# PILOT TRIALS FOR BIOLOGICAL TREATMENT OF KILN WASTEWATER

*Nick Dempsey, Mott MacDonald; Chris Knight, Mott MacDonald.*

## ABSTRACT

The process of kilning timber produces condensates which although low in volume, contain high concentrations of organic compounds. If this wastewater is to be discharged to land or waterways, a significant proportion of these components need to be removed. If further removal of organics can be achieved, then the resulting water has considerable value for reuse in on-site kilning and wood treatment processes.

The fixed film Submerged Aerated Filter (SAF) technology was selected as preferred for a trial for its ability to treat kiln condensates, and meet the needs of wood processors in being simple to operate, robust, and low cost. The trial was carried out at Rosvall Sawmill with the aim of gathering “typical” influent and effluent data, evaluating potential organic removal rates, and determining maximum loading capacities. Additionally, risks associated with the solids generation, nutrient deficiency, inhibition, and the fate of CCA (copper, chrome and arsenic) treatment metals were investigated.

A pilot plant was installed, commissioned, and then operated for a series of trials over a period of 4 months. The SAF was found to achieve high levels of treatment effectiveness, removing up to 90% of the $BOD_5$ load, and 77% of the COD load.

## KEYWORDS

**Submerged aerated filter, SAF, kiln condensate, industrial wastewater treatment**

# 1 INTRODUCTION

The process of kilning timber produces condensates which although low in volume, contain high concentrations of organic compounds. If this wastewater is to be discharged to land or waterways, a significant proportion of these components need to be removed. If further removal of organics can be achieved, then the resulting water has considerable value for reuse in on-site kilning and wood treatment processes.

Mott MacDonald was engaged by Windsor Engineering and Solid Wood Innovation (SWI) to identify potential technologies to treat kiln condensates, ~~and~~ conduct trials to prove the performance capabilities, and set loading requirements. Rosvall Sawmill in Whangarei was selected as an ideal site for the trial to be conducted, as they already had a pressing need to treat their wastewater in order to meet discharge consent conditions.

The Rosvall Sawmill has a number of kilns which are used to dry Radiata pine at temperatures between 90 and 140°C. This process generates a significant quantity of condensate, which drains out of the kilns. The condensate stream, when mixed with other site wastewater, was previously discharged across farmland, but there was a desire to treat it to a level appropriate for disposal to local waterways, and also for potential reuse within the sawmill. Reuse options included make up water for kiln steaming baths and for use in a ~~the~~ possible future copper chrome and arsenic (CCA) treatment plant.

The site owners and their engineers installed a chemical oxidation pilot plant at the sawmill in 2010 in an attempt to provide this treatment. However, this did not generate the anticipated beneficial results. Mott MacDonald was therefore engaged to assess potential alternatives for treatment of the condensate. Due to the previous investments, one of the key drivers for the study was to minimise additional capital spend where possible (re-using existing infrastructure), and to provide some level of certainty by trialling proposed solutions before committing to them.

Mott MacDonald carried out a brief literature search of the expected wastewater parameters for kiln condensate, and based on this identified Submerged Aerated Filter (SAF) technology as an ideal candidate for a pilot plant. The system is a fixed film biological treatment process with downstream solids separation. Initial investigations highlighted that SAF technology was well proven in the municipal market, and appropriate for this process, but would require a trial to confirm suitability for the specific industrial wastewater. The trial would confirm feasible limits for loading the SAF system, allowing the sizing of full scale systems for application at this and other kiln sites across the country.

Forest Research of New Zealand has produced some data on typical kiln condensate concentrations (Dare & Riley, 2003), which are presented in Table 1 below.

*Table 1 – Summary of condensate characteristics from untreated radiata pine (Dare & Riley, 2003)*

| Parameter | Unit | Average | Range |
|---|---|---|---|
| Chemical Oxygen Demand (COD) | mg/L | 2,600 | 750 – 4,700 |
| Soluble COD (sCOD) | mg/L | 2,000 | 680 – 2,400 |
| Dissolved Organic Carbon (DOC) | mg/L | 565 | 26 – 1,400 |
| Total Phosphorus (TP) | mg/L | 5.5 | 5 – 6 |
| pH | s.u. | 5.6 | 4.7 – 8.0 |
| Total Kjeldahl Nitrogen (TKN) | mg/L | 13.2 | - |

# 2 TRIAL AIMS

The goal of this trial was to determine the operating parameters for the design of a full scale SAF process for treating kiln condensate, and how far the loading of such a system can be pushed. As well as determining the ideal loading rates for kiln wastewater and a suitable operational range, the information gathered needed to address and resolve some of the risks highlighted in the initial project risk workshop, and attempt to reduce their impacts to future industry installations. The highlighted project risks were:

- ***CCA (chrome, copper, arsenic)***, arising from the redrying of CCA treated timber, flows may cause toxicity to the biological treatment process, or reuse problems;

- ***High temperatures*** could cause problems for biological processes;

- ***Nutrient deficiency*** – Likely for biological process (nitrogen & phosphorus) based on literature waste parameters. Can be resolved by dosing fertilisers.

- ***Solids capture/sludge*** – Quantity and characteristics (e.g. thickness) are unknown. Can be evaluated better in pilot trial.

- ***Metals in biosolids*** – These could be high if CCA process water is treated. Can be evaluated in pilot trial.

- ***Residuals management*** – Where can these be disposed of?

- ***Data*** – The lack of data currently available is of concern and needs to be addressed in a pilot trial or at least a sampling regime.

- ***Foam*** – A black wood-extractives based ooze is known to be an issue with kiln wastewater treatment, and may require an additional lid, or antifoaming agent dosing, or pre-selector.

