NEW ZEALAND'S FIRST FULL SCALE BIOSOLIDS SOLAR DRYING FACILITY

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ABSTRACT

The Pines II Wastewater Treatment Plant (WWTP) in Rolleston, Canterbury was designed for an ultimate connected population of 60,000 and construction is being implemented progressively in two stages. The first stage of the ultimate capacity was constructed for a connected population of 30,000 and was completed at the beginning of 2013. The current Pines II WWTP consists of an inlet works (fine screens and grit removal), secondary treatment in two bioreactors comprising anoxic and aerobic zones for advanced nitrogen removal, secondary clarifiers and UV disinfection. Treated wastewater is irrigated to dedicated land adjacent to the WWTP. The solids stream consists of gravity thickening, aerobic digestion, sludge dewatering and solar drying in two halls (steel glass house structures). The current flow and load to the WWTP is in the order of 20 000 population equivalent.

The waste activated sludge (WAS) is removed from the bioreactors to maintain a target solids retention time (SRT) of 15 to 20 days in the bioreactors. The WAS is pumped into the Gravity Thickener where it settles and is thickened to 1 to 1.5 % dry solids. The thickened WAS (TWAS) is pumped into a compartmentalised Aerobic Digester with alternating aeration and mixing zones for a period of 8 to 10 days. The aerobically digested sludge is dewatered in centrifuges to 18 to 20% dry solids and transferred to the solar drying halls via screw conveyors.

The solar drying halls are fed automatically by conveyors and the automated turning and transport system (SludgeManager™) spreads the cake across and along the hall. The SludgeManager™, and the ventilation and extraction fans are automatically controlled by the solar dryer controller. The amount of time the sludge is retained within the drying halls is automatically controlled according to the weather conditions. The solar dryer was designed to achieve a minimum dryness of 70 % dry solids in winter. The solar dryer was commissioned in May 2013 and the dry solids concentration has increased gradually during winter and the current dry solids concentration at the end of the hall is well above 80 %.

This paper presents the selection process, design considerations, one year operational experience, operator input and performance of the first full scale solar drying facility in New Zealand.

KEYWORDS

Wastewater Treatment, Sludge Stabilisation, Biosolids, Solar Drying Facility, Minimising Operating Costs.

1 INTRODUCTION

A large portion of the operating cost of the original Pines WWTP consisted of the handling and disposal of waste activated sludge (WAS). The waste activated sludge was taken by tanker off-site to a landfill at a concentration of about 1.2 % dry solids resulting in high transport and disposal costs.

Developing an innovative, cost effective and efficient solution for the disposal of biosolids was one of the most significant challenges of the Eastern Selwyn Sewerage Scheme (ESSS). Several treatment and disposal options were considered and assessed on a 30 year NPV (Net Present value) analysis. While there are multiple treatment options, the majority of restrictions on disposal to land are common to all options. The key requirement being the default nitrogen loading of 200 kgN/ha/year.

Based on the multi-criteria analysis (MCA) the highest scoring option was sludge dewatering, solar drying and application to land assuming that solar drying will achieve stabilization Grade A biosolids. The surrounding land has been consented for the disposal of Grade Aa biosolids.

