BENEFITS OF THERMOPHILIC DIGESTION AT CHRISTCHURCH WASTEWATER TREATMENT PLANT

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ABSTRACT

In 2010, two 7,000m³ anaerobic digesters were commissioned at the Christchurch Wastewater Treatment Plant (CWTP), which now operates a Temperature Phased Anaerobic Digestion (TPAD) process – thermophilic and mesophilic in series. This paper outlines the thermophilic commissioning process including difficulties, solutions and contingency plans, and the improvement in digester performance.

From the existing digester arrangement (four off 5,000m³ mesophilic digesters in parallel) to the new TPAD digester arrangement (two off 7,000m³ thermophilic digesters in parallel followed by four off 5,000m³ mesophilic digesters in parallel), the methane production was seen to increase by 67%. From the interim mesophilic operation of the new digesters, it is estimated that two thirds of this increase is due to increased solids retention time, with the remainder due to the increased activity of the thermophilic digesters. About 85% of the biogas is produced in the thermophilic digesters at a typical concentration of 61% methane, compared to 65% from the mesophilic digesters.

Similarly, the volatile solids destruction increased 19% from an average of 65% to 77%, which reduced the dry solids content of the digested sludge from 1.9% to 1.4% and the volatile content of the digested solids from 69% to 62%.

KEYWORDS

Thermophilic, Mesophilic, Temperature Phased, Anaerobic Digestion, Commissioning

1 INTRODUCTION

Since the Christchurch Wastewater Treatment Plant (CWTP) was commissioned in 1961, it has used mesophilic anaerobic digestion (33 to 37°C) for sludge stabilisation. Biogas has been used in engines coupled to pumps or to alternators for electricity generation, and in boilers for sludge heating.

Additional sludge quantities from 2002 to 2005, due to increased industrial loads and an enhanced secondary treatment process, resulted in marginal retention times in the four 5,000 m³ mesophilic digesters. This resulted in a digestion process upset in September 2002, with release of odours, and ongoing intermittent foaming. To cater for the increased loads and future growth, two 7,000 m³ digesters were designed and completed in early 2010 (Archer et al, 2008). These digesters were designed to operate at thermophilic temperatures, typically 55°C. During design it was anticipated that the temperature phased anaerobic digestion (TPAD) system would increase the biogas production by approximately 15%. This paper outlines the thermophilic commissioning process including difficulties, solutions and contingency plans, and the observed improvement in digester performance.

Figure 1 shows a simplified process flow diagram of the new TPAD arrangement.

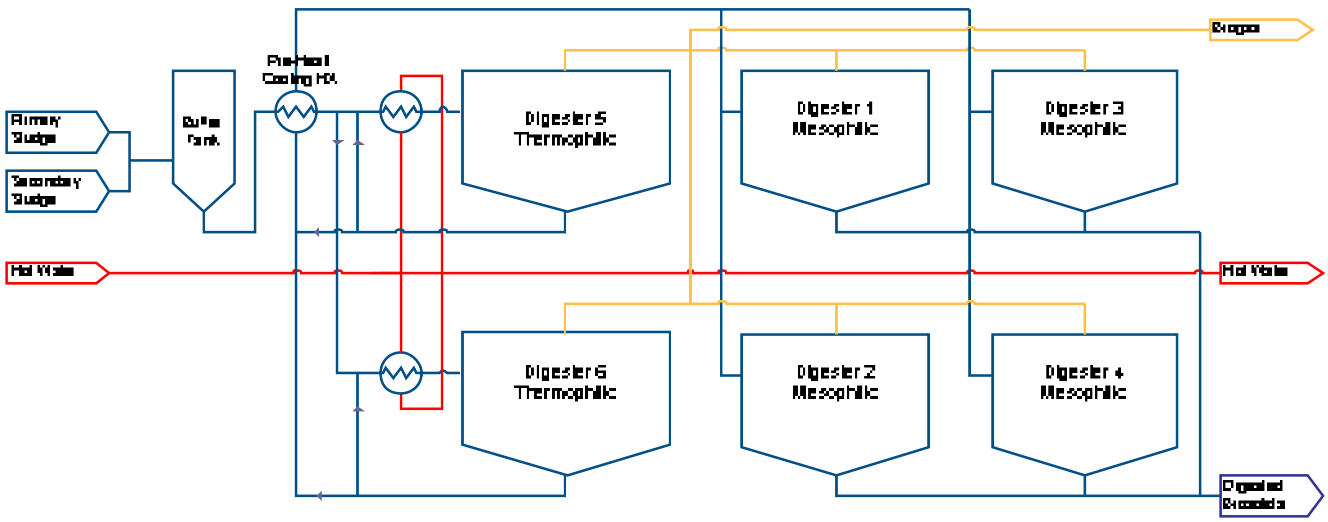

Figure 1: CWTP simplified process flow diagram of the Temperature Phased Anaerobic Digestion System

