GETTING TO THE BOTTOM OF SCUM – A NEW PROCESS FOR THE SEPARATION AND DEWATERING OF CLARIFIER SCUM

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ABSTRACT

New Plymouth District Council (NPDC) have recently completed a major upgrade of their sludge thickening facility at New Plymouth Wastewater Treatment Plant (WWTP), to substantially improve the performance of the existing Picket Fence Thickeners. This includes the introduction of a new process to remove water from the scum (consisting of fats, filamentous microbes, floating solids, much from trade waste sources), which is collected and removed from the surface of the secondary clarifiers, and introduced into the sludge stream.

Prior to the upgrades, scum was collected and incorporated directly into the Waste Activated Sludge (WAS) stream, so that it could be treated through the sludge thickening, dewatering and drying processes. This led to significant quantities of carry-over water being introduced into the solids stream, which resulted in poorer sludge thickening and dewatering performance, and ultimately greater energy use in the thermal drying process. It also caused carry-over of scum to the surface of the Picket Fence Thickeners (PFTs), which resulted in the scum being reintroduced to the headworks.

As part of the upgrades, the scum was separated from the WAS pumping process and a Baleen Filter was installed to remove free water from the scum, prior to the solids being incorporated into the thickened sludge storage tank (prior to dewatering). The Baleen Filter is typically used in the food industry to dewater products or waste streams, but was identified as a novel cost-effective approach to remove free water from scum at New Plymouth WWTP. Based on trials undertaken by NPDC, further enhancement of the Baleen Filter process has been made by retrofitting a flocculation system.

This paper presents the project from inception to operation, including the outcomes of early trials and the key matters and lessons learnt that influenced the design and construction, recognising the increasing importance of effective scum management in WWTP operations.

KEYWORDS

Scum, Scum Separation, Baleen Filter, Sludge Thickening

PRESENTER PROFILE

Chris French is an Associate in Beca's Water team has over 15 years' experience in the design and project management of municipal wastewater treatment plants. Chris was the design project manager for the initial design phases of the New Plymouth WWTP upgrades, and has provided ongoing technical and commissioning and advisory services.

Graham Morris is the Optimisation Engineer for New Plymouth District Council. A chemist by trade, he has worked for the Council as Trade Waste Officer, and Treatment Lead for water, wastewater and landfill operations. Graham has been heavily involved in major upgrades of the New Plymouth WWTP.

David Grace is a Senior Mechanical Engineer at Beca, who has over 8 years of experience in design, project management, construction management, and technical review of mechanical systems including significant industrial and water / wastewater treatment projects. David was the lead Mechanical Engineer for the recent New Plymouth WWTP Upgrades.

1 INTRODUCTION

1.1 OVERVIEW OF NEW PLYMOUTH WWTP

The New Plymouth Wastewater Treatment Plant (WWTP) provides tertiary treatment of municipal wastewater for the city of New Plymouth and the satellite communities of Inglewood, Waitara and Oakura, serving a total population equivalent of 104,245. This includes a trade waste component, predominantly from chicken processing, which contributes approximately 18-20% to the total average daily flow.

The original plant, constructed in the early 1980's, provides preliminary treatment including fine screening and grit removal; secondary treatment using extended aeration activated sludge "carousels" together with secondary clarifiers; and chlorine disinfection. Several upgrades have been undertaken to the plant to address growth and asset life cycle demands, most notably including the introduction of a thermal rotary (drum) dryer process in 1999, to dry waste activated sludge (WAS) that has been thickened (through the picket fence thickener process) and dewatered by the direct coupled gravity belt thickener and belt presses.

A significant upgrade of the sludge dewatering process is in its final stages of completion. During early planning for this upgrade, it was identified that there was a significant opportunity to readily remove water from the scum off the secondary clarifiers, which has been traditionally incorporated with the WAS prior to thickening and dewatering. Therefore, as part of the sludge thickening and dewatering upgrade programme, NPDC sought to substantially improve the scum removal and handling process.

