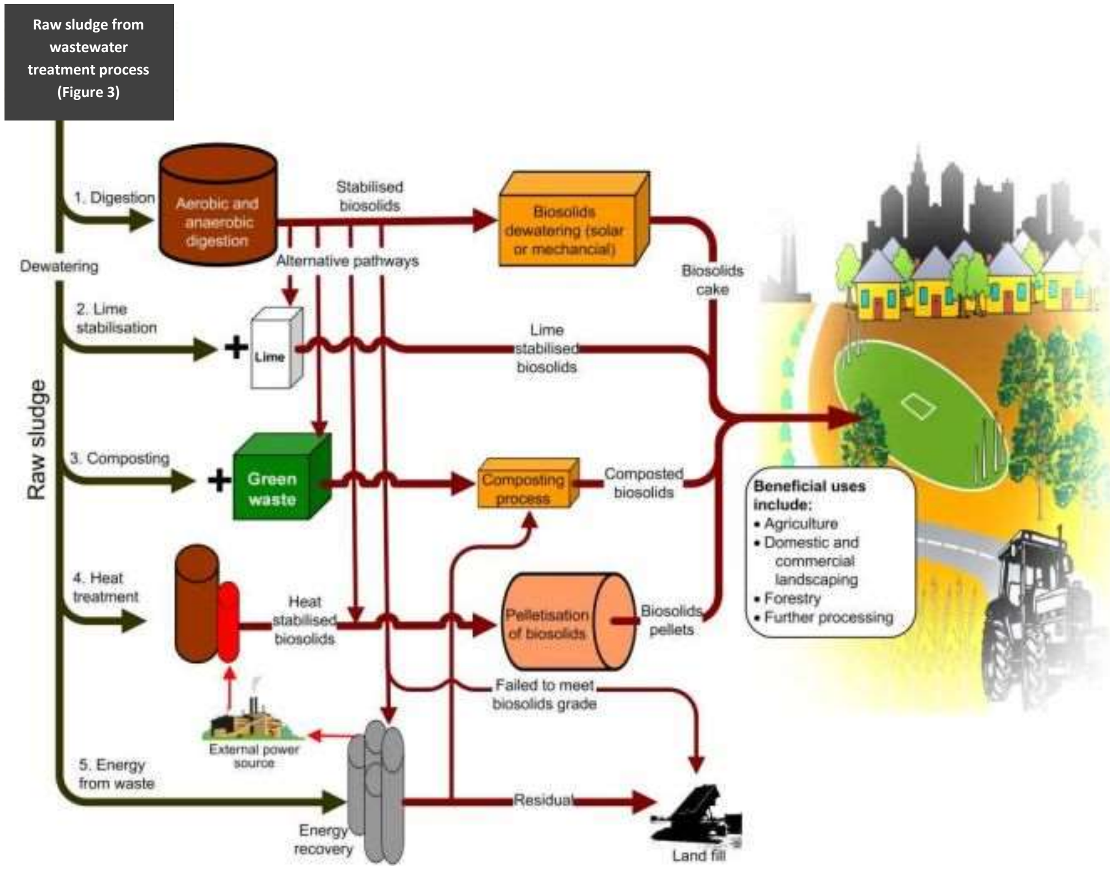


Figure 4 - Five typical production systems for biosolids with possible alterative productions pathways. Source: Australian Water Association.

Biosolids are graded according to chemical composition and the level of pathogens remaining after production. Not all biosolids can be used for all applications. Lower qualities are typically used for road bases and mine site rehabilitation. Only the highest grade of biosolids can be used to grow crops for human consumption. In Australia regulators, such as State Departments of Health and Environment strictly control the production, quality and application of biosolids. In New Zealand the regulators follow the *Guidelines for safe application of biosolids to land 2003*6

In Australia and New Zealand, biosolids have been used for:

- Land application in agriculture (vine, cereal, pasture, olive)
- Co-generation/power production/energy recovery
- Road base
- Land application in forestry operations
- Land rehabilitation (including landfill capping)
- Landscaping and topsoil
- Composting
- Oil from sludge (experimental).

Other uses include:

- Bricks and construction material
- Vitrification (glass manufacture)
- Solid biofuel
- Fuel substitute (cement works)

2.5 Composting or anaerobic digestion of source separated organic wastes

Currently, the most common method of processing organic waste is by composting. This traditional method dates back many centuries when farmers would leave organic wastes in the open to decompose slowly and naturally on their land. Nowadays, in New Zealand the disposal of compost to land is covered by *NZS 4454:2005, Composts, Soil conditioners and Mulches* which sets out the minimum quality criteria for composting facilities and their products for their beneficial use.

Despite the compost's beneficial soil-conditioning properties and process operational simplicity, composting is not suitable for all organic waste. These are for example animal by-products such as meat which, even composted, cannot be used as a soil conditioner where animals graze. There are also very wet organic wastes which are better suited to anaerobic digestion than composting where drier matter is more appropriate.

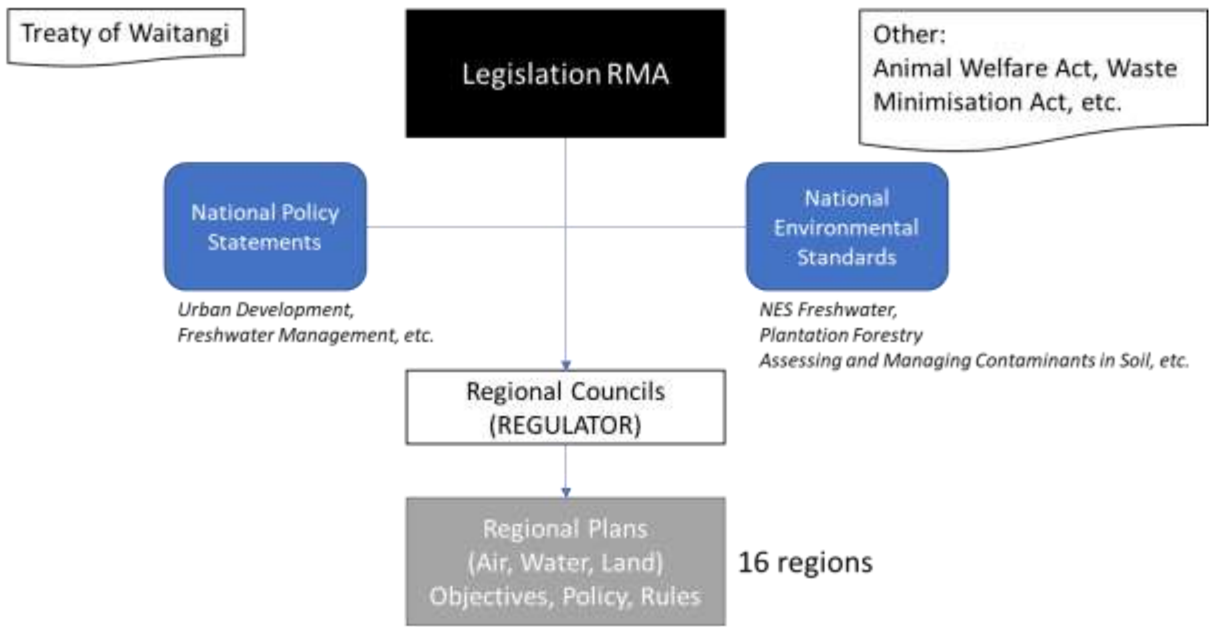
Anaerobic digestions and composting should therefore be viewed as complimentary technologies and their merits and risks need to be assessed on a case-by-case basis. Among other factors, consideration needs to be given to the type of waste available, footprint and location of the processing site and market demand for the product.

[6] https://www.bioenergy.org.nz/resource/biosolids-guidelines-report-2003

2.6 Digestate within the current New Zealand Regulatory framework

Other than the fish waste digestate product produced by Globe Fisheries in their large on site digester in the 1990's and 2000's which received BioGro certification and was used for many years in pastoral farming the application of digestate as biofertiliser has not previously been validated in New Zealand due to the scarce utilisation of the AD process to date. Conversely, the lack of clear regulatory framework for the application of digestate on land has been identified as one of the key barriers for wider utilisation of the technology.

The underlying legislation governing the application of any organic material products (including digestate) to land in New Zealand is the Resource Management Act 1991 (RMA). Apart from direct regulations, the RMA is used as a basis for development of region-specific resource management plans that ultimately define the rules applicable to the use of digestate on land.



Further to that, there are currently three key documents that are directly or indirectly related to the use of digestate as fertiliser:

- *Guidelines for safe application of biosolids to land 2003*[7] (Biosolids Guidelines)
- Water NZ - *Guidelines for Beneficial Use of Organic Materials on Productive Land*[8] (The Guidelines)
- Soil replacement requirements specified for urban and rural areas embedded in individual regional resource management plans

[7] https://www.bioenergy.org.nz/resource/biosolids-guidelines-report-2003

[8] https://www.waternz.org.nz/Projects

Other legislation (e.g., the Agricultural Compounds and Veterinary Medicines Act, the Health Act, the Land Transport Act) may have a direct or indirect bearing on a given manufacturing or distribution project depending on the specific feedstocks and technology used.

The main governing document (Biosolids guidelines 2003) is currently undergoing a revision with the revised document (The Guidelines for Beneficial Use) expected to be released in 2021[7]. Although the new Guidelines will not have a regulatory status, it is anticipated that all councils will adopt the revised Guidelines when evaluating and consenting the production and use of digestate.

However, in the context of the new Guidelines, digestate, regardless of its origin, its beneficial properties or nutrient quality, is considered to be waste. As such, biosolids and/or digestate require testing to prove they possess low risk for the receiving environment. The level of testing is dependent on the source of the feedstock and the form of treatment.

A fundamental premise of the revised Guidelines is that, rather than focusing only on biosolids, the scope has been widened so that a wide range of organic materials can be beneficially recycled to land. Provided that both the process of product manufacture and the process of applying the material to land are subject to adequate management control, and providing the organic material is applied at a rate that does not exceed the agronomic nitrogen requirements of crops.

The relationship between TG8 and the Guidelines is similar to that of the New Zealand Standard 4454:2005 - Composts, Soil Conditioners and Mulches, in that there is a hierarchy of guidelines with the Guidelines being the overarching document. If the methods and limits for protecting soil, the environment, and public health change or differ in the Guidelines then the Guidelines methods and limits will take precedence over TG8. The reason for this hierarchy is that the Guidelines have been developed with and will be endorsed by Government agencies including The Ministry of Health, The Ministry for Primary Industries and The Ministry for the Environment.

TG8 is an industry specific guide sitting within the Guidelines. It is important that individual industries develop their own specific guidelines that provide tailored solutions for specific product streams. The Bioenergy Association works to ensure that TG8 is aligned with the contaminant limits and risk management practices in the Guidelines to ensure the safe and beneficial re-use of organic waste in NZ.

2.7 Digestate within the Australian Regulatory framework

In the Australian jurisdictions, AD is a recognised treatment method of treating sewage sludge at WWTPs so that it can be applied to land as biosolids. Australian regulations for the use of biosolids are set individually by states. All regulations require the digestate to ensure pathogen and seed elimination, compliance with other legislation as well as set limits on heavy metal concentrations.

There is a lack of consistent national regulation for the digestate from source-segregated organic waste, which prevents the industry from maximising its use. Specifically, the conditions for using it as a commercial product need to be clarified, as well as the specifications of its composition.

2.8 Digestate within the United Kingdom regulatory framework

The use of digestate, derived from source segregated biodegradable waste, as a beneficial source of nutrients has been successfully adopted in the UK via the framework outlined below. This framework is valid for AD plants that process waste of animal or plant origin that can be biologically decomposed. As such, this framework does not apply to AD plants processing biosolids or other waste of human origin.

Within this framework, digestate can be applied on land in two forms:

1) As a biofertiliser product which requires compliance with
   a) BSI PAS 110 - minimum digestate quality criteria[9]
   b) The Anaerobic Digestate Quality Protocol[10]
   c) Biofertiliser Certification Rules

2) As waste, which requires:
   a) compliance with BSI PAS110 compliant digestate
   b) provision of an EPA deployment permit.
   c) The AD plant operators may seek Quality Assurance Certification to boost the credibility of their output/digestate.

The application of biosolids on agricultural land is regulated by The Sludge (Use in Agriculture) Regulations 1989[11] and the Safe Sludge Matrix[12].

The Biofertiliser Certification Scheme[13] is the only independent scheme in the UK aligned and providing a framework for independent assessment and certification of digestate to BSI PAS 110, the Anaerobic Digestate Quality Protocol, the Scottish Environment Protection Agency's (SEPA's) regulatory position statement, and the BCS Scheme Rules.

Any UK producer can choose to apply for BSI PAS 110 certification, irrespective of the country/ies in which the digestate is used and according to whether it is intended to be supplied as a ‘product' or a ‘waste'.

The Anaerobic Digestate Quality Protocol sets out end of waste criteria for the production and use of quality outputs from anaerobic digestion of source-segregated biodegradable waste. To be Quality Protocol compliant for this material, people will need to be certified against the BSI PAS110 certification scheme, which is managed by the Environment Agency.

[9] https://www.wrap.org.uk/content/bsi-pas-110-producing-quality-anaerobic-digestate
[10] http://www.biofertiliser.org.uk/adqp
[11] http://www.legislation.gov.uk/uksi/1989/1263/made
[12] https://www.fas.scot/downloads/safe-sludge-matrix/
[13] https://www.biofertiliser.org.uk/

BSI PAS 110 - Producing quality anaerobic digestate[14]

The publicly-available specification (PAS) BSI PAS 110 aims to remove the major barrier to the development of AD and its markets for digestion process outputs by creating an industry specification against which producers can verify that they produce a product which is of consistent quality and fit for purpose.

BSI PAS 110 covers all AD systems that accept source-segregated biowastes. It specifies:

- Controls on input materials and the management system for the process of anaerobic digestion and associated technologies;
- Minimum quality of whole digestate, separated fibre and separated liquor; and
- Information that is required to be supplied to the digestate recipient.

The Quality Protocol for Anaerobic Digestate[15]

The Anaerobic Digestate Quality Protocol sets out criteria for the production and use of outputs from anaerobic digestion of source-segregated biodegradable waste.

The Quality Protocol (QP) gives official status to the PAS 110 in England, Wales and Northern Ireland.

To be Quality Protocol compliant for this material, people will need to be certified against the BSI PAS110 certification scheme, which is managed by the Environment Agency.

The protocol provides a set of criteria for the production, placement on the market, storage and use of products derived from suitable types and sources of waste, such that any risks to the environment and to human and animal health are acceptably low when any such product might, under certain circumstances, be used without waste regulatory controls. The Protocol also sets out how compliance with its criteria should be demonstrated.

Additional information on the processing of residual organic waste in the UK is available from WRAP UK[16].

3 Role of Technical Guide 8

This Technical Guide (TG8) focuses on the use of digestate produced from source separated organic waste as biofertiliser, providing information to help farmers, suppliers, retailers and manufacturers benefit from digestate use on crops, whether produced on site at the farm or from offsite AD plants.

The TG8 provides specification for digestate producers to achieve consistent quality digestate suitable for certification and sale as biofertiliser. TG8 sets out the minimum quality required for the operation of

[14] http://www.wrap.org.uk/content/bsi-pas-110-specification-digestate
[15] https://www.wrap.org.uk/content/bsi-pas-110-producing-quality-anaerobic-digestate
[16] https://www.wrap.org.uk/

an anaerobic digester facility treating source segregated organic waste to consistently produce digestate compliant with the product quality criteria as specified in the document.

3.1 Waste or Biofertiliser Product

While compliance with TG8 ensures consistent and high quality of digestate, the TG8 compliant digestate continues to carry a legal status of waste, and the handling and use of the digestate is regulated within the waste-relevant regulatory framework. In New Zealand, the main guiding document is the *Guidelines for Beneficial Use of Organic Residues* (Water NZ, 2020).

To minimise regulatory costs and maximise the revenue attainable from sale of digestate as biofertiliser it is recommended that the AD facilities undergo further certification in order to decouple the digestate product from the regulatory framework related to waste. The digestate produced at so certified AD facilities will carry the status of Biofertiliser.

The framework for TG8 is shown in Figure 5.

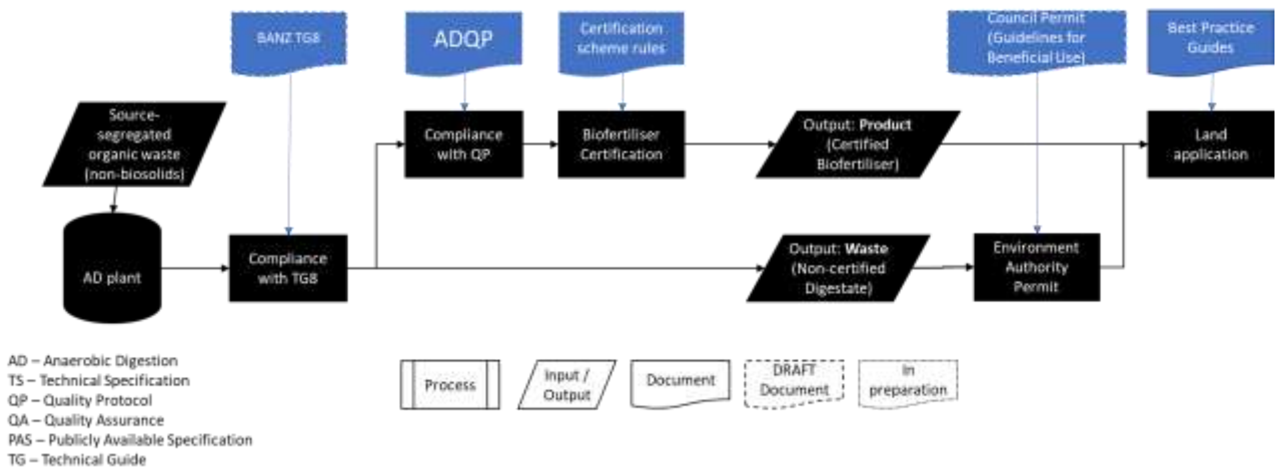


Figure 5 - Proposed framework for use of digestate from anaerobic digestion of source-segregated organic waste.

As shown in Figure 5 source-segregated organic waste can go down either the pathway covered by TG8 which results in a product able to be sold as a certified biofertiliser, or the pathway covered by the Guidelines which can result in a non-certified fertiliser product. It is recommended that organic waste be processed by AD plant into a certified biofertiliser which will provide increased revenue and reduced processing costs because the processing facility requires reduced testing as it operates within a quality assurance system, rather than the quality control system specified by the Guidelines.

The facilities that choose not to or cannot pursue the biofertiliser certification due to feedstock composition or other reasons, are encouraged to refer to the TG8 for best practice guidance for safe, reliable and stable operation of anaerobic digestion processes.

3.2 Non-certified Digestate

Regional councils in New Zealand regulate the disposal or use of non-certified digestate onto land and this may be a prohibited, permitted or discretionary activity depending on the digestate treatment and quality as specified in the Biosolids Guidelines 2003 (the Guidelines) or its revised version the *Guidelines for Beneficial Use of Organic Residues* (TBA 2020). The Guidelines set out extensive quality control testing requirements.

This TG8**,** as well as the existing NZS4454 Composting Standard or any other future certifications and standards, adopts the same product quality requirements as specified in the Guidelines and recommends that, with predictable AD plant operation (Quality Assurance) and provided that consistent source segregated waste feedstock is used, an alternative more cost-effective approach can be taken to achieve compliance with The Guidelines. These limits specified in the Guidelines have been approved by the Ministry of Health, Ministry for Primary Industries and the Ministry for the Environment as safe for all, humans, animals and plants.

The authors acknowledge that the matters discussed in the TG8 may bear importance to Māori culture and traditions. The governing document, the *Guidelines for beneficial use of organic materials* prepared by Water NZ, has been extensively consulted with iwi authorities. The consultation of the TG8 with iwi authority will therefore take the form of public announcements and invitations for feedback.

This TG8 will therefore be of assistance to consenting authorities to allow digestate to be a permitted activity thus reducing regulatory and compliance costs.

Customers purchasing digestate that has been produced following this best practice guide will be assured that the digestate quality meets the requirements of The Guidelines.

This technical guide applies only to anaerobic digestion of source segregated organic feedstock. However, facilities digesting non-source segregated feedstock may use elements of the guide where appropriate.

3.3 Biofertiliser Certification

Waste-derived digestate that achieves certification is no longer classed as a waste and can be spread beneficially to land without the need for the extensive environmental permitting process set out in The Guidelines.

Certification of AD facilities treating controlled source-segregated organic waste, will reduce compliance costs and increase regulator comfort that the biofertiliser produced from the AD facility is safe and of high quality. The digestate produced in a so-certified facility will receive a status of a Biofertiliser and its use will follow the same regulatory requirements applicable to conventional fertiliser.

The details of the Certification requirements and process will be provided in a separate document.

The approach in TG8 is similar to the BioGro or Fertmark approach where BioGro/Fertmark certified primary producers make products suitable for use on their certified properties.

3.4 Why follow Technical Guide 8?

The TG8 promotes the process-oriented Quality Assurance approach over the product-focused Quality Control approach specified in the Biosolids Guidelines. The QA approach encourages good selection, design and operation of the treatment processes and provides benefit to those that select processes that are inherently more robust and therefore less likely to fail to adequately treat.

Higher emphasis on Quality Assurance increases the reliability of the treatment outcome, while allowing reduction in frequency, extent and consequently the cost of the end product testing currently prescribed in the Guidelines. Conformance with the TG8 provides assurance to consumers, farmers, food producers and retailers that digestate produced from the AD facility is safe for human, animal and plant health and compliant with the regulatory quality requirements.

4 Scope and General

4.1 Scope

This Technical Guide 8 (TG8) provides specification for anaerobic digestion systems treating **source-segregated organic waste** to produce digestate of consistently high quality that can be readily applied on land as biofertiliser.

This TG8 specifically excludes digestate from anaerobic digesters treating municipal sludges of human origin, utilisation of which is governed by the Biosolids Guidelines 2003 or its valid revision. Animal waste carrying a risk of disease is also excluded from the scope of the TG8.

TG8 specifies:

- Quality assurance system requirements for AD plant operators
- Type and control of input materials
- Management of the digestion facility including ancillary equipment
- Minimum quality of digestate or products derived from further processing of digestate
- Testing requirements

4.2 Objective

The TG8 aims to remove a major barrier to wider uptake of AD for processing of source segregated organic waste by providing a clear specification to plant operators for the production of consistently high-quality market-acceptable biofertiliser.

With the exception of compost, production of which is regulated by NZS4454-2005, application of organic waste materials on land is governed by the Biosolids Guidelines (2003) and its successor version, the *Guidelines for Beneficial Use of Organic Materials on Land* (expected release in 2020). As such, the use of digestates are subject to an extensive permitting process.