Therefore the goals of this trial were defined as follows:

- Gather influent and effluent data (flows and concentrations);

- Determine the optimum and maximum loading capability of the SAF process with kiln wastewater;

- Measure the quantity and consistency of solids generated by the SAF process;

- Confirm that influent temperatures are within recommended operational limits;

- Measure the extent of nutrient deficiency in the kiln condensate wastewater, and quantify dosing requirements;

- Measure the quantity of metals in the biosolids and wastewater when the CCA redrying condensate is discharged to the treatment plant;

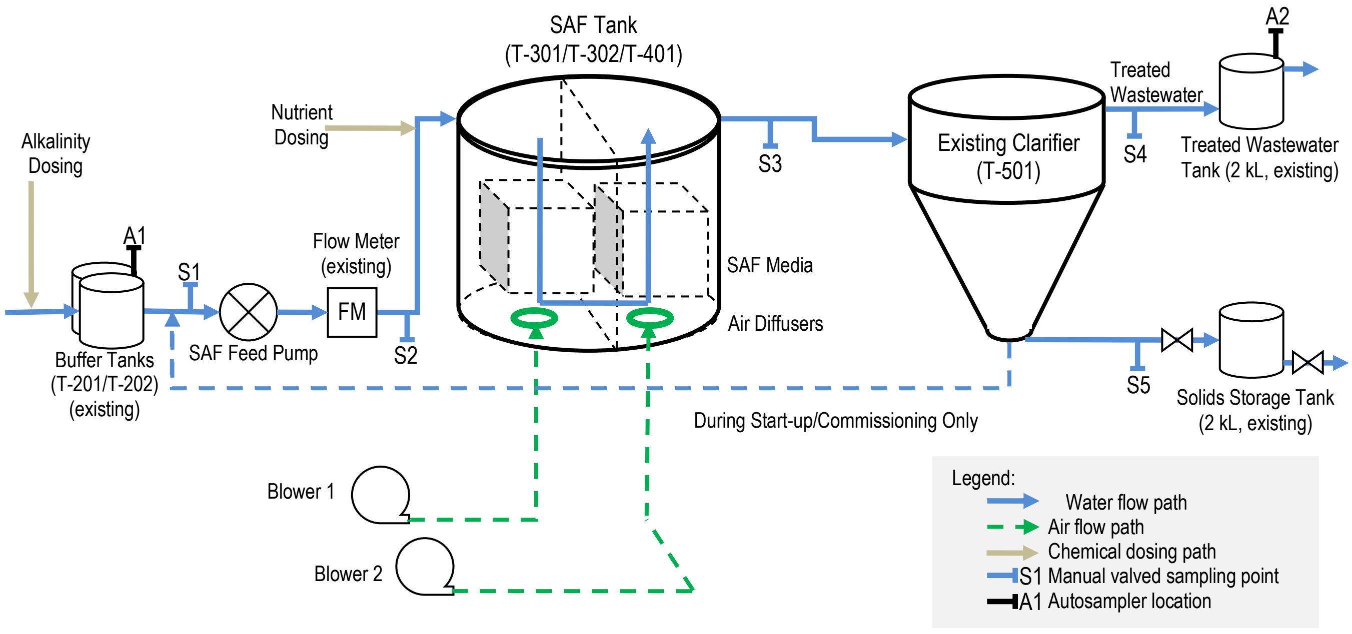
- Monitor foaming issues and identify manageable solutions;

- Observe inhibition effects and advise on requirements for inhibition testing (especially for CCA condensate, if made available at the trial site).

# 3 EQUIPMENT

A disused SAF Pilot Plant was sourced from a local council for the trial work, and a system design was developed to maximise the use of the existing equipment installed at the Rosvall Sawmill site. Figure 1 below highlights the key components of the trial plant, with further explanation included on the following pages.

*Figure 1: Trial plant schematic*




The trial equipment served the following purpose:

- ***Kiln water tank (T-102)*** – The existing 1 m³ tank, which collects kiln water from the sawmill was used to divert a small portion of the site wastewater to the buffer tanks (T-201/T-202) to be fed to the pilot plant.

- ***Buffer tanks (T-210/T-202)*** – These existing 25 m³ tanks were used to buffer load variations at the site. The feed to the buffer tanks was controlled using dedicated float valves in each tank to ensure that sufficient levels were maintained to feed the SAF plant.

- ***SAF feed pump*** – The SAF feed pump was used to adjust the load to the SAF tanks during the trial. It was coupled with a flow meter and control valve for coarse flow control. The flow was monitored manually and the valves adjusted accordingly.

- ***Influent flow meters*** – The existing helix flow meter and flow totaliser meter measured the influent flow to the SAF unit. Return lines and valves to the buffer tanks also allowed finer tuning of flows.

- ***SAF tank (T-301/T-301/T-401)*** – The SAF tank was an existing unit which came complete with fixed film media, internal pipework, air blowers, and air diffusers. The SAF reactor tank was a 10 m³ concrete tank. The tank included division walls which divide the tank into two reactors. The two staged SAF system incorporated a 9" flexible membrane diffuser, situated in the bottom of each SAF reactor. Above each diffuser sits 1.5 m³ of media. Each diffuser was supplied by a dedicated 120 W blower and connecting valved pipework to enable air supply from either blower. The blowers were powered by the electrical control box situated on the exterior of the SAF tank. The media in the tanks allowed for the attached growth of biomass. The two SAF zones were connected with a 110 mm interconnecting pipe though the tank wall. The outlet to the secondary SAF zone flowed to a clarified settling zone. The accumulated solids in this zone were collected along with the solids from the clarifier (T-501) to measure solids generation.

- ***Air blower package*** – The blowers and diffusers were included as part of the SAF pilot plant system. These were operated continuously throughout the trial period.

- ***Clarifier (T-501)*** – The existing site clarifier was available from the previous treatment plant installation. It was oversized for this trial, but reused in order to reduce trial costs. The solids were allowed to accumulate in the bottom of the clarifier and then drawn off to measure the volume and solids content. Some risk of solids carry-over due to digestion and denitrifying existed, and was carefully monitored.

