



Assets Planning and Delivery Group
Engineering

DESIGN STANDARD DS 114

Granular Media Filtration

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FOREWORD

The intent of Design Standards is to specify requirements that assure effective design and delivery of fit for purpose Water Corporation infrastructure assets for best whole-of-life value with least risk to Corporation service standards and safety. Design standards are also intended to promote uniformity of approach by asset designers, drafters and constructors to the design, construction, commissioning and delivery of water infrastructure and to the compatibility of new infrastructure with existing like infrastructure.

Design Standards draw on the asset design, management and field operational experience gained and documented by the Corporation and by the water industry generally over time. They are intended for application by Corporation staff, designers, constructors and land developers to the planning, design, construction and commissioning of Corporation infrastructure including water services provided by land developers for takeover by the Corporation.

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[Overview of Western Australia's Work Health and Safety \(General\) Regulations 2022 \(dmirs.wa.gov.au\)](https://dmirs.wa.gov.au)

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Head of Engineering

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REVISION STATUS

The revision status of this standard is shown section by section below:

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Granular Media Filtration

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1 Filtration

1.1 Filter types

1.1.1 Pressure filters

Specification shall be based upon Strategic Product Specification SPS 250 – GRP Filter Vessels. Metallic filter vessels are generally not preferred and require a request for approval to the Senior Principal Engineer - Water Treatment. The request should explain why metallic filter vessels are suitable for the proposed application.

Pressure filters should be specified with plenum floors and nozzles (nozzle plates), because plenum floors are much more robust than laterals and are suitable for air scour.

Garnet should be used for the support layers. Garnet has a higher density than gravel and thus is less prone to disturbances. Two 100-150 mm layers of garnet 2.4 to 4.8 and 1.2 to 2.4 mm respectively have been used successfully. The coarse layer should cover the nozzles by at least 60 mm.

Ensure that exposed filter components have sufficient UV resistance. Gebel have given excellent service at Laverton, without shelter; conversely, at Derby WTP filters made by ODIS Filtering Ltd showed external deterioration after about five years, even with shelter from direct sunlight.

All filters should have a shade structure. This reduces the risk to operations staff working on them in elevated temperatures (e.g. Fitzroy Crossing), and avoids problems from thermal cycling (especially heating of pipework while the filter is not running) and limits temperature de-rating to maximum ambient temperature rather than maximum black body temperature. UV protective coating is required for all vessels regardless of whether they are exposed or in protected conditions. The additional coating will increase asset life and reduce hazards associated with operations staff getting fibreglass splinters when touching the vessel.

At Derby WTP, Maric flow regulating valves were installed on each filter inlet to prevent high inlet flow to an individual filter, and on the backwash outlet line for backwash flow control. This was a useful innovation and should be considered for future installations, especially where there is sufficient “excess” pressure available upstream for correct operation of Maric flow regulating valves (typically 0.8 - 1 bar differential pressure (minimum) is required for correct Maric valve operation).

All pressure filter vessels (SPS 250 compliant or otherwise) shall be compliant with AS1210 or ASME Boiler and Pressure Vessel Code Section VIII. The designer shall provide a hazard level calculation according to AS4343 for Principal approval and for vessels assessed as hazard level A through D, the designer shall register the design with Worksafe WA and provide a design registration certificate to the Principal.

The Principal notes that when conducting a hazard level calculation for vessels containing treated wastewater at temperatures between 0 and 90°C, the fluid shall be rated as non-hazardous liquid.

1.1.2 Rapid Gravity Filters

The development of base and underdrain systems has increased the performance and robustness of rapid gravity filters to the extent that they are preferred over pressure filters (Leopold—Picton WTP, and De Nora—Mundaring WTP); however, they have a minimum practical/economic size which may result in their not being suitable for small capacity plants. Modern gravity filters offer the following advantages:

- easy inspection;
- uniform drainage and backwash flow distribution;
- no nozzles to replace;
- no gravel support layers; and
- allow integration of air-scour if required.

Neerabup WTP has sophisticated flowrate control through each filter, and this should be considered for future installations. Each filter shall have a flowmeter and online turbidity analyser on the outlet. Inlet flow metering is acceptable where there is only a single filter.

Rapid gravity filters should be sheltered from direct sunlight, or even housed. This reduces algal growth and contamination from debris and animals. If chlorine is dosed prior to open top filters, direct sunlight causes significant destruction of chlorine during daylight hours (up to 0.35 mg/L at Wanneroo WTP, 2012).

1.1.3 Continuous Wash Upflow Filters

These filters (such as the Dynasand™ brand) have a deep bed of sand media that is continuously circulated and washed. The circulation is achieved with an air-lift pump that draws solids-laden sand from the bottom of the filter bed up to a counter-current sand-washer at the top of the filter. After being washed, the clean sand drops onto the top of the filter bed; hence, the sand bed gradually moves downwards as the water being filtered flows upward through it.

1.2 Redundancy

In addition to the duty filtration capacity, a minimum of one standby filter shall be installed to allow continued production at normal capacity while one filter is off-line for maintenance or repairs. During normal operation when all filters are available this standby filter should be utilized as part of the normal filter backwash rotation sequence such that changes to the rate of flow through each online filter are minimized when a filter is taken offline for backwashing.

Single points of potential failure with long lead times (such as backwash pumps and blowers) shall be installed as duty/standby equipment.

1.2.1 Rationale

This requirement applies to potable water production facilities. It also applies to most water recycling facilities because the downtime for filter repairs or replacement is unlikely to be tolerable to forgo the opportunity to dispose of treated wastewater for an extended period, and also has reputational impacts because of the inconvenience for customers of recycled water.

1.3 Solids Loading Rate

At a filtration rate of 10 m/hour, solids¹ loading rates up to 10 mg/L can generally be handled by direct filtration. At higher solids loading rates, an upstream solids removal process (such as a clarifier or DAF) shall be used to reduce the filter influent solids concentration to less than 10 mg/L.

Multi-media filters have greater storage capacity for entrapped solids and so typically can accept higher solids loading rates than mono-media filters. The surface layer employs large grain size, but low particle density material such as anthracite coal, to allow entrapment of a high volume of material, and underlying is a fine grain size, but relatively dense material such as silica sand, for entrapment of smaller particles and lastly a layer of finer and high density material such as garnet sand.

1.4 Filter Media

A standard recommendation is dual-media filtration with 500 mm of 1.1 mm filter coal and 500 mm of 0.6mm filter sand.

¹ The relevant concentration is the oxidised, coagulated and flocculated solids present e.g. in an iron removal plant, the solids will consist of ferric hydroxide and possibly also manganese oxide and polyelectrolyte, if used.

Filter coal shall be anthracite with Uniformity Coefficient (UC) <1.5, Effective Size (D10) 1.2-1.3 mm and >99% as carbon.

Filter sand shall have UC<1.3, Effective Size (D10) 0.6mm and >99% quartz silica.

The supercut quartz sand (from Margaret River, by Cook Industrial Minerals) is an angular fine sand that is suitable for multi-media filters.

Coarser sand is required for Continuous Wash Upflow Filters, for which brown sand (Carnarvon River Sand from Cook Industrial Minerals) is suitable.

Filter media quality requirements are detailed in this document: [Appendix B: Filter Media Procurement and Commissioning Guideline.](#)

1.4.1 Filter media for manganese removal

Filter coal and supercut quartz sand are recommended media for manganese removal filters. Filter coal develops a durable manganese dioxide layer (Wanneroo WTP) when a continuous free chlorine residual is maintained in the filter feedwater. Note that careful selection of sand is required because some WA grey sand does not easily develop a durable manganese dioxide layer. The supercut quartz sand (from Margaret River, by Cook Industrial Minerals) is an angular fine sand that is suitable for multi-media filters. Coarser sand is required for Continuous Wash Upflow Filters, for which brown sand (Carnarvon River Sand also available from Cook Industrial Minerals) is suitable.

Specialty media: DMI-65 and manganese greensand are not recommended because of cost and durability concerns.

Filter media quality requirements, and media pre-conditioning are detailed in [Appendix B: Filter Media Procurement and Commissioning Guideline](#)

1.5 Functional Control Description

Filters shall operate (e.g. in production and backwash modes) fully automatically.

Each filter shall have continuous recording (trends) provided on the plant SCADA as per the table below.

		FILTER TYPE			NOTES
		Pressure Filters	Rapid Gravity Filters	Continuous Wash Upflow Filters	
PARAMETERS ON SCADA	Required for each filter				
	Flow Rate (feed or filtrate)	✓	✓	✓	
	Filtrate Turbidity	✓	✓	✓	
	Differential Pressure (head loss)	✓	✓		
	Water Level		✓		
	Inlet Valve Position	○	○	○	Required where flow to each filter is controlled by an actuated valve at the filter inlet.
	Outlet Valve Position	○	○	○	Required where flow through each filter or filter level is controlled by an actuated valve at the filter outlet.
	Filter Run Time (since last backwash)	✓	✓		

	FILTER TYPE			NOTES
	Pressure Filters	Rapid Gravity Filters	Continuous Wash Upflow Filters	
Common for all filters				
Backwash Flow Rate	✓	✓	✓	
Scour Air Flow Rate	○	○	○	Where air scour and/or combined air-water wash is used during filter backwash

Table 1 - SCADA Input Requirements for Major Filter Types

1.5.1 Process stability

The following requirements are mandatory for drinking water treatment plants and shall be considered (i.e. only adopt where justified by risk) for water recycling plants:

- Where it is not practical to achieve continuous operation, then a WTP should target single runs of 8 to 24 hours with a minimum of 4 hours.
- Where intermittent operation of a WTP is unavoidable, any filter having accrued >75% of design terminal headloss is to be backwashed prior to start up.
- Where operation is such that the plant only operates 2-3 days per week then a backwash should occur prior to shut down.
- Where multiple parallel filters are on-line, the flow split shall be within 5% of the average.

1.5.2 Control Criteria

The following criteria shall be used when monitoring Process Control Point performance.

