KNOW YOUR FILTERS

Paper Presented by :

Sandy McGregor

Author:

Sandy McGregor, *Water Treatment Technologist,*

Gippsland Water

64th Annual Water Industry Engineers and Operators' Conference
All Seasons International Hotel - Bendigo
5 and 6 September, 2001

KNOW YOUR FILTERS

Sandy McGregor, *Water Treatment Technologist*, Gippsland Water

ABSTRACT

This paper provides engineers and operators with helpful information for the identification and remediation of poor filter performance, based on experience gained by Gippsland Water in filter management. The following points are covered:.

- The importance of well operated and maintained filters.
- Operator's knowledge of filter performance.
- Observations from failures and their reasons.
- Rebuilds, modifications and simple remedies.
- Re-establishment of performance and ongoing monitoring.
- Performance monitoring tools.

KEY WORDS

Filter; Performance; Failures; Operator; Modifications; Turbidity

1.0 INTRODUCTION

Gippsland Water has adopted the Hazard Analysis And Critical Control Point (HACCP) management philosophy for the operation of its filtration plants. Under HACCP the filters in a treatment plant are considered to be a critical control point.

As it is the filter that provides the physical barrier to pathogens in the treatment process it is necessary to ensure that they are in top operating condition at all times. To monitor and assess this, improvements in on-line instrumentation and physical assessments / inspections have been a main focus over the last four years.

Gippsland Water has made progress in this area and now actively monitors the performance of its filtration plants and encourages its operators to look at the operation of their plants and perform some of the work discussed in this paper themselves. It is from this work that much of the information in the following discussion is derived.

Note: Due to the variety of filter types and designs the information given is a guideline only.

2.0 DISCUSSION

2.1 Normal operation

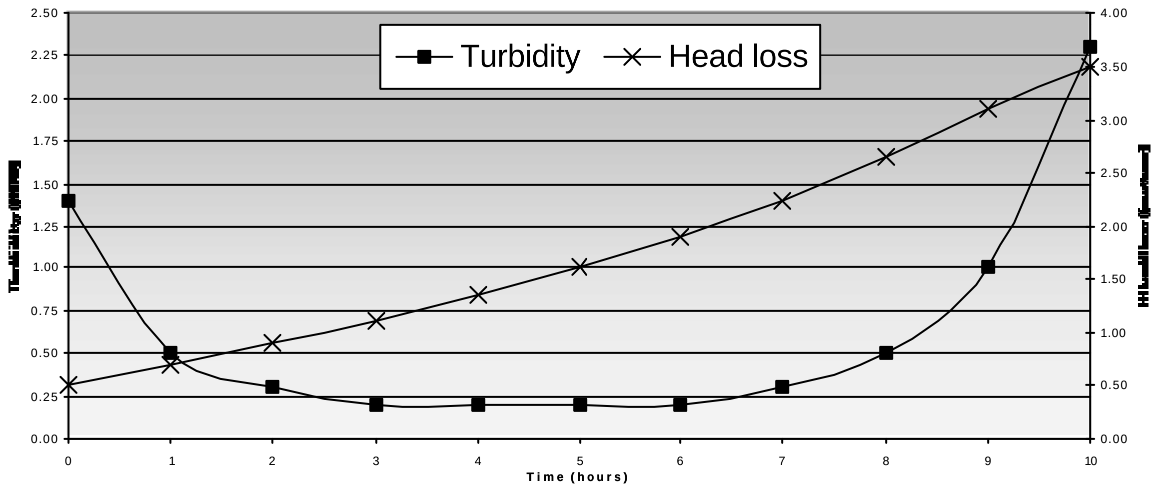
A typical water treatment plant filter operated under normal conditions should produce filtered water with a turbidity of less than 1 NTU most of the time, with an average of less than 0.5 NTU being desirable. Well-operated treatment plants with properly maintained filters can produce filtered water of less than 0.05 NTU when operated at optimum.

Backwashing frequency of 8 to 96 hours are common. In general, if turbidity breakthrough occurs in less than 8 hours, questions relating to the economy of plant performance need to be addressed. Excessive filter run durations are not encouraged as the risk of taste and odours due to anaerobic floc increases. For example, filter runs greater than 96 hours.

Head loss build up during a filter run is expected see figure 1 for an example of a typical filter run detailing the increase in head loss and the changes in turbidity. Typically two meters is used as the trigger level for a backwash. However it is suggested that total filter bed depth be used as the head loss set point.

Values greater than two meters lead to more rapid head loss increases, which can become unsustainable. Unsustainable head losses result in blinding off of filter. Allowing this to happen frequently will compromise the backwash regime as the filter becomes more difficult to clean. (Refer to Figure 1:)

Figure 1: ***Turbidity & Head loss over Time (Water Training Centre)***



2.2 Filter performance criteria

Filter performance criteria is a benchmark for monitoring the performance of your filter/s. Table 1 is an example of the filter performance criteria used by Gippsland Water.

