INITIAL RESPONSE IN AN EMERGENCY: CHRISTCHURCH WWTP FIRE

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ABSTRACT (500 WORDS MAXIMUM)

On 1st November 2021, a fire at the Christchurch Wastewater Treatment Plant (CWTP) caused significant damage to both trickling filters, and the associated infrastructure. The trickling filters are an integral part of the treatment process, converting about 80% of the soluble BOD into “secondary solids” which are removed in the secondary clarifiers. Loss of the trickling filters has a significant detrimental impact to the CWTP performance. This paper describes the immediate actions undertaken to keep CWTP operational, as well as initial measures put in place to maximise the available treatment and restore secondary treatment. Central to the success of the fire response has been a highly collaborative approach between Christchurch City Council (CCC), Jacobs, suppliers, and contractors.

Currently CWTP is providing adequate treatment, discharging treatment wastewater largely within the required consent limits. The success to date is the result of a highly collaborative approach, with design and construction occurring hand in hand. It has relied on open and frequent communication between CCC stakeholders, Jacob’s designers, equipment suppliers and contractors. Co-locating key members of the design team at CWTP has ensured information is shared quickly and supported robust decision making.

KEYWORDS

Wastewater treatment, emergency response, activated sludge, wastewater modelling, procurement,

PRESENTER PROFILES

Mr Adam Twose is the Manager Operations for Christchurch City Council in the 3 Waters Department. He is responsible for the management of the Council’s Water & Wastewater Treatment facilities across Christchurch and Banks Peninsula. Adam has a long history and extensive experience in operating and managing water and wastewater treatment plants in both NZ and the UK.

Dr Becky Macdonald is Principal Wastewater Engineer, based in the Jacobs Christchurch Office and Regional Solutions Director for ANZ Water Infrastructure. She has worked extensively across New Zealand on water and wastewater projects, both small and large. Becky has a focus on the safety in all phases of the project cycle, from concept, through design, construction, and operation. She is a Fellow of the Institute of Chemical Engineers (IChemE) and Adjunct Professor at Canterbury University.

1 INTRODUCTION

1.1 OVERVIEW

The Christchurch Wastewater Treatment Plant (CWTP) is the second largest in New Zealand and treats the wastewater from Christchurch City, a population of over 400,000 people. On 1st November 2021 a fire at the Christchurch Wastewater Treatment Plant (CWTP) caused significant damage to both trickling filters, and the associated infrastructure.

Figure 1: Trickling filters during the fire event

The trickling filters are an integral part of the treatment process, converting about 80% of the soluble BOD into “secondary solids” which are removed in the secondary clarifiers. Loss of the trickling filters has a significant detrimental impact to the CWTP performance. This paper describes the immediate actions undertaken to keep CWTP operational, as well as initial measures put in place to maximise the available treatment and restore secondary treatment.

Figure 2: fire damaged trickling filter

1.2 BACKGROUND

Prior to the 2021 fire, the CWTP treatment process involved both primary and secondary treatment, disinfection in the polishing ponds, and disposal via an ocean outfall. CWTP had numerous flow paths, allowing for alternative modes of operation and flexibility depending on treatment, operational and maintenance needs, such as wet weather flows.

The general process description for the liquid stream at CWTP, pre fire, is shown in Figure 1 and includes:

- Screening to removal larger particulate contaminants in the raw wastewater
- Grit removal to remove of grit and sand
- Primary sedimentation (PST) removes the readily settleable “primary solids” which are transferred to an anaerobic digester for treatment.
- Trickling filters (TF) which biologically converts about 80% of the soluble BOD converting it to “secondary solids”
- Solid Contact Tanks (SCT) where air is bubbled through the TF effluent, providing some further biological treatment but mainly secondary solids flocculation
- Secondary clarification to remove the secondary solids which are transferred to an anaerobic digester for treatment
- Polishing ponds which provide some nutrient removal but primarily disinfect the wastewater (pathogen removal) using natural sunlight

The sludge treatment train at CWTP was not damaged by the fire event. It comprises thermophilic and mesophilic anaerobic digestion with biogas captured, processed, and consumed in various methods to meet operational needs and resrouce consent requirements (boilers, generators, and flares).

