BIOSOLIDS INCINERATION AT TAHUNA WWTP – FUELLING A $10 MILLION CAPITAL SAVING

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ABSTRACT

Dunedin City Council operates the only biosolids fluidised bed incinerator in Australasia. The system uses 3.5m^3 of sand as the fluidising medium, which operates at a combustion temperature of 830°C.

This paper outlines the conclusion to the Tahuna Wastewater Treatment Plant upgrade project, being the biosolids disposal strategy. The original project had committed capital funding of $14.6 million for a biosolids beneficial re-use or disposal facility. However, by reusing the existing 1980 fluidised bed incinerator, DCC has been able to reduce this budget by $10 million and deliver several environmental benefits.

DCC is embarking on a project to optimise the existing incinerator, including re-conditioning the asset, automating the system for unmanned 24/7 operation and installing an ash removal system. Investment in an ash removal system has made the decision to reuse existing infrastructure an environmentally sustainable one. Without an ash removal system, the ash from combustion would accumulate in the treatment process, lowering the calorific value of the waste biosolids, resulting in the need to use diesel to augment combustion. In the absence of ash removal, only 36% of waste biosolids could be incinerated to prevent ash build up in the treatment plant; the remaining 64% requiring disposal to Landfill.

KEYWORDS

Fluidised Bed Incinerator, biosolids, ash removal, optimizing, Tahuna Wastewater Treatment Plant, Dunedin

1 INTRODUCTION

The completion of the Stage 2 Tahuna Wastewater Treatment Plant (WWTP) upgrade in January 2013 was the penultimate step of the Dunedin City Council (DCC) wastewater upgrade strategy adopted in 1991/92. The upgrade work at Tahuna WWTP has included a 1.1 km ocean outfall (stage 1 upgrade), construction of a high rate activated sludge treatment process, biological trickling filters, UV disinfection, new biosolids de-watering facility, and increased odour control capability (stage 2 upgrade). DCC has currently invested approximately $200 million in the overall wastewater strategy to ensure that the standard of wastewater treatment meets the community's aspirations and resource consent conditions.

Stage 3, the Tahuna WWTP Biosolids Disposal Project, is the conclusion to the DCC wastewater upgrade strategy. The original project scope had committed capital funding of $14.6 million for a bio-solid beneficial re-use or disposal facility. Preliminary design of this facility included a digester and biosolids dryer. However, in November 2009, just prior to the Stage 2 upgrade construction works, DCC put the biosolids component of the upgrade strategy on hold.

The Tahuna WWTP Upgrade Project Control Group resolved:

"That the implementation of the solids side was put on hold until 2013/14 in order that a more holistic approach with respect to treatment, beneficial reuse and disposal may be considered."

Since 2010 a number of biosolids disposal technologies have been evaluated including:

1. STERM biosolids drying process – This was a preferred technology, however the process did not develop beyond the pilot plant stage and the pilot plant in Hamilton ceased operation.
2. Pacific Pyrolysis – Due to the large equipment footprint and volume of green waste required, this process was not considered practical for the Tahuna WWTP application.
3. Biosolids Dryer – This was demonstrated to be an expensive option, both in capital and operational costs. Operational costs exceeded other options by $155,000 per annum.
4. WETOX (Wet Air Oxidation) - This biosolids disposal process began trials in Palmerston North in May/June 2013. The technology was not proven at full scale.
5. TERAX process (a variation of Wet Air Oxidation) – This process begun trials at Rotorua. The technology was not proven at full scale.

In April 2011 an intermediary proposal to reuse Tahuna WWTP biosolids in the Green Island (GI) WWTP digesters was adopted. This project comprised:

1. Using the underutilised Green Island digesters to process 9 wet t/day of biosolids from Tahuna WWTP (approximately 30% of the total daily biosolids volume) to produce methane gas that can be used to offset waste treatment energy costs, and reduce the processed biosolids by 40% in volume.
2. Send residual biosolids from Tahuna directly to the Green Island landfill where it will aid future methane gas production.
3. Pipe the collected methane gas from the Green Island landfill to power a new gas electricity generator located at the Green Island Wastewater Treatment Plant.

A 625 kW Gas Engine at the Green Island WWTP was installed and commissioned in May 2012.
However, by 2012, a suitable full scale alternative biosolids disposal technology that could be used at Tahuna WWTP had not eventuated.

Prior to the Stage 2 upgrade, DCC had operated the only WWTP biosolids fluidised bed incinerator in Australasia. Re-using the incinerator was not considered during the original evaluation of bio-solid disposal options due to the impending expiry of the Discharge to Air resource consent on 30 June 2013. At the time it was considered unlikely that the consent would be renewed because of more stringent air discharge requirements. However, in parallel with investigating alternative biosolids disposal technologies, DCC conducted an independent evaluation and verification that emissions from their existing fluidised bed incinerator would have no more than minor effect on the environment. An air discharge consent was applied for and a 35 year consent term was approved with only minor changes to the existing consent conditions. Consequently, an alternative option that was not originally expected became available. Options for maximising the use of the incinerator for biosolids disposal were then considered as part of the holistic approach to the Stage 3 biosolids disposal project.

2 BACKGROUND

The DCC biosolids fluidised bed incinerator uses 3.5m3 of sand as the fluidising medium, which operates at a nominal combustion temperature of 830°C.

A schematic of the Tahuna WWTP Fluidised Bed Biosolids Incineration Plant is shown in Figure 1.