Table 1: ***Typical filter performance criteria values***

Parameter	Units	Nominal	Max	Comment
Filtered water turbidity	NTU	< 0.5	1.0	Turbidity greater then 1NTU increases the potential for poor disinfection due to increases chlorine demand and shielding of bacteria.
Head loss	m	1 – 2	3	Pending bed depth. May be reported as outlet valve position.
Particle counts	counts/ml	NA	<200	Gippsland Water aims for <200 counts/ml in the 2 – 15 um size range 95% of the time. Refer Murray B.A 1995
Filtration rate	m/hr	8 – 12	15	Filtration rates are a factor of the design and loading. Australia does not apply any upper limit on filtration rates, unlike some foreign countries.
Filter inlet turbidity	NTU	<2	5	Target for pre-treatment systems and reference point for filter solids loading for future performance data.
Backwash rate	m/hr	36 – 46	50	This is usually determined by Filter media used, bed depth and the height of the wash trough from the media.
Wash water turbidity at end of wash.	NTU	5	NA	The parameter is plant dependent.
Shake test result	%	<5	<10	Refer- 'Assessment of filter state & condition'
Time to form clear patches during backwash	min	<8	10	Approximate values which should be determined by trials.
Residual Coagulant	mg/L	<0.1	0.2	Based on Aluminium residual values as detailed in the Australian drinking water guide lines 1996

Due to the variety of filter types and designs the information given is a guide line only, and should be verified and determined by carrying out the filter performance tests discussed in this paper.

The performance trial should take at least two weeks or longer. During the trial the filter should be subjected to varying conditions, both high and low solids loading, flow rates and extended filter runs. Solids loading trials and be carried out by changing the off take at the supply reservoir or by changing the conditions of upstream process such as the clarifier operation.

During the trials the filter should be monitored for the following:

- Inlet & Outlet turbidity and particle counts.
- Head loss (or outlet valve position) and Water Level.
- Backwash waste stream Turbidity and adequate backwash duration.
- Residual Coagulant and Chlorine demand.
- Residual Iron, Manganese and Organic Carbon.
- Measured filtration rate and Backwash rate.

When trended or graphed this data can be used to determine the operational limits of the filter as well as providing the baseline data for future reference, and can indicate deterioration of the filter performance. (The graph becomes a control chart)

2.3 Assessment of filter state & condition

Good filter performance and condition monitoring returns benefits in the form of early detection of potential causes for filter failure. It can also be sed that where a filter has failed due to an operational practice, it is also common to find poor filter monitoring. But this is not always the case.

Performance monitoring tools such as on-line instruments and data trending is the first point of call. Trends or graphs of data such as filtrate turbidity and head loss enable changes in performance to be seen over very long periods. Additional information such as the filter inlet turbidity, backwash waste stream turbidity, filtration rates and particle count data all enable better filter management.

In addition to on-line instrumentation, periodic physical inspections of filters and observing the backwashes are important. Since 1997, Gippsland Water has carried out assessments and inspections of most of its filters. These assessments have led to filter refurbishments, modification work, and supplementary on-line instrumentation at some sites.

A typical performance inspection would involve the following.

- Searching records and checking plant for design data.
- Observing the backwash routine.
- Physically inspecting the media.
- Taking media samples for shake testing.
- Documenting findings and reporting results including recommendations.

By observing the backwash it is possible to determine how healthy the filter is. Two of the most useful observations during a backwash are the level of bed fluidity of the media, and air scour pattern. Both of these observations tell us information about the condition of the filter bed. The fluidity can be determined by a long handled (4 metres) probe, with a surface area of approximately 75cm square at the end. The resistance to the probe being lowered into the filter indicates the amount of fluidity. If the probe has to be pushed in to the media then the backwash rate can be considered as inadequate or localised clogging of the bed has occurred. Further physical inspection may be required. Media boiling during the wash phase indicates that the support media has been irreversibly disturbed. The degree of boiling will indicate the extent of the failure and will indicate if the bed needs to be replaced.

In consistency of the air scour pattern, say large volcano type patches or very still areas can also indicate problems with the support media or problems with the under drain pipe work. See figures 8 & 9. Broken pips or cracking of the filter bed are also causes for backwash problems. The physical inspection of the media is carried out by scratching around and feeling the media. In doing this you are able to detect foreign matter, media cracking, and support media on the surface. You are also able to get a rough estimation of the media cleanliness and presence of mud balls, (Refer Figures 2 to 6). Figures 4, 6 & 8 are examples of foreign matter trapped in the filter bed.

