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A NOVEL METHOD FOR FILTER BACKWASH PERFORMANCE ASSESSMENT

A method developed by Sydney Water and applied at Water Treatment Plants at Sydney Water

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ABSTRACT

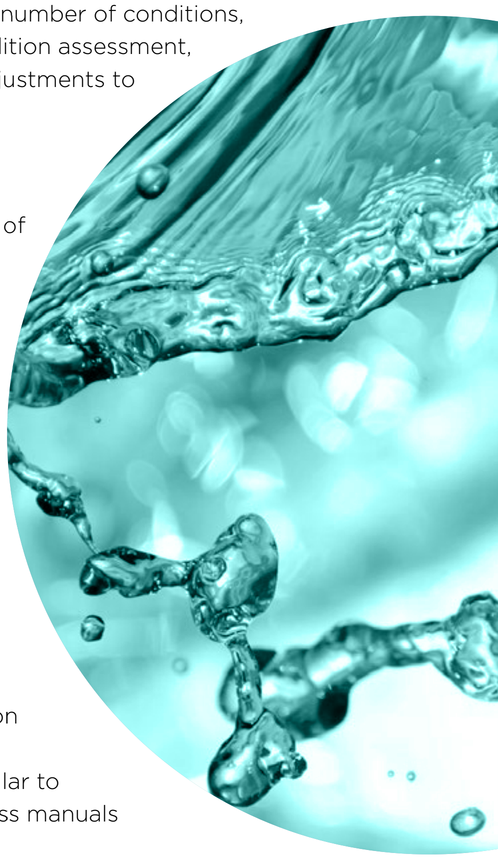
This paper presents a novel method for filter backwash assessments including the use of a new low cost tool, a modified secchi disk (Figure 1), which has been developed and manufactured in-house at Sydney Water. This paper also documents the trial and application of this method at one Water Filtration Plant which resulted in significant improvements. These included: better filter media cleaning, reduction in backwash cost, removal of mudballs and the potential of extending the filter media life.

INTRODUCTION

Water Filtration Plants (WFP's) at Sydney Water use dual media filters to remove coagulated particles and pathogens from raw water. These filters require regular cleaning through backwashing steps to maintain filtration performance and to achieve target drinking water quality and quantity. Historically operators would assess filter backwash performance by visual inspection of the filter during air scour, low and high rate water backwash, and media bed surface post backwash. The operator would then make any process adjustments as required, and record observations.

The method for filter backwash assessment discussed here combines existing visual inspections with empirical measurement of certain parameters during a backwash to gain an understanding of filter backwash performance. The method also includes assessment of all filters at the treatment plant across a number of conditions, including a baseline condition assessment, and after any process adjustments to the backwash.

Application of this novel method allows physical/empirical measurement of backwash performance following process changes. This improves understanding of the factors influencing filter backwash and identifies opportunities for improvement.



BACKGROUND

WFP operators assess filter condition and backwash performance through visual observation during a backwash cycle. The assessments are similar to those described in process manuals (Beverly, R. P., 2013).

The operator visually inspects filters for air scour pattern, boiling or dead spots, low and high rate backwash with water, clarity of backwash effluent water at the end of backwashing, media condition on the surface and uniformity of the media bed surface. Typically an operator will assess one or two filters at the plant per month depending on the size of the plant.

METHODOLOGY

The new method for assessing backwash performance builds on the existing visual observations by including empirical measurements of certain parameters during a backwash cycle.

The parameters measured as part of the novel method using the newly developed tool, a Secchi disk, include:

- Water drain down level before air scouring
- Media bed expansion and fluidisation
- Verification of backwash flow rate /meter
- Media bed depth and uniformity of bed surface
- Media bed expansion profile over a range of backwash water flow rates
- Inspection of media condition and presence of mudballs

The following parameter is also measured as part of the new method:

- Backwash effluent water turbidity profile every minute over the period of a backwash

Measured values for the above parameters allow the operators to better understand backwash performance, and adjust key set points as required to improve performance.

Figure 1. Modified Secchi disk used for filter assessments

The objective of this testing is to improve and optimise the backwash cycle at the filtration plant and assess the condition of the filter. The target performance measures are; expansion for effective cleaning of the bed of 15 – 20% (Anderson, K. and Chescattie, E., 2003) and turbidity of the backwash water at the end of the backwash of <10 NTU (Chipps M. J., et al. 2002) to indicate that the majority of the dirt has been removed.

The newly developed tool used for empirical measurements of the parameters is a modified Secchi disk on the end of a telescopic pole (Figure 1 and Figure 2). The concept of this tool was first reported by Anderson, K. and Chescattie, E., 2003 describing the design of the tool for measuring the height of the media bed during a backwash cycle. The newly developed tool, is a modified Secchi disk, designed to be of stronger construction to collect samples of the media and mudballs for examination as well as empirical measurements of all other parameters listed above under the new method. The telescopic pole has gradations marked to measure depth against a reference point, for example a handrail or the edge of the filter block, and the pole can be expanded or contracted based on the need. This tool is also relatively inexpensive and simple to construct.