Operators of AD plants may, at the discretion of consenting authorities[17], obtain exemption for their digestate from the permitting process for disposal to land by achieving a status of biofertiliser via:

- further treatment of digestate in a composting facility certified by an accredited certifier, or
- obtaining Anaerobic Digestate Biofertiliser Certification (in development[18])

Compliance with TG8 specifications sets out a baseline quality assurance for achieving compliance for the latter with respect and reference to the quality limits imposed in the Biosolids Guidelines (2003) or its effective revised version.

Figure 6 shows the relationship between the different feedstock categories and the regulatory requirements.

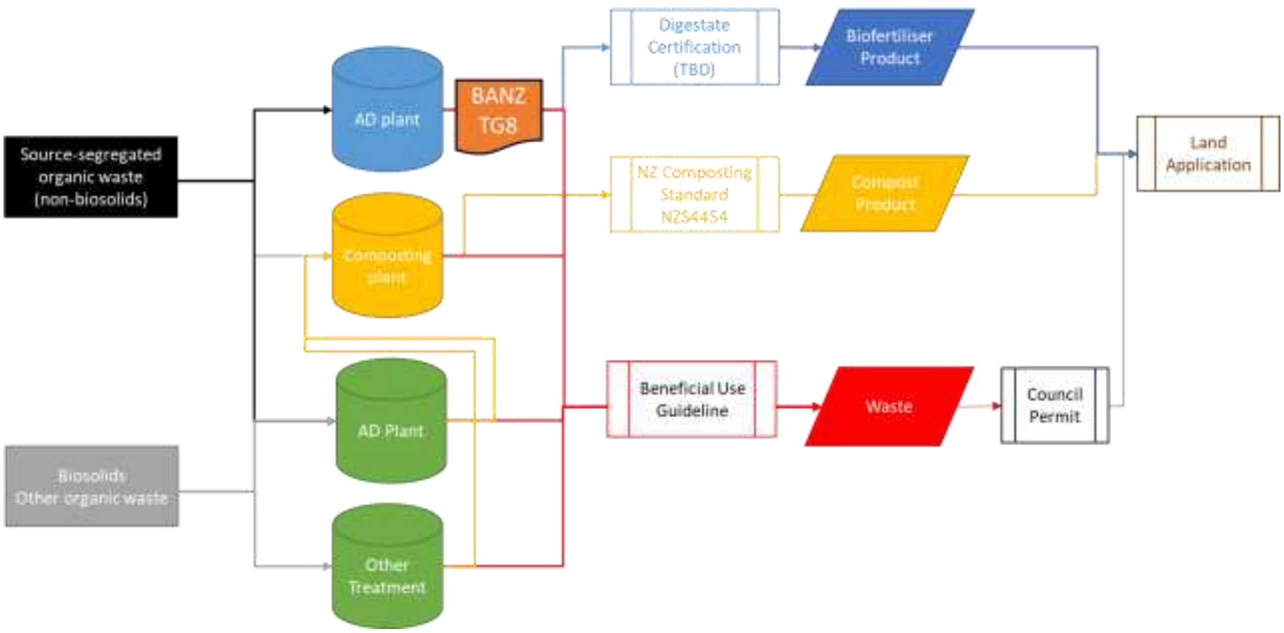


Figure 6 - The three available pathways for processing and beneficial use of organic waste on land in New Zealand.

Complying compost may be combined with a certified biofertiliser to produce a mixed product which in itself may be certified as suitable for use on productive land. Similarly, certified biofertiliser may be mixed with a pasteurised biosolid material for use as a fertiliser or soil conditioner but that is beyond the scope of this document.

Digestate from a specific feedstock can be mixed with digestate derived from another feedstock to produce a specified fertiliser which could be certified if TG8 is followed throughout. This allows for a diversified range of application focused liquid biofertiliser formulations. For example, fish waste turned

[17] Regional Councils acting as consenting authorities operate within the Rules in their Regional Plans. These Rules are only changed when the Regional Plan is reviewed. As a consequence the certification framework set out in TG8 will only be recognized at the discretion of Council.

[18] In New Zealand Fertmark have expressed an interest in certifying digestate as biofertiliser and Bioenergy Association is working with them to establish criteria and processes.

to fish fertiliser digestate and then blended with molasses and pasteurised high P, K digestate from other co-digestion systems.

4.3 Link to international best practice

This guide draws on the success and extensive experience of the United Kingdom anaerobic digestion industry's best practice and regulatory guidelines for processing organic waste to biogas and digestate.

The United Kingdom *BSI PAS110 Specification for whole digestate, separated liquor and separated fibre derived from the anaerobic digestion of source-segregated biodegradable materials* is the general international standard used in many countries. Along with the *Quality Protocol for Anaerobic Digestate* it has been in use for over 10 years and is highly respected. This Technical Guide references sections of PAS110 and the Quality Protocol. Other aspects have been modified to be applicable to the New Zealand and Australian markets.

5 General Requirements

Anaerobic digestion (AD) is a natural process in which micro-organisms decompose organic matter (feedstock) in airtight digester tanks to produce biogas and digestate. Almost any organic material can be processed with anaerobic digestion. The selected feedstock can include animal manures, agricultural crops, agro-food processing residues, food residues, the organic fraction of household waste, organic fractions of industrial wastes and by-products, sewage sludge, municipal solid waste, etc. The feedstock, sometimes also referred to as substrate, can be either a single input (e.g. animal manure) or a mixture of two or more feedstock types (this is termed co-digestion). Most biogas plants use more than one substrate. When the dry matter content of the feedstock is below 15% the AD process is called 'wet' digestion (or 'wet' fermentation); when it is above this level the process is referred to as 'dry' digestion (Lukehurst, Frost, & Al Seadi, 2011).

Anaerobic digestion is a scalable technology with applications ranging from individual on-site digesters for industrial plants or farms to community and regional digester facilities. Anaerobic digestion is also a well-established technology. It is proven in New Zealand with the processing of sewage sludge at 11 municipal wastewater treatment plants and manure treatment in some smaller scale, on-farm digesters. In most of these situations the digestate is treated as a problematic waste rather than as a potential revenue stream from use as a biofertiliser, disposing the digestate to landfills. In some instances (e.g. Mangere WWTP), digestate is dewatered and used for rehabilitation of land for recreational purposes.

The Technical Guide 8 is divided into the following sections:

- Quality Assurance System
- Feedstock Control
- Process Management
- Product Management
- Application Management

5.1 Quality Assurance System

Note: AD facilities not meeting the scope of this guide for production of biofertiliser need to refer to The Guideline for further requirements that may apply to their Quality Assurance System.

Operators of any Anaerobic Digestion facility should adopt and implement a Quality Assurance system in order to ensure that the produced digestate is of consistently high quality. **Quality assurance (QA)** is a way of preventing mistakes and defects in manufactured products and avoiding problems when delivering products to customers. Quality Assurance is part of quality management system focused on providing confidence that product quality requirements will be fulfilled.

Within the context of this Technical Guide, higher emphasis on Quality Assurance increases the reliability of the treatment outcome, while allowing reduction in frequency, extent and consequently the cost of the end product testing currently prescribed in The Guidelines.

Note that The Guidelines require "Accredited quality assurance" for compliance with Grade A and recommend "Verified quality assurance" for Grade B. Refer to The Guidelines for further Quality Assurance requirements.

The QA system needs to encompass the following:

- Controls on the input materials
- A hazard analysis be conducted to define critical performance parameters
- A pasteurisation process or approved alternative
- A verification process that includes the process monitoring
- Specific components of the quality management system

5.1.1 Quality Management System

The four main components of a quality management process are Quality Planning, Quality Assurance, Quality Control and Continuous Improvement.

Each AD Facility needs to establish and maintain a specific Quality Management System (QMS). This QMS will be based on EN ISO 9001 and applied to the appropriate and relevant extent to each facility.

The key aspects of QMS for AD facilities are:

1. **Management engagement and leadership** – senior management needs to demonstrate and communicate commitment to the established quality management system and to continuous improvement.
2. **Adequate resourcing** – for both, operation and maintenance of the facility as well as of the QMS. This requires securing and/or developing appropriate competence and skills, provision of training and processes and tools for effective knowledge transfer.
3. Clear **definition of roles and responsibilities** and effective communication of these to the staff.

4. **Quality commitment** from management to meeting quality standards and customers' requirements in form of quality policy.
5. **Effective communication** internally and externally of relevant parts of the QMS, including quality standards, processes and results.
6. **Regular reviews** in form of regular internal audit and management review of the QMS and the HACCP plan. The outcome of the reviews needs to be appropriately recorded, communicated and actioned.
7. **Reporting** of facility performance and in particular of incidents and accidents or complaints and concerns
8. **Document control** of documents relevant to the QMS needs to be established and maintained. This includes establishing of document approval, identification, access, storage and archiving processes.

5.1.2 Hazard Analysis

Hazard analysis forms a key part of the process design and plant operation in order to ensure consistent production of high-quality specified digestate. The hazard analysis aims to identify risks that need to be reduced to acceptable levels, avoided, or eliminated.

The recommended framework for conducting the analysis is Hazard Analysis and Critical Control Point (HACCP) planning. The main principles of the HACCP planning are:

Principle 1: Conduct a Hazard Analysis - listing the steps in the process and identifying where significant hazards are likely to occur with a focus on hazards that can be prevented, eliminated, or controlled by the HACCP plan. A justification for including or excluding the hazard is reported and possible control measures are identified. These hazards will include:

- Pathogens and toxins that adversely affect human or animal health
- Odours offensive to people who live or work in close proximity to the facility or location of digestate use,
- Inert material such as stones, plastics, wood, glass, etc.
- Sharps that may adversely affect human and animal health.

Principle 2: Determine Critical Control Points - A critical control point (CCP) is a point, step or procedure at which control can be applied and a safety hazard can be prevented, eliminated or reduced to acceptable levels. Acceptable level is equivalent to the minimum digestate quality required in this document. The number of CCP's needed depends on the processing steps and the control needed to assure product safety.

Principle 3: Establish the Critical Limits - A critical limit (CL) is the maximum and/or minimum value to which a biological, chemical, or physical parameter must be controlled at a CCP to prevent, eliminate, or reduce to an acceptable level the occurrence of a product or safety hazard.

Principle 4: Establish Monitoring Procedures - for the measurement of the critical limit at each critical control point. Monitoring procedures should describe how the measurement will be taken, when the measurement is taken, who is responsible for the measurement and how frequently the measurement is taken during operation.

Principle 5: Establish Corrective Actions - procedures that are followed when a deviation in a critical limit occurs to prevent potentially non-compliant digestate from being produced and the steps that are needed to correct the process. This usually includes identification of the problems and the steps taken to assure that the problem will not occur again.

Principle 6: Establish Verification Procedures - Those activities, other than monitoring, that determine the validity of the HACCP plan and that the system is operating according to the plan, such as auditing of CCP's, record review, instrument calibration and product testing as part of the verification activities.

Principle 7: Establish Record-Keeping Procedures – in order to secure information that can be used to prove that the digestate was produced safely. The records also need to include information about the HACCP plan, product description, flow diagrams, the hazard analysis, the CCP's identified, Critical Limits, Monitoring System, Corrective Actions, Recordkeeping Procedures, and Verification Procedures.

5.2 Feedstock Control

Note: AD facilities not meeting the scope of this guide for production of biofertiliser need to refer to The Guideline for further requirements that may apply to Feedstock Control

Anaerobic micro-organisms can decompose all kinds of organic materials. The most abundant types of feedstock in New Zealand suitable for AD treatment are animal manures, industrial waste from dairy and meat processing plants (DAF sludge), sewage sludges (not of relevance within the TG8) and source segregated organic fraction of municipal solid waste (OFMSW).

5.2.1 Feedstock composition

5.2.1.1 Composition

Feedstocks vary in their biodegradability and content of macro- and micro- nutrients. Biodegradability and nutrient content, along with the efficiency and stability of the digestion process, determine the final fertiliser composition of the digestate. While the organic matter gets degraded in the course of AD by 50-70%, the majority of the nutrients remain in the digestate. For the organic matter that does not get fully degraded (typically fibre and ligno-cellulosic compounds) this can provide beneficial carbon to provide structure to soils and improve water retention qualities. Appendix A provides generic information on the composition of common AD feedstocks.

5.2.1.2 Nutrients

Macronutrients (N, P, S) and micronutrients are essential for life and growth of all plants, animals and all live organisms. Animals absorb nutrients from their feed, but only to a very limited extent and a large majority of the nutrients are excreted. Plants absorb nutrients from soil at the rate required for their growth. Animal manures, plant residues and food waste are therefore an optimum feedstock for biofertiliser production. The elements essential for plant growth get utilised when digestate is applied as biofertiliser, closing the nutrient loop within the food cycle.

From the biogas production perspective, animal manures give relatively low biogas yields and are often co-digested with other biogas-potent materials, such as industrial sludges, waste fat or supplementary agricultural crop material. The AD facility operators are usually limited in selecting feedstocks by their availability within the “catchment”. It is however important to pay attention to the nutrient content of the individual feedstock types since a well-balanced nutrient feedstock mixture positively affects the bacterial activity as well as the value of the digestate product.

5.2.1.3 Contamination

Feedstock contamination can be divided into the following categories:

- Heavy metals
- Persistent organic pollutants
- Physical contaminants
- Biological contamination

Along with nutrients, waste materials usually contain a certain level of heavy metals and in some cases, also potentially toxic or non-degradable (persistent) organic compounds. Some heavy metals (so called trace elements such as cobalt, copper, selenium, zinc and others) are in small quantities essential nutrients for healthy life, but most heavy metals have the potential to become toxic at higher concentrations or when metabolised and accumulated in soft tissues (Al Seadi & Lukehurst, 2012).

Persistent organic pollutants (POPs) cannot be degraded in the environment and are often directly toxic to living matter. Heavy metals and POPs will not be removed through AD and will remain in the digestate. While nutrients get utilised when digestate is applied as biofertiliser, heavy metals or persistent organic molecules can also be absorbed.

Herbicides and fungicides may be an issue when supplementary agricultural crop material is being digested. While the probability of transfer of most pesticides through digestate application back to land appears to be relatively low (Al Seadi & Lukehurst, 2012), there is still debate around the persistence of some common herbicides such as glyphosate (Kissane & Shepherd, 2017).

Physical contaminants can be present in the form of large clumps of digestible material or non-biodegradable objects, such as metal, plastic, wood or packaging material.

Feedstocks derived mainly from animal by-products may contain biological risks, such as transmissible bacteria, viruses, intestinal parasites, weed and crop seeds and crop diseases. Although AD has a certain degree of sanitation effect, some additional measures may need to be taken so that the produced digestate is free of these entities. In order to avoid contamination, some feedstock or the resulting digestate may require pasteurisation either at the production site or at the AD site. Digestate is a biologically active biomass and as such requires continuous quality monitoring and rigorous observance of safe production and handling practices. Refer to section 5.3.3 for more details.

The presence of chemicals arising from processing (e.g. chemical flocculants and preservatives) and feedstock production (e.g. synthetic fertilisers) may preclude the digestate as being defined as an organic fertiliser. It is not the intention that digestate certification would specify the digestate as “organic”.

The high biological risk, along with heavy metal contamination, is the reason why co-digestion of sewage sludge (i.e. solid residue from treatment of municipal sewage) in AD plants using digestate as biofertiliser is strictly controlled and has been excluded from the scope of this TG8.

5.2.2 Feedstock control

Rigorous selection and quality control of the AD feedstock is the most critical point in the production of digestate.

In order to ensure appropriate quality of the digestate, AD plant operators must have complete control over the quality of the feedstock being treated in their facility. Adequate records of all feedstock composition must be obtained, recorded and made available to the digestate customers/users.

The AD plant operators are responsible for making sure that the feedstock suppliers understand the importance of and the risk associated with the quality of the supplied material on the performance of the plant and quality of the output material.

Basic information, which should be provided by feedstock suppliers includes:

1) The origin of the material (location, producer),
2) Product Description
3) Amount (volume and weight)
4) Collection, pre-treatment and handling practices (e.g. waste collection system),
5) Physical description (odour, colour),
6) Contaminants (physical, chemical, biological)
7) Handling and storage instructions.
8) Date delivered

This information can be provided as part of the feedstock supply agreement with a condition to inform the AD operators of any substantial deviation in the feedstock quality or composition. The supply agreement should also comprise a declaration that each input material is fit for purpose and is free from any contaminants specified by the AD operator.

The above information would not generally be required in detail for AD facilities where the feedstock is generated and digestate used within the same co-operative or holdings, provided feedstock comprises only manures, unprocessed/processed crops, crop residues or animal bedding and provided the risk of contamination with foreign materials is practically eliminated. In particular this applies when the digestate is used for forestry or energy crop operations that recycle digestates and capture the full digestate value in their bottom line.

For every load of feedstock delivered to the AD plant, the operators should record the following:

- weight of each load
- type of material,
- supplier,
- date delivered,
- acceptance/rejection.

Each feedstock load should be visually inspected for quality prior to storage or processing in order to avoid cross-contamination of other feedstock materials or digestate.

All rejected material needs to be stored away from the processing AD plant in order to avoid cross-contamination and removed as soon as practicable. The operators should record the mass and type of rejected material.

5.2.3 Feedstock pre-treatment

Feedstock pre-treatment prior to anaerobic digestion will affect the quality and quantity of the digestate. Generally, feedstock is pre-treated in order to:

- Reduce the water content of feedstock
- Increase digestibility of the feedstock
- Sanitise the feedstock material.

In order to reduce the cost of the feedstock transport and treatment, feedstock with low dry matter content (e.g. pig slurry) can be pre-separated into liquid and solid fractions, with the solid fraction being supplied to the AD plant and the liquid fraction being used for irrigation. To some extent, the selection of separation technology also affects the distribution of nutrients between the liquid and solid fraction of the feedstock, which may be an important factor with regards to the expected quality of the digestate (Table 7 in Appendix A).

Digestibility of the feedstock can be improved via several pre-treatment methods, ranging from the basic removal of non-digestible material (contaminants), mashing or homogenisation. The more advanced pre-treatment methods usually target rigid organic structures via maceration, thermal and chemical hydrolysis or ultrasound treatment in order to make them more accessible to anaerobic microorganisms.

Sanitation/Pasteurisation aims to achieve production of pathogen-free digestate (refer to section 5.3.3). The sanitation/pasteurisation process can be applied to all or selected feedstock or the digestate. In AD plants treating mixed feedstock, it can be more cost-effective to sanitise only specified high-risk feedstock as it reduces the cost of the sanitation process. In such cases, it has to be ensured that cross-contamination of the entire feedstock mixture prior to sanitation is prohibited. The sanitation can also be carried out at the producer’s site in order to reduce the biological hazard during the transport of un-sanitised material.

5.3 Process Management

Note: AD facilities not meeting the scope of this guide for production of biofertiliser need to refer to The Guideline for further requirements that may apply to Process Management.

The AD facilities seeking compliance with this TG8 are to be designed, constructed and operated in manner so as to ensure consistent production of appropriate-quality specified product. Such facilities will also effectively minimise odour and gaseous emission that will or may be generated as by-product of the process.

5.3.1 Process Control

In addition to the feedstock control described in Section 5.2, the key aspects for achieving consistently compliant quality of digestate are to:

- Avoid cross-contamination of the final digestate product with un-treated, partially treated, unwanted or rejected material.
- Control and monitor all processes within the plant within the acceptable operating levels specified for the critical performance parameters (CPPs).
- Provide pasteurisation of feedstock or digestate product unless exemption is granted.
- Provide and maintain adequate equipment for the processes required.

Any portion of the digestate which does not meet the biofertiliser specification needs to be kept separate from biofertiliser conforming product in order to prevent cross contamination.

Any identified change in the input material, production process or required digestate quality needs to be adequately justified and recorded. Any significant change that results in production of products not meeting the specification may result in the need for re-validation of the production facility as a whole.

5.3.2 Process documentation

The digestate producer shall write and implement **operating procedures** that cover as a minimum:

a) a written description and annotated flow diagram of the digestate production system;
b) input material storage;
c) reception area;
d) any input material preparation prior to digestion (e.g. pasteurization, cleaning, maceration);
e) the steps for producing digestates at the digestion facility;
f) which steps consist of, or include, control measures that represent a CCP and the critical levels (operating conditions/parameters) of each CCP;
g) the monitoring points and parameters monitored and their critical levels and acceptable ranges, monitoring methods and frequency;
h) any applicable step for separating whole digestate;
i) storage of whole digestate and/or separated liquor, and any applicable storage conditions and minimum timescales;
j) any maturation step and storage for separated fibre;

k) any recirculation of whole digestate or separated liquor;
l) the digestate sampling points;
m) process management evaluation;
n) corrective actions to be followed in the event of deviation from critical levels at any CCP, quality failure of a sampled portion of production, or any other occurrence that causes, or might cause, quality failure;
o) dispatch of digestates from the digestion facility;
p) process inspection and maintenance, from acceptance of input materials to dispatch of digestates and rejected materials;
q) procedures to be followed in the event of system failure, equipment failure and accidents or incidents that affect the digestion process or the quality of digestates;
r) a procedure for establishing the corrective action(s) appropriate for a previously unforeseen circumstance that does, or could, result in digestate quality failure(s);
s) control of vermin; and
t) a statement of the known or estimated input material throughput and quantities of digestate output types for the past 12-month period.

Further to that, documentation describing the operation and maintenance of equipment, including records of any maintenance checks and repairs, needs to be established and made available for the operators and managers.

The list above only covers parts of the system that affect digestate quality. The producer's QMS documents may, for completeness, cover biogas aspects, including any biogas quality criteria set by the producer.

Other documents required for compliance with environmental regulations, pollution prevention and control regulations, such as emergency response procedures, need to form part of the process documentation.

The producer shall record all actions taken relating to operation of the AD process.

5.3.3 Pasteurisation

All compliant AD sites will employ a pasteurisation step, unless exempt from the requirements by The Guidelines.

Pasteurisation is a process step during which the numbers of pathogenic bacteria, viruses and other harmful organisms in material undergoing AD are significantly reduced or eliminated, so that the resulting digestate presents acceptably low risk to humans, animals, crops or the wider environment.

The most commonly applied pasteurisation method involves heating the sludge to a temperature of 70–80°C for approximately 30 minutes. The Guidelines define the temperature treatment requirement based on the following time-temperature relationship:

a) materials containing ≥ 7% DS
Within the relationship $t = \frac{131{,}700{,}000}{10^{0.14T}}$; t = days, T = °C,
where T ≥ 50°C and t ≥ 15 seconds, or

b) materials containing < 7% DS
Within the relationship
$t = \frac{50{,}070{,}000}{10^{0.14T}}$; t = days, T = °C,
where T ≥ 50°C and t ≥ 30 minutes

It is possible to achieve pasteurisation by other means. Any alternative technique must be tested for its ability to achieve a defined level of kill of indicator organisms introduced into the pasteurisation system. A facility seeking to adopt an alternative approach to heat-pasteurisation needs to undertake a validation process by which operators can demonstrate that their process, operated by their personnel, is sufficiently effective at reducing pathogen risk. A recommended validation process is described in a technical note: *A consideration of the PAS110:2010 pasteurisation requirements, and possible alternative* (WRAP, 2013).