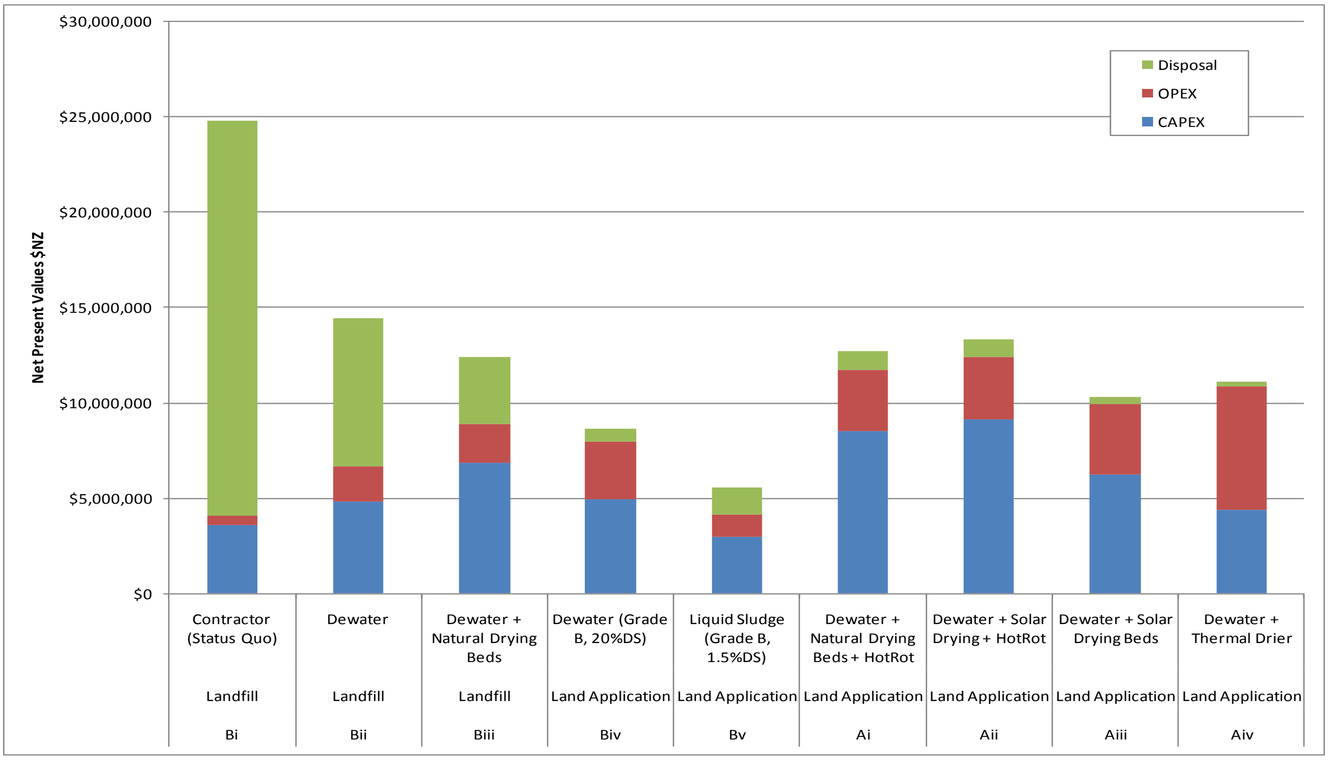
To determine the effectiveness of solar drying in Canterbury sludge drying trials were conducted in open and covered drying beds over a 6 month period (January 2010 to July 2010).

2 COMPARISON OF OPTIONS

Eight (8) appropriate treatment and disposal options were selected and evaluated and compared to the *status quo* where liquid sludge is taken off site.

The life cycle costs expressed as net present value (NPV) of the options are compared in Figure 1. All processes have either an aerobic storage tank or aerobic digester as the initial sludge processing/storage system

Figure 1: *NPV Cost Model of Selected Treatment and Disposal options*



The NPV analysis generally decreases as the dryness of the sludge increases due to the smaller volume of biosolids to be transported to disposal, and there is a further decrease when disposal is by land application rather than to landfill. The NPV analysis reaches a minimum of around $ 10 million where the capital and operating costs balance any advantages in disposal costs.

Options B.iv and B.v (application of Grade B Biosolids to land) have the lowest whole of life cost, but have other negatives such as public perception and difficulty in making an application for change of consent condition from grade Aa to grade Ba due to the higher level of pathogens present in Grade B sludge. Of the two options, disposal of liquid Grade B biosolids at 1.5 % dry solids is the lowest cost and likely to be the easiest to handle as it can be pumped to the disposal area.

The thermal drying option has a relatively low capital cost, but is sensitive to the fuel cost to provide drying energy.

To evaluate either a short list or preferred list of options, a set of evaluation criteria were developed from discussions with Selwyn District Council (SDC). The key objectives identified were as follows:

- Environmental outcome;
- Operational advantages;
- Cultural considerations;
- Economic

Table 1 outlines the selected evaluation criteria, criteria weighting and scores for each of the options.

Table 1: *Results of the Multi-Criteria Analysis[1] (MCA) of Treatment and Disposal Options*

			Landfill			Land Application					
	Project Objective	Weight	Contractor (Status Quo)	Dewater	Dewater + Natural Drying Beds	Dewater (Grade B, 20%DS)	Liquid Sludge (Grade B, 1.5%DS)	Dewater + Natural Drying Beds + HotRot	Dewater + Solar Drying + HotRot	Dewater + Solar Drying Beds	Dewater + Thermal Drier
1	**Operational Advantages** - Simple Reliable process - Low risk - Certainty of Outcome	0.20	5.0	4.0	3.0	3.0	4.0	3.0	3.0	4.0	4.0
2	**Sustainability** - Clean, green - Beneficial reuse - Low energy/emissions	0.15	1.0	1.0	1.0	3.0	3.0	4.0	4.0	5.0	3.5
3	**Positive Environmental Outcome** - Minimal environmental impact - Reduced consenting issues - Favourable image	0.15	2.0	2.0	2.0	2.0	2.0	5.0	5.0	5.0	5.0
4	**Economic** - Low cost - Low future costs	0.10	1.0	2.0	2.0	3.0	5.0	2.0	2.0	3.0	2.0
5	**Future Proofing** - Flexible - Future opportunities - Separation of green waste and sludge	0.10	1.0	1.0	1.0	1.0	1.0	2.0	2.0	4.0	4.0
6	**Cultural** - Separation from food chain and isolation of waste stream	0.20	4.0	4.0	4.0	3.0	4.0	3.0	3.0	3.0	3.0
	TOTAL SCORE	**0.90**	**2.5**	**2.4**	**2.2**	**2.4**	**3.0**	**3.0**	**3.0**	**3.6**	**3.3**