Figure 1. Detail of modified Secchi disk used for filter assessments

The novel method for filter backwash assessment also includes the following stage wise assessment of all the above-mentioned parameters to systematically assess the performance and improvement at a range of conditions:

- Baseline condition assessment at the existing backwash parameters
- Interim assessment after making a process change identified in the baseline testing
- Final assessment after applying all process changes identified from previous testing
- Follow up assessment approximately 8-12 months after the final changes

Using the modified Secchi disk, the filter drain down level before air scour is accurately measured at various sections of the filter block, and adjustments in the drain down level can be made for effective air scouring.

Media bed expansion is calculated using the level of the bed at rest and the level of the bed during a backwash by using the developed Secchi disk (Equation 1).

$$\text{Bed expansion (\%)} = \frac{L_b - L}{d} \times 100\%$$

Where:

- L = level of the bed at rest (m)
- L_b = level of the bed during a backwash (m)
- d = total depth of the media excluding support gravel (m)

The level of the bed at rest is measured after a backwash to mitigate any effects of run time on bed compaction. Where possible, expansion measurements are taken at multiple points around the bed to determine any variance in expansion across the bed.

Depth of fluidisation of the media can be measured by allowing the Secchi disk to fall through the bed during a backwash. For this assessment, the measure of fluidisation is if the disk can reach the sand layer under the anthracite or not. If no sand can be captured on the disk, then the bed is not fully fluidised and may require a higher backwash flow rate.

The backwash performance relies on having an accurate flow meter to control the backwash water flow rate to the filter. The modified Secchi disk is used to measure the rate of rise of water in the filter block at the start of the backwash. This is then converted to a flow rate by multiplying by the filter surface area. This test enables the operator to verify the backwash rate flow meter reading.

With the use of the Secchi disk a trial of the media bed expansion can be carried out at various backwash water rates to generate a bed expansion profile against backwash rate. Measurement of the bed expansion profile gives the operators the ability to make informed adjustments to the backwash flow rate to improve filter cleaning by achieving a target bed expansion.

Using the Secchi disk, media and mudballs sample are collected after the backwash for media and mudballs inspection. Mudballs are examined for size, shape and firmness.

Measurement of the turbidity profile from a sample of backwash effluent water every minute allows for further improvement of the backwash cycle by optimising backwash times, potentially using less water and chemicals, and reducing filter downtime.

RESULTS

The novel method for filter backwash assessment was applied at Cascade WFP, a contact filtration plant, where there are six dual media filters some of which contain filter media of approximately 20 years old. The filters are identical in design and operate as rate controlled filters with fixed operating level and inlet flow splitting. The media specifications for Cascade WFP are:

- surface area, 30 m^2 per filter
- Anthracite media, 1.55 m deep, media size 1.7 mm
- Sand media, 0.15 m deep, media size 0.8 mm

The filtration media is supported by two layers of gravel each 75mm deep with particle size 3 – 6 mm and 6 – 12 mm

The findings, results and improvements using this method and tool are described below. The process set points for each condition are summarised in Table 1.

Table 1. Summary of backwash set points for each condition assessment

Parameter	Initial	Interim	Final
Drain down level (mm)	180 - 350	150	150
Air scour duration (min)	15	15	15
Low flow rate (L/s)	100	100	100
Low flow time (s)	60	60	60
High flow rate (L/s)	400	400	550
High flow time (s)	430	430	250

Baseline condition assessment

Visually, all the filters had a thick layer of sludge on the surface (Figure 6), and there was a layer of mudballs present, some up to 80mm in diameter and quite firm to touch (Figure 2). The baseline testing found that, although most filters had a uniform bed level and very good air scour pattern, the media bed expansion was only 5-10% at the backwash water rate of 400 L/s, which was well below the target bed expansion of 15-20%. However, in all filters, the media was fluidised all the way to the sand level.

Figure 3. Examples of mudballs found during baseline testing collect after a backwash.

The water level after drain down and before air scour was found highly variable between filters and generally too high for effective air scouring. The baseline test revealed that the backwash water rate is not effectively cleaning the filter by lifting flocs and particles.

The turbidity profile of the backwash water was found to be stable (3.0 NTU) after approximately 6 minutes of backwashing, with the remaining 2 minutes giving no benefit to cleaning the filter (see Figure 7). Refer to Table 2 for a summary of the results.