Target limit	operational limit; allows corrective action to be taken to avoid unacceptable aesthetic impact, i.e. discoloured water. Note that there may be a period where this target is not met (e.g. filter ripening period) and an alarm is generated if the target is not met after the timer has expired.
Alert limit	gives warning that a target limit has been breached; it can initiate a plant shut down on high-high or low-low alarms in order to prevent unacceptable aesthetic or public health impacts, e.g. discoloured water.

1.5.3 Flow monitoring

Individual filter flow is monitored and trended.

- Flow for each filter shall be displayed in both volumetric flow rate units and as filter loading rate in m/hour.
- Combined (summation of all filters) volumetric flow rate shall be displayed.

1.5.3.1 Flow alarms

- Generate a warning alarm (“filter N outside flow range” alarm) if flow for any filter is continuously outside the design range for a preset duration (default 5 minutes).
- Generate a warning alarm (“uneven flow” alarm) if any filter is not within 5% of the target instantaneous average flow for a preset duration (default 5 minutes).

1.5.4 Process monitoring

Processes such as oxidation and removal of metals require monitoring and trending of other important parameters in addition to turbidity. They typically use parameters such as free chlorine residual or ORP and pH, pre and post-filter.

The full suite (low low, low, high, high high) of alarms shall be provided and recorded.

Provide warning alarms when each of the low or high target is exceeded (for longer than a setpoint delay time e.g. 10 minutes).

Provide warning alarms when each of the low or high target is exceeded for more than 5% of the previous rolling month.

Provide urgent alarms when each of the low low or high high target is exceeded (for longer than a setpoint delay time e.g. 10 minutes).

Where low low or high high alarms are identified as Critical Control Points then direction shall be sought from the Water Corporation design manager regarding any required automatic shutdown interlocks for the offending filter, pumping system or WTP.

1.5.5 Turbidity monitoring

Turbidity is monitored and trended for the outlet of each duty filter.

Even if a turbidimeter is shared (e.g. between a duty/ standby pair of filters), the SCADA tags and trends shall be unique to each filter.

1.5.5.1 Turbidity alarms

Provide a warning alarm when the high turbidity target is exceeded (for longer than a setpoint delay time e.g. 10 minutes).

Provide a warning alarm when the high turbidity target is exceeded for more than 5% of the previous rolling month.

Provide an urgent alarm when the high high turbidity target is exceeded (for longer than a setpoint delay time e.g. 10 minutes) and seek direction from the Water Corporation design manager regarding any required automatic shutdown interlocks for the offending filter, pumping system or WTP.

Provide a low flow alarm for when the flow to the turbidity analyser is less than the required minimum flow rate.

- General filters (3.5 log Cryptosporidium & Giardia): ≤ 0.15 NTU high alarm limit 95% of the time (monthly); and ≤ 0.3 NTU high high alarm limit at all times.
- Pressure filters (2.0 log C&G): ≤ 0.2 NTU high alarm limit 95% of the time (monthly); and ≤ 0.5 NTU high high alarm limit at all times.
- GAC filters (0.5 C&G): ≤ 0.15 NTU high alarm limit 95% of the time (monthly); and ≤ 0.3 NTU high high alarm limit at all times.

1.5.6 Particle counting

Where particle counts are used, the high target for particles in the size range 2- 15 μ m is <20/mL, with a critical (high high) limit of <100/mL.

1.5.6.1 Particle count alarms

Provide a warning alarm when the high target is exceeded (for longer than a setpoint delay time e.g. 10 minutes).

Provide a warning alarm when the high target is exceeded for more than 5% of the previous rolling month.

Provide an urgent alarm when the high high target is exceeded (for longer than a setpoint delay time e.g. 10 minutes) and seek direction from the Water Corporation design manager regarding any required automatic shutdown interlocks for the offending filter, pumping system or WTP.

1.5.7 Backwashing

- Backwashes are triggered automatically by water quality (turbidity or particle count), head loss and run time. For each filter, provide events on SCADA to record which type of trigger initiated each backwash.
- Once triggered for backwash, the filter is shut down automatically and placed in a backwash queue.
- During drain down, prior to backwashing, controls are to be in place to ensure the filtration rate does not increase.
- During backwashing, any increase in flow to those filters remaining on-line during the backwash is to be <20%. Alarms required on SCADA. Target is 100% compliance. If available, a standby filter is to automatically brought online as inflow is stopped to the filter being backwashed with the aim of minimizing the flow disturbance on all filters. On completion of the backwash the clean filter would then become the standby.
- Combined air scour/low rate backwash, if present, is < 15 m/hr.
- Clean bed head loss (CBHL) is monitored during operation and trended. Alarm limit basis: For a given filter flow rate, the clean bed head loss (after backwash) should remain within a target of 5% of original CBHL.
- In plants without filter to waste (i.e. using ETSW backwash strategy), the ripening period after backwashing does not exceed the critical limit for any longer than:
 - 0.5 NTU for <30 min provides 3 log credit
 - 0.5 NTU for < 15 min provides 3.5 log credit
 - 0.3 NTU for < 15 min provides 4 log credit.

Alternative limits can be set for low risk reuse plants if filtration is targeting only a reduction in suspended solids, not pathogens. The ripening period shall be monitored with display of monthly data indicating number of “ripening periods within target” as a percentage of total number of ripening periods. Target is > 95% compliance. Provide event alarm for individual ripening period exceeding target and provide warning alarm when monthly target not met.

1.5.7.1 Backwashing - Control Description

Each filtration unit² requires a periodic backwash to eliminate the solids built up on the filter media through the filtration process. During backwash the Filtration PLC starts the backwash pump, and opens the backwash valve(s) to purge solids laden washwater.

Backwashing is triggered by:

- filter differential pressure transmitter when the pressure differential across the filters exceeds the set point for backwashing
- filtered water turbidity (or particle count) when the quality exceeds the set point for backwashing;
- filter run-time timer (maximum cumulative filter run time since the last backwash – typically 24 – 72 hours)
- time since last backwash timer (maximum interval between backwashes irrespective of filter running – typically 172 hours); or
- Operator initiating from the OIP or SCADA.

Backwashing employs an Extended Terminal Sub-fluidisation Wash (ETSW) strategy which incorporates variable wash rates. The ETSW³ backwash strategy reduces or eliminates the turbidity spike when filtration resumes following a backwash, and does so using less backwash water compared to filtering-to-waste during the filter ripening period.

Flow rate control of backwash pumping is required for:

- achieving variable rate backwash;
- controlled ramp up of backwash flow rates to avoid excessive disturbance of the media layers; and
- controlled ramp down for better settling of the media upon cessation of backwash.

The variable backwash rate is typically achieved by VSD control of the backwash pump flowrate monitored by a backwash magflow meter. Typical backwash sequence, flowrates and duration set points are:

- Low rate backwash 20 m/hr for 1 min⁴ and while this is underway add air scour; then
- Stop air scour; commence high rate backwash at 40 m/hr for 5 mins; then
- finish with very low rate backwash (sub-fluidisation for ~10 m/hr) for sufficient time to flush out one filter cell volume (typically ~10 mins).

The backwash pump VSD shall be used to ramp up and down the flow rates because if the backwash is initiated too quickly and/or at too high a flow rate and/or terminated too quickly, the filter media bed can be severely disturbed.

The washwater cycle can be monitored at the local OIP as well as on UWSS.

This instantaneous backwash flow rate will be transmitted to the PLC and then used for the following purposes:

- To control the VSD speed of the Filtration Backwash Pump when in ‘Backwash’ mode. The VSD is used to ensure constant product flowrate equivalent to backwash rates of 10, 20 and 40 m/hr.

² This excludes Continuous Wash Upflow Filters (CWUFs) which instead backwash continuously.

³ ETSW is an extension of the normal backwash duration with a low flow rate – subfluidisation i.e. little or no bed expansion – for the amount of time to displace the volume of water contained in the filter cell.

⁴ At Dalyellup WTP, the air scour is 3 minutes.

- To stop the Filtration Backwash Pump if a flowrate fault or alarm occurs.

The totalised flow volume will also be used to record and display on SCADA:

- Totalised daily Filtration Backwash disposal to the sludge drying beds (reset daily at midnight)
- Overall totalised Filtration Backwash disposal to the backwash recovery system or sludge drying beds (for reporting), which cannot be reset
- Total backwash volume for Filter 1 (i.e. flow total accumulated when Filter 1 backwashing); and
- Similar (total backwash volume) for each filter through to the last filter (Filter N).

The flow rate can be monitored at the OIP/local SCADA viewer as well as on UWSS.

High turbidity alarms are masked with a delay timer following commencement of a filtration sequence.

The duty filter rotates every 24 hours (e.g. at 8 AM) if the other filter is available and has been in standby for at least 22 hours.

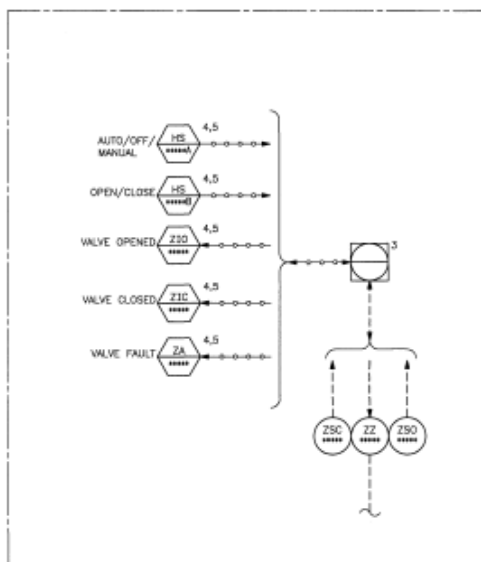
A setpoint minimum filter run time shall be used to generate a warning alarm if a filter repeatedly (i.e. two or more times) backwashes (e.g. if the DP or turbidity triggers are reached before the minimum filter run timer expires).