1.2 WHAT IS SCUM?

In terms of wastewater treatment plant operations, scum can be described as the floatable matter that may accumulate on water surfaces in the treatment plant process units. This floatable matter typically consists of fats, filamentous microbes, foam, and floating solids and debris (such as cotton bud tips). In quiescent conditions, such as on the water surface of primary and secondary clarifiers, the scum will often form as a film across the surface of clarifier that must be accumulated prior to disposal. Without intervention to accumulate and dispose of the scum, excess scum build-up may occur, leading to carry-over into the clarifier effluent.

In "conventional" radial clarifier arrangements, the scum is accumulated by a scraper mechanism fitted to the bridge mechanism of the clarifier, which slowly rotates and is angled to migrate the scum to the side of the clarifier. The scraper system will then usually "push" the scum over a beach mechanism, which enables the scum to be discharged to a wet well or similar for further handling.

At New Plymouth WWTP, a wet beach system is employed, whereby the beach is essentially submerged. With each discharge of scum from the clarifier (once per rotation of the clarifier bridge mechanism), a significant amount of "carrier water" is discharged with the scum. While this may be disadvantageous in terms of the volume of scum matter collected, it does aid in conveying the sum matter over long distances. In any case, dry beaches had been used on the clarifiers in the past at New Plymouth WWTP, however the volume of flushing water incorporated in the scum to enable it to be handled was equitable to the volume of carrier water produced by a wet beach system.

Figure 1: Photo of Wet Scum Beach on Secondary Clarifier at New Plymouth WWTP.

2 THE CASE FOR SCUM SEPARATION

2.1 SCUM HANDLING & TREATMENT PRIOR TO THE UPGRADE

Prior to the upgrade, scum collected from the three clarifiers was discharged to a common Scum Pump Station. The scum was discharged from this pump station into the suction side of the waste activated sludge (WAS) pumps, for co-mixing with the WAS. The scum was therefore essentially treated as part of the sludge stream, undergoing thickening, dewatering and ultimately thermal drying.

2.2 THE OPPORTUNITY AND NEED FOR UPGRADE

The opportunity to improve scum handling by removing water from it was driven by the opportunity for operational cost savings and process performance improvements in the sludge handling and treatment process train in which the scum is incorporated.

2.2.1 THERMAL DRYER OPERATIONAL IMPROVEMENTS

As previously noted, a thermal dryer process is employed at New Plymouth WWTP to dry the thickened and dewatered waste activated sludge (WAS) stream. Master planning for New Plymouth WWTP identified that the existing Thermal Drying Facility (TDF) does not have sufficient capacity for future solids loads based on the dry solids content of the sludge cake achieved from the sludge dewatering process (prior to its recent upgrade).

In addition, the thermal dryer uses natural gas as its fuel source for heating. By increasing the dry solids content of the sludge, the evaporative load on the dryer can be reduced (per tonne of sludge material processed), thereby reducing energy use and bringing operational cost savings. In the current thermal dryer operation, a 1% increase in dryness of the raw material (dewatered sludge feed to the thermal dryer facility) translates to a 6-7% reduction in gas use, or $15,000 to $20,000 per year of operational cost savings.

2.2.2 SLUDGE THICKENING AND DEWATERING OPERATIONAL IMPROVEMENTS

An upgrade of the of the extended aeration activated sludge process, was undertaken in 2013 to convert the existing carousels to a nutrient removal plug flow configuration (known as the "Bioreactors"). During the upgrade, a process return activated sludge (RAS) target concentration of 1% was identified as necessary to ensure RAS pumps would have sufficient capacity to manage the mixed liquor suspended solids (MLSS) inventory between the Bioreactors and the secondary clarifiers, under the wide variation of flows entering the plant.