Table 2. Summary of the backwash performance for all filters – baseline assessment

Performance measure	Average
Drain down level (mm)	247 (n=6)
Expansion (%)	8% (n=12)
Turbidity at end of backwash (NTU)	3.0 (n=6)
Time to reach <10 NTU (min)	5.8 (n=6)

After the normal backwash, each filter was manually backwashed at a range of flow rates to reassess bed expansion. The flow rate was increased incrementally and expansion recorded at each step. The Secchi disk was also used to check for any media carry over at the higher flow rates, with the maximum flow slightly above design capacity. At the highest flow, very little media carry over was observed. The expansion profiles for each filter varied slightly, but each followed the same trend (Figure 8). The trends suggested that a flow rate ≥550L/s would be required to achieve the target bed expansion of 15-20%. During this testing, it was also observed that small mudballs and large floc were being lifted out of the bed at flows ≥550L/s, even when the bed had just been backwashed. This indicates that the normal backwash flow of 400L/s was not enough to effectively clean the bed, even though the backwash turbidity was very low at the end of the backwash.

The thick layer of sludge could have been physically removed via scarping the top layer of media out and replacing with fresh media. However, this would have a cost to the business, and the manual backwashing was indicating that the sludge and mudballs could be removed by optimising the backwash cycle. Therefore, the following improvement opportunities were identified:

- Reduce the water level before air scouring,
- Increase the backwash flow rate to increase media bed expansion, and
- Reduce the backwash duration.

Interim condition assessment

For the interim condition assessment, only the drain down level before air scouring was changed. The drain down level above the media was set at 150mm, reduced from 180 – 350mm and all other backwash parameters remained the same. The interim testing was completed 2 weeks after reducing the water level before air scour. This was to determine if the lower level had an impact on backwash performance. The expectation was that the reduced water level above the media would give effective air scour and assist in breaking down the large mudballs.

However, there was little observable change in the condition of the mudballs. It is likely that it would take a longer operational period to see an impact on mudball size. There was also little change in the other backwash performance characteristics (Table 3); expansion was relatively the same at 6%, and the backwash duration could be reduced to around 5 – 6 minutes.

Table 3. Summary of the backwash performance for all filters – interim assessment

Performance measure	Average
Drain down level (mm)	133 (n=6)
Expansion (%)	6% (n=12)
Turbidity at end of backwash (NTU)	2.8 (n=6)
Time to reach <10 NTU (min)	5.6 (n=6)

The reduced drain down level did have a benefit of increasing the amount of freeboard at the start of the backwash. This allows for more air bubbles to be released from the bed during the start of the backwash before the water reaches the launders. If bubbles are still present when the backwash water reaches the launders, there is a risk that media will be lifted by the air and washed out. This becomes more important when the backwash rate is increased as:

- The water will reach the launders faster, and therefore there is less time for the bubbles to escape
- The bed expansion is greater; therefore, the media is closer to the launder while the bubbles are escaping

Final Condition assessment

For the final condition assessment, the backwash high flow rate was set at 550L/s and the high rate backwash duration was reduced from 430 seconds to 250 seconds. The backwash rate was increased based on the bed expansion trial in the Baseline and Interim assessment, and the backwash duration was set using the turbidity profile curves in Figure 7 where the turbidity had reached <10 NTU after 5 – 6 minutes.

At the changed backwash rate, the filters' media bed expansion measured was in the range 12% - 14% which was closer to the target bed expansion. The drain down level was also close to the target of 150mm. Refer to Table 4 for a summary of the results.

In terms of visual observations, more dirt and smaller mudballs were observed washing out at the start of the backwash than the baseline assessment backwash flow rate. Backwash effluent water was also clean at the end of the backwash (average turbidity was 5.9 NTU) even though the duration was reduced by 3 minutes (Figure 9).

Table 4. Summary of the backwash performance for all filters – final assessment

Performance measure	Average
Drain down level (mm)	163 (n=6)
Expansion (%)	14% (n=12)
Turbidity at end of backwash (NTU)	5.9 (n=6)
Time to reach <10 NTU (min)	4.1 (n=6)

It was also observed that the mudballs had reduced in size compared to the baseline condition, with no mudballs found over 50mm and only very few of these were of 50mm size (see Figure 3 and Figure 11). A large quantity of the smaller mudballs appeared on the surface of the bed after 3 weeks of operation which could be due to either breakdown of larger sized mudballs or have been lifted from inside of the bed at the higher backwash rate, and potentially will be washed out over a period of time.

The media bed expansion was examined at a range of flow rates (Figure 10), and it verified that a flow rate of 550 L/s should be sufficient to maintain the target bed expansion.

Figure 4. Examples of mudballs found during the final assessment. Note that although the amount has increased, the size is much smaller than previously observed

During the trial period, operators observing backwashes on a regular basis reported no media loss during washing after increasing the rate.

The process changes made in the final condition assessment resulted in an overall water and cost saving for the backwash, although the flow rate was increased, the backwash time was reduced resulting in net water saving.