From the MCA evaluation the highest scoring option was Dewatering + Solar Drying + application to land, if solar drying produces stabilisation Grade A. The option of Dewatering + Thermal Drying+ application to land was marked down because of high energy use and the sensitivity to the unit price of power. The only viable alternatives to solar drying were:

1. Dewatered biosolids to landfill, or
2. Thermal drying to achieve Grade A.

Neither of these alternatives is acceptable or evaluated to be viable long-term solutions and have scored low in MCA evaluation. Disposing of biosolids to landfill is likely to progressively increase in cost and is generally unacceptable as it does not provide beneficial reuse. A thermal drier would guarantee that Grade A[2] biosolids are produced, however it has a high operating cost due to reliance on a suitable fuel to provide heat (e.g. gas or woodchips).

Solar drying technology is in line with a more sustainable approach, particularly when combined with beneficial reuse in the form of land application, and lower overall operating costs. Solar drying would increase

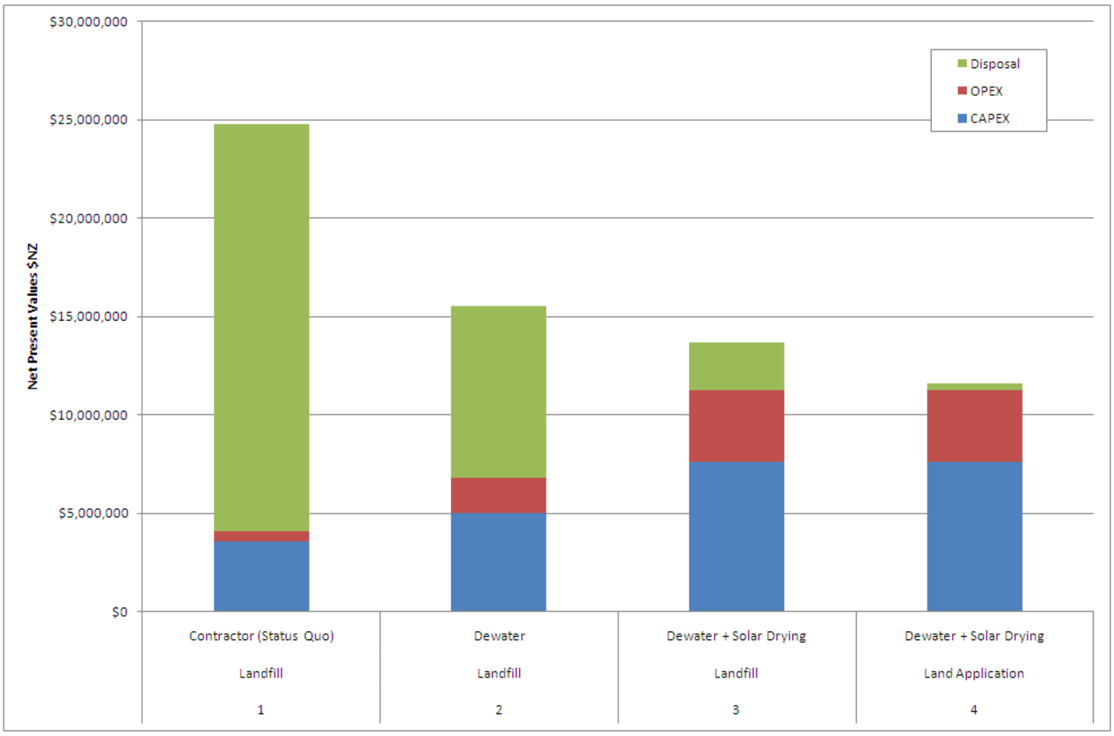
[1] MCA evaluation done using 1 for poor outcome and 5 very good outcome

[2] NZ Biosolids Guidelines defines Grade A for pathogen quality-Table 4.1

the initial capital cost, but overall offers a reduction in operating costs compared to landfilling dewatered sludge or thermal drying.