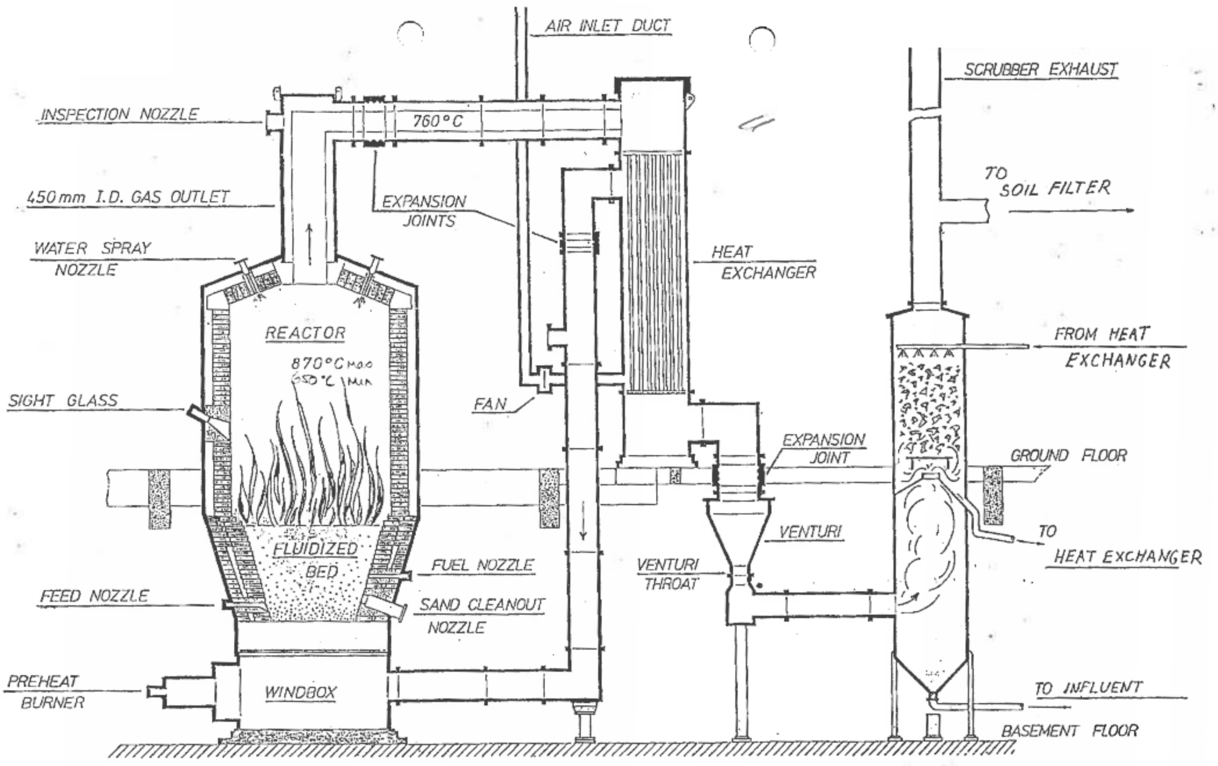

Figure 1: Tahuna WWTP Fluidised Bed Biosolids Incineration Plant

The fluidised bed incinerator is a vertical cylindrically shaped, refractory-lined steel shell that contains a sand bed and fluidized air diffusers called tuyeres. The sand bed sits on a refractory-lined dome, which contains the grid of tuyeres through which air is injected into the furnace to fluidize the bed and provide oxygen for combustion. The bed expands to approximately 200% of its at-rest volume. The temperature of the bed is controlled between 800° and 850°C by feeding biosolids and / or supplementary fuel into the sand bed. The residence time within the combustion zone is several seconds.

The exhaust fluidised air gas passes through a recuperator (heat exchanger), on route to the discharge. The recuperator cools exhaust air from approximately 780°C to 400°C and heats the fresh fluidising air from approximately 25°C to 400°C. The fly ash generated by the incinerator is carried out the top of the furnace and captured from the exhaust gas in the venturi scrubber and then separated in the cooling tower. This ashwater stream is then removed from the bottom of the cooling tower and recycled into the influent wastewater. After passing through the cooling tower, exhaust air is discharged to a bark media odour biofilter at approximately 25°C.

3 DISCUSSION

3.1 INCINERATOR TRIAL OPERATION

The upgraded treatment process at Tahuna WWTP has been operating since January 2013. In March 2013, the feasibility of re-using the incinerator on the new treatment process was tested. Prior to the Stage 2 upgrade at Tahuna WWTP, primary sludge was thickened in a Gravity Tank Thickener (GTT) and dewatered by duty/standby belt presses before incineration. The introduction of biological growth solids (activated sludge and trickling filter waste biomass) resulted in a change in characteristics of the dewatered biosolids. The new thickening and dewatering equipment (a Gravity Belt Thickener (GBT) and centrifuge) achieves reduced biosolids dryness (26 - 30% compared to 35-39% previously).

During early incinerator operation on the new biosolids cake, approximately $25,000/month of supplementary diesel fuel was required to maintain temperature in the incinerator. This was considered a result of the reduced biosolids dryness, which required supplementary fuel to drive off additional moisture and maintain temperature in the incinerator.

To minimise the use of supplementary fuel, autothermic combustion is desirable. Therefore additional investigations and trials were undertaken to determine if improvements to the process could be implemented to achieve autothermic combustion.