Do not attempt to carry out any filter entry with out adequate safety equipment and supervision, as most filters are confined spaces.

Figure 2: ***Uneven media surface, as a result of the filter inlet design***

Figure 3: ***A 50mm Sludge layer that clearly shows cracking and shrinkage***

Figure 4: ***Rubbish removed from within the filter during refurbishment at Morwell***

Figure 5: ***Mud ball found in a filter that had completely failed at Traralgon***

<u>Figure 6:</u> ***Rubbish removed from within the filter during refurbishment at Sale***

<u>Figure 7:</u> ***An example of a shake test. Layers of media, sludge and water can clearly be seen***

The shake test is a simple procedure that can be completed by anyone, and is done to indicate the effectiveness of the backwash. The shake test is done after a backwash and is carried out be taking a 500ml core sample from various locations and depths from the filter. Vigorously shake the sample in one litre of water and allow to stand for 20 minutes, then determine the percentage of settled sludge versus the volume of media. If the result of the test is greater than 15% sludge, then the backwash regime should be reconsidered as this indicates poor backwashing. Values less than 8% are considered normal. (Refer Figure 7).

Generally failures can be attributed to problems with, the design, the construction, or operation of the filter. Design failures are difficult to overcome, as they are often an integral part of the filter structure. See Figure 2 for example. Construction failures generally relate to the way in which the media bed is laid. These failures often become evident as sink holes in the media or boiling during backwashes. In most cases the filter bed needs to be replaced, with the possibility of some underdrain work. Operational failures are probably the most common type and are often represented by blinding of the media, mud ball formation, and high filtrate turbidity during the filter run. (Refer Figures 3, 5 & 10) Figure 10 was the result of an underdrain failure, which affected the performance of the other filters at the plant.

These failures may require minor or major work to rectify. Chemical washing, physical removal of the offending material, or possible total replacement of some or all of the filter media may be required.

Figure 8: ***A plastic bag covering an under drain nozzle***

Figure 10: ***Result of a broken under drain nozzle. Sand entered the backwash tank and was redistributed to other filters. This required significant work to remove the sand and resulted in other filter rebuilds.***

Figure 9: ***Support gravel has been completely displaced. A still area in the air scour pattern was the first indication***

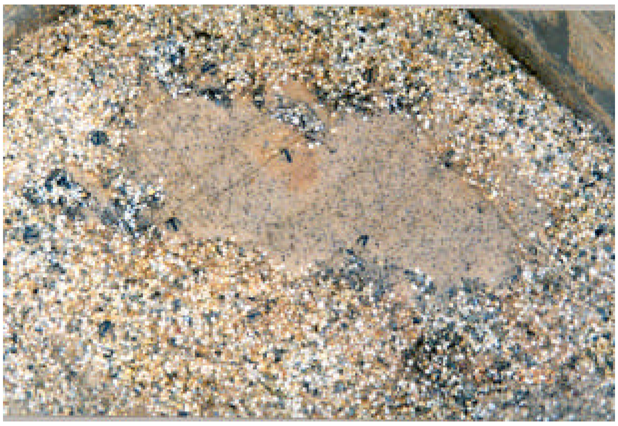
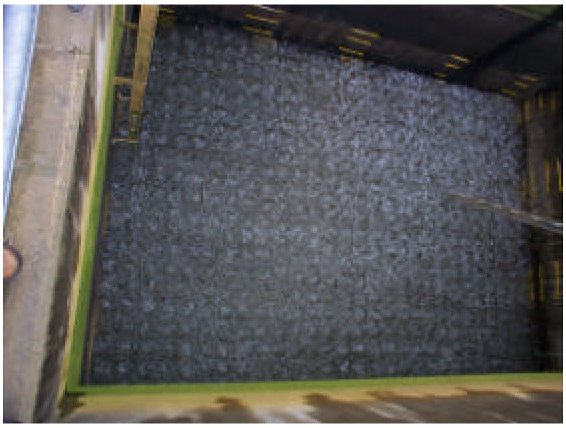


Figure 11: ***Typical of a good air scour pattern during testing***



2.4 Remedial action

Modifications and simple remedies are the most common approaches to fixing filter problems. As in the example described below the remedial action to overcome the failure was simple. However, it may not always be so easy.

In the case of a polymer over dose, the filter media may be blinded off to the point that it is necessary to chemically clean the filter by washing it with highly concentrated solutions of caustic, hypo, acid or other chemicals such as detergents. Regained performances can range from 60 to 100% of original design, depending on the situation. The drawback is that large quantities of contaminated water are left for disposal. Chemical cleaning of the filter media can also be used to eliminate lime build up where lime is used as a coagulant for the removal of iron, manganese or chemical binding by calcium and for treatment of algal build ups.