An exemption from the requirement to pasteurise applies to:

- Input materials derived from processes including thermal treatment(s) equivalent to at least 70°C for half an hour,
- Digestate made only from manure, unprocessed crops, processed crops, crop residue, glycerol and/or used animal bedding that arise within a single or co-operative's premises or holding and, after digestion, are returned to, and used entirely within the same premises or holding,
- Digestate made only from manure, unprocessed crops, processed crops, crop residue, glycerol and/or used animal bedding that arises within a single or co-operative's premises or holding, if such input materials are co-digested with pasteurised organic waste/biodegradable material from any source(s) outside the premises or holding. This is conditional upon all the digestate being used within the originating single or co-operative's premises or holding, in a way consistent with the single premised or holding.
- Materials specifically exempt from pasteurisation by The Guidelines.

The AD facility operator needs to ensure that any non-pasteurised material does not contain any non-biodegradable materials or residues of any toxic substances that represent unacceptable risk to human or animal health, or the environment, before and after digestion. Examples of such non-biodegradable materials are veneer, paint or laminate, wood preservatives, etc.

5.4 Product Management

Note: AD facilities not meeting the scope of this guide for production of biofertiliser need to refer to The Guideline for further requirements that may apply to Product Management.

5.4.1 Digestate composition

The quality of digestate is determined by the digestion process used and the composition of the feedstock (Makadi, Tomoscik, & Orosz , 2012). During anaerobic digestion the feedstock biomass is broken down to non-digestible residue (under AD process conditions), water and biogas consisting mainly of methane and carbon dioxide. While this reduces the dry matter concentration of most AD feedstock by up to 70-90%, the nutrient content of most macro and micronutrients is preserved – apart from nitrogen and sulphur, where gaseous losses in the low single digit per cent range have been recorded (Munzert & Hueffmeier, 1998). When applied correctly on land (typically using surface and subsurface application rather than spraying), these nutrients may re-enter the food chain via uptake by plants and crops, creating a closed-loop nutrient cycle (Figure 7). Additionally, the effect of residual organic matter in digestate on soil organic matter is a vital additional aspect. Note the figure below shows an idealised nutrient recovery; significant nutrient loss can occur through volatilisation and run-off through over application, or application to saturated soils.

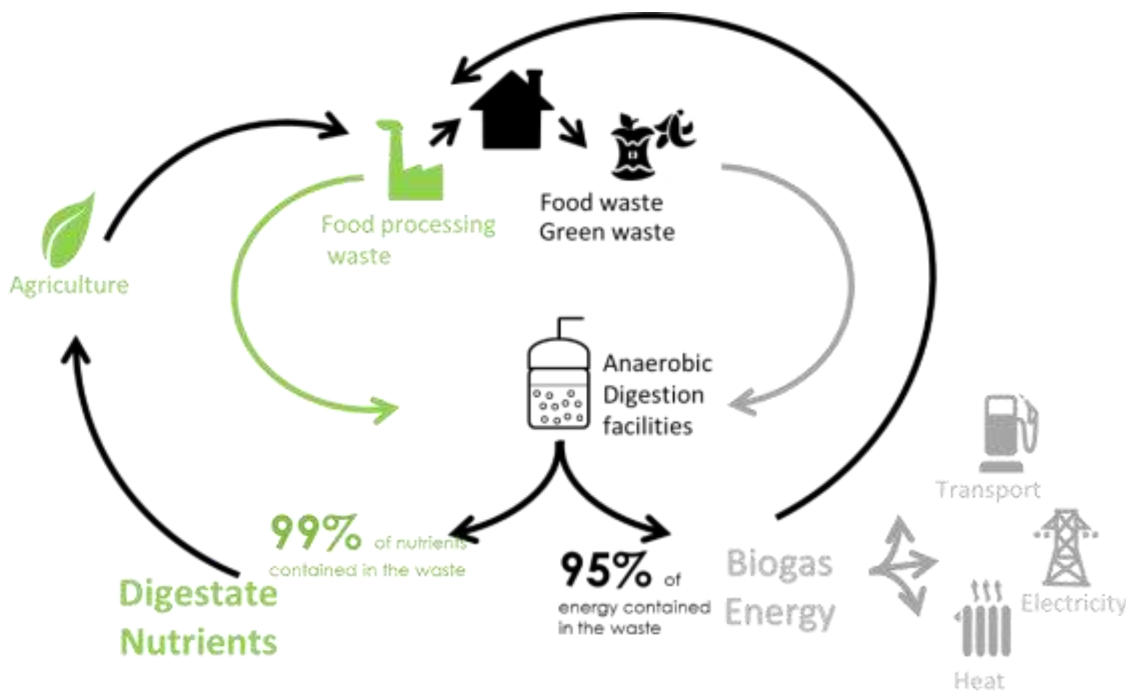


Figure 7 - Closed Nutrient Cycle.

The mass loss caused by the anaerobic digestion mainly depends on the nature and the proportions of the starting feedstock, where the content of organic solids and their biodegradability are two decisive factors. The AD operating conditions are also important; in particular the retention time and the temperature in the digester have an influence on the degradation rate and on the mass loss. The mass loss equals the amount of biogas produced. Reference values for the mass loss are 3% for manure and 20 to 30% for silage. In the case of food residue, 70 to 80% mass loss may be expected (Wager-Baumann, 2011). For high fat oil and grease substrates such as DAF sludge and grease trap waste 90% mass loss of the organic material has been recorded.

While the total content of most nutrients is preserved, the form and availability of some of these is significantly changed by the AD process. During the decomposition of organic matter, organically bound nitrogen (proteins) and phosphorus are partially oxidised into ammonia and orthophosphates, respectively, hence becoming readily accessible to plants when applied to land. Sulphur is reduced to sulphide and, depending on the pH and presence of suitable metals, it either forms metal sulphide precipitates or becomes hydrogen sulphide.

Besides the above-mentioned nutrients, digestate also supplies slowly decomposable organic materials that stimulate the formation of humus in the soil. Humic substances increase the soil's aggregate stability (friability) and contribute to its ability to retain water and nutrients. Due to the fact that many soils tend to lose organic substances, the use of digestate has proven to favour the development of stable organic matter in the soil (Wager-Baumann, 2011). Poorly degradable or non-degradable organic matter such as lignin and cell debris will remain unchanged during the process of AD.

Table 8 (Appendix A) shows characteristics of feedstock and liquid digestates from different origins. These are mean values and will differ on a case-by-case basis. It is recommended that the quality and composition of digestate is monitored on a regular basis.

Digestate can be mechanically divided into liquid and solid phases and applied separately. Depending on the separation process and its efficiency, the digestate components distribute between the two phases. The majority of the ammonia nitrogen and potassium remain in the liquid phase, while dry matter and phosphorus tend to get separated as the digestate solids (Figure 8).

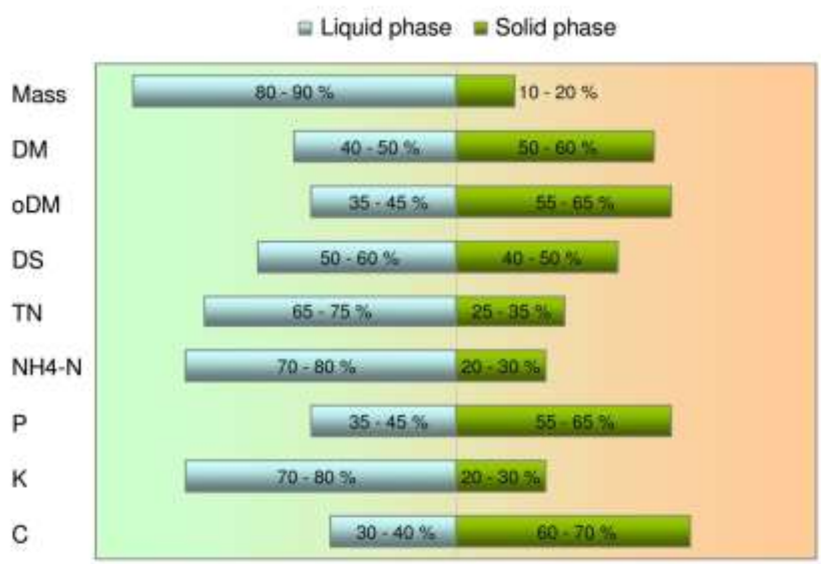


Figure 8 - Distribution of digestate components between solid and liquid phase (Wager-Baumann, 2011).

5.4.2 Digestate handling and storage

High quality digestate is a stable product with minimal risk of pathogen transfer. Recontamination from raw feedstock is therefore the main concern during handling, storage and transport of digestate. Correct storage reduces ammonia, methane and unpleasant odour emissions to atmosphere. To achieve correct storage requires a number of precautions at the biogas plant as well as other digestate storage areas, such as:

- Since anaerobic digestion is best carried out continually, sufficient storage capacity must be available for digestate produced outside of the growing season. Depending on the geographical location, soil type and winter rainfall, crop rotation and local climate, storage capacity of as much as 9 months may be required.
- Storage facilities can be located at source, i.e. at the biogas plant, or, more conveniently, close to the place of utilisation. In order to eliminate emission of odours or greenhouse gasses into the atmosphere, digestate storage is usually carried out in above ground storage tanks, covered ponds, or storage bags.
- It is important that all digestate storage facilities are gas sealed and appropriately vented through emission-destructing equipment (flare, biofilter, etc.) or combined with biogas collected within the main AD reactors, in order to minimise ammonia volatilisation and greenhouse gas emissions.
- Handling and storage of digestate in a dedicated “clean area” strictly ensuring no contact with the raw feedstock material or equipment that has been in contact with the raw material without prior disinfection (clothing, vehicles, etc.).
- No feedstock to be supplied from suppliers where health issues have been detected.
- Avoid cross-contamination between farms by using dedicated trucks and days/times of services.
- All transport trucks should be washed down after delivery of each load. Where there are biosecurity concerns this wash down should also include sanitation.
- Where physically and economically viable, feedstock can be pumped to the biogas plant using individual pipework.
- Regular analysis and recording of digestate composition from each truckload.
- Storage facilities should be covered.

5.4.3 Digestate Sampling

Digestate sampling should be carried out at the end of the digestion and storage process (if required), prior to dispatch of digestate from site.

Each sample should be representative of the batch or portion of production sampled. If stored prior to despatch from site, the digestate should be sampled from the storage tank, preferably before any new batch of digestate enters the storage vessel. The storage tank should be mixed prior to sampling to ensure a homogenous sample.

If separated into liquor and fibre (solids), these should be sampled after full separation and any other treatment or maturation. As with whole digestate, each sample of separated liquor or fibre should be representative of the batch or portion of production sampled.

A batch or portion of production is defined as a unit of digestate (liquor, fibre) produced by a single AD production process, using uniform critical control points and critical limits, or a number of such units, when stored together, and that can be identified for the purposes of retreatment or disposal, should monitoring checks or sample tests necessitate such action.

The size of the batch or portion of production is defined by the producer in the QMS system. Factors to consider when defining batch size for sampling are minimum necessary HRT, OLR or digestion vessel configuration (single, series or parallel).

Each batch of digestate, separated liquor or fibre should be assigned a unique code for quality management purposes.

Adequate records need to be produced and kept for each sample taken, including:

- Sampling date and time
- Sample type (whole digestate, separated liquor, fibre)
- Batch code
- Digestion facility name
- Name of person who carried out sampling

Note: The Guidelines (Section 6) provide detailed guidance on obtaining representative samples.

5.4.4 Validation

In the context of this Technical Guide, Validation is a process of obtaining and evaluating evidence that the elements of the quality management system (including the HACCP plan) are effective for producing digestate of the quality to which the producer has committed in the quality policy.

As such, Validation is required when:

- a new process is commissioned,
- changes are made to an existing process; and/or
- any of the routine samples exceed the limits set for quality requirements.

There are two steps required for validation of conformance with this Technical Guide:

- Process validation
- Product validation

5.4.4.1 Process Validation

The AD facility must meet the control requirements as defined in its individual Quality Management System and relevant HACCP plan. The producer needs to:

a) ensure that the quality and proportions of input materials are within the plant design and operation parameters,
b) operate all of the critical control points (CCPs) within their critical limits (CLs),
c) check that monitoring results show that the process is performing as planned, particularly at the CCPs,

d) if there is deviation beyond any CL, carry out corrective action in time to avoid adverse changes in output quality,
e) where feasible, identify the cause when a CCP operates outside of its CLs or a quality failure occurs, and record the cause and the corrective action taken,
f) send samples of whole digestate and any separated liquor and separated fibre fractions, for testing, as specified in 5.4.4.2
g) check that test results of whole digestate, and any separated liquor or separated fibre fractions, conform to the corresponding minimum quality requirements specified in 55.4.4.2 and any additional specifications the producer has committed to meeting in the quality policy, i.e. the digestate specified quality;
h) change the HACCP plan if the process is under control (the CCPs are operating within their CLs) but is not producing sufficient quality whole digestate, separated liquor and/or separated fibre; and
i) repeat steps a) to g) inclusive if h) is carried out.

5.4.4.2 Product Validation

During the validation process, AD facilities not accredited for production of biofertiliser need to meet the quality requirements of digestate and sampling frequency specified in The Guidelines. Accredited AD facilities need to meet the quality protocols as defined in the relevant Accreditation scheme.

Note: The Guidelines refer to Validation as "Verification".

In order to meet the product validation pathogen requirements of this guide the following pathogen standards in Table 1 and must be met. These are derived from Table 5.4 of The Guidelines.

Table 1: Product Pathogen Standards

Pathogen	**Standard**
Verification Sampling	
E. coli	less than 100 MPN/g
Campylobacter	less than 1/25 g
Salmonella	less than 100 MPN/g
Human adenovirus	less than 1 PFU/0.25g
Helminth ova	less than 1/4 g
Routine Sampling	
E. coli	less than 100 MPN/g

In order to meet the product validation contaminant requirements of this guide the following pathogen standards in Table 2 and must be met. These are derived from Table 5.5 of The Guidelines.

Table 2: Product contaminant concentration limits

Parameter	Concentration Limit (mg/kg dry weight)
Metals	
Arsenic	30
Cadmium	10
Chromium	1500
Copper	1250
Lead	300
Mercury	7.5
Nickel	1500
Zinc	135
Emergent Organic Compounds (EOCs)	
Nonyl phenol and ethoxylates (NP/NPE)	50
Phthalate (DEHP)	100
Linear alkydbenzene sulphonates (LAS)	2600
Musks – Tonalide	15
Musks – Galaxolid	50

In addition to the quality requirements specified above, the digestate producer needs to monitor the following:

- Stability of the whole digestate, separated liquor or fibre (details of stability testing methods and limits are provided in Appendix B)
- Physical contaminants (details of physical contaminant testing methods and limits are provided in Appendix C).

During validation, the three most recent digestate sample test results shall not exceed the corresponding upper limit for the two additional digestate stability parameters.

For each batch or portion of production from which a sample **is not taken** for testing, the producer needs to ensure that quality management process is followed to ensure the product quality requirements are met.

For digestate made only from manure, unprocessed crops, processed crops, crop residues, glycerol and/or used animal bedding that arises within the producer's/cooperative's premises or holding, no Physical contaminant testing is required. The digestate shall be used entirely within the same premises or holding.

In the case of digestates made from input materials arising within a single or co-operative's premises or holding, and that are entirely used within the same premises or holding, the human and animal pathogen indicator species tests are only required if any input material contains, or is at risk of containing, human and/or animal pathogens.

5.4.4.3 Failure of test result

Batch or portion of production that fail to meet any one of the specified quality limits must be either

- Disposed of and not sold as a biofertiliser, or
- Re-processed and re-tested so as to gain evidence of conformance with the quality requirements before dispatch as a biofertiliser.

A reprocessed product needs to be re-tested only for the failure parameter(s).

Where the digestate producer chooses to re-process or take other corrective actions to a non-conforming liquid product (whole digestate, separated liquor), then following implementation of the corrective action, an additional batch or portion of production of digestate may be mixed with the re-processed/corrected batch. The new mixed batch can then be re-tested for compliance after thorough mixing.

A re-processed/corrected batch or portion of production of separated fibre must be re-tested prior to introduction of a new batch or portion of production.

5.4.5 Product Monitoring

After the validation process is completed, AD facilities not accredited for production of biofertiliser need to meet the quality control requirements of digestate and sampling frequency specified in The Guidelines. This will often involve extensive batch testing. Accredited AD facilities need to meet the quality assurance protocols as defined in the relevant Accreditation scheme. (Quality assurance ensures that the system is managed and operated so that all product produced is complying product. A quality control approach, as set out in The Guidelines, requires testing of the product as it is produced. A quality control approach is labour and cost intensive whereas ensuring that the process will produce complying product is usually easier and less costly).

[Quality assurance monitoring criteria is under development]

Note: The Guidelines refer to after-validation testing as “Routine testing”.

In addition to the quality requirements specified in The Guidelines, the digestate producer needs to monitor the following:

- Stability of the whole digestate, separated liquor or fibre (details of stability testing methods and limits are provided in Appendix B)
- Physical contaminants (details of physical contaminant testing methods and limits are provided in Appendix C).

After validation, the testing frequency required for monitoring of the two additional parameters is as follows:

- Digestate stability – 2 representative samples per 12 months and not within 3 months of each other, or sooner if significant change in the process or input material occurs. Testing should occur 6 HRT cycles after the change has occurred to allow for any process changes to take effect.
- Physical contaminants – 1 representative sample per 6,000 m^3 of whole digestate (or separated liquor or fibre) produced[19], or 1 representative sample per 3 months, whichever is the soonest.

For each batch or portion of production from which a sample **is not taken** for testing, the producer needs to ensure that quality management process is followed to ensure the product quality requirements are met.

For digestate made only from manure, unprocessed crops, processed crops, crop residues, glycerol and/or used animal bedding that arises within the producer's/cooperative's premises or holding, no Physical contaminant testing is required. The digestate shall be used entirely within the same premises or holding.

In the case of digestates made from input materials arising within a single or co-operative's premises or holding, and that are entirely used within the same premises or holding, the human and animal pathogen indicator species tests are only required if any input material contains, or is at risk of containing, human and/or animal pathogens.

5.4.5.1 Failure of test result

The same conditions apply as specified in 5.4.4.3.

If a producer dispatches digestate or separated liquor or fibre prior to receiving a failed test result, the producer must inform the digestate customer/user and any other appropriate regulatory body immediately of the nature of the failure.

5.4.6 Digestate conditioning and utilisation

Digestate can be applied directly to land without any treatment once it is removed from the digester and cooled down. However, the low solids content of whole digestate increases the cost of storage and transport. This makes digestate dewatering and volume reduction an attractive option (Al Seadi & Lukehurst, 2012).

The common digestate processing and utilisation technologies applied at present to digestate are presented in Figure 9.

Digestate treatment, which has the main purpose of enhancing quality and marketability of the digestate as a useful product is generally called *digestate conditioning*, while the practices aiming to remove nutrients and residual organic matter are called *wastewater treatment*. The water content has a decisive influence on the costs of the treatment of digestate. Whereas most of the solids can be removed by means of simple technologies like a screw press separator, the remaining liquid phase requires much

[19] digestate holding tank must be fully mixed

more complex and costly procedures for both, conditioning as well as wastewater treatment (Wager-Baumann, 2011).

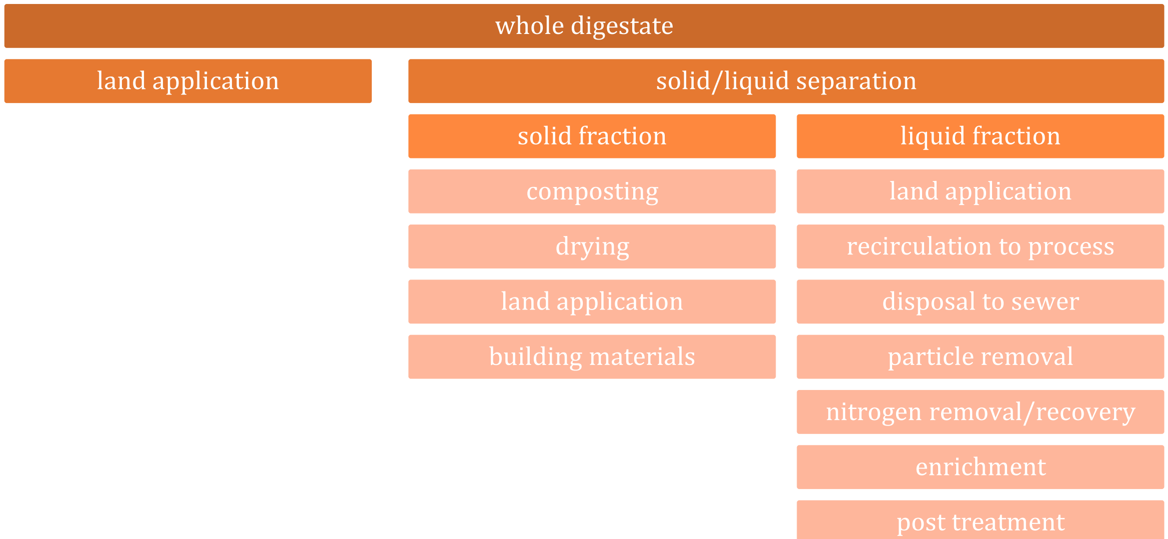


Figure 9 - Digestate treatment and utilisation.

The selection of a solids-liquid separation technique should be based on the required efficiency, required throughput, capital cost and operating cost of the processing machinery. These aspects are compared for a selection of separation techniques in Table 9(Appendix A). Particle size of the digestate solids is one of the main factors affecting the efficiency of the equipment. While screw presses are limited to particles larger than 1 mm, decanter centrifuges are efficient in removing solids as small as 0.02 mm.

The solid fraction of the digestate can be directly applied to land as soil conditioner. Alternatively, the solids can be composted or dried and pelletised.

Other non-agricultural uses for digestate also exist. The production of composite construction materials using separated digestate solids is a relatively new application and is still mostly in development stage. Dried digestate solids can also be incinerated for heat or energy production.

The liquid fraction can be directly applied to land or reused within the AD plant for wetting of dry feedstock materials. Advanced filtration technologies (micro-filtration, ultra-filtration, reverse osmosis) or evaporation are used for enrichment of the digestate. Nutrients can be recovered from the digestate in solid form by precipitation (MAP – magnesium ammonium phosphate) or ammonia stripping, or removed using conventional biological treatment methods. In some cases, liquid digestate can also be directly disposed of by discharge to local sewer.