- ***Solids storage tank***– Solids from the base of the SAF and the clarifier were drained using manual valves every 1-4 days into a drum located in the solids storage tank. The drainage flows were visually monitored and stopped once they ran clear. The contents of the drum were thoroughly mixed to give a uniform suspension at which time the liquid height was measured and a sample taken for solids and CCA testing. The solids tank remained isolated by a manual valve and manually discharged to storage ponds once measurements were completed.

- ***Treated wastewater tank*** – The 10 m³ treated wastewater tank provided a location for sampling of treated wastewater. Wastewater was continuously discharged to re-combine with the existing site discharge.

- ***Nutrient dosing*** – Nutrient dosing was introduced manually into the top of the SAF tank as required to achieve a C:N:P ratio of approximately 100:5:1.

- ***pH and alkalinity correction*** – The site's existing pH dosing facility was re-commissioned to manually mix and dose soda ash (caustic soda).

# 4 START-UP AND COMMISSIONING

## 4.1 WATER TESTING

Water testing was carried out prior to filling the tanks with kiln condensate, to allow for leak detection on connections etc. Once leak testing was completed, commissioning the mechanical plant commenced, and then condensate wastewater passed through the plant.

## 4.2 START UP

Initial start-up required the accumulation/growth of biomass on the submerged media. Seeding was carried out by collecting a tankerload of mixed liquor from the nearby Fonterra Kauri biological WWTP, and depositing it in the SAF tank. During this start-up process, the sludge captured in the clarifier was returned to the start of the process, so that biomass had a higher chance of establishing.

Eventually the plant reached a steady state. At this point equilibrium between the influent organics (food) and the biomass on the media (organisms) was reached, such that the effluent organics concentration was relatively stable.

## 4.3 TRIAL OPERATION

During this period the plant was run with minimal operator intervention. The flow rates entering the plant were adjusted approximately twice per week, and samples collected as per the trial programme, and solids cleared and measured from the clarifier.

# 5 METHODOLOGY

The trial plant was set up as described in Figure 1 above.

Wastewater from the kilning process was directed through the kiln water tank. This break tank was fitted with an overflow which allowed the flow to continue back to the usual site wastewater disposal path. This break tank allowed the SAF plant influent pump sufficient head to allow priming, as well as a location for sampling of the influent. Influent pumping to the SAF plant was controlled by manual valves to provide adjustment to "tune" the desired flow to the plant. The influent pump discharge entered zone 1 of the SAF plant, where the effluent is aerated by a diffuser at the bottom of the tank supplied with air by a dedicated blower. The submerged media allows a surface for biomass attached growth and in the presence of dissolved oxygen the biomass partially oxidises the organic material in the wastewater. The wastewater then flowed to a second zone (2) where the remaining load is oxidised in the same manner.

The SAF Feed Pump ran continuously throughout the trial, with the flow adjusted regularly to modify the pollutant load to the SAF plant. Initial feasibility study calculations indicated that a lowly loaded system could operate with approximately 2 m³/d of wastewater on average (1.39 L/min). This was estimated to be at the lower end of the system loading curve, and as such, was used as a starting point. The system was started and commissioned at the lower flow rate, with the flow rate then increased twice per week. Table 2 below summarises the loading regime planned prior to the trial. These loads were calculated on the basis of a wastewater influent BOD concentration of 700 mg/L. Once the actual wastewater influent was measured, the loads were re-calculated (see later sections).

Following the SAF stages, treated wastewater bypassed the in tank clarification zone and entered directly into the clarifier. Clarified wastewater was then collected in the treated wastewater tank. The solids collected in the base of the clarifier, and were manually discharged for measurement and analysis.

*Table 2 – Trial loading schedule*

| Test Phase | Week | Influent Flow Rate | | Input Load (1) | Influent |
|---|---|---|---|---|---|
| | | $m^3/d$ | L/min | kg BOD/d | |
| 1 | 1 | 2.0 | 1.39 | 1.40 | Untreated Condensate |
| 2 | 1 | 2.25 | 1.56 | 1.58 | Untreated Condensate |
| 3 | 2 | 2.5 | 1.74 | 1.75 | Untreated Condensate |
| 4 | 2 | 2.75 | 1.91 | 1.93 | Untreated Condensate |
| 5 | 3 | 3.0 | 2.08 | 2.10 | Untreated Condensate |
| 6 | 3 | 3.5 | 2.43 | 2.45 | Untreated Condensate |
| 7 | 4 | 4.0 | 2.78 | 2.80 | Untreated Condensate |
| 8 | 4 | 5.0 | 3.47 | 3.50 | Untreated Condensate |
| 9 | 5 | 6.0 | 4.17 | 4.20 | Untreated Condensate |
| 10 | 5 | 7.0 | 5.56 | 5.60 | Untreated Condensate |
| 11 | *6* | *3.0* | *2.08* | *2.10* | CCA Condensate (2) |
| 12 | *6* | *3.5* | *2.43* | *2.45* | CCA Condensate (2) |
| 13 | *7* | *4.0* | *2.78* | *2.80* | CCA Condensate (2) |
| 14 | *7* | *5.0* | *3.47* | *3.50* | CCA Condensate (2) |

*Notes:*
*(1) The input load applies only to the first zone of the two SAF zones (which are operated in series).*
*(2) Once the loading capacity of untreated kiln condensate was understood, the CCA loading rates were to commence two to three flow setpoints back from the point where effluent quality dropped off with the untreated trial.*

Once the flow rate (and therefore load) to the plant was adjusted, the effect on the plant was then measured approximately three to four days later. This allowed for changes and sample collections to be made on Monday and Thursday each week for example. It must be emphasised however, that it is assumed that the adjustment period was sufficient for the system to equalise, but that this is an unknown. Timing limitations for the trial would not allow for longer periods of testing.

Two sampling programmes are prescribed in Table 3 and Table 4 below. The first highlights samples and measurements taken during start-up and commissioning to assist the operator in identifying when the steady state is reached and trial work can commence. The second schedule lists the measurements taken during the trial proper to measure the treatment plant loading.