Practical example of remedial action. An automated treatment plant built in southern NSW, was designed with data from seven years of dry wether. The plant was commissioned with a backwash routine adequate for the plant loading under dry conditions. As time progressed the through put was increased due to demand and the weather became wet again.
As a result the filter was running at above design rates and the raw water quality changed. The plant's chemical dosing system was programmed to cope with this, but the backwash routine

remained unchanged. As a result the filter was not backwashing as efficiently as it should have and eventually caused turbidity breakthrough and finally blinding of the media. Action was taken to rectify this by consecutive backwashes until the filter was considered to be clean again. The backwash was reassessed and optimised to handle the new operating conditions of the plant.

2.5 Rebuilds & modifications

Rebuilds are often a last resort as the cost of this work can be very high. Other remedial action that can be taken to prevent filter failures is the replacement of media and modification of the way in which the filter operates.

For example- At the Mirboo North Water Treatment Plant an air scour system and backwash pump VSD were installed. This was done to improve the backwashing of the filter. The installation of a blower meant that air scouring could now be employed. The installation of the VSD allowed controlled ramping of the wash water rate. Controlled ramping of the wash water removed the risk of the support media being disturbed due to sudden surges of water. The modification has also enabled the use of combined air scour and water backwashing.

At the Heyfield Water Treatment Plant it was noticed that during the filter run turbidity spikes occurred. This was investigated using a particle counter. The turbidity spikes were attributed to valve operation. For example, when the plant started a backwash the filter outlet valves would open to about 80% to allow the filter to drain. This increased the flow through the filter to a point that allowed turbidity break through. This was rectified by restricting the valve operation to only open to approximately 10% above the last operating position. The reduced valve movement slowed the flow through the filter and stopped the turbidity spike. The investigation also found that when the filter was put back on line the ripening duration was extreme. It was found that the filter level control loop was not correctly tuned, which resulted in the filter outlet valve swinging wildly while trying to maintain level set point. To rectify this the valve operation was slowed and the control loop re-tuned. The result was a much-improved level of control and a reduction of the turbidity and particle counts exiting the filter. A commonly neglected but very important functional check, which can prevent filter failure is the Air Scour test.

This test is carried out before adding the filter media on an empty filter with approximately 150mm of water in the bottom and the air blower running. This test gives a clear indication of the distribution of the air pattern. If the air distribution is not correct the filter will not backwash correctly. This will lead to long-term degradation in performance. (Ref Fig 11)

2.6 Re-establishment of performance criteria.

After a filter has been modified or rebuilt, it is good practice to re-determine its performance. This will provide new reference data for comparison in the future. A performance trial is also used to verify the effectiveness of a modification.

3.0 CONCLUSION

The importance of well-operated and maintained filters is essential, as a filter that is in poor operational condition or is being operated poorly, increases the chance of compromising the quality of the product water delivered to our customers.

The operator’s knowledge of filter performance and how to monitor and improve it is important too, as most of the time it is the operator who is responsible for the operation and maintenance of his / her site. It is also the operator who has to determine what is happening when the plant performance is not up to scratch and what to do about it. *"And as we all know, this often happens when we least need problems."* Therefore it is important that he / she has a good understanding of the water treatment process and has an inquisitive nature that draws them to observe their plant closely. References and design texts are ideal for gaining additional knowledge. Some useful texts are listed under 'References'. However it is the "getting your hands dirty" experience that reinforces the text book knowledge, as you get to see aspects of filtration and plant performance required to ensure that plants are running at their optimum.

The monitoring of filter performance and integrity may not bring dividends in the short term, but will enable you to avoid water quality and health incidents. It will also keep your plant ahead of the changing and more stringent regulations of the future.

4.0 ACKNOWLEDGMENTS

The author wishes to thank Dr Peter Mosse for actively encouraging the preparation of this manuscript, Ms Michelle Colwell for reviewing the manuscript and Gippsland Water Treatment Plant operators for their patience during filter assessments and refreshments.

5.0 REFERENCES

Kawamura, S; 1991; I*ntegrated design of water treatment facilities*; A Wiley-Interscience Publication

Faust, S D; Aly, O M; *Chemistry of water treatment Second Edition*; Ann Arbor Press

Mc Clellan; 1998; *Royal Commission inquiry into the Sydney Cryptosperidium event.*

NHMRC and ARMACANZ; 1996; *Australian Drinking Water Guidelines*; Commonwealth of Australia.

Murray, B.A; 1995; *Particle counting in water treatment*; Water, 22 : 37 – 40

Certificate in water operations stream studies; March 1992; *Filtration subject code CW.13*; Water Training Centre