Follow up assessment

Follow up assessment of the filters was completed approximately 8 months after the final round of testing. The purpose of this testing was to determine if there had been any long-term improvements in the filter condition, or if the backwash performance had changed. There were some small changes to the backwash process due to a change in the backwash valve, which meant that the low rate wash had been disabled and the high rate wash extended to compensate. The high rate flow was kept the same at 550L/s.

Under this condition, the media bed expansion was slightly higher than the final assessment (Figure 4), however, not enough to conclude that there was a significant change. The drain down level had increased from previous tests by 89mm on average. This was from a reduction in the bed depth, which suggests media carry over. However, as previously mentioned, operators had not observed a significant amount of media being washed out during the backwash. It is possible some of the level reduction was caused by the removal of the mudball layer that was previously covering the surface of the bed.

The backwash water was clean at the end of the backwash with an average turbidity of 3.1 NTU. Figure 12 suggests that it is possible for the backwash duration to be reduced, however it was kept the same to allow for any changes to the loading on the filters during peak demand periods.

Table 5. Summary of backwash performance for all filters – follow up assessment

Performance measure	Average
Drain down level (mm)	252 (n=5)
Expansion (%)	15% (n=14)
Turbidity at end of backwash (NTU)	3.1 (n=5)
Time to reach <10 NTU (min)	3.8 (n=5)

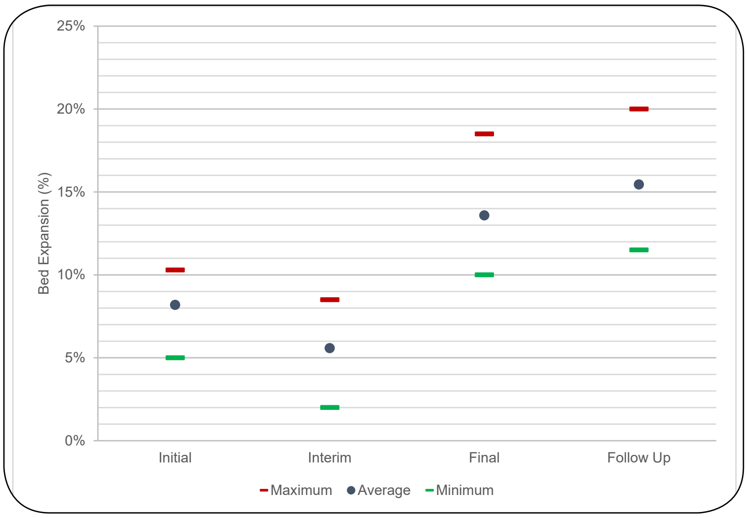


Figure 5. Media bed expansion for each assessment

As in previous tests, samples of media were collected using the Secchi disk and examined for mudballs. The media was much cleaner than at the time of the final testing, with a significant reduction in the number and size of the mudballs. Figure 5 is an example of the quality of the media after a backwash. This picture was typical of most of the filters at the treatment plant. Figure 14 is a picture of the surface of the media bed after backwashing, which has significantly improved over previous occasions in Figure 6 and Figure 11.

Due to the reduction in the mudballs, some of the planned maintenance of the filters, such as media replacement, was postponed. This was a significant cost saving for the plant budget.

CONCLUSION

The use of this novel method for filter backwash assessments, combined with the modified Secchi disk, has allowed process engineers and operators to have better knowledge regarding the performance of dual media filters, particularly during the backwash cycle. Through the sequential method of testing, a solution was found that not only improved the filter condition, but also reduced the operating costs and extended the life of the filter media. This same process is being applied at other plants at Sydney Water, including Recycled Water and Wastewater plants that use media filters in their process, to improve filter condition and backwash performance.

Figure 6. Example of media condition after a backwash – follow up assessment

Figure 7. Appearance of filter bed after a backwash during baseline testing. The orange colour is a layer of sludge and mudballs on the surface of the bed