2 COMMISSIONING

2.1 PROCEDURE

Table 1 outlines the steps involved in commissioning the digesters as well as the time taken to perform the tasks. The new digesters were filled with water and air for pre-commissioning tests which included the usual pump and systems tests plus a specific investigation of how rapidly heat could be transferred into the digesters. To avoid the biomass being exposed to “no man’s land” temperatures from 40° to 50°C, the time taken to transition from mesophilic to thermophilic temperatures should be as short as practical. From this investigation it was determined thatthe heat exchangers were of sufficient capacity and a heating rate of 7°C/day could be achieved, buta larger heat sourceswere required.

After clean water commissioning, to prevent the creation of an explosive atmosphere inside the digesters,the headspaces were purged with carbon dioxide (CO_2). Purging of the headspace when full with water reduced the CO_2 required. Next the water was drained, and replaced with biogas drawn in from the biogas network. The digesters were then fed with digested sludge from the existing mesophilic digesters with the biogas released into the biogas network. Raw sludge was then fed to the digesters in increasing quantities, with the biogas preferentially used in boilers or flared off until the methane content had reached a satisfactory concentration. Once both digesters had gone through this process, a two week trial period of mesophilic operation was undertaken.

Before starting the transition to thermophilic temperature,the digester levels were lowered, gas mixing turned off, and the digesters were starved. The lower level (less volume) allowed the digesters to be heated more quickly (The final heating rate achieved was 9°C/day), and gave some space for any foam that might form during the transition. The gas mixing was turned off to reduce foam formation. The starving also reduced the risk of foaming during the meso-thermo transitional phase. The digesters were then heated as quickly as possible to 55°C.

The possibility that large quantities of foam could be produced was debated extensively in pre-commissioning planning, and supplies of antifoam chemical were kept at the plant. Thankfully, foaming was minor, the gas foam separators worked as intended, and the anti-foam chemical was not needed

Once at 55°C, raw sludge was fed to the digester in increasing quantities slowly filling the digesters and creating thermophilic anaerobic biomass. During this period, care was taken avoid excessive volatile acid concentrations, with a target of <2,000mg/l total volatile acids. Figures 2 and 3 show the profile of volatile acids during this time. Biogas mixing was restarted once the digesters had reached full level which the “gaslifter” mixing arrangement requires.

When the raw sludge feed to Digesters 5/6 had increased to half of the total raw sludge, the discharge from the thermophilic digesters was changed from wasting direct to dewatering, to feeding the existing mesophilic digesters, and the feed to the thermophilic digesters was gradually increased to be 100% of the sludge.

Table 1: Digester Commissioning Timeline

Action / Event	Date Action Taken / Event Occurred	
	Digester 5	Digester 6
Digester Leak test (water at 37°C)	15-22 Jan 2010	8-15 Feb 2010
Digester Leak test (water at 55°C)	1-8 Feb 2010	23 Feb-2 Mar 2010
CO_2 purge of head space	11-13 Feb 2010	3-5 March 2010
Water drain down – biogas drawn in	14-17 Feb 2010	6-8 March 2010
Filling with digested sludge	18-26 Feb 2010	9-16 March 2010
Start feeding raw sludge	3 March 2010	16 March 2010
Mode A operation (all 6 digesters in parallel at 37°C)	24 March -7 April 2010	
Start digester starvation	7 April 2010	15 April 2010
Lowering digester level (D5 -3.2m, D6 -1.4m)	7-19 April 2010	19-25 April 2010
Digester heating to 55°C	26-28 April 2010	2-6 May 2010
Increase digester fill rate (thermophilic digesters stabilising)	18 May 2010	
Digester full (note when D5 full it discharged into D6)	4 June 2010	6 June 2010
Digester upset (digesters <51°C)	22 June 2010	
Biological commissioning complete	Mid July 2010	