1.5.7.2 Air scour

If air scour is used, the air scour blower discharge pipework requires a normally open motorised de-loading valve that discharges to atmosphere and which slowly closes after the blower starts. This allows gentle introduction of air scour supply (“soft start”), so as to avoid media loss.

1.5.8 Automatic isolation valves

Automatic isolation valves shall be equipped with position switches in accordance with the control and monitoring requirements shown in Detail 2 of drawing GB72-60-0-5 (repeated below in Figure 1 - 1). If the filter uses modulating valves, then those valves shall be in accordance with Detail 3 on drawing GB72-60-0-5.



DETAIL 2 – ACTUATED VALVE WITH FEEDBACK

Figure 1 - 1 Control requirements for actuated isolation valves

1.6 Operation

1.6.1 Stable Operation

Treatment plants produce better water quality with stable operation. The following requirements are mandatory for drinking water treatment plants and shall be considered for water recycling plants (i.e. only adopt where justified by risk):

- The process stability requirements described in section 1.5.1.
- Filter outlet valve and level controls operate without hunting.

1.6.2 Labelling and Identification

All pits, pipes, valves, instruments, dosing points and sampling points, including the direction of flow in pipes shall be clearly labelled. Labelling should be consistent with plant P&IDs, equipment list, valve list, instrument list and SCADA screens.

Exposed pipework shall be colour coded in accordance with the Water Corporation’s standard colour coding drawing EG71-1-1. For pipe contents not covered by EG71-1-1 then base the colour upon AS1345. Where colour painting is not practicable (e.g. stainless steel pipework, HDPE pipework) or desirable (e.g. dark colour exposed to direct sunlight), identification labels and colour banding labels shall be applied regularly enough along the pipework to ensure that personnel can readily identify the contents.

1.6.3 Monitoring, Sampling and Analysis

Measure	Rationale	Additional Information
The design filtration rate is known and the plant operates within the design specifications.	Exceeding the design specifications is likely to result in poorer performance of the process element and consequently poorer pathogen removal.	Requires flow measurement. Calculate and display filtration rate (m/hr) on SCADA system together with alarms.
Individual filter flow is monitored and trended.	Monitoring is necessary to ensure equal flows and loads to each filter. Unequal flows can result in differential performance of filters.	
Sufficient dilution, mixing and contact time is provided for any chemicals dosed. Sample points are to be located at first opportunity after the required zones for mixing and reaction. In addition to any online analysers, provide manual sample points at (a) a location upstream of the dosing; (b) on the filter inlet at a location after the water is well mixed; and (c)	Any chemical reaction (oxidation or coagulation) requires uniform pH for complete reaction with uniform formation of particulates and floc.	Typical chemicals used include: lime, soda ash, caustic soda, chlorine, polyelectrolyte, and carbon dioxide. The chemicals should be well mixed with the water prior to any unit process. Typically, a dilution ratio of at least 20:1 is preferred.

Measure	Rationale	Additional Information
<p>on each individual⁵ filter outlet as well as the combined filter outlet pipework.</p>		
<p>Turbidimeters are provided for the outlet of each duty filter. Required for drinking water treatment plants and for plants whose product water has high risk of human exposure i.e. not mandatory for those water recycling plants categorised as low risk reuse schemes.</p> <p>Even if a turbidimeter is shared (e.g. between a duty/ standby pair of filters), the SCADA tags and trends shall be unique to each filter.</p>	<p>Allows assessment of individual filter performance and detection of poorly performing filters. Turbidity is relevant to effectiveness of disinfection, and is a surrogate for monitoring to confirm iron and manganese removal.</p>	<p>General filters (3.5 log C&G): <= 0.15 NTU alarm limit 95% of the time (monthly); and <= 0.3 NTU alarm limit at all times.</p> <p>Pressure filters (2.0 log C&G): <= 0.2 NTU alarm limit 95% of the time (monthly); and <= 0.5 NTU alarm limit at all times.</p> <p>GAC filters (0.5 C&G): <= 0.15 NTU alarm limit 95% of the time (monthly); and <= 0.3 NTU alarm limit at all times.</p>
<p>Provide means to control and regularly check that flow through the turbidimeters is within manufacturer's recommended ranges.</p>	<p>Zero or inconsistent flows compromise the quality of key monitoring data.</p>	<p>To provide consistent flow rate consider use of a pressure regulating valve accompanied by a downstream pressure gauge to allow setting and checking of the pressure.</p> <p>Provide a flow gauge (variable area flow meter) and throttling valve so that the sample flow rate can be set to the manufacturer's flow specifications. The flow gauge shall be fitted with a low flow switch to verify presence of adequate sample flow rate.</p>
<p>Continuous recording and display of turbidity, filter flow, head loss and filter level or filter outlet valve position, is provided on the plant SCADA.</p>	<p>Essential for filter optimisation and problem diagnosis.</p>	
<p>Where particle counts are used, the target for particles in the size range 2- 15µm is <20/mL, with a critical limit of <100/mL.</p>	<p>Particle counting is considered to be a more sensitive measure of filter performance (compared to turbidity), and therefore whether pathogen breakthrough may have occurred. Particle count checks are recommended for a WTP treating high source risk water.</p>	

⁵ The reason that sample points are required on the outlet of individual filters is to facilitate Log Book and trouble-shooting requirements.

1.6.3.1 Media attrition and liberation

There are multiple factors affecting media attrition and liberation. Annual media sampling and sieve analysis is recommended to confirm media depth and particle size is in keeping with design specifications, which will inform decision on when media replacement should be undertaken.

1.6.3.2 Strainer on filter outlet

One method of monitoring the integrity of filter nozzles and plenum is to provide a small diameter in-line strainer on a side stream at the filter outlet to detect whether sand is escaping. Escaping filter sand is not normally detectable by online turbidity analysers which are not sensitive to coarse solids. Full flow inline strainers are not normally warranted due to high cost (especially on large filters) but may be justified where media filtration is followed immediately by inline UV disinfection. This is to prevent damage to UV tubes from any filter media that escapes from the filter(s).

1.6.4 Backwashing

Measure	Rationale	Additional Information
Once triggered for backwash, the filter is shut down automatically and placed in a backwash queue.	Any filter showing turbidity breakthrough must not be allowed to continue filtering. Log removal of pathogens at this stage is very low.	O&M manual to also require filter backwash after any maintenance work on the filter.
Combined air scour/low rate backwash, if present, is < 15 m/hr.	The combination of high rate water wash and air scour can result in damage to the filter under drain system and displacement of the support gravels.	
During drain down, prior to backwashing, controls are in place to ensure the filtration rate does not increase.	Any increase in flow through a filter particularly at the end of a filter run results in particle and pathogen shedding.	
Backwashes are triggered automatically by water quality (turbidity or particle count), head loss and run time.	All three triggers should be enabled to provide adequate protection against the passage of pathogens.	Events on SCADA to indicate the type of trigger of each backwash that occurs. This event data shall be recorded on PI.
Clean bed head loss (CBHL) is monitored during operation and trended.	Any sustained increase in CBHL indicates fouling of the media and likely poor log removal efficiency.	Alarm limit basis: For a given filter flow rate, the clean bed head loss (after backwash) should remain within a target of 5% of original CBHL.
Backwashing of dual media filters should achieve 20 - 30% expansion of the filter coal, and fluidisation of the full filter media depth.	Poorly backwashed filters result in reduced plant capacity and pathogen removal.	For each filter: <ul style="list-style-type: none"> • Media fluidisation depth >95% • Coal expansion 20% - 30%
Backwashing of mono-media sand filters with water or combined air and water should achieve 20% - 30% bed	Poorly backwashed filters result in reduced plant capacity and pathogen removal.	For each filter: <ul style="list-style-type: none"> • Fluidisation depth >20% • Media expansion 20% - 30%

Measure	Rationale	Additional Information
expansion and some fluidisation of the bed.		
During backwashing, any increase in flow to those filters remaining on-line during the backwash is <20%.	Removal of a filter for backwashing without a reduction in plant flow results in sudden increases in flow rate through the remaining filters, resulting in shearing of floc and possibly the passage of pathogens through the filter.	Alarms required on SCADA. Target is 100% compliance.
In plants without filter to waste (i.e. using ETSW backwash strategy), the ripening period after backwashing does not exceed the critical limit for any longer than: 0.5 NTU 30 min (3 log credit) 0.5 NTU 15 min (3.5 log credit) 0.3 NTU 15 min (4 log credit). Alternative limits can be set for low risk reuse plants if filtration is targeting only a reduction in suspended solids, not pathogens.	Any increase in turbidity represents increased risk to consumers. The ripening period is generally associated with a lower log removal of pathogens. The ripening period is defined as the time from the start of the filter run after backwashing until the target turbidity is consistently achieved.	The ripening period shall be monitored with display of monthly data indicating number of “ripening periods within target” as a percentage of total number of ripening periods. Target is > 95% compliance. Provide event alarm for individual ripening period exceeding target, and provide warning alarm when monthly target not met.
Air scouring is required where polymer is employed in the treatment process. Air-scour might also be required at higher solids loading rate between 2-10mg/L.	Polymer residual can carry over to filters and bind filter media. Air scouring is necessary to break the bonds between the floc polymer and the media. Air scouring may also be required in some plants not using polymer, e.g. Iron (Fe) and Manganese (Mn) removal plants (refer 1.6.4.1).	
Backwash time is set based on the backwash water at the end of the backwash having a turbidity of <10 NTU.	Over-backwashing of filters can result in lengthy ripening of the filter and is associated with an increased risk of the passage of pathogens.	Provide manual sample point for verification of backwash water turbidity and for undertaking root-cause analysis using backwash turbidity profiles.
Where filter to waste is provided, it should have the capacity to accept the full filter flow and the waste period is adjusted to remove as much of the ripening peak as possible.	Water produced during the ripening period has a higher turbidity and has a lower pathogen removal.	