An added benefit was that less WAS would need to be pumped to the sludge thickening process, meaning that they could be operated within their maximum design flow of 40 m^3/h per Picket Fence Thickener (PFT). However, the daily scum volume of 250 to 300 m^3/d added to the WAS meant that WAS concentration was reduced to 0.6 – 0.7 % dry solids, and resulted in sludge flow rates exceeding the design maximum for the sludge thickening process.

Poor settling sludge and filamentous microbiology meant foam would overflow from the thickeners as recycle seeding the influent and perpetuating the problem. With the recent upgrade of the sludge thickening process, where one of the PFTs to a thickened sludge buffer tank, it was essential to address the scum issue to prevent additional operational issues.

Therefore in summary, the benefits of installing a process to remove carrier water from the scum include:

- Scum solids no longer dilute the WAS, thereby significantly reducing the sludge volume sent to thickening process.
- The PFT loading rate is reduced, which has delayed the need for a third conventional PFT or the conversion from PFTs to Dissolved Air Floatation (DAF) systems.
- The dry solids content of the thickened sludge has risen from an average of 1.4%DS to approximately 2%DS.
- The recycle rate from PFT is reduced and sludge quality improved.

2.3 POTENTIAL OPTIONS CONSIDERED

As part of a plant upgrade in 2007 which saw the construction of the third secondary clarifier at New Plymouth WWTP, wet scum beaches were fitted to all three secondary clarifiers. The wet beaches were found to give better performance for effective removal of scum form the clarifier water surface, and calculations indicated similar volumes of water would be entrained into the sludge as for the original dry beaches fitted to secondary clarifiers no. 1 and 2.

In 2014, NPDC began investigating potential options to separate carrier water from the scum. The only potential technology that could be identified, that could be procured from a New Zealand Supplier, was a "Baleen Filter". A description of the baleen Filter process is provided later in this paper.

2.4 THE BALEEN FILTER TECHNOLOGY

2.4.1 OVERVIEW OF BALEEN FILTER PROCESS

The Baleen Filter is a skid mounted, automated filter unit with a typical filter size in the range of 20 micro to 2 mm aperture. The filter table is mounted t an incline, with the raw (unfiltered material entering the top and passing over the table under gravity conditions). Filtrate is collected in the base of the unit, while filtered material discharges to a trough at the lower end of the filter table.

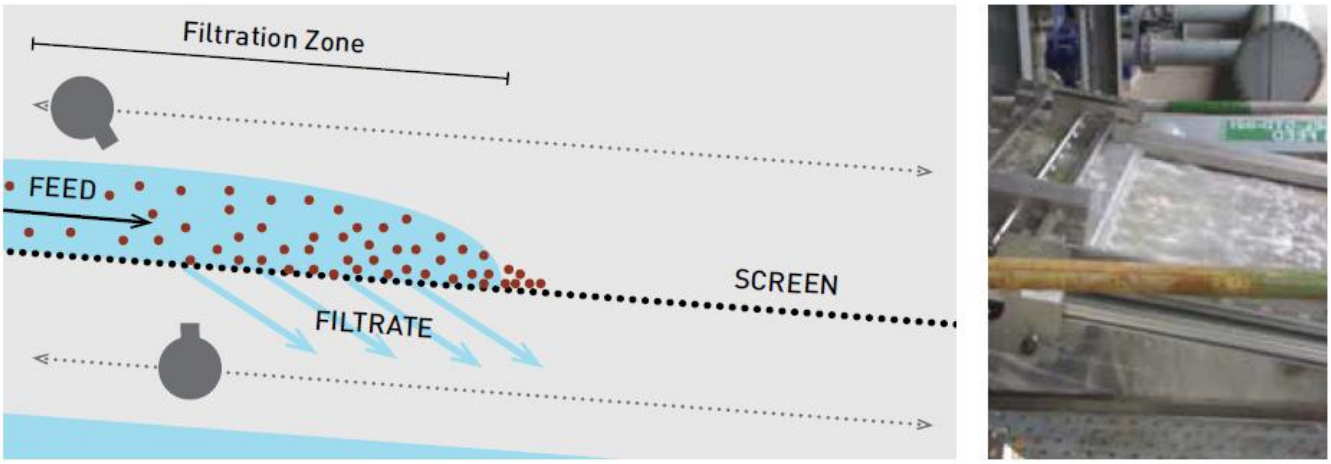
Clearing of the filter (screen) is achieved by a double action approach of high pressure, low volume wash water sprays provided by a moving spray bar, which is powered by compressed air. As shown in Figure 2 overleaf, one of the sprays is used to unblock the filter media by spraying upwards, while the other transports the filtered material over the table towards the discharge trough (Baleen International). A control system is used to control these washwater sprays to achieve filter clearing and the clearance of the filtered material.

