HAMILTON WATER TREATMENT STATION – OPTIMISATION OF FILTRATION PROCESS USING PCDM TECHNOLOGY

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ABSTRACT

In the mid 1990's Hamilton City Council (HCC) made a decision to trial a new locally supplied Porous Ceramic Dual Media (PCDM) filtration system, at their Water Treatment Station (WTS). After positive results from the trial unit, HCC proceeded in the full refurbishment of an existing conventional sand filter to the PCDM system.

Intensive monitoring of water quality and filter performance of the initial refurbished filter, confirmed that the installation of the PCDM technology had optimised the filtration process by increasing filter capacity and run times between backwashing with no degradation to filter water quality. Since that time, HCC has implemented an ongoing programme to optimise the filtration process by refurbishing the remaining conventional sand filters to the PCDM system.

1.0 INTRODUCTION

Hamilton is a major service centre and is New Zealand's seventh largest city and fourth largest urban area. It is located within the Waikato region in the upper central North Island of New Zealand. The HCC WTS is situated on the southern bank of the Waikato river within the city boundary.

The treatment plant was constructed in 1971 as a standard Patterson Candy (PCI) design with coagulation, rapid sand gravity filtration and chlorine gas disinfection. At the time of construction the plant capacity was 64 ML/day but this was increased to approximately 85ML/day with the addition of polymer dosing in the 1980's.

Previous studies have confirmed that the total WTS capacity was limited by the filtration process. Water demand forecasts based on population projections indicate that Hamilton water consumption will increase substantially over the next 10 years, which will exceed the current WTS capacity.

HCC has a strong commitment to maintaining a high level of compliance with the Drinking Water Standards of New Zealand (DWSNZ) and maintaining it's Ministry of Health 'A' grade for it's treatment plant and source water. To comply with the current and future DWSNZ, in particular stringent protozoa compliance criteria, it is necessary for the HCC filtration process to consistently produce high quality water with a turbidity of less than 0.1NTU. Historically, the ability of the conventional filters to achieve this benchmark consistently over a variety of source water conditions was questionable.

An ongoing solution for these filtration issues needed to ensure an adequate & safe water supply for the future. The continued implementation and use of the PCDM technology at the HCC WTS has resulted in an optimised filtration process that has seen a cost effective increase in filtration and total plant capacity, with consistent filtered water quality.

2.0 DISCUSSION

2.1 General Information on PCDM Technology

PCDM nozzles are fabricated from patented ceramic (New Zealand patent, no.212330), and are made from waste crushed glass and titanomagnetite sand. A feature fundamental to the design of nozzles systems is the irregular nature of the ceramic pores resulting from the irregular shapes of the constituent crushed glass particles. Average pore sizes can be controlled by mesh size of the crushed glass, which is important to optimise water collection as well as air and water distribution during backwashing. The combination of high porosity, inertness, and mechanical strength make these improved nozzles ideal for sand filtration.

The nozzles used by the HCC WTS are hollow ceramic discs (in fact 2 discs cemented face to face to form a hollow core) and attached using a modified plastic stem.

Figure 1: ***Photograph of a PCDM nozzle and stem***

2.2 PCDM Technology -Technical Comparison

The HCC WTS currently have four original PCI single media and six dual media rapid gravity sand filters. Five of the dual media filters have been refurbished to the PCDM filter system with the objective of being able to achieve higher throughput rates and one filter has fine silica sand overlying a Garnett media layer.

The four single media filters originally consisted of a 0.5-0.6mm diameter effective size media. Over time topping up of the single media using coarser material has given them the current profile:

- Approx. 600mm of sand, effective diameter 0.6-2.0mm
- 100mm of coarse sand
- 100 of fine gravel
- Convention plastic rose nozzles & plastic attachment bolts.