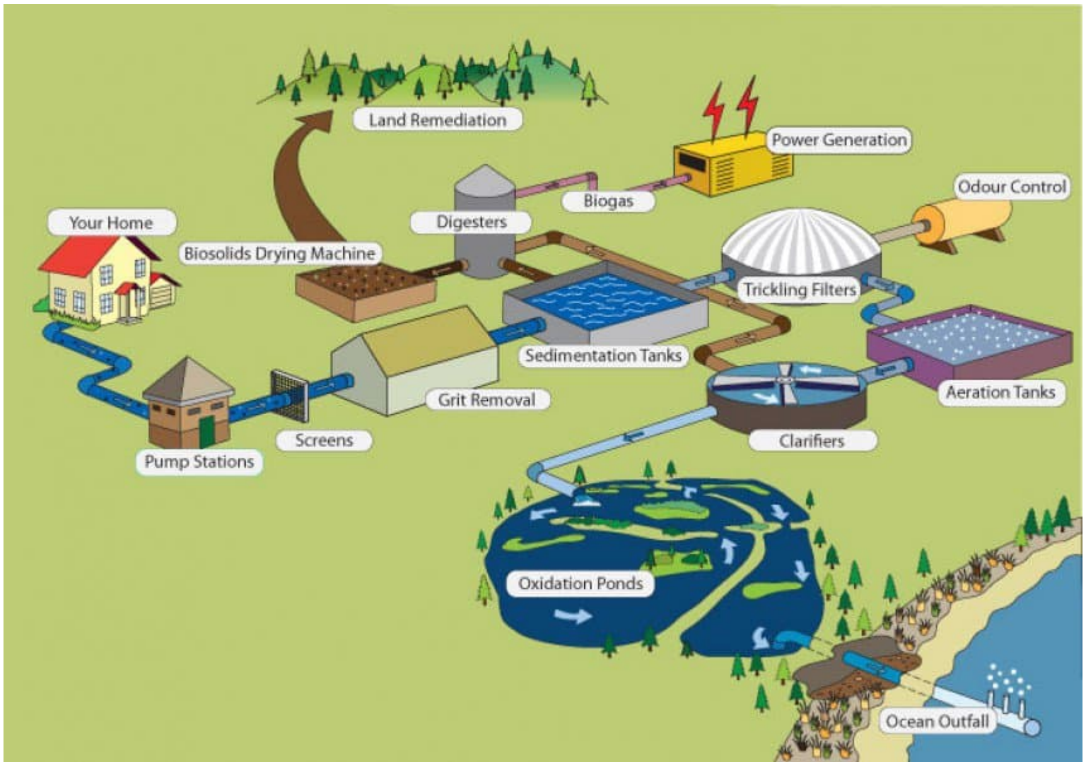

Figure 3: CWTP prior to the 2021 fire event

1.3 INTRODUCTION

For the last 50 years the powerhouse of the CWTP treatment process has been two trickling filters, operating in parallel, which provided the majority of the BOD removal. The 2021 fire caused catastrophic damage to the trickling filters (rendering them unusable), damaged the odour management in the screen room, and disabled the wastewater flow path through the trickling filters to the SCTs, isolating Pump Station A from the process. Pump Station B remained connected and operable, which allowed a portion of the flow to bypass directly from the PSTs to the SCTs and then on to the secondary clarifiers.

Full secondary treatment with the SCT's and clarifiers was not possible due to the flow and aeration constraints. As a result, partially treated wastewater (largely just primary treated) was discharged to the ponds changing their operation from polishing ponds, to full oxidation ponds.

The significant process implications of the damage caused by the 2021 fire event are summarised below:

- The trickling filters were rendered inoperable due to the direct damage caused by the fire, essentially removing all of the secondary treatment process and significantly reducing the BOD removal capability of the process.

- During the fire event, wastewater passed through the trickling filters as part of the firefighting effort to extinguish the fire. This resulted in contaminated material from the fire flowing into the treatment process which was toxic to the biology.
- Pump Station A was isolated from the downstream process, limiting the flows through the SCT and clarifiers to approximately half the average dry weather flow. This resulted in approximately half of the primary treated wastewater being diverted directly to the ponds.
- Immediately post fire, the waste activated sludge (WAS) from the secondary treatment process was contaminated with compounds from the fire damaged trickling filters. This negatively impacted the operation of the digesters and alternative WAS handling and disposal was required.
- The change in feedstock to the anaerobic digesters, to just primary solids, impacted their performance, resulting in a change to the biogas composition.
- The screen room odour management was connected to the trickling filter air handling system, which was destroyed by the fire.

2 IMMEDIATE EMERGENCY RESPONSE

The immediate emergency response included a number of mitigations that were put in place, under urgency, in the days and weeks immediately following the fire.