It should be noted that it was not deemed necessary to carry out $BOD_5$ tests as frequently as noted. These are costly and time consuming tests, which were instead measured approximately once per week, and then compared with the COD test (a faster and less costly test), to establish an average ratio between the two.

Standard Operating Procedures (SOPs) were developed to assist operators with making changes to the plant, recording measurements and sampling.

*Table 3 – Start-up sampling schedule*

| Location | Tests(1) | Method | Frequency |
|---|---|---|---|
| **Influent (A1)** | fCOD, TN, TP, Alk | Grab sample | Once or twice per week until steady state achieved. |
| | Flow | Flowmeter | Daily record |
| | Temperature, pH | Manual measurement | Daily |
| **Effluent (A2)** | fCOD, TN, TP, Alk | Grab sample | Once or twice per week until steady state achieved. |
| | pH | Manual measurement | Daily |

*Table 4 – Trial sampling schedule*

| Location | Tests(1) | Method | Frequency |
|---|---|---|---|
| **Influent (A1)** | $BOD_5$, COD, TSS, TKN, TP, Alk | Grab sample | 2-3 days (after system changes) |
| | Flow | Flowmeter | Daily record |
| | Copper, Chromium, and Arsenic | Grab sample | 2-3 days (after system changes) for *CCA wastewater only* |
| | Temperature, pH | Manual measurement | When samples collected |
| **Effluent (A2)** | $BOD_5$, COD, TSS, TKN, TP, TN, $NH_3$, Alk | Grab sample | 2-3 days (after system changes) |
| | Copper, Chromium, and Arsenic | Grab sample | 2-3 days (after system changes) for CCA wastewater only |
| | pH | Manual measurement | When samples collected |
| **Solids (S5)** | TSS, %DS | Grab sample | 2-3 days (after system changes) |
| | Copper, Chromium, and Arsenic | Grab sample | 2-3 days (after system changes) for *CCA wastewater only* |
| | SVI | Grab sample | Measured onsite 2-3 days after each system changes |
| **Solids (solids storage tank)** | Solids volume | Open discharge valve and measure tank depth in the Solids Storage Tank when the flow first runs clear. | 2-3 days (after system changes), empty tank after measurement. |
| **Total site kiln condensate flows** | Flow | Flowmeter | Daily record from site operators |

*Notes: (1) The abbreviated tests are as follows – $BOD_5$ = 5 day biochemical oxygen demand, COD = chemical oxygen demand, fCOD = filtered COD, TSS = total suspended solids, TKN = total Kjeldahl nitrogen, TP = total phosphorus, TN = total nitrogen, $NH_3$ = ammonia, %DS = percentage that is dry solids, SVI = Sludge Volume Index, Alk = Alkalinity.*

## 5.1 OTHER MONITORING REQUIREMENTS

### 5.1.1 SITE FLOW

In addition to measuring the flow to the trial plant, we recommended that total site wastewater flow over the trial period should be measured for later design work. It is essential that a good body of flow data is gathered to confirm the average daily flows, as well as the peak flows and durations. These would allow for the informed design of flow buffering capacities and treatment plant size. As the site drains are typically open drains, it would have been necessary to set up a temporary flow gauge, as a full bore flow measuring devices would not be suitable. Unfortunately it was not possible for the site to undertake these measurements.

### 5.1.2 NUTRIENT DEFICIENCY

Nutrients are required for biological growth. The two most common requirements in biological wastewater systems are nitrogen and phosphorus. Wastewaters from wood sources are typically deficient in these two nutrients and as a result it was necessary to dose fertiliser so that biological growth was not hindered.

During commissioning, a small number of samples were collected to determine influent concentrations of nitrogen and phosphorus. Typically, nutrients should be available at a weight ratio of approximately 100:5:1 for $BOD_5$:N:P for complete BOD removal. The nutrient dosing rates were increased as the organic loads increased so that similar ratios were maintained.

### 5.1.3 FOAMING

Foaming is known to be problematic for aerated treatment systems treating kiln condensate. As a result, the state of the biological reactor was monitored at every inspection to determine whether foaming was problematic. Anti-foaming agents were to be used if foam became an issue.

### 5.1.4 INHIBITION

It was possible that the addition of CCA condensate would cause inhibition to the biological treatment process in the SAF plant. By measuring the treatment capacity at the same loading rates as the non-CCA condensate, an indication of the impact was obtained. If this had been significant, then more detailed laboratory based inhibition testing would have been necessary to determine the appropriate CCA concentration requirements for treatment.

# 6 RESULTS

## 6.1 LOADING RATE

The influent quality to the SAF plant varied greatly throughout the 8 week trial period. The biological oxygen demand ($BOD_5$) ranged from 89 mg/L to >664 mg/L and the chemical oxygen demand (COD) varied from 370 mg/L to 1,500 mg/L. This high variability in $BOD_5$ and COD, attributable to the cyclical nature of batch kiln drying, was also a result of poor buffering and highlighted the need for a correctly sized buffer tank system. In addition, the $BOD_5$ and COD measured exiting the buffer tanks differed from the raw influent concentrations due to relatively high detention times in the buffer tanks particularly at the beginning of the trial when SAF feed rates were low. This suggested that the wastewater was reacting in the buffer tanks and thus not representative of the actual wastewater quality exiting the kiln process.

It is important to note that due to time restrictions for this trial, steady-state conditions could not be guaranteed for the entire trial period. However for the last two weeks of the trial during which CCA treatment commenced and the SAF flow remained constant, the COD and $BOD_5$ removal values were relatively stable.

The addition of CCA condensate did not appear to have noticeable inhibitory effects on biological activity in the SAF plant. Excellent $BOD_5$ and COD average removal rates were achieved using flow from the CCA process; 88% and 71% removal respectively at an average flow of 4.6 $m^3$/day. See Table 5 below.