The Water Corporation uses rapid sand filters and Continuous Wash Upflow Filters (CWUFs). By their design, CWUFs continuously backwash whereas rapid sand filters intermittently backwash. The following backwash control and air scour requirements apply only to intermittent backwashing filters.

1.6.4.1 Air scour

If no flocculant and/or no coagulant are used and the solids loading rate is low, then backwashing with water alone may be suitable for maintaining filter condition. Otherwise, to avoid “mud-balling” as a result of leaving too many solids in the filter bed, backwashing must be supplemented by air scouring. Note that some raw waters naturally coagulate due to iron oxidation or high dissolved organics, in which case air scour may be necessary.

A high solids loading rate will require use of air scour in the backwash cycle. Solids loading rates equivalent to a filtration rate of 10 m/hour with iron > 2 mg/L and / or manganese > 0.08 mg/L require air scour.

If air scour is included then provide a Maric (or equivalent) flow restrictor on fixed speed backwash pump discharge to ensure the backwash pump remains at design duty flow if the filter vessel still contains some air after air scouring.

1.6.5 Access for Inspections

Measure	Rationale	Additional Information
Provide access to allow a full filter inspection (including, where relevant, the plenum space) to be carried out at least once per year or after significant dirty water events.	Filter media and underdrains can deteriorate significantly and compromise filter performance.	
Provide access to allow quarterly checking and any required top-up of filter media.	Loss of media in any filter increases the risk of turbidity and pathogen breakthrough.	
Provide access and means for quarterly drainage (or in the case of pressure filters drainage and opening) for a surface inspection. N.B. Surface inspection does not require entry to the filter.	Filter media can deteriorate significantly and relatively rapidly resulting in compromised filter performance.	

1.7 Polyelectrolyte Dosing for CWUFs

Continuous Wash Upflow Filters are commonly used for iron and manganese removal at small WTPs. There are two scenarios where polyelectrolyte will be required in order to achieve the treated water quality targets:

- Feed water quality with relatively low solids concentration (Fe < 2 mg/L, Mn ~ 0.05 mg/L). The inlet water requires a minimum solids concentration for effective removal without polyelectrolyte. To improve floc formation a low dose (typically in the range 0.01 – 0.05 mg/L) of polyelectrolyte is required; or
- Feed water containing Iron (VI) complexes (organically bound). The organics preferentially oxidise before the iron, which can result in the iron passing through the filter bed before it is oxidised. Therefore, improve flocculation with polyelectrolyte.

1.7.1 Polyelectrolyte Dose Location

Selection of dose location shall ensure that there are minimal shear forces downstream which can reduce the effectiveness of the polyelectrolyte. The most robust means of ensuring this is to provide individual

dose points for each filter as near as practical to each filter inlet. Use of a common dose point should only be considered if the pipework design ensures minimal shear forces.

1.8 Backwash Recovery

Consideration should be given to process efficiency (water conservation) whereby backwash water recovery systems are adopted for low pathogen risk sources (source risk 1). For higher pathogen risk sources, backwash recovery systems should be avoided or shall include appropriate pathogen removal treatment process(es) for the recovered backwash water before it is returned to the head of the WTP. The required pathogen removal treatment processes shall be determined using a pathogen balance for the overall WTP (bacteria, virus and protozoa) and shall ensure that recovered backwash water achieves pathogen concentrations that are at least 2 log lower than the WTP feedwater for each class of pathogens.

1.9 Ammonia Removal

Some water sources (especially bores) are beginning to show signs of increased ammonia concentration. When the source water exceeds 0.1 – 0.15 mg/L of ammonia then additional treatment may be required to achieve breakpoint chlorination rather than it being economic and practical to rely upon increased chlorine dose rates. Treatment options include use of zeolite media in filters, particularly as the absorption life is similar to normal life expectancy of filter media. If the treatment also includes manganese removal, then there is uncertainty whether accumulation of manganese dioxide coating on the zeolite media will reduce its ammonia absorption capacity in the long term. If this is found to be a problem, then a solution would be to operate filters in series with the zeolite filters upstream which would allow the metals to pass through in dissolved form, then be oxidised on the inlet to the second filter.

1.10 Commissioning

Commissioning of filters and commissioning of filter media shall be in accordance with the procedures described in Appendix B: Filter Media Procurement and Commissioning Guideline.

As part of the commissioning process, the sand layer should be backwashed then scraped to remove the first 1-2cm of sand. This removes sand fines which are known to cause latent process issues such as elevated differential pressure, shorter run times and solids breakthrough.

For manganese removal filters, the media requires conditioning to establish a manganese dioxide coating on the filter media. This shall occur immediately after loading and washing of the filter media.

Samples shall be taken from manual sample points on each filter outlet for verification of filter performance (e.g. grab samples for iron and manganese concentration) and samples shall also be taken for verification of backwash performance during commissioning.

2 Iron Removal

2.1 Introduction

The Water Corporation target for iron at the WTP outlet is <0.1 mg/L. The ADWG limit for iron (<0.3 mg/L) is based on consumer health and aesthetics; it does not consider distribution issues. At concentrations below the ADWG limit, significant iron deposits may still form in assets such as tanks and pipes and cause many problems. In particular, sometimes these deposits are mobilised, and then the ADWG limit is breached at the consumer. See Appendix A: Drinking Water Quality Bulletin No 2 - Iron and Manganese.

Iron precipitate settles in water distribution tanks to some extent, but this settling is not a reliable means of meeting the target. For some waters, even after oxidation with chlorine, the settling is poor. Iron that does settle in tanks can accumulate on the tank floor. Such settled iron sludge can be easily disturbed

at a later time (for example during a low tank level event) resulting in complaints of dirty water from consumers. Increased sludge accumulation also provides an environment for potential pathogenic microbiological growth. To reliably meet the target, treatment for iron removal is normally necessary, including filtration.

Microbiological processes for iron removal exist, but these will not be considered here.

Iron may be present as many species and Figure 2 - 1 presents a breakdown of these and removal mechanisms.

The preference is to oxidise the iron to ferric and remove precipitated ferric hydroxide. Other removal alternatives should only be considered if there is good justification. For example, iron which is complexed strongly by organics may also be removed by treatment that is targeted at removal of the complexes (e.g. coagulation, settling and filtration).

2.2 Oxidation to Form Solids

To ensure complete oxidation of ferrous to ferric, the key variables to manage are pH, Oxidation-Reduction Potential (ORP) and detention time.

Increasing ORP will greatly increase oxidation kinetics and reduce or remove the need for detention, which is a significant capital cost. ORP can be increased easily by dosing chlorine (or hypochlorite), which treatment plants usually have onsite for disinfection. Common practice is to apply aeration for preliminary oxidation and removal of dissolved gases, then dose chlorine to ensure rapid iron oxidation, and then remove solids by clarification and/or filtration. There are exceptions, and these will be obvious during preliminary design and jar testing; e.g. capital cost of aerators versus chemical cost saving from lower chlorine dose.

Another important consideration with exposed clarifiers and filters is algal growth, which adds solids, dissolved organics and sometimes cyanotoxins. To minimise algal growth, an ORP >450 mV may be required (Wanneroo WTP, 2007).

As oxidant is consumed, the ORP will decrease, and oxidation rate will decrease, and the process may even move to a zone where oxidation will no longer occur. Therefore, robust plant operation requires maintenance of a suitable ORP after complete oxidation.

Separate chlorine dose points shall be provided for oxidation and for disinfection. This allows the oxidation and disinfection processes to be separately optimised without performance of either being compromised.

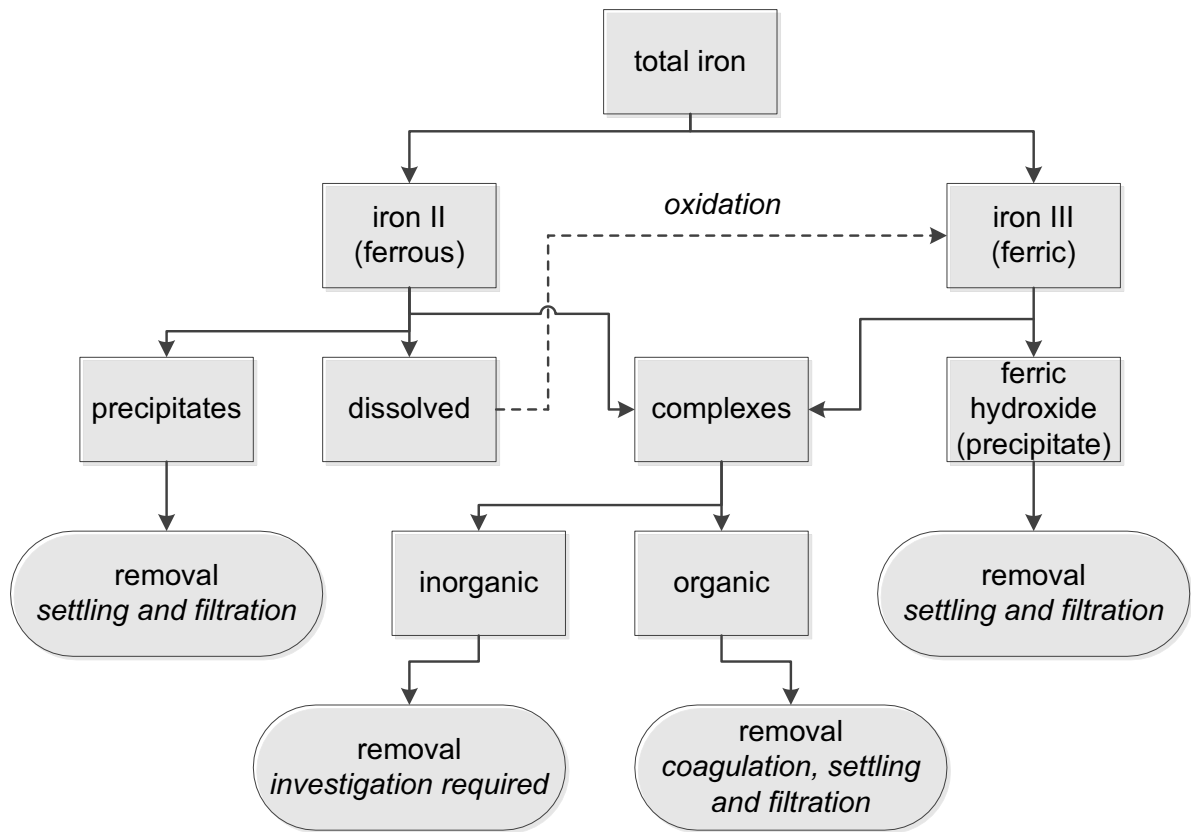


Figure 2 - 1 Iron species diagram, adapted from (Degremont, 2007, p. 625)

2.2.1 pH

The rate of oxidation by aeration increases 100-fold with an increase of one pH unit (Faust & Aly, 1998, p. 357). Oxidation is also catalysed by Cu^{2+} , MnO_2 and H_2PO_4^- (Faust & Aly, 1998, p. 358)

2.2.2 Air

Aeration alone may provide an ORP up to around 375 mV (James, 2004), so if the pH is high enough, ferrous iron can be oxidised to ferric given sufficient detention time. Provided that the iron is not organically-complexed, the iron can be completely oxidized in about 15 minutes at pH values around 7.5 to 8.0.