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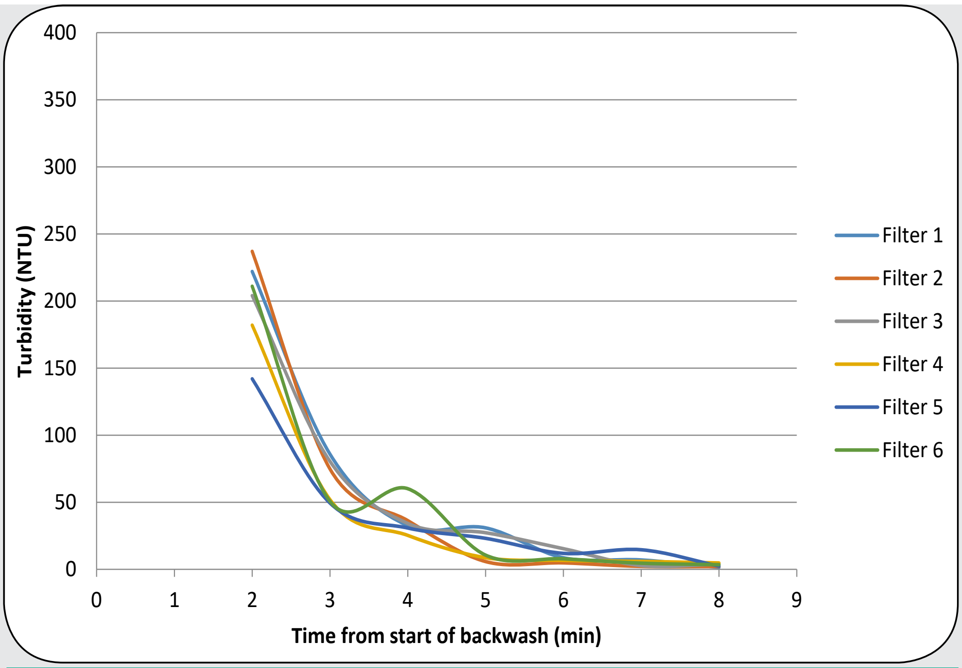

Figure 8. Wash water turbidity profile during normal backwashing for the baseline testing

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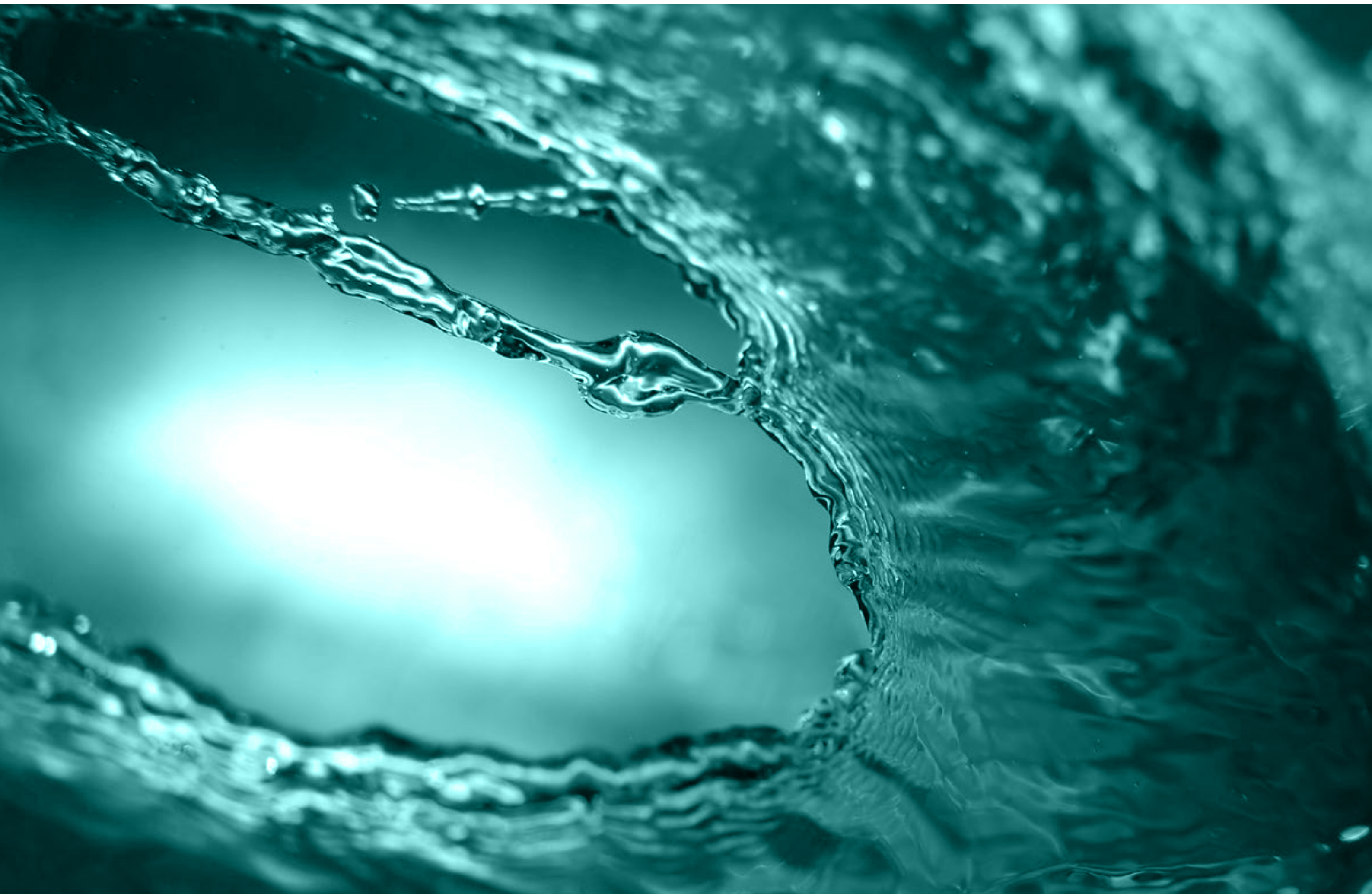

