Technical Memorandum
EFFGO Limited New Zealand

Organic Waste Treatment – EFFGO Supercritical Water Oxidization
EFFGO Limited

TO:	Simon Jury (EFFGO)	**REF:**	J2786
FROM:	Gareth Williams	**DATE:**	15 February 2021

INTRODUCTION

The sustainable management and disposal of organic waste, sludge and biosolids produced from municipal and industrial wastewater treatment plants in New Zealand is an ongoing issue. Population growth and increasing primary industry development have put pressure on current approaches to sustainable management practices, which have focused on biological treatment and land application or reclamation.

This approach, while reducing the diversion of sludge and biosolids to landfills, has encountered a number of issues including:

- High costs related to transport and disposal
- Variable treatment performance
- Public acceptance
- Odours
- Health and safety issues associated with the handling and disposal
- Stringent acceptance criteria
- Effects on receiving environments

A demand is emerging for a reliable and sustainable form of sludge processing that does not suffer from these drawbacks. EFF-GO Limited (EFF-GO) has identified a semi mature process known as Supercritical Water Oxidization (SCWO) and has refined and adapted it for the wastewater industry. EFF-GO's SCWO process resolves many of the drawbacks associated with conventional treatment processes.

This memo discusses significant sources of sludge, organic waste and biosolids in New Zealand and describes the EFF-GO process and its potential applications.

MUNICIPAL SLUDGE AND BIOSOLIDS GENERATION

The three major population centres – Auckland, Wellington and Christchurch, are responsible for the majority of municipal wastewater and biosolids generated in New Zealand.

In 2017/18 New Zealand municipal plants produced approximately 500,000 tonnes of dry biosolids, with the majority (56% - 280,000 tonnes) of biosolids being disposed of to landfill[1], identifying the need for cost effective, alternative disposal routes.

The tipping fees associated with disposing of biosolids to landfill can be estimated at $280/tonne[2],resulting in an annual cost of approximately $78M NZD, excluding any costs associated with processing.

Aging infrastructure is also expected to increase the cost of sludge processing and transport. In January 2020, Wellington Water experienced a dual sludge pipeline failure resulting in the need to transport 1,000 m^3 of wet sludge daily, at a cost of $100,000/day[3].

Municipal biosolids are characterised by a very high organic and nutrient content and can have a high metals content due to stormwater run-off from roads, contributions from trade waste and corrosion in reticulation networks[4].

Municipal utilities companies including Watercare and Christchurch City Council are increasingly utilizing highly treated biosolids for land rehabilitation and fertilizer, driven by growing landfill disposal costs and an industry shift towards energy and nutrient recovery. However, given the strict standards required for biosolids re-use and the generally poor marketability of human waste derived fertilizer, disposal to landfill is often kept as a back-up option.

INDUSTRIAL ORGANIC WASTE, SLUDGE AND BIOSOLIDS GENERATION

Key New Zealand industrial sources of sludge and organics include the following:

- Dairy Processing
- Paper and Pulp Processing
- Meat Processing

Dairy wastewater is typically characterised as being highly biodegradable with significant organic, nutrient and fat content[5]. Due to its composition and increasing regulatory requirements, particularly for disposal to sensitive environments such as rivers, secondary biological treatment is typically employed, with sludge a significant by-product of this treatment.

Fonterra alone discharges over 25,000,000 m^3 of treated wastewater annually across all their operations to river[6]. Dairy wastewater treatment plants (WWTPs) typically produce large quantities of sludge, owing to the significant concentrations of carbonaceous biochemical oxygen demand (cBOD) present in the raw wastewater.

A high-level review of dairy activated sludge treatment plants suggests a waste activated sludge (WAS) generation in the order of 0.02 m^3 WAS/m^3 wastewater (at 4% dry solids). Based on Fonterra's river discharge volumes, this equates to a generation of 500,000 m^3 WAS annually. WAS and other wastewater sludges from dairy activities are typically discharged to land where possible. However, the volume that can be disposed of is often limited by restrictions on the

levels of key nutrients that can be discharged to land. In order to ensure compliance with regulatory requirements, excess sludges require alternative disposal routes, often involving trucking of the sludge or biosolids to landfills.

New Zealand paper mills are estimated to produce in the order of 200,000 tonnes of organic waste[7]. Key organic waste products from paper processing includes primary and secondary pulp mill solids. Primary pulp mill solids are the main organic by-product and are typically high in organics but low in nutrients, limiting its land applicability, typically resulting in disposal to landfill. Secondary pulp mill solids have better nutrient ratios and are more suitable for disposal to land.

There are close to 50 meat processing facilities operating in New Zealand, with the majority centred around key farming regions including the Waikato, Manawatu-Wanganui, Canterbury and Southland[8].