3.2 AUTOTHERMIC COMBUSTION

Figure 2 below shows a simplified process flow diagram of the incinerator and recovery system including the recuperator (heat exchanger), venturi scrubber and cooling tower.

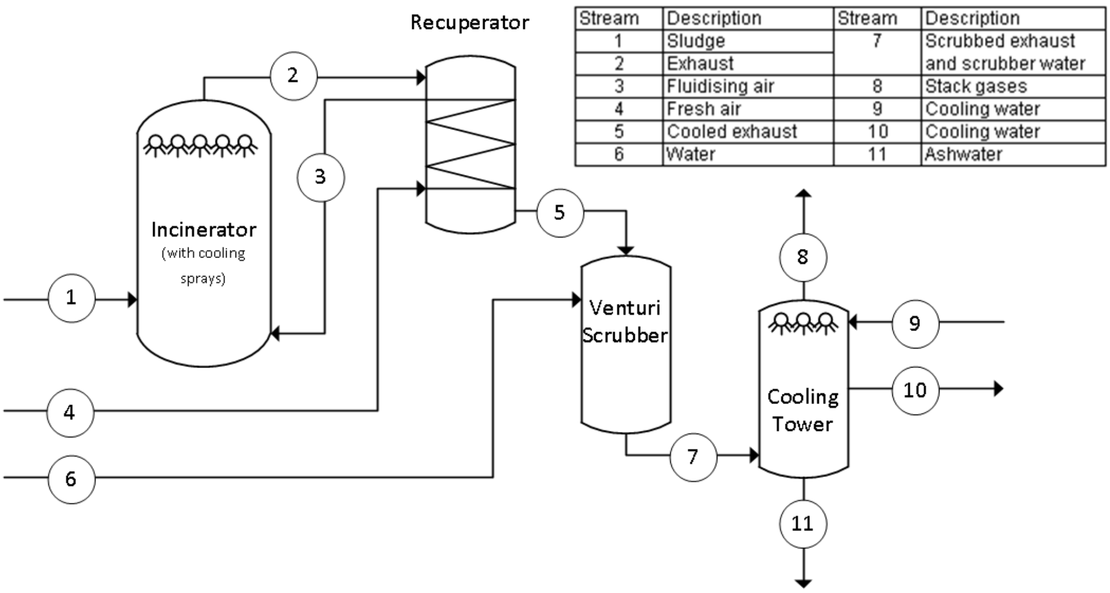

Figure 2: Incinerator Process Flow Diagram

Analysis of the incinerator indicated that autothermic combustion could be achieved in one of two ways:

- Pre-dry the biosolids (to achieve a higher dry solids content)
- Separate the ash.

The incinerator operation had the ash water (Stream 11) fed back to the inlet works of the plant where it is reincorporated into the biosolids. This leads to a build-up of ash within the system. The build-up of ash increases the inert solids content of the biosolids and hence decreases the calorific value (CV), resulting in the need to use supplementary fuel to augment combustion. This is illustrated in Figure 3

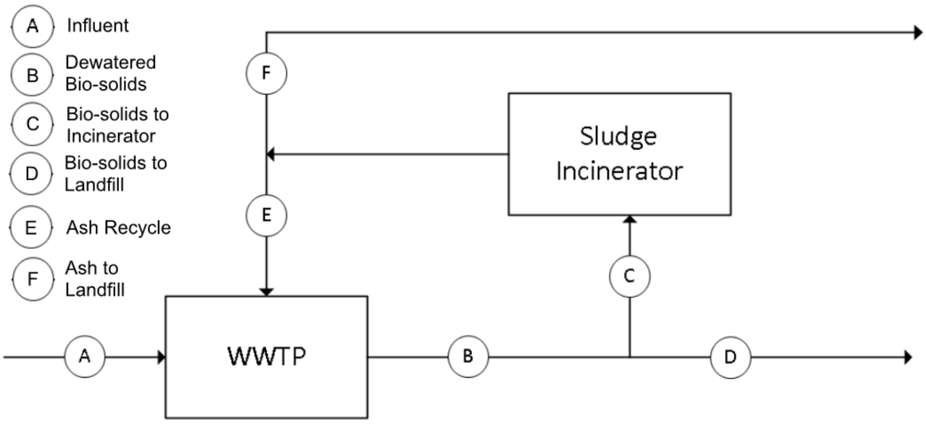

Figure 3: Ash flows between WWTP and Incinerator

Further analysis was conducted on the two options to achieve autothermic combustion and reduce supplementary fuel use: heat recovery from the incineration process for biosolids pre-drying, and ash separation. These options were compared against the 'no incineration' option, which involved disposing all Tahuna WWTP biosolids to landfill.

3.3 ASH REMOVAL FOR AUTOTHERMIC COMBUSTION

Mass and energy balances showed if most of the ash is separated from the incineration process and disposed of, with only a small percentage of uncaptured ash being fed back to the plant inlet works (design allowance up to 20% uncaptured), then autothermic combustion would occur without the need for pre-drying.

The mass balance in Table 1 is based on the existing Tahuna WWTP biosolids production of 29 wet t/d, with 60% of the biosolids fed to the incinerator and 40% disposed at landfill. Without ash separation, some disposal to landfill is necessary to eventually remove ash from the system (i.e. by carting some to landfill instead of recycling from incineration). In the ash separation option, 20% ash recycle is included to account for the incomplete capture of the ash separation process. Stream codes A to F are defined in Figure 3.