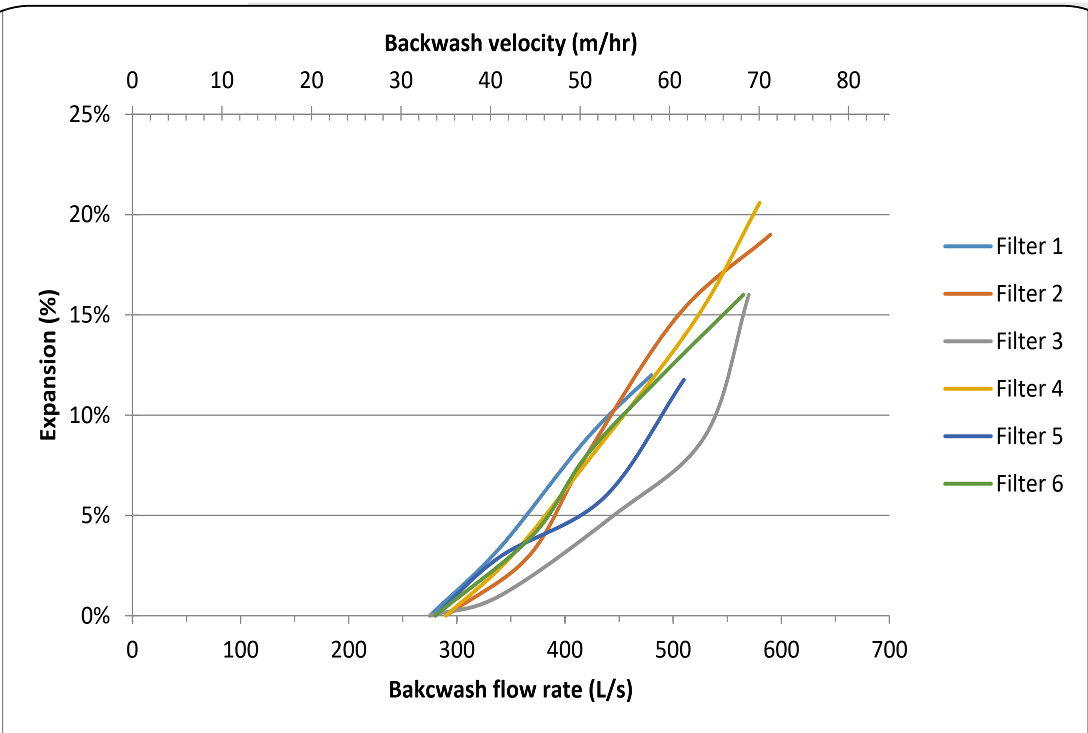

Figure 9. Media bed expansion measured at a range of flow rates for all filters during the baseline testing