While the method of use of the digestate is outside the scope of this guide, the application of digestate to land should be done in such a way as to minimise the loss of nutrients to ground and surface waters via run-off and to the air via volatilisation. This requires the product to be applied at suitable hydraulic and agronomic loading rates, and using methods such as direct application to soils to prevent volatilisation.

5.5 Health and safety during digestate production and handling

Production, storage and handling of digestate must be carried out in compliance with the NZ Health and Safety in Employment Act 1992. Several codes of practice are available for waste handling and biogas production, which can provide valuable information regarding safe practices during these activities, such as:

- *NZS 5528:1987 – Code of practice for the production and use of biogas, farm scale operation* (Standards Association of New Zealand)
- *WasteMINZ 2012: Liquid and Hazardous Wastes Code of Practice*
- *WasteMINZ 2012: Liquid and Hazardous Wastes (Operators' Handbook)*

A systematic assessment of human-health hazards associated with production, handling and use of digestate should be carried out for each plant. The hazards should include pathogens and toxins that adversely affect human health and odours offensive to people who live or work in close proximity to the location of production or use.

Safe practices shall be adopted and strictly observed for the transport and pre-treatment of feedstock in order to prevent or minimise the exposure of the staff to potentially hazardous material. Personal Protection Equipment (PPE), such as rubber gloves and respirators should be worn during loading and unloading of the feedstock material and during its handling in enclosed spaces.

Anaerobic digestion of organic material produces large amounts of biogas containing explosive and toxic gases (methane, hydrogen sulphide, etc.). As such, AD plants need to be designed and operated to the highest safety standards. Operating staff should be provided with personal gas detectors and appropriate PPE.

Residual methane producing and other biological processes during storage of digestate may lead to evolution of harmful gases. This needs to be taken into account during the design and operation of the digestate storage facilities, but also during transport of digestate to the location of use. Personal gas detectors and appropriate PPE, combined with safe practice procedures should be developed and used at all times.

5.5.1 Labelling, marking, dispatch of digestate

5.5.1.1 Digestate dispatched for internal use (within producer's premises)

The producer shall record the following:

- Amount of digestate
- Type of product
- Date of production
- Location of production
- Production batch number
- An alert in cases where pasteurisation was omitted (in accordance with rules specified in 5.3.3)

- Health warning –
    - "This biofertiliser product may contain a variety of living micro-organisms, some of which on rare occasions can cause illness in humans. Serious infection is rare but can happen for older people and those with reduced immunity. Please take the following precautions:
        - Avoid opening the bag in enclosed areas.
        - Avoid inhaling the biofertiliser.
        - Always wear gloves and wash hands after use.
        - See your doctor if you develop a high fever, chill, breathlessness or cough."

5.5.1.2 Digestate dispatched for external use (outside of producer's premises)

A customer receiving a consignment of digestate, separated liquor or fibre, for use outside of the producer's premises needs to receive a document with the following information:

- producer name and contact details;
- digestate process date,
- or process identification code, (Includes batch code or other identifier to provide traceability in case of complaint) ;
- product description
    - statement of whether whole digestate, separated liquor or separated fibre;
    - approximate particle size range
    - typical fertiliser characteristics: (derived from laboratory test results)
        - pH value;
        - total nitrogen;
        - total phosphorus;
        - total potassium;
        - ammoniacal nitrogen (NH4-N);
        - dry matter (also referred to as "total solids"); and
        - loss on ignition (also referred to as "volatile solids" and a measure of organic matter).
- information on the product's origins (e.g., if it includes animal products or manures)
- health warning –
    - "This biofertiliser product may contain a variety of living micro-organisms, some of which on rare occasions can cause illness in humans. Serious infection is rare but can happen for older people and those with reduced immunity. Please take the following precautions:
        - Avoid opening the bag in enclosed areas.
        - Avoid inhaling the biofertiliser.
        - Always wear gloves and wash hands after use.
        - See your doctor if you develop a high fever, chill, breathlessness or cough."

The producer shall make and keep a copy of the record for each consignment of whole digestate, separated liquor or separated fibre, which shall include:

- the customer name and contact details;
- delivery address;
- product identifier to allow traceability from production to customer;
- quantity dispatched, by weight or volume; and
- date of dispatch.

6 DIGESTATE APPLICATION MANAGEMENT

Note: AD facilities not meeting the scope of this guide for production of biofertiliser need to refer to The Guideline for further requirements that may apply to digestate utilisation.

6.1 Characteristics

The main aspects farmers should consider regarding the application of digestate as biofertiliser are:

- Nutrient content – the nutrient profile and fertiliser value of AD digestate is dependent on the feed-stock composition.
- Carbon content – this can help in enhancing soil structure. For most biological materials the carbon content is between 45 to 60 percent of the volatile solids fraction.
- Distance to source – in the majority of cases, the user will need to cover the cost of the transport of digestate to the place of utilisation. This distance to source may have a decisive influence on the economic viability of such practice.
- Price of conventional fertiliser – the cost of digestate fertiliser is made up of the cost associated with transport of the feedstock, biogas plant operation and any digestate treatment (if applied). In order for the use of digestate bio-fertiliser to be economically viable, the digestate "fertiliser" value of the nitrogen, phosphorus or potassium needs to be lower than that of conventional mineral fertilisers when expressed in $/kg.
- Incentives offered by the AD facility such as subsidised cost of digestate.
- Storage – digestate should be applied only during the growing season in order to ensure prompt and high nutrient uptake and in order to eliminate nitrate leaching into the soil with consequent groundwater pollution.
- Farm product users – the use of digestate as biofertiliser must be accepted by the users of the products grown on the farm. Regulatory requirements regarding the digestate quality may differ in different countries, which may create problems during export of the products overseas.

6.1.1 Microplastics

Most household and municipal organic waste is contaminated with plastic, which cannot be completely removed using even the most advanced separation technologies. Processing of these wastes in anaerobic digesters will inevitably result in size reduction and partial breakdown of plastics and presence of residual microplastics (< 5 mm in size) in the digestate.

While the extent of the environmental and health effects of microplastics is not completely clear, studies have found they are detrimental to the health of organisms such as earthworms and rodents, and that they make their way into human food supplies. However, the lack of adequate understanding of the fate of microplastics during and post anaerobic digestions, their health effects and the absence of effective monitoring methodology prevents setting and enforcing plastics concentration limits.

The authors of the Guidelines for Beneficial Use reached an agreement with the New Zealand Ministry of Health and the Ministry for the Environment that no microplastic concentration limits will be set until more knowledge is attained and monitoring methodology developed. Since the TG8 has adopted the same contaminant limits as specified in the Guidelines, it is adequate for the TG8 to adopt the same strategy.

It is important that maximum effort is made along the whole supply chain to eliminate or minimise the amount of plastics entering the feedstock for the AD facility. This includes, but is not limited to:

- public education by local authorities and waste recycling operators on the impact of plastics along the value chain,
- visual inspection of the waste bins by the waste collectors upon collection,
- site acceptance processes – waste inspection upon delivery, and
- processing technologies – de-packaging equipment, etc.

6.2 Application of whole digestate to land

The use of digestate must be integrated in the fertilisation plan of the farm in the same way other sources of nutrients would be and it must be applied at even and accurate rates (Al Seadi & Lukehurst, 2012). In New Zealand, the use of the OverseerFM software is promoted within the agriculture sector for a comprehensive science-based nutrient balance analysis.

As discussed throughout this document, the application of digestate to arable land is beneficial in various aspects from providing macro- and micronutrients to plants, reducing soil acidification, enhancing moisture retention and improving microbiological activity of soil (Makadi, Tomoscik, & Orosz, 2012). However, hydrolysis of organic nitrogen to ammonia during AD accompanied by a higher pH in the digestate may induce ammonia volatilisation and nitrogen losses due to gaseous emissions during handling and application. This is of relevance to the famers for two reasons.

a) Emissions during application - Ammonia losses and odour emissions are the main risk factors as far as digestate application method is concerned. In general, equipment used for application of raw slurry can be used for digestate with the exception of splash plate application, which has been banned in some countries due to the high ammonia volatilisation effect. On the other hand, trailing hose, trailing shoe and shallow soil injection have proven to be the most efficient (Table 9, Appendix A).

b) Reduction of digestate nutrient content due to ammonia volatilisation. Where digestate is used as the sole source of nutrients, this may lead to under-fertilising. It is therefore essential that the receiving soil nutrient properties are monitored through regular testing.

Other potential issues associated with the use of digestate as biofertiliser is the risk of phytotoxicity, nitrate leaching and odour evolution during and after application. The risk of phytotoxicity can be minimised by careful evaluation of digestate quality and quantity applied. Nitrate leaching can be reduced or eliminated by a high control of the application rates based on soil quality and crops requirement and by careful selection of most suitable application time.

Figure 10 - Tanker fed sub-soil injection system.

Figure 11 - View of injector system mounted on the tanker rear.

7 CERTIFICATION

In the UK the Biofertiliser Certification Scheme run by the Renewable Energy Association provides operators of AD facilities producing biofertiliser, consumers, farmers, food producers and retailers confidence that digestate produced from anaerobic digestion is safe for human, animal and plant health. The certification is in terms of the standards BSI PAS 110 and the Anaerobic Digestate Quality Protocol.

In New Zealand consent authorities may accept that digestate derived from source-segregated organic waste which is produced by AD facilities that are designed and operated in accordance with this Technical Guide 8 and have been certified according to the Biofertiliser Certification scheme (TBA) carries the status of Biofertiliser.

Compliance with the certification protocol provides assurance to consumers, farmers, food producers and retailers that the produced digestate is safe for human, animal and plant health.

Consenting authorities may accept that the certified Biofertiliser is removed from the scope of the Guidelines for Beneficial Use of Organic Residues (Water NZ, 2020) and its handling and use no longer requires consent of the Regional Authority. Refer to Section 3.1 for more details.

Other non-certified digestates will however need to be tested and verified against the quality requirements and testing protocols specified in the Guidelines and, depending on the digestate quality, may require consent of the Regional Authority for application.

The Biofertiliser Certification Scheme is under development. In New Zealand discussions are underway to get biofertiliser included under the Fertmark certification scheme.

8 GLOSSARY

Anaerobic digestion - process of controlled decomposition of biodegradable materials under managed conditions where free oxygen is absent, at temperatures suitable for naturally occurring mesophilic or thermophilic anaerobic and facultative bacteria species, that convert the inputs to biogas and whole digestate.

Biodegradable - capable of undergoing biologically mediated decomposition

Biofertiliser - Digestate derived from organic matter which is produced by AD facilities that are designed and operated with this Technical Guide 8 and have been certified according to the Biofertiliser Certification Scheme (TBA).

Biosolids- sewage or sewage sludge derived from a sewage treatment plant that has been treated and/or stabilised to the extent that it is able to be safely and beneficially applied to land. Biosolid is a Biowaste Product that contains waste material of human origin.

Certification – third-party attestation of products, processes, systems or persons.

Control - <noun> state wherein correct procedures are being followed and criteria are being met; <verb> take all necessary actions to ensure and maintain compliance with criteria established in the HACCP plan.

Control measure - action and activity that can be used to prevent or eliminate a digestate safety hazard or reduce it to an acceptable level

Co-operative - natural or legal persons who form a group under a written agreement, who exercise only agricultural, soil-/field-grown horticultural or forestry activities and who, as a group, carry out one AD process at one location within the cooperative's holdings

Corrective action - action to be taken when the results of monitoring at the critical control point (CCP) indicate a loss of control

Critical control point (CCP) - last step at which control can be applied and is essential to prevent or eliminate a hazard or reduce it to an acceptable level of risk

Critical limit (CL) - criterion which separates acceptability from unacceptability

Deviation - failure to meet a critical limit

Digestate (or whole digestate) - whole digestate resulting from an AD process, and any subsequently separated fibre or liquor fractions. NOTE Includes any separated fibre that undergoes a subsequent aerobic maturation step, without addition of further materials.

Digester - closed vessel system in which biodegradable materials decompose under anaerobic conditions

Exemption - exemption from the need to hold an authorization.

Feedstock – see input material

Harm - physical injury to, or damage to, the health of people, or damage to property, or to the environment. NOTE In the context of this Technical Guide, "harm" also includes injury or damage to the health of animals and plants. Harm can be caused by one or more unwanted biological, chemical or physical agents in, or by misuse of, whole digestate, separated liquor or separated fibre.

Hazard - potential source of harm

Hazard analysis - process of collecting and evaluating information on hazards and conditions leading to their presence, to decide which are significant in relation to the production of digestates that can be used without harm. NOTE This should be addressed in the HACCP plan.

Hazard analysis and critical control point (HACCP) - system used for the identification, evaluation and control of hazards that are significant in relation to the production of digestates that can be used without harm

HACCP plan - document prepared in accordance with HACCP principles, to ensure control of hazards that are significant in relation to the production, storage, supply and use of digestates that can be used without harm

Holding - all the land units managed by a farmer/land manager within New Zealand

Hydraulic retention time (HRT) - average time that material stays in the digester vessel, determined by the loading rate and operational digester capacity. NOTE Hydraulic retention time can be calculated by dividing the digester working volume by the rate of flow of input materials into the digester, i.e. HRT (days) = digester volume (m^3) / influent flow rate (m^3 per day).

Input material - biodegradable material intended for feeding, or fed, into an AD process. In the context of this Technical Guide, Input material is source-segregated organic material, fit for anaerobic digestion.

Manures - slurries and solid manures, including farmyard manures and dairy shed effluent.

Maceration - to make biodegradable input materials into a more consistent and readily flowing and pumpable mixture by means of shredding, chopping, crushing or mincing the input materials and/or soaking them in a liquid

Maturation - optional period of treatment or storage of separated fibre under predominantly aerobic conditions

Mesophilic - organisms for which optimum growth temperatures are within the temperature range 30 ºC to 43 ºC

Method of test - procedure for testing a sample of digestate. NOTE Where available for any one or more parameters, this Technical Guide specifies recognized international standards

Monitor - act of conducting a planned sequence of observations or measurements of control parameters to assess whether a CCP is under control

Operating procedures - carried out and documented procedures for producing digestates

Organic loading rate (OLR) - weight of organic matter fed to a unit volume of the digester per unit time NOTE OLR = kg COD m^{-3} day^{-1} or kg VS m^{-3} day^{-1}, where COD is chemical oxygen demand and VS is volatile solids. A similar way to describe OLR is weight of organic dry matter added per day (kg VS d^{-1}) divided by digester volume (m^3).

Pasteurisation - process step during which the numbers of pathogenic bacteria, viruses and other harmful organisms in material undergoing AD are significantly reduced or eliminated by heating the material to a critical temperature for a minimum specified period of time or by other appropriate methods. NOTE 1 Pasteurization could occur either as part of the AD process or as a separate step. Pasteurization does not aim to achieve sterilization, which destroys all life forms. NOTE 2 Pasteurized material might contain beneficial and other, non-harmful, microorganisms.

Personal Protective Equipment (PPE) - any garments of clothing or equipment that is used to guard you and your employees against hazards in the workplace. For details of required PPE refer to the adequate H&S legislative documentation.

Producer - business enterprise, organization, community initiative or person(s) responsible for the production of digestates

Putrescible - material that has the capability to become putrid. NOTE In this context, those fractions of organic waste or biodegradable material with relatively high proportions of readily biodegradable carbon-based molecules and moisture.

Quality control - part of quality management focused on fulfilling quality requirements NOTE Implemented through a series of systems and activities, which are integrated in daily work, and enable frequent, or continuous, verification of product quality. Examples are checks on process conditions throughout every processing step, digestate sample test results and the effects of any corrective actions taken.

Quality management system (QMS) - management system to direct and control an organization with regard to quality [SOURCE: ISO 9000:2005] NOTE In the context of AD, it is a system for planning, achieving and demonstrating effective control of all operations and associated quality management activities necessary to achieve digestates that are fit for purpose. Where specific controls are applied, they should be monitored and recorded, and their efficacy evaluated both during and after process validation. Corrective actions should be defined.

Quality Protocol (QP) - set of criteria for the production, placement on the market, storage and use of products derived from suitable types and sources of waste, such that any risks to the environment and to human and animal health are acceptably low when any such product might, under certain circumstances, be used without waste regulatory controls, in those countries in which the protocol applies. NOTE A Quality Protocol also sets out how compliance with its criteria should be demonstrated. Products should be used in accordance with good practice, and appropriate guidance is referred to where available and suitable for use of those products in end markets allowed by that specific QP.

Risk - combination of the probability of occurrence of harm and the severity of that harm [derived from ISO/IEC Guide 51] NOTE It can mean the potential realization of unwanted, adverse consequences to human life and health, property or the environment associated with a hazard.

Separated fibre (SF) - fibrous fraction of material derived by separating the coarse fibres from whole digestate. NOTE At least 15% of its mass should be dry matter in order that the sample is suitable for laboratory tests as a “solid” material. It should contain sufficient dry matter to be capable of being stacked in a heap if it undergoes an aerobic maturation step; a mass fraction of 23% dry matter is a guideline figure.

Separated liquor (SL) - liquid fraction of material remaining after separating coarse fibres from whole digestate. NOTE It is normally the fraction remaining following the use of a separator or centrifuge to remove coarse fibres. Less than 15% of its mass should be dry matter in order that the sample is suitable for laboratory tests as a "liquid" material. It should contain sufficient moisture to be pumpable; a suitable mass fraction percentage of dry matter content should be determined in practice and the dry matter result declared for any tested portion of production. If the user desires that no significant solids residue remains on crop leaves after applying separated liquor, it should contain no more than a mass fraction of 4% dry matter.

Specified digestate or biofertiliser – A digestate or biofertiliser where the physical and fertiliser characteristics are known and identified.

Sharps - man-made contaminants that are greater than 2 mm in any dimension that might cause physical injury to a person who handles digestates without protective gloves or to a person or animal who comes into contact with these materials. NOTE Organic components such as twigs and woody fragments can puncture skin but this risk is considered acceptably low and so has been omitted from this "sharps" definition. Omitted also are rock-derived "mineral" particles and aggregated particles of all sizes, including, for example, gravel and stones.

Soil improver/conditioner - material added to soil in situ primarily to maintain or improve its physical properties, and which may improve its chemical and/or biological properties or activity

Source-segregated - materials or biowastes that are stored, collected and not subsequently combined with any nonbiodegradable wastes, or any potentially polluting or toxic materials or products, during treatment or storage (whether storage is before or after treatment). NOTE Source-segregated materials can include collection of a mixture of biowaste/biodegradable material types, from more than one source. Such materials do not include sewage sludges and their derivatives. It is acknowledged that low levels of physical contamination might occur, which might trigger rejection of an input material load or physical contaminant removal prior to loading the biowaste/biodegradable material into the working digester.

Stability - quality of being stable

Stable - point at which the rate of biological activity has slowed to an acceptably low and consistent level and will not significantly increase under favourable, altered conditions. NOTE Stable digestate should not be attractive to vermin or wild animals and should not be so odorous that its storage or use causes nuisance to humans. In a stable but immature state, it might still contain insufficiently biodegraded natural or man-made substances that exert phytotoxic effects in some applications; this should be taken into account in guidelines for digestate use.

Stabilization - biological and chemical processes that, together with conditions in the material being treated, aim to achieve stable, treated material NOTE after stabilization, biodegradation will continue to occur, albeit at a slower rate.

Step - point, procedure, or operation in the digestate chain, including raw materials, from primary production to final use of digestates and the consumption of food or fodder grown on land that has received such material

Thermophilic - organisms for which optimum growth temperatures are typically within the temperature range 45 ºC to 80 ºC

Total Solids (TS) - those solids in a sample of material that remain after the drying of the sample at 105 ºC, to the point such that they lose no more moisture. NOTE also referred to as ”Dry Solids”, or “dry matter (DM)”.

User - individual or organization that obtains digestates from a producer or third party with the intention of using them

Validation, validate - obtaining and evaluating evidence that the elements of the HACCP plan are effective. NOTE 1 In the context of this Technical Guide, this includes obtaining and evaluating evidence that the QMS is effective for producing digestates of the quality to which the producer has committed in the quality policy.

Verification, verify - application of methods, procedures, tests and other evaluations, in addition to monitoring, to determine compliance with the HACCP plan and other relevant quality requirements.

Volatile fatty acids (VFA) - fatty acids, or organic acids, with a carbon chain of six carbons or fewer

Volatile solids (VS) - those solids in a sample of material that are lost on ignition of the dry solids at 550 ºC NOTE 1 Volatile solids are also referred to as “loss on ignition (LOI)”, which is a measure of organic matter (OM).

9 WORKS CITED

ADAS UK Ltd, C. C. (2007). *Nutrient Value of Digestate from Farm-Based Biogas Plants in Scotland. Report for Scottish Executive Environment and Rural Affairs Department - ADA/009/06.* Retrieved October 10, 2013, from http://www.scotland.gov.uk/Resource/Doc/1057/0053041.pdf

Al Seadi, T., & Lukehurst, C. (2012). *Quality management of digestate from biogas plants used as fertiliser.* IEA Bioenergy.

Birkmose, T. (2007). Digested manure is a valuable fertilised. The future of biogas in Europe III. *Proceedings of the EC-sponsoredPROBIOGAS conference, June 2007*, (p. 91). Esbjerg, Denmark.

Chadwick, D. (2007). Bulding the market for digestate as a fertiliser. . *Biogas STakeholders Workshop, 4th September 2007.* Exeter University, UK: DEFRA (with contributions from Ken Smith, ADAS).

Colleran, E. (2000). Hygienic and sanitation requirements in biogas plants treating animal manures or mixtures of manures and other organic wastes. In E. H. Ørtenblad, *Anaerobic Digestion: Making energy and solving modern waste problems* (pp. 77-86). AD-NETT, Herning Municipal Authorities. Retrieved October 10, 2013, from http://www.digestaat.nl/DS4%20Colleran.pdf

Environment Agency UK. (2009). *Anaerobic digestate quality protocol*. Retrieved October 11, 2013, from http://www.environment-agency.gov.uk/research/library/consultations/54367.aspx

German Biogas Association. (2011). *Informationen über Clostridium botulinum.* Retrieved November 28, 2013, from http://www.biogas.org/edcom/webfvb.nsf/id/DE_Informationen-ueber-Clostridium-botulinum/$file/11-12-23_positionspapier_botulismus.pdf

Lukehurst, C. T., Frost, P., & Al Seadi, T. (2011). *Utilisation of digestate from biogas plants as biofertiliser.* IEA Bioenergy.

Makadi, M., Tomoscik, A., & Orosz , V. (2012). Digestate: A New Nutrient Source - Review. In S. Kumar, *Biogas* (pp. 295 - 310). InTech. Retrieved from http://www.intechopen.com/books/biogas/digestate-a-new-source-review

Munzert, M., & Hueffmeier, H. (1998). *Pflanzliche Erzeugung* (11th edition ed.). Munich, Germany: BLV Verlagsgesellschaft.