Table 1: WWTP Dry Basis Mass Balance with Ash Recycling (60% of Biosolids to Incineration)

		A	B	C	D	E	F
Description		Influent	Dewatered Biosolids	Biosolids to Incinerator	Biosolids to Landfill	Ash Recycle	Ash to Landfill
With Ash Recycle							
VS	kg/d	n/a	6,896	4,138	2,758	0	0
Ash	kg/d	1,514	3,785	2,271	1,514	2,271	0
TS	kg/d	n/a	10,681	6,409	4,272	2,271	0
With Ash Separation							
VS	kg/d	n/a	6,896	4,138	2,758	0	0
Ash	kg/d	1,514	1,653	992	661	139	853
TS	kg/d	n/a	8,549	5,129	3,420	139	853

Table 1, shows that ash recycling reduces the volatile solids content to 64.6% (from Stream C in Table 1, 4,138 kg Volatile Solids (VS)/d ÷ 6,409 kg total solids (TS)/d). This equates to a reduction in calorific value from 26.6 MJ/kg_{DS} with 100% disposal to landfill compared to 21.0 MJ/kg_{DS} with 40% disposal. Changes to the volatile solids content and calorific value for other landfill disposal proportions are given in Figure 4.

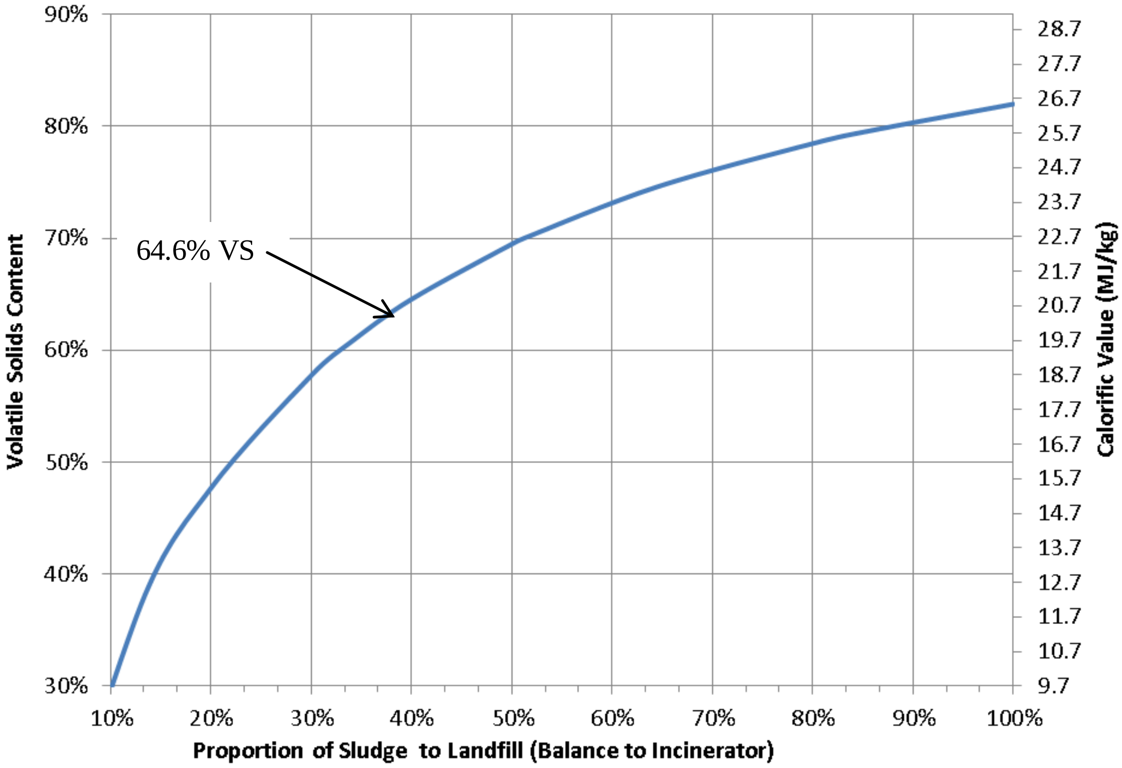

Figure 4: Change in Volatile Solids Content and Calorific Value as a Result of Ash Recycling with Varying Proportional Feed to the Incinerator

Table 2 summarises the results of the mass and energy balance for this scenario. Stream flows 1 to 5 in Table 3 are defined Figure 2.

Table 2 Incinerator Mass and Energy Balance with Ash Separation

	1	2	3	4	5
Description	Sludge	Exhaust	Fluidising Air	Fresh Air	Cooled Exhaust
Flow, kg/h	1,293	8,534	7,241	7,241	8,534
Temperature, °C	10	840	325	10	661
Energy, kW	15	3,309	669	20	2,660

This energy balance shows that to maintain the temperature of the incinerator at 840°C, the temperature of the fluidising air only needed to be preheated to 325°C. Under normal operation the fluidizing air is preheated to approximately 400°C. Therefore bypassing some of the inlet air around the recuperator or a water quenching system would be required to avoid the incinerator head space running too hot. The mass balance identified that at least 80% of the ash needed to be captured for autothermic combustion.