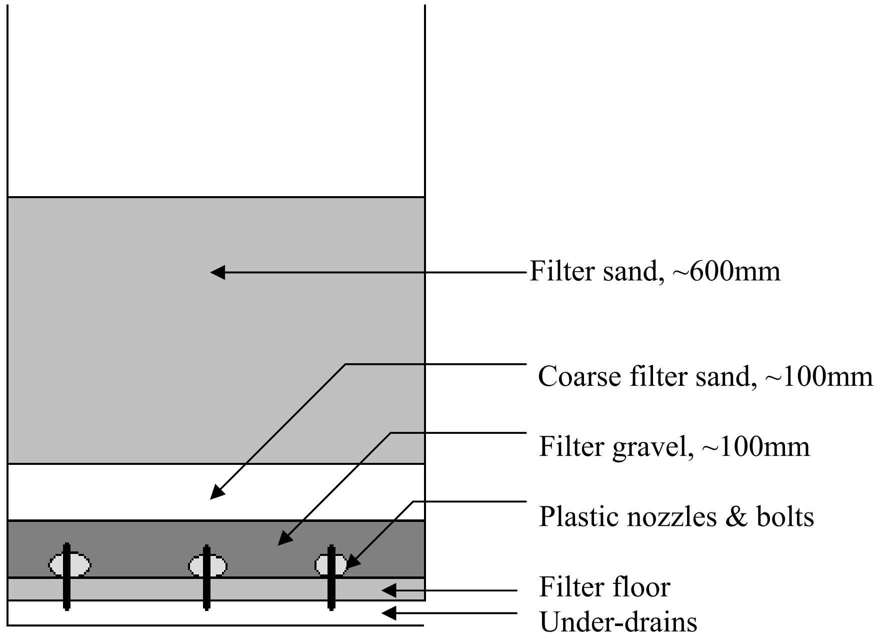

Figure 2: ***Single sand media (conventional) filter schematic***

Multiple trials, studies and reports have been completed on the effectiveness of PCDM filters. The outcomes of these were used to champion the further use of this technology at the HCC WTS.

PCDM filters use the same principles of regular sand filtration, but with several differences.

- A layer of silicon sponge (1.5 - 2.5mm diameter modified pumice) replaces the top layer of sand.
- The larger grain size allows greater flow through the media & physical properties such as high surface area (approximately $5m^2g^{-1}$ porosity) and negative charge for attraction of positively charged flocs give it improved filtering properties.
- Lower specific gravity of the Silicon sponge ($1.4g/cm^3$ vs. sand at $\sim 2.6g/cm^3$) allows improved fluid backwash, creating better expansion and agitation.
- Silicon sponge is harder than anthracite and is more resistant to abrasion.
- A second fine sand layer (0.3 - 0.6mm diameter) supports the Silicon sponge. This sand provides secondary filtration. The Silicon sponge removes a majority of floc carryover and so protects the fine sand layer, which would normally reduce flow rate through fine media.
- A thin layer of pea metal replaces the bottom layer of gravel (~3mm diameter vs. coarse stones). This layer ensures even distribution of air and water through the filter during the backwash cycle.
- Lastly, ceramic nozzles replace the more conventional PCI plastic nozzles. These nozzles eliminate the need for gravel and thick sand normally required to stop fine sand from passing through the plastic nozzles. Sand is unable to pass through the porous ceramic nozzles. The ceramic nozzles are attached using a redesigned plastic stem to existing under-drains.

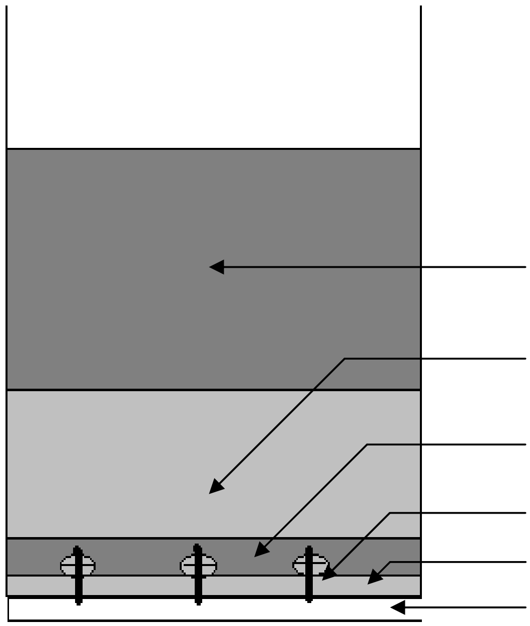

Figure 3: ***PCDM filter schematic***

2.4 PCDM - Advantages and benefits

- Flow rates in PCDM filters can be up to twice that of single sand with equivalent water quality output. This is due to higher hydraulic conductivity of silicon sponge compared to that of regular filter sand.
- Under extreme conditions (settled water turbidity 1.0NTU) PCDM filters consistently ran for double the time of the existing single sand filters before backwashing was required.
- Due to the ability of the silicon sponge layer to shield the underlying sand layer, the run time of PCDM filters is much longer and the period of time between backwashing is increased.
- A higher backwash rate is required for PCDM filters but the energy cost is offset by the runtime of the filter in comparison to single sand filters.
- PCDM filters have shown to be less prone to filter cracking, especially over long runtimes or high turbidity loadings.
- Slower headloss development occurs in comparison to conventional sand filters (most headloss occurring in first 4 cm of silicon sponge layer).
- Costs of refurbishment equivalent to refurbishment with more conventional medias.
- Significant reduction in capex investment due to the construction of extra conventional filters not being required as the projected flows could be obtained by refurbishment of existing conventional filters to PCDM (estimated NZD$2 million savings).

2.5 Required changes to install PCDM

One of the advantages of the PCDM technology in HCC's instance is that there is little change to the physical structure of the existing filter and under-drains.

Pre-existing media and plastic nozzles are removed, the under-drains cleaned, inspected and repaired as required. The concrete filter floor is then ground back to ensure a reasonably smooth surface before the ceramic nozzles and media are set in place. Increased filter bed depth, fluidisation, and expansion due to the lower specific gravity of pumice media during backwash meant that a stainless steel baffle had to be installed to prevent loss of Silicon sponge media. This baffle is mounted to the existing washout channel wall.