2.4.2 INITIAL PILOT TRIALS TO CONFIRM TECHNOLOGY SELECTION

Initial bench trials were undertaken by the equipment vendor, which were sufficient to confirm that it would be worthwhile to undertake further trials using a small pilot plant at the site. Pilot trials were undertaken by pumping from the Scum Pump Station to the temporarily installed pilot unit in 2016.

The initial trial period indicated that a Baleen Filter fitted with a 90 micron screen would remove approximately 70 – 80% of the scum solids, however this was halved if a 150 micron screen was used. As this was deemed unsatisfactory, additional testing was undertaken which included the addition of polymer and although quantitative results could not be obtained, it was clear the scum coagulated well and better separation on the pilot plant was achieved.

To quantify the effectiveness of polymer addition, bench trials were undertaken and was very conclusive. Using the cationic polymer Crystalfloc ELH12, as used on the New Plymouth WWTP belt presses, 90 – 95% removal of solids could be achieved from the scum using a 150 micron filter with a polymer dose rate of $4 g/m^3$.



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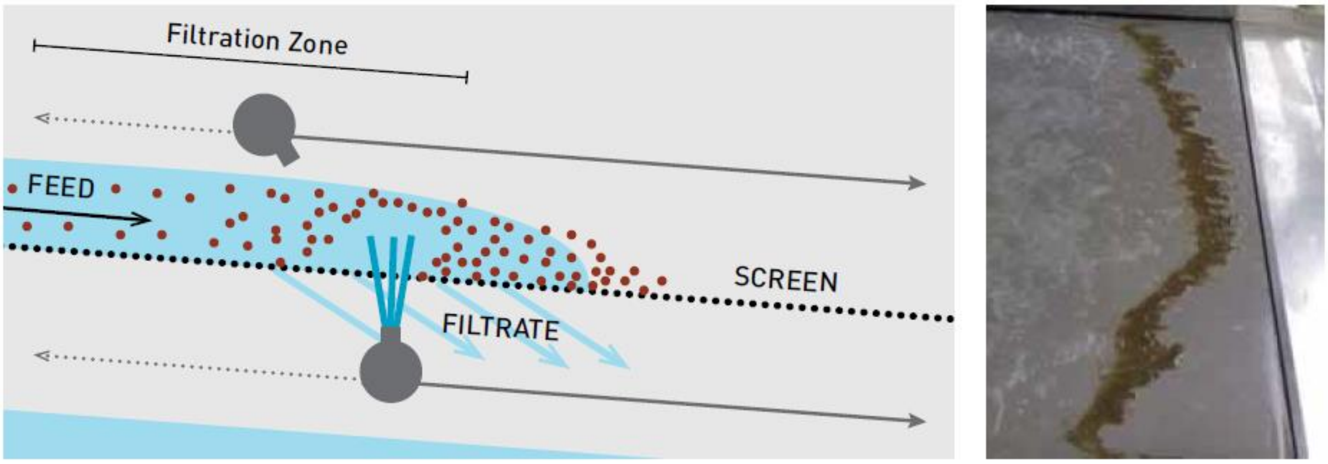