3.4 BIOSOLIDS PRE-DRYING FOR AUTOTHERMIC COMBUSTION

As demonstrated in Section 3.3, when the total volume of biosolids fed to the incinerator increases (which includes a proportion of ash) an increasing proportion of ash in the biosolids subsequently lowers the calorific value. Therefore to achieve autothermic combustion the biosolids must get progressively drier with increasing feed volumes. Drying the biosolids lifts the incinerator temperature as less energy is wasted in vaporising the water associated with the feed and heating the resulting steam.

A mass and energy balance carried out on the design basis biosolids flow of 29 wet t/d, with 40% of the biosolids disposed to landfill and 60% fed to the incinerator is shown in Table 3. This equates to VS content of 65% and CV of 21.0 MJ/kg_{DS} as per Figure 4. The stream flows 1a to 5 in Table 2 are defined in Figure 2 with the addition of 1a being biosolids feed to a pre-dryer and 1 being pre-dried biosolids.

Table 3 Incinerator Heat Balance with Biosolids CV of 21.0 MJ/kg and Biosolids Pre-Drying to 40%

	1a	1	2	3	4	5
Description	Biosolids	Pre-Dried Biosolids	Exhaust	Fluidising Air	Fresh Air	Cooled Exhaust
Flow, kg/h	1,293	1,148	8,389	7,241	7,241	8,389
Temperature, °C	10	100	840	400	10	538
Energy, kW	15	135	3,071	823	20	2,268

The biosolids dry solids content required to achieve autothermic combustion for varying landfill disposal proportions is given in Figure 5. This shows that the required biosolids feed dryness is sensitive to the proportion of biosolids sent to landfill. At an incinerator proportional feed rate of 66%, (which equates to 34% sent to landfill, a VS content of 61% and CV of 19.7 MJ/kg as per Figure 4), the feed biosolids would need to be dried to 48% to achieve autothermic combustion.

To evaporate water, a pre-dryer needs to heat the biosolids to 100°C, which in itself is a contribution towards autothermic combustion (i.e. the biosolids are heated closer to their combustion temperature). The flat line in Figure 5 indicates the point where pre-drying is no longer required but pre-heating is. Neither pre-drying nor pre-heating is required if 64% of the biosolids are disposed to landfill.

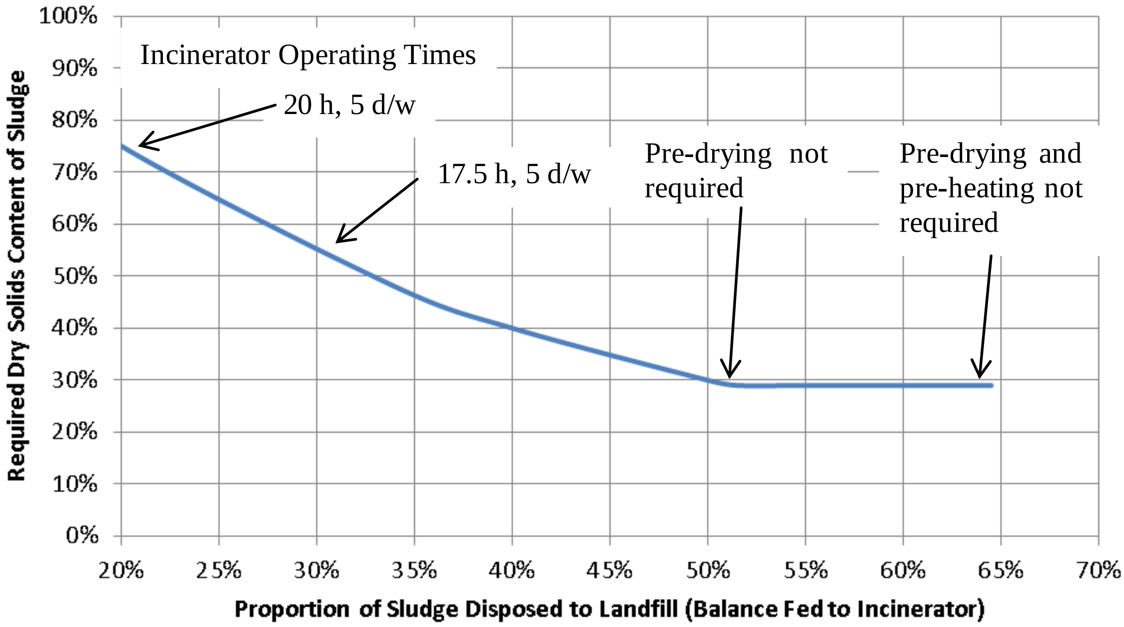

Figure 5 Change in Dry Solids Content Required for Autothermic Combustion.

As biosolids are progressively dried they enter a 'sticky' or 'plastic' phase, which becomes comparable to sticky rubber and difficult to process. This typically occurs between 45% and 65% dry solids content, but can occur as low as 40%. Therefore a design dryness of 40% was adopted to maximise the use of the incinerator without operating in the sticky or plastic phase. As Figure 5 shows, at a dry solids content of 40%, autothermic combustion can be achieved at up to 60% of the biosolids being fed to the incinerator.

The mass and energy balance shows that in the absence of ash removal, at 29% dry solids only 36% of waste biosolids produced at Tahuna could be incinerated in order to prevent ash build up, the remaining 64% would require disposal at Landfill.