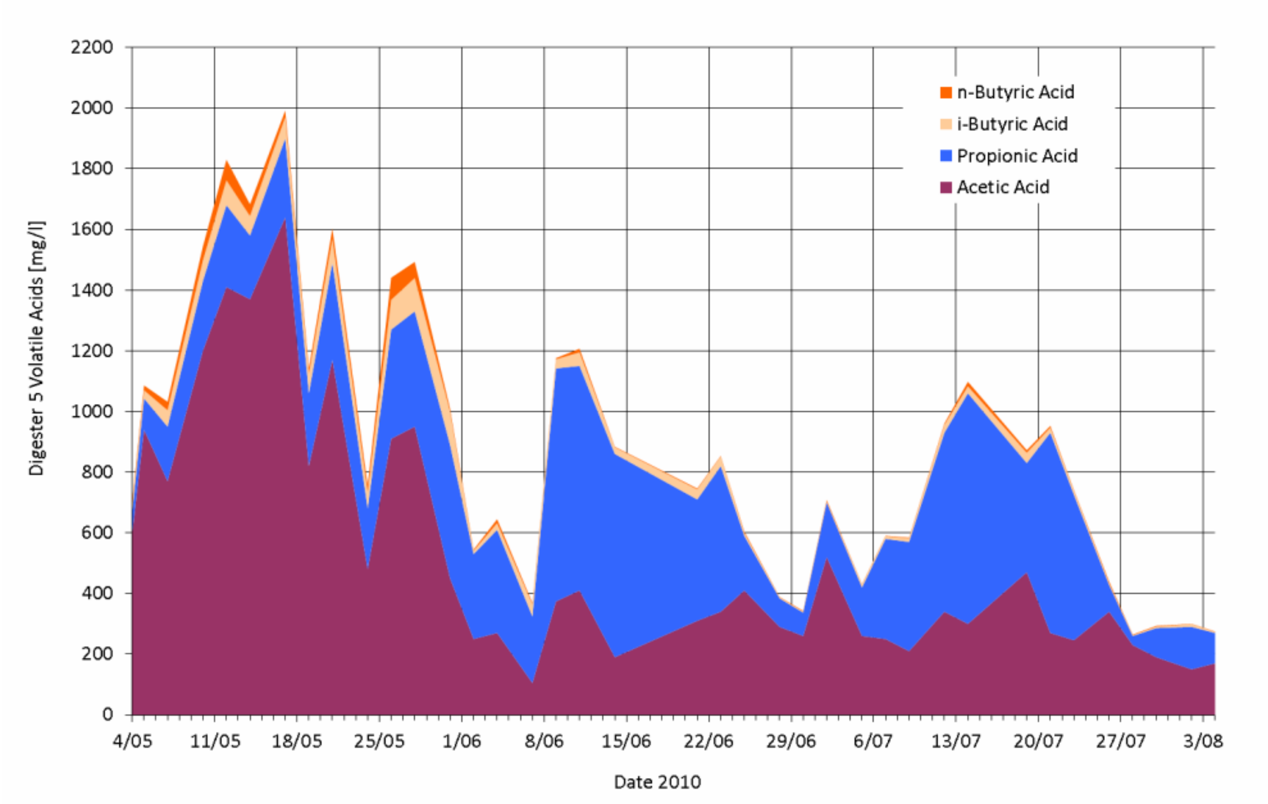

Figure 2: CWTP Digester 5 Volatile Acid Composition during Commissioning

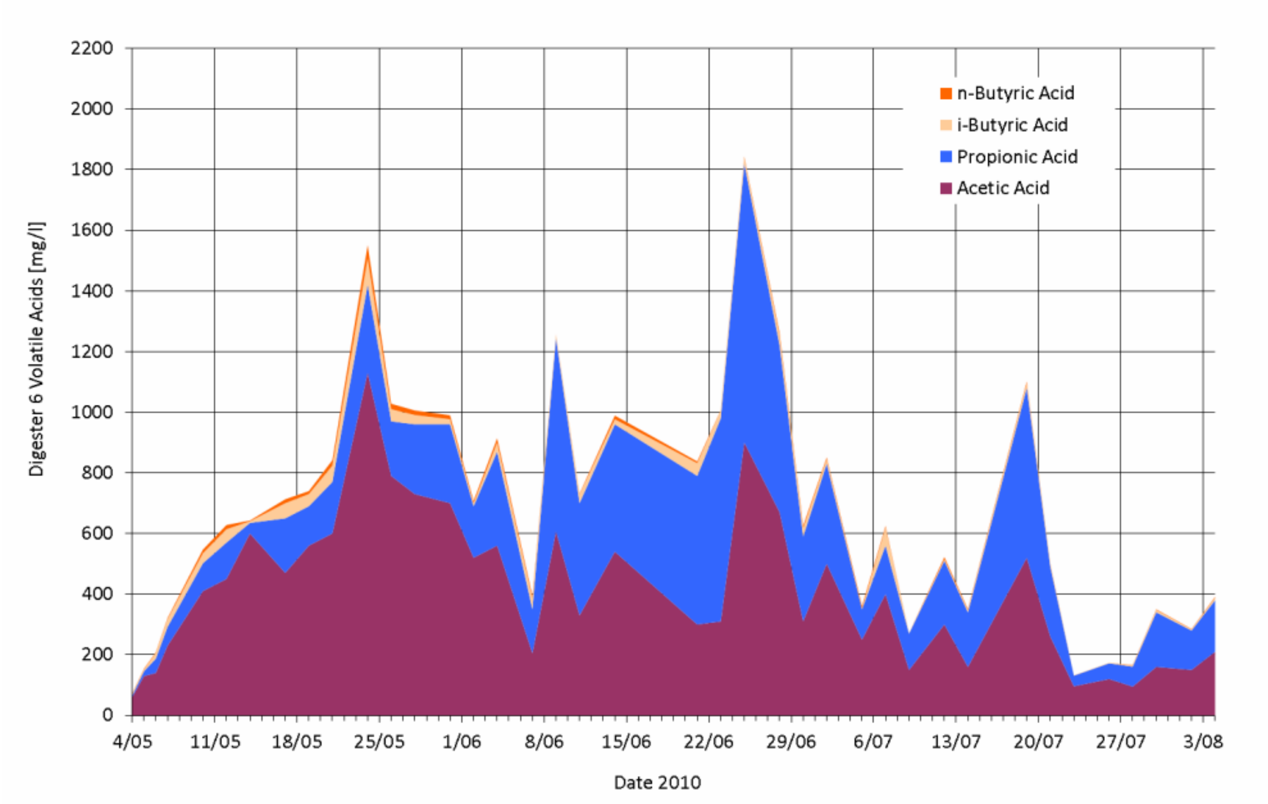

Figure 3: CWTP Digester 6 Volatile Acid Composition during Commissioning

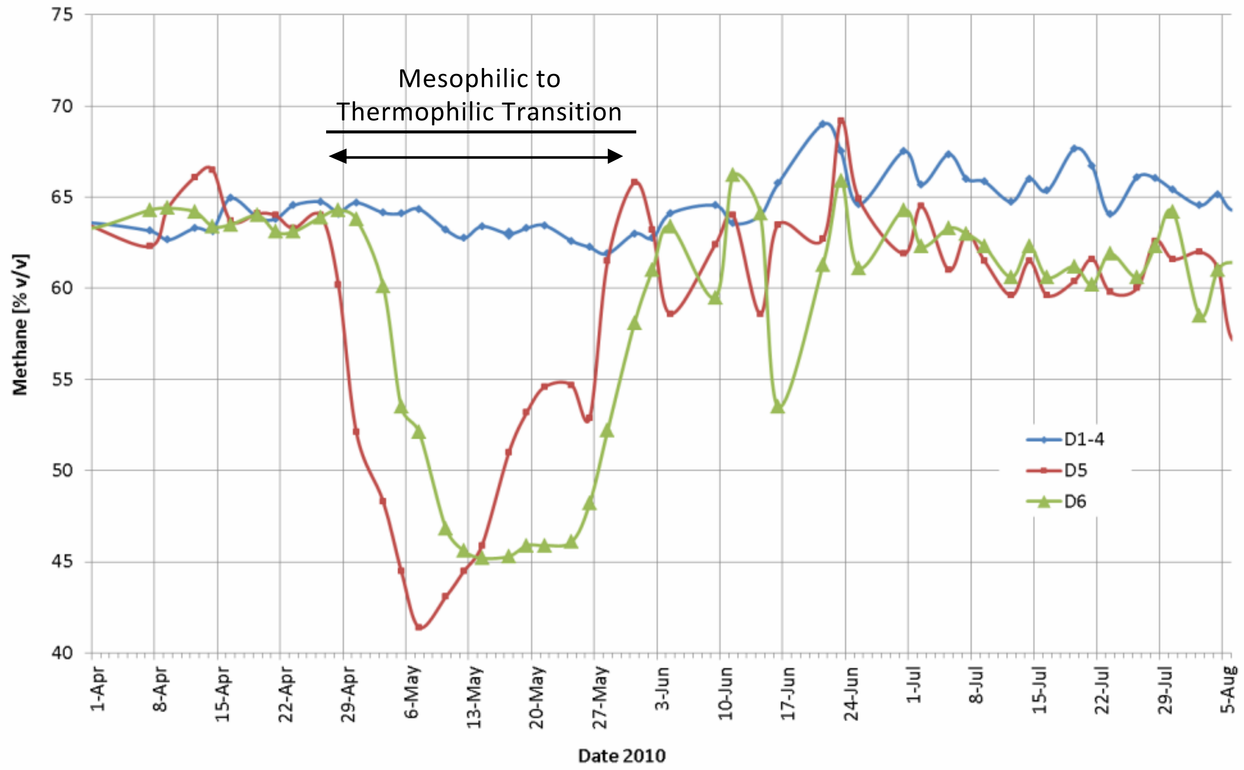

Figure 4: CWTP Digester 1-4 and 5/6 Biogas Methane Content During Commissioning

2.2 CHALLENGES

Some of the challenges during commissioning included:

- Obtaining quick Laboratory results
  A high level of communication between Lab and engineering staff was required to overcome this challenge.