Based on the above evaluation and achieving the key objectives four options for sludge handling and disposal have been revisited for comparison on a 30 year NPV basis:

Figure 2: *NPV Cost Model of Selected Treatment and Disposal options*



Overall solar dried sludge has a cost advantage because it reduces the volume and mass of sludge to be disposed thereby reducing operating cost so that even without reaching Grade A standard solar drying is the best economic option. Options 3 and 4 differ in the disposal route, with option 4 being available if either:

- Grade Aa[3] is achieved prior to land application, or
- If a consent variation for 'almost or lenient Grade Aa' is granted (with a higher pathogen compliance limit)

Consideration was given to hybrid options such as land application over summer and disposal to landfill over winter (combination of options 3 and 4), if Grade A is achieved seasonally. Overall solar drying provides a lower treatment and disposal cost potentially up to 25% if biosolids are applied to land and 10% if landfilled.

Solar drying was selected as preferred system due to the lowest life cycle cost and being a sustainable solution. The only potential drawback of solar drying was the uncertainty to comply with grade A biosolids and the need for additional processing. Due to the acceptance of wastewater from existing well established communities such as Lincoln, the potential to comply with the contamination Grade 'a', or 'little a ', is uncertain due to the possible elevated levels of copper and zinc from old plumbing systems.

[3] NZ Biosolids Guidelines refers to the 'a' as the contaminant quality of biosolids-Table 4.2

3 SLUDGE DRYING TRIALS

3.1 INTRODUCTION

To provide confidence in the selection of solar drying as the preferred option SDC conducted sludge drying trials on open and covered drying beds. The trials were conducted on dewatered sludge over a 6 month period from January 2010 to July 2010.

3.2 CENTRIFUGE DEWATERING TRIAL

SDC hired a trial Westfalia centrifuge for a 6 month period, which operated 7 to 7.5 hours a day, 5 days a week. Thickened sludge from the WAS tank of the original Pines WWTP at a 1.0 to 1.2 % dry solids concentration was pumped into a small holding tank and then pumped into the centrifuge at a rate of 4 to 5 m^3/h. The typical polymer dosage was 10 to 12 kg/t dry solids and the dewatered sludge achieved a dry solids concentration of 19 to 21 % dry solids.

The dewatered sludge was then used to conduct sludge drying trials. Samples of dewatered sludge were spread on the beds in small 'cells' and the dry solids concentration monitored each week using a Sartorius[4] moisture meter onsite.

***Photograph 1**: Natural Drying Trial Beds*

***Photograph 2:** Solar Drying Trial Beds*

3.3 NATURAL DRYING

The initial results showed that air drying is possible during dry weather in winter, but rainfall rewets the sludge so the overall result is a low dry solids content. During the trial the sludge dryness fluctuated between 15 and 35% dry solids with some drying occurring between periods of rainfall. After one month the sludge had a maximum dryness of about 30% dry solids.

Between periods of rain the average drying rate observed was about 1% dry solids/day, although the data gathered was very limited due to the frequency of rainfall.

As expected, natural drying did not perform well because of the wet weather conditions. Drying during summer should be more successful as rainfall would be less frequent and the average rate of evaporation higher.

3.4 SOLAR DRYING

The solar drying beds performed well due to its cover from the rain, reaching up to 80% dry solids by the end of one month. The layer of sludge used in the trials was relatively thin, so it represents well-turned sludge similar to that of a full scale solar drying system with an automated rotary tiller/hoe. The average drying rate over the period was about 1.8% dry solids/day, with a range of 1.3 to 2.1% dry solids/day

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[4] Sartorius the supplier of automated moisture determination instruments to measure moisture in sludge

The results of the solar sludge drying trial indicate that a dry solids concentration of 70 % can be achieved during winter and higher during the summer. Previous discussions between MWH and European solar drier suppliers confirm expected performance in a Christchurch climate is in the order of 70% dry solids during winter and up to 85% dry solids during summer.