2.1 INLET SCREEN ROOM

Foul air ducting from the inlet screen room was connected to the tricking filter foul ducting. The fire damage the trickling filter foul air ducting and fans. Biofilter 1 including the biofilter fans, were not damaged and continued to provide treatment of air from the gravity belt thickener building which was separately conveyed to the biofilter

In the weeks following the fire, new ducting was installed to convey foul air from the screen room to the foul air handling system for the gravity belt thickener building. From here the air is combined with the foul air from the gravity belt thickener building for conveyance to Biofilter 1 for treatment.

Figure 4: new foul air ducting from the inlet screen room

2.2 TRICKLING FILTER DISCONNECTION

During the fire event wastewater continued to be circulated through the trickling filters to assist with fire suppression. This continued for approximately two weeks to support the fire service in the management of hot spots and minimise the possibility of a flare up. The consequence was that wastewater contaminated with combustion byproducts flowed into the down-stream the treatment processes. This proved toxic to the biology in the solids contact tanks, with the biomass quickly disappearing. Only a small number of simple, and slow-moving microbes (ciliates) were evident a month after the fire.

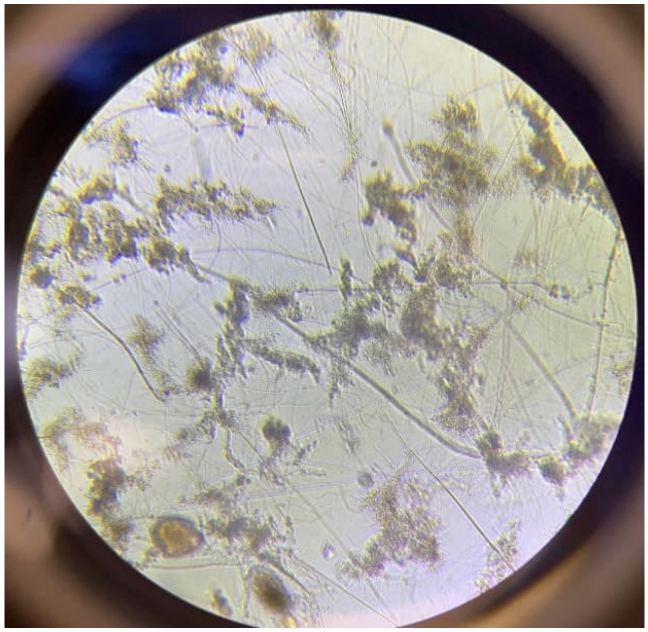

Figure 5: microscopy showing very little biological activity (and fiberglass fire debris)

The flow into the trickling filters was turned off once the NZ Fire Service confirmed that the fire was fully extinguished. However, water would fall onto and flow through the exposed trickling filter media into the process during rain events, re-introducing toxic compounds. To mitigate this, gates were installed in the pipeline connecting the trickling filters from the treatment process. This disconnected not only the trickling filters, but the flow path from Pump Station A.

An alternative flow path, from Pump Station B, via an existing trickling filter bypass was activated. This flow path has a significantly reduced capacity, up to approximately 1 m^3/s, compared to up to 5.4 m^3/s for Pump Station B. However, it enabled a portion of CWTP flow to continue to pass through to the secondary contact tanks (SCTs) and on to the secondary clarifiers.

2.3 PRIMARY SEDIMENTATION ENHANCEMENT

Following the fire, the primary sedimentation tanks (PSTs) were the main mechanism for providing treatment for Christchurch's wastewater. The PSTs allow readily settleable solids to be separated from the liquid stream, reducing the total solids and BOD. Maximizing the primary treatment was an important aspect of the immediate emergency response. This was achieved by dosing a flocculating polymer into the inlet channel to the PSTs.

A polymer make-up and dosing plant was sourced from a local supplier and connected with temporary piping to a dosing location. The BOD and TSS removal through the PSTs were 64% and 55% respectively. Resulting in approximately 20,100kg/d BOD and 15,900kg/d TSS flowing through to the rest of the process and onto the ponds for treatment.

2.4 SLUDGE MANAGEMENT

Waste activated sludge (WAS) at CWTP is normally co-digested with primary sludge in the thermophilic and mesophilic anaerobic digesters. A key concern was that the WAS may be contaminated with toxic combustion products that would have negatively impact the anaerobic digesters.