2.2.3 Chlorine Gas and Hypochlorite

1 mg/L of chlorine oxidises 1.58 mg/L of iron (II) (Kawamura, 2000, p. 524).

Chlorine is usually used for disinfection at WTPs. This availability makes it the most convenient oxidant.

Note that chlorine gas reduces pH, while sodium hypochlorite increases pH. For some situations, choosing sodium hypochlorite may mean that pH correction is not required.

Disinfection byproduct formation must be considered if using chlorine or hypochlorite for oxidation of iron.

2.3 Detention and Clarification

If oxidation is slow (refer 2.2.2), then detention is required to achieve complete oxidation—designers should always consider the option of dosing an oxidant in addition to aeration (especially chlorine) to produce rapid oxidation with minimal detention, effectively comparing the capital cost of aeration plus

detention against the capital and operational cost of chemical oxidation. NPV calculations can then indicate the preferred option.

If additional detention time is required, contact tanks with mixers can be used—settling must not occur in contact tanks.

A common recommendation is that if the iron concentration is >5 mg/L, clarification is required prior to filtration (Kawamura, 2000, p. 524) (Degremont, 2007, p. 627). This should be considered together with the competing objective of minimising treatment process complexity. An exception is Continuous Wash Upflow Filters such as Dynasands (refer 2.4.1), which can cope with a higher loading of oxidised iron.

Depending on the characteristics of the water, additional alkalinity may be required for good settleable floc formation suitable for clarifier operation. If the water contains dissolved carbon dioxide, dosing sodium hydroxide pre-aeration may be beneficial to increase both pH and alkalinity. Initially jar testing should be performed; however, in practice both pre and post aeration dosing points for sodium hydroxide should be included in plant design for optimisation purposes.

Water Corporation experience has shown that water with low iron concentration (e.g. Dalyellup Bore 1/05) can lead to poor performance of clarifiers due to inadequate solids contact (collisions of solids). In such cases, clarifier design should include the option to recirculate solids from the clarifier bleed to clarifier inlet.

2.4 Filtration

All iron must be oxidised before filtration. The filtration itself is not specialised, it must simply meet the particle removal required to produce total iron concentration <0.1 mg/L.

Rapid gravity filters are preferred, but for flowrates lower than several ML/d, capital costs are prohibitive, so pressure filters are then preferred. NPV analysis should guide the choice of filter type.

The filtration rate shall be a maximum of 12 m/h, unless a pilot study has been performed, or a very similar installation exists (Hendricks, 2006, p. 579).

2.4.1 Dynasand Filters

Continuous wash upflow sand filters (such as Dynasand brand of filters) are suitable for inlet iron concentrations up to 10 mg/L. Dynasand filters have high backwash losses, so backwash recovery is usually justified.

Experience has shown that when the iron concentration is below 10mg/L the filtrate iron target of <0.1 mg/L can generally be met; however, above this concentration the target cannot be achieved consistently e.g. Australind WTP.

2.4.2 ‘FRP’ Combined Clarifier and Filter Units (PWD design)

These units provide effective treatment for iron at 19 mg/L (Australind WTP).

Notes:

1. There must be sufficient iron to form a good blanket in the clarifier—if in doubt add solids recirculation.
2. They are unsuitable for Level III and higher sources due to compromised monitoring of outlet turbidity.

2.5 Process Monitoring

Process monitoring requirements for iron and manganese removal are defined in Appendix C: S524 – Process Monitoring at Iron and Manganese Removal Water Treatment Plants.

Target ranges must be developed for ORP and pH, pre and post-filter. ORP may change significantly across the filter, but pH probably will not.

Turbidity monitoring is required on the filter outlet, though that is more for performance of the filter rather than directly monitoring the iron and manganese removal.

2.5.1 Analyser location

In order to minimise process control time, the sample point for the analyser should be at the first available opportunity (i.e. on the inlet, if practical). However, this requires the reaction to be complete, which in the case of manganese most WTPs rely on catalytic oxidation within the media bed; hence, monitoring should⁶ be on the filter outlet. Another disadvantage with monitoring on the filter inlet is that the analyser is at risk of fouling and clogging due to exposure to water containing high concentrations of iron and manganese. Therefore, for water containing high iron and manganese concentrations, the most practical sample point location (for monitoring oxidation performance) is on the filter outlet.

Typically, there will be a single oxidant dose point upstream of the filters, and therefore it will be sufficient to have a single sample point for a single analyser (that samples water in common for the filters). Manual sample points shall be provided for verification of the on-line analysers.

2.5.2 Analyser selection

Selection of analyser type should be made in consultation with those responsible for operating and maintaining the treatment plant. Monitoring of free chlorine is often preferred as it is a normal operations practice to maintain and calibrate chlorine analysers. However ORP analysers may be technically the best choice because they are likely to be more stable and require less maintenance, though a limitation is that they require stable pH (note that surface water is likely to have greater diurnal and seasonal variation in pH than groundwater). If pH is monitored together with ORP, then note that reliability of the pH probe may be the limiting factor. In applications where an analyser is used to monitor a chlorine solution line (to verify that it contains chlorine, not just solution water), an ORP analyser should be used because they are more reliable than pH analysers.

Advantages of online ORP analysers:

- ORP analysers cost less than online free chlorine analysers,
- ORP analysers typically have lower maintenance requirements than online free chlorine analysers,
- ORP analysers measure the water quality variable that is most directly related to iron oxidation.

Note that for high iron concentrations, neither ORP nor free chlorine analysers are suitable due to high fouling (unless a sensor is used which can be specified with an automated cleaning flow cell e.g. Yokogawa FU20 ORP sensor); online monitoring can only then be done after clarification or filtration. This may limit the effectiveness of any automatic feedback control that might be required due to high process lag time across the clarifier or filter.

In applications where media filters are used as pre-treatment to reverse osmosis membranes, then ORP may be the preferred parameter for confirming that oxidising agents are not present in the feed water to the RO membranes.

3 Manganese Removal

3.1 Introduction

The Water Corporation target for manganese at the WTP outlet is <0.02 mg/L. The ADWG target for manganese (<0.1 mg/L) is based on consumer health and aesthetics—it does not consider distribution issues. At concentrations below this target, significant manganese deposits may form in assets such as tanks and pipes, which can cause many problems. Sometimes these deposits are mobilised, and then the

⁶ At Derby WTP, we use ORP on the inlet to the filters. This appears to work well to manage feed back control. Importantly, the retention time between offtake and analysis should be <5minutes.

ADWG target is breached at the consumer. See Appendix A: Drinking Water Quality Bulletin No 2 - Iron and Manganese.

Regarding manganese removal, manganese precipitate settles in tanks to some extent, but this settling is not a reliable means of meeting the target. To meet the target, designed treatment which includes filtration, is required.

Microbiological processes for manganese removal exist, but these will not be considered here.

The preferred method of treating manganese is removal by oxidation and filtration, and this is discussed below.

3.2 Oxidation to Form Solids

To ensure complete oxidation of manganese(II), the key variables to manage are pH and ORP. Catalysis by manganese dioxide coating on the filter media is also essential. Note that accumulation of adequate manganese dioxide coating on new media can take at least several weeks and possibly months; hence, alternative strategies to hasten establishment of presence of manganese dioxide coating are used such as mixing with existing media (perhaps from another WTP) or temporary dosing (or “soaking”) with potassium permanganate⁷. Failure to condition the media is likely to result in an extended commissioning period in which treated water quality targets are not achieved, and the process operation may require frequent adjustment.

Increasing ORP will greatly increase oxidation kinetics. ORP can be increased easily by dosing chlorine (or hypochlorite), which treatment plants usually have onsite for disinfection.

Detention is not usually worthwhile for manganese removal, because it takes a significant time for manganese dioxide to form, even with high pH and ORP (25 minutes at pH 8 with an excess of chlorine and no bromide (Allard, 2013)).

Normal clarification is not useful because the initial precipitation of manganese is very fine particles which do not settle easily. Ballasted clarification may be useful, but no case studies could be found.

As oxidant is consumed, the ORP will decrease, and oxidation rate will decrease, and the process may even move to a zone where oxidation will not occur. Therefore, robust plant operation requires maintenance of a suitable ORP after complete oxidation.

Separate chlorine dose points shall be provided for oxidation and for disinfection. This allows the oxidation and disinfection processes to be separately optimised without performance of either being compromised.

3.2.1 Air

Aeration alone may provide an ORP up to around 375 mV (James, 2004), so if pH is high enough, manganese(II) can be oxidised through aeration. At a pH of 9.5 it takes about one hour of detention for manganese(II) to oxidise. Such high pH and long detention times are not normally practical in WTPs.