NZWWA. (2003). *Guidelines for the safe application of biosolids to land in New Zealand.* Wellington, New Zealand: New Zealand Water and Wastes Association.

PAS110. (2010). *Specification for whole digestate, separated liquor and separated fibre derived from anaerobic digestion of source-segregated biodegradable materials.* Retrieved October 10, 2013, from http://www.biofertiliser.org.uk/pdf/PAS-110.pdf

Siebert, S. (2008). Quality requirements and quality assurance of digestion residuals in Germany. *ECN-Workshop "The Future for Anerobic Digestion of Organic Waste in Europe", 16. - 17. January*

2008. Nurnberg, Germany. Retrieved from Kompost.de: http://www.kompost.de/uploads/media/Quality_Requirements_of_digestion_residuals_in_Germany_text_01.pdf

Standards Association of New Zealand. (n.d.). Code of practise for the production and use of biogas, farm scale operation. *NZS5528:1978* .

Van der Meer, H. (2007). Optimising Manure Management for GHG Outcomes. *Green House Gas and Animal Agriculture Conferrence (GGAA), 26-29.11.2007.* Christchurch, New Zealand.

Wabnitz, G., Humphrey, A., Thiele, J., Jones, K., Renquist, R., & Huebeck, S. (2011). *Biogas Strategy 2010 to 2040.* BANZ Biogas Interest Group.

Wager-Baumann, F. (2011). *Physical and biological methods for the treatment of the liquid fraction of anaerobic digester effluent.* Vienna: University of Natural Resources and Aplied Life Science.

Waste Solutions, W. (2007). *Bioenergy Options Project PROJ-12011-ORI-FRIO.* Forest Research Institute (SCION).

WasteMINZ. (2012). *Liquid and Hazardous Wastes Code of Practice.* Retrieved November 28, 2013, from http://www.wasteminz.org.nz/wp-content/uploads/LHWCoP-final.pdf

WasteMINZ. (2012). *Liquid and Hazardous Wastes Operators' Handbook.* Retrieved November 28, 2013, from http://www.wasteminz.org.nz/wp-content/uploads/Waste-Operators-handbook-FINAL.pdf

Water NZ. (2020). *Guidelines for Beneficial Use of Organic Materials on Productive Land.* Retrieved from Waternz.org.nz: https://www.waternz.org.nz/Article?Action=View&Article_id=1212

Williams, J., & Esteves, S. (2011). *Digestates: Characteristics, Processing and Utilisation.* Retrieved October 10, 2013, from http://biomethaneregions.cra.wallonie.be/img/download/TrainingTheTrainers_UK_Digestate_Characteristics_and_Processing.pdf

Wood, S., & Cowie, A. (2004). *A review of greenhouse gas emission factors for fertiliser production.* Research and Development Division, State Forests of New South Wales.

WRAP. (2013). *A consideration of the PAS110:2010 pasteurisation requirements, and possible alternative.* Retrieved from http://www.aquaenviro.co.uk/wp-content/uploads/2015/10/A-consideration-of-the-PAS110-2010-pasteurisation-requirements-and-possible-alternatives-WRAP-Report.pdf

APPENDIX A: FEEDSTOCK CHARACTERISTICS

Table 3 Typical nutrient concentration of selected AD feedstock (in kg/m3 or kg/t of fresh weight). 1 – (Longhurst 2017), 2 – (Lukehurst, Frost, & Al Seadi, 2011):

Feedstock	TS (%)	Total N	N-NH₄	P	K	S	Mg
Dairy shed effluent[1]	0.5-1.2	0.15-0.3	0.05	0.07	0.4	0.07	0.04
Dairy cow manure slurry (housed)[1]	11	3.1		0. 7	5.8	0.6	0.9
Pig slurry[2]	4.0	4.0	2.5	0.9	2.1	0.4	0.2
Poultry: [2] Layer manure Broiler/turkey litter	 30 60	 16 30	 3.2 12	 5.7 10.9	 7.5 15	 1.5 3.3	 1.3 2.5
Grass silage[2]	25-28		3.5-6.9	0.4-0.8			
Maize silage[2]	20-35	1.1-2	0.15-0.3	0.2-0.3	4.2		
Dairy waste[2]	3.7	1.0	0.1	0.4	0.2		
Stomach contents[2]	10.1	3.1	0.3	0.7	0.5		
Blood[2]	10.9	11.7	1.0	0.4	0.6		
Food leftovers[2]	9-18	0.8-3	2.4	0.7			

TS = Total solids, N = nitrogen, $N\text{-}NH_4$ = Ammoniacal nitrogen , P = Phosphorus, S = Sulphur, Mg = Magnesium

Table 4: Approximate trace elements and heavy metals concentrations (mg/kg dry matter) in some feedstock types (Lukehurst, Frost, & Al Seadi, 2011).

Feedstock	Zn	Cu	Ni	Pb	Cr	Cd	Hg
Animals							
Dairy slurry	176	51.0	5.5	4.79	5.13	0.20	
Pig slurry	403	364	7.8	<1.0	2.44	0.30	
Poultry (egg layers)	423	65.6	6.1	9.77	4.79	1.03	
Crops							
Grass silage	38-53	8.1-9.5	2.1	3.0		0.2	
Maize silage	35-56	4.5-5.0	5.0	2.0	0.5	0.2	
Agri-food products							
Dairy waste	3.7	1.4	<1.0	<1.0	<1.0	<0.25	<0.01
Stomach contents	4.1	1.2	<1.0	<1.0	<1.0	<0.25	<0.01
Blood	6.1	1.6	<1.0	<1.0	<1.0	<0.25	<0.01
Brewing wastes	3.8	3.7	<1.0	<1.0	<1.0	<0.25	<0.01

Table 5: Time required for 90% destruction of some pathogenic bacteria in AD systems (Al Seadi & Lukehurst, 2012).

Bacteria	**53°C (hours)**	**35°C (days)**
Salmonella typhimurium	0.7	2.4
Salmonella Dublin	0.6	2.1
Escherichia coli	0.4	1.8
Staphylococcus aureus	0.5	0.9
Mycobacterium paratuberculosis	0.7	6.0
Coliform bacterial	-	3.1
Groups D Streptococci	-	7.1
Streptococcus faecalis	1.0	2.0

Table 6: Survival of weed seeds (% germination) after mesophilic AD expressed in number of days (d) at 37°C (Al Seadi & Lukehurst, 2012).

Plant species	**2d**	**4d**	**7d**	**11d**	**22d**
Brassica Napus (Oil Seed Rape)	1	0	0	0	0
Avena fatua (Wild Oat)	0	0	0	0	0
Sinapsis arvensis (Charlock)	0	0	0	0	0
Fallopia convolvulus (Bindweed)	7	2	2	0	0
Amzinckia micranta (Common Fiddleneck)	1	0	1	0	0

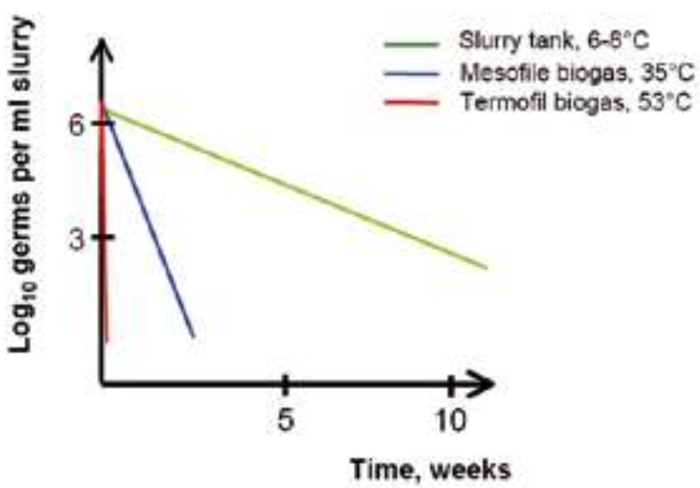


Figure 12 - Comparative rates of pathogen reduction in digestate and undigested slurry measured by the log 10 FS (Streptococcus faecalis) method (Al Seadi & Lukehurst, 2012).

Table 7 Separator efficiency (%) of some common mechanical manure separators for dry matter (DM), nitrogen (N), phosphorus (P), potassium (K) and volume reduction (VR). Without polymer addition unless otherwise stated. Values expressed as percentage of component in total slurry input that was partitioned to solid fraction. (Lukehurst, Frost, & Al Seadi, 2011)

Technology	**DM**	**N**	**P**	**K**
Belt press	65	32	29	27
Centrifuge	54-68	20-40	52-78	5-20
Screw press	20-65	5-28	7-33	5-18
Sieve centrifuge	13-52	6-30	6-24	6-36
Brushed screen (cattle slurry)	36	18	26	15
Brushed screen (pig slurry)	19	6	7	5
Decanter centrifuge (pig slurry) no polymer with polymer	 53 71	 21 34	 79 93	 9 11
Decanter centrifuge (cattle slurry) no polymer with polymer	 51 65	 25 41	 64 82	 13 13

Table 8 Comparison of analysis results for undigested and digested feedstock (ADAS UK Ltd, 2007)

	TN	**NH_4-N**	**P_2O_5**	**K_2O**	**DM**	**pH**	**feedstock**
	kg/m^3	kg/m^3	kg/m^3	kg/m^3	%	-	
Feedstock Digestate Change %	3.0 3.4 +13	2.0 2.3 +15	1.4 1.6 +18	3.5 3.2 -7	4.7 4.2 -10	7.3 7.75 -	dairy cattle/pig slurry (Suffolk, UK)
Feedstock Digestate Change %	7.6 nr -	3.5 4.9 +40	0.65 0.61 -6.2	1.3 nr -	2.33 1.84 -21	7.6 8.1 -	pig slurry (Yorkshire, UK)
Feedstock Digestate Change %	4.9 4.2 -14.3	2.3 2.5 +8.7	Nr Nr -	nr nr -	8.8 6.5 -26.1	7.2 7.7 -	beef cattle slurry, beef housed on slats (Northern Ireland)
Feedstock Digestate Change %	4.63 5.11 +10.4	2.16 2.88 +33.3	1.86 1.92 +3.2	nr nr -	11.32 67.2 -25.2	7.4 7.9 -	Beef cattle slurry (New York State, USA)
Feedstock Digestate Change %	3.48 3.25 -6.6	1.70 2.12 +24.9	1.79 1.64 -8.4	nr nr -	8.81 5.69 -35.4	7.6 8.2 -	Beef cattle slurry (Wisconsin, USA)

Note: TN – total nitrogen, DM – dry matter, nr – no record.

Table 9: Efficiency of main solid-separation techniques used for processing of digestate (Williams & Esteves, 2011).

Technology	**Input DM (%)**	**Output DM (%) Solid fraction**	**Energy consumption (kWh/t)**	**Typical throughput (m^3/h)**
Sedimentation	0.5	5		
Flotation	0.5	5		
Screen sieves	0.5-5	10	0.2-0.9	10
Belt press	3-7	21-25	0.08-0.12	10-40
Centrifuge	1.7-8.1	18-30	1.8-7	0.7-40
Screw press	1-16	25-40	0.24-1.1	2-100

Table 10: Example from Denmark summarising the characteristics of four digestate and raw slurry application methods (Lukehurst, Frost, & Al Seadi, 2011).

	Trailing hose	**Trailing shoe**	**Injection**	**Splash plate**
Distribution of slurry	Even	Even	Even	Very uneven
Risk of ammonia volatilisation	Medium	Low	Low or none	High
Risk of contamination of crop	Low	Low	Very low	High
Risk of wind drift	Minimal after application	Minimal after application	No risk	High
Risk of smell	Medium	Low	Very low	High
Spreading capacity	High	Low	Low	High
Working width	12-28 metres	6-12 metres	6-12 metres	6-10 metres
Mechanical damage of crop	None	None	High	Low
Cost of application	Medium	Medium	High	Low
Amount of slurry visible	Some	Some	Very little	most

APPENDIX B – DIGESTATE STABILITY TESTING

Table below sets out the compliance requirement for stability determination as required in this Technical Guide, in Section 5.4.3.

Alternative methods for determining stability as set out in Table below may be used, where those alternatives demonstrate an equivalent limit to that set in the Table.

Table 11: Alternative methods for determining stability of digestate.

Parameter	Method of test	Upper limit and unit [A]
Stability of whole digestate, separated liquor or separated fibre		
Residual biogas potential (RBP)	OFW004-005	0.21 L biogas/g Volatile Solids
Volatile Fatty Acids	Gas chromatography	0.43 g COD / g VS
[A] Assessment of RBP test pass or fail shall use the average of the triplicate RBP values that each sample test generates.		
NOTE The concentration of volatile fatty acids (VFA) in a sample may be determined ahead of an RBP test. If a digestate sample's VFA result exceeds 0.43 g COD/g VS, this might indicate that the sample will fail a subsequent RBP test. VFAs may be determined by gas chromatography.		

APPENDIX C – DIGESTATE PHYSICAL CONTAMINANTS TESTING

Table 12: Digestate physical contaminants testing.

Physical contaminant in whole digestate, separated liquor of fibre											
Stones > 5 mm				NRM method JAS-497/001 [N3]				Declare on a fresh weight basis			
Total glass, metal, plastic and any "other" non-stone, man-made fragments > 2 mm				NRM method JAS-497/001 [N3]				Declare on a fresh weight basis			
Total nitrogen (N)	kg/t	Less than 1	1 - 1.9	2 - 2.9	3 - 3.9	4 - 4.9	5 - 5.9	6 - 6.9	7 - 7.9	8 - 8.9	9 or more
Total stones	kg/t	3.2	6.4	9.6	12.8	16	19.2	22.4	25.6	28.8	32
Total physical contaminants (excluding stones)	kg/t	0.04	0.07	0.11	0.14	0.18	0.22	0.25	0.29	0.32	0.36
No "sharps"											
NOTE 1 Total nitrogen is the limiting factor for physical contaminant contents. For example, a total nitrogen content of between 2 and 2.9kg/t means that stones could not exceed 9.6kg/t. Methods for testing total nitrogen are listed below in this table. **NOTE 2** Separated liquor is exempt from physical contaminants tests only if the separation technology used by the producer results in all particles being < 2 mm in the separated liquor fraction.											

APPENDIX D - CASE STUDY - REGIONAL ANAEROBIC DIGESTION FACILITY TREATING RESIDENTIAL AND COMMERCIAL FOOD WASTE

1 OVERVIEW

This case study demonstrates the application of the TG8 validation framework for the use of digestate, from anaerobic digestion facilities treating organic waste, as a fertiliser and soil conditioner substitute. The case study considers a regional anaerobic digestion facility treating source-segregated residential and commercial food waste. The facility is designed and operated to meet the requirements specified in the BANZ Technical Guide 8 and Digestate Certification Scheme (to be developed). The digestate will be supplied as biofertiliser to local farmers for application on pastural or arable land.

The proposed facility as a system promotes the principles of sustainable development and circular economy. The transition to a more circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised, is an essential contribution to efforts to develop a sustainable, low carbon, resource efficient and competitive economy. Such a transition is the opportunity to transform our economy and generate new and sustainable competitive advantages[20].

1.1 Situation

1.1.1 Feedstock

The anaerobic digestion facility is designed to process up to 70,000 tonnes of source segregated organic waste, consisting of:

- kerbside-collected residential kitchen waste,
- unsold de-packaged food waste from supermarkets,
- food and kitchen waste from restaurants and cafes.

The waste is collected and delivered to the facility by a contracted waste company based on a long-term supply contracts.

1.1.2 Process

The process shown in Figure 13 consists of the following steps:

[20] Closing the Loop – an EU action plan for a circular economy; 2015

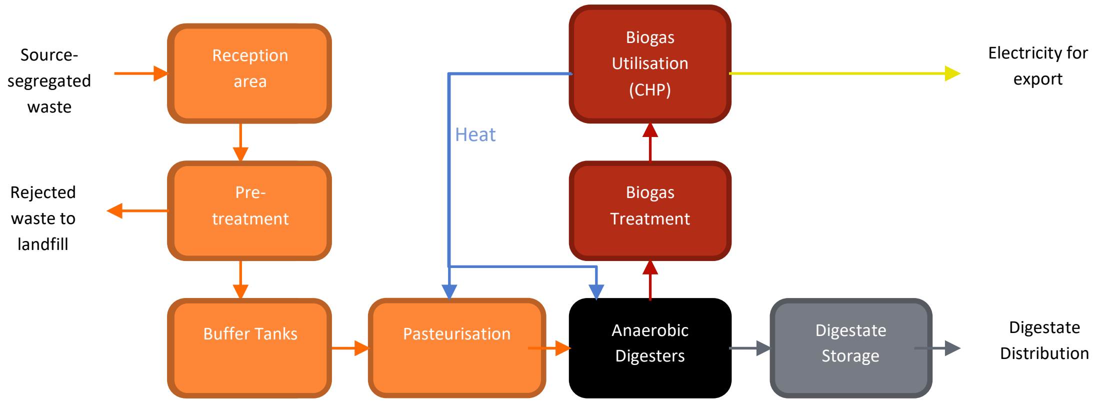


Figure 13 - Facility waste processing components.

The raw waste is pre-treated in a series of steps, consisting of grit-removal, shredding and homogenisation. Pasteurisation comprises heat treatment of the waste mixture for 1 hour at 70°C. Anaerobic digesters operate at mesophilic temperature (37°C) and Hydraulic Residence Time of 35 days. Digestate is stored on site in covered storage tanks for up to 50 days prior to distribution to the end users. Biogas is conditioned and used in Combined Heat and Power (CHP) units to generate heat for pasteurisation and digester heating and electricity for on-site use and distribution to the grid.

Table 13: Anaerobic Digestion facility design capacity.

Parameter	Unit	Value
Waste capacity	t/year	70,000
Digester volume	m^3	3 x 3,500
Heat production	MW_{th}	2.2
Electricity production	MW_{el}	2.0
Digestate production	t/year	92,000
Nitrogen load in digestate	t/year	361
Phosphorus load in digestate	t/year	58
Potassium load in digestate	t/year	171

1.1.3 Digestate Validation and Utilisation

The facility is designed, validated and operated in compliance with the Bioenergy Association *Technical Guide 8: The Production and Use of Digestate as Fertiliser*. The management adopts a robust Quality Management System, governing the areas of feedstock quality control, process management based on HACCP (Hazard Analysis and Critical Control Point) Plan and product (digestate) management and control.

The quality of the digestate produced at the facility meets the A1 class quality requirements specified in The Guidelines for Beneficial Use of Organic material and the additional criteria specified in the Technical Guide 8 relating to physical contaminant and residual biogas production.

The facility therefore has three main options for digestate validation as shown in Figure 14:

1. apply digestate on land as organic material under the Permitted Activity planning control,
2. apply digestate on land as biofertiliser by securing accreditation under the Digestate Certification Scheme (under development), or
3. apply digestate on land as compost by supplying digestate (whole or as separated fibre only) to a certified composting facility.

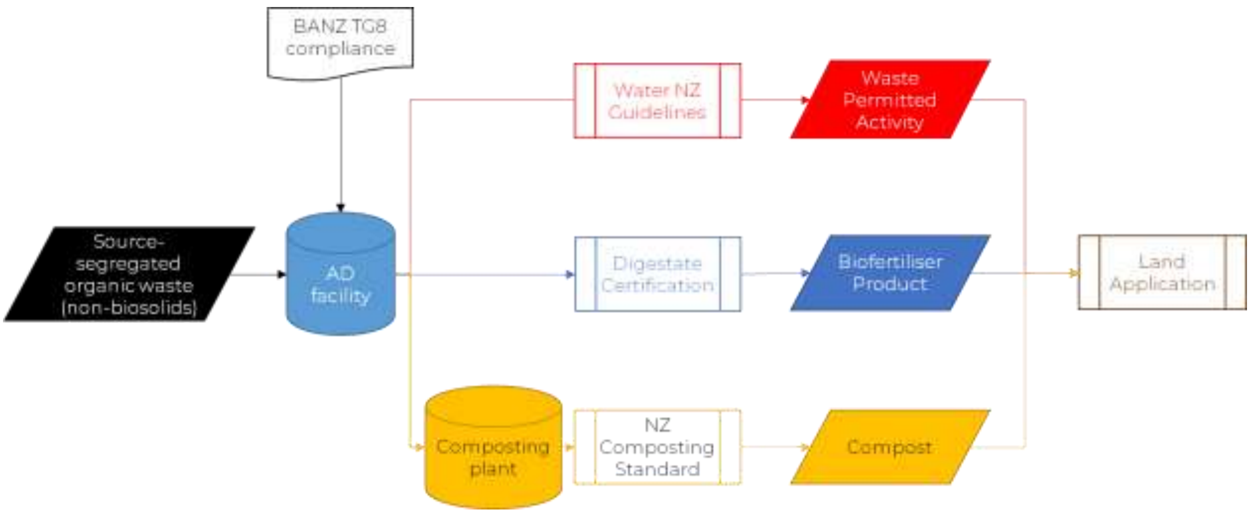


Figure 14 - Alternative pathways for digestate validation.

1.2 Solution

The facility management carried out a cost-benefit and risk analysis of the three product options available:

Table 14: Product options.

Option	Benefits	Risks/Drawbacks
1 – waste	Low cost - no permit required (subject to local regional authority)	Subject to change in legislation
		Low product credibility
		Relies on long-term contracts
		Extensive product testing required
2 – biofertiliser	Highest value product	Cost of certification
	Recognition in agriculture, horticulture	Rigorous Input/Feedstock quality control required
	Customer/User's confidence in safe and of consistent quality	High emphasis on Quality Assurance
3 – compost	Low set-up cost	Relies on long term availability of composting plant
		Generates low value product

1.2.1 Option 1 – Waste

Under this option, the facility is expected to meet the requirements of The Guidelines *for Beneficial Use of Organic Products on Land* (2020). The owner of the facility needs to seek confirmation from the local Regional Authority that application of the produced digestate is considered a Permitted Activity and does not require any further permits.

Figure 15 - Tanker fed sub-soil injection system.

The Guidelines (2020) require that the operators establish a rigorous product quality testing programme to demonstrate ongoing compliance with the quality criteria specified in the Guidelines.

The digestate leaves the facility as a waste product and as such its use is subject to legislation governing waste management. It carries low product credibility despite its high nutrient content. Due to the perceived low value of the product, the producer is recommended to seek long-term supply contracts with local farmers to reduce the risk associated with product sale.

This option has a low set-up cost, yet the cost of frequent product compliance testing is high. The producer is unlikely to receive any revenue from the supply of digestate. In fact, in more AD-saturated markets, producers are required to pay farmers for the offtake of the digestate (up to $10/tonne)[21]. For the purpose of this case study, it is assumed that the offtake of digestate is cost-neutral.

1.2.2 Option 2 – Biofertiliser

Certified Biofertiliser in terms of Technical Guide 8 signifies that the digestate was produced using an effective quality management system. This provides an assurance that the materials have a consistent quality and are safe and reliable to use.