4 FULL SCALE SOLAR DRYING FACILITY

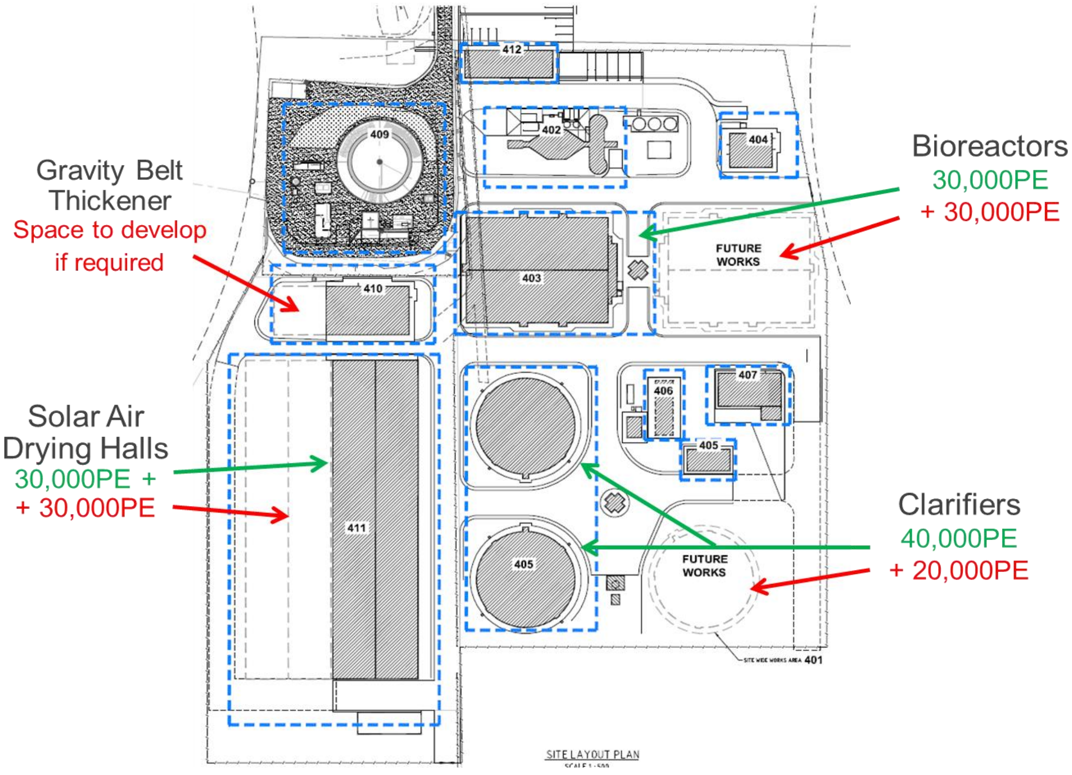
4.1 TREATMENT DEVELOPMENT

The new Pines WWTP commissioned at the beginning of 2013 with an initial treatment capacity of 30,000 person equivalent (PE) and allowance has been made in the layout and some of the unit processes to increase the capacity to meet the ultimate population of up to 60,000 PE.

The design of the new WWTP considered the use of the structures of the existing Pines I WWTP. The existing doughnut bioreactor/clarifier was converted into an aerobic digester and gravity thickener prior to transferring of the digested sludge through to the new centrifuges. The existing blowers were re-used for the aerobic digester and the existing structure served the dual purpose of thickening of WAS and aerobic sludge stabilization.

The layout and staging of Pines WWTP is shown in Figure 3.

Figure 3: *Layout and staging of Pines WWTP*



4.2 SOLAR DRYING FACILITY

The solar drying facility consists of two glass halls each 12 m wide, 100 m long with a clearance height of 3.5m. The halls have a concrete floor and side walls 2 m high to support the structure for the sludge turning equipment also referred to as the patented SludgeManager™. The roof and walls of the halls are constructed with 4 mm toughened glass (tempered), similar to the ones used in motor vehicles with high transparency.

Each hall has been provided with 17 fans. The drying facility has been designed for a throughput of 500 tonnes DS/year at an inlet dry solids concentration of 18% achieving an outlet concentration of higher than 70% dry solids.

Photograph 3: *Aerial View of Solar Drying Halls*

Photograph 4*:* *SludgeManager*

4.3 CLIMATE CONTROL

For uniform ventilation and an optimum drying performance a ventilation system is used. The ventilators (fans) are mounted on a frame over the drying surface. The whole drying facility is automatically controlled by the Thermo System ClimaControl^{TM}, software package with remote supervision. All relevant parameters inside and outside of the drying halls like temperature and relative humidity of the air, solar radiation, wind speed, the height of the sludge layer in the whole plant and other process parameters are measured, evaluated and supervised continuously.

The ClimaControl^{TM} software calculates the optimum process conditions automatically and controls and monitors all components like the ventilation system, the flaps and the SludgeManager^{TM}.

4.4 SLUDGE TURNING AND MIXING

The dewatered sludge from the centrifuges is conveyed by inclined screw conveyors to two transfer conveyors which discharge into the inlet of the drying halls at a single point. The sludge will be automatically and uniformly distributed over the entire width of the drying hall. The turning and mixing process as well as the conveying of the sludge through the dry hall is automated in accordance with the amount of sludge supplied, the climatic conditions as well as the sludge moisture content.