*Table 5 – BOD and COD removal rates with and without CCA*

| Visit Date | Trial Number | Totaliser Influent Flow rate | Biochemical Oxygen Demand ($BOD_5$) Removal | Chemical Oxygen Demand (COD) Removal |
|---|---|---|---|---|
| | | $m^3/d$ | % | % |
| 21st Jan 2013 | Trial 1 | 2.2 | 4% (1) | 48% (1) |
| 24th Jan 2013 | Trial 2 | 2.0 | - | 65% |
| 29th Jan 2013 | Trial 3 | 1.9 | 62% | 66% |
| 31st Jan 2013 | Trial 4 | 2.3 | - | 65% |
| 4th Feb 2013 | Trial 5 | 2.9 | 75% | 75% |
| 7th Feb 2013 | Trial 6 | 3.2 | - | 67% |
| 11th Feb 2013 | Trial 7 | 5.0 | 49% | 54% |
| 14th Feb 2013 | Trial 8 | 6.0 | - | -139% (2) |
| 18th Feb 2013 | Trial 9 | 10.4 | -7% (2) | -24% (2) |
| 21st Feb 2013 | Trial 10 | 4.0 | - | 11% (2) |
| 28th Feb 2013 | Trial 11 (CCA 1) | 5.2 | 88% | 63% |
| 4th Mar 2013 | Trial 12 (CCA 2) | 4.6 | 91% | 73% |
| 7th Mar 2013 | Trial 13 (CCA 3) | 4.2 | - | 77% |
| 11th Mar 2013 | Trial 14 (CCA 4) | 4.4 | 86% | 72% |

*Notes:*
*(1) Excessive holding times in buffer tanks due to low SAF flows.*
*(2) Issues with insufficient wastewater production rates in kiln process to supply SAF pilot plant.*

To find the optimum loading rate for the SAF unit, the removal rates were graphed against the $BOD_5$ and COD loading rates (Figure 2 and Figure 3). Outliers were removed for both data sets for two reasons. Firstly, the data points for the period 14th to 21st of February were omitted due to kiln wastewater production being lower than the required flow for the SAF resulting in low or negative BOD and COD removal. Secondly, the first set of tests carried out on the 21st of January was excluded as they skewed the results significantly, likely due to improperly established biomass on SAF media.

The COD concentrations used in Figure 3 came from two sets of data; COD measured externally by Whangarei District Council (WDC) Laboratory and COD measured internally by Mott MacDonald. The Mott MacDonald COD samples were filtered whereas the COD measurements at WDC Laboratory were carried out on unfiltered samples. For this reason, Mott MacDonald results present a higher COD removal due to additional COD removal in the filtering step. This additional COD testing by Mott MacDonald was carried out to benefit the trial phase only by providing faster data acquisition for process monitoring. However, only the WDC Laboratory results were used for data analysis.