Under the certification scheme, the Biofertiliser is recognised by local authorities and potential users for its nutrient value. The monetary value of the digestate depends upon what mineral fertiliser

[21] http://www.organics-recycling.org.uk/uploads/category1060/Financial_impact_assessment_for_anaerobic_digestate.pdf

pricing benchmark is adopted. Digestate typically replaces a broad based NPK fertiliser containing all three of the primary macronutrients: Nitrogen (N), Phosphorus (P) and Potassium (K).

Based on its current market prices of mineral fertiliser, the equivalent price for digestate is $10-$20 NZD/tonne. This price factors in the increased cost of transport and spreading compared to mineral fertilisers. A conservative price of $5/tonne is assumed for the purpose of this case study to reflect the low maturity of the current digestate market.

This analysis does not quantify the monetary value of the other benefits of applying digestate that do not apply with mineral fertilisers, such as an increase in soil fertility, through the addition of organic matter, ultimately leading to maintaining soil nitrogen (N), enhancing fertility and productivity, increasing soil biodiversity, and reducing erosion, leaching and water pollution.

The higher perceived value of the Biofertiliser product, in comparison to digestate as waste or compost, increases the size of the market and reduces the risks associated with the offtake of digestate from the facility.

The annual cost of maintaining the Certification for this facility is estimated to be in the order of $10,000 – $15,000 NZD[22].

The facility needs to adopt a Quality Assurance System and carry out a hazard analysis that is conducted to define critical performance parameters for process control. The management needs to establish rigorous quality control for the received input waste. Feedstock quality requirements will form an essential part of the feedstock supply agreement with a condition to inform the AD operators of any substantial deviation in the feedstock quality or composition.

1.2.3 Option 3 - Compost

Under this option, the facility is expected to comply with NZS 4454:2005, Composts, Soil conditioners and Mulches NZS. The digestate quality and testing will be subject to the requirements of the receiving Composting facility.

The supply cost of digestate to the Composting facility is likely to be negotiated individually but may be as high as $50-$100/tonne based on current commercial rates. This is due to the relatively high operating cost of composting facilities and low value of compost as a marketable product.

The highest risk of this solution lies in the reliance on a long-term offtake contract with the receiving composting facility.

For the purpose of this case study, it is assumed that a favourable rate of $5/tonne can be negotiated with the composting facility and the product quality monitoring cost will be similar to lower than those required in the other two options.

[22] https://www.biofertiliser.org.uk/pdf/BCS-cost-benefit-analysis.pdf

1.3 Option Comparison

1.3.1 Commercial model

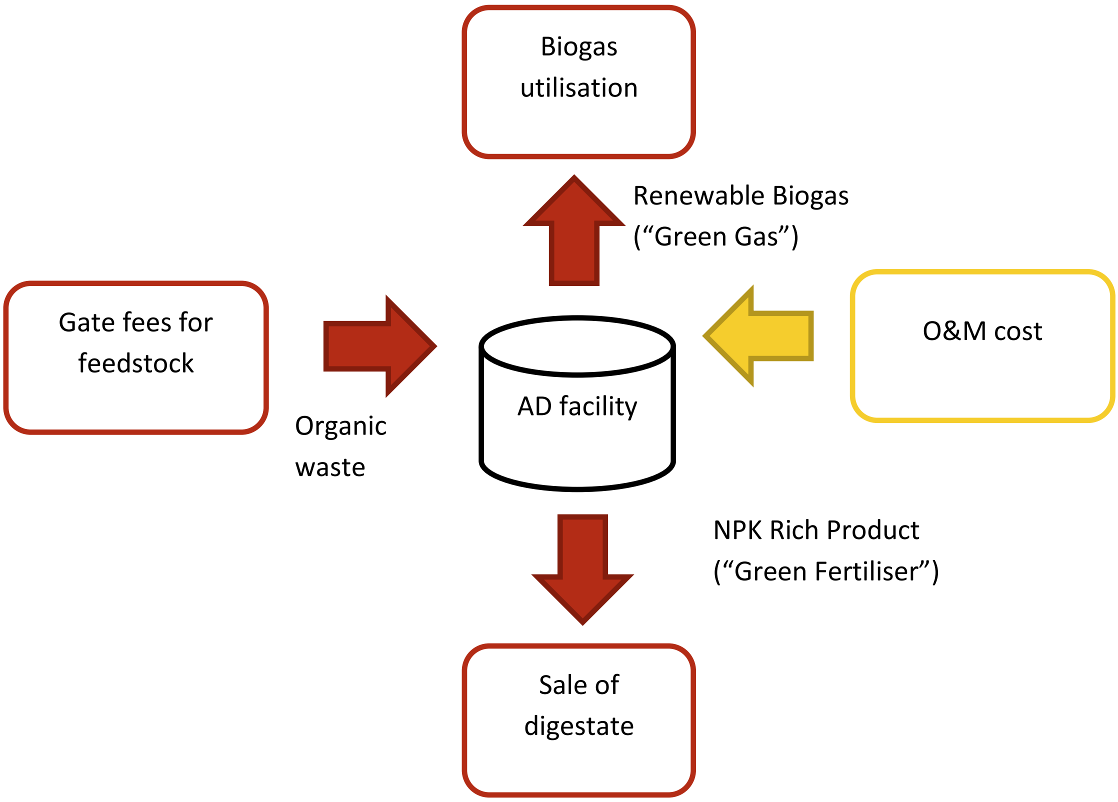


Figure 16 - Commercial model for an AD facility.

A typical business model for a commercial AD facility treating source segregated organic waste draws on revenue from gate fees (collected from feedstock suppliers or as avoided disposal cost), revenue from biogas utilisation (in form of heat, energy, CO_2), and the sale of digestate as biofertiliser, compost or for direct use.

Construction of an AD facility involves a large capital investment, which presents a substantial risk to the project developer/owner. Therefore, the contractual commitments for waste supply, biogas and fertiliser sales need to be long-term (> 10 years) to justify the investment.

The (feedstock/biogas/biofertiliser) customers' key risk during this period is whether the negotiated price becomes expensive compared to future alternative options for waste disposal, fertiliser and energy supply.

It should be acknowledged that policy decisions introducing a cost of carbon to reduce emissions (from waste disposal, industrial heat and fertiliser usage) suggest that the cost of traditional alternative options will increase in real terms over time.

1.3.2 Options comparison

It is assumed that the revenue from feedstock gate fees and sale of biogas will be the same for all three options. Similarly, the operation and maintenance cost of the facility is the same for all three options. Option 1 will comply with The Guidelines and Option 2 with TG8. Option 3 will comply with NZS 4454:2005.

Table 15 lists the variable cost and revenue for the three presented options. The facility selling digestate (@ $5/tonne) as a certified biofertiliser has an opportunity to generate substantial revenue.

Table 15: Evaluation of digestate sale options.

Option	Annual Cost		Annual Revenue	
1 – waste	Monitoring	$10,000	Sale of digestate	$0
2 - biofertiliser	Certification	$12,000	Sale of digestate	$460,000
3 - compost	Monitoring	$5,000	Sale of digestate	-$460,000

Based on the equivalent nutrient value (as kg N/ha applied), the assumed Biofertiliser price needs to be competitive with commercial mineral fertiliser and other biofertilisers to provide financial incentive to its users. Detailed feasibility assessment of potential AD projects demonstrate that the digestate sale value can be as high as $20/tonne, depending on the digestate composition.

1.4 Conclusions

This case study explains the application of the proposed validation framework for the use of digestate from anaerobic digestion facilities treating organic waste. The risk and cost-benefit analysis of the three proposed options demonstrates the value of obtaining Biofertiliser Certification for the produced digestate due to the larger market potential for high-quality product and a potential revenue that may be generated from its sale.

A Certification scheme for digestates to standardise and increase their quality is expected to stimulate the development of the anaerobic digestion option and the available markets for the products. This will provide more certainty in the marketplace and consequently reduce costs and improve the public acceptance of the products. The Certification scheme is also expected to reduce the costs of marketing by providing users with information/knowledge about the product and thereby stimulate confidence.

APPENDIX E - CASE STUDY - ANAEROBIC DIGESTION FACILITY TREATING FARM WASTE

1 OVERVIEW

This case study relates to a farm digester treating manures and/or crop residues. The facility is designed and operated to meet the requirements specified in Technical Guide 8 and a Digestate Certification Scheme (to be developed). The digestate is applied to arable land that is part of the farm holding or sold to neighbouring farms.

1.1 Situation

1.1.1 Feedstock

The anaerobic digestion facility is designed to process up to 70 m^3/day of dairy farm effluent from a 750 head herd. The cows are milked twice a day and kept indoors on a covered feed pad for 12 hours a day. The equivalent herd size for the same organic load where the cows are on the feed pad for only 4 hours would be about 1,800 cows.

1.1.2 Process

The digestion process is set out in Figure 17.

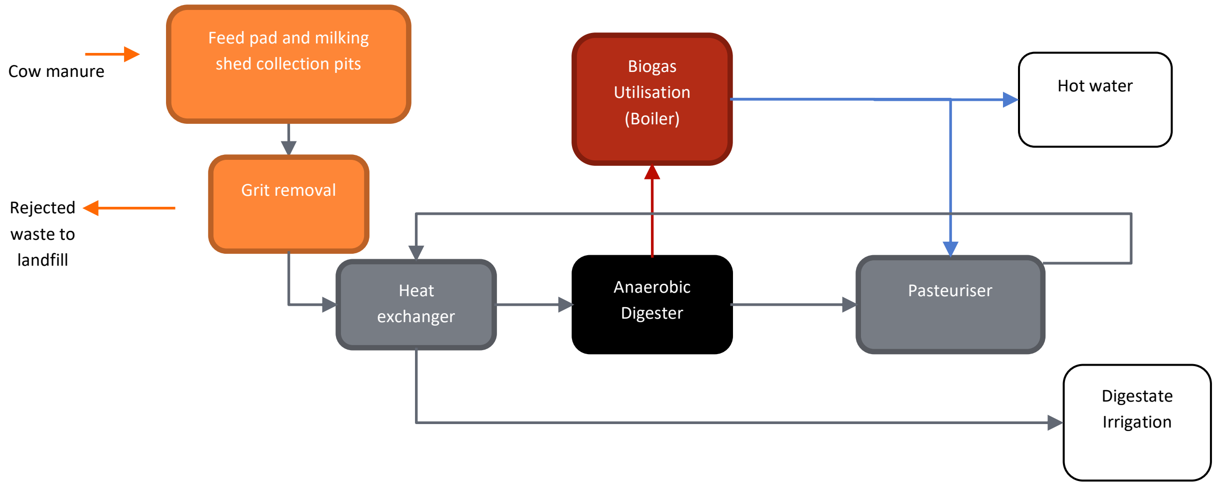


Figure 17 - Farm digester process.

The raw waste from the milking shed is washed down to collection pits for each milking. The manure from the feed pad is scraped down daily followed by a washdown. From the collection pits it flows through grit removal traps to a holding sump. The contents of the holding sump are pumped into the bottom of a covered lagoon digester. The lagoon has been designed and built to the DairyNZ /IPENZ guide[23]. The mesophilic digesters operate at 35°C and with a Hydraulic Residence Time of 60 days. Digestate is stored in the storage ponds for up to 50 days prior to irrigation on to pasture. The biogas can be used directly to generate heat for pasteurisation of the digestate (if required) and heating of

[23] https://www.dairynz.co.nz/publications/environment/ipenz-21-farm-dairy-effluent-pond-design-and-construction/

milk tank wash-down water. Heat from the digestate is recovered in a heat exchanger to heat the incoming effluent.

Table 16 – Anaerobic Digestion facility design capacity.

Parameter	Unit	Value
Waste capacity	t/year	21,000
Digester volume	m^3	1 x 5,000
Heat production	MW_{th}	0.365
Digestate production	t/year	21,000
Nitrogen load in digestate	t/year	73
Phosphorus load in digestate	t/year	8.5
Potassium load in digestate	t/year	75

1.1.3 Digestate Validation and Utilisation

The facility is designed, validated and operated in compliance with the Bioenergy Association *Technical Guide 8: The Production and Use of Digestate as Fertiliser*. The management adopts a robust Quality Management System, governing the areas of feedstock quality control, process management based on HACCP (Hazard Analysis and Critical Control Point) Plan and product (digestate) management and control.

The quality of the digestate produced at the facility meets the A1 class quality requirements specified in The Guidelines *for Beneficial Use of Organic material* and the additional criteria specified in the Technical Guide 8 relating to physical contaminant and residual biogas production.

As shown in Figure 18 the facility has two (2) main options for the beneficial use of their digestate:

1. Business as usual; apply digestate on land as waste organic material under the existing effluent discharge consent,
2. Apply digestate on land as certified Biofertiliser by securing accreditation under the Digestate Certification Scheme (under development).

Option 1 meets the requirements of The Guidelines and has 2 options which is for use as a fertiliser on the on-site farm (Option 1a), or for sale to neighbouring farms (Option 1b)

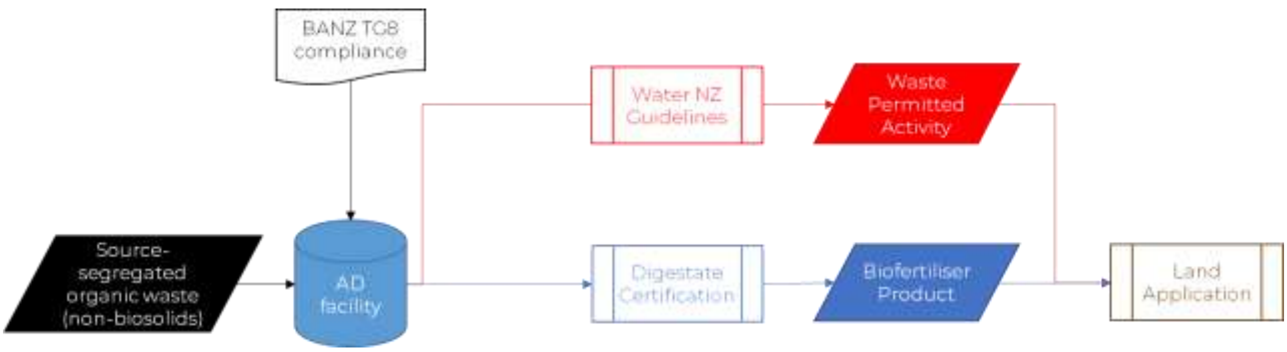


Figure 18 - Options for processing and selling digestate.

In option 2 the biofertiliser is produced to the requirements of TG8 and is assumed to be sold in a liquid form as it is for on-farm use. The option of drying the biofertiliser for sale to other parties could be possible but with the underdeveloped state of the biofertiliser market the option of drying and selling the biofertiliser would not generally be economic. This could be a future option.

1.2 SOLUTION

The facility management carried out a cost-benefit and risk analysis of the two options available as shown in Table 17:

Table 17: Benefits and Risks of Options.

Option	Benefits	Risks/drawback
1 – Discharge to land as waste	Low cost – standard consent required	Subject to change in legislation
	Nutrient benefit when applied to own land	Low product credibility and low/negative return when applied to off-farm sites
2 – Certified Biofertiliser	Higher value product	Cost of certification
	Recognition in agriculture, horticulture	Additional cost for pasteurisation
	Customer/User confidence as safe and of consistent quality	Additional cost for delivery

1.2.1 Option 1 – Discharge to land (Business as usual).

Under this option, the facility is expected to comply with The Guidelines *for Beneficial Use of Organic Products on Land* (2020). The owner of the facility needs to seek confirmation from the local Regional Authority that application of the produced digestate is considered a Permitted Activity and does not require any further permits. If the regional plan has provision for digestate to be applied as a permitted activity then this can be done otherwise the dairy farm would discharge under their existing effluent consent. In either case there would be no need for pasteurisation.

The digestate could be applied to neighbouring land without pasteurisation (Option 1b) provided a controlled activity discharge consent were obtained. The digestate would leave the facility as a waste product and as such its use would be subject to legislation governing waste management. It carries low product credibility despite its high nutrient content. Due to the perceived low value of the product, the producer is recommended to seek long-term supply contracts with local farmers to reduce the risk associated with product sale. Assuming the application to land is consented as a controlled activity, this consent will apply to a particular land area so security of access to that land for discharge is also important.

The producer is unlikely to receive any revenue from the supply of digestate. In fact, in more AD-saturated markets, producers are required to pay farmers for the offtake of the digestate (up to

\$10/tonne)[24] due to its perception as a waste product. In addition to this there would be significant transport or reticulation costs to get the digestate to the neighbouring farms.

1.2.2 Option 2 – Certified Biofertiliser

Certified Biofertiliser signifies that the digestate was produced using an effective quality management system. This provides an assurance that the pathogen free materials have a consistent quality and are safe and reliable to use.

Under the certification scheme, the Biofertiliser is recognised by local authorities and potential users for its nutrient value. In some markets, this is sufficient for the producer to generate revenue from the sale of digestate. Based on its estimated nutrient value, the equivalent price for digestate from a dairy effluent digester is \$10.25 NZD/tonne. A conservative price of \$5/tonne is assumed for the purpose of this case study to reflect the low maturity of the current digestate market.

The cost of transport needs to be considered. It is unlikely that trucking of 70 m^3/day of digestate would be a viable option so the most likely scenario would be reticulation of the digestate to the receiving farm within 5 km. The cost of this reticulation could range from \$50,000 to \$500,000 depending on the distance and terrain. A typical set up cost of \$300,000 spread over ten years has been assumed giving an annual cost of \$30,000. The cost of delivery also limits the available market for the product as the end user needs to be in reasonable proximity to the digestion facility.

The higher perceived value of the product increases the size of the market and reduces the risks associated with the offtake of digestate from the facility.

The annual cost of maintaining the Certification for this facility is estimated to be in the order of \$10,000 – \$15,000 NZD[25].

The facility needs to adopt a Quality Assurance System and carry out a hazard analysis that is conducted to define critical performance parameters for process control. The management needs to establish rigorous quality control for the received input waste. Feedstock quality requirements will form an essential part of the feedstock supply agreement with a condition to inform the AD operators of any substantial deviation in the feedstock quality or composition.

In order to be supplied to farms outside the holding the product would need to undergo pasteurisation. This would require the input of an additional 84kW of heating. While the heating can be provided by the burning of the biogas this might result in lost opportunity to use the gas for other purposes. 84 kW represents about \$30,000 assuming \$0.05 per kWh commercial gas rates.

For this option it is assumed that Regional Councils will apply a permitted activity rule based on the application of a certified fertiliser.

Securing the facility certification also enables the facility to receive and treat wastes other than manure provided these comply with the source-segregated waste specification of the accreditation

[24] http://www.organics-recycling.org.uk/uploads/category1060/Financial_impact_assessment_for_anaerobic_digestate.pdf

[25] https://www.biofertiliser.org.uk/pdf/BCS-cost-benefit-analysis.pdf

scheme and the TG8, and do not compromise the quality of the digestate. Typical drivers for treating other wastes are:

- Improving the digestate nutrients content,
- Generating more biogas energy for use on farm or for export, and/or
- Improving the project economic viability through additional revenue from gate fees and increased output volumes.

1.2.3 Option Comparison

The business case comparison of the two options is presented in Table 18. It is assumed that the operation and maintenance cost of the facility is the same for all options as all will need to comply with the requirements specified in the Technical Guide 8. Note the business case is limited to the use of digestate; additional revenues such as power savings/income and potential carbon credits are not included.

Table 18: Cost, Revenue and Gross Profits for Options.

Option	Annual Cost		Annual Revenue	
1a – Discharge to own land as waste	Consent costs and monitoring	$5,000	Sale of digestate	$0
			Gross Profit (1a)	**-$5000**
1b – Discharge to neighbouring land as waste	Consent costs and monitoring	$5,000	Sale of digestate	$0
	Reticulation	$30,000		
			Gross Profit (1b)	**-$35,000**
2 – Sale as Certified Biofertiliser	Certification	$12,000	Sale of digestate	$105,000
	Reticulation	$30,000		
	Pasteurisation	$30,000		
			Gross Profit (2)	**$33,000**

1.3 Conclusions

This case study examines the options for the use of digestate from anaerobic digestion facilities treating dairy shed and feed pad waste. The risk and cost-benefit analysis of the three options demonstrates that while there may be little benefit in obtaining biofertiliser certification when applying digestate to one's own land, there could be value in obtaining Biofertiliser Certification when providing digestate to outside users, due to the larger market potential for a high-quality product and the potential revenue that may be generated from its sale. However the analysis is sensitive to the price the product can command and the cost of delivery to the end user, and it is these factors which will most likely determine the viability of obtaining Biofertiliser Certification.

APPENDIX F - CASE STUDY - REGIONAL ANAEROBIC DIGESTION FACILITY CO-TREATING FOOD INDUSTRY LIQUID WASTE WITH MUNICIPAL BIOSOLIDS

1 OVERVIEW

"The biogas plant is the hub in the future circular economy. Streams of excess materials, previously regarded as waste, from industrial processes, agriculture and other human activity can be processed through biogas digesters and converted to useful energy carriers, nutrient-rich organic fertiliser and novel materials" (International Energy Agency, 2018)[26].

Consistent with these international developments, primary production industries (dairy, meat, viticulture, food products) have a unique advantage through treating available liquid waste within existing municipal wastewater treatment digester capacities. This has been shown to achieve full treatment and stabilisation of selected source-segregated liquid organic waste materials from food processing industries and of fat, oil and grease rich liquid waste[27] from urban sources.

One key for success of these municipal WWTP infrastructure upgrades towards a circular economy transition is the selection of concentrated liquid waste that are rich in biochemical oxygen demand (BOD), fat oil and grease (FOG) and are low in N,P.K nutrients[28]. This maximises the treatment benefit, the production of useful energy carriers, carbon mitigation and further supports nutrient capture while reducing nutrient release to waterways. Further improvements are feasible with improved N-nutrient recovery.

This case study demonstrates the application of the Bioenergy Association proposed validation framework for the use of digestate from anaerobic digestion facilities treating organic waste within municipal wastewater treatment plants (WWTP's). It relates to a regional anaerobic digestion facility treating source-segregated food processing industry liquid organic waste (DAF sludge), grease trap waste from regional commercial food processors and restaurants and cheese whey from the region.

This facility is an upgrade of an existing municipal WWTP digester for dual purpose use (co-digestion of plant biosolids and imported organic liquid waste) and is designed and operated to meet the requirements specified in Technical Guide 8 and Digestate Certification Scheme (to be developed).

Due to the unique digestion process conditions (trade waste co-digestion), optimised to reduce treatment costs in the regional facility, the food waste digestate becomes mixed with WWTP biosolids digestate and is then processed in the WWTP into treated wastewater and dewatered digestate biosolids. The digestate will therefore not be supplied to local farmers for application on pastural or arable land.