The mass balances correlated well with previous incinerator operation. DCC used to work two manned shifts to operate the incinerator for ten hours per day for five days per week. This allowed approximately 50% of the biosolids to be processed through the incinerator, while the other 50% was processed via a DEWA belt press and disposed to landfill. At 35 – 39% dry solids and 50% disposal to landfill, ash accumulation had not been witnessed as a problem in past operation. However, with DCC's desire to maximise environmental benefits, such as minimising waste to landfill and reducing cartage carbon emissions, ash separation was demonstrated to be an important consideration.

3.5 COMPARISON OF OPTIONS FOR AUTOTHERMIC COMBUSTION

Table 4 gives the predicted sludge and ash outputs of the two options at the design basis biosolids flow along with the No Incineration option.

Table 4 Sludge and Ash Output for Pre-Drying (with ash recycle) and Ash Separation

Parameter	Units	No Incineration	Incineration with Pre-Drying	Incineration with Ash Separation
Sludge to GI WWTP	kg/d (wet)	9,000	9,000	9,000
Sludge to incinerator	kg/d (wet)	0	22,100	20,600
Incinerator operating times	hr/d, 5 d/wk	0	17.0	15.9
Sludge to GI Landfill	kg/d (wet)	20,000	5,700	0
Ash to Landfill	kg/d (wet)	0	0	2,300
Transport (GI WWTP + GI	truck loads/d	1 + 2.5	1 + 0.7	1 + 0.3

Parameter	Units	No Incineration	Incineration with Pre-Drying	Incineration with Ash Separation
landfill)				

As noted in Table 4, incineration with pre-drying or ash separation would require approximately sixteen to seventeen hours of operation, five days per week. To maximize the benefits of implementing either system would require operator split shifts to process the majority of Tahuna WWTP biosolids. Including start up, shutdown and handover time, incinerator operation with autothermic combustion would require a minimum of two shifts per day. As a responsible employer, DCC were keen to minimize operator shift work and therefore investigated upgrading the incinerator for unmanned twenty four hours per day, seven days per week operation in parallel with autothermic combustion investigations.

3.6 ASH SEPARATION OPTIONS

The fly ash generated by the incinerator is captured from the exhaust gas in the venturi scrubber with the use of process water then separated in the cooling tower. This ashwater stream is then removed from the bottom of the cooling tower and recycled into the influent wastewater.

Options investigated for ash separation were:

- Ash Lagoons: the ashwater is sent to a lagoon which is periodically dewatered and emptied with mechanical equipment
- Mechanical Thickening and Dewatering: the ashwater is thickened in a gravity thickening tank (GTT) or hydrocyclone, then dewatered by belt press or vacuum filter.

Dry ash separation methods were not considered because these are generally used on multiple hearth furnaces and dust generation can be an issue.

Given the cost associated with construction, covering and venting lagoons, the land footprint required, and sensitivity of the Tahuna WWTP site to odour release, ash lagoons were not considered suitable.

Mechanical thickening and dewatering options considered were:

- Hydrocyclone for Thickening - Hydrocyclones require fast settling ash characteristic to achieve good capture. The settling curve of the Tahuna ash sample indicated that the fly ash would not settle quickly enough for a hydrocyclone to achieve significant ash separation.
- Gravity Thickening Tank for Thickening – An existing GTT at the plant was not fully utilised following the Stage 2 upgrade and investigations indicated it was suitable to thicken ash
- Vacuum Filter for Dewatering - Vacuum filters can have a horizontal belt or a rotary drum. As the belt or drum is rotated, a vacuum sucks the water and solids onto the filter with the water passing through the filter and the solids building a filter cake on the outside of the belt or drum. Investigations indicated a vacuum filter was suitable to dewater the ash. The Duffin Creek Water Pollution Control Plant in Ontario, Canada processes incinerator ash using GTTs to thicken ashwater and then vacuum drum filters are used to dewater ash to 67% dry solids.
- Salsnes Filter for Dewatering – Salsnes filters have a rotating filter mesh that removes solids from the effluent. However, given the particle size distribution of the ash, capture rates would be too low to achieve the ash removal required for autothermic sludge combustion.
- DEWA Belt Press for Dewatering - Prior to the Stage 2 upgrade, the DEWA belt press was used to dewater thickened sludge. DEWA's NZ agent indicated the belt press would also be suitable for dewatering ash.

To progress preliminary design for option comparison purposes, two options were considered further for ash separation as follows:

The ash separation recommended option was to trial re-using the GTT to thicken the ash and the DEWA belt press to dewater the ash following re-conditioning of the incinerator. If re-using the existing infrastructure did not achieve the required 80% ash capture rate, then a worst case ash separation option was also carried forward for option comparision. The worst case ash separation scenario allowed additional capital expenditure for a hydrocyclone and vacuum drum filter.

3.7 SLUDGE PRE-DRYING OPTIONS

To achieve a design dryness of 40%, the following options were investigated to pre-dry the sludge prior to incineration:

- Paddle Dryer - A paddle dryer uses a heat source of thermal oil and contains rotating heated paddle shafts which mix biosolids in a radial direction. The biosolids are dried as they progressively move to the outlet. A paddle dryer was considered suitable for pre-drying Tahuna biosolids
- Drum Dryer – A drum dryer would use the heat from the incinerator exhaust which would pass through a large rotating drum. The biosolids would be pre-dried as they rotated through the hot exhaust air. A drum dryer was not considered suitable at Tahuna as they are typically used to dry to a high solids content (90%), have higher health and safety risks with fire and dust, and difficult to achieve consistent dried product.