- High hydrogen sulphide concentration in the gas
  Up to just under 3,000ppm during the transition to thermophilic, but quickly reduced to 100 to 300ppm once the digesters reached 55°C.

- Temporary loss of heating
  With changing biogas composition, the main gas engine stopped over a weekend and with reduced heat input, the digesters started cooling down to 51°C. The digestion process was upset with biogas production dropping off and volatile acid concentrations rising. Once the temperature recovered, digestion was quickly restored.

- Blending biogas of varying quality
  Due to the arrangement of the biogas network, when biogas is stored it was preferentially taken from Digesters 1-4 which under TPAD operation,have a high methane content. Reintroducing this gas caused problems with the gas engines. To overcome this, the draw point for biogas storage was moved to take a blended gas.

- Sludge odour
  The thermophilic sludge was particularly malodourous, and during the short period when thermophilic sludge was wasted directly to dewatering, this caused localisedodour release.

3 IMPROVED PERFORMANCE

3.1 BIOGAS PRODUCTION

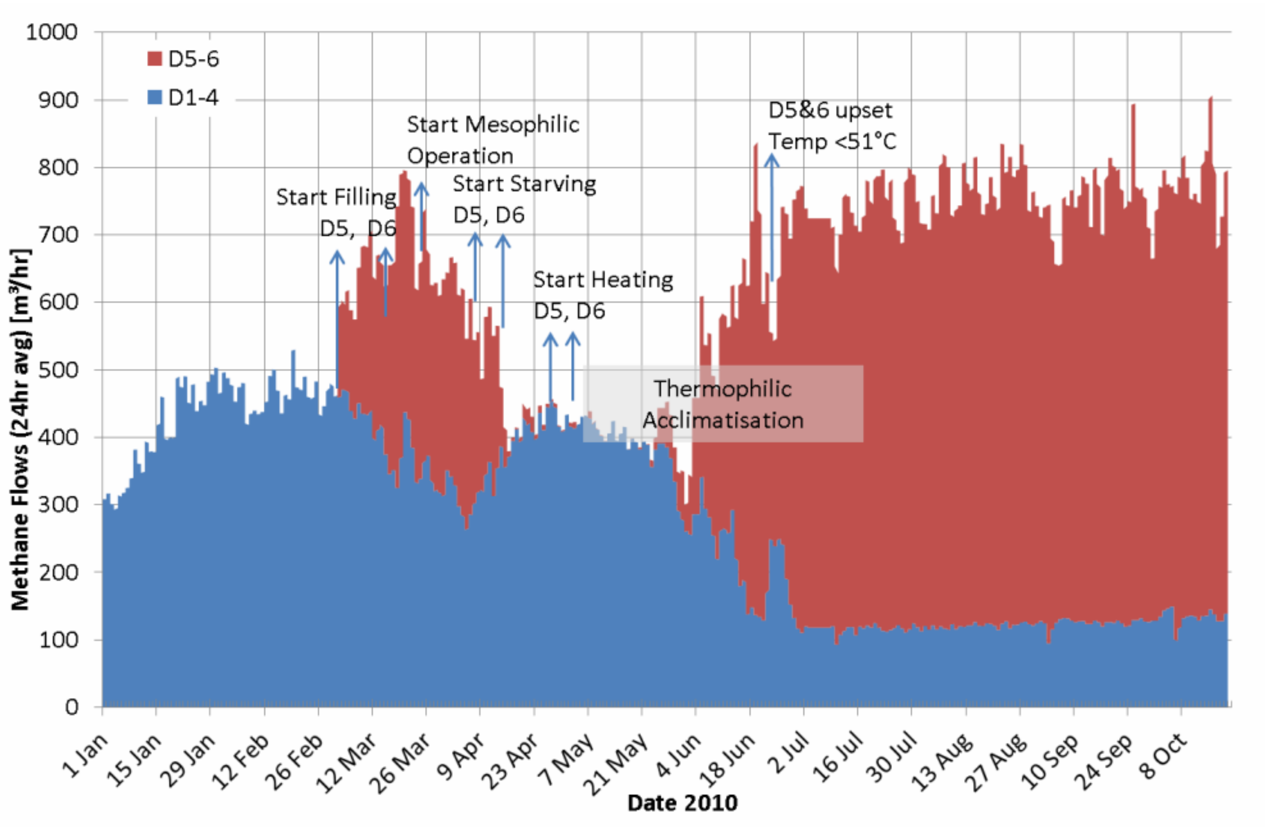

Figure 5: CWTP Digester Methane Production 2010

Prior to Digesters 5/6commissioning, Digesters 1 – 4 produced an average of 450m³/hr of methane in a biogas consisting of 65% methane and 35% carbon dioxide. When Digesters 5/6 operated as mesophilic digesters in parallel with Digesters 1 – 4 this increased to 650m³/hr. Once the TPAD process was established this was further increased to 750m³/hr. Overall this was an increase of 67% with approximately two thirds of this increase being due to increased solids retention time, and the remainder due to the increased activity of thermophilic digestion. In theTPAD process, about 85% of the biogas is produced in the thermophilic digesters at a typical concentration of 61% methane, compared to 65% from the mesophilic digesters.

This increase in biogas will allow the Christchurch City Council to expand its biogas utilisationsystem, with a new gas engine generator set currently being installed at CWTP and ultimately,digester biogas being piped to its civic building and art gallery in the CBD when the current Burwood Landfill gas supply is depleted.

3.2 SOLIDS DESTRUCTION

The combined primary and secondary sludge fed to the digesters at CWTP has an average dry solids content of 4.8% and an average volatile solids content of 79%. Prior to Digesters 5/6, Digesters 1 – 4 typically reduced this to 1.9% dry solids and 69% volatile solids, which equates to a total volatile solids destruction of 65%. Once the TPAD process was established, the digested sludge reduced to 1.4% dry solids and 62% volatile solids, which equates to a total volatile solids destruction of 77%, a 19% increase. The change in performance is shown in Figures 6 and 7. The spike in dry solids and drop in volatile solids in Digesters 5/6 is due to an influx of silt from liquefaction that occurred during the 4 September earthquake in Christchurch. Unfortunately, Digesters 5/6 were not operated as mesophilic digesters for long enough to determine how much of this increase to due to additional solids retention time, and how much is due to the TPAD process.

This 27% decrease in total solids out of the digesters has flow-on benefits such as reduced total polymer used for dewatering (belt presses) because there is less to dewater, and less energy needed for biosolids drying, and reduced disposal costs, because there is less solids to dewater, dry and dispose.

Unfortunately, because of the Canterbury earthquakes and the change in sludge composition there hasn't been the opportunity to fully evaluate the impact of the TPAD process on biosolids dewaterability, and whetherthe polymer dosing rate (in kg of polymer / t of dry solids) can be reduced.