*Figure 2: BOD loading against BOD removal across SAF pilot plant*

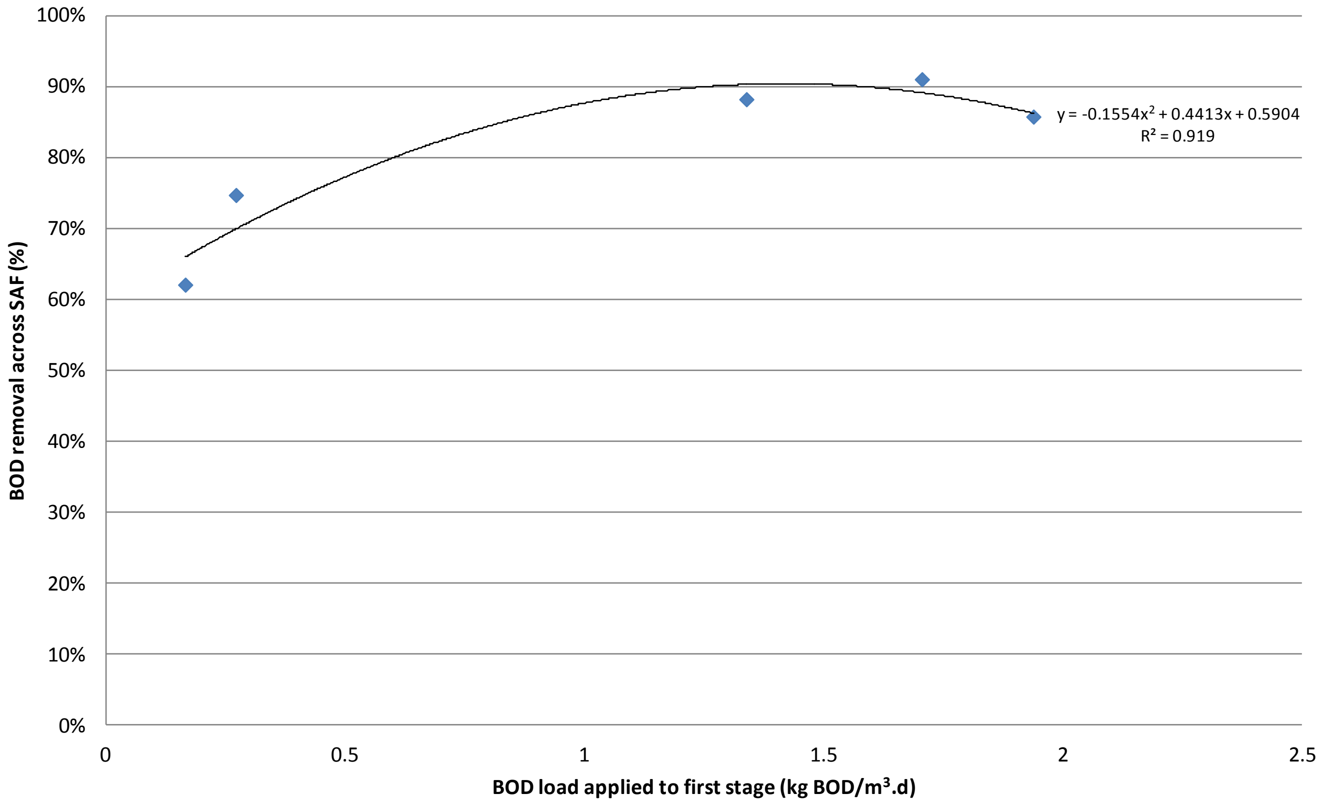
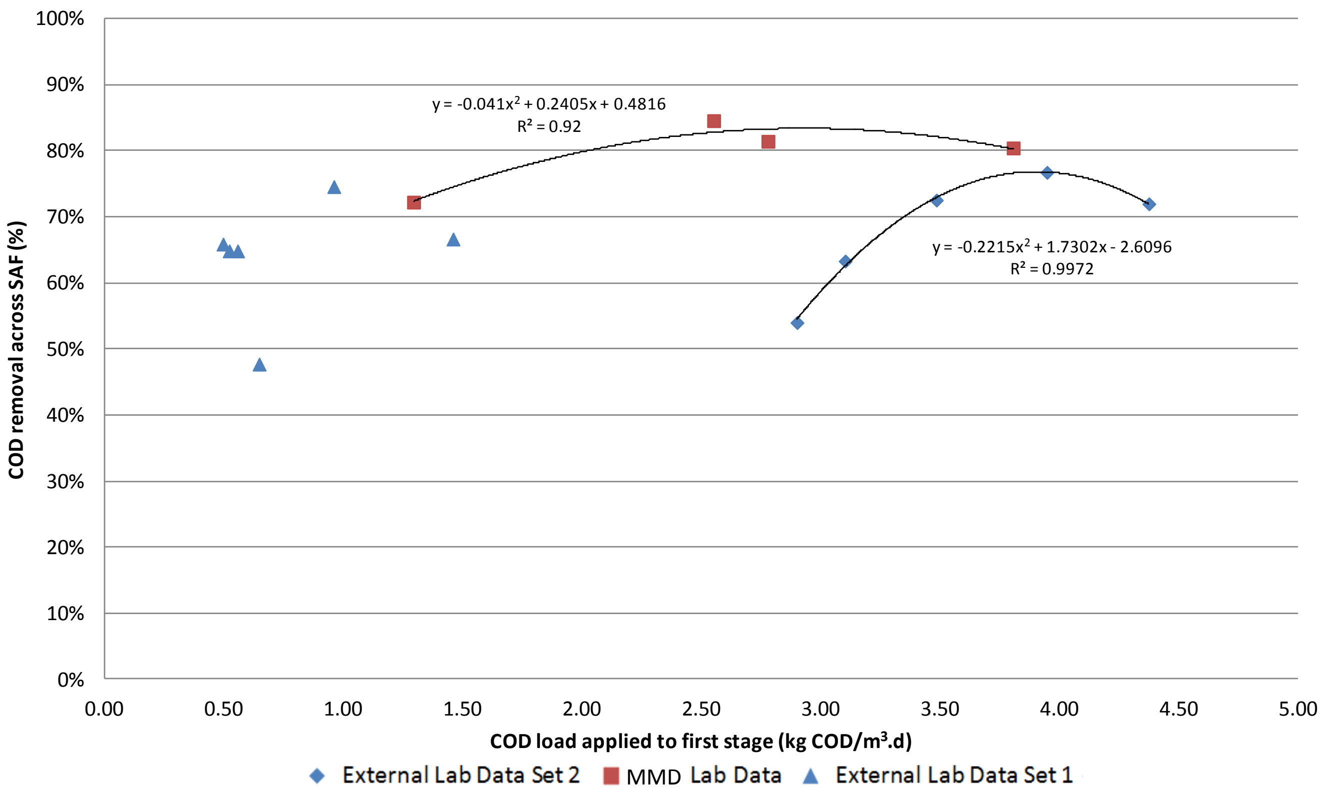