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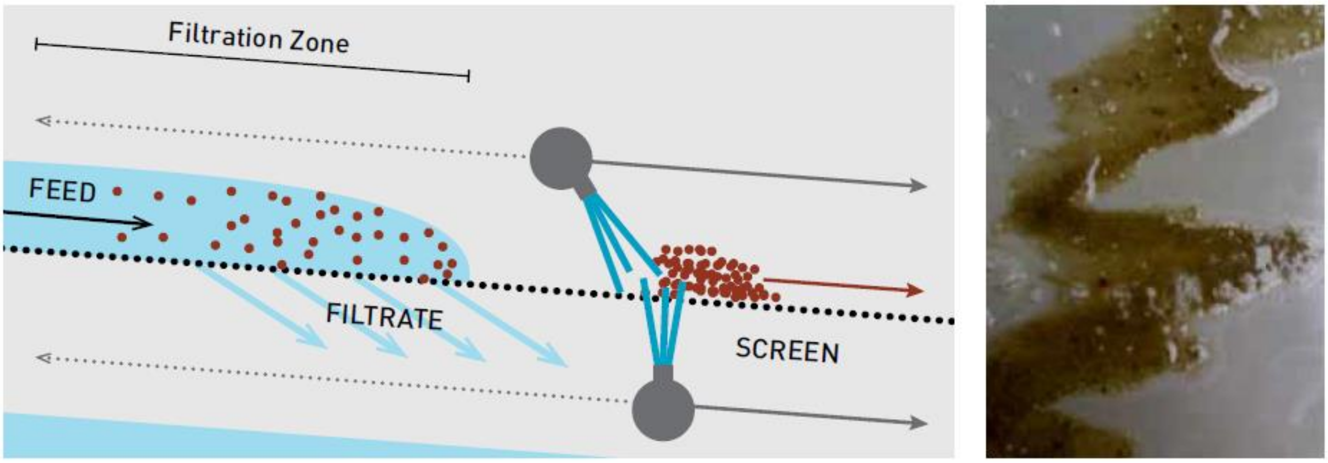

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Figure 2: Overview of Cleaning Process for Baleen Filter. Courtesy: Baleen International.
(a) The Filtration Zone advances as the Screen blocks (without self-cleaning action); (b) Self-cleaning pass initiated – Unblocking the Filtration Zone (by counter flow action only); (c) Self-cleaning pass concluded – Clearing the Filtration Zone (by combination counter and clearing flows).

Figure 3: Early Pilot Trails of the baleen Filter at New Plymouth WWTP. Courtesy: Bioholdings New Zealand Ltd.

3 KEY DESIGN AND CONSTRUCTION CONSIDERATIONS

3.1 PROCESS BASIS OF DESIGN

Table 1 presents a summary of key process design criteria for the scum separation process, which were deduced from site information, vendor information for the Baleen Filter, and sieve analyses undertaken by NPDC on the scum. The sieve analysis indicated a lower level of removal than the previous pilot trials had indicated, however it was thought appropriate to use these for conservative process sizing, given that the technology was novel for this application.

Table 1: Process Design Parameters for Scum Dewatering Process at New Plymouth WWTP.

Parameter	Design Basis
Flow Rate, Peak Instantaneous:	36-54 m^3/h
Average Daily Flow Range:	300-400 m^3/d
Scum solids content, prior to separation:	1200 mg/L (0.12%DS)
Scum solids moisture content, after separation:	Approximately 15000 mg/L (1.5%DS) based on information from Baleen Supplier.
Filtrate solids moisture content, after separation – based on 150 micron sieve:	Approximately 400 mg/L (0.04%DS) based on information NPDC sieve analysis. Indicates a 66% solids removal efficiency.
Filtrate solids moisture content, after separation – based on 150/90 micron sieve:	Approximately 200 mg/L (0.02%DS) based on information NPDC sieve analysis. Indicates a 78% solids removal efficiency.
Average solids removal efficiency based on sieve analysis:	Indicatively 72% (66-78% range based on data collected)

Parameter	Design Basis
General description of scum consistency:	Scum is a homogeneous mixture as the scum is pumped from the wet well to the filter.