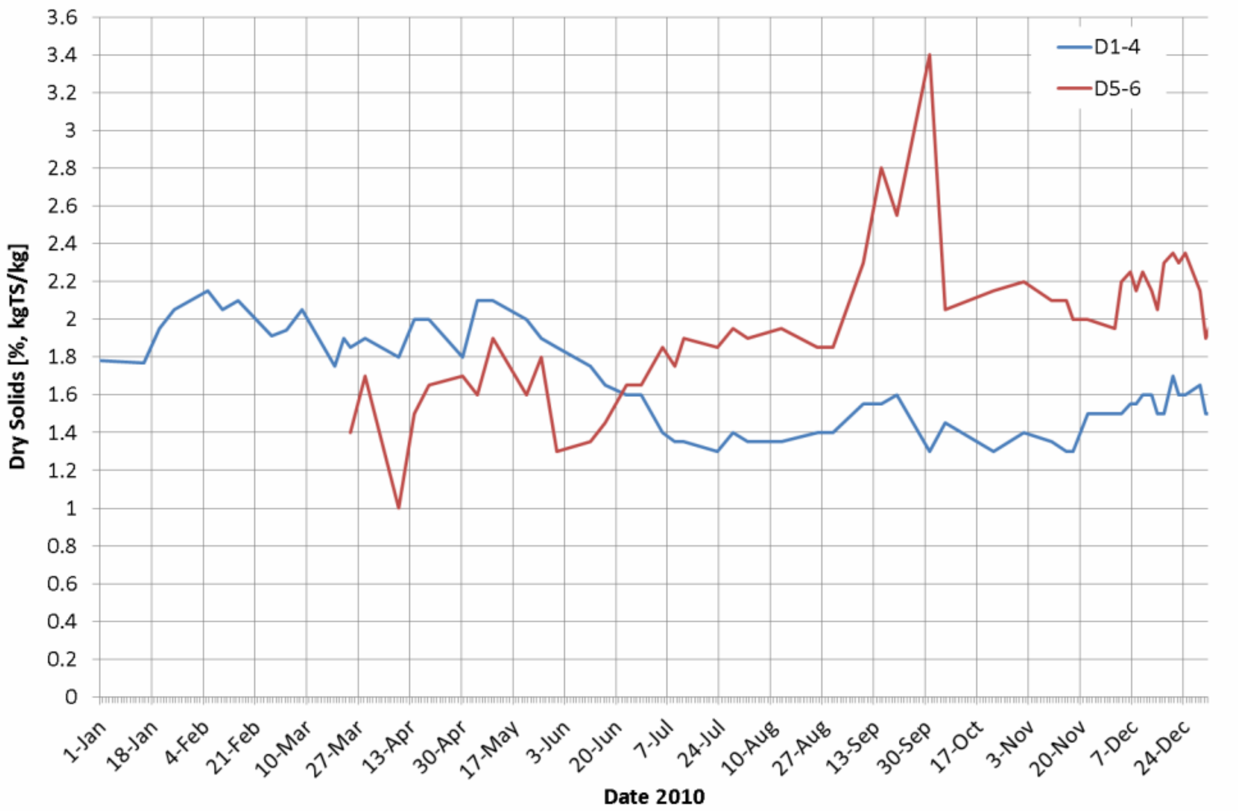

Figure 6: CWTP Digester Dry Solids Content 2010

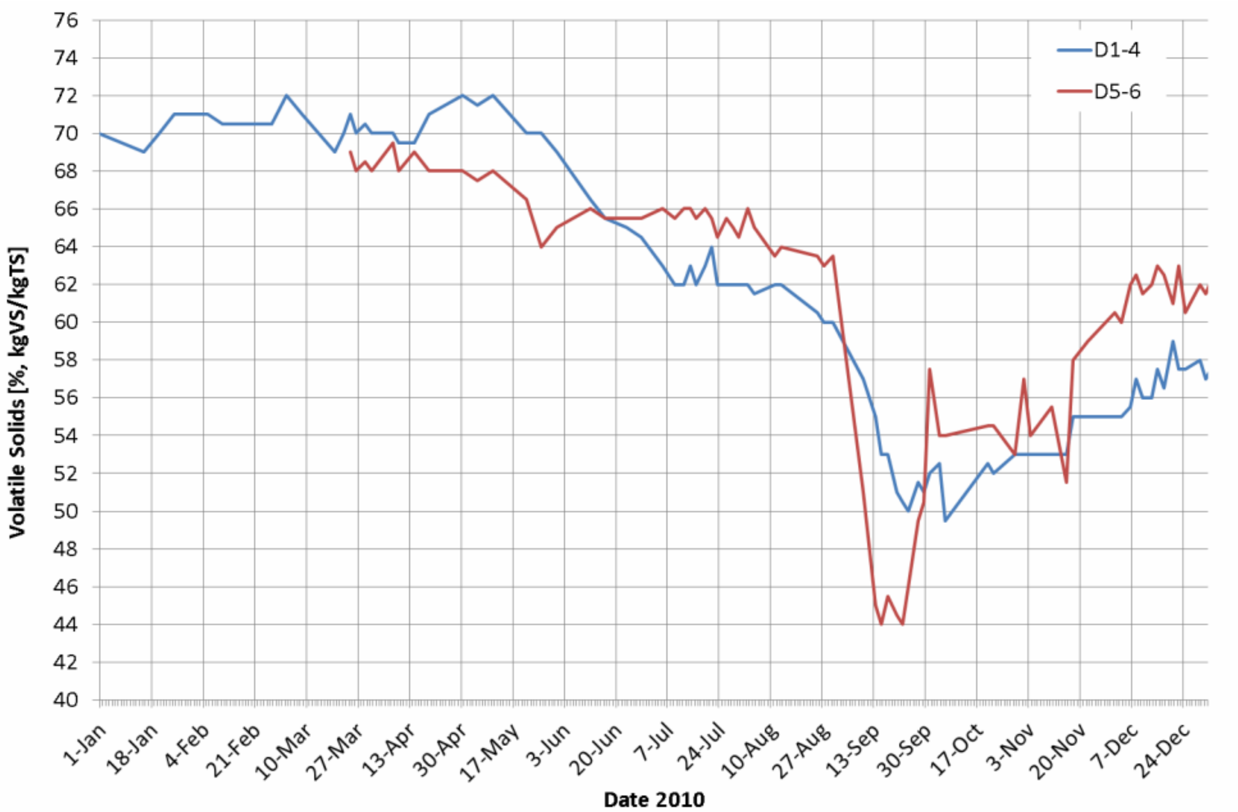

Figure 7: CWTP Digester Volatile Solids Content 2010

3.3 DISINFECTION

The pathogen indicator reduction performance, while not critical to the process at CWTP, is noteworthy. Prior to TPAD operation, E Coli in the digested sludge was around 1,000,000 cfu/100ml. Post TPAD, this reduced to just above 1,000 cfu/100ml, (see Figure 8) which is below the Grade A pathogen standard as stated in the NZ Biosolids Guidelines of 100 MPN/g(equivalent to 10,000 cfu/100ml).Also,Salmonella was detectable in the pre-TPAD digested sludge, but not detectable after TPAD was implemented.