Other dryers such as belt or plate press dryers were investigated and considered potentially suitable. The recommendation if calling for tenders for a sludge dryer, was to specify the performance requirement and constraints (such as size and location of heating sources) and consider all dryer options presented by the market.

Figure 6 shows a process flow diagram for the preferred sludge pre-drying option, which included;

- Paddle dryer
- Oil heater after the recuperator
- Diesel start-up oil heater.

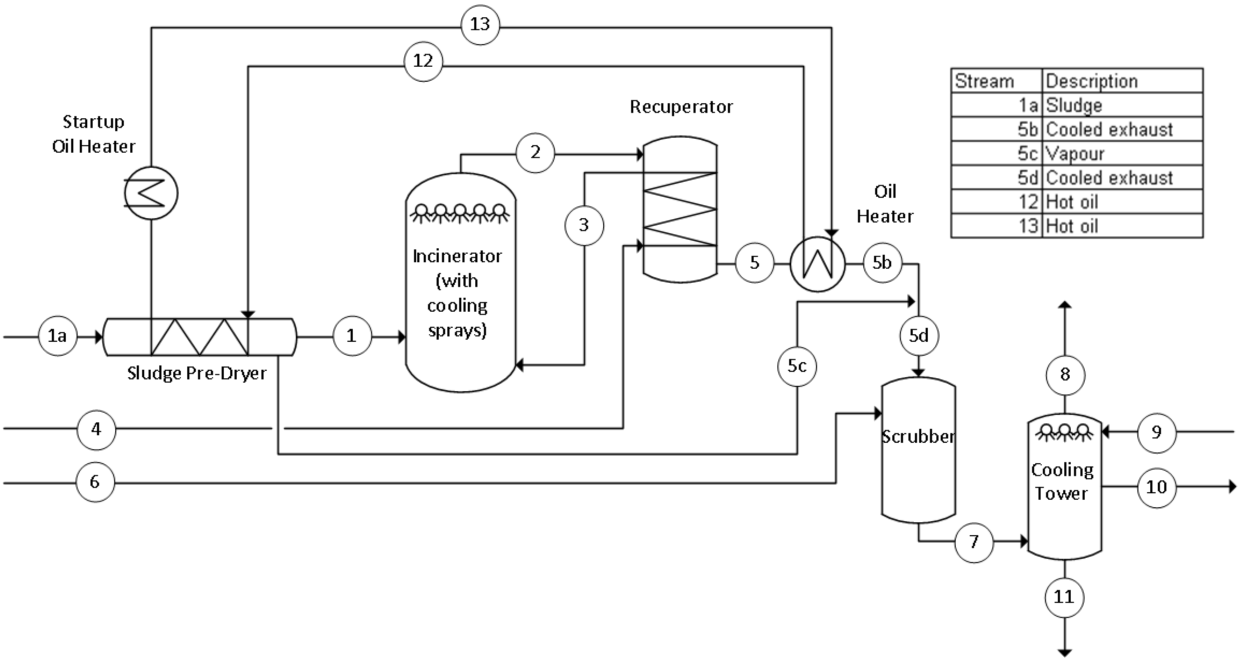

Figure 6 Process Flow Diagram for Recommended Sludge Pre-Drying for Autothermic Combustion

The preferred thermal fluid for the paddle dryer is thermal oil at 200°C. Pressurised hot water at a low temperature or steam at a higher temperature was also considered suitable. Analysis showed that a thermal oil could be heated in a bare tube heat exchanger after the recuperator, Stream 5 (as specified in Figure 2). A bare tube heat exchanger would incorporate the hot exhaust gases flowing vertically down through the casing over the tubes and the hot oil flowing inside the tubes in multiple cross-counterflow passes.

3.8 NET PRESENT VALUE ANALYSIS

Table 5 summarises the biosolids pre-drying and ash separation preferred options alongside the no incineration option and presents the Net Present Value (NPV) estimates.

Assumptions for NPV analysis, with GST excluded, are:

- Discount rate: 7.5%
- Inflation 0.0%
- Annual sludge increase 1%
- Disposal cost – sludge and ash $151.22 /t
- Disposal cost – stabilised ash $18.15 /t
- Cement cost $355 /t
- Incinerator O&M $140,000 /yr
- Transport cost $7 /m³
- Electricity cost $0.14 /kWh
- Polymer cost $10 /kg

Table 5 NPV Summary of Options

Parameter	Units	No Incineration	Incineration - Pre-Drying Option	Incineration - Ash Separation Option
Sludge to incinerator	kg/d (wet)*	0	22,100	20,600
Incinerator operation	hr/d, d/wk	0.0, 0	17.0, 5	15.9, 5
Sludge to GI WWTP	kg/d (wet)*	9,000	9,000	9,000
Sludge to GI Landfill	kg/d (wet)*	20,000	5,700	0
Ash to Landfill	kg/d (wet)*	0	0	2,300
Transport cost	$/yr	53,000	27,000	21,000
Incinerator operation cost	$/yr	0	140,000	140,000
Electricity cost	$/yr	0	53,000	59,000
Maintenance cost	$/yr	0	94,000	49,000
Polymer cost	$/yr	0	0	4,500
Disposal cost	$/yr	788,000	225,000	91,000
Capital cost	$	0	3,910,000	1,710,000
NPV (over 20 years)	$	9,742,000	10,013,000	5,596,000