Meat processing wastewater is typically split into several streams at the source, with separate streams for wastewater with a high blood content or high faecal material content. Sludge from wastewater treatment, including WAS or sludge associated with primary treatment processes, is typically disposed of to land or composted, with landfill disposal used if the sludge is deemed unsuitable.

Typical New Zealand meat processing plants produce in the order of 10,000 m^3/d of wastewater.[9] A high level assessment of meat processing activated sludge plants indicated a sludge production (prior to thickening) in the order of 2% of the total flow, indicating the average meat processing plant could produce around 200 m^3/d of un-thickened sludge.

Ongoing regulatory action and increasing public awareness of industrial discharges has necessitated the adoption of secondary and tertiary treatment processes. A by-product of further treatment, namely secondary biological treatment, results in the generation of large quantities of sludge. This sludge is typically disposed of to land, however these discharges are often nutrient (or toxicant e.g. heavy metals) limited, can be seasonally dependant and can rely on third party owned land, potentially compromising future discharge security. As a result of this, a number of drivers exist for an alternative sustainable disposal method.

SUPERCRITICAL WATER OXIDIZATION (SCWO)

Supercritical Water Oxidization (SCWO) is a semi-mature technology that can be used to treat organic matter in wastewater with extremely high efficiencies (> 99.99%). SCWO is an autothermic process which causes organic matter and oxygen to approach 100% solubility through high temperatures (> 374°C) and pressures (> 221 bar), facilitating the highly efficient and rapid chemical combustion of organic matter.

SCWO has previously been used to treat municipal, commercial and industrial waste, which demonstrated chemical oxygen demand (COD) removals >99.9%[10], a realization of the expected theoretical treatment efficiencies. However, SCWO has in the past suffered from several fundamental difficulties including salt precipitation and corrosion, which have hindered SCWO's wider industry uptake.

EFF-GO Limited (EFF-GO) have devised novel solutions to the underlying issues associated with SCWO and are in the process of obtaining funding to undertake a bench scale trial of the EFF-GO modified SCWO process. An indicative process flow diagram (PFD) of the process is attached to this document.

APPLICATION OF SCWO TO SLUDGE AND BIOSOLIDS

SCWO can be utilized as the primary or back-up treatment method for sludge and biosolids. As a result of the process, pathogens are destroyed and emerging contaminants including endocrine disruptors are transformed into their component parts[11].

SCWO is also a physical-chemical process, thus does not suffer from the treatment variability and inability to cope with toxic or abnormal sludge compositions commonly associated with biological sludge stabilization methods.

As SCWO can rapidly treat sludges and biosolids, the requirement for standard time intensive treatment methods, including sludge digestion and drying, are reduced by several orders of magnitude. EFF-GO have identified their SCWO reactor has a very small footprint relative to a WWTP's size, with a reactor size of only 0.24 m^3 required to treat a sludge generation of 30 m^3/d. As such, the process could likely be retrofitted to most existing WWTPs without the need for expansion or significant changes to existing processes. Furthermore, the EFF-GO process is modular, facilitating straightforward increases in treatment capacity.

EFF-GO have identified the cost of their SCWO treatment as ranging from $120 – 175/tonne, significantly cheaper than standard sludge processing means and landfill disposal.

As the wastewater industry is shifting towards the use of biosolids as a resource (dependant on an acceptable final composition), SCWO can also be used as a back-up process for treatment. Currently, unsuitable biosolids post-treatment are disposed of to landfill. However, further treatment utilising EFF-GO's SCWO process would enable previously unsuitable biosolids to be beneficially utilised elsewhere.

OPPORTUNITIES FOR THE REUSE OF BY-PRODUCTS FROM THE SCWO PROCESS

The by-products of EFF-GO's SCWO process include carbon dioxide (CO_2), water, ammonia (NH_3) and inorganics. As an alternative to NH_3, increasing the temperature of the reaction will result in the generation of nitrogen gas (N_2). Any grit or unsuitable material can be recycled to the headworks of the WWTP. By-products of the process can be readily captured as they are discharged from a point source.

CO_2, and NH_3 can be recovered and effectively utilized in algaculture, agricultural and horticultural activities by providing key elements required for production in a consistent and sustainable manner. Post SCWO process water will contain inorganic salts and oxides. Membrane treatment of the process water will render it suitable for re-use for a number of applications including irrigation and wash water, and with minor additional treatment, potable water.

CONCLUSION

EFF-GO's novel SCWO resolves many of the drawbacks associated with traditional sludge processing and disposal methods. This process can be utilized as the fundamental municipal, commercial and industrial sludge and biosolids treatment method, both in New Zealand and abroad.

By-products of the process can be beneficially reused in a number of applications, meeting industry demand for a reliable and sustainable sludge processing method.

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APPENDIX A
EFF-GO PROCESS FLOW DIAGRAM