3.2.2 Chlorine Gas and Hypochlorites

Chlorine demand is estimated on the basis that 1 mg/L of chlorine oxidises 0.78 mg/L of manganese(II) (Kawamura, 2000, p. 524). In addition, it is typically required to achieve between 0.15 and 0.50 mg/L free chlorine in the filter outlet water in order to maintain an optimum oxidation potential across the media bed.

Chlorine is usually used for disinfection at WTPs: this availability makes it the most convenient oxidant.

Note that chlorine gas reduces pH, while sodium hypochlorite increases pH. For some situations, choosing sodium hypochlorite may mean that separate pH correction is not required.

⁷ Water Quality business unit’s Treatment team have protocols for conditioning media for manganese removal, and uses several chemicals, not just potassium permanganate. This information remains subject to IP and licensing agreements.

3.2.3 Potassium Permanganate

Potassium permanganate is an effective oxidant. It has the advantage that it enables quicker formation of a manganese dioxide surface layer on filtration media. It also has the disadvantage that overdosing creates coloured (pink) water, giving a visual indicator of a problem. Compared to site chlorine, it has the disadvantage of being an additional chemical to handle.

3.3 Filtration

Fine particle removal is essential—if fine manganese dioxide particles are not removed they will be measured as total manganese.

A surface layer of manganese dioxide is also essential to catalyse oxidation.

3.3.1 Filter Types

The following filters have demonstrated good performance for manganese removal:

- Rapid gravity filters. Reference: metropolitan groundwater TPs.
- Pressure filters. Reference: Camballin WTP.

Dynasand filters may be considered, but fine particle removal is less reliable, so designers must have confidence in the application.

Membrane filters are fouled by manganese dioxide, so are not suitable.

3.4 Process Monitoring

Process monitoring requirements for iron and manganese removal requirements are defined in Appendix C: S524 – Process Monitoring at Iron and Manganese Removal Water Treatment Plants.

Target ranges must be developed for ORP and pH, pre and post-filter. ORP may change significantly across the filter, but pH probably will not.

Refer section 2.5.1 regarding analyser location and refer section 2.5.2 regarding analyser selection.

Recommended online monitoring:

- Filter inlet: pH and free chlorine (or ORP)
- Filter outlet: free chlorine (or ORP)

It is not always necessary to measure ORP. ORP and free chlorine are related, and a high minimum free chlorine concentration may be adequate, but this must be validated. For plants with all chlorine dosing and suitable pH pre-filter (e.g. Wanneroo WTP, Camballin WTP, Australind WTP), disinfection control will usually ensure effective manganese oxidation.

4 Bibliography

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- [S524 – Process Monitoring at Iron and Manganese Removal Water Treatment Plants](#). Water Corporation

5 Appendix A: Drinking Water Quality Bulletin No 2 - Iron and Manganese

<https://nexus.watercorporation.com.au/otcs/cs.exe/link/50161723>

(as pasted below)

1 May 2014

Drinking Water Quality Bulletin No 2

To all employees working in drinking water quality operations

The purpose of the Drinking Water Quality Bulletin is to keep you informed of any **important issues affecting drinking water quality operations**. The information contained in this Bulletin should be shared and discussed with teams at team meetings. Further information can be obtained from Drinking Water Quality Branch.

Managing iron and manganese in drinking water

What are iron and manganese?

- Iron (Fe) and manganese (Mn) are metals that naturally occur in many source waters. Higher concentrations are most common in groundwater.
- Iron and manganese cause aesthetic problems in distribution systems, which affect the customer perception of water quality. High concentrations of these metals result in unpleasant taste, discoloured water and staining of laundry and household fixtures.

Iron and manganese targets

ADWG targets (in retic)

- o Fe < 0.3 mg/L
- o Mn < 0.1 mg/L

Water Corporation targets (outlet of WTP)

- o Fe < 0.1 mg/L
- o Mn < 0.02 mg/L

Why are the targets different?

- Water Corporation experience shows the ADWG targets are quite generous;
- At the ADWG limits large quantities of iron and manganese are still being sent into the distribution system:
 - o For example, in a water treatment plant (WTP) averaging 10 ML/day (e.g. Australind) and producing water with an iron concentration of 0.3 mg/L, more than 1000 kg of iron is being sent into the distribution system each year!
 - o Over time, iron and manganese precipitates build up in the distribution system, service reservoirs, tanks and low lying areas.
 - o Discoloured water events typically occur during peak demand, change in hydraulic conditions such as a reverse flow due to a system change, pipe bursts or hydrant flushing.
- Removing iron and manganese at the WTP to Water Corporation targets is more cost effective than the increased frequency of tank cleaning and mains scouring required to manage the build-up of iron and manganese.

Water treatment plant monitoring

- Weekly grab samples of iron and manganese are taken at the WTP.
- WTP performance can be highly variable and grab samples may not be representative of the average performance.

- Having online monitoring at the WTP to drive consistent iron and manganese removal is as, if not more, important than grab samples. Online monitoring should include:
 - o Chlorine residual immediately post filter and prior to disinfection chlorine dosing to ensure complete oxidation of iron and manganese;
 - o Turbidity post filter as a surrogate for iron and manganese breakthrough; and
 - o Coagulation pH, where chemical dosing for coagulation is required.

Note: There is no on-line instrument that can measure Mn or Fe

Need more information?

For more information please contact the Treatment Team on 9420 2819



6 Appendix B: Filter Media Procurement and Commissioning Guideline

<https://nexus.watercorporation.com.au/otcs/cs.exe/link/49690973>

(as pasted below)



Filter Media

Procurement & Commissioning Guideline

Prepared by Don Kuai
25 May 2016

Updated by Jessica Le
7 May 2017

watercorporation.com.au



Purpose

This document provides a guideline to the procurement and commissioning of approved filter media types which are in use across Western Australia.

Background

The Water Corporation uses a variety of different Filter Media types across Western Australia. These include traditional and non-traditional media approved for the purpose of Water Treatment. Filter media includes any material or chemical placed in a filter that comes into contact with drinking water thereby changing the quality of the water.

Media filter needs to be approved by the Department of Health (DoH) for contact with drinking water. Traditional media is approved under a Memorandum of Understanding (MoU) between the Department of Health (DoH) and Water Corporation, and Non-traditional media is approved for use under Schedule 7 in *Materials and Substances in Contact with Drinking Water*, as shown in Table 1. The types of media filter associated with traditional and non-traditional media are listed below.

Filter Media Types

Traditional Filter Media:

- Sand
- Anthracite
- Garnet (support layers)
- Gravel (support layers)

Non-Traditional Filter Media

- Adsorbsia As600
- Calcite
- Granular Activated Carbon
- Zeolite
- DMI-65 (MnO₄ coated sand for manganese removal)
- AFM (activated glass filter media)

Basic Filter Types

Current Basic Filters in Operation:

- FRP(combined gravity filter/Clarifier)
- ~~Dynasand~~
- Gravity Filter
- Pressure Filter

Filter Media Procurement Guideline

Table 1 outlines the filter media and their approval status in use across the state:

Filter Media Type	Approval	Responsibility	SPS*
Traditional			
Sand, Anthracite, Garnet, Gravel	PM-#2515454	Manager DWQ/Supplier	N/A
Non-Traditional			
Adsorbia As600	DoH Water	Manager DWQ/Supplier	N/A
Calcite Pellets	DoH Water	Manager DWQ/Supplier	SPS-439
Calcite Seed	DoH Water	Manager DWQ/Supplier	SPS-440
Granular Activated Carbon	DoH Water	Manager DWQ/Supplier	N/A
Zeolite	DoH Water	Manager DWQ/Supplier	N/A
DMI-65	DoH Water	Manager DWQ/Supplier	N/A
AFM	Not Approved	Manager DWQ/Supplier	N/A

Table 1 Procurement Guideline for Filter Media (*SPS = Strategic Product Specification).

Table 1 should be updated and reviewed on a regular basis (annually) to ensure Department of Health approval for the filter media is understood and obliged to. The DoH approval document was last updated November 2016.

Filter Media Commissioning Guideline

Table 2 outlines the filter media commissioning guideline across the state:

Filter Media Type	Standard	Supporting	Guideline	Locations**
Traditional				
Sand, Anthracite, Garnet, Gravel	AWWA B100-09 AWWA C653-13	PM-#2176527 PM-#5427366 PM-#6006914	PM-#16372326	Picton Woodridge, Australind
Non-Traditional				
Adsorbia As600	N/A	PM-#14847355 PM-#6035771	PM-#16372333	Yaloo , Menzies
Granular Activated Carbon	AWWA B604-12	PM-#13852573 PM-#2177230	PM-#16372334	Fitzroy Crossing, Lake King
Calcite	N/A	PM-#6742266 PM-#4014570	PM-#16372335	Augusta
Calcite Seed	N/A	PM-#6742266	N/A	Neerabup
Zeolite	N/A	N/A	N/A	N/A
DMI-65	N/A	N/A	N/A	N/A
AFM	N/A	PM-#14872702	N/A	Beverly (WWTP)

Table 2 Commissioning Guideline for Filter Media (not all locations are shown, prime examples have been selected).

The commissioning of filter media is a case-by-case procedure. It may also depend on the filter type, however this is not discussed. The commissioning guidelines assume the placing of the media has been completed.

7 Appendix C: S524 – Process Monitoring at Iron and Manganese Removal Water Treatment Plants

<https://nexus.watercorporation.com.au/otcs/cs.exe/link/80789616>

(as pasted below)

		S524 – Process Monitoring at Iron and Manganese Removal Water Treatment Plants	
Doc ID Nexus # 80789616	Custodian Manager – Treatment, WQBU	Approved Head of Water Quality	
Version Date 25 November 2019	Accountabilities Framework Level 1 – Manage Drinking Water Quality	Stakeholders Water Quality Business Unit	
Next Review Date 25 November 2022	Level 2 – Manage DWQ System Analysis & Operations	Regions Engineering Business Unit	

1 Purpose

The purpose of this standard is to specify the minimum requirements for process monitoring at the water treatment plants that are operating to achieve removal of iron and manganese. The standard applies to all water treatment plants where the raw water iron and manganese concentrations exceed the Water Corporation target values (0.1 mg/L for iron and 0.02 mg/L for manganese).