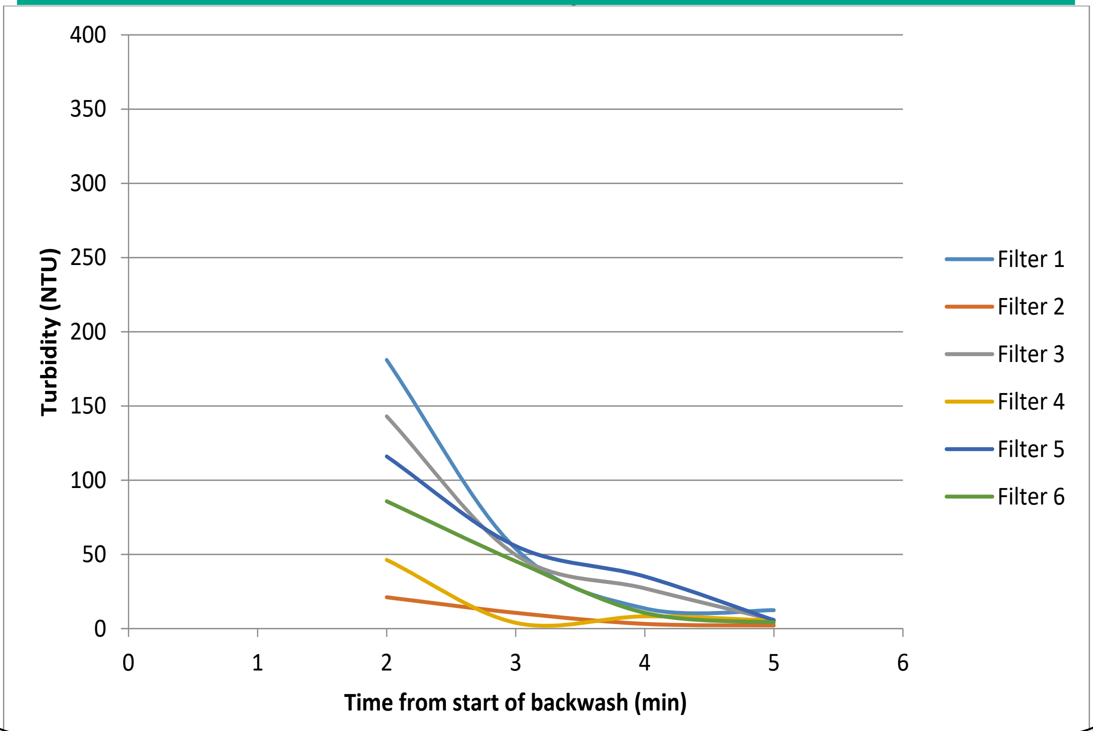

Figure 10. Wash water turbidity profile during normal backwashing for the final assessment

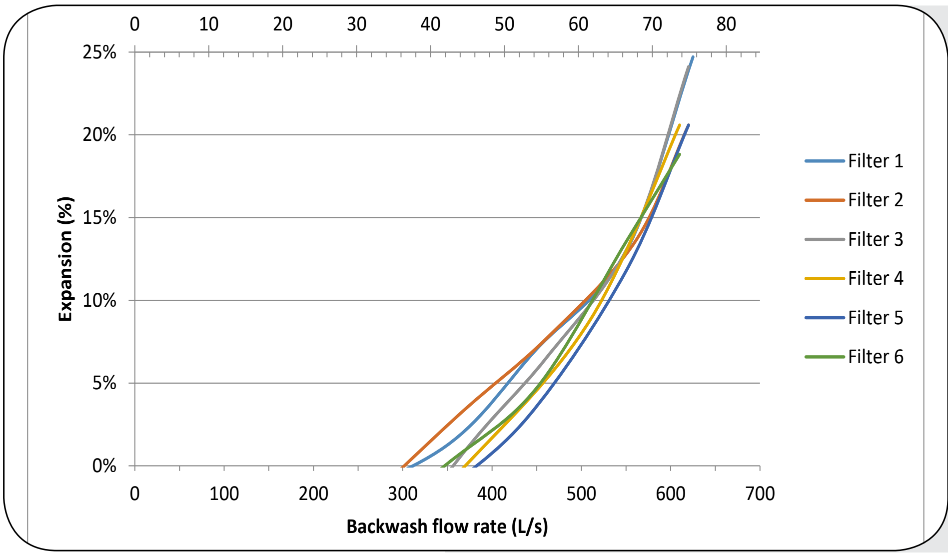

Figure 11. Media bed expansion at a range of flow rates during the final testing after all process changes had been made.

Figure 12. Appearance of filter bed after a backwash for the final testing

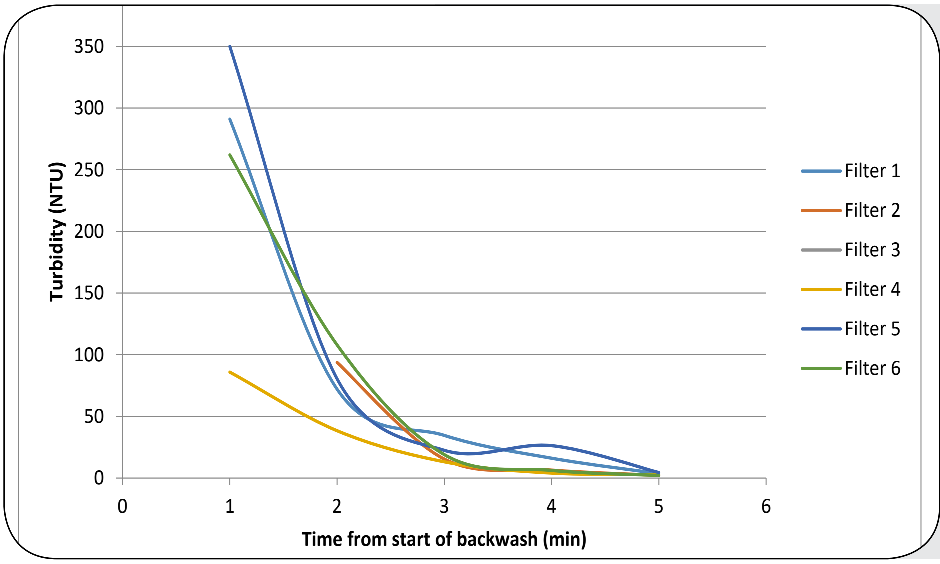

Figure 13. Wash water turbidity profile during normal backwashing during the follow up assessment