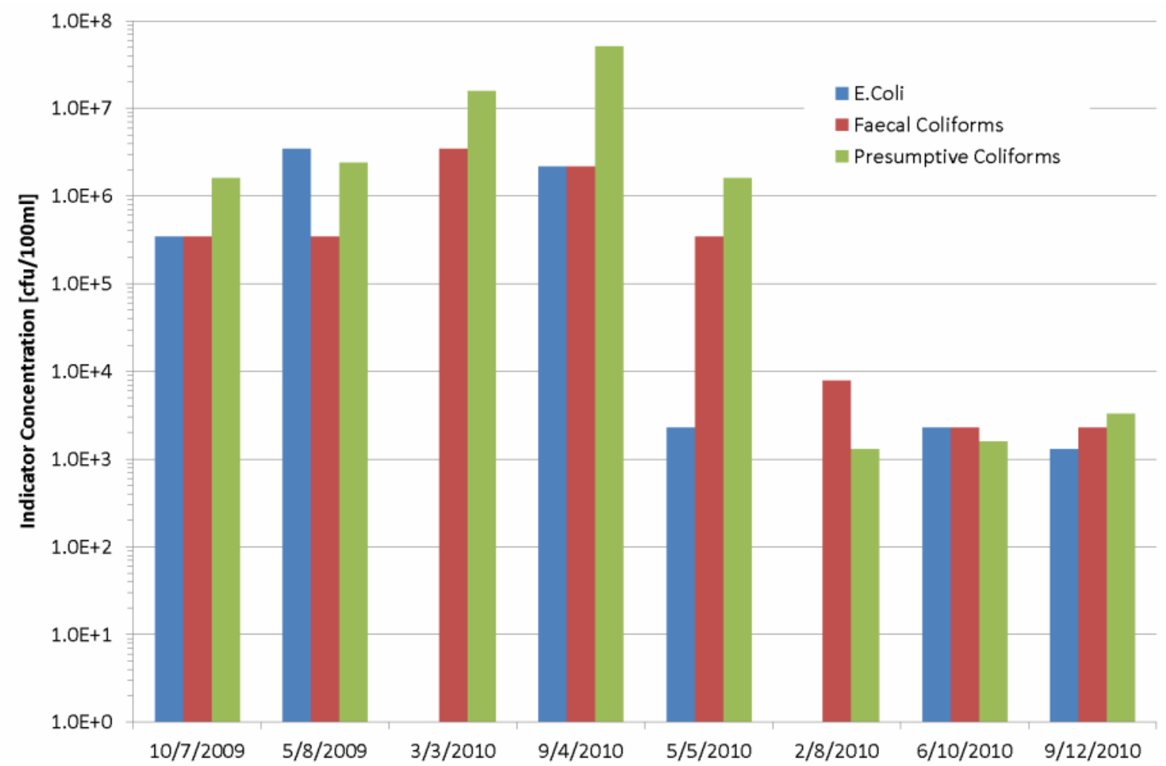

Figure 8: CWTP Pathogen Indicators in Digested sludge

3.4 ACIDITY

The average pH values in the mesophilic Digesters 1-4 went from 7.3to 7.5, while the thermophilic Digesters 5 and 6 have an average pH of 7.8.pH in the digester is a product of acid produced and NH_4 produced. In general as methanogenesis continues, acids are used up (converted into methane and basic salts) and NH_4 concentrations increase – raising the pH.Methanogenic bacterial need nitrogen for survival and over time will metabolise the NH_4 - so what we are seeing is a classic pattern where high rates of methanogenesis are leading to increased levels of NH_4 (and hence pH) and as the process progresses the NH_4 is used up and the pH decreases slightly. The pH is up in Digesters 1-4 due to the longer retention time and the greater methanogenesis.

4 CONCLUSIONS

Detailed planning, identification of risks and implementation of mitigation measures, resulted in a troublefree start-up of the thermophilic digesters.

Significant improvements have resulted from the increased digestion capacity and adoption of temperature phased anaerobic digestion at CWTP, such as:

- A 67% increase in methane production with approximately two thirds of this increase being due to increased solids retention time, and the remainder due to the increased activity of thermophilic digestion.

- A 19% increase in volatile solids destruction, which equates to a 27% decrease in total solids out of the digesters with flow-on benefits such as reduced total polymer used for dewatering (belt presses), less energy needed for biosolids drying, and reduced disposal costs

ACKNOWLEDGEMENTS

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