The filling height of sludge inside the drying halls is adjustable up to 800 mm deep and can be operated at different heights to achieve maximum dryness. While mixing, aerating and moving the sludge in the halls the SludgeManager^{TM} is continuously measuring the actual height of the sludge above the floor. During the operation the height is automatically adjusted to the set value. Ultrasonic sensors are used to measure the sludge level.

The sludge turning machine unit is very versatile and sludge can be automatically transported to any location along the longitudinal and transfer axis of the hall.

4.5 ENERGY REQUIREMENTS

The installed power supply requirements for fans, sludge managers and dewatered sludge conveyors are in the order of 90 kW. Due to the intermittent operation of most of the drives the estimated power consumption is about 12 kW/h, which equates to approximately 105,000 kWh per annum. At 500 tonnes dry solids per year the power consumed to dry the dewatered sludge from 18 % dry solids to above 70 % dry solids is 206 kWh/tonne dry solids.

At a unit rate of 20 c/kWh the cost to dry the sludge is about $ 41/tonne dry solids. The mass of water to be evaporated per annum is 2,060 tonne which equates to 50 kWh per tonne of evaporated water.

5 RESULTS

The sludge drying facility was commissioned in May 2013 and has received about 1,275 wet tonnes of dewatered sludge at 18 to 19 % DS from the centrifuges. At 19 % DS this equates to a throughput of 240 tonnes of dry solids. The temperature at the solids within the sludge layer was measured on two occasions and the results are presented in Table 2.

Table 2: *Biosolids temperature readings*

Distance from entry of hall	Lane 1 Temperature (^{0}C)						Lane 2 Temperature (^{0}C)					
	Top		Middle		Bottom		Top		Middle		Bottom	
	Sept 2013	June 2014	Sept 2013	June 2014	Sept 2013	June 2014	Sept 2013	June 2014	Sept 2013	June 2014	Sept 2013	June 2014
0 m	13.7	13.1	12.5	12.7	11.8	13.5	13.8	17.1	11.9	22	11.4	18
25 m	25.6	13.4	14.5	13.9	16.3	14.8	20.2	15.4	13.9	16	15.3	16.2
50 m	26.4	14.4	16.1	18.3	15.7	19.5	27.3	18.1	14.6	24.9	14.9	24.5
75 m	29.1	14.4	23	14.2	24.2	15.7	32.9	15.4	15.2	15.7	15.9	16.4
100m	No solids	14	No solids	14.1	No solids	15	No solids	14	No solids	15.3	No solids	13.8

The solar drying process is not listed as one of the time-temperature processes to achieve stabilization Grade A as the temperature cannot reach 50^{o}C within the hall but the long retention time (> 6 months) should achieve the pathogen product standard during summer. According to the Pathogen Standards routine sampling should achieve an *E coli* < 100 MPN/g which is achieved at the end of the drying hall (100 m). Samples were taken during summer, and the results of the pathogen concentrations are presented in Table 3

Table 3: *Summer Pathogen levels after drying*

Sample Date	*E coli* MPN/g
02/10/13	< 2
07/01/14	< 18
04/03/14	68

Based on these results the biosolids can achieve stabilization Grade A in summer. However samples taken during June 2014 contained *E coli* numbers considerably higher (Refer to Table 4) than those measured during the 2013/2014 summer months.

To achieve a stabilization Grade A the biosolids must have an accredited quality assurance system and meet at least one of the accepted pathogen-reduction processes, plus one of the accepted vector attraction reduction methods and all of the pathogen standards as specified in the 'Guidelines for the Safe Application of Biosolids to Land in New Zealand'.

The results of samples taken on 15 June 2014 are in Table 4.

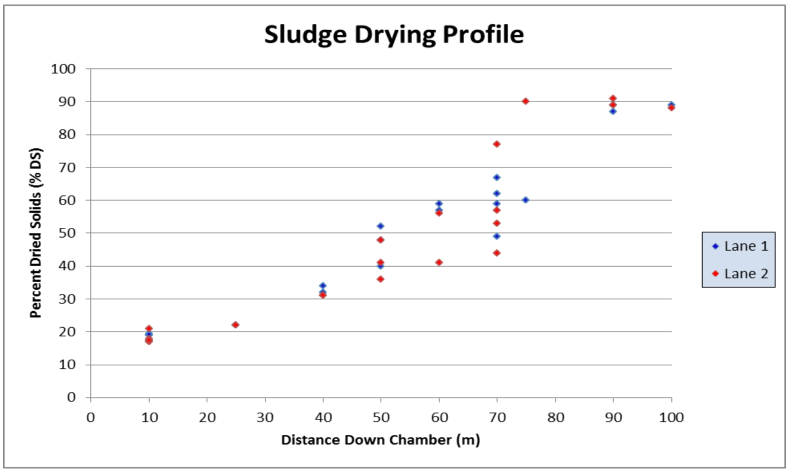
Table 4: *Pathogen levels after drying*

Pathogen	Unit	Guideline Pathogen Standard	Lane 1	Lane 2
E coli	MPN/g	< 100	5,400	3,500
Campylobacter	g	< 0.04	Detected per 25g	Detected per 25g
Salmonella	g	< 0.04	Not detected	Not detected
Helminth ova	g	0.04	< 0.45 per 4 g	< 0.45 per 4 g

According to the above results the biosolids do not fully comply with stabilisation Grade A during winter.