2 Scope


All water treatment plants operating to achieve iron and manganese removal shall, as a minimum, comply with the requirements of this standard. In addition, the monitoring outlined in [Source Protection Operations Manual \(SPOM\)](#), [S010 - Drinking Water Quality Performance](#) and [DS 114 - Granular Medium Filtration - Iron and Manganese Removal](#) shall also be applied.

3 Definitions

- ADWG** The Australian Drinking Water Guidelines are designed to provide an authoritative reference to the Australian community and the water supply industry on what defines safe, good quality water, how it can be achieved and how it can be assured. The Guidelines address both the health and aesthetic quality aspects.
- CCP** Critical Control Point. A point, step or procedure at which control can be applied and which is essential to prevent or eliminate a hazard or reduce it to an acceptable level. The Corporation has defined certain CCP's as per the guideline: [Drinking Water Critical Control Points Management](#).
- WQ** Water Quality
- ODSS** Operational Data Storage System. This is the Corporation's repository of information that supports the operational functions of water supply, distribution and water quality.
- PCP** Process Control Point. A point, step or procedure at which control can be applied and which is essential to making operating decisions, and supports the achievement of a critical control point.
- WHO** World Health Organisation
- WQMS** Water Quality Management System. This is the Corporation's drinking water quality database. It is used to support water quality management requirements, from the planning of sampling programs to the generation of performance reports.
- WTP** Water Treatment Plant
- WSP** Water Safety Plan

4 References

- Procedure: [Managing and Responding to DWQ Incidents – Primary Chlorination Failure \(58545203\)](#)
- Procedure: [Managing and Responding to DWQ Incidents – UV Disinfection System Failure \(58540007\)](#)
- Guideline: [Drinking Water Critical Control Points Management \(58569503\)](#)
- Manual: [Source Protection Operations Manual \(SPOM\) \(58553745\)](#)
- Manual: [Surface Treatment Manual \(58539013\)](#)
- Standard: [S010 - Drinking Water Quality Performance \(58539231\)](#)
- Standard: [S211 Chlorine and Chloramine Residual Monitoring Frequency \(58541762\)](#)
- Design Standard: [DS 114 - Granular Medium Filtration - Iron and Manganese Removal \(58583291\)](#)

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Design Standard: [Specification for the Selection of Appropriate Turbidity Analysers \(58583842\)](#)
NH&MRC: [Australian Drinking Water Guidelines 2011](#)

5 Introduction

Iron and manganese are common elements in the natural environment and are often present in varying concentrations in groundwater and surface water supplies. Regulatory standards for levels of iron and manganese in drinking water are generally set from the point of view of avoiding adverse aesthetic impacts. Manganese also has a health guideline value, which is primarily driven by the investigations carried out by the World Health Organisation (WHO) in 1973 and is derived from the upper range value of manganese intake.

The primary impact of iron and manganese at concentrations exceeding the Water Corporation target values in the distribution system is discoloured water events. This may result from:

1. Water treatment plant failure or under-performance; and
2. Sudden changes in water velocity and/or directions of flow in the distribution system.

Discoloured water events from iron occur normally after a period of build up (generally months/years) in the reticulation system. Elevated manganese concentrations can cause discoloured water events almost immediately.

As a result of discoloured water events, the following range of activities can be implemented:

1. Planned and interventional flushing and scouring;
2. Optimisation/enhancement of the water treatment plant;
3. Water mains replacement and rehabilitation;
4. Water carting.

This standard outlines the key performance criteria for typical water treatment processes used for iron and manganese removal.

If the water treatment plant is also a pathogen removal plant, the targets set out in this standard are superseded by the targets set out in the [Surface Treatment Manual](#), Table 7 - Process Unit Operations and Performance Criteria for pathogen removal.

6 Iron and Manganese Removal Processes

The selection of treatment processes depends on the form and concentration of iron and manganese in raw water. Iron and manganese can be present in dissolved, particulate or colloidal forms and it is generally influenced by raw water pH, redox potential, hydrolysis, water temperature and the presence of complex forming inorganic and organic substances.

The most common removal principle is to convert reduced (dissolved) iron and manganese into oxidised (undissolved) compounds that can be removed through filtration. Chlorine is typically dosed to achieve oxidation of iron and manganese. Any of the following processes can be incorporated pre filtration to achieve effective removal of iron and manganese:

1. Aeration and/or chlorine dosing for oxidation;
2. pH correction (higher pH increases oxidation rates);
3. Coagulation/flocculation;
4. Clarification;
5. Filter media conditioning with KMnO_4 (for Mn removal).



S524 – Process Monitoring at Iron and Manganese Removal Water Treatment Plants

7 Monitoring Principles

7.1 Monitoring of Barrier Performance

Monitoring of chlorine residual is optimally undertaken at a point pre filtration where sufficient chlorine contact time has been achieved to ensure complete oxidation. At low concentrations of iron and manganese online chlorine analysers can be used, but for water containing high iron and manganese (e.g. Australind) probe fouling issues occur. It is therefore preferential for WTPs with high iron and manganese concentrations to monitor oxidation performance after the filter.

If chlorine is used for oxidation, continuous online monitoring of free chlorine or Oxidation Reduction Potential (ORP) is required. Monitoring of free chlorine is preferred as it is a normal operations practice to maintain and calibrate chlorine analysers. ORP analysers are however likely to be more stable and require less maintenance and can be considered for locations where there is stable pH.]

The ORP, measured as voltage potential required to achieve oxidation at a given pH is defined by Pourbaix diagrams. The chlorine residual required to achieve complete oxidation can then be determined by working out how much chlorine needs to be dosed to meet the ORP. In addition to online chlorine residual monitoring (or online ORP monitoring), routine in situ monitoring occurs for validation of the performance.

Where pH correction is utilised, continuous monitoring occurs at a point downstream of chemical dosing using an online pH analyser. In addition to online pH monitoring, routine in situ monitoring occurs for validation of the performance.

As it is impractical to continuously monitor removal of iron and manganese across an operating water treatment plant, industry best practice recommends the measurement of surrogate parameter and in situ monitoring by commercial hand held instrumentation for validation of the performance of a water treatment barrier.


A surrogate measurement for iron is online turbidity monitoring, which is a process parameter that provides instant feedback on the efficacy of the filtration process. The turbidity set points are defined by the turbidity vs. iron profile. In addition to online turbidity monitoring, routine in situ monitoring is used for validation of the performance. Where more than one filter is used, in situ monitoring of iron and manganese shall be completed for each individual filter, whilst turbidity monitoring can be performed on each individual filter or/and on the combined filter outlet.

7.2 Operating Criteria

The following criteria shall be used when monitoring process control point performance for iron and manganese removal treatment processes.

- Target limit
- operational limit;
 - allows corrective action to be taken to avoid unacceptable aesthetic impact, i.e. discoloured water.
- Alert limit
- gives warning that a target limit has been breached;
 - it can initiate a plant shut down on high-high or low-low alarms in order to prevent unacceptable aesthetic impact, i.e. discoloured water.

The target and alert limits described above are formally set through the Water Safety Planning process, endorsed by the Head of Water Quality Business Unit and listed in the Water Safety Plan for each scheme.

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7.3 Target Criteria

During normal operation of the treatment process, it is expected that the alert limit will not be reached. However, it is acknowledged that following certain process operations target criteria may not be achieved for a short period of time. To avoid transient fluctuations triggering an alarm, the default elapsed time that a condition must persist continuously before an alarm is triggered is to be determined by stakeholders and then implemented.

Some common examples are listed below. WQ Business Unit should be consulted for other site and criteria specific applications.

1. Filter Ripening

After a filter backwash for granular media filters there will be a filter 'ripening' period where the target criteria may not be achieved for a short period of time. A mass balance must be completed to ensure that adequate blending occurs in the clear water tank, where composite iron and manganese concentrations after a backwash are below the target criteria. The filtrate turbidity alert limit does not need to be met for this period of time. Practically, this means that the PLC must allow the filtrate turbidity to exceed the alert limit before generating a PLC/SCADA alarm by means of integrating a delay function, or temporary reading of turbidity on the clear water tank outlet. Treatment plants that have a 'filter to waste' capability effectively have no ripening period so the time the alarm limit that can be exceeded is reduced to avoid 'metering noise' potentially generating false alarms.

2. Flow Rate Changes and Hydraulic Shocks

Typically occurs when there is a sudden increase in flow rate through a filter when one filter is taken offline for backwashing, and subsequently there is an increase in the filtration rate in the remaining filters. A mass balance must be completed to ensure that adequate blending occurs in the clear water tank, where composite iron and manganese concentrations during a backwash are below the target criterion. Practically, this means that the PLC must allow the filtrate turbidity to exceed the alert limit before generating a PLC/SCADA alarm by means of integrating a delay function. Treatment plants where the flow is reduced to maintain a design filtration rate, or where the flow is stopped while backwashing is occurring, will effectively experience filter ripening only.

Where flow rate is increased as part of the operational requirements, filter backwash initiation should be adjusted if the backwash is not initiated on turbidity exceedance.

7.4 Instrumentation

Chemical dose rates determined by using a flow meter are preferred, however, weekly draw down tests are acceptable where calibration tubes have been installed.

Detailed recommendations for turbidity meters are provided in [Specification for the Selection of Appropriate Turbidity Analysers \(58583642\)](#).

8 Data and Reporting

8.1 Operations Logbook

An Operations Logbook shall be prepared for each treatment plant. This will be used to define and record operational monitoring data for field measurement of in situ samples and online measurement.

A monitoring program shall be established in WQMS or ODSS reading schedule for all Water Safety Plan measurements.