*Figure 3: COD loading against COD removal across SAF pilot plant*



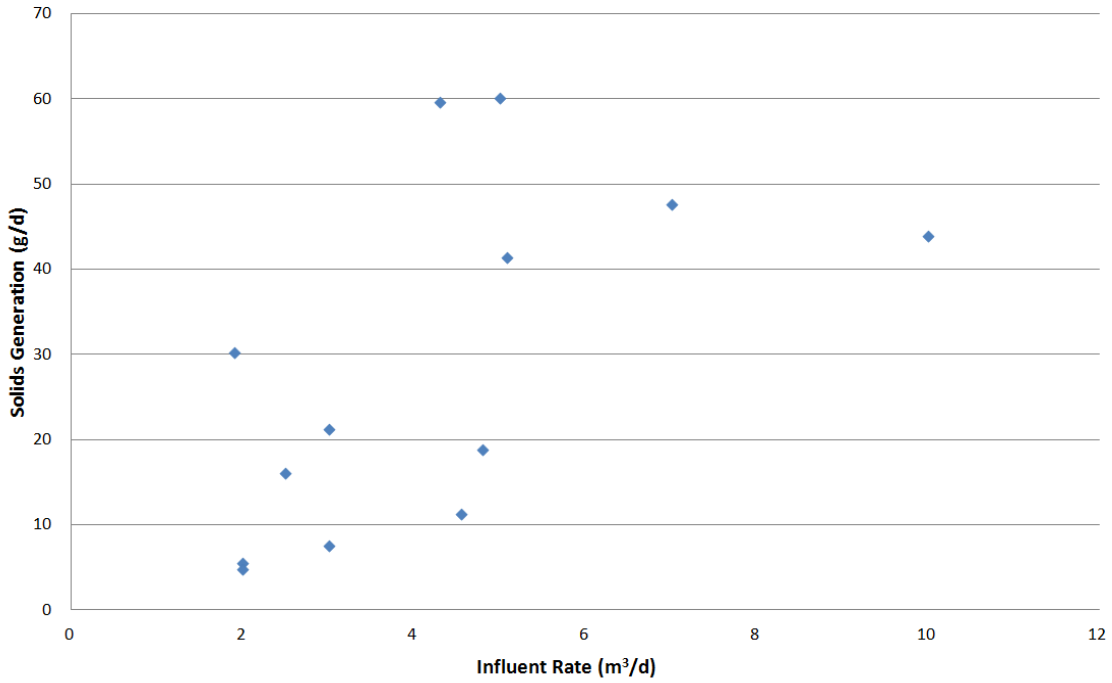

COD data set 1 in Figure 3 corresponds to data collected in the early stage of the trial and does not give a stable relationship between COD removal and COD loading. This may be due to unsteady state operation with the biomass still establishing or as a result of the buffer tank storage being too large at the initial lower flows resulting in different degrees of 'pre-treatment' of the feed stream in the buffer tanks. COD data set 1 was used to select a suitable flow rate for the remainder of the trial. The selected flow rate was acceptable in view of the fact that COD data set 2 gave much more stable results while providing a high COD removal at a much lower SAF volume.

The loading rates identified were similar to typical municipal loading rates, which are expected to be optimum at between 0.3 and 2 kgBOD/m³.d (depending on second and first stage loading rates respectively.

## 6.2 SOLIDS PRODUCTION

The solids production in the SAF unit and the clarifier was measured throughout the trial period and is presented in Figure 4 below.

*Figure 4: Solids generation in SAF and clarifier against SAF influent rate*




The solids yield throughout the trial reached a maximum of 0.06 gTSS/gCOD removed with an average daily yield of 0.018 gTSS/gCOD removed. As can be seen in Figure 4, the variability in solids production is high, however with so many changes in load over a short period of time, and only rudimentary measurement methods available, this is to be expected.

## 6.3 NUTRIENT DOSING

Nitrogen and phosphorus to $BOD_5$ ratios were monitored in the kiln condensate. The results are presented in Table 6 below.

*Table 6 – BOD:TN:TP ratios for Rosvall Sawmill effluent*

| Date | $BOD_5$:TN:TP |
|---|---|
| 21st January 2013 | 100:10:3 |
| 29th January 2013 | 100:5:2 |
| 4th February 2013 | 100:4:3 |
| 11th February 2013 | 100:2:1 |
| 18th February 2013 | 100:2:1 |
| 28th February 2013 | 100:2:1 |
| 4th March 2013 | 100:1:1 |

A $BOD_5$:TN:TP ratio which does not limit biological growth is understood to be 100:5:1. Total phosphorus (TP) concentrations in the SAF feed were adequate but total nitrogen (TN) was deficient.

Using a target ratio of 10:1 of COD to N, the required dose rate of nitrogen (less nitrogen already present in kiln effluent) was calculated to be approximately 40 gN/m³ treated effluent.

A readily available consumer fertiliser (27% N) was used as the nitrogen source and dosed manually into the SAF unit on a daily basis starting on the 14th of February 2013.

## 6.4 FATE OF CCA

Copper, chromium and arsenic (CCA) entering the SAF from the site CCA process was distributed to the SAF effluent and biosolids according to the figures in Table 7.

*Table 7 – Average proportions CCA in biosolids and final effluent*

| | Copper | Chromium | Arsenic |
|---|---|---|---|
| Proportion in effluent | 93% | 99% | 98% |
| Proportion in biosolids | 7% | 1% | 2% |

As greater than 90% of CCA remained in the liquid effluent, this highlights an opportunity to recycle CCA by reusing treated SAF effluent in ~~the~~C~~-C~~CA treatment processes. In addition, due to its high CCA content, the treated effluent may not be suitable for disposal to waterways. A disposal route for the low CCA biosolids will also need to be investigated further, but appears to carry less risk with the majority of CCA exiting in the effluent.

If the removal of CCA is preferred in the sludge (for example at sawmill sites which have stringent effluent discharge requirements), then chemical precipitation with a metal salt prior to clarification may assist with this. Simple jar tests can be carried out on the Rosvall effluent to confirm the dosing requirements.

## 6.5 POLLUTANT REMOVAL AND EFFLUENT QUALITY

The effluent quality produced from the SAF during the ideal loading period (with CCA) in weeks 6-8 of the trial is presented in Table 8 below.

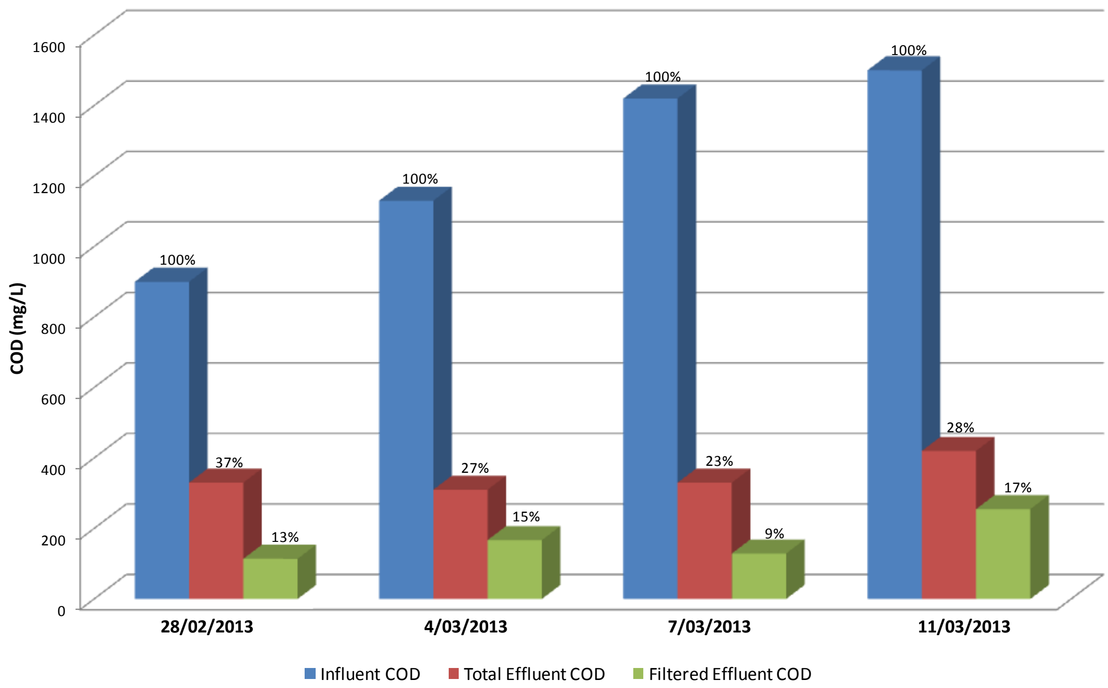
*Table 8 – Effluent quality exiting clarifier (post SAF) during CCA dosing*