Figure 4 provides a summary mass balance schematic of the Baleen Filter system based on this process design basis.

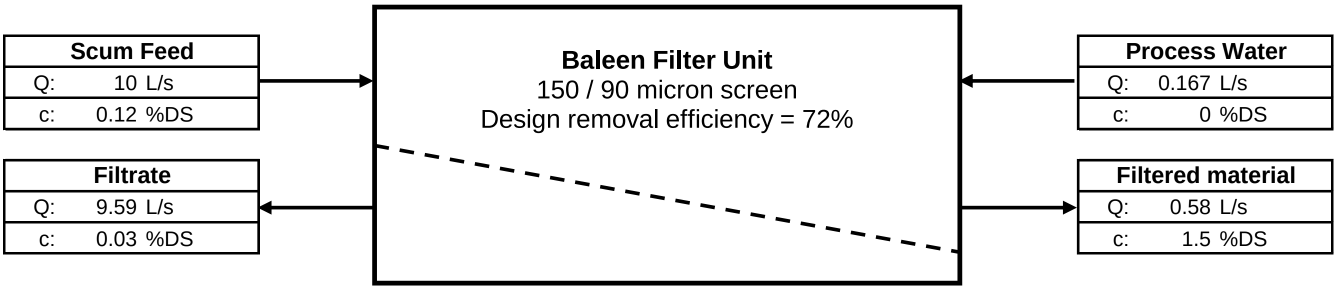


Figure 4: Simplified Mass Balance of Scum Dewatering Process at New Plymouth WWTP.