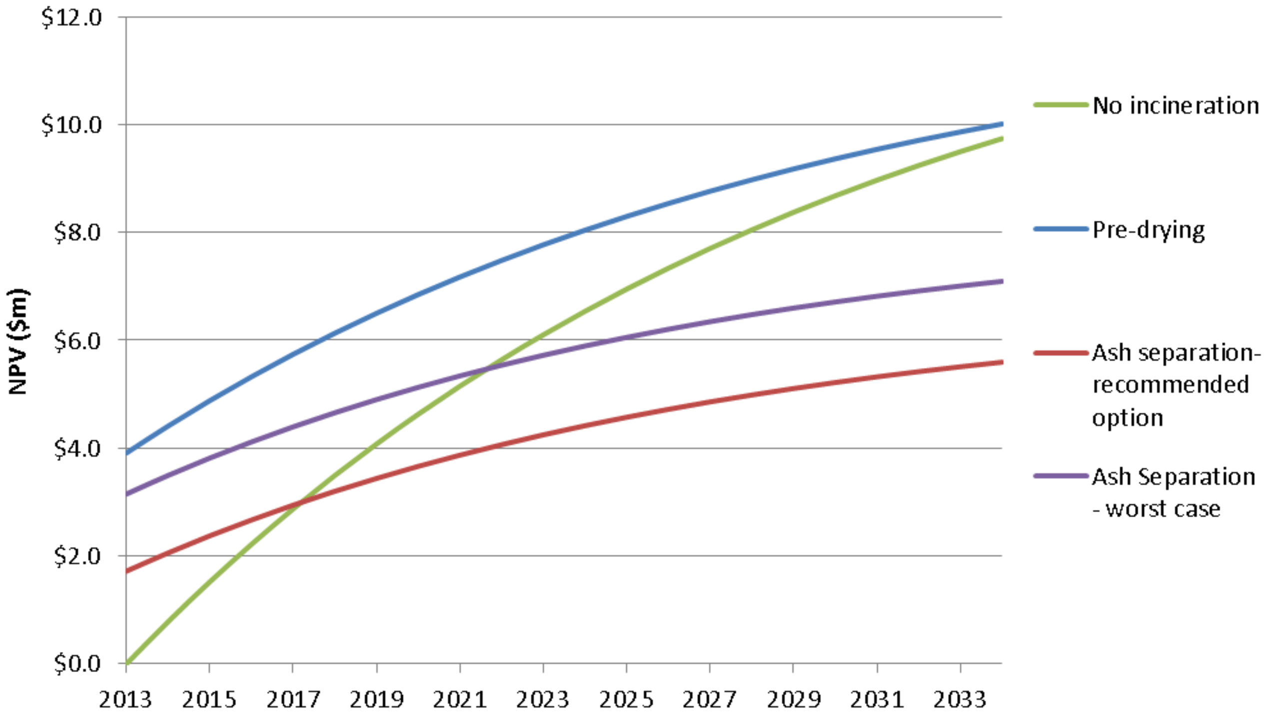

Figure 7 Cumulative Net Present Value (NPV) Analysis

The ash separation option allowed for all the sludge that is not carted to Green Island (GI) WWTP to be incinerated (i.e. no landfill disposal required), and had the lowest operating cost. Combining this with the lowest capital cost gave the ash separation the lowest Net Present Value. A further benefit of ash separation is the reduced risk of odour complaints given only ash is carted to landfill; almost all odour complaints generated by Tahuna WWTP relate to the trucking of waste biosolids. In comparison, the pre-drying option has significant capital cost associated with the pre-dryer and still requires some sludge to be carted to landfill.

4 CONCLUSIONS

In November 2013, DCC adopted a strategy to refurbish and upgrade their existing fluidised bed incinerator with an ash separation system for biosolids disposal. No suitable alternative biosolids disposal technologies had reached full scale operation in New Zealand or Australia, and any such technologies that could emerge in the short to medium term were considered to require high levels of capital investment and were unlikely to provide substantial benefit over the proposed use of the incinerator. This incinerator re-use strategy reduced planned capital expenditure by $10 million and met a number of Council strategies and plans including:

3 Waters Strategy:

- Make best use of existing infrastructure
- Limit cost increases to current affordability
- Improve the quality of discharges, i.e. in accordance with Tahuna air discharge consent "adopt the best practicable option to remove or reduce any adverse effect on the environment"

Sustainability

- Number of truck movements reduced by over 50% and associated Carbon emissions reduced by 10 tonnes per annum.
- Reduced reliance on non-renewable energy sources i.e. Diesel fuel.

Levels of service

- Odour complaints – Almost all odour complaints generated by Tahuna WWTP relate to the trucking of waste biosolids.

- Odour complaints – A significant number of odour complaints generated by Green Island landfill relate to bio-solid disposal.
- Waste Minimisation – Approximately 2,500 tonnes less biosolids disposal at landfill per annum.

The significant reduction in waste biosolids disposal at Landfill also increases the remaining life of the landfill, in particular in relation to the availability of disposal pit locations, and also assists in reducing the potential for leachate contamination from Landfill.

In order to optimise the use of the incinerator, an additional investment was required to refurbish the aging infrastructure and provide an ash removal system. This refurbishment includes a new incinerator furnace, exhaust ducts and recuperator including new refractory. The refurbishment works also include automation upgrades so the incinerator can operate unmanned for twenty four hours per day, seven days per week. This is planned to be delivered for $4.5 million including a project contingency. This allowed DCC to reduce the combined 14/15 and 15/16 wastewater capital budgets by $10 million.

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