| Date | Week | $BOD_5$ (mg/L) | COD Ext. (mg/L) | COD MMD (1) (mg/L) | TKN (mg/L) | SS (mg/L) |
|---|---|---|---|---|---|---|
| 28th February 2013 | 6 | 46 | 330 | 114 | 22 | 71 |
| 4th March 2013 | 7 | 50 | 310 | 167 | 15 | 74 |
| 7th March 2013 | 7 | - | 330 | 129 | - | 149 |
| 11th March 2013 | 8 | 95 | 420 | 255 | 22 | 138 |
| **Average** | **-** | **64** | **348** | **166** | **20** | **108** |

*Note: (1) The Mott MacDonald (MMD) COD effluent results were filtered to give a more representative value for soluble COD, which will better represent results with a full scale post filtration system.*

COD tests undertaken by Mott MacDonald were filtered samples whereas COD tests conducted at the external laboratory were unfiltered samples thus giving higher values. Filtered sample results will give a more representative view of the actual effluent quality that can be achieved with a full scale SAF unit followed by an appropriately sized clarifier and filter. The reduction in COD across the SAF unit in terms of both unfiltered and filtered effluent COD is presented in Figure 5 below.

*Figure 5: Reduction in COD across the SAF unit*




The suspended solids content of the clarifier effluent was high, likely due to the clarifier not being appropriately sized for the receiving flow. Long residence times and slow biosolids removal from the base of the clarifier can result in denitrification and biomass digestion, which can in turn cause poor settlement and release of organic load, along with solids loss in the overflow.

If the effluent is intended for reuse, improved solids removal using a smaller appropriately sized clarifier followed by filtration is recommended.

## 6.6 FOAM

The foam produced in the SAF unit during the trial was a light white foam and not the black 'extractives' foam that is commonly observed with kiln wastewater treatment. Light white foam is a common occurrence during the start-up of wastewater treatment plants. The quantity produced varied from a thin layer of foam covering a portion of the SAF surface to on one occasion reaching the SAF lid. The highest quantities of foam were generated when the SAF was overloaded, i.e. at very high flow rates.

Examples of the range of foaming intensity observed during the trial in the main chamber of the SAF tank are presented in Photographs 1 and 2 below. The foam was not deemed to be problematic, was easily destroyed with manual water sprays, and is likely to be easily controlled with either manual or automatic sprays in a full scale system.

*Photographs 1 & 2: Foam production observed during the trial in the main chamber of the SAF unit*


# 7 CONCLUSIONS

The optimum loading rates based on the influent and effluent data gathered throughout the trial were established, and determined to provide approximately 90% $BOD_5$ and 77% COD removal. Phosphorus concentrations were adequate for good biological activity but nitrogen was deficient and the required additional dose was estimated at 40 $gN/m^3$ of treated wastewater for this site. CCA condensate had no evident inhibitory effects on biological activity and an opportunity to recycle CCA was identified due to >90% of CCA exiting SAF in the effluent in comparison to the amount taken up by the biomass.

The solids yield in the SAF was variable throughout the trial, ranging from an average of 0.018 gTSS/gCOD removed up to a maximum of 0.06 gTSS/gCOD removed. However, some of these solids were likely to be leaving the system in the clarifier effluent highlighting the need for an appropriately sized clarifier followed by a filter if the effluent is intended for reuse onsite. In addition, foaming in the SAF was not excessive and the light constitution of the foam would allow it to be easily controlled with spray water if required.

SAF technology was clearly demonstrated to be appropriate for treating the Rosvall Kiln wastewater. Design parameters generated in this trial have since been used to develop full scale treatment plant for the site, which was installed in 2014.

After a prolonged commissioning and bedding in period, the full scale plant is now generating excellent effluent quality, such that the site operators are aiming to reuse the treated effluent in upstream site processes in the near future. Pictures 3 through 6 below present the full scale SAF treatment plant installation in operation.

*Photograph 3:   Full scale treatment plant with SAF plant in the foreground and two large 20 m³ buffer tanks*


*Photograph 4:   Full scale treatment plant with existing tanks reused*

*Photograph 5: Full scale treatment plant SAF tank aeration pipework and media access points*

*Photograph 6: Full scale treatment plant SAF tank foaming*

## ACKNOWLEDGEMENTS

This paper would not have been possible without the input of the following key stakeholders, and the authors thank them additionally for permission to publish this information:

**Solid Wood Innovation (SWI)**, for sponsoring this study, with particular thanks to Chief Executive, Dr Keith Mackie.

**Rosvall Sawmill**, for taking part in the trial, providing daily operator assistance, regular feedback, and use of existing infrastructure. Particular thanks to Managing Director, Mark Hansen.

**Windsor Engineering**, for partial sponsorship and installation of the trial plant. Particular thanks to Engineering Manager, David Parle.

## REFERENCES

Dare, P., and Riley, S. (2003). 'Liquid Condensate Emissions from Kilns Frying Radiata Pine.' *8th International IUFRO Wood Drying Conference.* Pages 477 to 480.