---

[26] The role of anaerobic digestion and biogas in the circular economy. IEA Bioenergy Task 37:2018:8

[27] JH Thiele (2012). Future proofing our wastewater treatment infrastructure. Proceedings of the Water New Zealand Annual Conference. 2012. Rotorua Energy Events Centre, 26 – 28 September 2012

[28] JH Thiele (2011). The Secret is in the Sludge. Proceedings of the Water New Zealand Annual Conference. 2011. Convention Centre, Rotorua, New Zealand.

The proposed facility as a system promotes the principles of sustainable development and circular economy. The transition to a more circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised, is an essential contribution to efforts to develop a sustainable, low carbon, resource efficient and competitive economy. Such transition is the opportunity to transform our economy and generate new and sustainable competitive advantages[29].

1.1 SITUATION

1.1.1 Feedstock

The anaerobic digestion facility is designed to co-process pre-thickened municipal biosolids (up to 60,000 tonnes per annum, tpa, 3-4 % dry matter) with up to 13,000 tpa of source segregated high strength liquid organic waste (12-15 % dry matter), consisting of:

- Dairy factory wastewater DAF sludge,
- Cheese factory whey,
- Grease trap waste from commercial catering and food processing.

The waste is collected and delivered to the facility by a contracted waste company based on long-term supply contracts.

1.1.2 Process

The process consists of the steps set out in Figure 19.

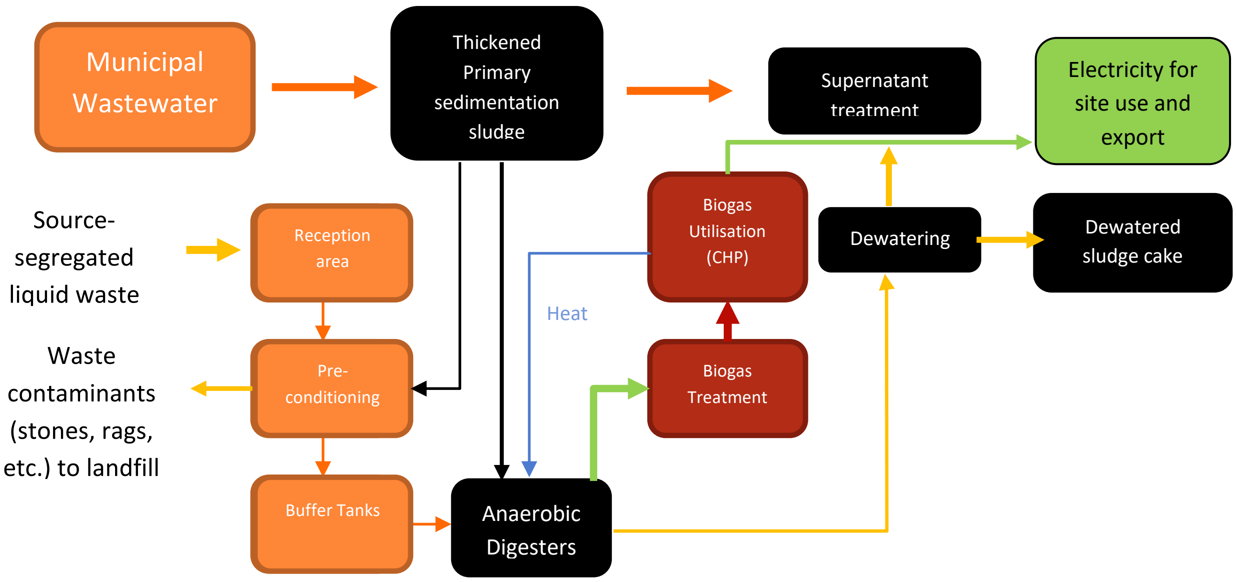


Figure 19 - Wastewater Treatment Plant processing of source segregated organic wastes.

The raw waste is pre-conditioned in a series of steps, consisting of grit-removal and contaminant removal. The two anaerobic digesters operate in co-digestion mode at a mesophilic temperature (37°C) and Hydraulic Residence Times (HRT) of 12-15 days. Biogas is conditioned with activated

[29] Closing the Loop – an EU action plan for a circular economy; 2015

carbon, blended with natural gas and used in a Combined Heat and Power (CHP) unit to generate power (3-4 times increased output compared to wastewater treatment sludge alone) and digester heating. Electricity is for on-site use and distribution to the grid.

Table 19: Anaerobic Co-Digestion facility design capacity.

Parameter	Unit	Value
Waste capacity	t/year	73,000
Digester volume	m^3	2 x 1,350
Heat production	MW_{th}	approx. 1
Electricity production	MW_{el}	0.7
Digestate production	t/year	N/A
Nitrogen load in digestate	t/year	N/A
Phosphorus load in digestate	t/year	N/A
Potassium load in digestate	t/year	N/A

1.1.3 Digestate Validation and Utilisation

The facility is designed, validated and operated in compliance with The Guidelines. While the management adopts a robust Quality Management System, governing the areas of feedstock quality control, process management based on HACCP (Hazard Analysis and Critical Control Point) Plan and product (digestate) management and control, the quality of the digestate produced at the facility is rated as a biosolid product. It does not meet the A1 class quality requirements specified in the 2017 DRAFT The Guidelines for Beneficial Use of Organic material[6]. It also does not meet the additional criteria specified in the Technical Guide 8 (physical contaminant and residual biogas production).

As the quality of the digestate produced at the facility is rated as a biosolid product, in order to sell the digestate the facility management should carry out an analysis of the main digestate quality criteria laid down in the 2020 The Guidelines for Beneficial Use of Organic Materials on Productive Land:

1. **Pathogen destruction**
   The digestion process has no process stage that is dedicated to an effective pathogen destruction (Table 5.2 in The Guidelines.)
2. **Vector attraction reduction**
   The digestion process has a process stage that is dedicated to an effective vector attraction reduction (> 50 % VS destruction achieved; Table 5.3 in The Guidelines.)
3. **Product pathogen standard**
   The digestion process has no process stage that is dedicated to achieve effective pathogen reduction to meet product pathogen standards (Table 5.4 in The Guidelines.)
4. **Contaminant limits**
   The digestion process has no process stage that is dedicated to reduce digestion product contaminant levels. Based on historical data[30] the metal content for the anaerobic co-

[30] NZWWA (1998). National Study of the Composition of Sewage Sludge. ISBN 1-877134-17-1

digestion digestate is likely to exceed the product contaminant concentration limits for most of the key monitored metal contaminants (Table 5.4 in The Guidelines.). This will need targeted verification of current metal contaminant levels in the digestate from the co-digestion process.

To be able to supply the digestate for disposal to land The Guidelines[31] require that the operators establish a rigorous product quality testing programme to demonstrate ongoing compliance with the quality criteria specified in the Guidelines.

The design and implementation of co-digestion process modifications to meet criteria 1 and 3 above would be cost prohibitive. The digestate leaves the facility as a waste product and as such its use is subject to legislation governing waste management.

Unless significant co-digestion process changes are implemented (see the case study in Appendix G), the production of biofertiliser or compost from the digestate is not possible.

1.1.4 Commercial model

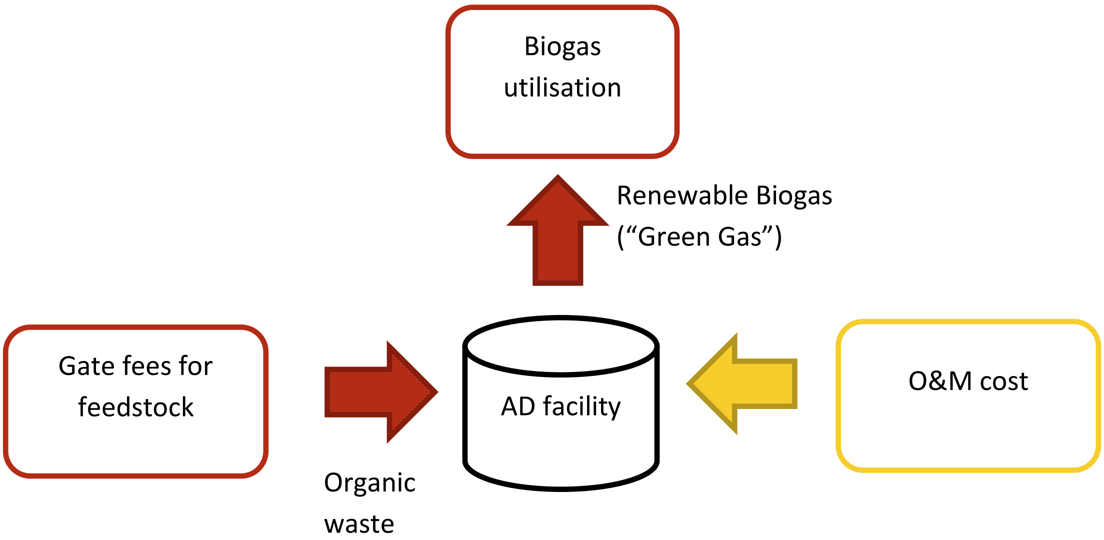


Figure 20 - Commercial model with no revenue from fertiliser sales.

Where revenue cannot be achieved from sale of digestate as a fertiliser a typical business model for a commercial AD facility treating source segregated organic waste draws on revenue from gate fees (collected from feedstock suppliers or as avoided disposal cost), revenue from biogas utilisation (in form of heat, energy, CO_2), and the sale of biosolid for non-land disposal uses. As detailed in Figure 20, the sale of biofertiliser is not realised in this liquid organic waste co-digestion business model.

However, a multiyear performance analysis of this plant[32] has shown that the added liquid trade waste with high FOG content had a neutral effect on the dry matter amount of digestate solids when compared with the digester plant operation without addition of trade waste. In general, the addition

[31] Guidelines for beneficial use of organic materials on productive land (WaterNZ, 2017, DRAFT)

[32] JH 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

of easily digestible organics to primary sludge digesters does improve the sewage sludge digestion efficiency, so there is no sludge disposal penalty incurred when co-digesting trade waste.

Construction of an AD facility typically involves a large capital investment, which presents a substantial risk to the project developer/owner. For example, for the situation described in the case study in Appendix D, construction costs of $30 million are estimated. Therefore, the contractual commitments for waste supply, and biogas sales need to be long-term (> 10 years) to justify the investment.

In case of the construction costs of added infrastructure for this case study, the construction costs were less than 1/10th of the Appendix D case study (Regional Anaerobic Digestion Facility treating Residential and Commercial Food Waste) construction costs and a simple payback of less than 4 years was calculated[7]. In this case, the waste supply contract with one supplier (dairy company) was sufficient and gate fees of the co-digestion facility during a 5 year period could be kept below 50 % of corresponding landfill gate fees. Table 19 shows the relative economics at two gate fee levels.

The (feedstock/biogas/biofertiliser) customers' key risk during this period is whether the negotiated price becomes expensive compared to future alternative options for waste disposal, fertiliser and energy supply.

Table 20: Anaerobic Co-Digestion facility expected business performance.

	Construction costs (incl. waste reception)	Operating cost	Revenue from trade waste gate fees	Revenue from biogas sales as genset fuel	Simple Payback Period
Gate fee: 30 $/m^3	$ 1.1 million	$ 0.2 million/ annum	$ 0.38 million/ annum	$ 0.15 million/ annum	3.3 year **(30 % ROI)**
Gate fee: 50 $/m^3	$ 1.1 million	$ 0.2 million/ annum	$ 0.63 million/ annum	$ 0.15 million/ annum	1.9 year **(53 % ROI)**

Electricity: 0.15 $/kwh. **Polymer:** 10 $/kg and 6 kg polymer/t DS.
Value of biogas: 0.025 $/kwhbiogas. **Trade waste processing capacity:** 13,000 wet t/annum

It should be acknowledged that policy decisions introducing a cost of carbon to reduce emissions (from waste disposal, industrial heat and fertiliser usage) suggest that the cost of traditional alternative options will increase in real terms over time.

1.2 Conclusions

This case study explains the application of the proposed validation framework for the use of digestate from anaerobic digestion facilities treating liquid organic waste by co-digestion on municipal wastewater treatment plants when biosolids cannot be sold as a fertiliser. Key conclusions include:

- Co-digestion of liquid organic waste with municipal biosolids waste at a wastewater treatment plant does not produce digestate of the required quality to achieve certification as a biofertiliser

- Only 1 of the four standards of The Guidelines are achieved so the A1 or B1 classification is not met – specifically speaking the vector attraction reduction standard.
- Achieving the required biofertiliser certification would require process modification to achieve standards for pathogens and other contaminant limits adding business risk (through additional investment costs) particularly given the uncertainty associated with the sale of biofertilizer.
- The benefits of co-digestion however include:
    - minimising capital costs and integrating the organic waste digestion into operating premises.
    - increase energy production at wastewater treatment plans offsetting energy costs and provide carbon mitigation.
    - Collecting gate fees for the treatment of the imported organic waste
- When the biosolids processing is separated from the organic waste processing (see case study in Appendix G), the financial risks are reduced due to the larger market potential for high-quality digestate product and potential additional revenue that may be generated from its sale.

Introducing the Biofertiliser Certification scheme for digestates to standardise and increase their quality is expected to diversify the development of the anaerobic digestion option and the available markets for the products. This will provide more certainty for digestate sales in the marketplace and consequently reduce costs and improve the public acceptance of the products.

The Biofertiliser Certification scheme is also expected to reduce the costs of marketing by providing users with information/knowledge about the product and thereby stimulate confidence. However, this case study demonstrates that the transition to circular economy based liquid organic waste management is possible in either case.

APPENDIX G – CASE STUDY - REGIONAL ANAEROBIC DIGESTION FACILITY PRODUCING BIOFERTILISER FROM FOOD INDUSTRY LIQUID WASTE, FOOD RESIDUALS AND BIOSOLIDS

1 OVERVIEW

This document presents one of four case studies demonstrating the application of the Bioenergy Association (BANZ) proposed validation framework for the use of digestate from anaerobic digestion facilities treating organic waste to produce fertiliser and soil conditioner substitute.

Recent cost reductions in municipal sludge digester technology (recuperative thickening) on municipal wastewater treatment plants (WWTP) have enabled councils, waste processors and utilities to upgrade existing sludge digesters to increase sludge solids treatment capacity 2-3 fold without significant CAPEX for construction of new digester tanks or ancillary plant[33&34]. This has been also adopted internationally (Sydney Water, Melbourne Water, others).

Consistent with these developments, New Zealand has now a proven unique advantage in utilising potentially added solids digestion capacities (about 18 sites) to process additional organic waste in municipal WWTP[3].

Prudent use of this "new normal" for organic waste co-digestion (see biofertiliser case 3) achieves

i. full stabilisation of selected source-segregated industrial organic waste, source segregated food residuals and of fat, oil and grease rich liquid waste[35] (about 13,000 tonnes per annum (tpa) per 100,000 population);
ii. 3-4 fold improved daily biogas production. Gas saleable as genset or boiler fuel;
iii. credits for reduced GHG emissions by diverting organic waste from landfills to digesters;
iv. production of nutrient-rich organic biofertilizer.

Key for success in point (iv) is the separation of the biosolids digestion train from the organic waste digestion train at the digester plant. Ideally, concentrated liquid waste and source segregated food waste slurry rich in biochemical oxygen demand (BOD), fat oil and grease (FOG) and N,P.K nutrients[36] are treated in one dedicated digester plant process train, WWTP biosolids are treated in another avoiding biofertiliser contamination with biosolids constituents. Further improvements are feasible at a later stage with improved N-nutrient recovery from the biosolids processing train.

This case study demonstrates the application of the Bioenergy Association (BANZ) proposed validation framework for the use of digestate from anaerobic digestion facilities treating organic waste in a dual train WWTP digester process[2]. It relates to a regional anaerobic digestion facility

---

[33] C Hearn and JH Thiele (2004). Design and Implementation of a large Digester Facility for Putrescible Waste – Process Implementation and Lessons Learned. 2004 Annual Conference, NZ Waste Management Institute.

[34] JH Thiele (2010). Municipal Sludge Digesters for Co-digestion of Primary Sludge and High Fat Industrial Waste. Proceedings of the Water New Zealand Annual Conference. 21-24 September 2009.

[35] JH Thiele (2012). Future proofing our wastewater treatment infrastructure. Proceedings of the Water New Zealand Annual Conference. 2012. Rotorua Energy Events Centre, 26 – 28 September 2012

[36] JH Thiele (2011). The Secret is in the Sludge. Proceedings of the Water New Zealand Annual Conference. 2011. Convention Centre, Rotorua, New Zealand.

treating source-segregated food industry liquid organic waste (DAFF sludge), grease trap waste from regional commercial food processors and restaurants, source segregated food residuals and cheese whey from the region. We also demonstrate options to optimise the business model for this.

The proposed facility as a system promotes the principles of sustainable development and circular economy. The transition to a more circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised, is an essential contribution to efforts to develop a sustainable, low carbon, resource efficient and competitive economy. Such transition is the opportunity to transform our economy and generate new and sustainable competitive advantages[37]*.*

1.1 SITUATION

1.1.1 Feedstock

The anaerobic digestion facility is designed to separately process pre-thickened municipal biosolids (up to 60,000tpa, 3-4 % dry matter) with up to 13,000 tpa of source segregated high strength liquid organic waste (3-15 % dry matter), consisting of:

- Dairy factory wastewater DAFF sludge,
- Cheese factory whey,
- Slurries of macerated source segregated food waste (8-10 % dry matter),
- Grease trap waste from commercial catering and food processing (1-5 % dry matter).

The organic waste is collected and delivered to the facility by a contracted waste company based on long-term supply contracts. The biosolids are produced from the sewage treatment operations at the site.

Note: In the real-life scenario, **no solid food waste** supply contract was able to be established as the AD facility was in direct competition with the adjacent composting plant and any solid food waste gate fees collected at the AD facility would have taken away from the adjacent composting facility that is owned by the council as well ("zero sums game").

1.1.2 Process

The process consists of the following steps:

[37] Closing the Loop – an EU action plan for a circular economy; 2015

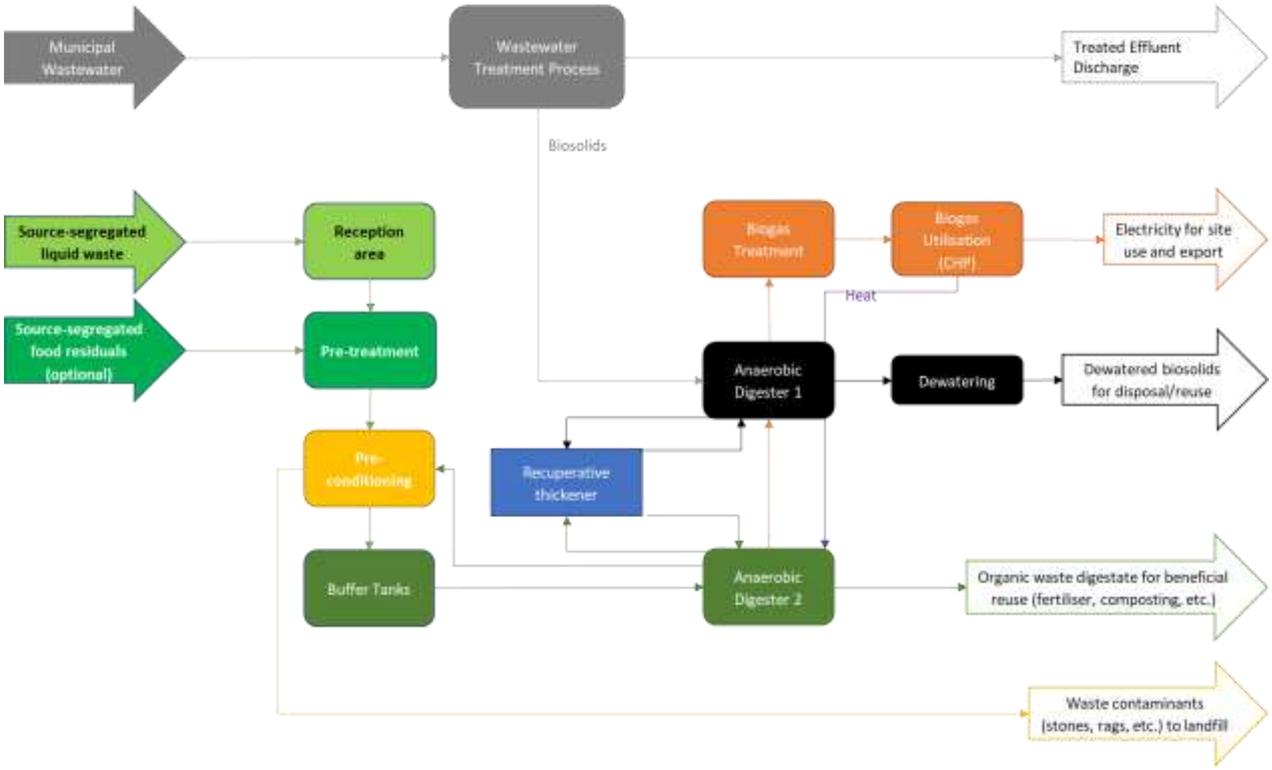


Figure 21 – Pathways for processing organic matter for application to land.

The WWTP biosolids are received from the existing WWTP infrastructure (primary sedimentation tank with sludge thickening). The source segregated liquid organic waste is received in a liquid waste reception in a series of steps, consisting of grit-removal and contacting. The source segregated solid food residuals are received in a dedicated food waste reception building, macerated, pre-conditioned and contacted with food waste digestate.

The anaerobic digesters (2 x) operate in parallel mode, at mesophilic temperature (37°C) and with Hydraulic Residence Times (HRT) of 12-15 days. Digester 1 operates typically in mono-digestion mode with pre-thickened primary sludge and without solid organic waste addition.

Digester 2 operates always in co-digestion mode with highly variable daily loads of rich liquid organic waste (high FOG, high BOD) and variable daily loads of solid food residuals. In rare occasions where the liquid industrial food waste and/or grease trap waste exceed the digester 2 treatment capacity, the surplus liquid waste can be added to digester 1 instead of digester 2.

The recuperative thickener (RT) facility is typically dedicated to digester 2 when all liquid organic waste is added to the food waste digester train (digester 2). The typical RT operation mode for digester 2 is to thicken digester contents to 3-3.5 % TS (typical upper solids capacity cap of municipal sludge digesters) with daily RT operation times of up to 20 hours/day. Solids residence times (SRTs) in the order of 30-40 days are expected.

When the upper solids capacity cap in digester 2 is reached, the RT facility can be disconnected from digester 2 and the digester operated for several weeks without use of the recuperative thickener. Typically, the digester then continues to operate stably and gradually reduces its solids content back from 3-3.5 % TS to 2-2.5 % TS (lower solids capacity bottom). This mode is called a “sea-saw RT operation”.