8.2 Performance Review

The performance of each treatment plant shall be reviewed monthly through the Water Quality Governance reporting process by the regional Service Delivery Manager. In addition to the monthly Governance reporting, each treatment plant shall be reviewed weekly by the Water Quality Treatment team.



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9 Minimum Monitoring and Performance Requirements

9.1 Raw Water Monitoring

Refer to raw water sampling requirements (tables 6 and 7) in [Source Protection Operations Manual \(SPOM\)](#), and the Water Safety Plan. More frequent sampling may be required if the source water has uncharacteristically variable iron and manganese levels.

9.2 Treatment Process Monitoring

Table 1: Treatment Process Monitoring

Measurement / Parameter	Treatment Process	Monitoring Frequency / Type / location	WSP	Logbook	Target Criteria	Alert Limit	Comments
OXIDATION / DISINFECTION (single dosing point – pre-treatment process)							
Low raw water Fe/Mn Free Chlorine (mg/L)	Clarifier, then Filter	Continuous Online (Clarifier inlet)	✓	✓	Limits set out in the WSP	Limits set out in the WSP	For combined oxidation/disinfection chlorinator where limits are set in the WSP to maintain residual in distribution system.
		Weekly in situ (Clarifier inlet)		✓			
		Weekly in situ (Filter outlet)		✓			
	Filter only	Continuous Online (Filter inlet)	✓	✓			
		Weekly in situ (Filter inlet)		✓			
		Weekly in situ (Filter outlet)		✓			
High raw water Fe/Mn Free Chlorine (mg/L)	Clarifier, then Filter	Continuous Online (Clarifier outlet)	✓	✓			
		Weekly in situ (Clarifier inlet)		✓			
		Weekly in situ (Filter outlet)		✓			
	Filter only	Continuous Online (Filter outlet)	✓	✓			
		Weekly in situ (Filter inlet)		✓			
		Weekly in situ (Filter outlet)		✓			
OXIDATION (dedicated chlorinator – pre-treatment process)							
Low raw water Fe/Mn Free Chlorine (mg/L)	Clarifier, then Filter	Continuous Online (Clarifier inlet)	✓	✓	Defined by site specific monitoring	Site specific limits apply for low, low-low, high, high-high alarms	Only for dedicated oxidation chlorinator. An ORP analyser can be substituted for a free chlorine analyser (refer to section 7.1). Continuous online oxidation reduction potential will be monitored instead of free chlorine, all other in situ samples will remain as free chlorine monitoring. Target criteria for ORP is also site-specific and can be obtained from Pourbaix diagrams.
		Weekly in situ (Clarifier inlet)		✓			
		Weekly in situ (Filter outlet– pre disinfection chlorinator)		✓			
	Filter only	Continuous Online (Filter inlet)	✓	✓			
		Weekly in situ (Filter inlet)		✓			
		Weekly in situ (Filter outlet – pre disinfection chlorinator)		✓			
High raw water Fe/Mn Free Chlorine (mg/L)	Clarifier, then Filter	Continuous Online (Clarifier outlet)	✓	✓			
		Weekly in situ (Clarifier inlet)		✓			
		Weekly in situ (Filter outlet– pre disinfection chlorinator)		✓			
	Filter only	Continuous Online (Filter outlet – pre disinfection chlorinator)	✓	✓			



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Measurement / Parameter	Treatment Process	Monitoring Frequency / Type / location	WSP	Logbook	Target Criteria	Alert Limit	Comments
		Weekly in situ (Filter inlet)		✓			
		Weekly in situ (Filter outlet – pre disinfection chlorinator)		✓			
COAGULATION							
Coagulation pH	Clarifier, then Filter	Continuous Online (Post dosing point)	✓	✓	Defined by site specific monitoring	Low, high alarm ± 0.2 pH units	All dosing systems require calibration tubes installed. Draw down tests are acceptable where calibration tubes have been accurately installed, labelled and maintained. Typically, coagulation is used when organic materials are also present in raw water.
		Weekly in situ (Post dosing point)		✓			
	Filter only	Continuous Online (Post dosing point)	✓	✓			
		Weekly in situ (Post dosing point)		✓			
Coagulant dose rate	Clarifier or Filter	Continuous (Dosing pump)		✓		Low, high alarm ± 10% from set point	
		Weekly pump drawdown		✓			
pH ADJUSTMENT							
pH	Clarifier or Filter	Continuous Online (Post dosing point)	✓	✓	Defined by site specific monitoring	Low, high alarm ± 0.2pH units	pH target is site specific and water quality dependent where alkali is used for pH correction. If pH adjustment is dosed in conjunction with coagulation dosing, a single pH analyser can be used for monitoring.
		Weekly in situ (Post dosing point)		✓			
CLARIFICATION							
Turbidity (NTU)	Clarifier	Continuous Online (Supernatant)	✓	✓	≤ 2.0 NTU	Site specific limits apply for high and high-high alarms	If online turbidity analyser is not available, weekly in situ sampling remains.
		Weekly in situ (Supernatant)		✓			
MEDIA FILTRATION¹							
Turbidity (NTU)	Filter	Continuous Online (Combined filter outlet)	✓	✓	Defined by turbidity vs. iron profile	Site specific limits apply for low, low-low, high, high-high alarms	If online turbidity analyser is not available, weekly in situ sampling remains.
		Weekly in situ (Combined filter outlet)		✓			
Iron in-situ (mg/L)	Filter	Weekly in situ (Combined filter outlet)	✓	✓	≤ 0.1 mg/L	>0.1 mg/L (WQMS alert)	Quarterly reticulation sampling is sufficient, only if targets are met. Higher sampling in reticulation is required if targets are not met.
		Site specific monitoring frequency for individual filters (individual filter outlet)		✓			
Manganese in-situ ² (mg/L)	Filter	Weekly in situ (Combined filter outlet)	✓	✓	≤ 0.02 mg/L	>0.02 mg/L (WQMS alert)	Asset deficiency should be highlighted in WSPs for those WTPs which cannot meet the target criteria.
		Site specific monitoring frequency for individual filters(individual filter outlet)		✓			
Differential Pressure (kPa)	Filter	Continuous Online (Individual filter)	✓	✓	Defined by site specific monitoring	Defined by site specific monitoring	
BACKWASH RECOVERY							
Turbidity (NTU)	Thickener	Continuous Online (Supernatant)	✓	✓	Defined by site specific monitoring	Site specific limits apply for low, low-low, high, high-high alarms	If online turbidity analyser is not available, weekly grab sampling remains.
		Weekly in situ (Supernatant)		✓			

¹ Dynasand, gyrosand, FRP, slow sand filters, pressure and gravity filters

² Only when composite raw water Mn is >0.02mg/L

9.3 Distribution System Monitoring

Refer to [S010 - Drinking Water Quality Performance](#), [S211 Chlorine and Chloramine Residual Monitoring Frequency](#), and the Water Safety Plan. These documents outline the minimum sampling frequencies required. More frequent sampling in distribution is required if targets outlined in Table 1 Treatment Process Monitoring are not met.

9.4 Implementation of Monitoring Requirements – Example

Example: Water Treatment Plant A

Water Treatment Plant A is designed to remove iron and manganese from raw water supplied from a borefield. The treatment processes include the following:

- Oxidation using chlorine;
- Media filtration for removal of oxidised compounds;
- Disinfection using chlorine.



Using Sections 9.1 – 9.3, the minimum monitoring and performance requirements for the Water Treatment Plant A will be:

Raw water monitoring:	As per Source Protection Operations Manual (SPOM) , Table 6 and 7 for raw water sampling requirements, and the Water Safety Plan.
Oxidation:	Filter inlet – weekly in situ free chlorine; Filter outlet – continuous free chlorine; Filter outlet – weekly in situ free chlorine.
Media Filtration:	Filter outlet – continuous turbidity; Filter outlet – weekly in situ iron; Filter outlet – weekly in situ manganese.
Disinfection:	Dosing point - continuous free chlorine.
Distribution monitoring:	As per S010 - Drinking Water Quality Performance , S211 Chlorine and Chloramine Residual Monitoring Frequency , and the Water Safety Plan.

10 Contingency Plans

10.1 Operational Response to Chlorine Residual Failure

This should be carried out in accordance with the Corporation's procedures for [Managing and Responding to DWQ Incidents – Primary Chlorination Failure](#)

10.2 Operational Response to Alert Breaches

Table 2 Contingency Plan details the recommended operational response to alert breaches for iron and manganese removal plants.

	<h2 style="margin: 0;">S524 – Process Monitoring at Iron and Manganese Removal Water Treatment Plants</h2>
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Table 2: Contingency Plan

	Operations Centre	Service Delivery
<p>Alert Limit Breached (Low or High alarm)</p>	<ol style="list-style-type: none"> 1 Acknowledge the alarm 	<ol style="list-style-type: none"> 1 Action is required to bring the process unit(s) in spec. 2 Check online instrument(s) for correct operation, calibration and maintenance. 3 Check effects of alert breach on other process units. 4 Check filter turbidity and differential pressure. 5 Check the clarifier turbidity, if applicable 6 Check the chemical dosing and adjust if out of range, if applicable. 7 Initiate the backwash cycle, if applicable. 8 Confirm the above action is effective. 9 Provide a briefing to line manager and record actions in the WTP Operations Logbook, if applicable.
<p>Alert Limit Breached (Low-low or High-high alarm)</p>	<ol style="list-style-type: none"> 1 Acknowledge the alarm 2 Advise the Regional contact of the exceedance by phone 	<ol style="list-style-type: none"> 1 Confirm that the treatment plant is shut down and no untreated water has been supplied to the customers. 2 Identify which alarms have initiated the treatment plant shut down. 3 Check effects of alert breach on other process units. 4 Action is required to bring the process unit(s) in spec. Assistance from DWQ Treatment may be required. 5 Confirm the above action is effective. 6 If inadequately filtered water will (or may) be delivered to customers, advise the Distribution and Systems Manager, DWQB. 7 Provide a briefing to stakeholders.

11 Records

Document Revision History	
November 2019	First published

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