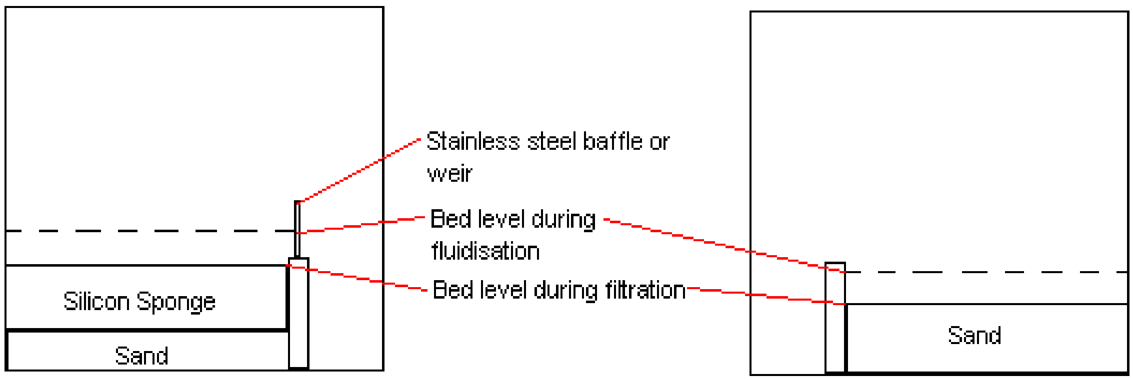

Figure 4: ***Washout channel baffle comparisons between PCDM and conventional filters***

2.6 Further Optimisation

Given that sand filters are primarily a polishing step in a coagulation/filtration plant, it made sense to optimise the processes up stream to gain maximum benefit. The coagulation, flocculation, sedimentation processes at the HCC WTS have been modified over the years to provide optimal treatment. Regular jar testing, dose timing, and use of streaming current (zeta potential) measurement and control, not to mention a raft of operator experience and patience, mean that the HCC WTS achieves very good clarified water quality. Turbidities can be as low as 0.05NTU in summer and less than 0.2NTU in the colder months.

Further changes have been made to filters during and as part of the filter refurbishment programme. Many of these improvements are driven by the requirement for further optimisation or to achieve best practice. Listed below are some of the improvements made to date.

- 10 year cyclical filter refurbishment plan for existing filters (1 filter per annum). This ensures all filter media will be replaced regularly and will reduce age effects on the filters and media, ensuring optimal filter performance. Some of the media in the conventional sand filters have not been changed (other than via repeated media ‘top-ups’) since the plant was constructed in 1971.
- Filter outlet control valves changed to controllable butterfly valves.
- Crossover valves between odd and even filters to facilitate even flow distribution from sedimentation tanks. Previously flow was unevenly distributed across two adjacent filter banks, severely misbalancing filter loadings.
- Under-drain access ways were cut into the common under-drain channel of each filter, allowing for better access and ease of cleaning during filter refurbishment.
- Stainless steel distribution plates have been installed in the inlet channels of each

filter to help lessen sand disruption during filter refilling after backwash cycles.

- Epoxy covering of exposed concrete on filter walls, which has been attacked by the acidic nature of alum treated water and regular water-blasting to remove algae build-up. Various compounds are being trailed in an ongoing search for a superior wall coating that both protects the concrete and also prevents algal growth or facilitates easy maintenance and cleaning.
- Several improvements and refinements to the filter system (media, nozzle, stems) have occurred since it was first trialed at the WTS in 1995. The HCC WTS has worked with the supplier on a number of variations of the PCDM technology. The change in nozzle structures, initially starting as tiles, then modified to single sided discs and further modified to the currently used double sided discs, as well as stem improvements for optimised air and water flow distribution, have all been investigated and improvements implemented.

2.7 Supporting Local Industry

Working closely with Works Filters, who marketed the PCDM products we used, has formed a useful partnership, allowing changes and improvements to the PCDM system to be implemented. The continued use of this technology at the HCC WTS has driven its progress forward, while supporting the company developing it, providing a unique product with huge potential in the water treatment industry.

3.0 CONCLUSIONS

The refurbishment of the original PCI rapid sand gravity filters at the Hamilton WTS using the PCDM filter system has optimised the filtration process and successfully assisted in achieving the following outcomes:

- Increased filter capacity and/or throughput treatment plant capacity, resulting in current and future water demands to be met without the need for further capex investment for the construction of extra filters.
- Consistent water quality (turbidity) results over a wide range of source water conditions, allowing compliance with the DWSNZ and retention of the Ministry of Health 'A' grade to be more achievable.
- Extended filter run times and reduced requirement to backwash resulting in lower operating costs.

4.0 ACKNOWLEDGEMENTS

HCC acknowledges the input and assistance of the supplier, Works Filter Systems in undertaking the trials and implementation of the PCDM filtration system at the Hamilton WTS.

5.0 REFERENCES

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