Immediately following the fire, the performance of the digesters was carefully observed. H2S levels in the digester biogas rapidly increased, from normally less than 500ppm, to approximately 1200ppm, peaking at 1700ppm. The pH in the thermophilic digesters started to climb, from normally about pH 7.3, up to as high as pH 7.8 two weeks after the fire. This indicated that the digesters were being stressed and the WAS feed to the digesters was stopped.

Due to the potential for WAS to generate odour, the only feasible, short-term option for the management of the contaminated WAS, was disposal to landfill. However, there was no existing mechanism to collect the WAS and dewater it for transport. The existing WAS is thickened using gravity belt thickeners ahead of digestion. The belt presses are only connected to the digested sludge and are located over 100m across site from the thickened WAS hopper.

Temporary modifications were made, running flexible pipe across the ground to connect the thickened WAS to the belt presses. Dewatered WAS from the belt press was deposited on the biosolids pad, where was collected and trucked to the landfill. Once the trickling filters were isolated, and the source of contamination removed, WAS was again conveyed to the digesters for treatment.

Figure 6: temporary connection from the gravity belt thickeners to the belt presses

Figure 7: dewatered WAS awaiting transport

2.5 POND OPERATION

Contaminated wastewater flowed into the ponds changing the colour from green (algae) to black.

With the loss of the trickling filters, the BOD of the plant effluent increased from normally stable 10 g/m^3 and 20 g/m^3 (filtered BOD) to fluctuating between 30 g/m^3 and 150 g/m^3 (average 133 g/m^3). This corresponded with a reduction on the dissolved oxygen in Pond 1 to below 1.0 g/m^3. This indicated that the ponds had changed operation from operating as maturating / polishing ponds for low strength secondary treatment wastewater, to operating as a highly loaded oxidation pond receiving primary treated wastewater. This creates a risk of anaerobic conditions forming across the full depth of the pond, resulting in odours from the ponds. Due to the large pond surface area, odour could be significant.

Figure 8: contaminated wastewater mixing in Pond 2

Increasing the available oxygen in the ponds was essential in order to enable BOD treatment of the wastewater in the ponds. An immediate mitigation was to introduce chemical oxygen to the ponds. Hydrogen peroxide dosing (H_2O_2) was installed at the inlet to the ponds to achieve a set point of 4.0 g/m³ dissolved oxygen at the inlet to Pond 1. However, this additional oxygen was quickly depleted with the outlet from Pond 1 remaining at below 1.0 g/m³.

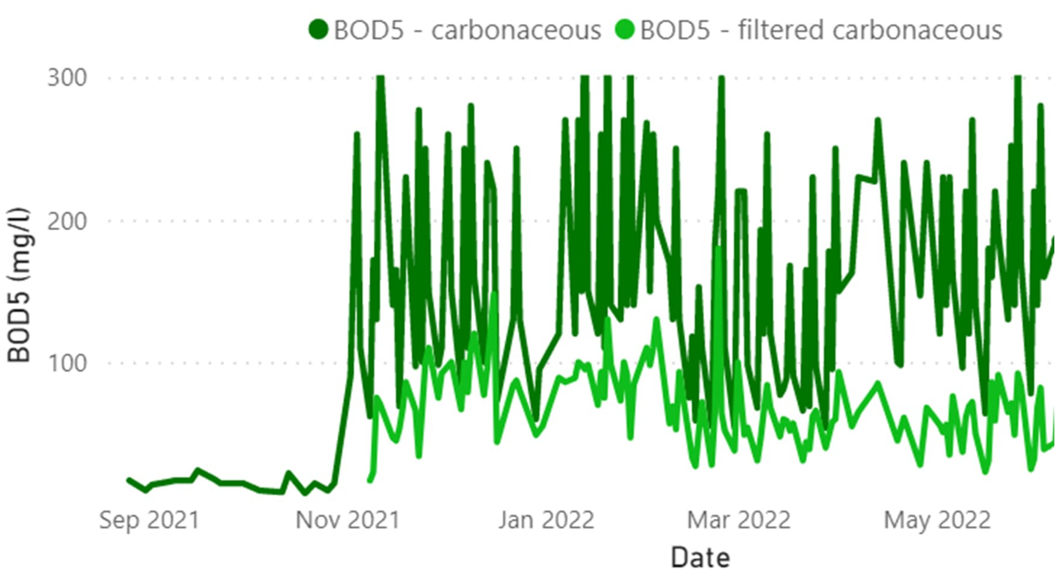

Figure 9: Plant effluent BOD_5 (filtered)

Mechanical aeration is a common technology used to enhance the dissolved oxygen of oxidation ponds. The CWTP ponds are shallow, less than 1.5m water depth, and only specific style of aerators can be used without risking damage to the base of the pond. Due to the size of the CWTP ponds (approximately 2.4 km^2), a large amount of aeration would be required to provide sufficient dissolved oxygen to mitigate the risk of odour. However, oxidation ponds in New Zealand are generally small, and therefore most of the aerators that are available are small.