4 LOCATION OF SCUM SEPARATION PLANT

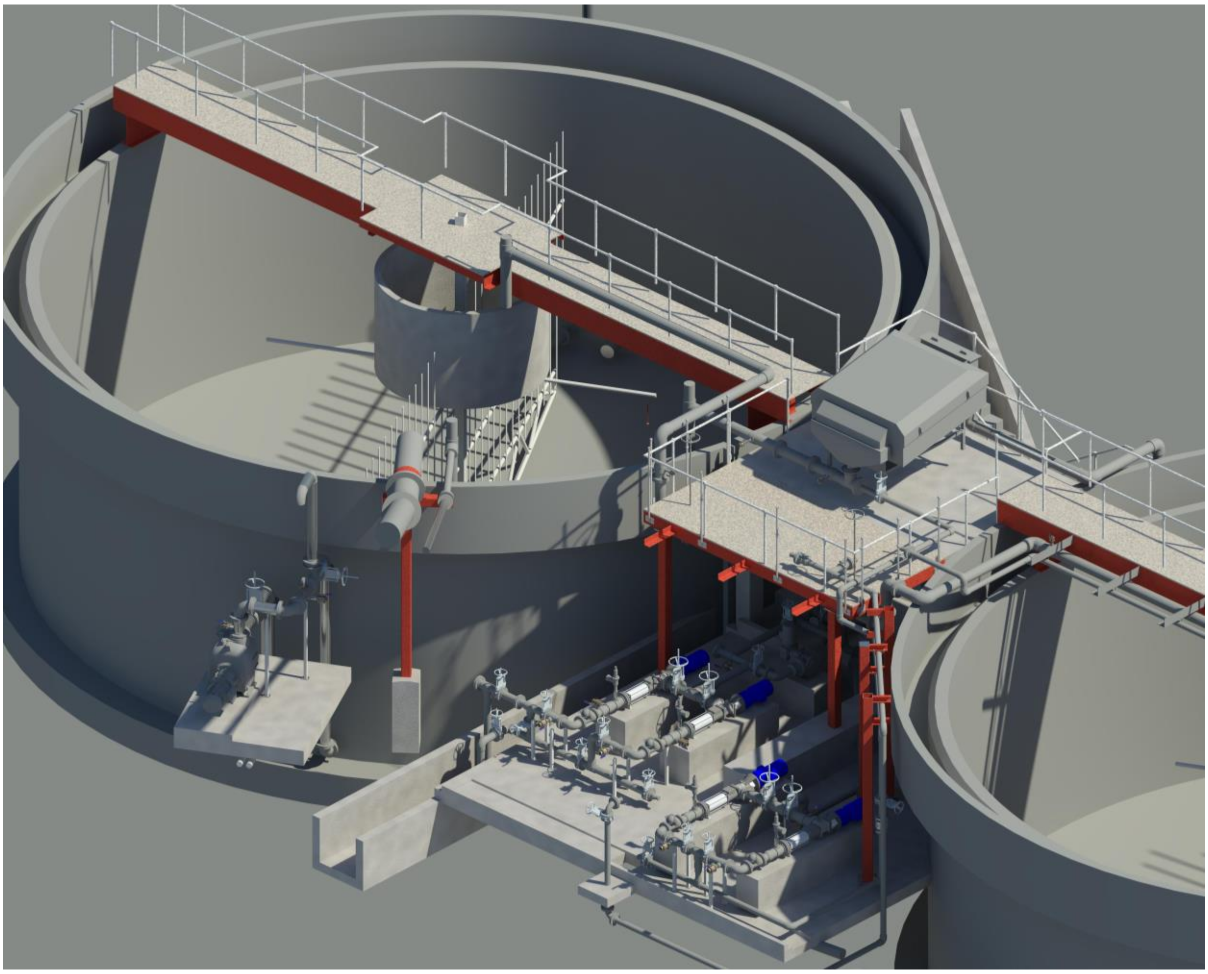
When developing the design of the new scum separation process, one of the key considerations was the proposed location of the Baleen Filter, given the constraints placed on the discharge point for both the separated scum product and the filtrate.

The separated scum product would contain a high level of fats and grease which, based on observations of the material from the pilot trials, was likely to lead to fat build-up and eventual blocking in conveyance pipes, given that there would be little or no carrier water to provide scour of these pipes. Therefore, the preferred solution would be to discharge the separated scum product as simply as possible into the thickened sludge buffer tank or a similar open vessel, with as small a pipe run as possible. The preferred location for discharge was identified as the sludge buffer tank.

Furthermore, fee discharge of the solids to a tank would require the Baleen Filter to be located above top liquid level in the receiving tank, or a non-return device (such as a valve or positive displacement pump to be fitted on the solids discharge). The latter option was considered undesirable because it introduced additional operational complexity and maintenance issues, particularly because of the expected rheology and viscosity of the dewatered scum material.

Consequently, of all the options considered, the preferred location was directly adjacent to the sludge buffer tank to which the Baleen Filter would discharge filtered solids. The Baleen Filter could be installed at high level by using an existing access platform, which needed to be extended. The only considerable risk of this option was that, being located outdoors, it could lead to potential discharge of odours. This would was alleviated by adding an odour connection to the Baleen Filter unit, which was incorporated into the sludge thickening and dewatering odour control system during the plant upgrades.

Figure 5 provides an overview of the 3D design model of the plant and photographs of the installed plant.



(a)

(b)

Figure 5: (a) Design Model Render of Baleen Filter on Access Platform between PFT (to the Right) and Sludge Buffer Tank (to the left of picture).

(b) Photograph of Baleen Filter Installation at New Plymouth WWTP (centre right).