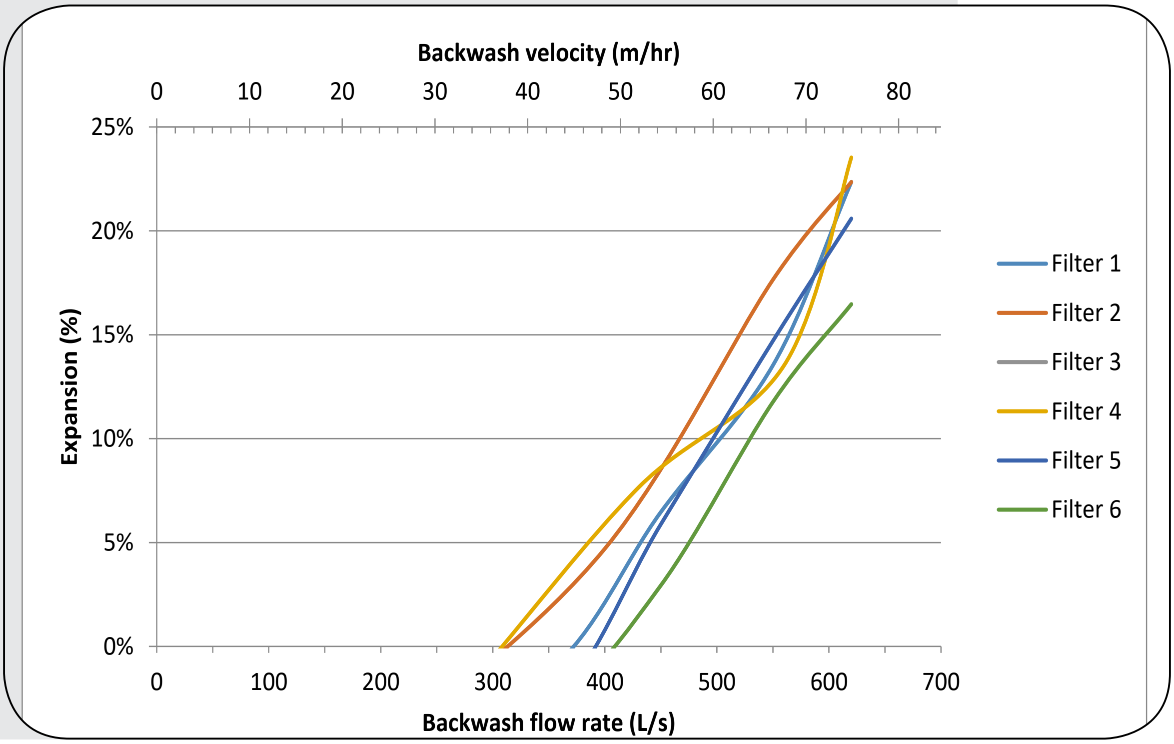

Figure 14. Media bed expansion at a range of backwash flow rates during the follow up testing

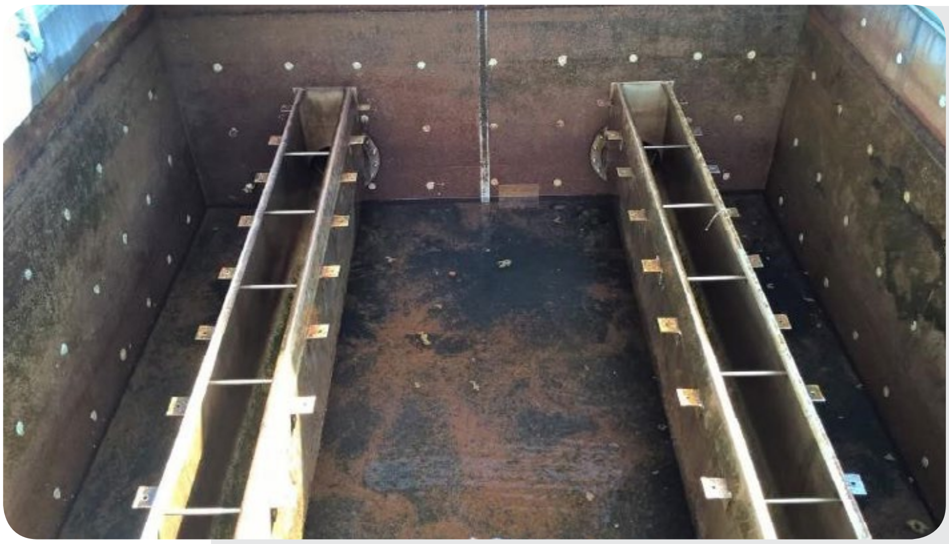

Figure 15. Appearance of the filter bed after a backwash at the follow up testing. Note the change in colour and reduction in surface mudballs and sludge on top of the filter. This is a significant improvement compared to Figure 12.