During the solids weaning phase of digester 2, the RT-facility is connected to digester 1. Typical digester 1 RT operation mode is to thicken the Digester 1 contents up to 2-2.5 % TS (typical operation range of municipal sludge digesters with co-digestion) with daily RT operation times of up to 20 hours/day. When 2-2.5 % TS is reached in digester 1 or digester 2 reaches 2-2.5 % TS (whichever comes first), the RT facility will be disconnected from digester 1, flushed with site process water (thickener and pipework), the flushwater returned to Digester 1 and Digester 1 then operated for several weeks without recuperative thickener. The RT function can be then transferred to Digester 2 or remain idle.

The thickener is the main potential source of cross contamination between digester 1 and 2. It is absolutely critical to follow correct rinsing protocol and prudent testing protocol to prevent cross contamination.

The digestion process has no process stage that is dedicated to an effective pathogen destruction (pasteurisation). Integration of such a step into the WWTP would be cost prohibitive due to the CAPEX, integration costs into the site heat loop with “pasteurisation priority”, high annual heat demand from the high annual digestate volumes (15,000 tpa) and the limited spare heating capacity in the WWTP site heat loop.

Biogas from both digesters is combined and once conditioned, i.e. de-humidified and de-sulphurised, used in a Combined Heat and Power (CHP) unit to generate power and heat for digester heating. Electricity is used for on-site use and distribution to the grid. When the genset fuel demand exceeds the biogas supply, the waste and biosolids digestion biogas is blended with some natural gas.

Table 21: Anaerobic Co-Digestion facility design capacity (combined trains).

Parameter	Unit	Value
Waste capacity (combined)	t/year	75,000
Digester volume	m^3	2 x 1,350
Heat production (combined)	MW_{th}	approx. 1
Electricity production (combined)	MW_{el}	0.7
Digestate production (Digester 2)	t/year	Up to 15,000
Nitrogen load in digestate (Digester 2)	t/year	Up to 35-63
Phosphorus load in digestate (Digester 2)	t/year	Up to 3 - 22
Potassium load in digestate (Digester 2)	t/year	Up to 20-80

1.1.3 Digestate Validation and Utilisation

The facility is designed, validated and operated in compliance with the Bioenergy Association (BANZ) Technical Guide 8: The Production and Use of Digestate as Fertiliser. The management adopted a robust Quality Management System, governing the areas of feedstock quality control, process management based on HACCP (Hazard Analysis and Critical Control Point) Plan and product (digestate) management and control.

Neither of the digestion process trains have a pasteurisation step or on-site digestate storage, a pre-requisite of compliance with the Biofertiliser certification quality protocol (to be developed).

Despite the lack of pasteurisation, the quality of the digestate produced at the facility from the food waste digestion train (Digester 2) meets the qualitative criteria specified in the Technical Guide 8, incl. physical contaminant and residual biogas production. It also meets the A1 class quality requirements specified in the 2017 DRAFT Water NZ Guidelines for Beneficial Use of Organic material[6].

The facility has three (3) main options to use for validation of their digestate:

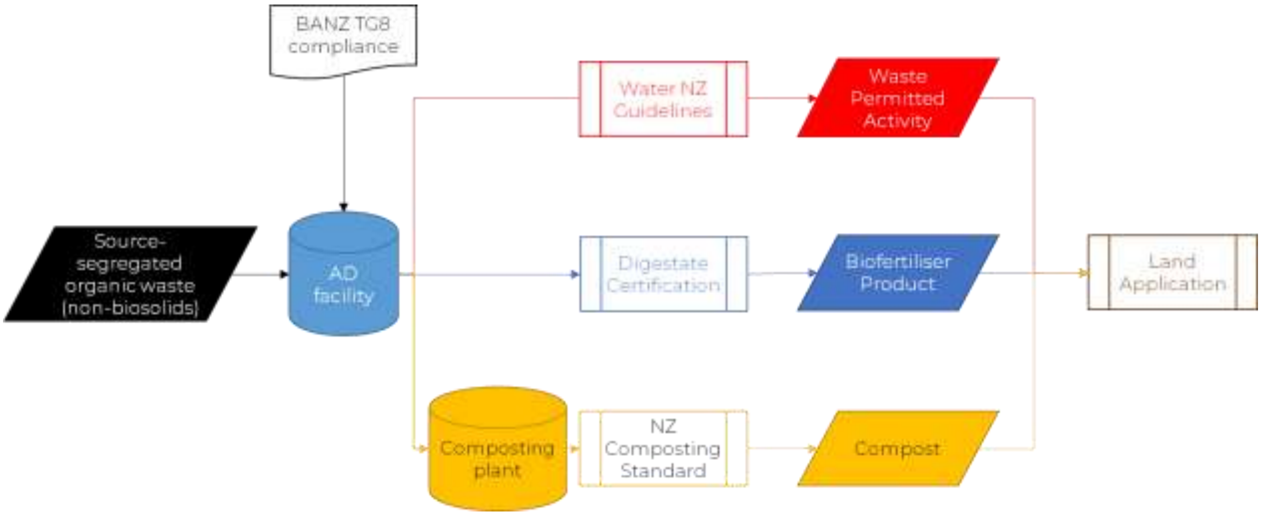


Figure 22 – Pathways for evaluation of organic matter for land application.

1.2 SOLUTION

1.2.1 Biosolids Digestion Training (Digester 1):

The digestate produced in Digester 1 originates from biosolids. The use and quality requirements are therefore governed by Water NZ Guidelines for Beneficial Use of Organic Materials on Productive Land. Technical Guide 8 specifically excludes this feedstock from its scope.

The biosolids digestion train digestate leaves the facility as a waste product and as such its use is subject to changes in legislation governing waste management.

1.2.2 Organic Waste Digestion Training (Digester 2)

The facility management carried out a cost-benefit and risk analysis of the three options available for the digestate from Digester 2 when operated in a food waste mono-digestion mode with liquid organic FOG, dairy and solid food residuals. The analysis methodology was identical to the options analysis in case 1 of this series of case studies:

Table 22: Options for processing organic matter for application to land

Option	Benefits	Risks/Drawbacks
1 – waste	Low cost – permit required (subject to local regional authority)	Subject to change in legislation
		Relies on long-term contracts
		Extensive product testing required
2 – biofertiliser	Highest value product	Cost of certification
	Recognition in agriculture, horticulture	Rigorous Input/Feedstock quality control required
	Customer/User's confidence in safe and of consistent quality	High emphasis on Quality Assurance
3 – compost	Low set-up cost	Relies on long term availability of composting plant
		Generates lower value product

1.2.3 Option 1 – Waste

Under this option, the facility is expected to comply with Technical Guide 8 and meet requirements of the DRAFT Water NZ Guidelines for Beneficial Use of Organic Products on Land (2017)[7]. The owner of the facility needs to seek confirmation from the local Regional Authority that application of the produced digestate is considered a Permitted Activity and does not require any further permits despite the lack of pasteurisation process.

The DRAFT Water NZ Guidelines (2017) require that the operators establish a rigorous product quality testing programme to demonstrate ongoing compliance with the quality criteria specified in the Guidelines.

The digestate leaves the facility as a waste product and as such its use is subject to changed legislation governing waste management. It carries low credibility despite its high nutrient content. Due to the perceived low added value of the product, the producer is recommended to seek long-term supply contracts with local farmers based on the NPK nutrient content to reduce the risk associated with product sale.

This option has a low set-up cost, yet the cost of frequent product compliance testing is high. The producer is unlikely to receive any revenue from the supply of digestate. In fact, in more AD-saturated markets, producers are required to pay farmers for the offtake of the digestate (up to $10/tonne)[38]. For the purpose of this case study, it is assumed that the offtake of digestate is cost-neutral.

1.2.4 Option 2 – Biofertiliser

Certified Biofertiliser signifies that the digestate was produced using an effective quality management system. This provides an assurance that the materials have a consistent quality and are safe and reliable to use, which increases the size of the market and reduces the risks associated with the offtake of digestate from the facility.

[38] http://www.organics-recycling.org.uk/uploads/category1060/Financial_impact_assessment_for_anaerobic_digestate.pdf

Under the certification scheme, the Biofertiliser is recognised by local authorities and potential users for its nutrient value. The monetary value of the digestate depends upon what mineral fertiliser pricing benchmark is adopted. Digestate typically replaces a broad based NPK fertiliser containing all three of the primary macronutrients: Nitrogen (N), Phosphorus (P) and Potassium (K).

Based on its current market prices of mineral fertiliser, the equivalent price for digestate is $10-$20 NZD/tonne. This price factors in the increased cost of transport and spreading compared to mineral fertilisers. A conservative price of $5/tonne is assumed for the purpose of this case study to reflect the low maturity of the current digestate market.

The higher perceived commercial value of a BANZ TG8 complying Biofertiliser product, in comparison to digestate use as waste or compost feedstock, is dependent on tested bacteriological qualities and the absence of metal contamination.

Bacteriological quality

A major problem with the food waste train (**Digester 2**) digestate compliance with the biofertiliser status is the inherent uncertainty of the bacteriological quality of the digestate. The food waste digestion process train **has no digestate pasteurisation step and no on site digestate storage**, a requirement of the TG8 and the future Biofertiliser certification quality protocol (TBD). The CAPEX required for installation of a pasteurisation step was assessed as unfeasible for the facility.

The Digester 2 train does not receive any faecal matter derived feedstocks and specifically excludes the use of sewage and manure derived materials and is based entirely on digestion of source segregated food industry feedstocks. Therefore, human and animal disease causing enteric bacteria, enteric viruses and prions are practically fully excluded by the feedstock types acceptance screen at the facility and are thus excluded from the digestate unless accidentally introduced by contamination at source.

Literature suggests that the beneficial pathogen-reducing effect of pasteurisation can be reproduced in digesters which are efficiently mixed and contacted[9&10][39]. In this case study 4, significant CAPEX resources have been invested for efficient mixing and prior to a digester upgrade for food waste digestion.

It is therefore possible that the digestate from Digester 2 train will comply with the bacteriological and pathogen content criteria despite the absence of the pasteurisation step.

Heavy metal content

Table 2 presents the expected metal content ranges in feedstocks as perceived by the New Zealand Waste Management Institute (WasteMINZ), Water NZ and NZ Crown Research Institutes[40]. It is clear from table 2 that concerning Copper (Cu) and Zinc (ZN) contamination can also be expected in certain

[39] Prescribed tests for digestate bacteriological quality using indicator organisms such as E. coli or FCB (faecal coliform bacteria) to control faecal matter contamination risks of the digestate could thus produce commercially harmful false positive results because the tests are not for specific pathogen types related to the feedstock source. TG8 and PAS110 err thus on the side of caution in their bacteriological quality testing of digestate.

[40] WasteMINZ 2013. The Beneficial Use of Organic Wastes in New Zealand, 24th October 2013

vegetable derived food stuffs in New Zealand conditions and can be extreme in chicken and pig manure and mushroom compost.

Therefore, depending on the make-up of the feedstock treated in the Digester 2 train, the digestate may comply with the heavy metal quality criteria specified in the TG8 for compliance with the future Biofertiliser certification status. This can be confirmed by consistent and regular testing of the feedstock and the produced digestate and/or selective treatment of low risk feedstocks.

Table 23: Metal contents in selected composting feedstock materials in New Zealand.

Product	As	Cd	Cr	Cu	Ni	Pb	Zn
Greenwaste & foodwaste	14	1.1	30	56	37	100	280
Chicken manure	26	0.06	23	43	6	6	295
Pig manure	1	0.06	2	49	2	2	580
Horse manure	3	0.02	6	13	3	8	87
Sheep pellets	3	0.10	9	22	4	17	140
Mushroom compost	36	0.08	8	94	6	10	270
Biosolids Guidelines (max)	**20**	**1.0**	**150**	**60**	**60**	**250**	**300**

Despite the potential to comply with the qualitative criteria of the Biofertiliser certification protocol (TBD), **the lack of a pasteurisation step in the processing train prohibits the facility and consequently the digestate product from receiving the status of a Biofertiliser under the current framework**.

The facility may attempt to gain the Biofertiliser status in the future by demonstrating the safety and complaint quality of the Digester 2 digestate via a long-term testing campaign. This is subject to acceptance by the Biofertiliser certification body.

The production of digestate within the wastewater treatment plant makes digestate marketing as biofertiliser impractical due to the product perception as having association with human waste processing, and due to issues related to site security and access, public health and safety.

In order to minimise the risk of cross-contamination with the biosolids-derived product, many comparable installations would physically separate the Digester 2-dedicated pasteurisation step (if included in the future), reception buffer tank and digestate offtake to outside of the WWTP boundary.

1.2.5 Option 3 – Compost

Under this option, the digestion facility is expected to comply with Technical Guide 8. The digestate quality and testing will be subject to the requirements of the receiving Composting facility.

The supply cost of digestate to the Composting facility is likely to be negotiated individually but may be as high as $50-$100/tonne based on current commercial rates. This is due to the relatively high operating cost of composting facilities and low value of compost as a marketable product.

The highest risk of this solution lies in the reliance on a long-term offtake contract with the receiving composting facility.

For the purpose of this case study, it is assumed that a favourable rate of $5/tonne can be negotiated with the composting facility and the product quality monitoring cost will be similar or lower than those required in the other two options.

The commercial model analysed for this case study 4 assumes that the food waste digestion train (Digester 2) digestate status as Biofertiliser was not attainable due to the lack of a pasteurisation step.

1.2.6 Commercial model

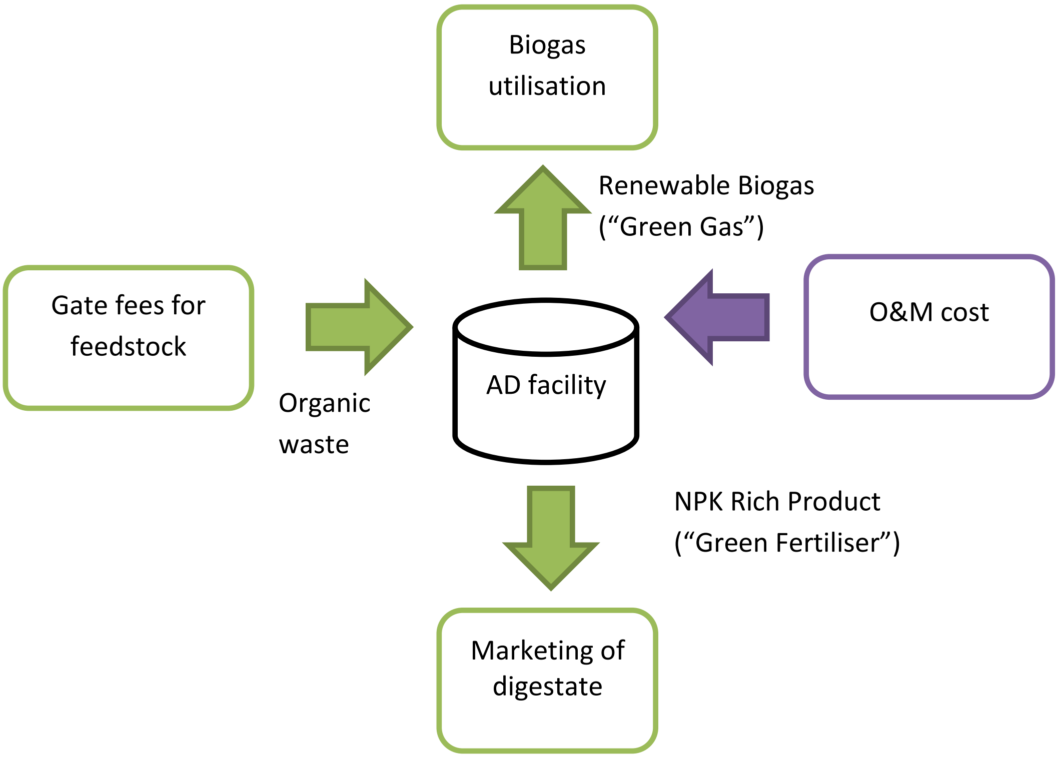


Figure 23 - Typical business model for a commercial Anaerobic Digester facility.

A typical business model for a commercial AD facility treating source segregated organic waste draws on revenue from gate fees (collected from feedstock suppliers or as avoided disposal cost), revenue from biogas utilisation (in form of heat, energy, CO2), and the sale of biofertiliser.

A multiyear performance analysis of this plant[41] when operated with liquid organic trade waste has shown that the added liquid trade waste with high FOG content had a neutral effect on the dry matter amount of biosolids digestate solids when compared with the digester plant operation without addition of trade waste due to the synergistic effect of co-digestion.

[41] JH 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

As detailed above, it is likely that the sale of biofertiliser into the open market in this organic waste co-digestion business model with separate digestion trains cannot be realised with significant revenue due to lack of a product pasteurisation step at the WWTP.

Digestate marketing into the open market as “controlled liquid waste” at “zero” digestate purchase cost to the buyer is likely (similar to liquid manure) because the heavy metal content of the digestate is low and the expected bacteriological quality is high and could be proven in separate resource consent applications as permitted activity for food crops, pasture and greens (golf course etc.) maintenance.

Construction of a new greenfields AD facility typically involves a large capital investment, which presents a substantial risk to the project developer/owner. For example, for the situation described in case study 1, the construction costs of $30 million are estimated (EcoGas Press release, 2019). Therefore, the contractual commitments for waste supply, biogas and Biofertiliser sales would need to be long-term (> 10 years) to justify the investment.

In case of the construction costs of added infrastructure for case study 3, the construction costs were less than 1/10th of the case study 1 construction costs and a simple payback of less than 4 years was calculated[14]. In the case study 3, the waste supply contract with one supplier (dairy company) was sufficient and gate fees of the co-digestion facility during a 5-year period could be kept below 50 % of corresponding landfill gate fees (Refer to Case Study 3 for more details).

In case of the construction costs of added infrastructure for case study 4, the construction costs were 1/10th of the case study 1 construction costs. However higher OPEX (staffing for solid food waste reception and facility) would give a simple payback of about 11 years at a gate fee of 30 $/t for the liquid food waste (table 3).

With two main liquid waste suppliers (dairy company, waste hauler for grease trap waste) gate fees at the co-digestion facility during a 10-year period could potentially be kept below 50 % of corresponding landfill gate fees.

The (feedstock/biogas/biofertiliser) customers’ key risks during this period is whether the negotiated price becomes expensive compared to future alternative options for waste disposal, fertiliser and energy supply.

Table 24: Anaerobic Digestion facility (2 parallel trains) – expected business performance.

	Construction costs (incl. waste reception)	Operating cost	Revenue from liquid organic waste gate fees	Revenue from biogas sales as genset fuel	Simple Payback Period
Gate fee: 30 $/m^3	$ 3 million	$ 0.26 million/ annum	$ 0.38 million/ annum	$ 0.17 million/ annum	< 11 year
Gate fee: 50 $/m^3	$ 3 million	$ 0.26 million/ annum	$ 0.63 million/ annum	$ 0.17 million/ annum	< 6 year

Electricity: 0.15 $/kwh. **Polymer:** 10 $/kg and 6 kg polymer/t DS.
Value of biogas: 0.025 $/kwhbiogas. **Trade waste processing capacity:** 13,000 wet t/annum

It should be acknowledged that policy decisions introducing a cost of carbon to reduce emissions (from waste disposal, industrial heat and fertiliser usage) suggests that the cost of traditional alternative organic waste disposal options (landfilling/ composting) will likely increase in real terms over time.

1.3 Conclusion

This case study explains the options for application of the proposed validation framework for the use of digestate from anaerobic digestion facilities on municipal wastewater treatment plants with separate digestion trains for organic waste and biosolids. Key conclusions include:

- Separate digestion of liquid and solid organic waste at a wastewater treatment plant does not produce digestate of the required quality to achieve certification as a Biofertiliser due to the lack of pasteurisation step.
- Achieving the required certification would require process modification to achieve standards for pathogens adding business risk (through additional investment costs) particularly given the uncertainty associated with the sale of biofertiliser
- The benefits of organic waste digestion on municipal WWTP however include:
    - minimising capital costs and integrating the organic waste digestion into operating premises,
    - increased energy production at wastewater treatment plans offsetting energy costs and providing carbon mitigation,
    - collecting gate fees for the treatment of the imported organic waste

The solution described in the case study 4 is very attractive from the perspective of the society, rate payers, decision makers and planners for the following reasons:

- An affordable transition to circular economy principles in organic waste management.
- Savings in the order of $ 0.5 – 1 billion in CAPEX costs that would be needed for an equivalent 20-30 large, dedicated food and organic waste digestion plants for the NZ organic waste industry[42].

[42] J H Thiele (2007). National Putrescible Waste Biofuel Potential Assessment. 44 pages. Report for SCION and Foundation for Research, Science & Technology, EnergyScape Project

- A significant landfill gas emission reduction and biofuel production from diversion of landfilled suitable industrial organic waste[43] into wastewater treatment plant-based co-digestion of organic waste (separate digester train model)[16].

In comparison to Case study 3, this proposed scenario offers the following considerations:

- When the biosolids processing is separated from the organic waste processing (this case study 4), the financial risks are increased due to the increased CAPEX costs compared to a liquid organic waste co-digestion only process (case study 3).
- When the biosolids processing is separated from the organic waste processing (this case study 4), “operation scale factored” financial risks are similar or slightly reduced compared to a dedicated greenfield facility for organic food waste digestion at a much larger scale (case study 1), despite a potential additional revenue that may be generated from biofertilizer sale in the large scale facility.
- The main reason for a somewhat lower financial risk for organic waste digestion at WWTP sites with smaller scale via retrofit of existing works are twofold; the lower overall organic waste digestion CAPEX for the added minor works that are required and the lower exposure to fluctuations in gate fees and waste supply contracts due to alternative disposal options.
- However, higher digestate re-use risks exist in terms of marketing, value add or even disposal in the municipal WWTP integrated organic waste processing case analysed here when compared to the dedicated greenfield facility for organic food waste digestion at a much larger scale (see case study 1).
- It needs to be clearly stated that one may expect resistance from the municipal WWTP owners and the operating staff against a case study 4 of organic waste digestion integration into municipal WWTP operations due to the following factors:
    1. The biogas production increase in case study 4 is only marginally higher than case study 3.
    2. Handling of solid food waste is more complicated than the handling of easily pumpable liquids.
    3. The risks to the operation of the balance of the treatment plant are higher due to the additional waste material, odour emission risks, vector attraction in reception areas, and higher N and P nutrient amounts in the digestate if disposal through the plant is required in case of emergencies.
    4. Higher vehicle traffic and site security risks.
    5. The trend of automation and staff rationalisation in the municipal WWTP industry makes it counterintuitive to add more process complexity and staff responsibility without significant financial incentives and rewards.

[43] JH Thiele (2017). The potential of further biogas plant in New Zealand. Proceedings of the BANZ workshop: Processing Food and Municipal Waste to Energy, Hamilton 19 September 2017