The system has been designed to achieve a minimum dry solids concentration of 70 % at the full throughput capacity of 500 tonnes per year but is currently achieving a dry solids concentration above 80 % at about 50 % utilisation. The sludge drying profile in the two lanes is shown in Figure 6. Samples were taken during summer and winter.

Figure 4: *Drying Performance through drying halls*



The final product has complied with contamination Grade A during summer but again this need to be confirmed once the drying halls are operating at full capacity.

Due to the spare capacity within the halls only thirty six (36) tonnes of the dry product has been taken to Kate Valley landfill at a cost of $ 12,000 during May 2014. The transport and disposal cost equates to $ 333/ tonne product at about 90% dry solids. Transport and gate charges of biosolids at 18 % dry solids would increase the overall disposal cost by a factor of five (5) due to the larger volume of biosolids.

The estimated disposal cost for the next financial year if the accumulated dried solids are transported to Kate Valley landfill will be in the order of $ 150,000. The total biosolids disposal will be 450 tonnes of dry product which includes accumulated dry solids from the 2013/2014 year. One of the added advantages of the drying halls is that the dry product can be stockpiled during winter prior to disposal in summer.

The depth of solids in the drying halls ranges from about 400 mm at the front end to about 300 mm at the back end of the drying hall plus a stored volume of dried solids about 9 m wide and 0.6 m deep.

6 OPERATIONAL EXPERIENCE

The operation of the Solar Dryer is accessed using the local touch screen PLC and two remote controls for the manual operation of each sludge manager. There are five (5) programmed operational modes for the sludge managers, each of which can be disabled/enabled, manually activated and can have some settings edited such as the tilling depth, frequency of operation, distance down the chamber to run etc. The layout of the system does take some time to get used to and can be a little awkward to navigate the interface.

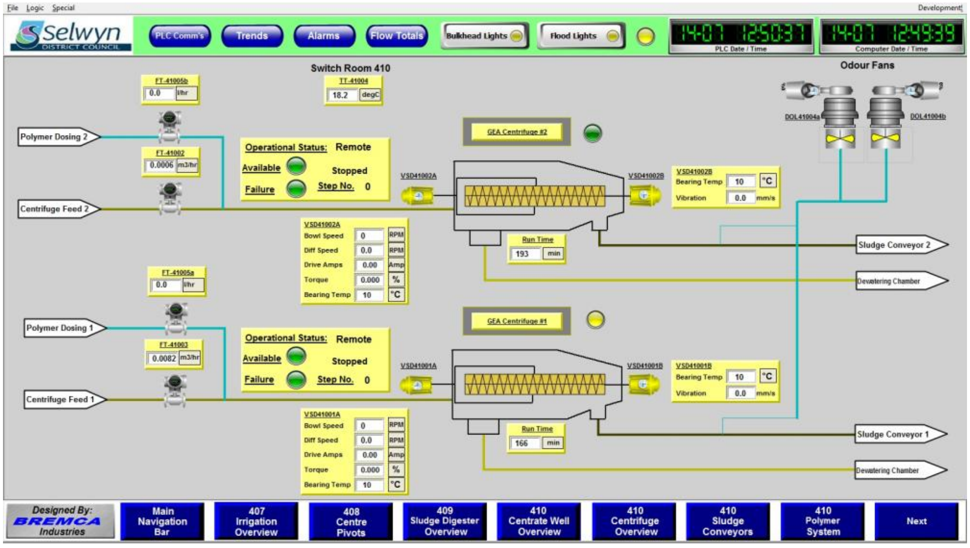
The settings are not easily configured, but can be edited by Thermo Systems. The time zone difference with Germany allows the operator to email the Thermo System service team at the end of the NZ working day in time for service team to receive it at the start of their working day. The operators have found them to be helpful and prompt to respond to any direct communications with them. Some faults have taken longer to resolve requiring increased local labour for monitoring and operation.