Initial investigation of NZ contacts found very few aerators were available, with only three, large, second hand aerators being located;

- One aspirating aerator owned by Fonterra and operated by Tasman District Council at the Takaka Wastewater Treatment Plant. This aerator is generally only used 3 months of the year when the milk flows are at the highest.

- Two directional surface aerators owned by Invercargill City Council that had been mothballed at the Invercargill Wastewater Treatment Plant.

All three aerators were relocated to CWTP and refurbished at the CWTP maintenance workshop. These aerators were installed close to the inlet of Pond 1. However, due to the very high BOD loading, the ponds rely on the production of oxygen by algae in the ponds. In winter when algae growth slows considerably, due to the lower temperatures and reduced sunlight, the current aeration is not sufficient to maintain aerobic conditions and odours are a nuisance.

Figure 9: one for the direction aerators from Invercargill

Figure 10: The aspirating aerator from Takaka

3 INTERIM TREATMENT PROCESS AND NEXT STEPS

3.1 INTERIM OPTIONS ASSESSMENT

Options for a medium-term, interim treatment process, based on repurposing existing infrastructure at CWTP have been considered. Three, feasible options that could be implemented within a few months were identified:

1. Conversion of two of the existing secondary clarifiers to bioreactor tanks and incorporating them with the existing Solids Contact Tanks (SCTs). This option was the subject of the initial memo (CWTP Activated Sludge Aeration Review),
2. Adding additional aerated tank volume with temporary tanks and incorporating these with the existing SCTs in a contact stabilisation configuration to enable treatment of the average dry weather flow (ADWF).
3. Providing standalone bioreactor tanks to replace the SCTs capable of treating the ADWF.

To assess the treatment performance modelling was carried out, using the SUMO modelling software (by Dynamita). Other factors included in the assessment and identification of the preferred option included, implementation timeline, capital cost and operating cost.

Option 1, repurposing two clarifiers for aeration, was identified as the preferred way forward, and the implementation is underway. This option has the fastest timeline to providing additional treatment in the form of BOD removal so that the BOD load to Pond 1 is reduced resulting in an anticipated reduction of odours from the WWTP. Following commissioning of the aeration, the installation of additional aeration on Pond 1 will be carried out to further mitigate odours as well as provide consistent and reliable treatment.

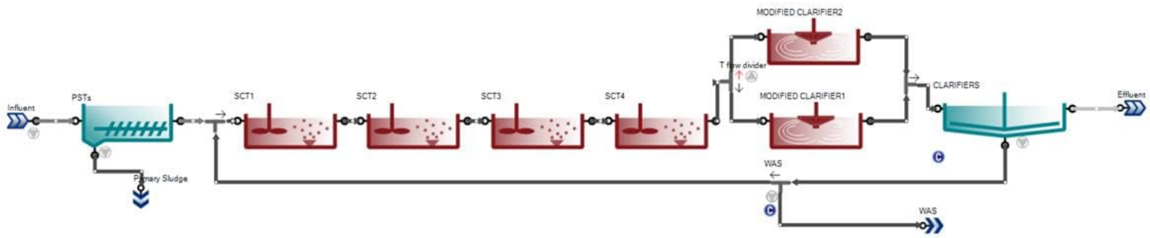

Figure 11: Sumo model set up for the preferred option, repurposing existing clarifiers

The other two options provide potential pathways to treating more of the flow and further reducing the BOD load to the pond. However, both have a significantly longer implementation time, and considerably more construction works associated with the tankage, pipes and pumping. Given that this this is only an interim solution, they are not preferred.

Construction is close to complete on the interim solution and process commissioning now underway.

3.2 POND AERATION

A limitation of the preferred option is the treatment capacity. Once fully commissioned modelling indicates that the interim solution should provide secondary treatment of about 75% of the average daily flow. This means that installing aeration on Ponds 1 should provide additional treatment capacity and future resilience until a final, long term solution is in place for CWTP.

Design is underway to install approximately 500kW of aeration on Pond 1 with careful consideration given to the location of aerators.

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