In addition, the filtrate product produced by the Baleen Filter would contain filamentous bacteria, because these were unlikely to be removed by the Baleen Filter. It was identified that it was preferable to discharge the filtrate in a location downstream of the Bioreactors, to reduce the potential for filamentous bacteria build-up in the reactors. This ruled out potential discharge of the filtrate to the Sanitary Wet Well (site return liquors pump station), inlet works, or the Bioreactors themselves. The closest discharge poi was therefore determined to be the outlet of the Bioreactors (after the Bioreactor effluent discharges freely over a weir).

5 PROCESS PERFORMANCE AND OPTIMISATION

As previously noted, early trials indicated that flocs were formed rapidly and successfully with dosing of polymer. To facilitate this in the final plant design, an old flocculation vessel was re-purposed from one of the gravity belt thickener plants at New Plymouth WWTP, and modified to be used as an inlet tank and flocculation vessel on the baleen Filter.

At the time of writing this paper, the polymer in use on the installed Baleen Filter is Crystal floc ELH12 and was being drawn from the old belt press system polymer dose tank. A dose rate of 5g/m3 was being used and scum pump speed had been set up so that a continuous 3.2l/s flow onto the Baleen is achieved. At this flow, the transfer from the Scum Wet-well is almost continuous. An alternative polymer, Nalco H71300, has been bench trialed as this polymer will be used for the foreseeable future in the upgraded screw press sludge dewatering plant. Trials with this polymer have also shown promising results.

Periodic cone tests on Scum liquid onto the Baleen and filtrate from the Baleen is undertaken and consistently shows excellent solids removal as illustrated in Figure 6.

Figure 6: Cone test of scum feed to Baleen Filter, and resulting filtrate (right).

One of the critical design considerations in the design of the new scum dewatering system was the scum feed arrangement (scum pumping and transportation to the Baleen Filter), to provide a relatively constant (or slowly varying) feed rate and prevent the break-up of scum particles as much as possible. Both of these consideration are critically important to the success of the operation.

To achieve this, changes were made to the Scum Pump Station to fit new pumps which approximately matched the design feed rate, and though changes to the level control system could enable slowly changes to pump speed (over a ramp period of 10 Hz per minute) and reduce pump start cycles. In addition, recessed impeller pump were selected to remove, to the greatest extent possible, the impeller face from the pumped media.

Since commissioning the Baleen Filter, the screen size has been increased from 120 to 150 microns. Working with the Baleen Filter vendor (Bio Holdings Ltd), this has been undertaken to optimize the wash cycles. Operation of the Baleen filter has now become routine and involves a once a day check and hose down and a once a fortnight chemical foam wash to control biological slime. Further work will be undertaken to optimize polymer dose as it is intended to dose the same polymer as will be used for the new sludge dewatering screw presses, once fully commissioned, to prevent having to operate two polymer systems if it can be helped.

During early operation, NPDC have noted that the solids load to the Baleen Filter is variable and changes in nature depending on how much foam is being transferred from the Bioreactors to the secondary clarifiers. This can be affected by fat from a local chicken abattoir generating Nicardia foams and fat globules. The Baleen Filter has handled these changes very well.

Figure 7: Photographs of Baleen Filer (with hood up) During Scum Dewatering operation.

6 CONCLUSIONS

Use of a Baleen Filter for scum removal is a novel approach to dewatering scum, which has overcome a number of technical issues associated with scum transport at New Plymouth WWTP, and enabled significant opportunities to be realized to improve the operational performance and cost of the sludge process train.

With minor changes to the operation of the Baleen Filter to further optimize it, and continued learning, the Baleen Filter process represents a very promising method of achieving scum dewatering in municipal wastewater treatment operations. If implementing this solution, it is recommended that:

- The opportunity is taken to undertake early pilot trials and identify appropriate filter sizes, polymer dosing options (if required) and the general viability of the technology.
- The proposed location of the baleen Filter, and the discharge points of the filtrate and dewatered scum stream, are critical design considerations.

ACKNOWLEDGEMENTS

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