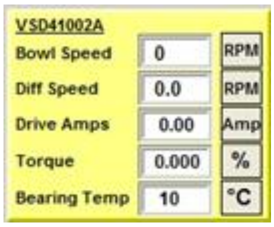
When the system is set in automatic control day-to-day labour requirements during sludge input is minimal at around a half hour a day (up to one and a half hours if there are difficulties such as torque faults). The maintenance for the Sludge Managers is about one hour every month and about four hours every sixth month.

Torque faults are more common during winter when the sludge dries more slowly and is colder as the sludge sticks to the tilling paddles of the Sludge Manager and can build up over time. The Thermo Systems service team monitored the patterns of the sludge managers where they frequently fail over the previous winter. Adjustments were made successfully to the programs to reduce the fault condition. This optimisation took a few months during which time many different permutations were trialed to find the ones that worked best.

Overall the solids drying facilities has been robust and reliable and the backup service from Germany has provided the operators with sufficient confidence to operate the system. The SCADA screenshots of the dewatering system and solar drying halls are shown in Figures 5 and 6 respectively.

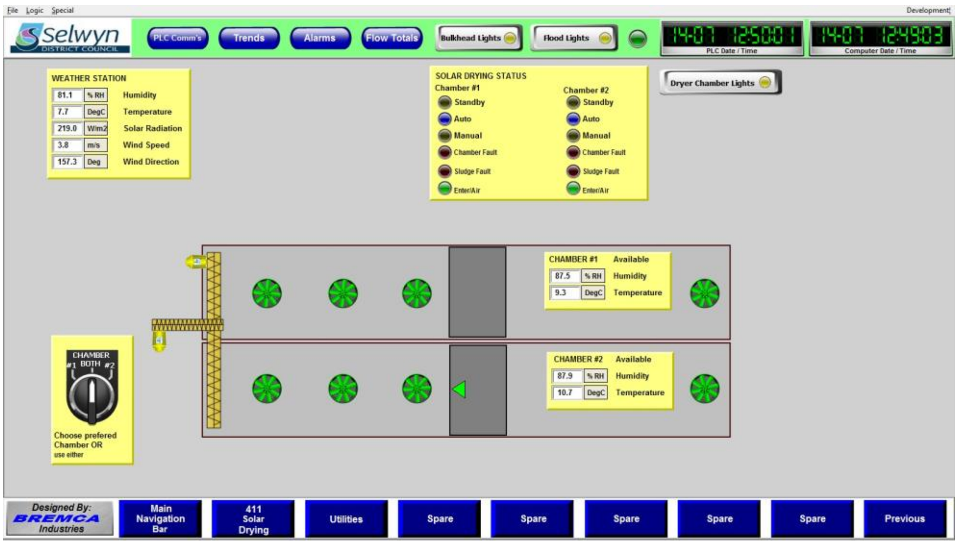
Figure 5: *SCADA screenshot of dewatering facility*

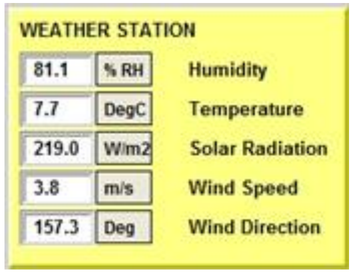




Centrifuge Controls

Figure 6: *SCADA screenshot of solar drying halls*





7 CONCLUSIONS

The construction and operation of the solar drying facility at the Pines II WWTP has clearly demonstrated that this innovative solution is cost effective and efficient in Canterbury, New Zealand. The facility has consistently achieved a biosolids concentration well in excess of the guaranteed value of 70 % DS which has resulted in minimal disposal costs. The 36 tonne of solids taken to the landfill site cost SDC about $12,000 and the estimated cost for the next financial will be in the order of $ 150,000 if taken to Kate Valley landfill, however SDC is investigating options to apply the solids to land mixed with greenwaste. This land application option will reduce disposal costs even further.

The operational experience with the solar drying facility in New Zealand is very positive and the operator input has been minimal. The Solar Drying Facility is a fully automated system that is robust and reliable and has a low energy requirement of about 206 kWh/t dry solids to dry the dewatered sludge from 18 % dry solids to over 70 % dry solids.

During summer the final product complies with stabilisation Grade A but there is insufficient data to confirm compliance or otherwise that stabilization Grade A is achieved during winter. The dry product will be stockpiled in winter at the end of the hall and disposal will be done during summer when it achieves Grade 'A'. The biosolids cannot comply with the contamination levels in the NZ Biosolids Guidelines for grade 'a' or 'b' due to elevated levels of zinc and copper.

ACKNOWLEDGEMENTS

The assistance and support of the Selwyn District Council in providing data and plant information is gratefully acknowledged, in particular Christopher Salkeld, Stuart Hildreth and Stewart Miller from Sicon Ferguson, have been helpful in providing valuable feedback on the operation of the facility.

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